NUREG/CR-5737
PNL-7688

Hydrogeologic Performance Assessment Analysis of the Commercial Low-Level Radioactive Waste Disposal Facility near West Valley, New York

Prepared by M. P. Bergeron, J. L. Smoot, M. L. Kemner, W. E. Cronin

Pacific Northwest Laboratory
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U.S. Nuclear Regulatory Commission

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Manuscript Completed: April 1991
Date Published: June 1991

Prepared by
M. P. Bergeron, J. L. Smoot, M. L. Kemner, W. E. Cronin

Pacific Northwest Laboratory
Richland, WA 99352

Prepared for
Division of Low-Level Waste Management and Decommissioning
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555
NRC FIN B2485

ABSTRACT

A hydrogeologic performance assessment of the commercial low-level waste site near West Valley, New York, was performed for two pathways: a shallow lateral pathway where trench water can potentially migrate laterally through fractured and weathered till to nearby streams and a deep vertical pathway where leachate can migrate downward through unweathered till and laterally offsite in a lacustrine unit.

Along the shallow pathway, little physical site evidence is available to indicate what the degree of lateral migration can be. Past modeling showed that overflowing trench water would migrate laterally some distance before migrating downward into the unweathered till. If water did reach a nearby stream, calculations show that decay, adsorption, and stream dilution would reduce leachate concentration to acceptable levels.

Within the deep pathway, tritium and ^{14}C were the only radionuclides released in any significant concentrations. Predicted tritium levels are well below regulatory limits; however, predicted peak ^{14}C concentrations, while meeting the 25 mrem/yr limit using the drinking-water-only exposure scenario, exceed the limit for the full garden scenario. Site information on ^{14}C release rates and geochemical behavior has considerable uncertainty and would need to be more fully evaluated in a licensing situation.

SUMMARY

The West Valley Low-Level Radioactive Waste burial site, which is located in Cattaraugus County in western New York, about 40 miles south of Buffalo, began operations in 1963. Fourteen trenches excavated at the site contain a variety of wastes interred primarily in steel drums. Tritium, ^{90}Sr, and ^{14}C constitute the primary radionuclides in the inventory. Operation was terminated in 1975, and the site is now under the custodianship of New York State Environmental Research and Development Authority.

The trenches at the site are excavated about 5 m into glacial till that has a thickness of about 28 m. The upper few meters of the till is fractured, oxidized, and weathered, while the underlying till is unweathered, contains few fractures, and reducing conditions prevail. Laboratory and field measurements indicate that the hydraulic conductivity of the unweathered till ranges between 2×10^{-8} and 6×10^{-8} cm/s. The till is underlain by a sequence of lacustrine sediments that are sandy at the top and grade into silts and varved clays with depth. The upper portion of the lacustrine unit is partially saturated.

Ground-water movement through the till is predominantly downward as indicated by measurements of hydraulic head. Computer simulations of ground-water flow adequately reproduce the measured configuration of hydraulic head at the site based on a hydraulic conductivity distribution that decreases with depth. In the best-fit simulation, hydraulic conductivity of the shallow, weathered, fractured till is 5 to 10 times higher than the deeper unweathered till. In addition, hydraulic conductivity at depth is reduced to 0.75 and 0.80 of the base value to account for compaction of the unweathered till. Previous work has calculated ground-water velocities of 1 to 8 cm/yr through the unweathered till assuming an effective porosity of 0.30.

Computer simulations of tritium, ^{90}Sr, and ^{14}C migration reproduced the observed concentration in the till beneath selected trenches. One-hundred-year projections indicate that tritium may migrate as far as 10 m beneath the trench floor and ^{90}Sr as far as 6 m beneath the trench floor.

In this hydrogeologic performance assessment, we evaluated two pathways for radionuclide migration: a shallow lateral pathway where trench water can potentially migrate laterally through the upper 1 to 2 m of fractured and weathered till to nearby streams and a deep vertical pathway where leachate can migrate downward through unweathered till and laterally offsite in a lacustrine unit.

While this previous modeling indicates the lateral pathway through the fractured till eventually moves downward before reaching nearby streams, the occurrence of migration of kerosene at the nearby burial area would seem to indicate that migration

could be significant. To evaluate this pathway, we made conservative estimates of the potential impact of the contaminated water overflowing from the trench to nearby Frank's Creek. Using trench leachate concentrations and conservative estimates of travel time to Frank's Creek, we evaluated which key radionuclides could be released from the site. With the exception of tritium and ^{14}C, the effects of decay and adsorption eliminated the majority of radionuclides in the inventory. The combined effect of decay and dilution offered by the annual average flow of Frank's Creek reduces levels of tritium and ^{14}C to below regulatory concern.

In the assessment of the deep vertical pathway, a one-dimensional streamtube transport code, TRANSS, was used in the analysis to predict radionuclide concentrations at 10 and 100 m downgradient of the site. The area of the trenches was used as a guideline to develop the overall dimensions of the streamlines that defined the streamtube of the model. Different streamlines were used for the north and south trenches, respectively. A period of 14 years corresponding to the operational life of the site was allowed before release to the environment; the only attenuation of activity during this time was due to radioactive decay. Travel times from the bottom of the trenches through 23 m of till to the lacustrine unit ranged between 300 to 2300 years according to Prudic's work. In this analysis, 300 years was used as a conservative estimate. Because of the relatively slow movement of water through the till, the effect of the waste containment was not considered, and the waste was assumed to be uniformly distributed throughout the bottom of the trenches.

The results of the performance assessment analysis indicate that tritium and ^{14}C would potentially be the only radionuclides released from the West Valley site in any significant concentrations. Peak tritium levels estimated in the assessment that ranged from 4.0 to 7.4 pCi/L 10 m downgradient of the site are well below regulatory limits. For ^{14}C, predicted peak concentrations meet the U.S. Nuclear Regulatory Commission limit for a 25-mrem dose using the drinking-water-only exposure scenario at 10 and 100 m downgradient of the site. However, predicted concentrations exceed the limit for the full garden scenario at both 10 m and 100 m downgradient of the trenches.

The release rate of ^{14}C from the individual trenches is the most sensitive parameter in the overall performance assessment. For this analysis, the release rate to the flow system is estimated from maximum measured trench water concentrations and the estimated infiltration rate. Experimental data on solubility for these radionuclides are generally not directly available for the West Valley site other than what can be inferred from direct measurements in trench leachate. The use of this information was based on the assumption that, because the trenches have historically had water in contact with the waste over a number of years, the measured concentrations of radionuclides in the trench leachate could possibly reflect reasonable solubility limits for the radionuclides in question. However, the validity of this assumption is not known in the context of the performance period. We acknowledge that if these concentrations continue to increase or decrease, the results of this performance assessment would not be valid and would need to be reevaluated.

Once released to the flow system, we have assumed that all forms of ^{14}C (organic and inorganic) have the same geochemical behavior. The validity of this assumption is unknown given the limited amount of geochemical information on the ^{14}C in the inventory. It is generally known that the ^{14}C can originate from a variety of sources, including organic wastes, such as pesticides, solvents, resin materials, and biological wastes, and inorganic wastes such as activated charcoal filters. The approach used in this study, which assumes minimal adsorption and retardation, in all probability presents an overly conservative case for transport. The range of geochemical behavior in the context of these complexities is the subject of much uncertainty and certainly would need to fully evaluated in a licensing situation.

ACKNOWLEDGMENTS

The authors wish to express their gratitude and appreciation to L. Deering, F. Ross, and R. J. Starmer of the U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, for providing useful comments and suggestions in their review of this report. We also would like to acknowledge the assistance of the following persons who provided reports and/or information that were useful in preparing this report: David Prudic, U.S. Geological Survey, Carson City, Nevada; Alan Randall, U.S. Geological Survey, Albany, New York; Dr. James Albanese, New York State Geological Survey, Albany, New York; and Carol Hornibrook, New York State Energy Research and Development Authority, Albany, New York.

ABBREVIATIONS

CEC	Cation Exchange Capacity
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
LLW	Low-Level Waste
NFS	Nuclear Fuel Services
NRC	U.S. Nuclear Regulatory Commission
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
NYSDOL	New York State Department of Labor
NYSDPW	New York State Department of Public Works
NYSERDA	New York State Environmental Research Development Authority
NYSGS	New York State Geological Survey
PNL	Pacific Northwest Laboratory
USGS	U.S. Geological Survey
WMGB	Waste Management Geotechnical Branch
WNYNSC	Western New York Nuclear Service Center
WRD	USGS Water Resources Division

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FIGURES

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1.0 INTRODUCTION

In December 1982, the U.S. Nuclear Regulatory Commission (NRC) published regulations setting forth specific evaluation criteria for licensing the land disposal of low-level radioactive waste (LLW). These regulations are contained in Title 10 of the Code of Federal Regulations, Part 61 (10 CFR 61), "Licensing Requirements for Land Disposal of Radioactive Waste." A specific requirement of these regulations, indicated in Section 61.5, Subpart D, states that land disposal of LLW "... shall be capable of being characterized, modeled, analyzed, and monitored...". Implicit in these requirements are that applications for future LLW sites would include sufficient information and analyses to provide reasonable assurance that performance objectives in the regulations be met. These analyses will likely include the use of transport models for prediction of radionuclide transport along the ground-water pathway from the prospective facility. To date, no LLW sites have been licensed under 10 CFR 61; the NRC technical staff can only speculate on the degree of complexity needed to model the performance of future LLW sites along the ground-water pathway with respect to the evaluation criteria of 10 CFR 61.

The Pacific Northwest Laboratory (PNL)(a) provides technical assistance to the NRC in developing performance assessment capabilities that will enable the NRC to evaluate the adequacy of future LLW sites following the congressional mandate in the Low-Level Radioactive Waste Policy Amendments Act of 1985. The overall objective of this project is to provide technical support to the NRC on the geologic, hydrogeologic, geochemical, and geophysical aspects of LLW disposal. Specific goals of this project are to

- Develop detailed reports describing the geoscience characteristics and general disposal design for existing commercial LLW disposal sites. Initial sites being evaluated are the commercial low-level radioactive waste disposal facilities at Sheffield, Illinois, and West Valley, New York.
- Develop a computerized geoscience data base for the existing commercial LLW disposal sites. This data base will be used by the NRC staff to analyze ground-water flow and transport at existing sites and to provide pre-licensing guidance for LLW disposal to states based on past experience.
- Select and apply hydrogeologic codes to existing commercial LLW disposal sites to gain insight into modeling strategies, data needs, and levels of detail needed to adequately model proposed LLW sites with respect to 10 CFR 61.

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute.

- Recommend and supply modeling codes as needed for NRC staff to evaluate the performance of proposed LLW sites. These performance assessment capabilities will be used to support findings on specific licensing requirements of 10 CFR 61.

This report summarizes the relevant environmental characteristics and the past performance of the LLW disposal facility situated near West Valley, New York. The purpose of the report is to present a summary of past investigations that are pertinent to performance assessment at the West Valley LLW site and to describe the performance assessment approach that was used to evaluate the long-term transport of radionuclides through the subsurface at the site. This report includes a review of pertinent past investigations and studies that have been conducted at the West Valley site by the site operator and various state and federal agencies over the operational and post-closure period of the facility. The information compiled in this report is also contained in a computerized geoscience data base developed for the West Valley site. The information provided the basis for the selection and application of appropriate codes for analyses of the ground-water pathway at the West Valley site.

Section 2.0 describes the disposal facility at the West Valley site and provides background on the physical and climatic setting. Previous investigations of the site's geology, hydrology, and subsurface radionuclide migration are discussed in Section 3.0. Section 4.0 describes the hydrologic and radionuclide transport analysis and results, Section 5.0 is a discussion of the results of the performance assessment, and Section 6.0 provides a summary and conclusions. References are listed in Section 7.0.

2.0 DESCRIPTION OF DISPOSAL FACILITY

The West Valley site is located on the grounds of the Western New York Nuclear Service Center (WNYNSC) in northern Cattaraugus County, New York (Figure 2.1). The site is contained within the glaciated Allegheny portion of the Appalachian Plateau Physiographic Province. The WNYNSC is about 6 km northwest of the town of West Valley and about 48 km south of Buffalo. The WNYNSC covers 13.5 km^2, of which about 4 ha (0.4 km^2) is allocated to the LLW burial site.

In addition to the commercial site, the WNYNSC contains a number of other facilities related to fuel reprocessing plant that operated within the center from the mid-1960s to the early 1970s (Figures 2.2 and 2.3). These facilities include a fuel reprocessing plant, a facility disposal area (FDA) used by the previous site operations for selected site radioactive waste, a high-level radioactive waste-storage tank complex, and a LLW water treatment plant and lagoon, as well as other related facilities.

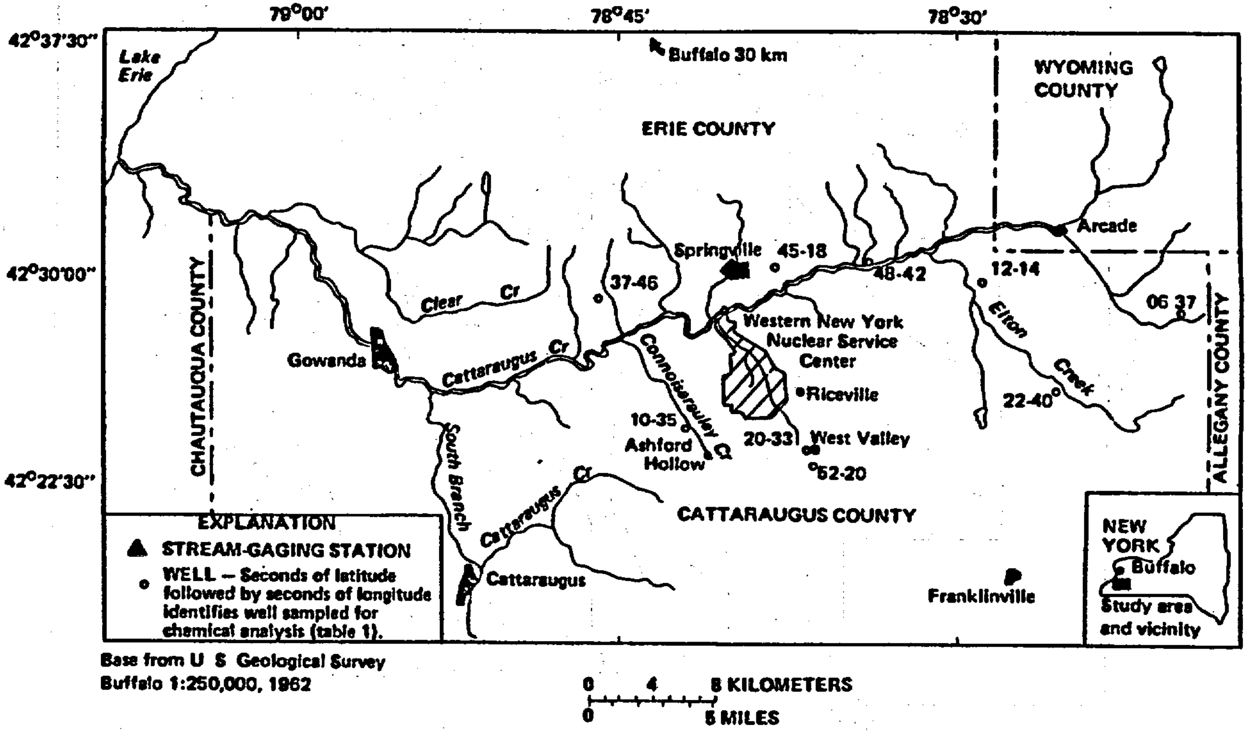
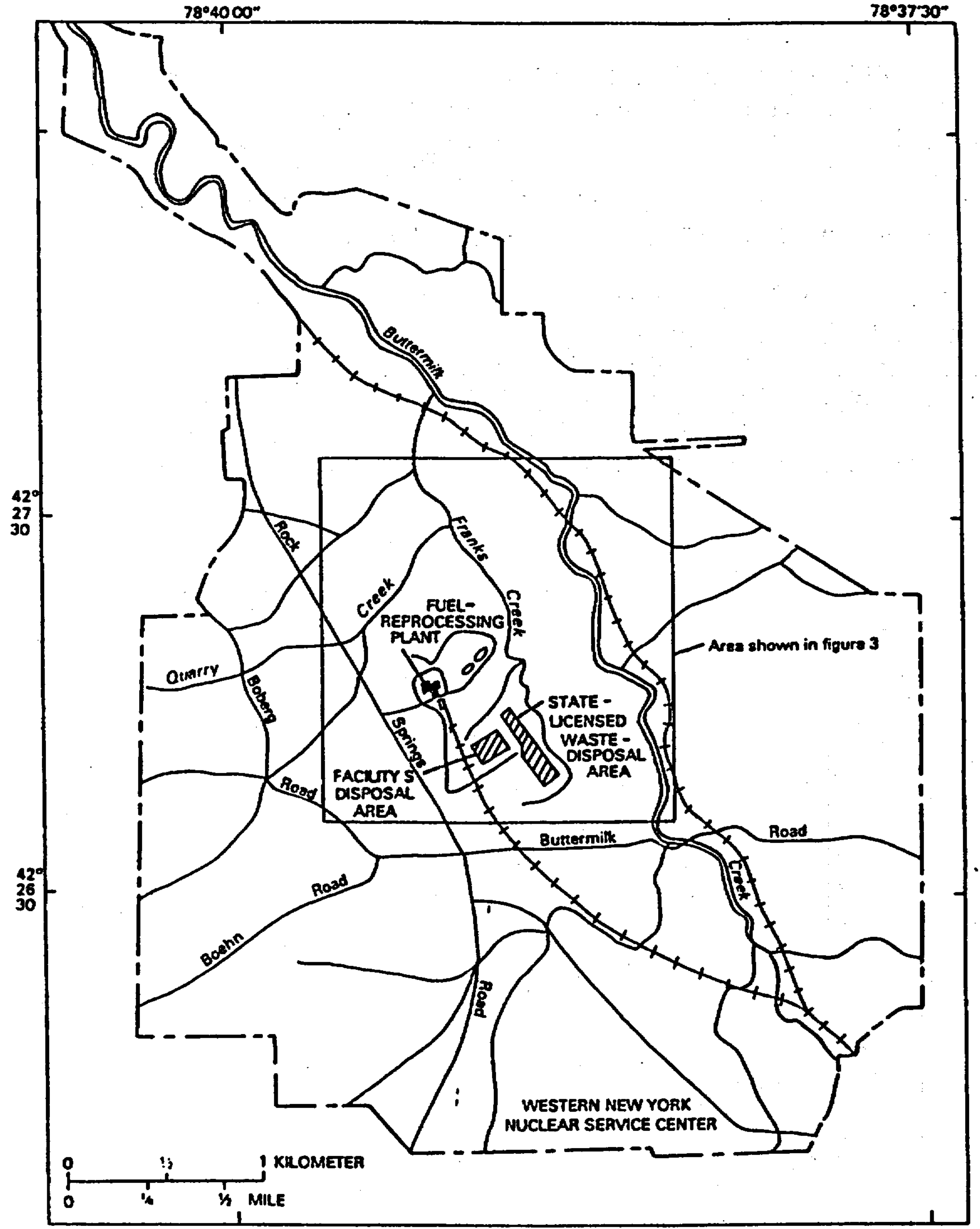
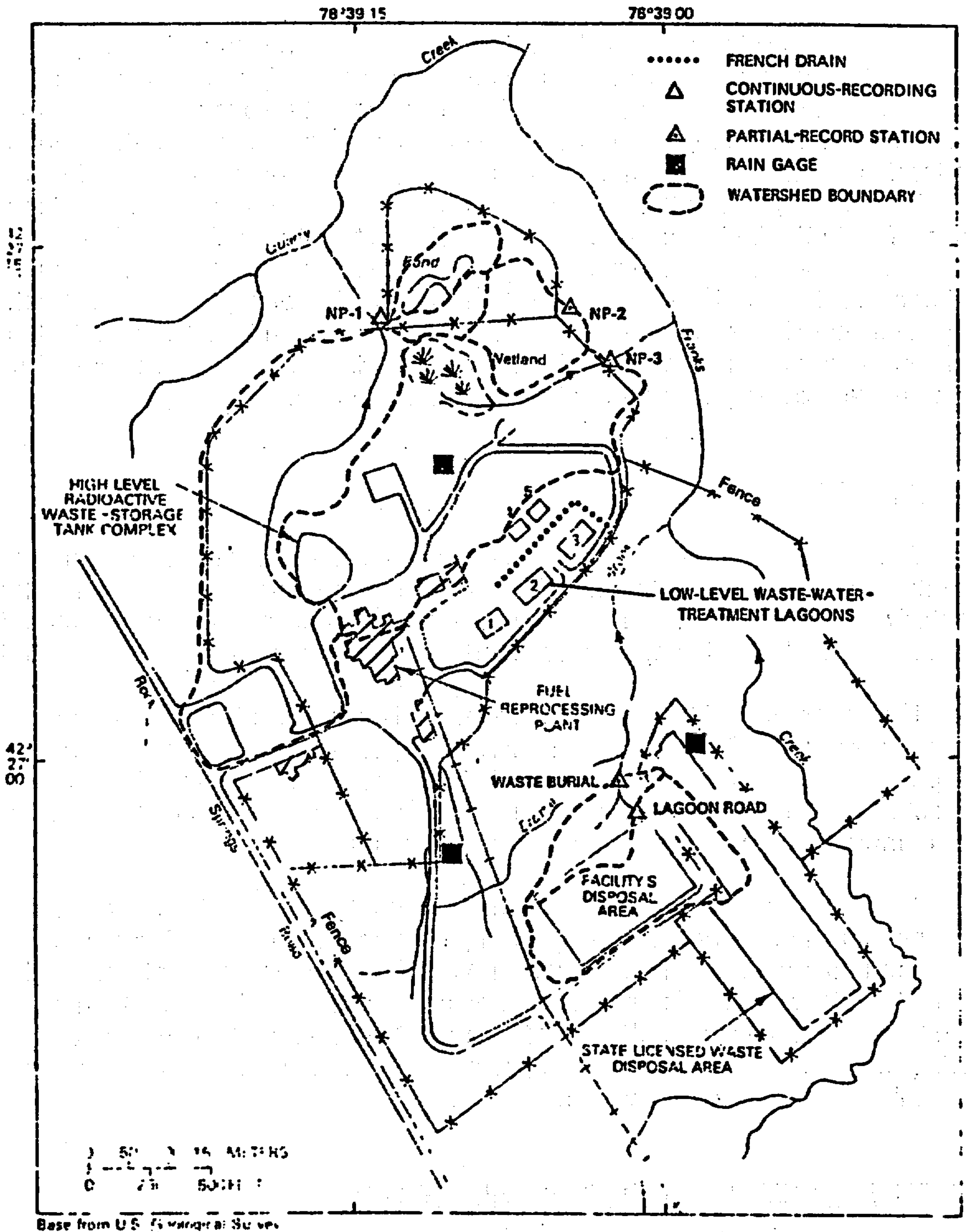


