MASTER

APPLICABILITY OF
A GENERIC MONITORING PROGRAM FOR
RADIOACTIVE WASTE BURIAL GROUNDS AT
OAK RIDGE NATIONAL LABORATORY AND
IDAHO NATIONAL ENGINEERING LABORATORY

DAMES & MOORE

JULY 1978

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Offices in principal cities

ANCHORAGE	
ATLANTA	
BILLINGS	
BOCA RATON	
BOSTON	
CHICAGO	
CINCINNATI	
CRANFORD	
DENVER	
FAIRBANKS	
HONOLULU	
HOUSTON	
LEXINGTON	
LOS ANGELES	
NEW ORLEANS	
NEW YORK	
NEWPORT BEACH	
PHOENIX	
PORTLAND	
SALT LAKE CITY	
SAN FRANCISCO	
SANTA BARBARA	
SEATTLE	
SYRACUSE	
WASHINGTON, D.C.	
WHITE PLAINS	
	ATHENS
	JAKARTA
	JOHANNESBURG
	KUWAIT
	LONDON
	MADRID
	MELBOURNE
	PERTH
	RIYADH
	SINGAPORE
	SYDNEY
	TEHRAN
	TOKYO
	TORONTO
	VANCOUVER

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

DAMES & MOORE

Consultants in the Environmental and Applied Earth Sciences

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

APPLICABILITY OF A GENERIC MONITORING
PROGRAM FOR RADIOACTIVE WASTE BURIAL
GROUNDS AT OAK RIDGE NATIONAL LABORATORY
AND IDAHO NATIONAL ENGINEERING LABORATORY

PREPARED FOR:

UNION CARBIDE CORPORATION
NUCLEAR DIVISION
UNDER SUBCONTRACT NO. 7167
OF CONTRACT W-7405-ENG-26

PREPARED BY:

DAMES & MOORE
20 HAARLEM AVENUE
WHITE PLAINS, NEW YORK 10603

JOB NO. 00651-132-23
JULY, 1978

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1.0 INTRODUCTION	1
2.0 SUMMARY	2
3.0 OAK RIDGE NATIONAL LABORATORY	4
3.1 Site Description	4
3.1.1 General Geologic Conditions	4
3.1.2 General Hydrologic Conditions	8
3.1.3 Bethel Valley Burial Ground Conditions	9
3.1.4 Melton Valley Burial Ground Conditions	10
3.1.4.1 Burial Ground 4	11
3.1.4.2 Burial Ground 5	14
3.1.4.3 Burial Ground 6	17
3.2 Selection of Burial Ground For Testing The Generic Monitoring Program at ORNL	18
3.2.1 Bethel Valley Burial Grounds	19
3.2.2 Melton Valley Burial Grounds	20
3.2.2.1 Burial Ground 4	20
3.2.2.2 Burial Ground 5	22
3.2.2.3 Burial Ground 6	23
3.3 Monitoring Programs	24
3.3.1 Burial Ground 4	25
3.3.2 Burial Ground 6	30
3.4 Cost Estimate - ORNL	36
4.0 IDAHO NATIONAL ENGINEERING LABORATORY.	40
4.1 General Description of INEL	40
4.1.1 General Geology	46
4.1.1.1 Eastern Snake River Plain	46
4.1.1.2 Radioactive Waste Management Complex	48
4.1.1.2.1 Surficial Deposits.	48
4.1.1.2.2 Snake River Group	48
4.1.2 General Hydrology	51
4.1.2.1 Surface Water	51
4.1.2.2 Ground Water	52
4.1.2.2.1 Unsaturated Zone	52
4.1.2.2.2 Saturated Zone	53
4.2 Monitoring Program	55
4.2.1 Source of Radiocontaminants	55
4.2.2 Means and Routes of Transportation	56
4.2.3 Radioactive Concentrations	57
4.2.4 Recommended Action	59

4.2.5 Recommended Programs	62
4.2.5.1 Monitoring Program	62
4.2.5.2 Supplemental Data Acquisition	66
4.3 Cost Estimate - INEL	69
5.0 REFERENCES	72
Appendix A	A-1
Appendix B	B-1
Appendix C	C-1

LIST OF TABLES

<u>Table</u>	<u>Page</u>
Table 3-1 ORNL Burial Ground Areas and Starting and Ending Dates of Operation	5

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
Figure 3-1 Locations of Waste Disposal Areas at ORNL	6
Figure 3-2 Hydraulic Flow Contours - Burial Ground 4	13
Figure 3-3 Burial Ground 5	15
Figure 3-4 Surface Water Monitoring Stations - Burial Ground 4	26
Figure 3-5 Boring Locations - Burial Ground 4	28
Figure 3-6 Subsurface Sampling Stations - Burial Ground 4	29
Figure 3-7 Water Table Elevation Measurement Stations - Burial Ground 4	31
Figure 3-8 Location of Monitoring Stations - Burial Ground 6	33
Figure 3-9 Boring Locations - Burial Ground 6	34
Figure 4-1 Location Map - INEL.	41
Figure 4-2 Topographic Map of RWMC Area	42
Figure 4-3 Recommended Locations of Deep Well Monitoring Station at RWMC	64

1.0 INTRODUCTION

During 1975 and 1976 Dames & Moore performed studies to develop monitoring programs which would be applicable to ERDA-owned low-level waste burial grounds. These studies led to the submission of a report to the U.S. Energy Research and Development Administration (ERDA) in July, 1976, entitled Development of Monitoring Programs for ERDA Owned Radioactive Low-level Waste Burial Sites. The report included the results of five principal tasks related to development of programs for monitoring the migration of radionuclides at low-level waste burial sites. These tasks included 1) a review of the known hydrogeologic and radiologic data for the low-level waste burial grounds at Oak Ridge, Tennessee; Hanford, Washington; Savannah River, South Carolina; Los Alamos, New Mexico; and Idaho Falls, Idaho, 2) a determination of the adequacy of the known data as it pertained to migration of radioactivity, 3) a priority rating for obtaining additional data at each site for use in defining a monitoring program, 4) the development of mathematical hydraulic and mass transport flow models for application in the design of monitoring programs, 5) the definition of generic approaches applicable to developing monitoring programs at waste burial sites. Upon conclusion of these studies, two ERDA-owned burial sites were chosen as being most appropriate for application of the generic monitoring program and it is this effort which is the subject of this report. The burial grounds at the Oak Ridge National Laboratory (ORNL) and the Idaho National Engineering Laboratory (INEL) were selected as sites for application of monitoring programs in saturated and unsaturated zones, respectively.

The purpose of the present study is to test the concept of the previously developed generic monitoring program. The previous work indicated that when there are several burial grounds or areas at a site, there are particular burial grounds or burial areas at which the installation of a monitoring network would provide the greatest amount of information with regard to radionuclide migration patterns.

Using these conclusions as guidelines, the tasks which were completed in the present study in order to test the generic monitoring approach are as follows:

- 1 - The burial grounds or burial areas at ORNL and INEL were evaluated to establish which burial ground or area should be singled out for the design of the monitoring program. This evaluation considered such factors as the location of the burial ground or area with respect to natural or selected boundaries, the available radionuclide migration data, the available hydrogeologic data and the potential for migration of radioactivity from one burial ground, crib or pit to another burial ground or area. Based on an analysis of these factors, specific locations were delineated which most clearly warrant the installation of monitoring programs.
- 2 - After the specific locations were selected, the known hydrogeologic and radiologic data applicable to these locations were reviewed and additional data requirements defined. It was concluded that additional data will be required in order to design a final reliable monitoring program. The data required to achieve these designs have been specified as have the field and laboratory programs necessary for the acquisition of these data. The field and laboratory programs have been specified as to sampling locations, procedures, equipment and personnel requirements and analytical techniques.
- 3 - Unit costs for installation of monitoring stations have been presented.

2.0 SUMMARY

The present investigation was initiated to perform confirmatory work with regard to a previous Dames & Moore study which reviewed

THIS PAGE
WAS INTENTIONALLY
LEFT BLANK

3.0 OAK RIDGE NATIONAL LABORATORY

3.1 Site Description

3.1.1 General Geologic Conditions

The ORNL is located in the Tennessee Section of the Valley and Ridge Province. This section is characterized by multiple elongated valleys which trend northeastward and are separated by ridges that are commonly 200 to 500 feet high. The ORNL Burial Grounds are located in the Bethel and Melton Valleys which are separated by Haw Ridge. Three major geologic formations of Paleozoic Age crop out in the area of Bethel and Melton Valleys. The first and youngest of these is the Chickamauga "Limestone" Group which underlies Bethel Valley, the second and oldest is the Rome Formation which underlies Haw Ridge and the third is the Conasauga Group which underlies Melton Valley. The formations in the area generally strike about N 55°E and dip toward the southeast at 30° to 40°. Local departures from the prevailing strike and dip are present, depending on the competence of the formation, particularly in the Conasauga Group (Ref. 1). The Copper Creek thrust fault, located on the west flank of Haw Ridge is a major structural feature in the area (Ref. 2).

The burial grounds are separated into two groups: those in Bethel Valley and those in Melton Valley. Table 3-1 gives the approximate area and the starting and ending dates of operations at each burial ground. Figure 3-1 shows the approximate locations of the six burial grounds. Bethel Valley which includes Burial Grounds 1, 2, and 3 is underlain by the Chickamauga Limestone Group which is typically a thin-bedded formation which ranges up to 2,000 feet in thickness (Ref. 1,3). The formation, which can be divided into eight lithologic units, is composed predominantly of limestone, although shale, siltstone and bedded chert "comprise a prominent minor part" (Ref. 3). Fractures and solution openings occur between the beds of the Chickamauga, but "it is believed that the rock is free of large openings" such as those found in other limestone formations (Ref. 2).

TABLE 3-1

ORNL BURIAL GROUND AREAS AND
STARTING AND ENDING DATES OF OPERATION

Burial Ground 1	1.5	1943	1944
Burial Ground 2	3	1944	5/1946
Burial Ground 3	5.5	5/1946	7/1951
Burial Ground 4	23	2/1951	7/1959
Burial Ground 5	33	7/1959	1973
Burial Ground 6	70	1973	In Operation

LOCATIONS OF WASTE DISPOSAL AREAS AT ORNL

Of the three formations in the area of interest, the Chickamauga generally exhibits the least thickness of residuum. It is composed typically of heavy yellow or yellow-brown clay containing small chips of white or yellow chert, fragments of porous brown limestone and small blocks of limestone (Ref. 1).

The Rome Formation underlies Haw Ridge and is made up of thin bedded shale, siltstone and sandstone. It is thrust faulted over Chickamauga and small faults and cracks are common within it (Ref. 1, 3). The formation has a relatively thin mantle of residual clay and a near-surface weathered rock zone less than 20 feet thick (Ref. 1). There are no burial grounds located in this formation.

Melton Valley which includes Burial Grounds 4, 5 and 6 is underlain by the Conasauga Group, also referred to as the Conasauga Shale, which has an estimated thickness of 1,500 feet (Ref. 4). Small anticlines and synclines are a common feature of the Conasauga Shale (Ref. 5). The general stratigraphic sequence is gradational and ranges from red-brown shale with thin-bedded siltstone and silty layers with very little limestone at the base of the sequence along the south-eastern flank of Haw Ridge to thin gray calcareous to silty shale layers interbedded with increasing thicknesses of limestone and siltstone at the top of the formation along the northwestern base of Copper Ridge (Ref. 1, 5). Conasauga Shale generally weathers to illite and vermiculite and the residuum ranges from silty brown-tan micaceous clay at the base of the formation to yellow-tan to brown clay with abundant shale chips and flakes with resistant sandstone lenses at the top of the formation. The silty brown-tan micaceous clay retains evidence of the bedding of the parent rock in most places and contains well developed joints that are open near the surface (Ref. 1, 6). This weathered zone, in general, is thicker in topographically high areas with an average thickness of 20 feet, but it can sometimes be found ranging up to 35-40 feet thick. At lower elevations the weathered zone has an average depth of 4-5 feet (Ref. 1, 2, 5).

3.1.2 General Hydrologic Conditions

All the burial grounds are in the White Oak Creek drainage basin with the exception of the southwest corner of Burial Ground 3. After leaving Bethel Valley, White Oak Creek receives the drainage of Melton Valley via the Melton Branch of White Oak Creek and drains to White Oak Lake and eventually to the Clinch River. The drainage occurs through surface runoff and intermittent streams that receive ground water from seeps located approximately at the stream elevation. The characteristics of the undisturbed overburden of the Chickamauga Limestone and the steep terrain underlain by the Rome Formation result in increased surface runoff and lowered infiltration rates. Although a substantial quantity of water is probably stored in the many small openings present in the Chickamauga Limestone within about 100 feet of the land surface, the rates and quantities of water movement for the most part are relatively small in this formation (Ref.1). The Rome Formation has very limited capacity for receiving, storing and transmitting water. It acts as a minor recharge basin for the Chickamauga and Conasauga Groups.

Subsurface water is restricted almost entirely to the upper 100 feet in the Conasauga Shale and the weathered zone contains a major part of this water. Within the unweathered zone the water movement is primarily along the strike and in the weathered zone it generally follows the gradient of the ground water table contours. Hydraulic conductivities in the weathered zone are not known accurately, but it has been noted that the greatest permeability is associated with the transition between the weathered and unweathered zones (Ref. 2). Recharge to the undisturbed Conasauga Shale due to precipitation infiltration is estimated to be low due to limited availability of unsaturated space in the small fractures and joints. This rate probably has increased within the burial grounds due to the disturbance caused by the excavation and backfilling procedures. Impact of the increased infiltration rates on the ground water table has not been adequately defined.

3.1.3 Bethel Valley Burial Ground Conditions

Prior to recognition of the Conasauga Shale as the more desirable solid-waste disposal medium, burial of low-level solid waste was performed in the Chickamauga Limestone of the Bethel Valley. During the operation of Burial Grounds 1 and 2, records of waste characteristics, radioactivity content and burial location were not kept. Records kept on Burial Ground 3 were destroyed by fire (Ref. 2).

Burial Ground 1 is located on the north side and at the foot of Haw Ridge and southeast of White Oak Creek. It was closed to operations some time in 1944 following the discovery of ground water in one of the burial trenches. The burial ground lies in the path of the surface water drainage from Haw Ridge to White Oak Creek and this leads to the development of marsh conditions in the topographically low portions of the area following periods of rain and during wet seasons. The ground water table has been reported to range from 7 to 14 feet below ground surface and the local ground water gradient suggests that the direction of ground water flow roughly parallels surface runoff (Ref. 2,7). Analyses of water samples taken from one seep located about 150 feet west and from two wells west of the burial ground has indicated that this burial ground is not a major contributor of radioactivity to White Oak Creek (Ref. 7). Maximum detected values of Sr-90 and Cs-137 concentrations were 0.18 and 0.012 pCi/ml, respectively.

Burial Ground 2 is located to the north of Burial Ground 1 northwest of White Oak Creek on the side of a low-lying hill. The site of this burial ground was selected to reduce the waste hauling time, to provide all-weather access, and to utilize an area that had low potential use as a building site. The characteristics of the buried waste are thought to range from construction debris and waste

from temporary sanitation facilities to highly contaminated alpha waste (Ref. 2). The ground water table has been reported to range from approximately 5 feet below ground surface near the base of the hill to nearly 30 feet below in the topographically high portion of the burial ground. The present state of ground water contamination is not known. "That groundwater contamination may have occurred at some time in the past is suggested by the removal of a contaminated tree found near the parking lot north of Building 4500" (Ref. 2).