FIGURE 2.1. Location of Western New York Nuclear Service Center, Streams, and Selected Wells Within Cattaraugus Creek Basin (after Prudic 1986)



Base from U S Geological Survey
Ashford Hollow, 1979 1:24 000

FIGURE 2.2. Overview of Major Physiographic Features and Major Western New York Nuclear Service Center Facilities



Base from U.S. Geological Survey
Ashford Hollow 1979 1:24,000

FIGURE 2.3. Detailed View of Major Physiographic Features and Major Western New York Nuclear Service Center Facilities

2.1 TOPOGRAPHY AND DRAINAGE

The glaciated terrain near West Valley is a gentle, rolling topography that is moderately dissected by streams. The surface is generally covered by glacial till composed predominantly of fine-grained silts and clays but also includes some gravel and cobbles. The vegetation in the area is deciduous hardwood forest, although much of the land in the area has been farmed for many years. The waste burial site sits on a knoll bordered by intermittent creeks and a small, swampy area on lowlands to the north. The LLW site is located on the west side of the Buttermilk Creek Valley in the Cattaraugus Creek drainage basin (Figure 2.4). Frank's Creek and a tributary called Erdman Brook drain the east and west sides of the burial area. Frank's Creek drains into Buttermilk Creek, which flows several kilometers north from the burial site to its confluence with Cattaraugus Creek. Cattaraugus Creek then flows about 50 km northwest before reaching its mouth at Lake Erie (Figure 2.1).

2.2 CLIMATE

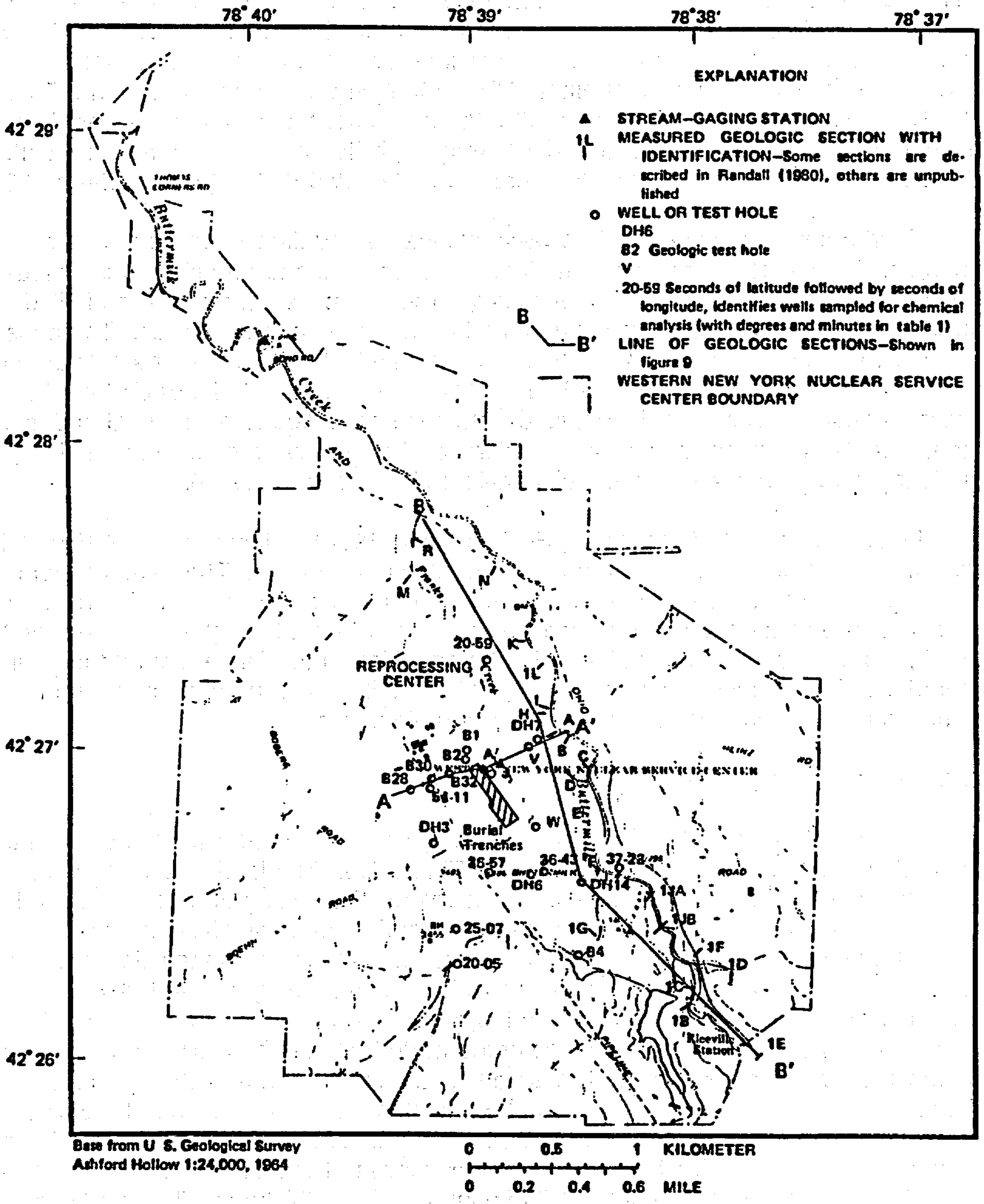
The West Valley area has a moist continental climate owing to the proximity of the Atlantic Ocean and Lake Ontario. The prevailing winds are from the west with southwesterly winds prevalent during the warmer months and northwesterly winds during the cooler months. Wind speeds are moderate, generally less than 15 km per hour.

The mean annual temperature at West Valley is about 7°C with mean monthly temperatures of -6°C for the January-February period and 20°C in July. Annual temperatures commonly range between -26°C and 32°C. Several days may be expected to be near each extreme annually. Approximately 100 to 120 frost-free days can commonly be expected during the growing season.

The average annual precipitation in the West Valley area is about 100 cm. Precipitation is distributed relatively evenly throughout the year. Rates of 9 cm/mo are common in the spring, early summer, and late fall. Winter precipitation, which averages about 7 cm/mo, commonly occurs as snow; accumulations of 30 cm or more may result from a single storm. Accumulations of 125 cm during two consecutive months during the winter are not uncommon, and continuous snow cover may be expected from mid-December to mid-March.

2.3 SITE OWNERSHIP AND DISPOSAL HISTORY

The West Valley site is owned by the State of New York. Nuclear Fuel Services, Inc. (NFS), who was the sole site operator under permit from the state, began site operations in 1963. The permit was initially administered by the New York State Department of Labor (NYSDOL) and the New York State Department of Health



Base from U. S. Geological Survey
Ashford Hollow 1:24,000, 1964

FIGURE 2.4. Location of Commercial Low-Level Waste Site, Fuel Reprocessing Plant, Streams, Wells, Test Holes, and Geologic Sections Within the Western New York Nuclear Service Center

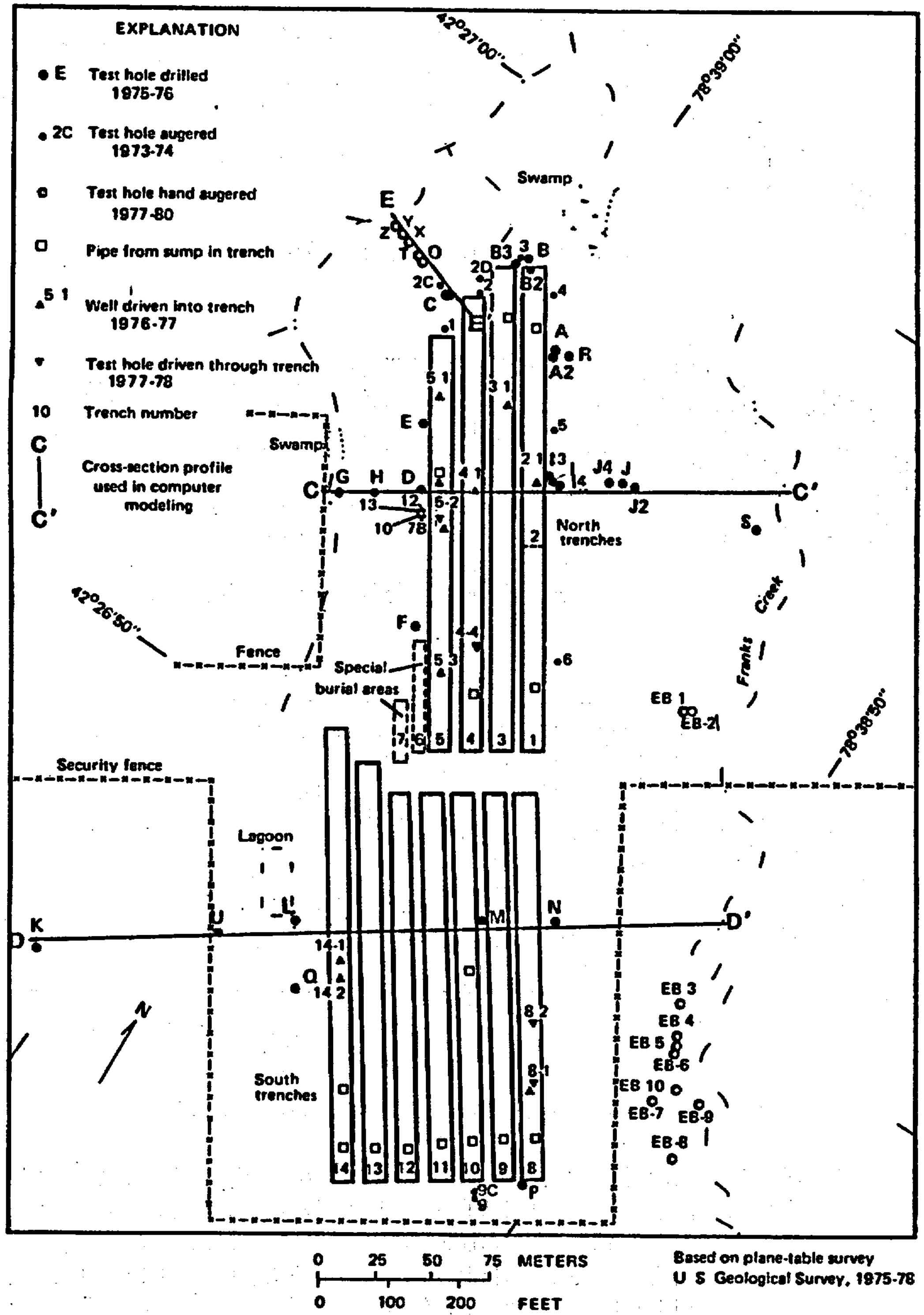
(NYSDOH) until 1974. The New York State Department of Environmental Conservation (NYSDEC) assumed control from the NYSDOH in October 1974. Radioactively contaminated water was discovered overflowing several of the trench covers in 1975, and operation of the site was terminated through a joint agreement between NFS and NYSDEC (Envirosphere 1986). As part of the agreement, a closure plan was developed that enabled the eventual transfer of responsibility for the site to the New York State Energy Research and Development Authority (NYSERDA) (Envirosphere 1986).

Fourteen waste burial trenches were excavated and filled over the period of operation (Prudic 1986) as shown in Figure 2.5. Trenches are numbered consecutively as they were constructed. Trenches 1 through 7 were constructed and filled during the first 6 years of operation and are known as the north trenches. Trenches 8 through 14, the south trenches, were constructed and filled during the next 6 years of operation. Major customers served during the operational period included medical and educational institutions, industrial clients such as radiopharmaceutical and instrument manufacturers, various levels of federal and state government, commercial nuclear power plants, and commercial haulers (Envirosphere 1986).

In a recent report of site status, Envirosphere (1986) indicated that NYSERDA is developing comprehensive site management plans for the site. The trench covers now support a thick stand of grass. Maintenance surveys are conducted semiannually to monitor the conditions of the trench covers. Water levels in each trench, except 6 and 7, are monitored monthly along with the condition of the fence around the perimeter of the site. Trench leachate is being occasionally pumped from a number of trenches to maintain leachate levels at acceptable levels.

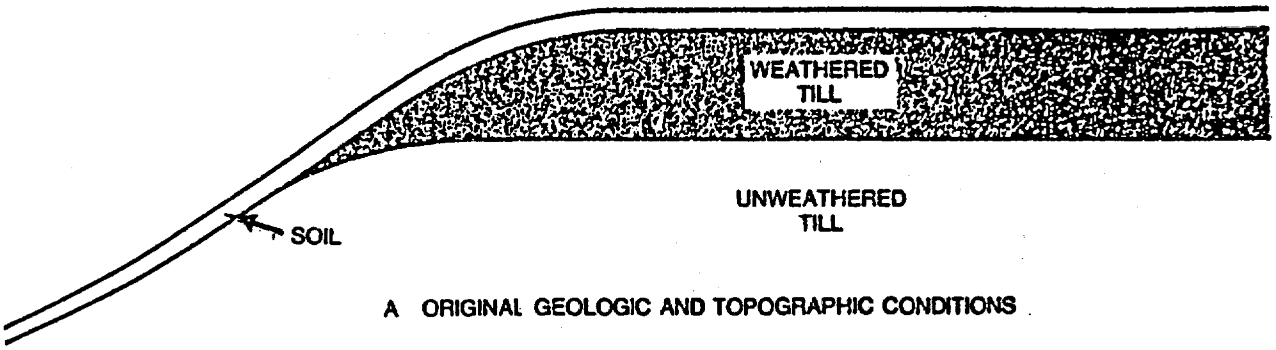
2.3.1 Trench Construction

The trenches at the West Valley site have been excavated using the cut-and-fill method, which is schematically illustrated in Figure 2.6. The land that the trenches occupy was cleared and graded before excavation. Trenching proceeded several tens of meters at a time to minimize the amount of time that any given portion of a trench was exposed to the elements. The excavated till was set to the side and used to cover the wastes when the trenches were full. As trenching proceeded, completed trenches were temporarily covered with the excavated material. Experience gained with the construction and maintenance of the north trenches has improved the quality of trench construction over time. Because less than 2 m separates the north trenches, the resulting thin trench walls tended to be unstable, causing slumping of the till sidewall into the trenches. In addition, the trench covers consisted of a relatively thin and poorly graded soil, leading to a reduced effectiveness at preventing infiltration. The south trenches were spaced at least 3 m apart and have thicker, well-graded caps. These two aspects have contributed to better overall performance of the south trenches, which have experienced much reduced infiltration.

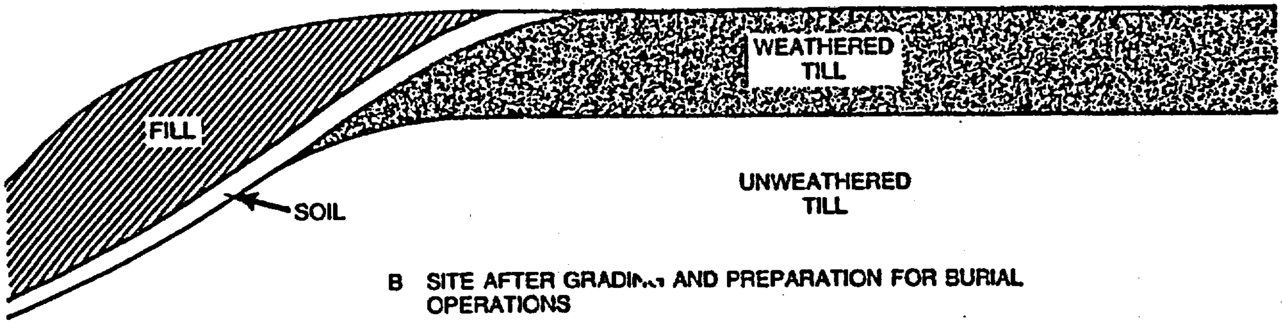


Based on plane-table survey
U S Geological Survey, 1975-78

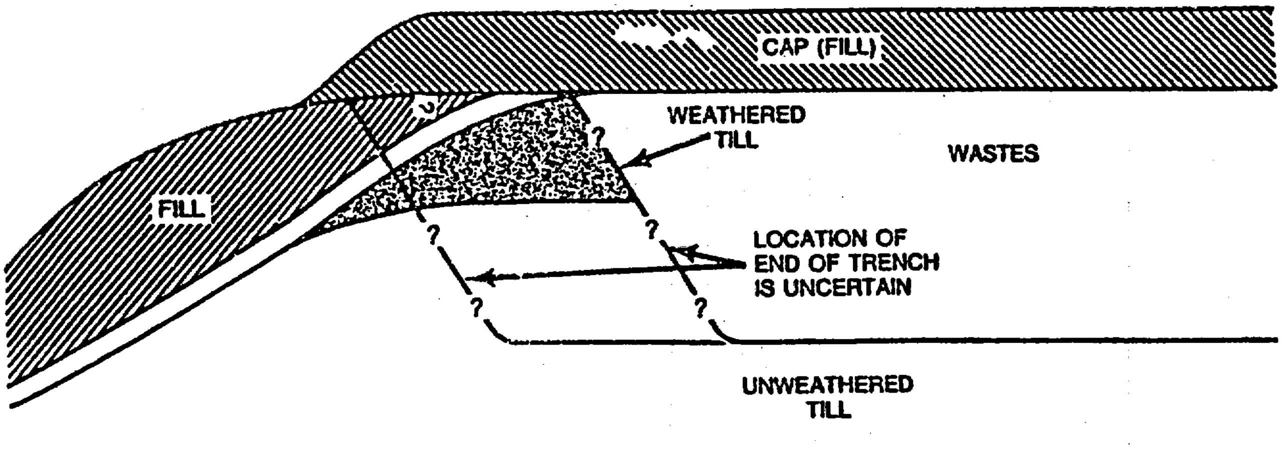
FIGURE 2.5. Locations of Waste-Burial Trenches and Nearby Test Holes and Wells (after Prudic 1986)



A ORIGINAL GEOLOGIC AND TOPOGRAPHIC CONDITIONS



B SITE AFTER GRADING AND PREPARATION FOR BURIAL OPERATIONS



C SITE AFTER BURIAL OPERATIONS COMPLETED

FIGURE 2.6. North-South Cross-Section of the North End of Commercial Low-Level Radioactive Waste Burial Grounds at Nuclear Fuel Services, West Valley, New York. The cross-sections interpret the geology of the north end of the burial grounds based on data from core holes, topographic maps and field observations (after U.S. Department of Energy 1979).

2.3.2 Waste Volume and Characteristics

Waste emplacement and burial at the site was relatively constant during the period of operation. About 67,000 m^3 of waste is interred at the site. Inventories for the waste burial trenches, listed in Table 2.1, are estimated inventories at the time of disposal developed by Kelleher and Michaels (1973). Tritium is generally the most abundant radionuclide followed by ^{14}C. The remaining radionuclides are generally listed in order of decreasing abundance in the inventory. The distribution of radionuclides for trenches 12 through 14 reflect average distributions from trenches 1 and 11. The distribution of ^{90}Sr in the inventory is not provided in Table 2.1. Most of the ^{90}Sr interred at the site is located in trench 4 where approximately 15,763 Ci were buried (Giardina et al. 1977). Only minor amounts of ^{90}Sr were buried in most of the other trenches; thus, they are listed separately in Table 2.1.

Several sources exist for the ^{14}C buried in the trenches. Some may be the result of disposal of activated charcoal filters used during the nuclear fuel cycle (Kelleher and Michaels 1973). Giardina et al. (1977) report on the shipment of pesticides containing organic ^{14}C to several of the trenches.

Table 2.2 lists the volume and types of waste containers for trenches 8 through 14 as described in Prudic (1986). The total waste volumes presented here differ slightly from those given in Table 2.1. At least half of the inventory is housed in metal containers. The next most abundant type of container is either cardboard or wood, depending on the trench. Each trench may contain up to several hundred cubic meters of both concrete containers and loose rubble. A few cubic meters of plastic containers are found in trenches 8 and 12.

TABLE 2.1. Estimated Inventory for Low-Level Waste Burial Trenches (after Ford et al. 1978)

Trench No.	Total Activity (Ci)	Waste Volume (cm^3)	Nuclide Concentration in Waste (uCi/cm^3)									
			^{3}H	^{14}C	^{60}Co	^{137}Cs	^{226}Ra	^{241}Am	^{238}Pu	^{239}Pu	^{235}U	^{232}Th
11	5.35×10^{4}	5.18×10^{9}	7.0	6.6×10^{-2}	5.1×10^{-2}	5.8×10^{-4}	1.9×10^{-3}	1.3×10^{-3}	7.6×10^{-2}	1.2×10^{-5}	2.3×10^{-6}	9.9×10^{-6}
10	5.49×10^{4}	5.17×10^{9}	6.1	6.4×19^{-3}	3.5×10^{-1}	5.8×10^{-4}	5.8×10^{-7}	7.7×10^{-7}	1.7×10^{-1}	7.5×10^{-4}	9.1×10^{-7}	2.5×10^{-6}
9	3.42×10^{4}	4.92×10^{9}	1.6	3.6×10^{-3}	2.8×10^{-2}	1.8×10^{-4}	2.8×10^{-6}	1.0×10^{-3}	2.1×10^{-2}	1.2×10^{-3}	1.6×10^{-6}	5.7×10^{-6}
8	3.87×10^{4}	7.15×10^{9}	2.2	4.9×10^{-3}	1.8	1.4×10^{-4}	2.3×10^{-4}	2.1×10^{-4}	3.1×10^{-2}	3.9×10^{-3}	3.8×10^{-6}	5.2×10^{-5}
5	9.29×10^{4}	7.88×10^{9}	1.4	3.8×10^{-4}	5.9	1.3×10^{-5}	5.6×10^{-5}	–	1.7×10^{-2}	2.3×10^{-3}	8.5×10^{-7}	3.3×10^{-5}
4	6.71×10^{4}	7.77×10^{9}	3.5×10^{-1}	1.0×10^{-3}	2.2×10^{-2}	3.9×10^{-4}	2.1×10^{-4}	–	–	3.8×10^{-3}	2.2×10^{-6}	–
3	1.71×10^{4}	5.62×10^{9}	1.2×10^{-1}	8.9×10^{-4}	7.1×10^{-1}	–	8.9×10^{-5}	–	7.2×10^{-4}	1.1×10^{-3}	6.8×10^{-7}	1.6×10^{-6}
2	2.2×10^{3}	3.24×10^{9}	2.5×10^{-3}	–	4.9×10^{-2}	–	6.2×10^{-5}	–	–	1.7×10^{-4}	4.3×10^{-7}	–
1	4.12×10^{3}	1.56×10^{9}	1.1×10^{-2}	6.4×10^{-4}	2.2×10^{-2}	–	–	–	–	–	3.9×10^{-6}	2.0×10^{-5}
7	1.57×10^{3}	7.00×10^{7}	–	–	3.6	–	–	–	–	–	9.0×10^{-6}	–
6	1.02×10^{4}	2.10×10^{6}	–	–	4.9×10^{3}	–	–	–	–	–	–	–
12[a]	1.12×10^{4}	5.49×10^{9}	2.2	9.8×10^{-3}	1.6	5.0×10^{-4}	1.1×10^{-4}	8.4×10^{-4}	6.2×10^{-2}	7.3×10^{-3}	1.7×10^{-6}	2.0×10^{-5}
13[a]	9.40×10^{3}	5.82×10^{9}	2.2	9.8×10^{-3}	1.6	5.0×10^{-4}	1.1×10^{-4}	8.4×10^{-4}	6.2×10^{-2}	7.3×10^{-3}	1.7×10^{-6}	2.0×10^{-5}
14[a]	1.23×10^{4}	4.72×10^{9}	2.2	9.8×10^{-3}	1.6	5.0×10^{-4}	1.1×10^{-4}	8.4×10^{-4}	6.2×10^{-2}	7.3×10^{-3}	1.7×10^{-6}	2.0×10^{-5}
Total	4.09×10^{5}	6.46×10^{10}										
Ave	–	–	2.2	9.8×10^{-3}	1.6	5.0×10^{-4}	1.1×10^{-4}	8.4×10^{-4}	6.2×10^{-2}	2.0×10^{-3}	1.7×10^{-6}	2.0×10^{-5}

(a) Nuclide Concentrations for Trenches 12, 13, and 14 taken to be average of Trenches 1-11 (omitting 6 and 7).

TABLE 2.2. Volume of Waste Containers in Trenches 8 Through 14 (after Prudic 1986)

	Trench 8		Trench 9		Trench 10		Trench 11		Trench 12		Trench 13		Trench 14	
Type of Container	Volume (m^3)	Percentage of Total	Volume (m^3)	Percentage of Total	Volume (m^3)	Percentage of Total	Volume (m^3)	Percentage of Total	Volume (m^3)	Percentage of Total	Volume (m^3)	Percentage of Total	Volume (m^3)	Percentage of Total
Metal														
Drums	3279	46	2543	53	2467	47	3034	59	3400	61	3893	66	4057	63
Tanks and boxes	164	2	39	1	84	2	165	3	266	5	46	1	408	6
Machinery, equipment	4	–	165	3	135	3	–	–	4	–	26	–	1	–
Pipes, beams, other loose pieces	1	–	59	1	6	–	15	–	216	4	23	–	25	–
Wood														
Boxes	1081	15	718	15	889	17	952	18	908	16	1030	17	1061	17
Lumber, other items	1	–	17	–	10	–	11	–	17	–	3	–	7	–
Concrete														
Casks	119	2	161	3	32	1	67	1	168	3	457	8	442	7
Cylinders, blocks	–	–	11	–	1	–	6	–	22	–	–	–	–	–
Paper, cardboard, fiberboard														
Boxes	1712	24	769	16	1016	20	423	8	294	5	240	4	146	2
Drums	342	5	24	1	73	1	31	1	52	1	65	1	137	2
Plastic	4	–	–	–	–	–	–	–	2	–	–	–	–	–
Loose dirt, gravel, slag, rubble	383	5	231	5	461	9	419	8	175	3	50	1	101	2
Miscellaneous														
Boxes, type unknown	56	1	80	2	22	–	41	1	29	1	36	1	27	–
Other	32	–	21	–	6	–	19	–	5	–	35	1	27	–
Total volume	7178		4838		5202		5183		5558		5904		6439	

-- indicates negligible amount.

3.0 PREVIOUS INVESTIGATIONS

Numerous investigations have covered many aspects of the West Valley site. The following discussion focuses on previous investigations related to the site geology, hydrology, and subsurface radionuclide migration that has occurred.

3.1 GEOLOGY

The West Valley site is found in the northwest Appalachian Basin. The geology is characterized by early Paleozoic marine sediments that form a broad syncline and are overlain by Pleistocene glacial deposits. The paleozoic sediments consist primarily of shales and siltstones with smaller amounts of sandstones and limestones, while the overlying glacial deposits are interlayered tills, lacustrine deposits, and lenses of coarser sediments indicative of several episodes of glaciation. A generalized stratigraphic column for the vicinity of the West Valley site is provided in Figure 3.1.

The site is located structurally on the north limb of a broad syncline. The rocks dip to the south at 6 to 8 m/km. The rocks exhibit regular bedding with little folding or faulting apparent. However, a well-developed set of approximately vertical joints or fractures is evident. In the few places where bedrock is exposed (Figure 3.2), individual joints tend to be about 30 cm long and 60 cm apart. The common orientations of the joints are N 68° E and N 45° W.

3.1.1 Bedrock Characteristics

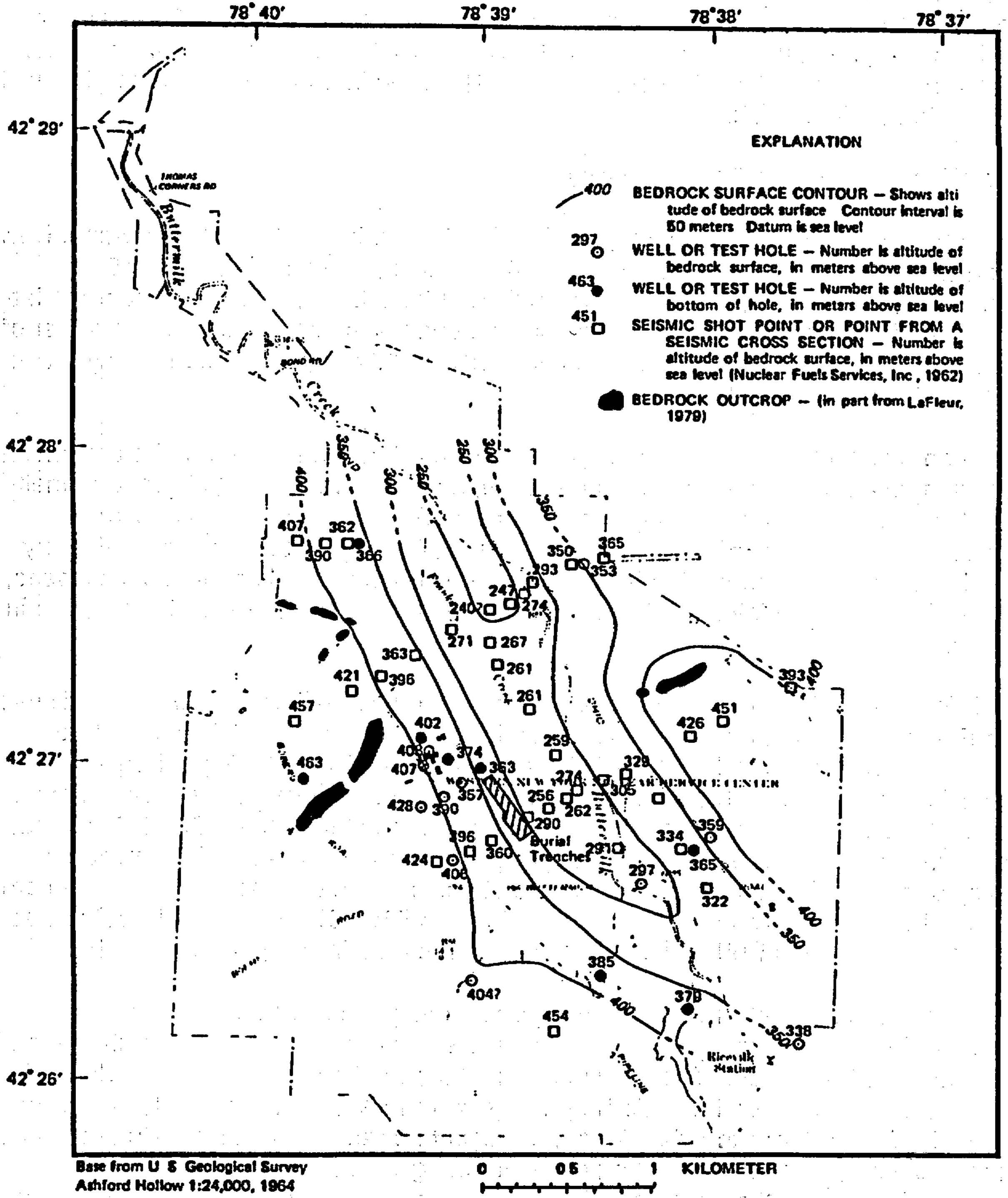
According to Colton (1961) and Eardley (1962), who provide detailed discussions of the bedrock stratigraphy in western New York, approximately 2300 m of Paleozoic rocks consisting predominantly of shales, limestones, and sandstones is present in the vicinity of the site. The upper bedrock in this portion of the Appalachian Basin is comprised of shales and siltstones of the Devonian Canadaway Group (Chadwick 1933). In the vicinity of the burial site, the Canadaway Group is highly jointed and about 300 m in thickness.

The Caneadea-Machias Formation comprises the upper 120 m of bedrock that underlies the glacial deposits and consists of moderately hard, thin-bedded shales and siltstones that are gray to black in color. Prudic (1986) describes the upper 180 m of bedrock as containing thin beds of gray shale and silty shale with a few scattered thin beds of light-gray calcareous siltstone.

The bedrock surface in the vicinity of the site displays a well-dissected paleotopography with as much as 300 m of relief between hills and valleys. A structural

System	Series	Unit	Thickness (m)	Approx. Depth (m)
Quaternary	Holocene	Alluvial fans; floodplain alluvium	0-6	3
	Pleistocene	Glacial till; fluvial sands & gravels	0-160	30
Devonian	Upper	Canadaway Group Java & West Falls Group Sonyea Group Genesee Group (shales)	580	610
	Middle	Tully Formation	5	615
		Hamilton Group (shale & limestone)	110	725
		Onondaga Limestone	50	775
Silurian	Upper	Akron-Bertie Salina Group	230	1005
	Middle	Lockport Group	70	1075
		Clinton Group	45	1120
	Lower	Medina (sandstone)	30	1150
Ordovician	Upper	Queenston Formation (red shales)	300	1450
		Oswego Formation (sandstone)	35	1485
	Middle	Lorraine Group Utica Formation	250	1735
		Trenton-Black River Group	255	1990
Cambrian	Upper	Tribes Hill-Beekmantown	30	2020
		Little Falls Dolomite	60	2080
		Theresa Formation	215	2295
		Potsdam Formation	30	2325
Precambrian				

FIGURE 3.1. Generalized Stratigraphic Column for the Vicinity of Western New York Nuclear Service Center (modified from U.S. Department of Energy 1982)



Base from U S Geological Survey Ashford Hollow 1:24,000, 1964

FIGURE 3.2. Bedrock-Surface Altitude in Buttermilk Creek Valley (modified from Randall 1980)

contour map of the bedrock surface in the vicinity of the burial site (Figure 3.2) indicates that the thalweg of the bedrock valley occurs at a depth of 90 to 120 m when it coincides with the current stream channel (Randall 1980). Directly east of the waste burial trenches, the thalweg is west of Buttermilk Creek in an area where the glacial fill may be about 150 m thick.

3.1.2 Glacial Sediment Characteristics

Broughton and Stewart (1963) and Stewart (in two letters to J. D. Anderson, New York State Office of Atomic Development dated April 3, 1962, and July 10, 1962) describe initial investigations of the glacial till and lacustrine sediments that comprise the valley fill. Subsequent work on the glacial deposits is documented in a number of reports which include Coates (1976), Muller (1977a, 1977b), and most notably LaFleur (1979, 1980) and Randall (1980).

According to LaFleur (1979), the unconsolidated sediments at the site are interbedded layers of glacial till, lacustrine, alluvial, and colluvial deposits formed in meltwater lakes and streams during glacial recesses. A generalized cross section representing the vicinity of the burial site, illustrated in Figure 3.3, shows pre-Lavery age tills as undifferentiated older deposits. More complete descriptions, thicknesses, and stratigraphic correlation of these deposits taken from LaFleur (1979) are given in Table 3.1.

Information about Olean, Kent, and Defiance (Lavery-Hiram) aged glacial till overlying Paleozoic bedrock has been revealed by wells drilled by the New York State Department of Public Works (NYSDPW), the New York State Geological Survey (NYSGS), and the U.S. Geological Survey (USGS) in the West Valley Area. A more recent till called the Valley Heads till is identified in the Cattaraugus Creek Basin but has either been eroded or was never deposited in the vicinity of the West Valley site. Geologic logs and construction details of test holes that have been drilled at the commercial site as well as all others drilled within the WNYNSC and several geologic sections measured along Buttermilk Creek are documented in Bergeron et al. (1985).

Much of the upper 2 m of the geologic section, given in Table 3.1, consists of reworked till (units 1 through 4). Slumping and soil creep have altered much of the till along the steeper slopes. The alluvium within these units is predominantly derived through the reworking of the underlying till by Buttermilk Creek and tributaries. Both valley fill and fan deposits exist along the present stream channels; alluvium-covered terraces developed as the streams down-cut through the till. Unit 4 is the only reworked till found in the area occupied by the trenches and is mappable only in the northern portion of the waste burial area.