Burial Ground 3 is located north of Haw Ridge and approximately one-half mile west of Burial Ground 1. Initially alpha wastes in drums were deposited in concrete-lined trenches in the northeast end of the burial ground. Later, alpha wastes were placed directly in unlined trenches and covered with concrete as the burial ground was extended to the west. Beta-gamma wastes were buried in separate unlined trenches and backfilled with the excavated soil. The depth of the trenches generally did not exceed 15 feet, and during the rainy season they often contained water (Ref.2). Hard rock was encountered several times during trench excavations. Although most of the burial ground is in the White Oak Creek drainage basin, a small part in the southwest corner drains into Racoon Creek. A small intermittent tributary of White Oak Creek runs through Burial Ground 3. The depth to the water table has been recorded to range from 8.9 feet in the northwest corner of the site, to 33.9 feet in the southwest corner (Ref. 2,3,7). Recent analyses of samples from the wells inside and around the burial ground have indicated a maximum Sr-90 concentration of about 0.45 pCi/ml (Ref. 7). Earlier investigations in 1964 showed the presence of Sr-89, Sr-90, tritium and trivalent rare earths in the ground water (Ref. 2).

3.1.4 Melton Valley Burial Ground Conditions

In March, 1948 a study of the stratigraphy, structural geology and hydrology of the Bethel and Melton valleys was undertaken to determine the suitability of the area for the disposal of liquid

radioactive waste (Ref. 3). After three years of study, it was concluded that underground contamination in the Chickamauga Limestone of Bethel Valley seemed inevitable and it was recommended that future radioactive waste be assigned to burial in the Conasauga Shale of Melton Valley. The basis for this recommendation was that the Conasauga Shale appeared more impermeable and less susceptible to dissolution by ground water than the Chickamauga limestone. This led to the development of seven liquid waste pits in the Melton Valley. Experimental evidence subsequently obtained from these pits showed that the permeability of the Conasauga Shale was greater than expected and that the primary mechanism inhibiting migration was the ion-exchange characteristics of the shale (Ref. 2). Burial Grounds 4, 5, and 6 were located in the Conasauga Shale in Melton Valley.

3.1.4.1 Burial Ground 4

Burial Ground 4 is located on the south side and at the foot of Haw Ridge west of White Oak Creek. This location is in the older part of the Conasauga Group. The burial ground is underlain by noncalcareous shale interbedded with calcareous shale and thin silty limestone. It was utilized for disposal of solid radioactive waste from both onsite and offsite facilities. The wastes were sorted according to the type and intensity of radiation emitted. The trench dimensions generally ranged from 50 to 400 feet in length, 8 to 30 feet in width, and 8 to 14 feet in depth. Beta-gamma contaminated wastes were buried in unlined trenches in the shale and were covered with the original soil. Alpha contaminated wastes were buried in unlined trenches, capped with 18 inches of concrete, and the trenches were backfilled with original soil. Recoverable higher level alpha wastes were placed near the northern edge of the burial ground in auger holes 1 to 2 feet in diameter and about 15 feet deep that were often lined with concrete. An exact inventory of wastes disposed of is not available, since the burial ground records prior to 1957 were destroyed in a fire (Ref. 6,7).

As shown in Figure 3-2, the surface and ground water drainage from the burial ground is primarily southeast toward White Oak Creek and its unnamed intermittent tributary running adjacent to the southeastern boundary. Surface runoff from the catchment area to the northwest at the base of the Haw Ridge has recently been limited by construction of an interceptor ditch on the north side of Lagoon Road and several conductor ditches across the burial ground. The water table ranges in depth from zero feet in low lying areas to 15 feet in topographically high areas. Until late 1973 the ground surface in this area was covered with fill in thicknesses ranging from a few feet near the Lagoon Road to 20 feet at the southeastern edge of the burial ground. This covering has resulted in a general rise of the water table in this area. Ground water table contours are a subdued replica of the surface topography (Ref. 7). The rate of ground water movement is not well known, although in areas where the soils have been disturbed and backfilled, more rapid movement has been observed in the undisturbed shale (Ref. 7). Three seeps currently exist in the burial ground. These are probably due to the semi-permanent perched water bodies within the trenches resulting from the more permeable nature of the backfill and the trench contents (Ref. 6,7).

The existing ground water regime is currently being studied with a shallow well ground water monitoring system. The system consists of thirty-seven wells drilled during the summer of 1973 at the eastern edge of the burial ground. The wells are located on a 30-meter grid system and have a maximum penetration of 12 feet (Ref.7). Twenty-one previously constructed shallow wells exist within and near the burial ground. Water table elevations are available from these wells, but the data are not reported on a consistent seasonal and/or annual basis.

Radionuclide concentrations have been reported in the water table aquifer beneath the burial ground, at the seeps, and at White Oak Creek. Sampling and analyses have been performed on an irregular basis at these locations since 1959. During the 1973-1974 period, sampling was performed in the newly established thirty-seven wells of the grid system, as well as in the old twenty-one wells. The concentrations of Sr-90 in the old wells ranged from negligible to 36

GROUND WATER CONTOURS - BURIAL GROUND 4

pCi/ml, and in the new wells ranged from 0.8 to 15 pCi/ml. The concentrations of Cs-137 in the old wells ranged from 0.0 to 0.5 pCi/ml, and in the new wells ranged from 0.01 to 0.6 pCi/ml. Monitoring of White Oak Creek showed that 1.19, 1.97, and 2.19 Ci/year of Sr-90 has been discharged from this burial ground to the stream for the years 1971, 1972, and 1973, respectively (Ref. 8).

3.1.4.2 Burial Ground 5

This burial ground (Figure 3-3) is underlain by the Conasauga Shale and is separated into two sections: a northern section to provide storage for recoverable alpha-contaminated wastes, and a southern section for the burial of low-level solid waste. The northern section is underlain by siltstone with interbedded shale and lenses of limestone. The southern section is located in well jointed, silty shale with interbedded siltstone and minor limestone lenses, and its southeasternmost zone is in beds of limestone as much as 10 inches thick interbedded with shale. The southern section is a gently sloping hillside with several ravines and localized areas with a high ground water table. The presence of these ravines, and an experimental hydrofracture site in the southwest corner of the burial ground reduce the area usable for disposal of waste to considerably less than the 33 acres comprising the site.

As in other burial grounds at ORNL, beta-gamma wastes were buried in trenches at depths up to 15 feet and were backfilled with the excavated soils. Alpha-contaminated wastes were similarly buried in unlined trenches with concrete caps. The trenches were generally excavated lengthwise from 40 to 500 feet in a direction normal to the strike of the Conasauga Shale. The longest trenches ever employed at ORNL are located in the southwest section of Burial Ground 5. Auger holes containing wastes with higher concentrations of radioactivity are also present (Ref. 2,7).

Surface water drainage is predominantly southeast towards Melton Branch and southwest toward White Oak Creek. The regional ground water contour map reveals that the steepest gradient is in the direction of the Melton Branch which implies that the prevailing movement

REVISIONS
BY _____ DATE _____

FILE _____

BY _____ DATE _____
CHECKED BY _____

0 100 200
FEET

Contour Interval - 5 feet

LOCATION MAP BURIAL GROUND 5

REFERENCE: COWSER, LOMENICK, AND MCMASTER

DAMES & MOORE

is to the southeast. Minimum depth to the ground water table during the wet season ranges from zero on the southern edge of the White Oak Creek floodplain to nearly 20 feet near the summits of the local hills. Thirteen seeps at the southern ends of the trenches have been documented. These seeps generally occur in sections where some of the longest trenches are located. They are probably due to the so-called "bathtub effect" which results from a combination of the length and incline of the trench with respect to the surface, higher permeability of the trench cover and contents, and the high precipitation (Ref. 2).

Only minor monitoring of the burial ground has been performed until recently. There are extensive measures being taken for water management in this area, measures such as the installation of surface water drainage systems, the capping of trenches and the installation of isolation dams within the long trenches. Information obtained as a result of the implementation of these measures will increase the available data.

Many wells exist along the periphery and within Burial Ground 5. Some wells penetrate only trench excavations, while others penetrate undisturbed soils. Early monitoring studies in 1964 detected the presence of Sr-89, Sr-90, Ru-106, tritium and trivalent rare earths in the ground water outside the trenches. Tritium found in the Melton Branch of White Oak Creek has been traced to this burial ground. Analyses of samples taken from seeps in 1974 have revealed Sr-90, Sb-125 and tritium. The average concentration of Sr-90 in eleven of the thirteen seeps below the south edge of the burial ground was about 10 pCi/ml. The other two seeps contained an average of 7,100 pCi/ml. Tritium concentrations for the seeps averaged 1.85×10^5 pCi/ml. The alpha in one seep was identified as Cm-244 and was at a concentration of 2.8 pCi/ml (Ref. 7). Stream monitoring at station No. 4 on the Melton Branch, has shown that about 0.61, 0.94, and 1.36 Ci/year of Sr-90 were discharged during the years 1971, 1972, and 1973, respectively. It has been estimated that 90 percent of this discharge may be attributable to Burial Ground 5 (Ref. 7).

3.1.4.3 Burial Ground 6

Burial Ground 6 is located northwest of White Oak Lake, southeast of Lagoon Road and Haw Ridge, northeast of the Clinch River, and southwest of an intermittent stream that separates it from the intermediate level liquid radioactive waste pits Nos. 2, 3, and 4. The site is underlain by calcareous shales interbedded with thin silty limestone and thin pure limestone lenses. The burial ground is divided into three sub-basins on the basis of the local topography and drainage. Several intermittent streams exist within ravines cutting through the burial ground.

Surface drainage and ground water movement is principally down-slope from the summits associated with each sub-basin towards the intermittent streams and finally toward White Oak Lake. Between one-fourth and one-third of the burial ground is unsuitable for waste disposal because of steep terrain or a shallow water table less than 6 feet below the ground surface. The ground water table beneath the site is a subdued replica of the local topography and ranges from less than 6 feet in the low-lying areas to over 21 feet near the summits of the local hills (Ref. 2,4).

Most of the waste trenches are located in areas where the highest ground water level is below the base of the trenches. Notable exceptions to this trend include the small trenches excavated on a low terrace adjacent to White Oak Lake where water levels as shallow as 8 feet below the surface have been observed during the seasonal rise in water table. The trenches are generally 15 to 20 feet in depth, about 10 feet in width, and less than 50 feet in length. In the earlier days of the operations, two trenches which exceed 100 feet in length were excavated in the northern section of the burial ground. Trenches are generally excavated lengthwise normal to the strike of the formation or at least at large angles to the strike in order to minimize slumping. The bottoms of the current trenches contain a thin layer of gravel to improve drainage. Wells with perforated pipes are installed before backfilling to provide individual monitoring stations for each

trench. In addition to the trench wells, there exist several wells for monitoring the ground water elevations. Some wastes with higher concentrations of radioactivity are disposed of in concrete or stainless steel-lined auger holes (Ref. 2,4). At the present time, no seepage or migration of radionuclides has been detected from this burial ground.

3.2 Selection of Burial Ground for Testing the Generic Monitoring Program at ORNL

In the previous study by Dames & Moore, it was determined that the location and distance between monitoring stations and the frequency of sampling are dependent on the direction and velocity of ground water flow and solution-soil interactions. It was decided that monitoring programs should be designed to detect radioactivity at an arbitrary chosen level of 0.1 MPC. It was also determined that the locations of primary monitoring stations and sampling frequencies must be selected so that at least one year would elapse between the time radioactivity exceeding the chosen level (0.1 MPC) was first detected and the time it reached selected natural boundaries in the area surrounding the burial ground.

It was determined that the areal configuration of monitoring stations and the frequency of sampling should be such that migrating radioactivity from an instantaneous point source release is intercepted. The flow direction of the transport medium determines the general area in which monitoring stations should be located. At a burial site where a unidirectional ground water flow is present, monitoring stations need be established only on the side of the burial ground toward which the ground water flow will carry dissolved radioactivity. The frequency of sampling and the spacing between stations is determined by flow velocity and dispersion characteristics. The rate of advance of a radioactive front is determined by the solution-soil/rock interaction and establishes the sampling frequency required to intercept a given radioactivity concentration. The number of stations necessary for reliable monitoring is determined by the distance from the burial ground boundary (worst case) to the nearest potential point of interception.

Six radioactive waste burial grounds exist at the ORNL site. Three of these, Burial Grounds, 1, 2, and 3, are located in Bethel Valley and three, Burial Grounds, 4, 5, and 6, are located in Melton Valley. A study of the conditions and the information available for each burial ground was conducted to select the site(s) at which it would be least costly to implement a monitoring program and more advantageous from the point of view of testing the efficacy of the generic monitoring concept.

3.2.1 Bethel Valley Burial Grounds

The three burial grounds in the Bethel Valley were collectively eliminated because of their geologic and hydrologic complexity and a lack of sufficient available background information. Difficulties that would be encountered in implementing a monitoring program at the Bethel Valley sites include the following:

- 1 - Precise locations of the burial trenches are unknown.
- 2 - Non-uniform burial practices were employed.
- 3 - Specific information is lacking on the contents of the trenches.
- 4 - Ground water contour maps are not recent enough or sufficiently detailed to provide an adequate understanding of time-dependent hydraulic flow patterns.
- 5 - The bedrock beneath the valley is a limestone which contains solution channels of unpredictable occurrence.
- 6 - No trench wells exist for sampling trench water.
- 7 - No quantitative geologic and hydrologic data of value exists.
- 8 - Water balance of the site is not known.

- 9 - Available data is insufficient for development of an understanding and preliminary prediction of radiocontaminant migration patterns in ground water.
- 10 - Very few lithologic logs exist for borings drilled at these burial grounds.

3.2.2 Melton Valley Burial Grounds

The Melton Valley burial grounds are underlain by the Conasauga Shale which presents fewer difficulties in establishing a monitoring program than does the Chickamauga Limestone which underlies the Bethel Valley. Even though at several places the Conasauga Shale exhibits erratic communication between fractures and joints, as evidenced by significant differences in ground water levels taken a short distance apart, it is not as complex as the Chickamauga Limestone which contains randomly distributed solution channels. Thus, hydrologic data collected in the Conasauga Shale can be extrapolated more reliably and reliable new data can be obtained more easily than in the Chickamauga Limestone.

The three burial grounds in Melton Valley were examined for viability as sites for testing the applicability of the generic monitoring approach. It was determined that monitoring programs should be instituted at two of the three burial grounds rather than at a single site. Burial Ground 6 was chosen for the development of a monitoring program because it was judged to be the most effective burial ground for testing the generic monitoring program. Burial Ground 4 was chosen, at the request of the Oak Ridge program manager, in order to define the current and future extent of leakage from this burial ground.

3.2.2.1 Burial Ground 4

Hydrogeologic conditions at this burial ground are simpler than those at other Melton Valley burial grounds. Burial Ground 4 exhibits

relatively simple surface and ground water hydraulic flow regimes which trend to the east and southeast and accordingly can be monitored with relatively few monitoring locations. The burial ground was closed in 1959 and the current hydrogeologic and radiologic conditions appear to be relatively stable.

There are a number of conditions at Burial Ground 4, however, which have contributed to the leakage and make it a more difficult burial ground to monitor. These conditions are summarized below:

- 1 - There are a number of seeps within the burial ground resulting from construction of very long trenches at angles to the ground surface.
- 2 - Buried wastes are periodically in contact with ground water.
- 3 - The placement of fill on top of the burial ground has resulted in a general rise in the level of the ground water table.
- 4 - The presence of a liquid waste transfer line outside the burial ground but in close proximity to it, presents a potential point source unrelated to the burial ground as does the presence of an old radioactive waste pond area adjacent to the southeast corner of the burial ground.
- 5 - The precise locations of burial trenches are not known.
- 6 - The composition of trench contents is not known.
- 7 - Few lithologic logs exist for wells.
- 8 - Ground water contour maps are not recent enough or sufficiently detailed to provide an adequate understanding of time-dependent hydraulic flow patterns.
- 9 - The values for several hydrogeologic parameters of soils are lacking or not site-specific.

10 - Water balance of the site is not known.

3.2.2.2 Burial Ground 5

After it was decided that a monitoring program would be set up at Burial Ground 4 to monitor the current leakage, it remained only to determine whether Burial Ground 5 or Burial Ground 6 would be most economically and technically suitable for testing of the generic monitoring program. Burial Ground 5 has associated with it a number of negative factors which would make it more costly and difficult to monitor. The most important of these is the fact that Burial Ground 5 is also known to be discharging radioactivity into the Melton Branch of White Oak Creek. The other factors which would preclude the selection of Burial Ground 5 for design of a generic monitoring program are given below:

- 1 - The hydraulic flow patterns at Burial Ground 5 are complicated by the fact that several ravines containing intermittent streams traverse the burial ground.
- 2 - There are a number of ongoing construction activities which continuously alter the hydraulic flow patterns at the burial ground and prevent them from stabilizing.
- 3 - The burial ground contains thirteen surface seeps.
- 4 - A number of very long trenches are present within the burial ground.
- 5 - A number of auger holes containing higher level wastes are located between the low-level waste trenches.
- 6 - Available data is insufficient for development of an understanding and preliminary prediction of radiocontaminant migration patterns in ground water.

7 - Available data is not site-specific.

8 - Water balance of the site is not known.

3.2.2.3 Burial Ground 6

Because Burial Ground 6 is the only burial ground in Melton Valley that has not been shown to be leaking, it was chosen as the burial ground most suitable for testing the generic monitoring program. Like Burial Grounds 4 and 5, Burial Ground 6 exhibits some features which make it less than ideal for implementation of a monitoring program. These features are:

- 1 - The topography within the burial ground consists of three small hills separated by ravines containing intermittent streams. This topographic configuration results in multi-dimensional hydraulic flow patterns which make monitoring more difficult.
- 2 - Burial activities are still going on at the site. Disturbance of soils during excavation and backfilling procedures results in altered hydraulic flow patterns.
- 3 - Available hydrogeologic and radiologic data is not site-specific nor is it sufficient for development of an understanding of radionuclide migration patterns.
- 4 - The water balance of the site is not known.

In spite of these difficulties, there are a number of positive aspects which tend to minimize the cost and effort required to design and implement a generic monitoring program at Burial Ground 6. These positive aspects include the following:

- 1 - Most of the trenches in Burial Ground 6 are relatively short, thus minimizing the possibility of development of trench seeps.

- 2 - Trenches are equipped with sumps and layers of gravel to aid drainage from their bottoms.
- 3 - Trenches are located in areas where the highest expectable ground water levels are below the buried wastes.
- 4 - Trench locations are accurately known.

In addition to these positive aspects an added benefit will be derived from the fact that Burial Ground 6 is underlain by the same formation, the Conasauga Shale, which underlies the other Melton Valley burial grounds. Since the other burial grounds are known to be discharging radioactivity beyond site boundaries, comparative studies can be done to determine the reasons for their leaking. The fact that Burial Ground 6 is not discharging radionuclides beyond its boundaries is thought to be due primarily to the modern burial practices in use there. By instituting an appropriate monitoring program at Burial Ground 6, the question of how effective superior burial practices are in preventing or reducing potential future radionuclide migration can be resolved.

Because most of the trenches in Burial Ground 6 are located in the northeast portion of the site, only that portion of the burial ground will be considered. This will simplify the task and reduce the costs of designing and implementing a monitoring program, since the northeast portion corresponds to one of the three hills inside the burial ground.

3.3 Monitoring Programs

This section presents monitoring programs for Burial Grounds 4 and 6 based on the available data and discusses additional data required for the design of a future monitoring program which will test the applicability of the generic monitoring approach. The currently available data on Burial Grounds 4 and 6 are not sufficient for

the development of an adequate understanding of radionuclide migration patterns which is necessary for the design and implementation of a reliable monitoring program. Therefore, the monitoring programs will be designed to define those components of the migration process perceived to be the most important and to define additional data requirements for the design of a final reliable monitoring program.

3.3.1 Burial Ground 4

Burial Ground 4 is known to be discharging radionuclides to White Oak Creek. It is necessary, therefore, to determine the concentrations of radionuclides at points of discharge. Other components of the migration process, such as point of origin, distance, direction and rates of movement, can be defined after the data necessary for the design of a reliable monitoring program has been obtained.

The monitoring program at Burial Ground 4 should include the location of surface water monitoring stations at all seeps attributed to burial ground operations and the installation of a minimum of three to five monitoring stations on White Oak Creek at the locations shown in Figure 3-4. Samples should be taken at least every two months or preferably every month and should be analyzed for dissolved and suspended radionuclide content and chemical composition. Analyses should include tests for ^3H , ^{90}Sr , ^{137}Cs , and ^{239}Pu . Specifications on surface water monitoring are located in Appendix A.

In order to design a monitoring program which tests the generic monitoring approach, additional data is required. The additional data requirements are roughly composed of two parts. The first part includes the measurement of hydrogeologic parameters and a better definition of the radiologic conditions at the site. The second part includes the determination of the hydraulic flow patterns and the water balance for the burial ground.

A test boring program would be necessary at the locations specified in Figure 3-5 to clarify the nature of subsurface geologic condi-

SURFACE WATER MONITORING STATIONS - BURIAL GROUND 4

tions and to obtain undisturbed soil samples for measurement of hydrogeologic parameters. It is estimated that at least five (as shown in Figure 3-5) and preferably eight borings will be needed in each of three critical areas: along the flood plain of White Oak Creek to the east of the burial ground, north of the intermittent stream which lies south of the burial ground, and between Lagoon Road and the burial ground. All borings are to be drilled at least a few feet into unweathered bedrock and at least two of the borings in each area are to be sampled continuously. Spacing of the borings will be such that the maximum areal coverage will be obtained. In general, mobility around the burial ground is considered poor. A "swamp buggy" mounted rig and/or a "skid rig" would be the most suitable type of equipment for drilling these borings. Access to the eastern and southern areas may be achievable only by passage down the paved conductor ditches which cut across the burial ground. Detailed discussion of methodology for completing these borings is presented in Appendices A and B.

Hydrogeologic parameters will be measured in the undisturbed samples using both field and laboratory testing techniques. The hydrogeologic parameters of primary importance are saturated hydraulic conductivity, effective porosity, distribution coefficients, storage coefficients, dispersion characteristics, and chemical properties. At least one determination of each of these parameters should be made in each boring for each distinctive stratigraphic unit, and a determination of vertical variability within units should be made if needed. Laboratory and field techniques and procedures relating to these parameters can be found in Appendix A.

A subsurface water sampling program is required to better define the radiologic conditions in Burial Ground 4. As shown in Figure 3-6, the stations should include some of the existing wells and some of the wells resulting from the recommended boring program. Samples should be taken monthly and should be analyzed for dissolved and suspended radionuclide content and chemical composition. Analyses should

BORING LOCATIONS - BURIAL GROUND 4

KEY:

- PERMANENT SEEP
- ▲ BORING LOCATION TO BE SAMPLED
- EXISTING WELL TO BE SAMPLED

SUBSURFACE SAMPLING STATIONS - BURIAL GROUND 4

include tests for ^3H , ^{90}Sr , ^{137}Cs , and ^{239}Pu . The program should continue until sufficient data is available to allow development of a reliable monitoring program to test the generic approach.

Hydraulic flow patterns should be determined by making measurements of ground water levels at locations indicated in Figure 3-7. The locations include the existing well field and the wells resulting from the boring program. Measurements should be made on at least a seasonal or preferably a monthly basis. To aid in determining the water balance for Burial Ground 4 two ring-type infiltrometers and one evaporation pan should be installed. Infiltrimeters should be placed on flat surfaces away from heavy vegetative cover. One infiltrimeter should be installed where the uncontaminated fill spread on top of the trenches is the thickest and the other where the fill is thinnest. Two possible infiltrimeter locations are indicated in Figure 3-7. The evaporation pan should be installed near one of the infiltrimeters. The data obtained from the evaporation pan and infiltrimeters, in conjunction with the hydraulic flow patterns and hydrogeologic parameters, should allow determination of the water balance for the site. The program should continue until a reliable monitoring program is established. After that the frequency of sampling can be adjusted.

3.3.2 Burial Ground 6

Burial Ground 6, as far as is known, is not discharging any radiocontaminants to its natural boundaries. Such a situation requires that the potential origins of radioactivity, i.e. the locations, types, and quantities of radiocontaminants that can migrate, should be defined. In addition, the monitoring program must be designed to detect any future migration of radionuclides via subsurface routes.

The proposed monitoring program for Burial Ground 6 is composed of two parts. The first part consists of surveillance of the existing

WATER TABLE ELEVATION MEASUREMENT STATIONS - BURIAL GROUND 4

trench sump wells and the established well field within the burial ground. The trench wells should be monitored to detect any accumulation of water in the trenches. Should water be found to accumulate in the trenches, it should be sampled for specific dissolved and suspended radionuclide content and leachate chemistry. Analyses should include ^3H , ^{90}Sr , ^{137}Cs , and ^{239}Pu . The sampling should be performed monthly or preferably twice a month. The existing wells within the burial ground (Figure 3-8) should be monitored to better define the radiologic conditions. Ground water in these wells should be sampled on a monthly basis and analyzed for gross-alpha, gross-beta, and tritium content. Should these analyses indicate the necessity, specific dissolved and suspended radionuclide content and water chemistry should be determined.

The second part of the monitoring program consists of the establishment of ground water stations (Figure 3-8) at the perimeter of the northeast section of the burial ground along the possible migration paths of ground water moving from the trenches to the natural boundaries. The monitoring stations constitute a monitoring line approximately parallel to the ground water contours. The wells should penetrate all stratigraphic layers where lateral ground water movement can potentially occur. They should be sampled on a monthly basis for dissolved and suspended radionuclide content and water chemistry. Analyses should include those for ^3H , ^{90}Sr , ^{137}Cs , and ^{239}Pu . The sampling frequency and the distance between sampling stations is detailed in Appendix C.

Additional data is required, for the design of a reliable monitoring program. The data requirements include the measurement of various hydrogeologic parameters and hydraulic flow patterns and the determination of the water balance in the burial ground.

A test boring program at locations specified in Figure 3-9 would be necessary to determine subsurface geologic conditions and to obtain undisturbed soil samples for measurement of hydrogeologic parameters.

It is estimated that twelve to twenty borings will be needed. All borings are to be drilled at least a few feet into unweathered bedrock and at least four of the borings are to be sampled continuously. A detailed discussion of the prescribed methodology for these borings is presented in Appendices A and B.

Hydrogeologic parameters will be measured in the undisturbed samples using both field and laboratory testing techniques. The parameters of primary importance are saturated hydraulic conductivity, effective porosity, distribution coefficients, storage coefficients, dispersion characteristics, chemical properties, and radionuclide content. At least one determination of each of these should be made in each boring for each distinctive stratigraphic unit. The vertical variability within units should be determined, if needed. Laboratory and field techniques and procedures for determining these parameters can be found in Appendix A.

The hydraulic flow patterns in Burial Ground 6 should be determined by taking measurements of ground water levels at locations indicated in Figure 3-9. These locations include the existing well field and wells drilled during the proposed boring program. Measurements should be made on at least a seasonal and preferably a monthly basis. A ring-type infiltrometer and an evaporation pan should be installed at the approximate location indicated in Figure 3-9. They should be installed on relatively flat surfaces and away from heavy vegetative cover. The data obtained from these instruments, in conjunction with the hydraulic flow patterns and site-specific hydrogeologic parameters, should enable a determination of the water balance for the site to be made. The program should be continued until a reliable monitoring program has been established. After that the frequency of sampling can be adjusted to suit existing conditions.

3.4 COST ESTIMATE - ORNL+

Installation plus operation for one year

BURIAL GROUND 4

I. Monitoring Program

A. Surface Water Monitoring Stations (3)

1) Flow proportional composite sampler	3 x \$1,400	= \$ 4,200
2) Flow meter with digital printer and Parshall flume	3 x \$3,000	= \$ 9,000
3) Installation	3 x \$3,000	= \$ 9,000
4) Professional Labor 12 man days	12 x \$100	= \$ 1,200
5) Sample Analysis (monthly)	3 sa** x 12 mo x \$300	= \$ 10,800
dissolved and suspended fractions	3 sa** x 12 mo x \$600	= \$ 21,600
6) Sample Collection 1 man day/month	1 x 12 mo x \$100	= \$ 1,200
	Task Total	\$ 57,000

B. Seep Monitoring (3)

1) Sample (monthly)	3 md*/year x \$100	= \$ 300
2) Sample Analysis (RN's)	3/mo x 3 mo x \$300	= \$ 2,700
	Task Total	\$ 3,000

II. Determination of Hydrogeologic Parameters and Radiological Conditions

A. Test Borings (15)

1) Drilling		
a. Mobilization and Demobilization (2 rigs)		= \$ 1,000
b. Footage - 12 holes @ 20 feet x \$40/ft		= \$ 9,600
- 3 holes @ 60 feet x \$40/ft		= \$ 7,200
2) Soil Sampling		
a. 11 holes-every 5 feet - 11 holes x 4 sa x \$30/sa		= \$ 1,320
b. 4 holes-continuous - 4 holes x 30 sa x \$30/sa		= \$ 3,600
3) Professional Supervision of Borings	25 md x 10 hrs x \$10/hr	= \$ 2,500
	Task Total	\$ 25,220

B. Field Testing

1) Pump Testing (3 wells)		
a. Pumping Phase	76 md x 10 hrs x \$10/hr	= \$ 7,600
b. Analysis	4 md x 10 hrs x \$10/hr	= \$ 400
c. Drill rig (3 wells)	3 x 3 days x 10 hrs x \$60/hr	= \$ 5,400
2) Tracer Tests (dispersion)		
a. Gross estimate	10 md x 10 hrs x \$10/hr	= \$ 1,000
	Task Total	\$ 14,400

+ Assumptions

1. Lab and field testing costs are estimated using normal commercial rates (as of 9/77).
2. All professional labor costs were estimated arbitrarily at \$10 per hour for uniformity and because rates may vary widely for performing some of the more complex tasks.