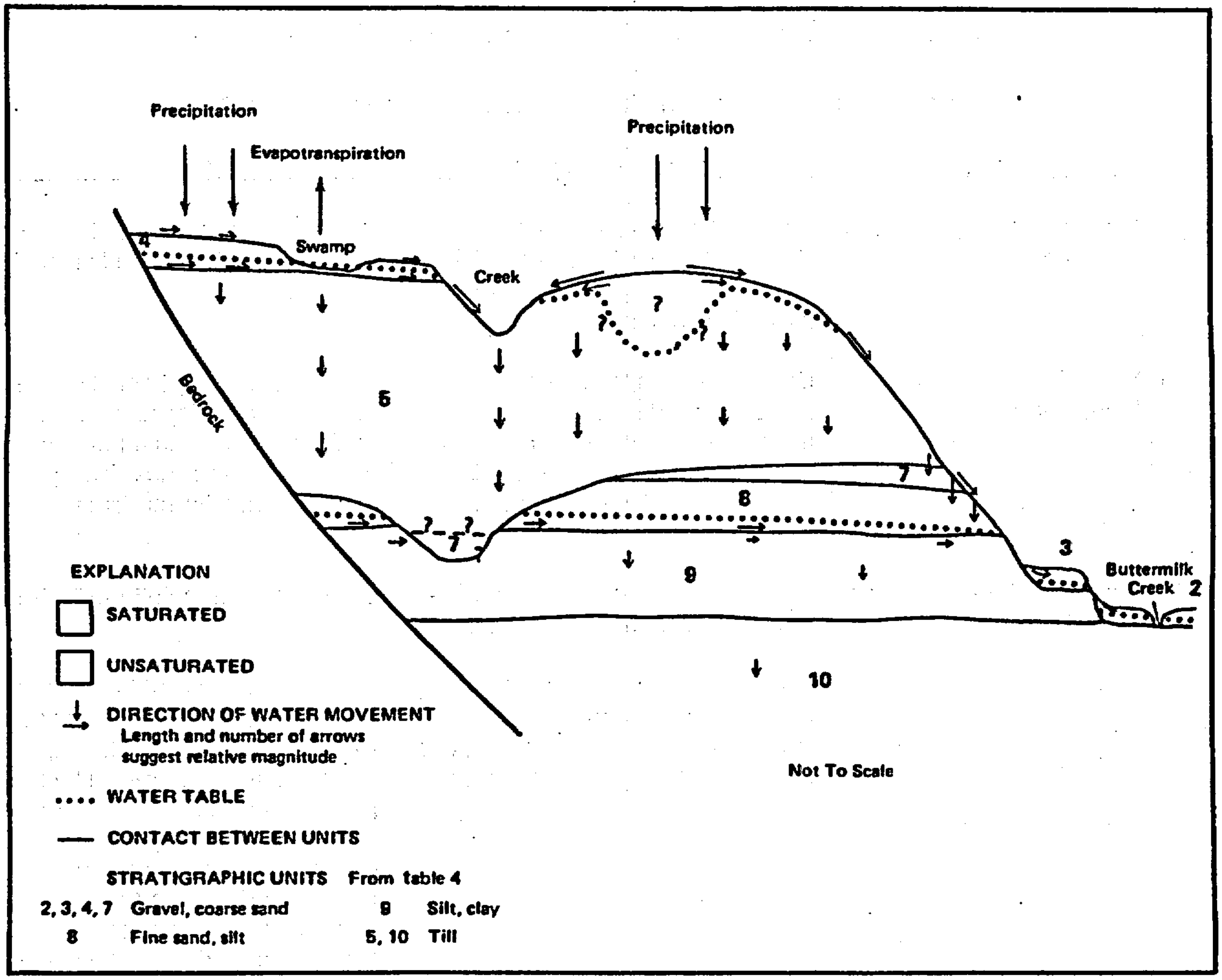


FIGURE 3.3. Idealized Cross-Section in Vicinity of Burial Site West of Buttermilk Creek Showing Inferred Distribution of Saturated and Unsaturated Material and General Directions of Ground-Water Flow

Lavery Till (unit 5) is exposed across much of the surface in the vicinity of the burial site. The till is approximately 28 to 30 m in thickness (Prudic 1986). LaFleur (1979) divides the Lavery Till into three facies: 1) a silty clay till matrix containing 10% to 20% stones, 2) a similar till matrix with occasional wisps of light-gray quartz silt containing less than 5% stones, and 3) lenticular, stratified, discontinuous deposits of sand and clay containing recognizable portions of the first till facies. The till matrices of facies one and two are similar in composition; grain size and mineralogical analyses indicate compositions on the order of 40% clay, 48% silt, and about 12% sand with the predominant mineralogies of the silt and clay being quartz, illite, and chlorite (Whitney 1977). The first facies accounts for about 70% of the Lavery Till. The second

TABLE 3.1. Stratigraphy of Quaternary Sediments in Central Buttermilk Creek Valley, Cattaraugus County, New York (after Prudic 1986)

[Locations (Riceville Station, Bond Rd., etc.) are shown in Figure 2.2]

Unit	Lithology and Distribution	Origin
(1) Slopes: typically 0.3 - 1 m Elsewhere: 0	A layer of chiefly soft, plastic pebbly silt (reworked till) 0.3 to 1 m thick on all slopes, also local slump blocks several meters thick.	Colluvium, formed by soil creep and local shallow-seated rational slumps.
(2) Valley bottoms: 0.6 - 2 m Elsewhere: 0	Gravel, pebbles to large cobbles, and sand, moderately silty; in part overlain by clayey silt with organic matter; includes local masses of colluvium, chiefly reworked till.	Stream alluvium (channel point-bar gravel, and silt deposited by overbank floods or in channel reaches ponded by mudslides) locally interbedded with mudslide deposits.
(3) Terraces: 0.6 - 2 m typical Elsewhere: 0	Ferruginous gravel and silt, underlies terraces along Buttermilk Creek	Older alluvium of Buttermilk Creek
(4) 0 - 6.2 m	Gravel and sand, moderately silty; coarser and siltier on alluvial fans formed where streams enter Buttermilk Valley at about 437 m altitude.	Deposited by upland streams that flowed onto the freshly exposed till plain, then northwestward, before significant incision by the present system. Alluvial-fan deposition near the valley wall probably continued after incision by Buttermilk Creek had begun. Absent on some higher areas of the till plain and where lingering ice blocks diverted flow.
(5) 5 m (Riceville Station) 22 m (Buttermilk Rd.) 28 m (burial site) 37 m (RR bridge over Buttermilk Cr.) 40 m (mouth of Frank's Cr to Bond Rd.)	Till, composed predominantly of clay and silt. Sixteen cores from drill holes near the burial site contained 50% clay, 27% silt, 13% sand, and 10% fine gravel on the average. LaFleur (1979) reports that 10-20% pebbles and cobbles is characteristic of most exposures. Typical non-sorted till interfingers randomly with a similar till containing many tiny blebs and torn, deformed wisps of quartz silt Although these two subfacies form crudely horizontal layers, each is internally deformed. Distributed throughout (at least within boundary of the center) are randomly	Deposited by a tongue of ice that readvanced as far south as West Valley through ponded water as much as125 m deep in Buttermilk Valley. During this readvance, which has been correlated by LaFleur (1979) with the Lavery readvance in Ohio, the glacier apparently floated free from the substrate periodically and allowed beds of silt and clay to accumulate Resettling of the ice to the lake floor, possibly in response to lowering of lake water by subglacial drainage or to more rapid advance of the glacier, would explain renewed till deposition as well as

TABLE 3.1. (contd)

Unit	Lithology and Distribution	Origin
	oriented pods and irregular lenses of stratified sand and gravel and rhythmic silt and clay. Excavations at the burial site and between Frank's Creek and Buttermilk Creek (Davis and Fakundiny 1978) consistently demonstrate that these stratified deposits are discontinuous, deformed, and rotated or transported from their original point of deposition. Although these lenses constitute only about 7% of core footage logged (Prudic and Randall 1979), two-thirds of the U.S. Geological Survey test holes in 1962 and 1975-78 near the burial site penetrated one or more lenses at depths of 3 to 11 m below natural grade. The till is present throughout Buttermilk Valley below about 437 m altitude.	the structural deformation observed in both the till and lacustrine-till subfacies. The apparent abundance of fragments of water-laid deposits in the upper part of the till led LaFleur (1979) to suggest a minor ice withdrawal and readvance across ice-frontal deposits near the end of this glaciation.
(6) 0-2.5 m	Layered clay or clay-silt rhythmites; may contain pebbles or grade upward into layered silty clay with scattered pebbles and then into till.	Deposited in proglacial lake dammed by advancing ice Missing in some places; not easily recognized unless well exposed. May be grouped with the overlying unit on basis of similar grain size and frequency with which the till grades into or incorporates lacustrine beds at various depths.
(7) 0-8 m	Gravel composed of pebbles and small cobbles, and sand; typically poorly sorted and moderately silty. Absent near the burial site and fuel-reprocessing plant (Figure 2.3); present consistently (but possibly discontinuous) near Buttermilk Creek. Where more than 3 m thick, interbedded with pebbly coarse sand, fine sand, and silt.	At least three modes of deposition are plausible. Deposits east and southeast of the burial ground may have originated as deltas in a declining post-glacial lake, and (or) as an alluvial blanket spreading across the former lake floor. Deposits near the mouth of Franks Creek are thin, 15 m lower in altitude, and rest on unit 9 rather than unit 8; they might have formed along stream channel(s) during interglacial incision (Erie Interstade) (LaFleur 1979).

TABLE 3.1. (contd)

Unit	Lithology and Distribution	Origin
(8) 0-8 m	Sand, very fine to fine, well-sorted and stratified, interbedded with much silt that becomes predominant with depth. Grades into underlying unit. Absent near mouth of Frank's Creek and generally along the west side of the valley.	Deltaic sediments deposited in a persistent glacial lake, probably by local streams, as indicated by distribution; northward flow indicated in two exposures, and gradation into underlying lake-bottom deposits without an intervening till or truncation.
(9) 6-16 (?) m	Interbedded coarse silt, fine silt, and clay, generally in rhythmic layers up to several mm thick; some fine silt layers are as thick as 30 cm, but close inspection commonly reveals regular partings of coarse silt; olive-gray except clay layers commonly pale grayish-red. At most locations, some intervals are marked by widely scattered pebbles, disturbed bedding, and (or) thin layers, blebs, and irregular masses of reddish-brown or greenish-gray pebbly sandy silt. This unit is present everywhere from Riceville Station to mouth of Frank's Creek, except close to sides of valley.	Units 9 and 11 consist of bottom deposits in a glacial lake characterized by icebergs and occasional readvances of a floating or occasionally grounded ice tongue. The Kent age (LaFleur 1979); it intervening till layer (unit 10) is inferred to be of appears to be a continuous unit but south of Buttermilk Road incorporates fragments of lacustrine sediment and may grade into or interfinger with lacustrine sediment that contains detritus dropped from floating ice. Furthermore, some borehole logs and geologic sections seem inconsistent with this simple threefold division of units (Randall 1980), perhaps because floating ice tongues that dropped scattered pebbles and sandy clay blebs in one locality may have been grounded in another locality and deposited till In any case, the deposits below the top of unit 9 were formed during repeated ice advance and retreat through proglacial lake water.
(10) 3-10 m	Till, similar to unit 5, perhaps darker, rare inclusions of grayish-red till; facies with torn, deformed wisps, slivers, or masses of coarse silt and in part with low pebble content predominates south of Buttermilk Road.	

TABLE 3.1. (contd)

Unit	Lithology and Distribution	Origin
(11)?	Predominantly clay, clayey silt, and silt in rhythmic layers, commonly disturbed much the same as unit 9; layered fine sand, coarse sand, and gravels locally present.	
(12)?	Till, much more sandy and stony than units 5 and 10; exposed and reported in test holes near the side of the valley, atop or close to bedrock.	May be an upland facies of unit 10, or an older till sheet; may incorporate or grade to silty gravel.

till facies comprises much of the remaining 30% of the till, with the third facies encountered only at shallow depths (2 to 4 m) (LaFleur 1979).

Fractures occur in the till, particularly in the upper few meters. Dana et al. (1979f) describe the orientation and spacing of fractures along the wall of a research trench excavated near the burial site. Most fractures are oriented approximately vertically, and major fractures are several meters apart. Several small fractures may occur locally within a meter of each other, particularly within the upper 2 m of till. Fractures are not evident beyond a depth of about 5 m in the till.

Approximately 80% to 90% of the till is derived from the local bedrock, which is composed of shales and siltstones of sodium-magnesium-silicate composition. However, the remaining 10% to 20% of the till contains allocthonous crystalline rocks from the Canadian Shield and sandstones and carbonates from northern New York. The small amount of carbonate is significant because the resulting ground-water chemistry is predominantly a calcium-carbonate regime rather than the sodium-chloride regime that would otherwise occur.

Underlying the Lavery Till is a sequence of lacustrine and deltaic deposits. These are described as units 6 through 9 in Table 3.1. Underlying these deposits are tills in units 10 and 12; the intervening unit 10 is a lacustrine deposit similar to unit 9. Prudic (1986) indicates that unit 10 is Kent-aged till based on work of LaFleur (1979). The underlying till (unit 12) is similar in composition to unit 10 and may also be Kent in age.

3.2 GROUND-WATER HYDROLOGY

Information on ground-water conditions of the West Valley site is available from a number of sources. Prudic and Randall (1977) conducted the most recent and significant ground-water investigations at the site. Their work included extensive test drilling and the installation of numerous piezometers to determine ground-water levels and analyze water samples for the presence of radionuclides. Other hydrogeologic evaluations on the trenches, trench covers, and surrounding till by the USGS are summarized in Prudic (1979a, 1979b, 1980, 1982). Prudic (1986) is a summary document that incorporates the results of all previous investigations at the site. Bergeron et al. (1987) provides descriptions of geohydrologic conditions at the WNYNSC site that includes the commercial waste site.

3.2.1 Major Hydrogeologic Units

Major hydrogeologic units in the vicinity of the waste burial trenches are the Lavery Till, the underlying lacustrine units, and the basal till. The Lavery Till is saturated in the vicinity of the waste burial site and is sufficiently impermeable to cause water infiltrating through trench covers to build up in the trenches. Prudic (1982) conducted extensive hydraulic tests of the till, employing both field and laboratory methods, that indicated that the till is approximately isotropic; average hydraulic conductivities ranged between 2×10^{-08} and 6×10^{-08} cm/s based on slug tests conducted in the field. Laboratory tests provided a wider range of values but generally were in agreement with the field tests.

The lacustrine sediments that underlie the Lavery Till are relatively coarse grained compared to the till. These sediments grade from fairly sandy near the contact with the Lavery till to silts and varied clays at their base. Lateral drainage in this unit coupled with a small water flux draining from the till tends to produce partially saturated conditions in the upper portions of the lacustrine sediments. No direct hydraulic testing of the lacustrine sediments has been done. The compositional difference between these sediments and the till indicates that the hydraulic conductivity is probably several orders of magnitude higher in the lacustrine sediments.

The basal tills and shale bedrock that underlie the lacustrine sediments are primarily finer-grained material with hydraulic conductivities likely to be similar to the Lavery till. The similarities of unit 10 (Table 3.1) to the Lavery till support this. The pressure exerted from overlying layers may significantly compact the till, producing even lower hydraulic conductivity. The underlying shale is probably about the same order of magnitude of hydraulic conductivity as the till. Although no direct hydraulic tests have been conducted at the site, hydraulic conductivity of shale commonly ranges between 1×10^{-7} and 1×10^{-11} cm/s (Freeze and Cherry 1979), which compares favorably with measured values for the till.

3.2.2 Direction and Rate of Ground-Water Movement

Prudic and Randall (1977, 1979), Prudic (1986), and Bergeron et al. (1987) indicate that much of the precipitation that falls on the site may be accounted for by evapotranspiration and runoff. The low hydraulic conductivity of the till allows very little deep percolation. Water tends to pond on the surface and run off. Steep slopes exist over much of the till surface causing precipitation to run off those areas before significant infiltration can occur.

A distribution of heads measured in piezometers at the site, illustrated in Figure 3.4, shows that infiltrating water moves in two primary directions. Although most of the precipitation that falls on the site either evapotranspires or runs off, some water infiltrates into the upper few meters of weathered, oxidized till and moves laterally

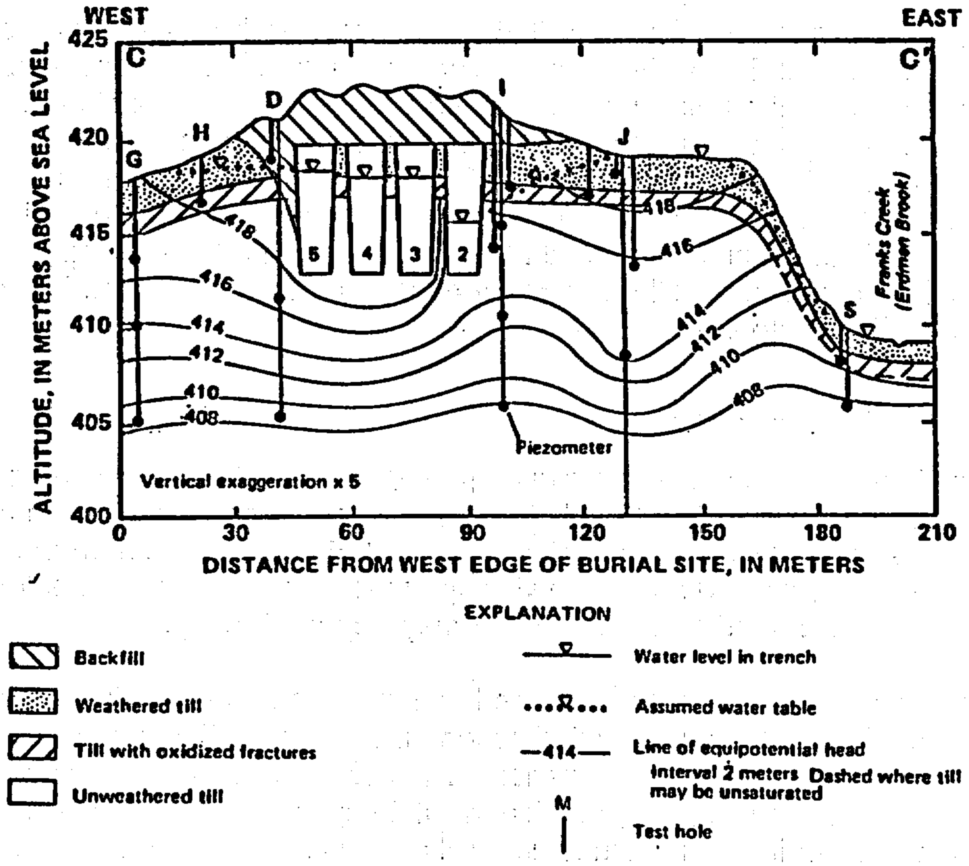


FIGURE 3.4. Vertical Sections Through Trenches Showing Head Distribution During February 1976: Section C-C' Through North Trenches (after Prudic 1986)

toward nearby streams. A small fraction of this water will infiltrate the underlying unweathered till and continue moving downward under a predominantly vertical hydraulic gradient.

3.2.2.1 Shallow Pathway

Within the shallow till, physical processes act on the till to increase its overall hydraulic character. These processes include wetting and desiccation, freezing as well as biological activity such as plant rooting and animal burrowing. These processes combine to create secondary features that cause the majority of water entering the upper till to flow laterally rather than infiltrate into the unweathered till at depth. Prudic (1986) notes an occasion where water discharged from a mole run during a period of high precipitation, indicating the reduced ability of the unweathered till to accept infiltration.

In modeling of the site, Prudic (1986) estimated that the upper weathered and fractured till was about 5 to 10 times more permeable than the unweathered till. However, other evidence at a nearby disposal area suggests that hydraulic properties of this unit could be higher. Bergeron et al. (1987) reported the lateral migration of kerosene from shallow disposal pits within the shallow till west of the site. In 1983, kerosene disposed in one of the pits in 1970 was detected in a monitoring well about 18 m away. This evidence is an indication that lateral migration rates may approach a few meters per year in the upper till layer, although these rates have yet to be coraborated at the commercial waste site.

3.2.2.2 Deep Pathway

A small amount of water is able to migrate downward from the weathered till zone into the unweathered till. Water levels from profiles of the north and south trenches at the West Valley site are shown in Figures 3.4 and 3.5. The distribution of hydraulic head indicate that ground water in the vicinity of the trenches moves predominantly downward; hydraulic head gradients locally may approach unity.