* md = man day = \$10/hour x 10 hours/day

** sa = samples

C. Laboratory Testing

1) Saturated Hydraulic Conductivity (K _s) (Est.) 4 stratigraphic units/hole x 4 holes	16 sa x \$150	= \$ 2,400
2) Porosity (n)	16 sa x \$25	= \$ 400
3) Distribution Coefficient (k _d)	16 sa x \$100	= \$ 1,600
4) Storage Coefficient (S)	16 sa x \$25	= \$ 400
	Task Total	\$ 4,800

D. Radiological Conditions

1) Analysis of Initial samples from Borings		
a. Chemical composition	31 sa x \$120	= \$ 3,720
b. RN	31 sa x \$300	= \$ 9,300
2) Subsurface Water Sampling (28 wells)		
a. Sample Collection (monthly)	3 md x 12 mo x 10 hrs x \$10/hr	= \$ 3,600
b. Chemical Analysis	28 x 12 mo x \$120	= \$ 40,320
c. RN	28 x 12 mo x \$300	= \$ 100,800
	Task Total	\$ 157,740

III. Hydraulic Flow Patterns and Water Balance Determination

A. Ground Water Level Measurements	3 md/mo x 12 mo x 10 hrs x \$10/hr	= \$ 3,600
	Task Total	\$ 3,600

B. Infiltrimeters (2) and Evaporation Pan (1) Installation		= \$ 2,000
	Task Total	\$ 2,000

Task IA	\$ 47,000
Task IB	\$ 3,000
Task IIA	\$ 25,220
Task IIB	\$ 14,400
Task IIC	\$ 4,800
Task IID	\$ 157,740
Task IIIA	\$ 3,600
Task IIIB	\$ 2,000

TOTAL BURIAL GROUND 4 \$ 267,760

* md = man day = \$10/hour x 10 hours/day

** sa = samples

BURIAL GROUND 6

I. Monitoring Program

A. Surveillance of Sumps (monthly)

1) Sample Collection	12 md/yr x 10 hrs x \$10/hr = \$	1,200
2) Analysis of Water Samples for Gross Alpha and Beta (assume 5 sumps/mo contain water)	5 sumps x 12 mo x \$50/sa = \$	3,000
3) Specific Radionuclides (Assume half of samples require testing)	30 sa x \$300 = \$	9,000
	Task Total	\$ 13,200

B. Sampling of Existing Wells (11)-(Monthly)

1) Analysis of Water Samples-some Gross Alpha and Beta	12 md x 10 hrs x \$10 = \$	1,200
	11 wells x 12 sa x \$50 = \$	6,600
2) Specific RN's (Assume 20)	20 sa x \$300 = \$	6,000
	Task Total	\$ 13,800

C. Monitoring Line - 23 Borings

1) Drilling		
a. Mobilization and Demobilization (1 rig)		= \$ 500
b. Footage 23 holes @ 25 feet	23 holes x 25 ft x \$40/ft = \$	23,000
c. Soil Sampling (every 5 feet)	23 holes x 5 sa x \$30/sa = \$	3,450
2) Analysis of RN's		
a. Sample Collection	12 md x 10 hrs x \$10/hr = \$	1,200
b. Gross Alpha and Beta	23 holes x 12 sa x \$50/sa = \$	13,800
c. Specific RN's	50 sa x \$300 = \$	15,000
3) Chemical Analysis	100 sa x \$120 = \$	12,000
4) Professional Supervision of Borings	30 md x 10 hrs x \$10/hr = \$	3,000
	Task Total	\$ 71,950

II. Hydrogeologic Parameters

A. Test Borings (12)

1) Drilling		
a. Mobilization and Demobilization (2 rigs)		= \$ 1,000
b. - 8 holes @ 20 feet x \$40/ft		= \$ 6,400
- 4 holes @ 60 feet x \$40/ft		= \$ 9,600
2) Soil Sampling		
8 holes x 4 sa/hole x \$30 =		= \$ 960
4 holes x 30 sa/hole x \$30		= \$ 3,600
3) Professional Supervision of Borings	30 md x 10 hrs x \$10/hr = \$	3,000
	Task Total	= \$ 24,560

* md = man day = \$10/hour x 10 hours/day

** sa = samples

B. Field Testing

1) Pump Test for K, k_d , n, S (3 wells)		
a. Pumping Phase	76 md x 10 hrs x \$10/hr	= \$ 7,600
b. Drill rig -	3 wells x 3 days x 10 hrs x \$60	= \$ 5,400
c. Pumps and Equipment		= \$ 3,000
2) Tracer Tests (dispersion)		
a. Gross estimate	30 md x 10 hrs x \$10/hr	= \$ 3,000
	Task Total	= \$ 19,000

C. Laboratory Testing

1) Saturated Hydraulic Conductivity (K_s)		
(Est.) 4 stratigraphic units/hole x 4 holes	16 sa x \$150	= \$ 2,400
2) Porosity (n)	16 sa x \$25	= \$ 400
3) Distribution Coefficient (k_d)	16 sa x \$100	= \$ 1,600
4) Storage Coefficient (S)	16 sa x \$25	= \$ 400
	Task Total	\$ 4,800

D. Chemical and RN Analysis

1) Sample Collection	16 md/yr x 10 hrs x \$10/hr	= \$ 1,600
2) Analysis	12 sa x 12 mo x (\$120 + \$300)	= \$ 60,480
	Task Total	\$ 62,080

III. Hydraulic Flow Patterns and Water Balance

A. Ground Water Level Measurements	12 md.yr x 10 hrs x \$10/hr	= \$ 1,200
	Task Total	\$ 1,200
B. Infiltrimeters (2) and Evaporation Pan (1)		
1) Installation		= \$ 2,000
	Task Total	\$ 2,000
	Task IA	\$ 13,200
	Task IB	\$ 13,800
	Task IC	\$ 71,950
	Task IIA	\$ 24,560
	Task IIB	\$ 19,000
	Task IIC	\$ 4,800
	Task IID	\$ 62,080
	Task IIIA	\$ 1,200
	Task IIIB	\$ 2,000

TOTAL BURIAL GROUND 6 \$ 212,590

BURIAL GROUND 4 \$ 267,760
BURIAL GROUND 6 \$ 212,590

GRAND TOTAL \$ 480,350

md = man day = \$10/hour x 10 hours/day

** sa = samples

4.0 IDAHO NATIONAL ENGINEERING LABORATORY

4.1 General Description of INEL

The Idaho National Engineering Laboratory (INEL) is located in southeastern Idaho on the eastern Snake River Plain, a part of the Columbia Plateaus Physiographic Province. The eastern Snake River Plain is located in a structural basin 200 miles long by 50 to 70 miles wide which projects eastward as a reentrant into the northern Rocky Mountains. The basin is filled with over 5,000 feet of basaltic lava flows interbedded with minor amounts of unconsolidated sediments. The INEL site is situated on a relatively flat plain which slopes gently toward the west and is surrounded on three sides by mountains. Elevations on the Snake River Plain average approximately 5,000 feet, while the surrounding mountains reach elevations of more than 12,000 feet. The climate of the eastern Snake River Plain is semi-arid receiving an average of 8 inches of precipitation per year (Refs. 8, 9).

INEL was begun in 1949 as a reactor testing facility, the National Reactor Testing Station (NRTS), for the U.S. Atomic Energy Commission. Radioactive wastes, both solid and liquid, resulting from these testing operations have been stored and disposed of at the site. This investigation is concerned only with the solid waste burial ground which is located in the southwestern part of the INEL site, approximately 3.5 miles north of the southern INEL boundary, 54 miles west of Idaho Falls and 22 miles southeast of the town of Arco (Figure 4-1). The solid waste burial ground has been in use since 1952 and contains a variety of stored and buried radioactive wastes including fission products, activation products, and transuranic wastes (Ref. 8, 9). The burial ground consists of approximately 100 acres of relatively flat land in a valley surrounded by low hills to the north, west and south (Figure 4-2).

The site was selected because of its proximity to major solid

LOCATION MAP-INEL

REFERENCE: BARRACLOUGH, ROBERTSON AND JANZER

DAMES & MOORE

0 1000 2000 feet

Contour Interval 10 feet, Datum is Sea Level

○ 88 Well (and Well Number) Tapping the
Snake River Plain Aquifer

TOPOGRAPHIC MAP OF RWMC AREA

DAMES & MOORE

radioactive waste-producing facilities (e.g. Experimental Breeder Reactor No. 1, Experimental Breeder Reactor No. 2, Test Reactor Area) and the general suitability of geologic, hydrologic and meteorologic conditions for waste disposal. The low permeability of surficial soils, the great depth to the regional ground water table and the aridity of the climate are the principal physical factors which make the site attractive for radioactive waste disposal. Burial of low-level radioactive waste at the burial ground was initiated on July 8, 1952. The wastes included contaminated laboratory implements, activation products resulting from neutron bombardment of materials in nuclear reactors and wastes contaminated with fission products such as strontium 90, and cesium 137. Beginning in 1954 transuranic wastes from the Rocky Flats Plant in Colorado were also buried and stored in the Radioactive Waste Management Complex. Wastes are buried in trenches and pits within the fenced burial ground which is a nearly triangular area 3,200 feet long in the east-west direction and an average of 1,700 feet wide in the north-south direction. The burial ground is located in the lowest part of the valley and is subject to flooding during periods of rapid runoff and during extreme flooding of the Big Lost River which lies to the northwest. The burial ground is approximately two miles southeast of the Big Lost River and is approximately 40 feet lower in elevation than the river. Evidence of past flooding of the burial ground by water moving from the river through two wind gaps west of the burial ground has been noted. The occurrence of flooding in the last 2,000 years is indicated and flooding in the last 200 years may have occurred. Flooding as a result of rapid runoff from the surrounding hills, generally during the spring thaw, has occurred periodically since operations at INEL began (Refs. 8,9).

The trenches and pits are excavated to depths of 5 to 25 feet in unconsolidated transported sediments of fluvial, lacustrine and eolian origin. The pits range from 50 to 300 feet in width and 25 to 1,100 feet in length. The trenches are generally 4 to 25 feet wide, 350 to 1,800 feet long, and are spaced about 16 feet apart. The pits are generally 5 to 15 feet deep and the trenches 5 to 25 feet deep.

The older pits and trenches were excavated in some cases down to the basalt bedrock or only a thin layer of soil was left to separate the wastes from the bedrock. Since 1970, new procedures have been followed which require that two to three feet of soil be left in place or backfilled to take advantage of the relatively low permeability of the soil and its ability to retard potential migration of radionuclides out of the trenches. Solid wastes are now being compacted into bales which are placed in fiberboard boxes or metal drums with plastic liners, stacked in pits and trenches and covered with soil. Transuranic wastes are packaged in fiberglass reinforced, polyester-coated boxes or 7.4 cubic foot steel drums lined with polyethylene. Originally transuranic wastes were stacked in trenches and pits and covered with at least two feet of soil. More recently a separate storage area, the Idaho Transuranic Storage Area (ITSA) has been set aside at the east end of the solid waste burial ground. In this storage area the wastes are stacked above ground on asphalt and covered with layers of plastic and soil (Refs. 8, 9).

Fifty-eight trenches in the solid waste burial ground were filled with waste from 1952 through 1974. From 1954 to 1970 transuranic wastes were also included. Thereafter they were relegated to the adjoining ITSA storage area. About six million curies of activity were disposed at the burial ground from 1952 through 1973. Approximately 250,000 curies of isotopes with longer half-lives, such as strontium 90, cesium 137, plutonium 238, 239, 240, 241 and americium 241, were disposed of at the site. Information is available on the volumes and content of the radioactive wastes and the types of storage containers used during the life of the burial ground, but some information, such as amounts of strontium 90 and cesium 137 disposed before 1970, is not available. In some cases only estimates of amounts of specific radionuclides, i.e., cobalt 60 and various plutonium isotopes, disposed in the earlier years of operation are available (Ref.8).

Ground water monitoring at the INEL site began in 1949 with

studies by the U.S.G.S. providing baseline data concerning the geology and hydrology of the subsurface in the area. Studies concerned with movement of ground water in both the saturated and unsaturated zones were done to provide information on rates of water movement, sources of recharge, directions of ground water flow and the dispersion of wastes introduced as a result of site operations. In the 1960's the movement of liquid wastes introduced directly to the Snake River Plain aquifer from deep injection wells and to the unsaturated zone from seepage pits and ponds were examined. The changes in the sizes of perched water bodies and concentration of radioactive and non radioactive wastes in these water bodies and in the regional ground water aquifer were studied in detail at the ICPP and TRA facilities (Ref.12).

It was not until the period of 1970 to 1974 that studies were instituted to examine the possibility of radioactive waste movement out of the solid waste burial ground, and to evaluate the geohydrologic and geochemical controls on such subsurface migration, if it had occurred. Evidence had been compiled at the burial ground to indicate that water had been in contact with buried wastes and had percolated downward into the unsaturated zone during periods of high precipitation and runoff. The digging of pits and trenches within the burial ground disturbed the natural soils and the procedures utilized in the past for waste emplacement allowed infiltration of water into the excavations while they remained open. Slumping and cracking of backfilled soils and consolidation of the soils resulted in formation of topographic depressions which helped to channel surface water into the waste-filled trenches and pits (Ref.8).

Ten observation wells were drilled for the 1970-1974 subsurface waste migration study. Six of the wells were located inside the fenced burial ground and were cored to depths ranging from 236 to 302 feet using air-rotary drilling methods. Coring, sampling and geophysical logging were performed in each well. The four remaining wells were located outside the burial ground fence and were drilled to the Snake River Plain aquifer using cable-tool methods. Analysis of samples from the principal sedimentary beds and basalts beneath the

burial ground area indicated the presence of significant concentrations of radionuclides including cobalt 60, strontium 90, cesium 137, barium-lanthanum 140, plutonium 238, 239, 240, and americium 241 in four samples from the exterior wells and in 23 samples from the interior wells. These results appeared to indicate radionuclide migration downward to major interbedded sedimentary layers at depths of 110 feet and 240 feet (Ref. 8). However, subsequent studies published in July, 1976 (Ref. 10) indicate that contamination of the core samples taken in the earlier study was responsible for the apparent presence of radionuclides at depth in the burial ground vicinity. During the later study extraordinary measures were taken to prevent contamination of samples obtained from three additional borings located within the burial ground with the result that none of the sample analyses were statistically positive and no detectable downward migration of radionuclides to or retention in either of the two major sediment beds at depths of about 110 and 240 feet could be detected.

A number of improvements in burial practices have been introduced at INEL since 1970 to assure that future migration of radionuclides from buried solid waste be eliminated or at least minimized. These include increasing the thickness of soil placed over pits and trenches, compaction of soils to fill slumps and cracks over pits and trenches, leaving a greater thickness of soil above the basalt surface in the bottoms of pits and trenches, frequent inspection for slumps, improvement of dikes which are part of the flood control system, installation of drainage channels and sumps, baling of wastes and covering them with plastic, improvement of container designs, and the use of air support buildings over handling and processing areas (Ref.8).

4.1.1 General Ecology

4.1.1.1 Eastern Snake River Plain

The Snake River Plain occupies an elongate structural basin which has been variously described as a downfaulted graben, a downwarp or a tensional rift. The graben hypothesis assumes that a block of

older rock was downdropped along normal faults and inundated by basalt flows which concealed boundary fault traces. The downwarp hypothesis assumes that the older rocks, presently exposed to the north and south of the Snake River Plain, were depressed or downwarped over a long period of time with accompanying extrusion of volcanic rocks gradually filling the depression. The tensional rift hypothesis attributes the origin of the basin to tensional thinning of the earth's crust and accompanying depression of the surface in response to a slow northwestward drift of the Idaho batholith. No definitive evidence has been found to date which would favor one hypothesis over the others. Whatever its origin, the basin was formed by subsidence of a part of the earth's crust over a long period of time beginning during the Pliocene Epoch approximately 7 million years before the present (B.P). Subsidence along the basin was accompanied by extrusion of volcanic rocks onto the surface in the form of volcanic ash, ash flows and lava flows. Total thickness of the volcanic rocks filling the basin has been estimated to be between 5,000 and 7,000 feet. Three major units make up the section of volcanic rocks. They are, from oldest to youngest, the Idavada Volcanics, the Idaho Group and the Snake River Group. The Idavada Volcanics consists of silicic volcanic rocks, predominantly ash flows with lesser amounts of rhyolitic lava flows. Dating by K-Ar yielded an age of from 4 to 5 million years or a middle Pliocene age for the Idavada Volcanics of the Snake River Plain. The next younger unit overlying the Idavada Volcanics is the Idaho Group, a thick sequence of basalt flows separated by relatively thin interbeds of unconsolidated lacustrine sediments. The Idaho Group of the eastern Snake River Plain ranges in age from early Pliocene to middle Pleistocene. The Group has been dated in the western Snake River Plain as 0.6 to 10 million years old. The youngest of the three volcanic units is the Snake River Group which consists of basalt flows interbedded with minor fluvial and lacustrine sediments. The Snake River Group ranges from late Pleistocene to Holocene in age and has been dated by K-Ar in the western Snake River Plain as being less than 0.54 million years old. In the eastern Snake River Plain the rocks that make up the group are generally even younger. Flows at Craters of the Moon National Monument, near INEL, have been dated by tree rings as having formed about 1,600 years ago (Ref.9).

4.1.1.2 Radioactive Waste Management Complex

4.1.1.2.1 Surficial Deposits

The INEL burial ground, now known as the Radioactive Waste Management Complex (RWMC), is underlain by variable thicknesses of unconsolidated sediments which are in turn underlain by great thicknesses of basaltic lava flows and interbedded sediments. The surficial sediments beneath the RWMC consist of fluvial, lacustrine, and eolian deposits ranging from 3 to 25 feet and averaging 14 feet in thickness. The fluvial sediments occur in channels ranging up to 11 feet thick and are predominantly made up of sands and gravels. The lacustrine sediments are mainly silts and clays and occur as lenticular masses interbedded and interfingering with the other types of surficial deposits. The wind deposited or eolian materials are composed of silts and fine sands produced by reworking of the fluvial and lacustrine sediments. The three types of unconsolidated sediments were deposited on an irregular surface of basaltic lava filling in and tending to smooth the irregularities of the underlying rock surface. Sediment thicknesses are, therefore, greatest where the elevations on the underlying bedrock surface are least and least where the bedrock surface is highest (Ref.8,9).

4.1.1.2.2 Snake River Group

The irregularities of the bedrock surface, developed on the rocks of the Snake River Group, have been attributed to two principal causes: 1) pressure ridges, collapse features, and other flow phenomena commonly associated with movement and solidification of viscous lavas, and 2) a poorly developed drainage pattern formed by running water subsequent to cooling of the lavas. Deposition of coarser grained fluvial materials occurred in channels utilized during floods, while deposition of finer grained lacustrine silts and clays occurred in the numerous closed depressions which are common on such an irregular topographic surface (Ref.8).

The thick sequence of basalts beneath the Radioactive Waste Management Complex has been determined by resistivity survey to be on the order of 2,500 feet thick. Individual basalt flows range from 10 to 75 feet in thickness. Individual flows have not been correlated in drilled wells, but four groups or series of flows have been distinguished beneath the burial grounds on the basis of gamma radiation boundaries which coincide with the occurrence of laterally persistent sedimentary layers between series of basalt flows. The two thickest and most persistent sedimentary layers occur at depths of approximately 110 feet and 240 feet. Each of these sedimentary units contains clays, silts, sands, and gravels in amounts which vary from place to place. The 110-foot sedimentary layer is generally coarser grained and exhibits higher hydraulic conductivities than the deeper layer. It ranges from less than 1 foot to 26 feet in thickness beneath the burial ground, but was apparently absent in some borings drilled within the INEL boundaries (Ref. 8). The 110 foot layer dips toward the east at approximately 20 feet per mile and ranges in elevation from 4,902 to 4,925 feet in the burial ground area. The sedimentary layer occurring at a depth of 240 feet ranges from 4 to 32 feet in thickness in the burial ground area and averages 14 feet in thickness. This deeper sedimentary layer also dips toward the east at a rate of approximately 25 feet per mile. The unit ranges from 4,762 to 4,795 feet in elevation in the burial ground area. Thicknesses of the two principal sedimentary layers vary inversely to one another beneath the burial ground, i.e., in areas where the shallow bed thickens the deeper bed is generally thinner, while thinning of the shallow bed generally coincides with thickening of the deeper sedimentary bed (Ref.8,9).

A number of other sedimentary beds are present and all sediments combined represent about 5% of the total thickness of the stratigraphic section underlying the RWMC. These beds are composed of fluvial and lacustrine sediments which are deposited in the intervals between successive outpourings of basaltic lava on the land surface. They are less persistent horizontally and cannot be correlated with as much certainty as the major sedimentary beds which separate the basalt flow series. They are generally irregular or lenticular in shape and

occur sporadically in borings (Ref.8). The lesser sedimentary interbeds represent shorter time intervals between successive lava flows or periods when less water was available to transport sediments across the plain. The more laterally persistent and generally thicker sedimentary beds between the basalt flow series apparently represent longer hiatuses in the sequence of periodic extrusions of basaltic lava. Alternatively they may represent periods of time when more water or sediment was available for transport and distribution over the surface of the basalt plain.

In addition to the subdivision of the bedrock sequence into series of flows, individual flows and intervening sediments, the individual flows themselves generally display three distinct zones. The upper parts of the flows are generally highly vesicular, exhibit numerous near vertical fractures and interstitial voids and generally have higher porosities and permeabilities. The upper zone is generally purplishgrey, red or brown in color. The center portions of the flow generally are grey, less vesicular, less jointed, and more dense and exhibit much lower porosities and permeabilities than are found in either the zones above or below. Intercrystalline permeability may be the only type present here. The lower zone of each basalt flow is similar to the upper zone with the exception that it is generally thinner and less permeable because of the presence of fewer vesicles and fractures (Ref. 8). Most of the porosity and permeability is primary and was developed during flowage and cooling of the lava. Vesicles, shrinkage cracks, lava tubes and tunnels, flow breccia and collapse features are abundant in the flows and may provide avenues for movement of ground water both above and below the water table. Joints in the basalt are generally near vertical, being mostly columnar joints and therefore forming at right angles to the surface of the flow. The jointing, however, may not always contribute appreciably to observed permeabilities because they have been found in many drill cores to be partially or completely filled with clay and sandy clay. No evidence of faulting has been found in the basalts of the Snake River Group at INEL.

4.1.2 General Hydrology

4.1.2.1 Surface Water

Surface water at INEL consists mainly of water flowing in three intermittent streams which originate in the mountains northwest of the site. The streams, Big Lost River, Little Lost River and Birch Creek, drain from the mountains onto the Snake River Plain and into the enclosed basin in which INEL is situated. The streams gradually lose their flow to diversion for flood control and irrigation purposes, to the subsurface by infiltration through their channel bottoms and into the sediments of a number of playas located in the north-central part of INEL. Except at times of very high stream flow, the waters are generally completely lost to diversion, irrigation and infiltration before reaching the playas and sometimes before reaching the boundaries of INEL (Ref.9).

Big Lost River exhibits by far the highest discharges and is the most significant to the hydrology of the waste burial ground at INEL. It carries significant amounts of water across the INEL site boundaries, provides water through infiltration to the principal ground water aquifer, the Snake River Plain aquifer, and is a possible flood threat to the solid waste burial ground. The stream originates in an intermountain valley in the Lost River Range. It flows southeastward in its valley and onto the Snake River Plain near the town of Arco. It turns toward the east and crosses the western boundary of INEL. The stream drains northeastward in the vicinity of the Radioactive Waste Management Complex and approaches within two miles of the complex. It begins losing water by infiltration through its channel bottom after leaving the intermountain valley and flowing onto the Snake River Plain. The distance the stream persists before surface flow ceases is then dependent on the existing discharge and infiltration conditions. Discharge in the river is, in part, artificially controlled by flood and irrigation diversion systems upstream from INEL. There is evidence that flooding of the Big Lost River in the past has caused water to move through two wind gaps west of the RWMC into the depres-

sion where the waste burial ground is presently located. Water moving through the wind gaps would accumulate in the lowest part of the small depression to the east which is occupied by the burial ground. In addition to stream flooding, some surface water flow occurs as a result of rapid runoff of direct precipitation in the area around and within the waste burial ground, especially during the spring thaw when the ground is frozen or ice- and snow covered. Improved burial practices and new methods of diverting or removing water have been instituted in the areas where the radioactive wastes are buried or stored to prevent contact of water with buried wastes (Ref.8,9).

4.1.2.2 Ground Water

4.1.2.2.1 Unsaturated Zone

The unsaturated zone beneath the RWMC is approximately 600 feet thick. It includes the unconsolidated surficial sediments, the basalts, and interbedded sediments of the upper part of the Snake River Group. Recharge to the regional aquifer, the Snake River Plain aquifer, must pass through the thick sequence of volcanic rocks and sediments of the unsaturated zone. Some information is available from testing done at the Test Reactor Area and the Idaho Chemical Processing Plant as to the behavior of ground water in the unsaturated zone. Since the stratigraphic section beneath the RWMC is similar, it is assumed that unsaturated flow in the subsurface at the RWMC will be similar. The water percolates vertically downward through the unsaturated zone until it encounters an impermeable or poorly permeable layer. Upon reaching such a horizon the water typically begins to build up and move outward along the perching bed creating a mound of ground water with a perched water table sloping steeply outward away from the main recharge area. Slopes of 150 to 200 feet per mile have been observed on the perched water bodies. To date only one perched water body has been identified beneath the RWMC. The presence of these perched water bodies above the regional ground water table indicates that some recharge is either delayed or halted by less permeable basalts and sediment layers as it percolates downward

through the unsaturated zone at several locations beneath INEL. The relatively constant size of some of the perched water bodies when recharge is constant indicates that the water does move through the perching layer, although at a slow rate, to provide recharge to the regional aquifer below. At the INEL site recharge to the perched water bodies is mainly from man-made seepage and waste disposal ponds and from the intermittent streams which enter the area. The greatest amount of direct recharge to the regional ground water aquifer, on the other hand, is from infiltration of irrigation water and water from the intermittent surface streams, especially the Big Lost River, as well as from deep injection wells for disposal of sanitary, chemical, and radiochemical wastes.

4.1.2.2.2 Saturated Zone

The principal ground water aquifer in the area is the Snake River Plain aquifer. It underlies most of the eastern Snake River Plain and is about 200 miles long by 30 to 60 miles wide. It underlies the entire area of the INEL site and ranges in depth from approximately 200 feet in the north to 900 feet in the southern part of the site. The ground water table beneath the Snake River Plain slopes at about 5 feet per mile and the direction of flow is generally toward the southwest (Refs. 11, 12, 13, 14). Locally the direction of flow is toward the northeast near the Big Lost River and at the RWMC where the rates of infiltration of river water are the highest. The ground water table beneath the waste management complex is at a depth of approximately 585 feet below the ground surface. The total thickness of the Snake River Plain aquifer is not known. Estimates of 1,000 to 10,000 feet have been made for the aquifer thickness. The upper 500 feet appear to exhibit the highest hydraulic conductivities and function as the most effective part of the aquifer (Ref.8,9).

The aquifer consists of interbedded basalt lava flows and unconsolidated sediments. Highly variable porosities and permeabilities give a strongly anisotropic character to the aquifer. It contains highly permeable materials such as fractured basalt, basalt rubble,

volcanic cinders, vesicular basalt and coarse gravels as well as poorly permeable materials such as dense basalts, silts, and clays. Because of the layered nature of the materials important differences between vertical and horizontal permeabilities also exist. Movements of chemical and low-level radioactive wastes discharged directly to the Snake River Plain aquifer have been observed in order to determine the nature of flow in the aquifer. Dispersion of wastes such as tritium, strontium 90, chromium, sodium, and chloride indicate that because of high horizontal conductivities only the upper part of the aquifer intercepts and transports wastes laterally beneath the INEL site. Wastes do not move downward for any great distance below the ground water table before they are picked up and transported in sheet-like or tabular bodies of water moving through relatively more permeable horizontal zones. Although the ground water table gradient in the region and throughout most of the INEL site is toward the southwest, it was found that in some cases the direction of greatest dispersal of contaminants is toward the south. This pattern has been interpreted as indicating the anisotropy and heterogeneity of the aquifer or the possible effects of channel branching and turbulent mixing in the relatively fast-flowing ground water (Ref.9).

4.2 Monitoring Program

The purpose of the monitoring program at the RWMC is to better define the three components which affect radionuclide migration in the burial grounds. The three components include the source or origin of radioactivity, the means and routes of radionuclide migration and the degree and areal extent of the resultant contamination. Although some information has been gained as to the migration of radioactivity at the RWMC, it is not sufficient to allow design and implementation of a reliable and cost-effective monitoring program. The collection of additional information will be required. Data obtained to date concerning subsurface conditions beneath the complex can be used to set up a program which is aimed at obtaining the necessary additional data for eventual implementation of a more comprehensive, cost-effective program. The preliminary monitoring program has been designed to make maximum use of existing wells and information gained from test borings and sampling, both at the RWMC and other INEL facilities.

4.2.1 Source of Radiocontaminants

The radioactivity source determines which isotopes will be available for migration and indirectly affects the concentrations and total amounts which can be picked up and transported from place to place. In the RWMC, the potential source of radioactivity consists of the 58 trenches and pits located within the fenced area of the shallow land burial ground. The trenches and pits contain activation and fission products as well as some transuranic wastes. It is known that water, a potential medium of transport, has been introduced into the trenches in the past and that it came in contact with containers and in some cases with low-level radioactive waste. This occurred on a number of occasions and in various ways (Ref. 8). Water entered the trenches at least twice (in 1962 and 1969) as a result of local runoff from rapid spring thaws. Heavy rain and snowfall directly on the burial ground has entered the trenches.

through slumped and cracked soil backfill. Precipitation has also entered trenches in the past, while they lay open awaiting gradual filling with radioactive wastes. Thus conditions have been present which could produce a potential mobile source of radionuclides. It is not known definitely whether water has ever become contaminated and to what degree, nor is it known whether contaminated water has ever migrated out of the trenches. Some contamination of surficial soils has been noted, but it is not known whether this contamination resulted from routine burial ground operations or from leakage of contaminated water from trenches.