Test drilling and outcrop observation have indicated that the till contains numerous lenses and pods of stratified sands, gravels, and silts that vary in size and shape as well in their degree of saturation. The behavior of water movement in and around sand and silt lenses and pods found within the till matrix and the effect of these features on the overall flow system is not well understood. Characterization efforts have suggested that they represent disconnected units which do not have much effect in short circuiting or enhancing horizontal or vertical water movement. Although the distribution and continuity or connectivity of these units has not been completely

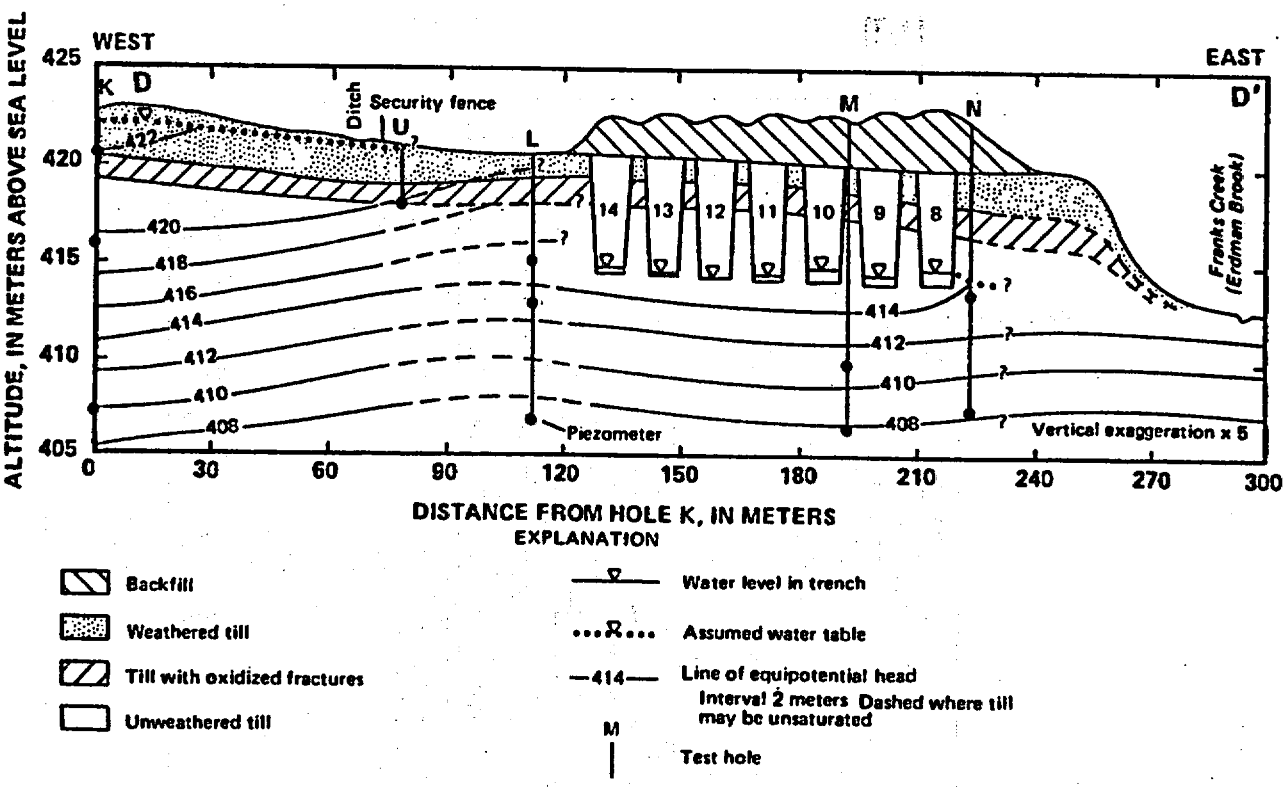
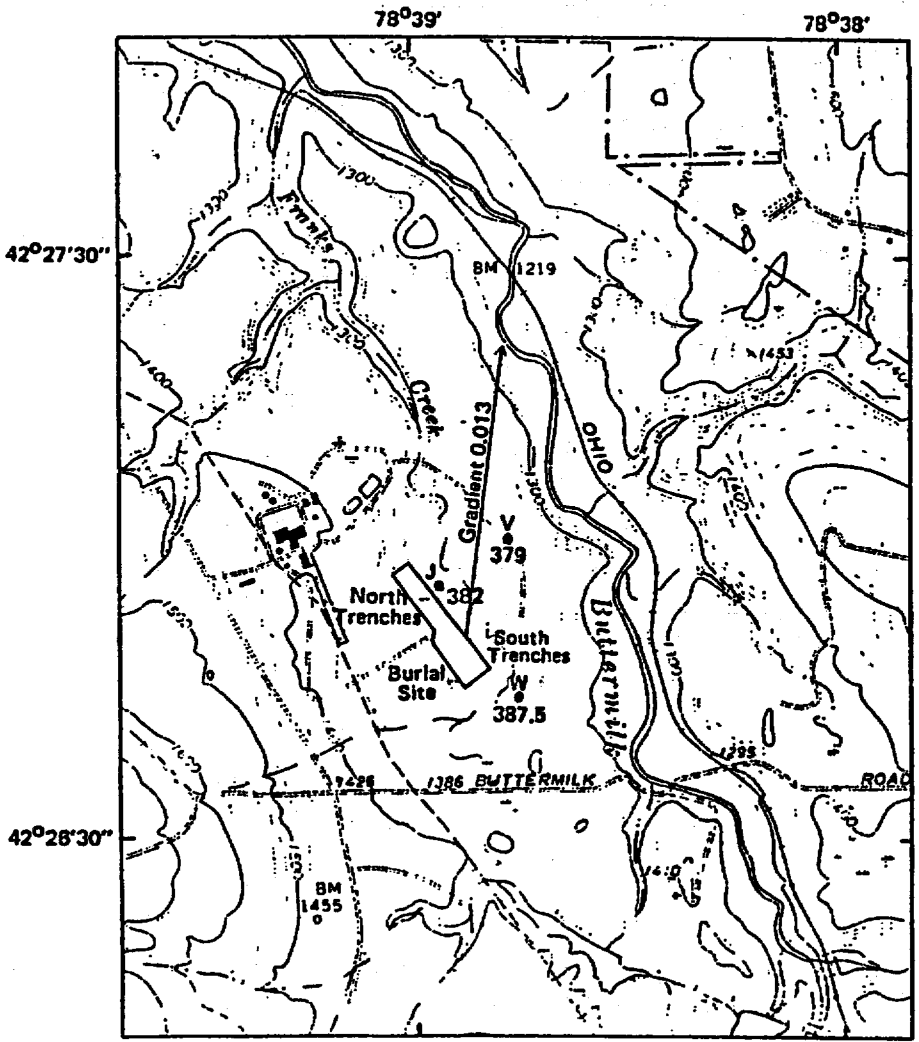


FIGURE 3.5. Vertical Sections Through Trenches Showing Head Distribution During February 1976: Section D-D' Through South Trenches (after Prudic 1986)

verified, the clay and silt-rich till matrix is accepted as the unit which dominates the flow system, and the impact of these lenses and pods on the water movement is minimal.

Prudic and Randall (1979) indicate the possibility that portions of the till are slightly to moderately unsaturated. Test holes L and Q west of trench 14 contain piezometers that have never intercepted measurable amounts of water. However, neutron moisture measurements do not differ significantly from those for proven saturated till, and the lack of water in the piezometers may indicate only that the till is slightly lower in hydraulic conductivity.

The lacustrine units that underlie the till serve as a drain to the till with water collecting in the lower portion of the lacustrine units (Prudic 1986). Once in the lacustrine unit, water moves laterally very slowly in a northeasterly direction before discharging in outcrop areas along the Buttermilk Creek Valley (Figure 3.6). The finer-grained till is unable to transmit as much water as the underlying lacustrine units are capable of receiving; consequently, the water supplied by the till is insufficient to maintain saturated conditions in the upper portion of the lacustrine units. Ground



Base from U. S. Geological Survey
Ashford Hollow 1:24,000, 1984

0 300 600 METERS
0 1000 2000 FEET

EXPLANATION

V 379 TEST HOLE — Number is altitude of water level in piezometer, in meters above sea level

FIGURE 3.6. Map Showing Lateral Direction of Ground-Water Flow in Lacustrine Sequence (after Prudic 1986)

water from the lacustrine units discharges to seeps along Buttermilk Creek, but discharge of these seeps is small, and no significant springs are apparent (Prudic and Randall 1979).

3.3 SUBSURFACE RADIONUCLIDE MIGRATION

State and federal agencies have carefully monitored the performance of the trenches at the West Valley burial site throughout its operational and post-closure history. Radionuclides mobilized by infiltrating water have migrated several meters both laterally and vertically from the trenches into the surrounding till. Tritium in the form of tritiated water has migrated the farthest. Favorable soil properties in the till have served to limit the migration of radionuclides. The most significant performance problems at the West Valley site have been related to the infiltration of precipitation through trench covers, which in turn caused a buildup of leachate in many of the trenches. Site closure resulted when overflowing leachate was detected in trench 5 at the north end of the burial ground.

3.3.1 Infiltration Through Trench Covers

Standing water in the trenches resulting from infiltration through the trench covers is the most serious performance problem at the West Valley site. A number of processes have contributed to this problem, which has reduced the effectiveness of the site trench covers in isolating wastes from precipitation.

One of the processes that has reduced trench cap effectiveness has been the compaction of trench wastes over time, which has led to collapses within the trench cover material. This compaction process has resulted in the creation of both smaller scale cracks and larger scale area of subsidence in the trench covers. Large-scale compaction of the wastes has probably contributed to the development of cracks corresponding to the edges of the trenches. Both Dana et al. (1978) and Prudic and Randall (1979) note that cracks commonly are parallel to the sides and ends of the trenches. Other cracks in trench covers have resulted from repeated wetting and desiccation of the fine-grained till that makes up the cover material. These types of cracks result from shrinkage of the till as it looses water to evaporation. Prudic (1986) measured cracks in the trench covers as deep as 60 cm using a steel measuring tape; cracks of 30 cm in depth were very common throughout the trench caps. Cracks that penetrate the entire thickness of the trench covers may result from the intersection of subsidence cracks developing from below with desiccation cracks developing at the surface.

Prudic (1986) tested the ability of cracks in several of the trenches to transmit water. He siphoned 2000 L of water into two sets of cracks at the south end of trenches 4 and 5 with no overflow observed. Similar observations resulted from the application of 110 L to a crack in the north end of trench 4. Other cracks required very little water before overflow was observed, however. Consequently, Prudic (1986) concluded that some of the cracks fully penetrated the trench caps.

Prudic (1986) indicated that the water-level rises in some of the trenches correlate with precipitation at the site (Figure 3.7). To circumvent infiltration problems with the trench covers, most of the covers have been regraded. Table 3.2 lists the approximate completion dates of each trench followed by the approximate date that regrading occurred. Regrading was accomplished during three phases: trenches 1 through 5 were regraded in August 1969, trenches 8 through 11 were regraded in July 1973, and trenches 12 through 14 were regraded in June 1975. All north trenches were also regraded in 1975. The effectiveness of regrading the north trenches in reducing the rate of trench filling is illustrated in Figure 3.8. Consequently, the high accumulation rates in the trenches appear to be directly related to the condition of the trench caps. Because forces such as subsidence, desiccation, and erosion will continue to act on the trench covers, periodic regrading will likely be necessary to maintain the integrity of the trench covers.

The water-level rises may also be the result of ground water infiltrating through the sides or bottom of a trench, but the low hydraulic conductivity of the till and the predominantly downward hydraulic gradient indicate that seepage from the till probably would not be nearly sufficient to produce the water-level rises observed in the trenches.

The high precipitation at West Valley coupled with the low hydraulic conductivity of the till tends to produce severe erosion in the vicinity of the site. Boothroyd et al. (1979, 1982) investigated the potential that erosion of the steep slopes adjacent to the trenches could compromise integrity of the trench covers and enhance contaminant migration. Their analyses of the sediment load in Buttermilk Creek indicate that erosion is actively occurring at the site. Consequently, erosion is a long-term management concern at the site, although Nicholson and Hurt (1985) conclude that given the depth of burial of the waste, sheet-wash erosion is not likely to disturb the waste for centuries.

3.3.2 Waste Leachate Characteristics

Sophisticated and in-depth studies of trench waters conducted by Brookhaven National Laboratory (Weiss and Columbo, 1979) and the NYSDOH Radiological Sciences Laboratory have shown that leachate present in the trenches are complex mixtures of inorganic and organic compounds because of the presence of various natural organic materials, organic solvents and pesticides, inorganic wastes, and radionuclides. Prudic (1986) notes that the nonradioactive constituents are similar to those described for several municipal landfills in Illinois and Indiana. Prudic (1986)

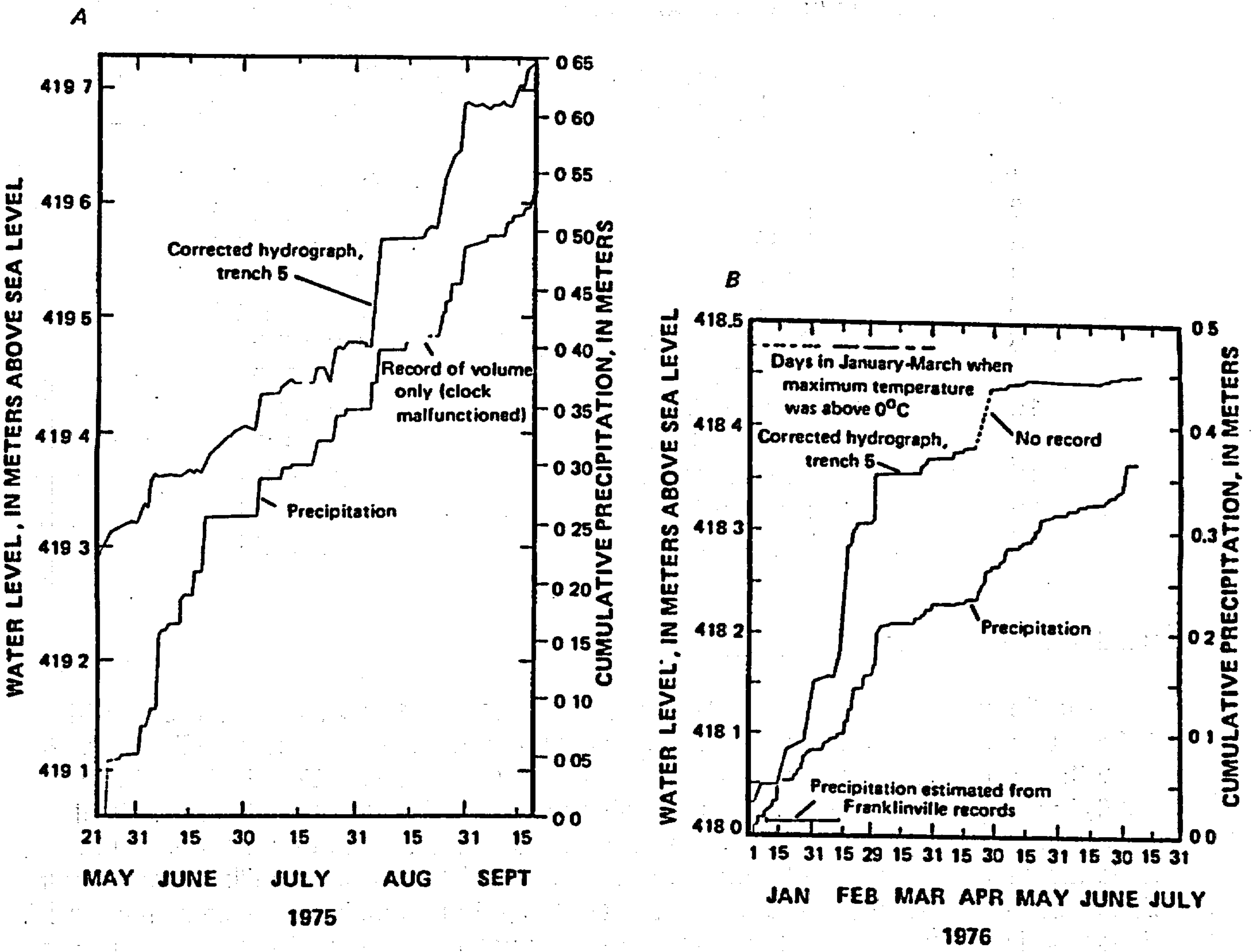


FIGURE 3.7. Water Level Changes in Trench 5 in Relation to Precipitation from May Through September 1975 and from January Through July 1976

also indicates that nonradioactive constituents from the West Valley leachate equal or exceed those measured at Maxey Flats, Kentucky, and Sheffield, Illinois.

Tritium, ^{90}Sr, and ^{14}C are the radionuclides that are present in the largest quantities in the trench waters sampled. A compilation from several sources listing the radionuclides found in a series of water samples taken from the trenches is presented in Table 3.3.

TABLE 3.2. Dates of Trench Completion and Regrading (after Prudic 1986)

Trench	Date Completed and Totally Covered	Date Cover was Regraded to Level of 1975-78
1	?	August 1969
2	?	August 1969
3	1966	August 1969
4	1967	August 1969
5	1969	August 1969
8	October,1970	July 1973
9	June 1971	July 1973
10	May 1972	July 1973
11	January 1973	July 1973
12	October 1973	June 1975
13	June 1974	June 1975
14	May 1975	June 1975

3.3.3 Extent of Measured Migration

Prudic and Randall (1977, 1979) and Prudic (1978, 1979a, 1979b, 1981, 1982, 1986) have conducted extensive investigations into the extent of radionuclide movement through the subsurface about the trenches. Dana et al. (1978, 1979a, 1979b, 1980) investigated the containment effectiveness of the site through the analysis of migration pathways. Monitoring wells around the waste burial trenches indicate that radionuclides have migrated from the trenches into the surrounding till; radionuclides do not appear to have penetrated more than 3 m either laterally or vertically into the till. Following is a discussion of the measured migration of specific radionuclides including Tritium, ^{90}Sr, ^{14}C, and a few others.

3.3.3.1 Tritium

Twenty-nine monitoring wells were drilled adjacent to the trenches during the period 1973 to 1975 (Prudic 1986). The holes were located between 2.5 and 5.0 m from the edges of the trenches (holes A-G, I-N, and P-R; see Figure 2.5). Core samples were obtained for each hole using the procedure described in Prudic (1979a). The samples indicate generally decreasing radionuclide concentration with depth. Profiles of tritium from selected wells are shown in Figure 3.9. Common to all of the profiles is a relatively high concentration of radionuclides near the surface that decreases with depth. The rate of vertical migration within the till appears to exceed the rate of lateral migration, which is in agreement with the predominantly vertical gradients through the till.