4.2.2 Means and Routes of Transport

The migration of radioactivity in the subsurface results from the movement of contaminated ground water horizontally or vertically in the saturated and unsaturated zones. Radionuclides are transferred by the ion exchange process to the soil and rock through which the contaminated water passes. Thus the migration of radionuclides in the subsurface relies upon the presence of porosity and permeable pathways along which ground water movement can take place. At the INEL site, data gathered from test borings indicate that ground water movement occurs along three principal types of pathways; interparticle pores, joints and interflow zones. Ground water movement through the surficial soils and through sediments interlayered between lava flows occurs as a result of primary interparticle porosity which is the space between particles or grains that make up the sediment. Because of the stratified and often lenticular nature of the sediments, horizontal permeabilities tend to be much higher than those in the vertical direction.

Primary interparticle porosity is very low in the basalt due to the crystalline nature of the rock. Some ground water flow may take place under saturated conditions in intercrystalline and intergranular voids of capillary size. The greatest part of the ground water flow within the basalt is thought to occur primarily along joints and interflow zones. Some ground water movement may also take place in the more vesicular zones within the flows.

Jointing is common in the basalts which underlie the RWMC and provides a second type of pathway through which contaminated ground water may move. The joints are nearly vertical and are mainly the result of shrinkage of the lavas during cooling. They are commonly filled or partially filled with silt or clay-size sediments which have filtered downward from the bedrock surface. The distribution and frequency of sediment-filled joints beneath buried bedrock surfaces indicates that this process was also common in the past. Extensive downward transport of sediment into the joints requires the passage of sediment-laden water through the openings indicating that this may be an important pathway for movement of potentially contaminated ground water. The jointing is probably the most important pathway for the vertical movement of water in the basalts.

Interflow zones are thicknesses of highly porous and potentially permeable basalt which occur between successive lava flows. These zones are characterized by the presence of highly vesicular and jointed basalt, thicknesses of volcanic rubble, lava tubes and tunnels, and other types of flow structures which produce voids. The void space and permeability of such zones may be very large and may provide important pathways for the rapid migration of ground water. The interflow zones occur along the line of contact between flows and may be composed partly of the rocks at the bottom of the overlying flow and partly of the rocks from the top of the underlying flow, since the tops and bottoms of flows generally exhibit similar features and enhanced porosity and permeability.

4.2.3 Radioactive Concentrations

Since the necessary conditions appear to be present for subsurface contamination, i.e. a mobile source and the means and routes of transport, the possibility exists that the soils, rock and/or ground water beneath the RWMC may have already suffered some radionuclide contamination. Samples of the bedrock, interbedded sediments, perched water and ground water from the Snake River Plain aquifer beneath the complex have been analyzed for radioactivity. Analyses of samples collected to date have yielded positive results for H^3 , $Co^{57\ 60}$, Sr^{90} ,

Cs¹³⁷, Pu²³⁹ and Am²⁴¹, however, nearly all of these findings have been either disproven or attributed to statistical error, analytical error and/or artificial sample contamination. The only evidence of radionuclide contamination at depth is the apparent downhole contamination of test borings drilled in 1972. Radionuclides were apparently introduced from surficial soils or other surface related sources. The soils apparently contain radionuclides at or near the ground surface, either as a result of routine burial ground operations or as a result of leakage from trenches and upward movement of trench water by capillary action. Analyses of samples obtained in 1975 from the sedimentary layers which occur at depths of 110 and 240 feet beneath the RWMC indicated that they do not contain statistically significant amounts of radionuclide contaminants, but that earlier samples which tested positive were very likely artificially contaminated by downhole introduction of contaminated surficial materials. Some radionuclide contamination of sediments filling joints in the basalts at relatively shallow depths was detected in borings which were drilled in 1975 to further study the subsurface soils (Ref.15). Schmaltz (Ref.16) also reported contamination of soils from a few inches to as much as 36 inches below the bottom of an exhumed burial trench. However, no statistically significant radioactivity has been found either in the perched water body discovered beneath the RWMC or in the regional aquifer beneath the complex. This is in spite of the fact that the site is located downgradient from deep disposal wells and seepage ponds which are injecting or leaking low-level radioactive wastes directly to the aquifer. Those radionuclides which have been detected during particular samplings appear to have been artificially introduced into the wells because they are no longer found in samples taken at a later date. In nearly every case some activity of man has been related to the appearance of contamination in a well. It can, therefore, be stated that, as far as is known, the waste burial grounds at the RWMC are not presently leaking radiocontaminants to the principal ground water aquifer.

4.2.4 Recommended Action

The waste burial trenches at RWMC are not known to be discharging detectable amounts of radioactivity to the Snake River Plain aquifer or beyond the natural boundaries of the site. It should, therefore, be the purpose of the proposed monitoring program to provide early warning, if any significant discharges should begin to occur and to provide additional information regarding the subsurface geologic and hydrologic conditions beneath the site to aid in implementing a final reliable and cost-effective monitoring program. Primary sampling stations are to be located using existing data concerning subsurface conditions so as to provide the required minimum time span of one year to install secondary stations, make measurements at these stations and take necessary corrective actions before the contaminated ground water reaches the selected boundaries. The conditions at the RWMC are not such that implementation of a simple saturated zone or unsaturated zone monitoring program could be expected to yield the desired results. It is necessary, therefore, that a more specialized program be developed to obtain the desired information and to aid in instituting a useful and complete monitoring program.

In order to understand and predict radiocontaminant migration, a reasonable degree of understanding of the subsurface conditions beneath the site must be achieved. The amount of information and the detail required depend on a number of factors. These are: 1) The simplicity of hydrogeologic and radiologic conditions. This includes such factors as geologic structure, stratigraphy, bedrock composition, complexity of hydraulic flow patterns and anisotropy of the porous medium. 2) The presence or absence of unusual features which affect site operations and maintenance. These include features such as trench seeps, unusually long trenches, higher level waste nearby, other waste disposal nearby, alteration of the natural water balance through site operations, prominent runoff channels and streams traversing the site. 3) The locations of natural boundaries relative to waste disposal areas. 4) The amount of information presently available. 5) The present and potential state of migration.

Hydrogeologic and radiologic conditions in the waste management complex at INEL are complex and will require detailed information

before a clear understanding of radionuclide migration can be developed. Numerous potential pathways exist in the subsurface and sufficient data is not yet available to indicate which of these pathways is/are actually utilized in the movement of migrating fluids. Vertical movement of ground water occurs primarily along high angle fractures in the basalts and through intercrystalline and interparticle pore space in basalt and unconsolidated sediments. Horizontal movement of ground water occurs mainly within surficial soils, in the interbedded layers of unconsolidated sediments and in the broken and fractured interflow zones between successive lava flows. Horizontal permeabilities are often much higher than vertical permeabilities because of the layered or stratified nature of both the lava flows and the intervening sediments. Vertical variation in the ability of the soil and rock to transmit water results in the potential for the formation of perched water bodies. To date only one perched water body has been identified beneath the RWMC extending over an interval from 196-215 feet beneath the ground surface. The existence of these high horizontal permeability zones in conjunction with the perching layers also points to the possibility that water which is slowed in its downward migration may move rapidly in the horizontal direction along more permeable pathways. If the permeability were high enough, the zone would not remain saturated and would not be recognized as an important migration pathway. Additional subsurface stratigraphic information must be obtained in order to be able to exclude the operation of such a mechanism as a significant pathway for radionuclide migration from the burial ground.

Radiologic conditions at the RWMC are also relatively complex. Trenches contain quantities of transuranic wastes as well as fission and activation products. Wastes were packaged in a number of different ways and often in unknown quantities. It is known that at various times a mobile source may have been developed. No significant contamination has been found in the major sedimentary layers which occur at depths of 110 and 240 feet below the ground surface. There is some indication, however, that some contamination of surficial soils has occurred and that fracture-filling sediments at depths above 110 feet

may also have been contaminated. It is not known at this time whether the latter is a steadily worsening condition or whether it is controlled by aridity and depth of penetration of fracture-filling sediments.

No natural boundaries are present near INEL which could be designated as the outer boundary for the monitoring program. The absence of seeps or localities where ground water is in contact with the surface dictates that an arbitrary boundary be selected. A circle with a 3 mile radius around the RWMC is chosen as the selected boundary for installation of secondary monitoring stations. The size of the boundary circle was chosen for a number of reasons. First, the 3 mile radius was chosen because it falls inside the closest (southern) boundary of the INEL reservation which is approximately 3-1/2 miles south of the RWMC. Second, a 3 mile radius is the largest which can be drawn without encroaching on the zone of subsurface contamination extending southward from the Test Reactor Area. Finally, the location of the selected boundary must allow at least one year between the detection of radiocontaminants at a primary monitoring station and their projected arrival at the line of secondary monitoring stations. At an assumed maximum velocity of 20 feet per day (Ref. 11), as measured in the Snake River Plain aquifer at the Test Reactor Area, ground water would be expected to move approximately 1.4 miles per year. A margin of safety of approximately 2.0 is incorporated because of the strong anisotropies which have been encountered in the aquifer during past investigations and also because the data upon which the estimates are based were not obtained at the RWMC but rather at the Test Reactor Area about 7 miles to the north-northeast.

The amount of information available regarding subsurface conditions at the RWMC is inadequate for development of a comprehensive long-term monitoring program. The data can be used to establish a monitoring program aimed at filling in the gaps in present knowledge. Although a number of borings have been drilled within and around the burial ground complex, sufficient data has not been obtained regarding subsurface stratigraphy and geohydrologic parameters. Some of this data is being obtained at the present time, but much of it will

require additional test borings and well installations. Some information, such as changes in water table gradients in wet and dry periods, will require monitoring for a period of time.

The present state of migration of radionuclides at the RWMC has been discussed previously. At the present time the waste burial ground is not known to be leaking. The potential state of migration is at present an unknown quantity. It is not known whether the aridity, sorption by sediments, and improved burial practices are maintaining an equilibrium condition in radionuclide migration or allowing slow progressive migration and at what rate.

4.2.5 Recommended Programs

The proposed monitoring program at the RWMC consists of two parts, 1) the installation of trench sumps and 2) the addition of deep wells for primary monitoring. Because of a lack of subsurface geologic and hydrologic data, a more comprehensive monitoring program cannot be presented at this time. The presentation of such a program will require the collection of additional data. The additional requirements are discussed below under Supplemental Data Acquisition.

4.2.5.1 Monitoring Program

1. Installation of Sumps - Because of the potential for numerous pathways by which radionuclides may migrate at the RWMC, possibly even escaping detection by monitoring stations, it is recommended that sumps be installed in future trenches excavated in the burial ground. The number of pathways by which radiocontaminants may migrate requires that more exact knowledge be gained as to the possible development of a mobile source in the waste burial trenches. In the event that such a source is developed, its character and mode of migration must be traced from the time of its inception. Since the bedrock underlying the surficial soils has an irregular surface and

numerous closed depressions, it is recommended that placement of the sumps be carefully considered so that they will be located at the most likely points of water accumulation. Backfitting of some of the filled burial trenches with sumps for water monitoring would also be desirable, if suitable locations can be determined. The sumps should be checked after wet periods for water accumulation in the trenches. Samples of any water encountered should be taken and tested for radio-nuclide contamination.

2. Installation of Deep Wells for Primary Monitoring - It is recommended that a ring of primary monitoring stations be set up around the RWMC by drilling six wells to the regional ground water aquifer. The wells should extend at least 50 feet below the level of the regional ground water table beneath the RWMC. Recommended locations for the wells are shown in Figure 4-3. The purpose of the wells is to monitor the aquifer for radiocontaminants which might move downward from the burial ground through the unsaturated zone to the regional ground water table. Anticontamination procedures, as described in Appendix B, must be utilized in drilling and installing the wells. All holes should be logged for lithology, natural gamma, neutron and hole diameter (caliper).

The recommended well locations were determined using the parameters and relationships set forth in Dames & Moore's final report for the development of monitoring programs for low-level waste burial sites (Ref. 17). Computations for the spacing of wells to intercept 10% of the 10CFR20 concentrations were done using dispersivity values derived by computer best fit analysis of observed contaminant plumes at the TRA and ICPP facilities at INEL (Ref. 11). A factor of safety was introduced to allow for the possibility that dispersivities at the RWMC might be lower or ground water velocities higher. The computations indicated the need for 5 monitoring wells for the RWMC with a spacing of approximately 4,700 to 4,900 feet. Six monitor-

0 1000 2000 feet

Contour Interval 10 feet, Datum is Sea Level

(X) WELL LOCATION

RECOMMENDED LOCATIONS OF DEEP WELL MONITORING STATIONS AT RWMC

ing wells were recommended for installation, however, spaced 3,400 to 3,700 feet apart. All computations assumed that contaminated water would move vertically through the unsaturated zone to the ground water table.

Available information indicates that ground water flow in the vicinity of the RWMC is toward the northeast in contrast to the regional flow which is toward the southwest. This reversal of the gradient is the result of recharge to the aquifer from the Big Lost River drainage diversion area located approximately one mile southwest of the RWMC. It is not known whether the prevailing flow direction changes in dry periods. A fairly regular distribution of monitoring stations around the burial ground was chosen to preclude the possibility that changes in the direction of the ground water gradients might allow migrating radiocontaminants to escape detection at the primary monitoring stations. Water levels should be measured every two months and water table contour maps drawn to see if there is any change in elevations, gradients or direction of ground water flow in wet and dry periods, i.e. periods when there is or is not water in the flood diversion area. Existing wells should be used for this purpose in addition to those wells drilled during the proposed boring program.

Water samples should be taken from the deep monitoring wells at least once every 2 months. The samples should be analyzed for dissolved and suspended radionuclide content and chemical composition. Analyses should include tests for H^3 , Sr^{90} , Cs^{137} , $Pu^{238,239,240}$, Am^{241} and Co^{60} . Specifications on ground water monitoring are presented in Appendix A. Samples of rock and soil should be obtained during drilling of the wells and the cross contamination prevention procedures presented in Appendix B must be adhered to.

4.2.5.2 Supplemental Data Acquisition

In order to design a final cost-effective monitoring program, it is necessary to gather additional information regarding the hydrologic parameters which control the movement of radiocontaminants through the subsurface materials at the RWMC. Some data has been gathered previously from other localities within the boundaries of INEL. To date, specific quantitative information regarding these parameters is lacking for the soils and rocks beneath the RWMC. In view of the extreme anisotropies exhibited by the basalts and sediments of the Snake River Group, it appears prudent that more site-specific information be developed for the burial ground.

1. Monitoring Major Sedimentary Interbeds - Wells should be installed in the 110- and 240-foot sedimentary layers to monitor them for the passage of contaminated water moving laterally out of the monitored area which surrounds the burial ground. These wells must be equipped with an alarm system which warns of the development of saturated conditions in the layer so that water samples can be obtained for testing. The samples should be tested for water chemistry, gross alpha, gross beta, $\text{Pu}^{238,239}$, Co^{60} , Cs^{137} , Sr^{90} , and Am^{241} .

The wells monitoring the 110-foot sedimentary layer will serve as an early warning system to indicate whether radiocontaminants have reached this depth. The bed cannot be relied on completely because it is apparently not continuous over the whole burial ground area. The layer was not found to be present in borings 76-1 and 76-2 and was found to be less than one foot thick in well 87 and less than 2 feet thick in well 92 (Figure 4-4). It is possible, therefore, that contaminants might escape through one of these "holes" before reaching one of the shallow monitoring stations. This, of course, would depend on the location of the contaminant source and the "holes" relative to the monitoring wells. If contaminants do escape the monitoring wells in the 110-foot bed by moving

downward through breaks in the bed, they should be intercepted by wells monitoring the 240-foot layer which has been found to be present in all wells drilled to date.

It is estimated that 12 wells will be required to ring the burial ground with wells able to monitor the principal sedimentary interbeds and to provide stratigraphic information on the upper 240 feet of the section. The wells will provide early warning of the downward migration of radiocontaminants from the solid waste burial facility. They could also aid in distinguishing RWMC-derived contamination of the regional aquifer from contamination derived from external sources, such as deep disposal well effluents from other INEL facilities.

The monitoring wells should be located both inside the burial ground and outside the boundary fence to provide maximum stratigraphic control. If the location of at least two of the 240-foot monitoring wells within the burial ground is deemed to represent too great a contamination hazard, then all of the wells should be located immediately outside the boundary fence or at least within 100 feet of it. The adequacy of the results of rock and soil testing of samples taken from the borings in predicting conditions beneath the burial ground will vary inversely with the distance of the borings from the burial ground. The greater the distance between the borings and the burial ground the less the assurance that the observed rock and soil conditions encountered are similar to those beneath the burial ground.

Five of the wells should tap the 110-foot layer and seven wells the 240-foot layer. The borings must be sampled continuously in both rock and soil to provide detailed subsurface stratigraphic information and samples for laboratory testing of parameters such as porosity, hydraulic conductivity and storage capacity. Representative soil and rock samples should be tested for gross alpha, gross beta, Pu^{238,239,240}, Co⁶⁰, Cs¹³⁷,

Sr⁹⁰, and Am²⁴¹. Cross contamination prevention procedures, as described in Appendix B, must be adhered to during drilling of all of the wells. All holes should be logged for lithology, natural gamma, neutron and hole diameter (caliper log). More detailed lithologic logging of cores and samples should be done after all the holes are drilled to determine whether more comprehensive stratigraphic correlation can be accomplished between borings and to identify any highly permeable zones which might act as pathways for lateral movement of radionuclide contaminated waters in the unsaturated zone.

2. Additional data is required concerning hydrogeologic parameters in the subsurface and the water balance at the RWMC. Information regarding hydrologic parameters in both the saturated and unsaturated zones must be obtained. In the unsaturated zone it will be important to identify zones of exceptionally high permeability in the upper 240 feet of the stratigraphic section. Such zones might serve as pathways for the lateral movement of contaminated water and thereby bypass the ring of deep monitoring wells surrounding the site. In order to identify and delineate any such zones encountered, it will be necessary that a geologist be assigned to each drilling rig. He will be required to log the core in detail and to identify zones of potentially high permeability such as volcanic cinders, breccias, rubble zones, permeable sediment layers, etc. In the event that such a zone is encountered, the interval should be noted and representative samples of the rock or soil should be taken for laboratory testing. Values for porosity, storage coefficient and hydraulic conductivity (Ku) should be determined using laboratory methods as described in Appendix A. Logs of borings can then be compared to determine whether significant zones of high permeability are laterally extensive and represent potential contaminant migration pathways.

Testing of hydraulic parameters in the saturated zone can be conducted in the laboratory and/or in the field. Values for hydraulic conductivity (K_s), distribution coefficients (k_d), storage coefficients (S), and dispersivities should be determined for each distinctive stratigraphic layer below the ground water table. Techniques for measuring these parameters are discussed in Appendix A. In situ testing below the ground water table must be carried out in the six deep perimeter wells to be drilled for the monitoring program.

3. An evaporation pan should be installed to determine evaporation rates at the site. In addition, ring type infiltrometers should be used to determine infiltration rates under varying seasonal conditions in undisturbed soils near buried trenches and in disturbed soils covering filled trenches. Data thus derived can be used to determine a water balance for the site.

4.3 Cost Estimate - INEL

An estimate of the total cost of the recommended program is provided below. The estimates are based on costs for previous work done at the RWMC, interviews with contractors or on previous experience of Dames & Moore personnel in doing similar work elsewhere in the United States. Allowance has been made for inflation and in cases where the amount of work required is uncertain a minimum figure was utilized.

The cost of analyzing water samples from the 110- and 240-foot layers for radionuclide concentrations could not be estimated because it is not known how often sampling will be necessary if at all. If the sedimentary layers do not become at least partially saturated, no samples can be collected.

4.3 COST ESTIMATE - INEL*

Installation plus operation for one year

BURIAL GROUND 4

1.	Installation of Sumps		
	a) Two sumps x \$2,000		= \$ 4,000
		Task 1 Total	= \$ 4,000
2.	Installation of Deep Wells		
	a) Drill 6 wells @ 640' x \$40/ft		= \$153,600
	b) Sampling - 60' sediments/well (average) x 6 wells = 180 sa x \$30/sa		= 5,400
	c) Drilling 192 md (assuming 20'/day)		
	Field Supervision 192 md x 10 hrs x \$10/hr		= \$ 19,200
	d) Borehole Logging - gamma, caliper, neutron (gross estimate)		= \$ 3,000
	e) Radionuclide Analysis (soils) 50 sa x \$300		= \$ 15,000
	f) Radionuclide Analysis (monthly) 6 wells x 12 sa/year x \$300		= \$ 21,600
	g) Soil sample parameter testing (K,n,S) - 4 sa/wells x 6 wells x \$100		= \$ 2,400
		Task 2 Total	\$220,220
3.	Installation of Shallow-Wells		
	a) 7 wells @ 260' x \$40/ft		= \$ 72,800
	b) 5 wells @ 125' x \$40/ft		= \$ 25,000
	c) Samples - Soil		
	7 wells (average 40' of sediment) 140 sa x \$30/tube		= \$ 4,200
	5 wells (average 25' of sediment) 62 sa x \$30/tube		= \$ 1,860
	d) Field Supervision 120 md x 10 hrs x \$10/hr		= \$ 12,000
	e) Radionuclide Analysis (Soil) 50 sa x \$300		= \$ 15,000
	f) Borehole Logging - gamma, caliper, neutron		= \$ 4,000
	g) Soil sample parameter testing (K,n,S) - 8 sa/well x 12 wells x \$100		= \$ 9,600
		Task 3 Total	\$144,460
4.	Field Testing = Saturated Zone Pump Test		
	Three wells (K, n, S, k _d)		
	a) Drill rig = 3 wells x 3 days x 10 hrs x \$60/hr		= \$ 5,400
	b) Pumps and equipment		= \$ 2,000
	c) Manpower 4 x 9 days x 10 hrs x \$10/hr		= \$ 3,600
	d) Analysis 4 md. x 10 hrs x \$10/hr		= \$ 400
		Task 4 Total	= \$ 11,400
5.	Evaporation Pan and Infiltrimeters		= \$ 2,000
		Task 5 Total	\$ 2,000

* Assumptions

1. Lab and field testing costs are estimated using normal commercial rates.
2. All professional labor costs were estimated arbitrarily at \$10 per hour for uniformity and because rates may vary widely for performing some of the more complex tasks.

Radioactive Waste Management Complex

Task 1	\$ 4,000
Task 2	\$220,200
Task 3	\$144,460
Task 4	\$ 11,400
Task 5	<u>\$ 2,000</u>
Grand Total	\$382,060

5.0 REFERENCES

1. McMaster, W.M., Waller, H.D., 1965, Geology and Soils of White Oak Creek Basin, Tennessee, ORNL-TM-1108.
2. Webster, D.A., 1976, A Review of Hydrologic and Geologic Conditions Related to the Radioactive Solid-Waste Burial Grounds at Oak Ridge Laboratory, Tennessee, U.S.G.S. Open File Report 76-727.
3. Stockdale, P.B., 1951, Geologic Conditions at the Oak Ridge National Laboratory (x-10) Area Relevant to Disposal of Radioactive Waste, ORO-58.
4. Lomenick, T.F., Wyrick, H.J., 1965, Geohydrological Evaluation of Solid Waste Storage Area 6, ORNL-TM-1327.
5. Cowser, K.E., Lomenick, T.F., McMaster, W.M., 1961, Status Report on Evaluation of Solid Waste Disposal at ORNL: I, ORNL-3035.
6. Lomenick, T.F., Cowser, K.E., 1961, Status Report On Evaluation on Solid Waste Disposal at ORNL: II, ORNL-3182.
7. Duguid, J.O., 1975, Status Report on Radioactivity Movement from Burial Grounds in Melton and Bethel Valleys: I; Contract No. W-7405-eng-26, ORNL-5017.
8. Barracclough, J.T., Robertson, J.B., and Janzer, V.J., 1976, Hydrology of the Solid Waste Burial Ground, as Related to the Potential Migration of Radionuclides, Idaho National Engineering Laboratory, with a section on Drilling and Sample Analyses by L.G. Laindon, U.S.G.S Open-file Report, IDO-22056 185 p.
9. Robertson, J.B., Schoen, R., and Barracclough, J.T., 1974, Influence of Liquid Waste Disposal on the Geochemistry of Water at the National Reactor Testing Station, Idaho, 1952-1970; USGS Open-file Report, IDO-22053, 231 p.
10. Burgus, W.H., and Maestas, S.E., 1976, The 1975 RWMC Core Drilling Program, A Further Investigation of Subsurface Radioactivity at the Radioactive Waste Management Complex Idaho National Engineering Laboratory, U.S. ERDA, TID-4500, 38 p.
11. Robertson, J.B., 1974, Digital Modeling of Radioactive and Chemical Waste Transport in the Snake River Plain Aquifer at the National Reactor Testing Station, Idaho: USGS Open-file Report-IDO-22054, 95 p.
12. Barracclough, J.T., Teasdale, W.E., Robertson, J.B., and Jensen, R.G., 1967, Hydrology of the National Reactor Testing Station, Idaho, 1966; U.S.G.S. Open-file Report TID-4500, 95 p.

13. Barraclough, J.T., Teasdale, W.E., and Jensen, R.G., 1967, Hydrology of the National Reactor Testing Station, Idaho, 1965; U.S.G.S. Open-file Report.
14. Barraclough, J.T., and Jensen, R.G., 1975, Hydrologic Data for the Idaho National Engineering Laboratory, Idaho, 1971-1973 U.S.G.S Open-File Report 75-318.
15. Rightmire, C., U.S.G.S., 1977, Personal Communication.
16. Schmalz, B.K., 1972, Radionuclide Distribution in Soil Mantle of the Lithosphere as a Consequence of Waste Disposal at the National Reactor Testing Station, U.S. AEC, IDO-10049, 80 p.
17. Dames & Moore, 1976, Development of Monitoring Programs for ERDA Owned Radioactive Low-Level Waste Burial Sites.
18. Robertson, J.B., 1974, Digital Modeling of Radioactive and Chemical Waste Transport in the Snake River Plain Aquifer at the National Reactor Testing Station, Idaho, U.S.G.S. Open-File Report IDO-22054, 41 p.

APPENDIX A: PROCEDURES AND METHODOLOGY

In this appendix, the procedures to be utilized in obtaining water and soil samples, and the methodology to be employed in determining the hydrogeological parameters are discussed.

During all these procedures extreme care must be exercised to preserve the integrity of the samples taken and to assure that the measurements accurately reflect the field conditions. Relevant precautionary measures and procedures are outlined in Appendix B.

A.1 Surface Water Sampling

Presently five flow proportional samplers are in use at ORNL. These systems utilize a variable volume and constant time mechanism. Water from the streams which drain through ORNL are impounded by Cippoletti Weirs at these locations. The hydraulic head of the impounded water is measured and converted into a flow rate. On a constant 15 second period, a sample pump is actuated and the pumping duration is adjusted according to the instantaneous flow measurements. The samples are measured remotely by probes for pH, dissolved oxygen, temperature, and beta-gamma activity and this information is telemetered back to an ORNL monitoring facility where it is recorded on strip charts. Samples are collected for potential laboratory analysis.

Devices of the type presently used should be employed at the specified additional locations. If the present flow proportional samplers cannot be duplicated in-house, modifications of systems like the N-CON Sentry 500 sequential composite sampler or the Lakeside Trebler sampler can be utilized. Water may either be remotely sensed by probes for pH, dissolved oxygen, temperature, and beta-gamma activity and/or they may be sampled for laboratory analysis of specific radionuclide content and water chemistry.

A.2 Ground Water Sampling

These samples should be obtained by a sampler such as Kemmerer-type (1.9" O.D.) which has the capability of sampling parcels from

discrete levels. A Kemmerer-type sampler enters the piezometric casing with both ends of the cylindrical sampler open to flow. When it reaches the specified depth, the apparatus is closed by a spring mechanism which is actuated by a falling weight trip device, thereby obtaining a sample from a discrete level. If a Kemmerer-type sampler is unavailable, a deep well multi-level sampler may be employed. This sampler has the capability of taking several discrete samples separated by spacing and is actuated by a solenoid valve. Pumped water sampling is undesirable due to risk of sample contamination.

A.3 Ground Water Level Measurements

Accurate ground water level measurements should be obtained by using Drop Lite-type (UOP-Johnson) or galvanometer-type (Soiltest, Powers, etc.) type water level recorders. The Drop Lite reader is preferable, since it does not require the continuous calibration necessary for the galvanometric type. Conversion of these depth recordings to elevation will require accurate ground surface or top of casing elevation. These surface elevations must be surveyed as soon after well completion as possible.

A.4 Lithologic Data Borings

In order to obtain the necessary lithologic information and obtain relatively undisturbed samples for the hydrogeologic data determination, a specific subsurface sediment and rock sampling program is indicated.

Drilling should be performed with a rotary type drill rig and by a competent drilling contractor or government drilling team. Each boring should be drilled with sufficient diameter to accommodate samplers up to 3.5" in diameter (3.75" tricone bit or larger). The driller should provide the following samplers in order to accommodate varying conditions encountered:

1. Standard Split Spoon - accommodations for the standard penetration test are recommended (140 lb. hammer with 30" drop).
2. Christensen core barrel with diamond bit, size NX or larger.
3. Three-inch Denison-type sampler - tubes for sampling will be supplied by the driller, will be made of stainless steel or brass, and will provide room for 24 inches of recovery.
4. Three-inch Osterberg-type sampler - tubes for sampling will be supplied by driller and will be made of stainless steel or brass, and will provide room for 24 inches of recovery.
5. Dames & Moore Type-U sampler - which can be leased from Dames & Moore. This sampler is 3-1/4" O.D., adaptable to both A and N type rods, and is capable of obtaining both relatively undisturbed hydraulically "pushed" samples and slightly disturbed hammer driven samples with a 300 pound hammer falling over a distance of 24 inches. It yields both undisturbed brass thin-walled samples for laboratory testing and/or slightly disturbed 12 inch split barrel samples contained in 12 one-inch deep and 2-1/2" O.D. brass rings. This ring setup is ideal for laboratory testing of hydrogeologic parameters for vertical variation.

The driller must also provide the capability of maintaining the integrity of the hole. If casing is used, it should allow uninterrupted passage of any of the above-mentioned samplers. In the event of cave-ins, casing would be emplaced to the depth of the cave-in and the hole cleaned to the satisfaction of the drilling inspector. Cleaning of the hole can be accomplished by circulating compressed air through the tricone bit. The driller should provide all the necessary pumps, compressors, casing driving and extraction equipment, and all the other equipment for successful sampling.