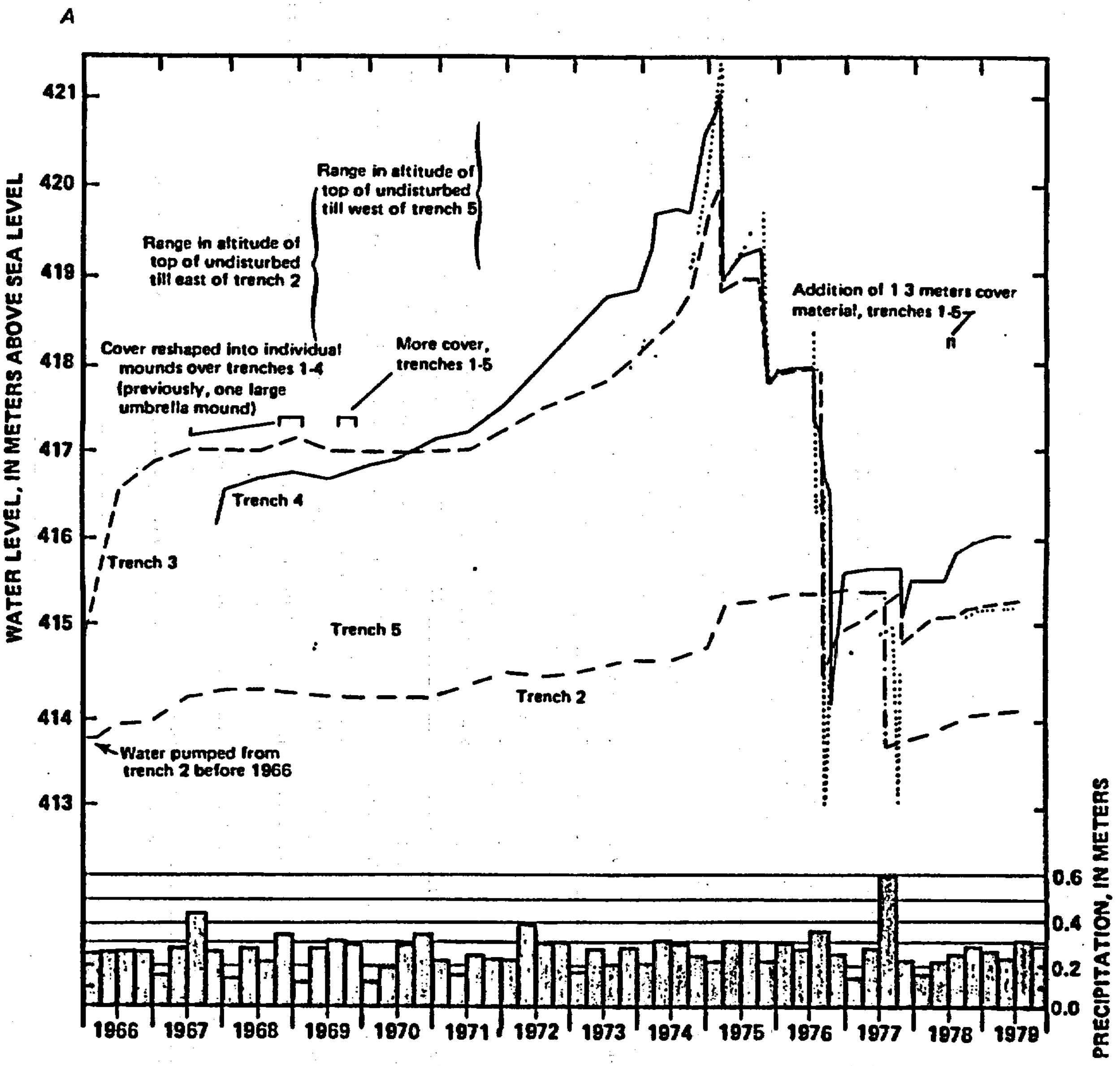


FIGURE 3.8. Water Level Trends in the North Trenches Showing the Effects of Regrading the Trench Caps

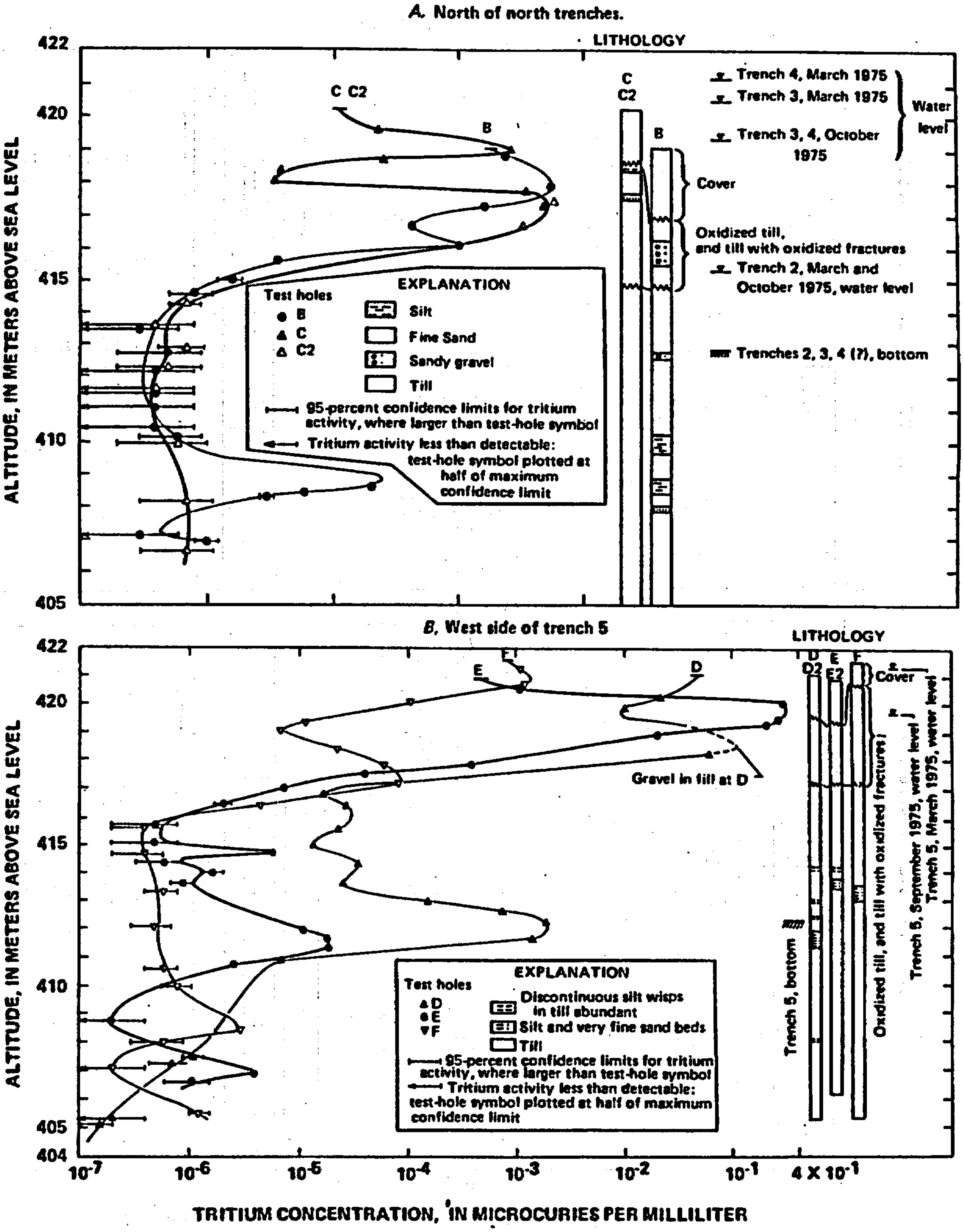
TABLE 3.3. Radionuclide Content of Water in Trenches

	Trench Number and Date of Sample Collection[a]											
Radionuclide	1 June 1976	2 November 1977	3 October 1978	4 October 1978	5 October 1978	8 October 1978	9 October 1978	10 August 1979	11 August 1979	12 June 1977	13 June 1977	14 June 1977
Gross alpha	1.6E-06 ± 25	1.6E-07 ± 1	7.3E-07 ± 14	1.4E-06 ± 11	8.9E-07 ± 11	1.3E-04 ± 1	2.7E-07 ± 15	1.33E-03 ± 3	8.2E-02 ± 3	1.8E-05 ± 11	2.9E-03 ± 1	8.5E-06 ± 16
Gross beta	7.6E-06 ± 8	8.0E-05 ± 2	2.9E-03 ± 1	1.7E-02 ± 1	4.7E-04 ± 1	4.7E-04 ± 1	1.2E-04 ± 3	1.42E=-4 ± 4	—	2.3E-03 ± 1	3.1E-02 ± 1	1.5E-03 ± 1
Tritium[b]	3.11E-04 ± 3	8.9E-02 ± 1	4.8E-01 ± 1	3.0E-01 ± 1	2.3 ± 1	3.7 ± 1	4.6E-01 ± 1	4.27 ± 3	2.77 ± 3	3.6E-01 ± 1	4.8E-01 ± 1	1.2E-01 ± 1
^{90}Sr	4.5E-06 ± 9	3.4E-5 ± 10	8.5E-04 ± 10	8.6E-03 ± 10	1.5E-04 ± 10	1.4E-04 ± 10	3.8E-05 ± 10	6.8E-04 ± 5	1.61E-04 ± 3	—	—	—
^{14}C (total)[c]	2.1E-06 ± 17	2.4E-05 ± 5	—	3.4E-05 ± 5	7.4E-05 ± 5	5.2E-04 ± 5	8.4E-05 ± 5	—	—	3.6E-04 ± 5	—	6.4E-05 ± 5
^{14}C (inorganic)[c]	—	—	—	—	—	1.8E-05 ± 5	2.2E-05 ± 5	3.32E-05 ± 5	2.44E-04 ± 5	5.8E-06 ± 5	—	1.1E-05 ± 5
^{238}Pu	1.9E-09 ± 52	3.3E-08 ± 24	7.6E-08 ± 14	9.8E-09 ± 40	1.3E-07 ± 10	1.6E-04 ± 10	2.8E-04 ± 10	2.8E-04 ± 15	3.1E-08 ± 19	—	—	—
^{239,240}Pu	N.D.	1.9E-07 ± 10	8.1E-08 ± 12	1.5E -08 ± 32	8.1E-08 ± 12	3.4E-07 ± 20	<3.0E-09	6.0E-07 ± 35	5.0E-09 ± 37	—	—	—
^{241}Am	1.4E-08 ± 64	N.D.	N.D.	N.D.	N.D.	2.0E-07 ± 57	N.D.	N.D.	2.1E-08 ± 31	N.D.	N.D.	N.D.
^{22}Na	N.D.	N.D.	1.5E-07 ± 40	1.3E-07 ± 21	4.3E-07 ± 8	2.7E-07 ± 11	3.9E-07 ± 9	2.13E-05 ± 5	1.47E-06 ± 24	1.1E-06 ± 24	8E-07 ± 25	4E-07 ± 32
^{40}K	—	4.7E-07 ± 35	4.5E-07 ± 72	1.5E-06 ± 20	N.D.	3.9E-07 ± 53	3.1E-07 ± 62	N.D.	N.D.	—	—	—
^{60}Co	N.D.	3.3E-07 ± 12	7.0E-05 ± 1	9.9E-07 ± 6	3.9E-07 ± 10	2.0E-07 ± 18	9.7E-07 ± 6	3.1E-07 ± 45	6.7E-07 ± 19	6.2E-06 ± 6	2.8E-06 ± 10	1.4E-06 ± 14
^{133}Ba	N.D.	N.D.	N.D.	9.3E-08 ± 65	2.7E-07 ± 57	4.5E-07 ± 23	8.0E-08 ± 52	—	—	—	—	—
^{134}Cs	N.D.	N.D.	N.D.	6.4E-08 ± 49	1.7E-06 ± 3	9.4E-07 ± 6	9.6E-07 ± 5	2.1E-06 ± 14	3.3E-06 ± 9	1.3E-05 ± 6	6E-07 ± 49	3.3E-05 ± 2
^{137}Cs	N.D.	2.7E-05 ± 1	1.0E-03 ± 1	1.1E-05 ± 1	3.3E-5 ± 1	1.4E-04 ± 1	2.6E-05 ± 1	5.46E-05 ± 4	4.23E-04 ± 3	9.0E-04 ± 1	4.9E-06 ± 5	2.4E-04 ± 1

(a) Data from following sources: Trench 1, Davis and Fakundiny (1978, table IV-6); trenches 2-9, Weiss and Colombo (1980, table 5.30); trenches 10 and 11, Dana et al. (1980, table 5); trenches 12-14, Weiss and Colombo (1980, table 4.10).

(b) Incorporated in molecules of water (HTO). Some additional tritium may be present in methane (CH_4) and other more complex organic molecules.

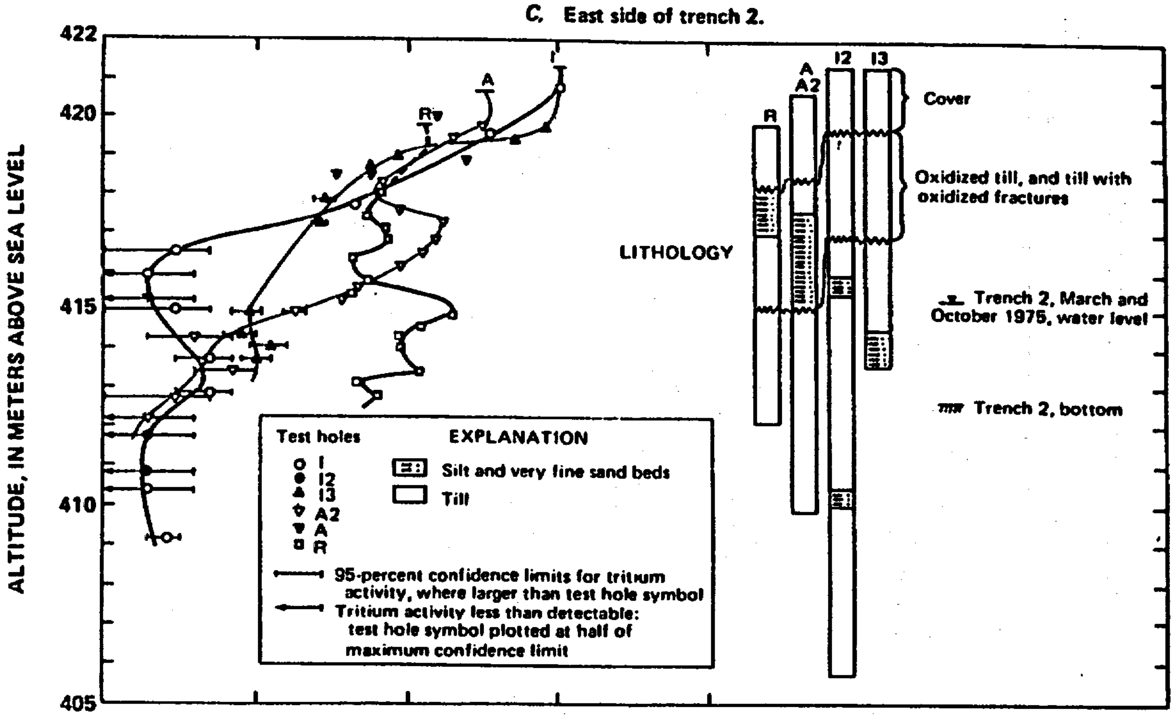
(c) Analyses by the NYSDOH, Radiological Sciences Laboratory, from samples collected in September 1977 except trenches 10 and 11, which are reported in Dana et al. (1980, table 5).



A. North of north trenches.

B, West side of trench 5

FIGURE 3.9. Changes in Tritium Concentrations with Depth in Test Holes Near the Burial Site (after Prudic 1986)


C. East side of trench 2.

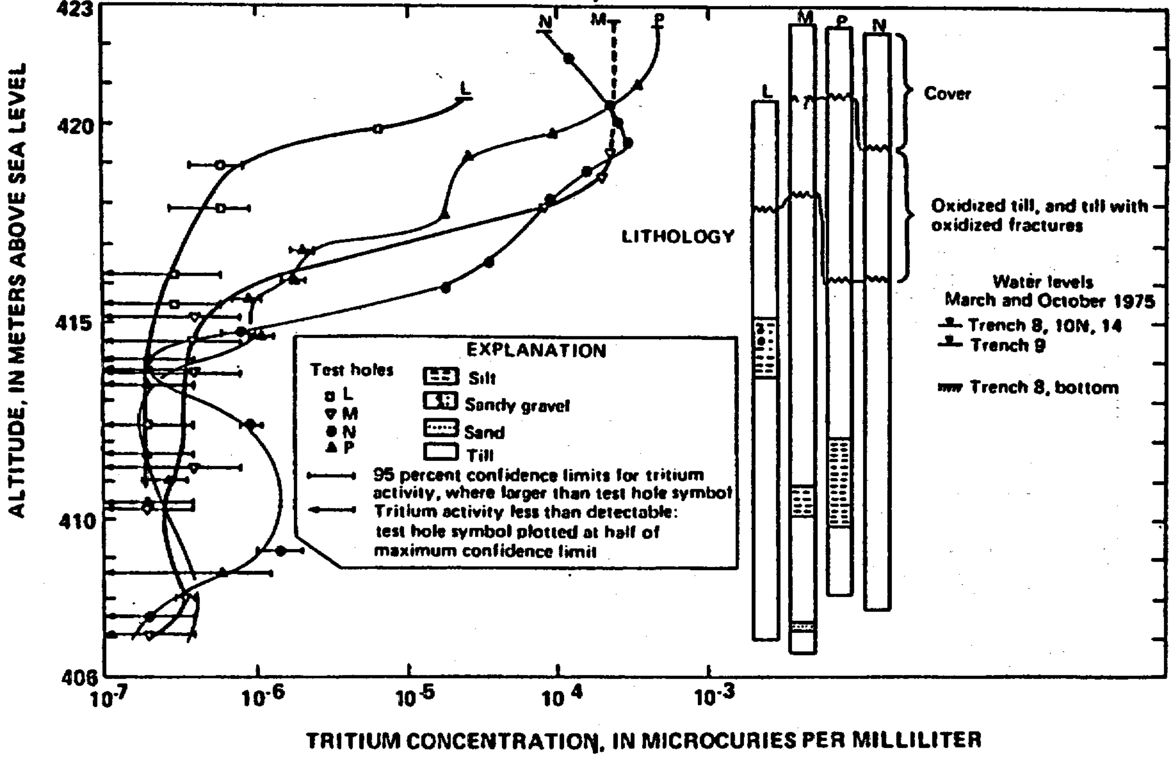

D. Vicinity of south trenches

FIGURE 3.9. (contd)

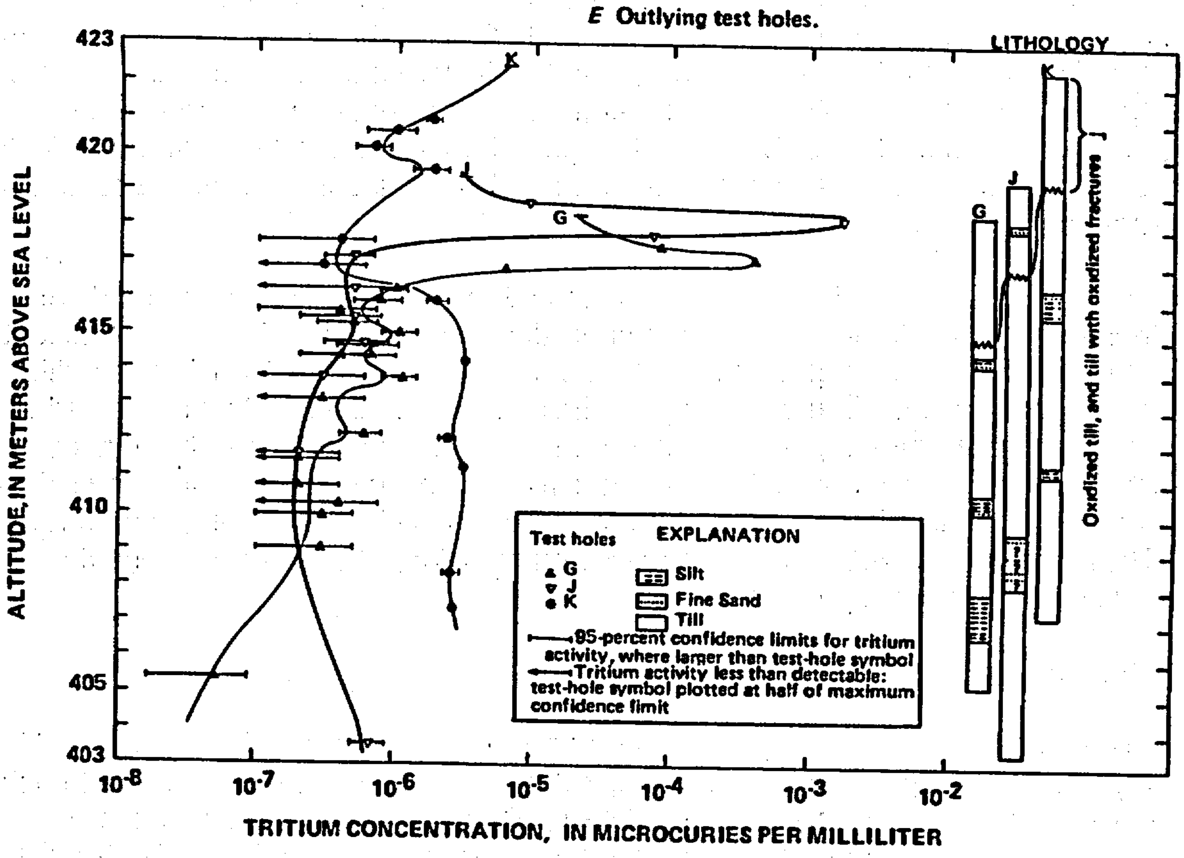


FIGURE 3.9. (contd)

Prudic (1986) indicates that the high concentrations evident near the surface (Figure 3.9) are most likely not the result of post-emplacement waste migration in ground water. He states that the most reasonable explanation appears to be "...some combination of surface processes such as 1) spills during emplacement of refuse or during removal of excess water from trenches, 2) redistribution of contaminated water by excavation equipment that entered the trenches, or 3) fallout from the stack at the nearby fuel-reprocessing plant."