Detailed boring logs of all samples and drill cuttings should be kept in the field. A standardized soil classification system such as the "Unified" or "Burmeister" can be employed. Following boring termination electronic logging of the hole should be performed. This procedure should be performed. This procedure should consist of neutron, electric, gamma, gamma gamma, and caliper logging in order to determine moisture content, resistivity, gamma radiation, density, and hole diameter, respectively.

Subsequent to completion of the sample borings, perforated pipe, preferably ASTM certified PVC, should be fitted and emplaced within the drill hole. The perforated casing must be 2" I.D. or larger to permit passage of a Kemmerer type water sampler (1.9" O.D.). The space between the hole and the casing should immediately be grouted.

A.5 Hydrogeologic Parameters

Laboratory determinations based on the undisturbed samples obtained in the boring program and the supplementary field determinations of several relevant hydrogeologic parameters are discussed below.

Hydraulic Conductivity (K_s)

Measurements of hydraulic conductivity should consist of both field and laboratory determinations. The field techniques will consist of pump tests and drawdown tests, if feasible. In the pump test, after recording the water level, the well will be pumped out to a new level and the rate of water level rise will be recorded and applied to empirical equations to determine the hydraulic conductivity. Since most empirical relations are based on idealized media, these determinations should not be expected to be entirely accurate.

In the drawdown tests, the effect of the pumping of a well on a nearby well is observed. Based on the pumping rate and the drawdown in the nearby well(s), hydraulic conductivity can be calculated.

Further validation of values of hydraulic conductivity may be obtained by laboratory determinations. Undisturbed samples from both the saturated and unsaturated zones can be subjected to permeability tests on permeameters or in triaxial soil compression chambers. Constant or falling head permeability measurements are acceptable, however, extreme care must be exercised both in sample procurement and handling since any disturbance may significantly effect the sample permeability. The use of a triaxial soil compression chamber has an advantage over the permeameter in that the sample may be loaded to simulate in situ overburden pressures. This method is somewhat more costly, but yields more accurate results.

The hydraulic conductivity may further be defined by application of a tracer test in the study area. Tracers such as iodine, bromine, (anions are preferable since they have lower propensity for ion exchange in clay sediments), or dyes such as sodium fluorescein may be employed. The selected tracer may be injected into a well which is upstream of several other wells.

Some measurements of the unsaturated hydraulic conductivity may be of value. Undisturbed samples from the unsaturated zone should be measured in the laboratory at varied moisture contents and suction to determine the relationship of moisture content with the hydraulic conductivity. Methodology chosen should adequately simulate in situ conditions (Refs. 19,20,21).

Porosity

Porosity determination is best performed on undisturbed samples in the laboratory. Reconstituted samples should never be used. The dry density and moisture content are determined so that the porosity may be calculated from the estimated specific gravity of the mineral constituents of the shale.

Storage Coefficient (S)

Storage coefficients may be determined in the laboratory on undisturbed samples using the moisture equivalent method where the moisture is evacuated from a test column by a differential pressure drop. The weight loss over the prescribed evacuation time is a reasonable estimate of the specific yield which, for an unconfined aquifer, is approximately equivalent to the storage coefficient.

Distribution Coefficients (k_d)

Distribution coefficients are usually determined through laboratory equilibrium experiments. Most distribution coefficients developed to date consist of batch or column tests where soil samples are saturated with volumes of radionuclide-spiked synthetic or actual waste solutions. Column equilibrium tests are done by counting the activity of the influent and effluent liquids, while in batch tests the supernatant liquid is monitored before and after saturation to determine equilibrium conditions. Limitations on these methods include poor simulation of actual fluid ionic strength and cation distribution. A newly developed technique presently being utilized at the ORNL environmental laboratories, makes use of thin layer chromatographic plates upon which reconstituted soils are emplaced in strips. The lower edges of these plates are immersed in synthetic ground water solutions which are spiked with the radionuclide of interest. The fluid is permitted to migrate up the soil laden plates and the distribution is monitored by counting the activity in the immersion and on the plates by a scanning detector. This method has obvious advantages over the batch method in that the natural flow conditions are more closely approximated. Reconstitution of the sample onto the thin layer plates is the chief drawback of this method, since it alters the particulate interaction present in situ. However, this method promises to produce much more accurate K_d values than other presently employed techniques.

Dispersion Characteristics

The dispersion coefficients (D_L , D_T) and/or dispersivities (α_L , α_T) can roughly be estimated from the soil type, grain size distribution, hydraulic conductivity and effective porosity. Accurate determinations can be obtained by field tracer studies or trial and error solution of the governing mass transport equation, if enough data is available. These latter two methods require expense and considerable time.

Another method used at ORNL in conjunction with the above detailed distribution coefficient determination is the same thin layer chromatographic plate methodology. In this method radionuclide spiked synthetic ground water solutions are eyedropped onto the thin layer soil strips and the activity of the radionuclides is monitored by scanning the length of the test strips. The Gaussian distribution is plotted and the standard deviation of the distribution is then utilized to calculate the dispersivities.

Water Chemistry

Chemical constituents, pH, and leachate parameters should be analyzed in all ground water samples scheduled for specific radionuclide analysis. Major element chemistry should include concentrations of calcium, magnesium, potassium, sodium, chloride, bicarbonate, sulfate, and total alkalinity. Cation determinations can successfully be defined by atomic absorption analysis, while the anions and the total alkalinity are determined by titration using standard methods. Measurement of hydrogen ion activity, pH, should be determined both immediately in the field with a portable pH meter and later on samples in the laboratory. Major element chemistry and pH are needed to establish predicted equilibrium status for radionuclides of concern as well as for the prediction of the adsorption and

substitution phenomena. Sulfate and chloride are not expected to be major constituents at ORNL and INEL, but baseline concentrations of these anions need be established so that they may be used as leachate tracers in monitoring samples. Leachate parameters of concern in addition to sulfate and chloride concentrations include nitrates, EDTA, and the organic acids such as propanoic acid which are often common to solid waste leachates. Presence of constituents in concentrations above baseline can act as a signal for leachate migration.

APPENDIX B: CROSS CONTAMINATION PREVENTION PROCEDURES

It is a major objective of both the monitoring program and the data accumulation program to obtain soil, rock, and water samples that accurately reflect the conditions at the sampling locations, i.e., they must be as free of procedural contamination as achievable. Procedural inaccuracies and cross contamination can seriously detract from the quality of the data. The following procedures are recommended for the data accumulation and monitoring programs.

B.1 Ground Surface Preparation

Since surface soils may contain greater radionuclide concentrations than those that may be encountered in the subsurface and contaminated drill cuttings may build up at the surface during drilling, it is necessary that movement of surface materials into the bore holes be kept to a minimum. It is also necessary to prevent surface runoff from entering the holes.

Initially the test boring or well site should be cleared of all vegetation and undesirable objects such as boulders. The site should then be graded such that the bore hole center is elevated above the surrounding ground surface and the surface should be covered with 4 to 6 inches of uncontaminated granular fill from offsite. This sand or gravel should be extended over the entire work surface up to a radius of about 50 feet to prevent ambulatory tracking of external contaminated materials into the working area. Subsequent to the driving of the outer casing into the hole, a flexible material, such as a plastic liner or asphalt should be laid down around the casing. If plastic is used, it should be fastened to the outer casing securely.

B.2 Work Area Preparation

During the drilling operation it will frequently be necessary to lay down the drilling apparatus and sampler.

Drill string sections should be stored on an elevated storage rack in order to prevent the rods from rolling and coming into contact with contaminated ground surface. A minimum of two wooden work platforms should be available to provide areas for the breaking of the rods and other drilling operations. Upon one of these platforms a wooden bench for sample handling activities should be constructed. These platforms will help to prevent contamination of dropped tools and sampling utensils.

B.3 Subsurface Protection

Prevention of surface soil collapse should be implemented by the installation of double casing downhole. All data boring and monitoring well holes should begin by drilling down to a 5-foot depth by rotary-air methods. In the case of continuous or discontinuous sampling in a data boring, obtaining the necessary samples from the first 5 feet should be followed by cleaning of the hole with the tricone roller bit, and then a casing of 8 inches or greater (I.D.) should be driven to allow a minimum of one foot of casing above ground. Subsequent to emplacement, the annular space between the casing and the surrounding soil should be filled with expanding cement to eliminate any potential transport through this space. After this procedure, the drilling should proceed in 5-foot increments. After each increment a 6-inch I.D. or larger inner casing should be driven to within approximately 3 feet of the deepest progress of the drill bit. For monitoring wells, no casing should be driven to within 5 feet of the bottom of the well (wellpoint elevation). This precaution is taken to ensure that soils from the upper horizons are not scraped and delivered to the screen depth. The inner casing will help maintain the integrity of the hole and will ensure that the drill string and sampling tools have little or no contact with the walls of the hole.

B.4 Sample Handling - Data Borings

Upon extraction of core barrels or soil samplers from the casing at the surface, these implements should immediately be transferred to a work bench for extrusion of core liner, tube, or rings. In the case of consolidated samples, the samples should be handled only by supervised personnel with fresh disposable gloves. The samples should be transferred into plastic bags and placed in clean core boxes. In the case of semi-consolidated or unconsolidated samples the tubes, liners or rings should be carefully removed from the sampler or corer. Tubes and ring samples should be sealed at both ends with low shrinkage wax. The ends of tube samples should be filled with molded aluminum balls to cushion the sample and to prevent cracking of the wax with subsequent influx or flow of fluids. The ends should finally be sealed with plastic caps and taped thoroughly and the caps rewaxed. Ring samples should be transferred to plastic bags and then into transportation cans with ends sealed by caps, wax and electrical tape. The work surface of the sample bench should be provided with disposable covering material such as aluminum foil or plastic sheeting which would be changed between all sample handlings. Once samples are shipped to the laboratory, stringent laboratory anti-contamination procedures must be followed. Any samples scheduled for radionuclide analysis must be extruded and trimmed such that any material in contact with the sampler will be removed and used for purposes other than radionuclide analysis.

All split core barrels or samplers should be thoroughly washed (4-5 rinsings) between sampling. The washing should be done at a distance from the bore hole and waste water properly contained and disposed of. Waste water should never be reused at the drill site.

B.5 Sample Handling - Well Water Samples

Well samples should be obtained only with a suitable discrete level sampler such as the Kemmerer bottle. The sampling bottle

should be rinsed 4 to 5 times with uncontaminated water which should never be reused. Waste water should be properly contained and disposed of. All cleansing operations should be done at a suitable distance from the hole.

B.6 Bore Hole Cleaning

Compressed air should be used for cleansing of drill cuttings, cooling and circulation. All air used for these purposes should be filtered through high efficiency air filters to prevent downhole contamination by foreign particulates and to protect personnel from excessive dust. Procedures for establishing and maintaining filter efficiency must be developed. Should the lithologic conditions at depth preclude the efficacy of the compressed air-rotary drilling through loss of air or fracturing, the hole should be terminated. If the hole is terminated before completion of all sampling activity a new hole should be started within 10 feet of the terminated boring.

B.7 Drilling Operations Regulation

All personnel inclusive of the drilling team should abide by the restrictions imposed by the qualified health safety officer present. All drill string pieces should be placed above ground surface on racks. All sampling equipment and related tools should never be allowed contact with surface soils. Sample handling should be carried out only with fresh disposable gloves. Drilling should not commence or continue if precipitation or significant wind occurs at the site. If all-weather sampling is desired, the operation must be based in a weatherproof shelter capable of accommodating the operation.

B.8 Verification of the Efficacy of Preventive Measures

The efficacy of the measures can be tested by the use of soluble and insoluble tracers. Prior to the drilling operation setup, salts of anions or cations whose concentration on site is negligible may be placed around the test boring site.

Acceptable soluble salts include ammonium bromide, potassium iodide, and dysprosium nitrate. These salts can be mixed gently with the surface soils over an area with a radius of up to 50 feet. Selected samples can be irradiated and analyzed for Br-82, I-131, or Dy-164. Other soluble salts with distinctive anions or cations may be applied. Control samples must be taken to validate the test. If the tracer does not show up in several random samples, the procedures may be assumed efficient. Insoluble tracers such as fluorescent-dyed fine sands may also be disseminated at the surface and random samples may later be examined by black light.

B.9 Preventive Measures for Existing Wells

Protective grading and surfacing of the areas surrounding existing wells is recommended. The area around the wells should be sloped away from the well and a flexible cover such as asphalt or protective sheeting should be laid down, and securely fastened, sutured or sealed to the well casing above the ground surface. It may prove valuable to install protective hoods for all existing and new monitoring wells to prevent particulates and precipitation from entering the casing.

APPENDIX C: Burial Ground 6 Monitoring Line

A portion of the monitoring program for Burial Ground 6 is composed of a monitoring line on which the sampling stations and sampling frequencies are determined according to the specifications and available data detailed below.

The criterion applicable to the determination of the sampling frequencies and distance between sampling stations is that at least 10% of any localized radiocontaminant concentration passing through the monitoring line shall be detected, i.e., at any given time no more than 10 times the radiocontaminant concentration values detected at sampling stations can possibly pass through the monitoring line either between the stations or between samplings or a combination of both.

Accordingly, the formula relating the distances between sampling stations and sampling frequencies is:

$$0.10 = \exp \left[-v^2 / (8f^2 \sigma_L^2) - s^2 / (8 \sigma_T^2) \right] \quad (C-1)$$

where

v = Ground water velocity (ft/day)

s = Distance between sampling stations (ft)

f = Frequency of sampling (1/day)

σ_L = Longitudinal dispersion parameter (ft)

σ_T = Transverse dispersion parameter (ft)

Values of σ_L and σ_T in the above equation can be obtained in two ways. The first is through an approximation of the radiocontaminant migration patterns by an analytical solution of the mass transport equation for a point contaminant source which yields

$$\sigma_L = 2 \cdot \alpha_L \cdot L_M \quad (C-2)$$

$$\sigma_T = 2 \cdot \alpha_T \cdot L_M \quad (C-3)$$

where L_M is the distance from the source (trenches) to the monitoring line, and α_L and α_T are the longitudinal and transverse dispersivities, respectively. The second method applicable to realistic problems is the use of mass transport models and computer codes. Using these models the transport of a point contamination from the source area to the monitoring line could be determined and parameters equivalent to σ_L and σ_T , defining the spread of the contamination front, could be calculated. This approach would be more accurate, but it requires accurate and sufficient data which is not available at the present time.

The parameters needed for computation through equation (C-1) are v , σ_L and σ_T . L_M is well known. For dispersivities σ_L and σ_T , a value of 1.1 ft can be used. This value was reported for the liquid waste pits area, and it appears to be representative of the vicinity. Then equations (C-2) and (C-3) can be used to approximate σ_L and σ_T . For velocity an approximate figure of 0.5 ft/day that was reported for the liquid waste pit area can be used or the velocity can be estimated using Darcy's Law and estimated parameters for hydraulic conductivity and porosity. Using a conservative value of 2 ft/day for hydraulic conductivity (the average value reported for liquid waste pits) and a presumably conservative value of 0.25 for the effective porosity yields 1.6 ft/day as the velocity for the northeastern corner of the northeastern portion of the site. These values were used to make a parametric study of the relationship between the distance separating sampling stations and the frequency of sampling.