Investigations at the site did not find the same level of shallow lateral migration for the trenches as was detected with the kerosene migration at the nearby FDA. Analyses of core samples reveal only two cases where tritium has migrated more than 2.5 m in the lateral direction. This occurred in holes D and E located just west of Trench 5 (see Figure 2.5). Highest subsurface concentrations of about 1×10^{-03} µCi/mL are found in hole D at an elevation of about 412 m corresponding to the bottom of trench 5. A less pronounced peak of 1×10^{-05} µCi/mL is evident in hole E at a similar elevation. Water levels may have risen sufficiently to produce head gradients able to move water laterally through silty till present near the bottom of the trench.

A similar peak between 1 x 10^{-5} and 1 x 10^{-4} µCi/mL was observed at an elevation of about 409 m in test hole B located about 12 m north of trench 2. Subsequent holes drilled closer to the trench do not reveal a similar peak at the same depth (Prudic 1986); consequently, the observed concentrations are probably not the result of lateral migration of tritium at depth. Other explanations for the reported concentration include improper handling of the sample and migration of surface spills through a collapsed borehole several meters away.

The absence of any large-scale (less than 3 to 5 m) lateral movement of contaminants at the site is reasonable based on the predominantly downward gradient at the site; wells drilled through trenches 4, 5, and 8 (Table 3.4) in 1977 indicate this downward movement. Figure 3.9 shows tritium concentrations below the tested trenches. Concentrations generally reach undetectable levels at depths of about 3 m below the trench floor for the 7 to 10 years since sampling occurred. Prudic (1986) indicated tritium detection at a depth of 3 m occurred in silty till but only 2 m in regular till. However, 3 m is probably a reasonable number for both cases because the trench floor elevation is inexactly known.

3.3.3.2 Other Radionuclides

The holes were tested for a full suite of radionuclides in addition to tritium. Values are reported as µCi/g in Table 3.3. Other radionuclides contained within the trenches appear to be less mobile than tritium. Unlike tritium, most of these species are charged ions which will be adsorbed, to varying degrees, by the till matrix. Therefore, these radionuclides would be expected to migrate shorter distances than tritium.

Chemical analyses of trench water (Table 3.3) indicated that ^{90}Sr and ^{14}C were the most abundant radionuclides after tritium. The greatest concentrations of ^{90}Sr are found in Trench 4. Samples 0.7 m below trench 4 contained detectable levels of ^{90}Sr. A zone of silty-till may have provided a high hydraulic conductivity conduit for movement of the ^{90}Sr. Strontium-90 only penetrated 0.14 m into till beneath trench 5. Carbon-14 appears to have migrated about 1.0 m beneath trench 5. However, the ^{14}C was difficult to measure because of the large number of carbon isotopes present and because the sampling procedure was intended primarily to detect tritium.

Cesium, cobalt, and plutonium also were found in detectable quantities beneath the trenches. The concentrations are shown in Table 3.4. Cesium-137 was detected at greater depths than either ^{134}Cs or ^{60}Co (Prudic 1986). Cesium-134 was detected at 0.5 m versus 0.48 m for ^{137}Cs. This may reflect a ^{134}Cs:^{137}Cs ratio of about 1:1000 in trench 5. Prudic (1986) does not report the depth for ^{60}Co. Plutonium-238 was detected in silty till about 1.06 m beneath the floor of trench 8 in hole 8.2A but only 0.8 m deep in hole 8-1C.

TABLE 3.4. Concentration of Selected Radionuclides Beneath Trenches 4, 5, and 8, November - December 1977 (after Data et al. 1979, 1980)

[All radionuclides are in microcuries per gram(a). Exponents expressed in scientific notation, where 1.1E-07 means 1.1 x 10^{-7}; numbers following ± are percentages; —samples not analyzed for particular radionuclide]

Depth Interval Below Land Surface (m)	Depth of Sample Midpoint Below Trench Floor(b) (cm)	^{14}C(c)	^{90}Sr	^{238}Pu	^{239,240}Pu	^{60}Co	^{134}Cs	^{137}Cs	Material in Each Core Segment
Trench 8, test hole 8-2B(d)									
9.22	0	—	1.85E-04 ± 5	—	—	1.67E-04 ± 4	8E-06 ± 25	4.5E-04 ± 4	Weathered Cardboard
9.22-9.24	1	—	2.02E-05 ± 3	—	—	7.2E-07 ± 22	3E-07 ± 37	1.52E-05 ± 5	Till
9.24-9.30	5	—	1.17E-05 ± 6	—	—	2.4E-07 ± 33	3.9E-07 ± 34	2.6E-07 ± 12	Till
9.30-9.37	12	—	3.88E-06 ± 4	—	—	<6E-08	<5E-08	4.6E-07 ± 17	Till
9.53-9.58	34 ± 7	—	<6E -08	—	—	<6E-08	<4E-08	1.0E-07 ± 50	Silt/clay
9.58-9.63	39 ± 7	—	2.5E-07 ± 31	—	—	<5E-08	<4E-08	4E-08 ± 63	Silt/clay
9.63-9.68	44 ± 7	—	3.2E-07 ± 23	—	—	<5E-08	<4E-08	2.5E-07 ± 24	Silt/clay
9.68-9.72	48 ± 7	—	1.15E-06 ± 10	—	—	1.5E-07 ± 60	<9E-08	1.75E- ± 10	Silt/clay
Trench 8, test hole 8-2A									
9.96-9.99(e)	76 ± 7	—	—	—	—	1.26E-05 ± 7	—	<5E-07	Till
9.99-10.02	79 ± 7	<3E-07	<1.1E-07	—	—	<1.5E-07	<3E-09	<6E-08	Till
10.02-10.06	82 ± 7	3.4E-07 ± 29	<9E-08	<2.8E-09	<3E-09	<1.6E-07	<4E-09	<7E-08	Till
10.09-10.18	92 ± 7	7E-07 ± 88	<5E-08	—	—	—	—	—	Till
10.27-10.30	106 ± 7	<1.6E-07	<6E-08	2.1E-07 ± 13	2.0E-08 ± 38	<8E-08	<4E-08	<5E-08	Silt/clay
10.31-10.43	115 ± 7	<5E-07	<3E-08	—	—	—	—	—	Till
Trench 8, test hole 8-1C									
10.09-10.11	80 ± 30	1.3E-07 ±69	1.5E-07	1.4E-07 ± 16	<5E-07	<1.5E-07	<4E-07	<7E-08	Till
10.11-10.14	83 ± 30	<9E-08	<1.2E-07	3.0E-08 ± 40	<1E-09	<1.5E-07	<1.1E-08	<5E-08	Till
10.19-10.29	94 ± 30	<4.5E-07	<1.4E-07	1.7E-08 ± 88	<5E-09	—	—	—	Till
10.29-10.38	104 ± 30	—	—	1.5E-08 ± 91	<5E-09	—	—	—	Till
10.38-10.40	109 ± 30	2.9E-07 ± 31	—	1.1E-08 ± 46	<1E-09	<1.5E-07	<4E-09	<7E-08	Till
10.53-10.66	130 ± 30	<5E-07	—	—	—	—	—	—	Till

(a) Error associated with each value above detection limit represents Gaussian standard error for that value at 95% confidence interval. When standard error exceeds sample count minus background count, values are considered below detection limits and are reported as less than the standard error.

(b) Uncertainty as to the exact depth at which the trench floor was penetrated by most holes (Prudic 1979) results in uncertainty in sample depth, as indicated by ± values. For hole 4-4A, depths of samples are in centimeters below horizontal projection of the trench floor penetrated by nearby hole 4-3A; uncertainty in trench-floor depth cannot be estimated from drilling data for hole 4-3A (Prudic 1979), but tritium profiles discussed in this report suggest the depths given are minimum values.

(c) Includes both inorganic and organic carbon.

[5] Above undisturbed trench floor.

(d) Sampling device lowered through trench water before being driven into trench floor to collect these samples.

(e) Core sample with impression of retractable point.

4.0 HYDROLOGIC AND RADIONUCLIDE TRANSPORT ANALYSIS OF THE GROUND-WATER PATHWAY

Hydrologic flow and transport models were used in the ground-water pathway analysis to simulate subsurface release of radionuclides and evaluate the performance the West Valley site. Previous flow and transport modeling by Prudic (1986) provided the primary basis for much of the work done in this assessment. Following is a brief description of the details of the previous model results relevant to this analysis. This background information is followed by a summary of the hydrogeologic performance assessment analysis and results.

4.1 PREVIOUS WORK

The USGS conducted most of the significant ground-water flow and transport modeling at the site. The work focused primarily on the development of two-dimensional ground-water flow models along transects of the north and south trenches followed by simplified one-dimensional transport modeling of selected radionuclides.

4.1.1 Ground-Water Flow Modeling

Prudic (1981) completed the most comprehensive modeling study of ground-water flow and transport at the West Valley site. He simulated ground-water flow at the West Valley site for both the north and south trenches by incorporating hydrogeologic data from the site with a two-dimensional finite-element hydrologic flow and transport code described by Reeves and Duguid (1975) and Duguid and Reeves (1976). The cross-section lines C-C' and D-D' are perpendicular to the trenches as shown in Figure 2.5.

Prudic (1986) indicated that the code was particularly suited for evaluation of the West Valley Site because simulations could incorporate 1) cross-sectional modeling of saturated and unsaturated flow with a changing water table, 2) ground-water discharge along the land surface, and 3) the existence of a solute transport code that could be coupled to the calculated flow distribution. The choice of a two-dimensional model for the trenches implies several assumptions. The cross-section through each set of trenches is assumed to be representative of conditions for any cross-section through that set of trenches. The cross sections at West Valley are probably reasonable approximations of conditions along the trenches, but do not include the special burial areas contained in trenches 6 and 7. Ground-water flow is also assumed to be effectively two-dimensional with no flow through the plane of the section. The predominantly downward gradient at the site supports this assumption.

The modeled section for the north trenches with discretization and boundary conditions is shown in Figure 4.1. No-flow boundaries were used at either end of the

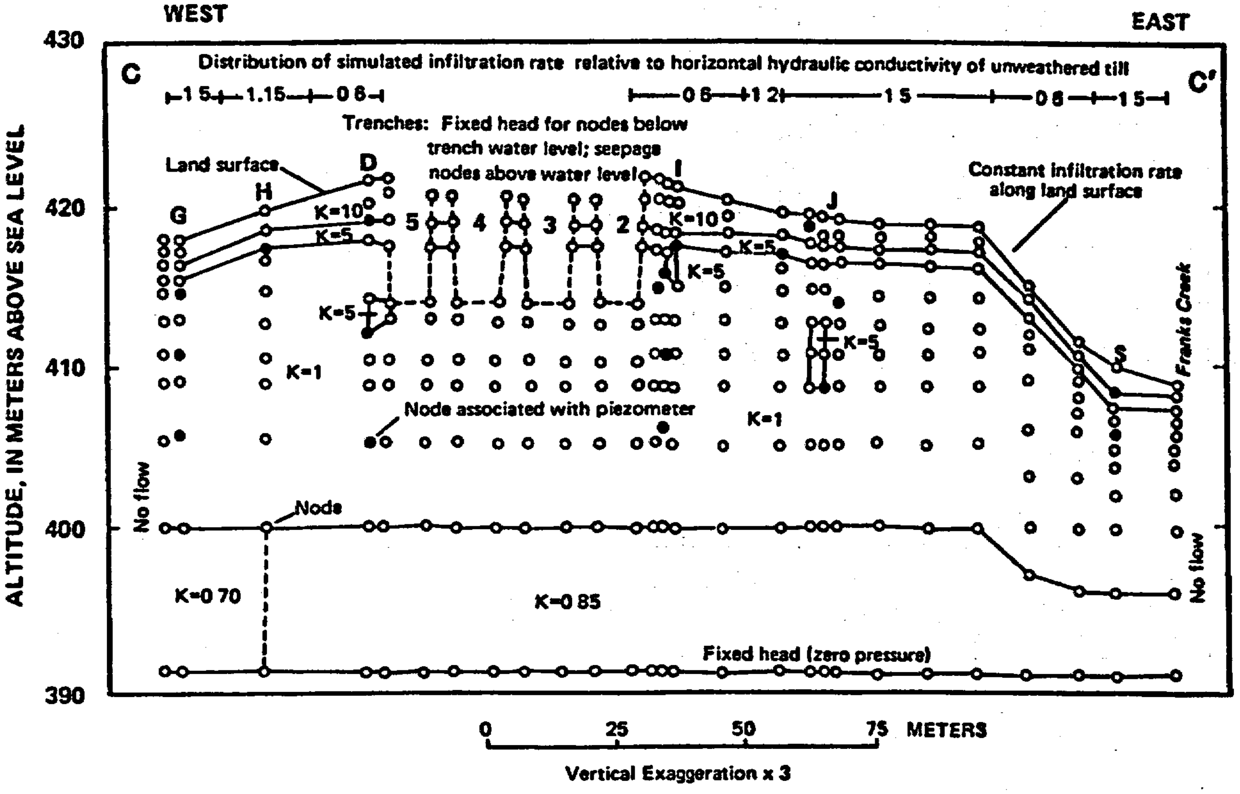


FIGURE 4.1. Vertical Section C-C' Through North Trenches Showing Computer Model Design Used in Best-Fit Simulation. Node arrangement, boundary conditions, relative hydraulic conductivity values, and relative infiltration rates (from Prudic 1986).

section. Pressure heads are set to zero (atmospheric) along the bottom of the model, corresponding to the contact between the till and underlying lacustrine sediments. Constant infiltration is applied to the land surface boundary corresponding approximately to the net precipitation after evapotranspiration and runoff are accounted for. Sufficient infiltration was used to saturate the till to near land surface. The trenches are represented by constant head nodes corresponding to 1976 and 1978 water level measurements with seepage permitted at greater elevations within the trenches.

Prudic (1981) modeled the site based on the hydrogeologic framework described previously. Initial simulations incorporated a uniform hydraulic conductivity throughout the problem domain with subsequent simulations containing increasing complexity (Table 4.1). The complexity reflects the observed conditions of weathered and fractured till near the surface, underlain by unweathered till and compacted unweathered till at depth. The complexity seems reasonable based on the hydrogeologic frame work. These concepts are incorporated in step-wise fashion beginning with case 1.

TABLE 4.1. Differences Between Heads Observed in February 1976 and Simulated Heads for Assumed Conditions (after Prudic and Randall 1979)

Case	Conditions	Mean Absolute Departure from Observed Heads of February 1976 (cm)
1	One isotropic unit	
	(a) Kx = Kz = 3.0×10^{-8} cm/s	201
	(b) Kx = Kz = 3.0×10^{-7} cm/s	201
2	One unit with anisotropy	
	(a) Kz = 0.1 Kx	161
	(b) Kz = 0.01 Kx	114
	(c) Kz = 0.001 Kx	116
3	Two isotropic units (weathered and unweathered till)	
	(a) K (weathered) = 10 K (unweathered)	123
	(b) K (weathered) = 100 K (unweathered)	127
4	Two anisotropic units (weathered and unweathered till)	
	Kx (weathered) = 10 Kx (unweathered)	
	(a) Kz = 0.1 Kx in each unit	93
	(b) Kz = 0.01 Kx in each unit	74
5	Two anisotropic units (weathered and unweathered till)	
	Kx (weathered) = 100 Kx (unweathered)	
	(a) Kz = 0.1 Kx in each unit	90
	(b) Kz = 0.1 Kx (weathered) Kz = Kx (unweathered)	109
	(c) Kz = 0.01 Kx (weathered) Kz = 0.01 Kx (unweathered)	92
6	Two anisotropic units (weathered and unweathered till)	
	Kx (weathered) = 10 Kx (unweathered)	
	Kz = 0.01 Kx in each unit	
	(a) Simulated sand and silt lenses near D, I, and J	65
	(b) As above plus increased heads at base of model near G	60

TABLE 4.1. (contd)

Case	Conditions	Mean Absolute Departure from Observed Heads of February 1976 (cm)
7	Three isotropic units (weathered, unweathered with fractures and unweathered till)	
	(a) K (weathered) = 10 K (unweathered) K (weathered) = 100 K (unweathered) K (unweathered w/fractures) = 10 K (unweathered)	121
8	Three anisotropic units (weathered, unweathered with fractures and unweathered till) with Kx the same as noted in case 7(a) above	
	(a) Kz = 0.1 Kx in each unit	96
	(b) Kz = 0.01 Kx in each unit	93
	(c) Kz = 0.01 Kx in each unit plus simulated sand and silt lenses near D, I, and J; increased head at base of model near G, and lower infiltration near holes D and I	57
	(d) Same as 8(c) except Kz = 0.1 Kx for each unit	53
9	Four isotropic units (weathered, unweathered with fractures, and 2 unweathered till units to compensate for overburden pressures) K (weathered) = 10 K (unweathered) K (weathered w/fractures) - 5 K (unweathered)	
	(a) K (lowest unweathered unit) = 0.5 K (unweathered)	120
	(b) K (lowest unweathered unit) = 0.7 K (unweathered)	104
	(c) K (lowest unweathered unit) = 0.85 K (unweathered)	107
	(d) K (lowest unweathered unit) = 0.7 K (unweathered) plus simulated sand and silt lenses near D, I and J; and reduced infiltration near D and I	31
	(e) as above, but K (lowest unweathered unit) = 0.85 K (unweathered) except beneath hole G where K (lowest unweathered unit) = 0.7 K (unweathered)	21

The case that incorporated the greatest amount of complexity (case 9) produced the smallest deviation from measured head values by introducing layering into the till to account for the weathering of the upper portion of the till and the compaction of the deepest till. The resulting distribution of hydraulic conductivity for case 9 is shown in Figure 4.1. The hydraulic conductivity of the unweathered till is 8 x 10^{-8} cm/s (Prudic 1981), although this was later revised (Prudic 1986) to about 4 x 10^{-8} cm/s. The hydraulic conductivity factors for the other layers are multipliers of the unweathered values. Most of the interior of the till is unweathered and has a relative hydraulic conductivity of $K = 1$ corresponding to the 2 to 6 x 10^{-8} cm/s calculated for the till. Weathering of the till was considered to be degradational from the surface with a thin, highly oxidized surficial layer with a relative hydraulic conductivity of 10 K underlain by a moderately weathered zone containing oxidized fractures, which has a relative hydraulic conductivity of 5 K. The bulk of the till underlies the weathered zone, having a relative hydraulic conductivity of 1 K. The basal portion of the till is divided into several zones having hydraulic conductivities ranging between 0.70 K and 0.85 K primarily because of compaction of the sediments.

Simulated distributions of hydraulic head for February, 1976, and February 1978, are shown in Figures 4.2, 4.3, and 4.4. These results agree well with measured water levels (see Figures 3.4 and 3.5).

4.1.2 Radionuclide Transport Modeling

Prudic developed a simple, one-dimensional method to calculate radionuclide migration rates from the trenches under the conditions of a downward gradient. His method is described in detail (Prudic 1986) and incorporates convective transport, hydrodynamic dispersion, radioactive decay, and instantaneous but reversible equilibrium-controlled sorption. He modeled releases of ^{3}H, ^{90}Sr, and ^{14}C. Prudic ruled out modeling additional radionuclides because of the relatively small concentrations measured in the trench water and the apparent small rates of migration indicated from core samples.

4.1.2.1 Tritium

Prudic (1986) assumed that tritium will migrate as tritiated water; consequently, tritium is modeled as an unretarded species. The distribution coefficient (K_d) is thus equal to zero, producing a calculated retardation factor (R) of 1. Other hydraulic and chemical coefficients input for tritiated water include a radioactive half-life (T_h) of 4.5 x 10^3 days, a diffusion coefficient (D_d) in water of 475 cm^2/yr at 10°C after Wang et al. (1953), a porosity (n) of 0.3, and a tortuosity factor (Å) ranging between 2.4 and 2.7. The diffusion coefficient, porosity, and tortuosity factor are used to estimate the coefficient of hydrodynamic dispersion (D') based upon Sherwood et al. (1975) as shown in Equation (4.1).

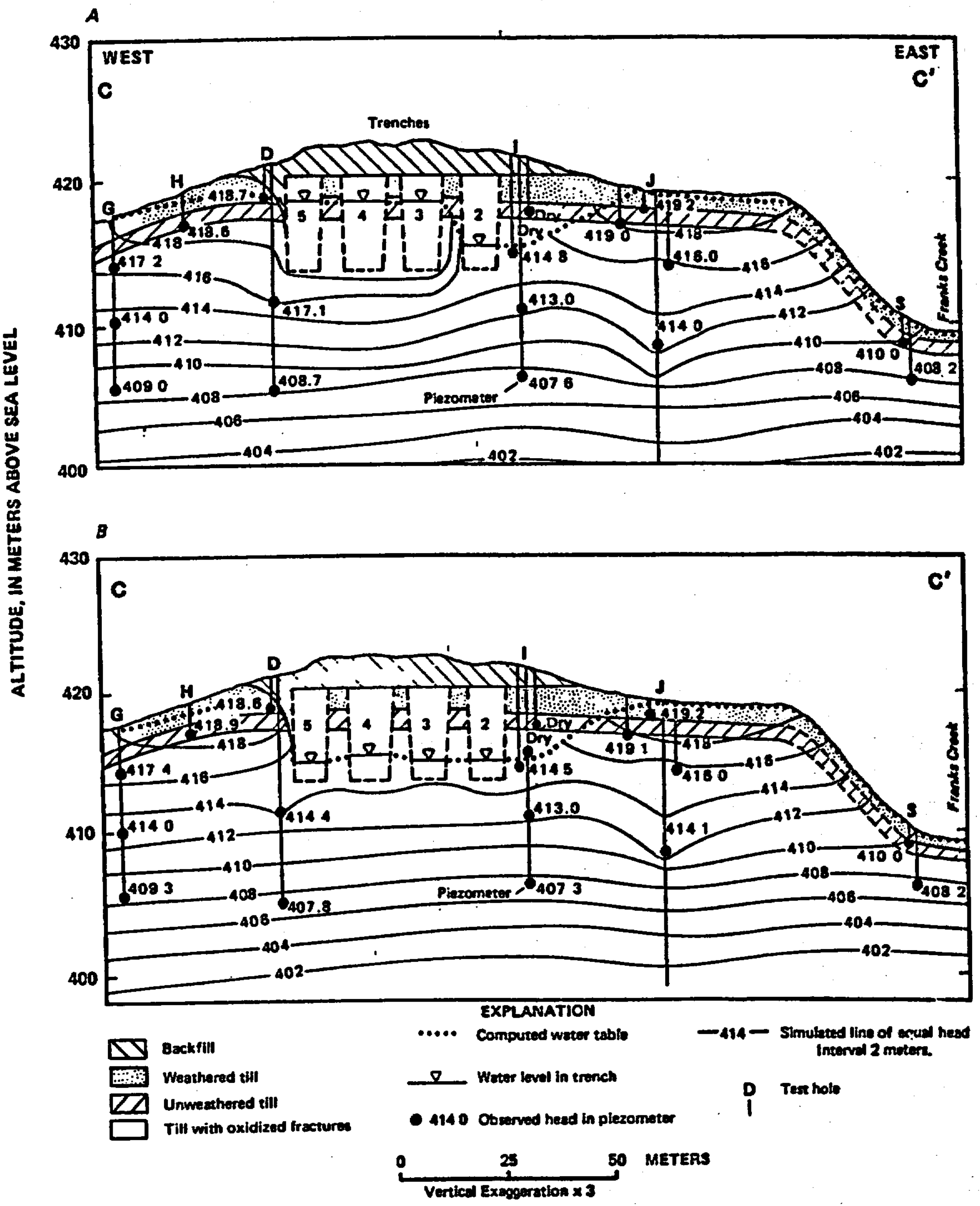


FIGURE 4.2. Vertical Section C-C' Through North Trenches Showing Computer-Simulated Distribution of Heads, A) February, 1976, B) February, 1978 (from Prudic 1986)

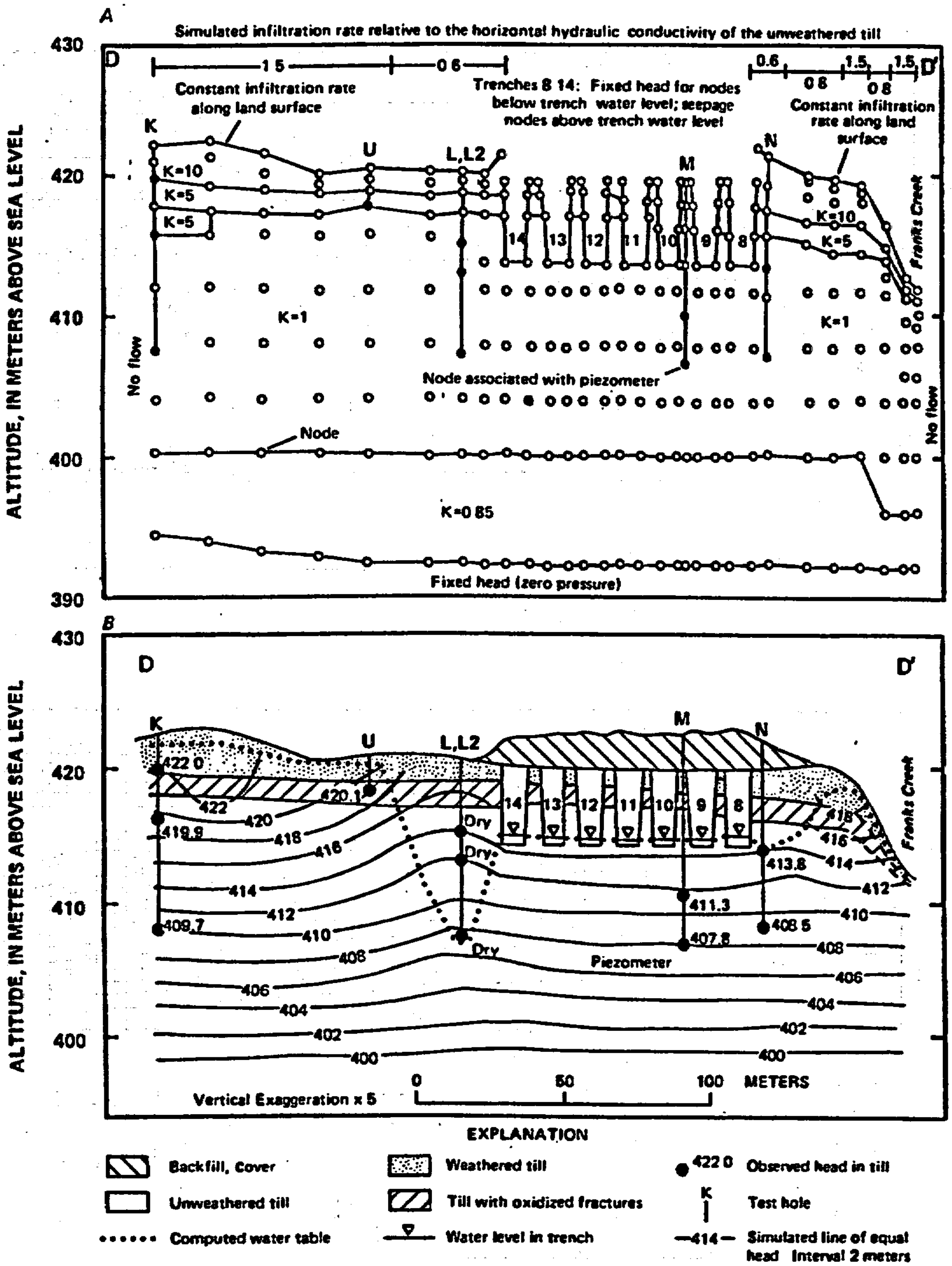


FIGURE 4.3. Vertical Section D-D' Through South Trenches Showing Computer Model Design, A) Node Arrangement, Boundary Conditions, Relative Hydraulic-Conductivity Values, and Relative Infiltration Rates Used in Best-Fit Simulations, B) Computer-Simulated Distribution of Heads for Till for February 1978 (from Prudic 1986)

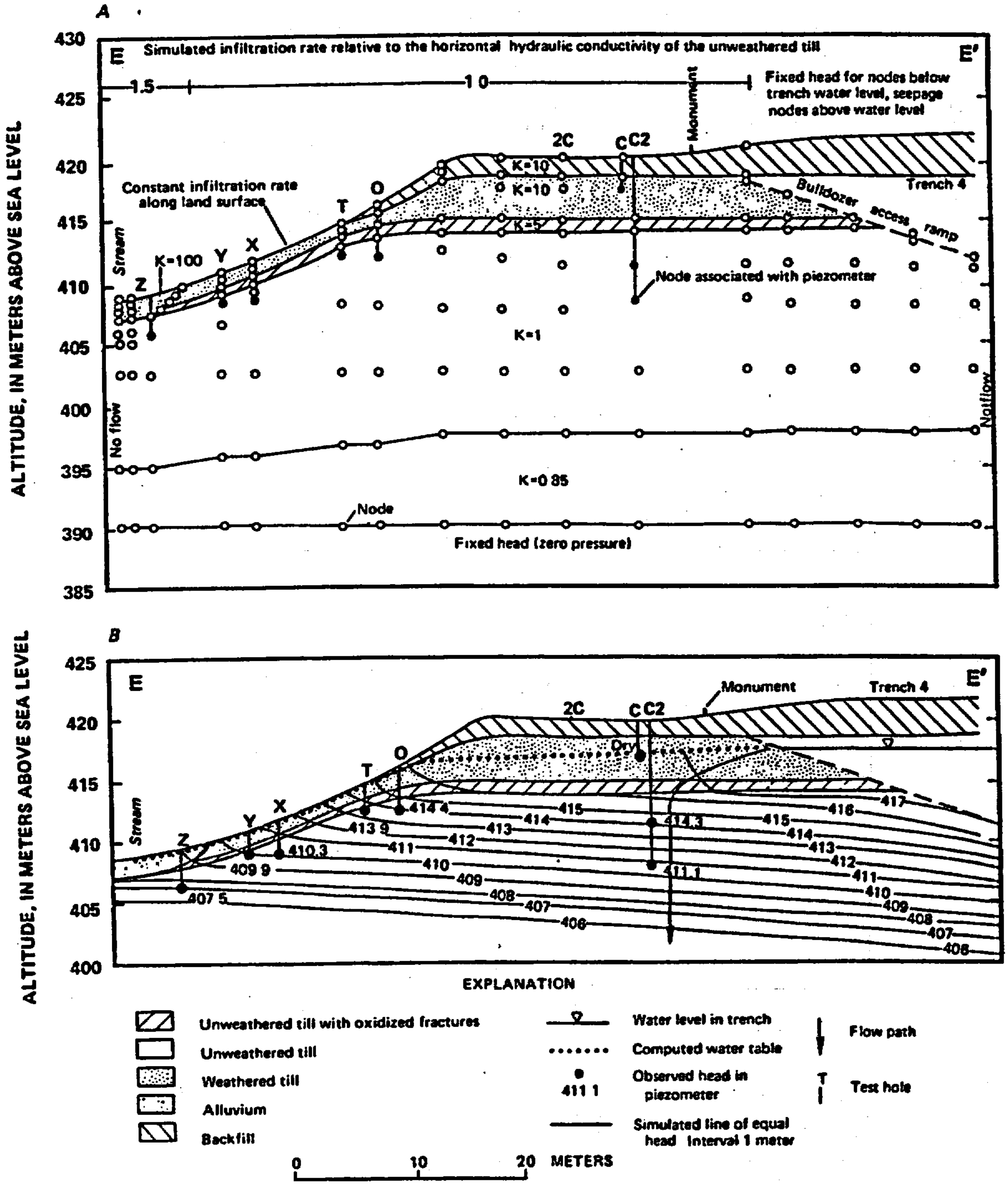


FIGURE 4.4. Vertical Section E-E' from Trench 4 Northward to Small Stream Showing Computer Model Design, A) Node Arrangement, Boundary Conditions, and Relative Hydraulic-Conductivity Values and Relative Infiltration Rates Used in Best-Fit Simulation, B) Computer-Simulated Distribution of Heads for February 1976 (from Prudic 1986)

$$D' \approx (D_d \cdot n) / \acute{A} \tag{4.1}$$

The calculated range for D' was between 53 and 59 cm^2/yr. Specific flux (q) was input based on the results of the ground-water flow modeling.

The best fit to the observed tritium distribution profiles measured below trench 5 and 8 was obtained using relatively low specific flux values between 0.30 and 1.2 cm/yr. The tortuosity factor was varied both above and below the 2.4 to 2.7 range to investigate sensitivity. Results of several runs are shown in Figure 4.5.

Prudic (1986) uses the model to project tritium profiles beneath trench 5. The projections are based on the assumption of steady-state conditions in the trench. Water levels in the trench and the corresponding specific flux of 0.7 cm/yr are presumed constant. The tritium source term concentration in the trench water is assumed to be constant, implying that the rate of radionuclide decay in the water will be exactly offset by the influx of leachate from the waste. Other factors such as the effective porosity of 0.3 and the tortuosity factor of 2.4 are also held constant. Based upon these assumptions, Prudic's model predicts that tritium will migrate about 10 m beneath the floor of the trench in 100 years.

4.1.2.2 Strontium-90

Prudic (1986) conducted similar simulations for ^{90}Sr based on the tritium analysis. The majority of the input coefficients used for tritium were used for ^{90}Sr simulations with several exceptions. The half-life of ^{90}Sr is 28.1 years. The diffusion coefficient of ^{90}Sr in water was assumed to be about 315 cm^2/yr based on work performed by Sherwood et al. (1975). The distribution coefficient was also assumed to be greater than zero (retardation factor greater than 1) because ^{90}Sr will undergo adsorption/desorption reactions with most soils and particularly clay-rich tills such as those in which the waste burial trenches are excavated. Core samples taken beneath the trenches indicated ^{90}Sr migration to be less than tritium (Prudic 1986). Strontium-90 will migrate in water as a cation with an electronic valence of +2; consequently, adsorption of ^{90}Sr by the till may be expected through mechanisms such as ion exchange, chemical precipitation-mineral formation, complexation-hydrolysis reactions, oxidation-reduction reactions, and colloid and polymer formation (Onishi et al. 1981).

Prudic (1986) modeled ^{90}Sr migration using distribution coefficient values ranging between 1 and 7 mL/g and similar ranges of specific discharge and tortuosity factor as used for tritium. Results are shown in Figure 4.6 for the ^{90}Sr profile beneath trench 8. The calculated profiles are similar in shape to the calculated tritium profiles but do not match the measured ^{90}Sr values as well because of the higher degree of

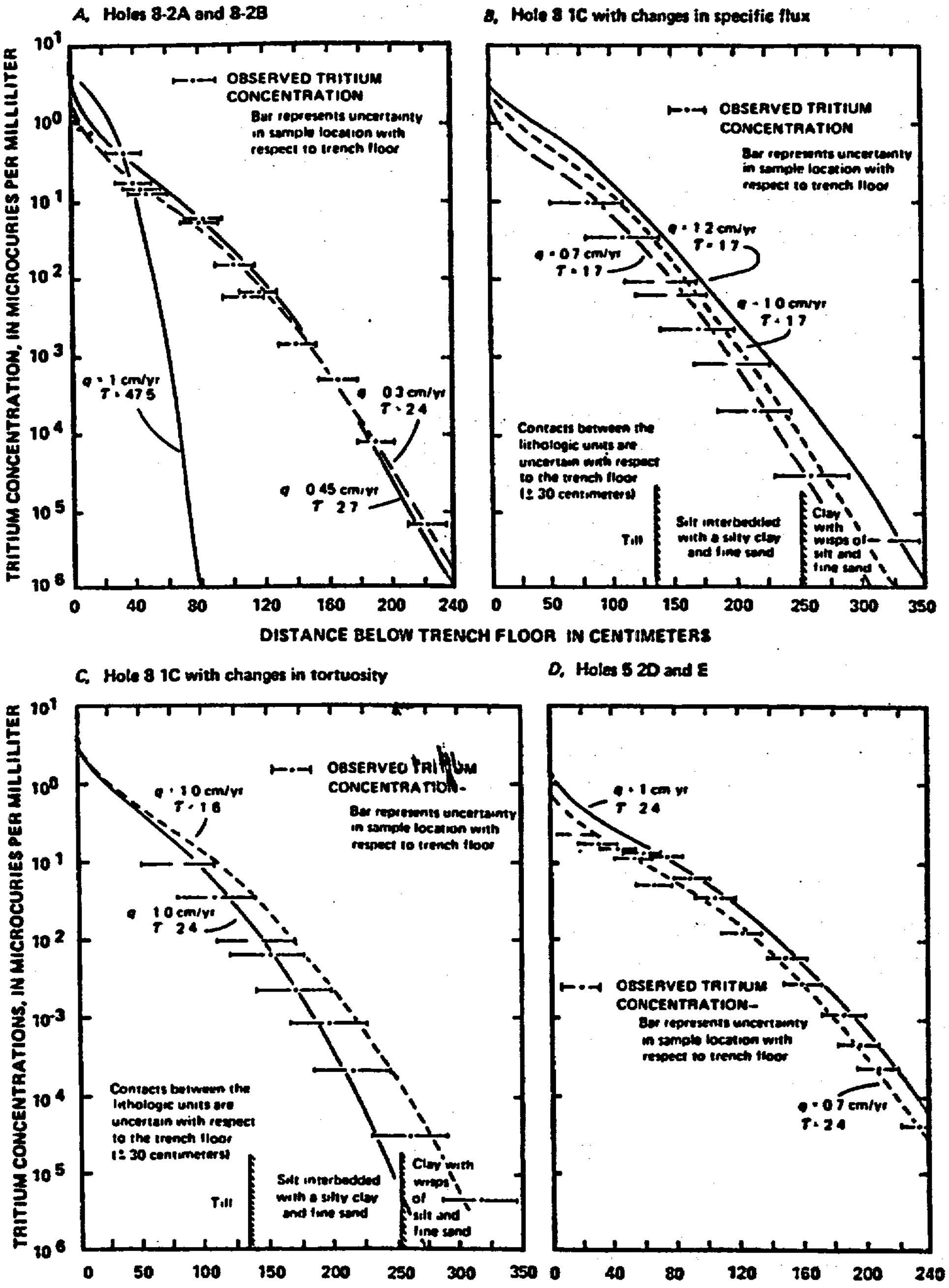


FIGURE 4.5. Comparison of Simulated and Observed Tritium Concentrations Beneath Trenches 5 and 8 (from Prudic 1986)

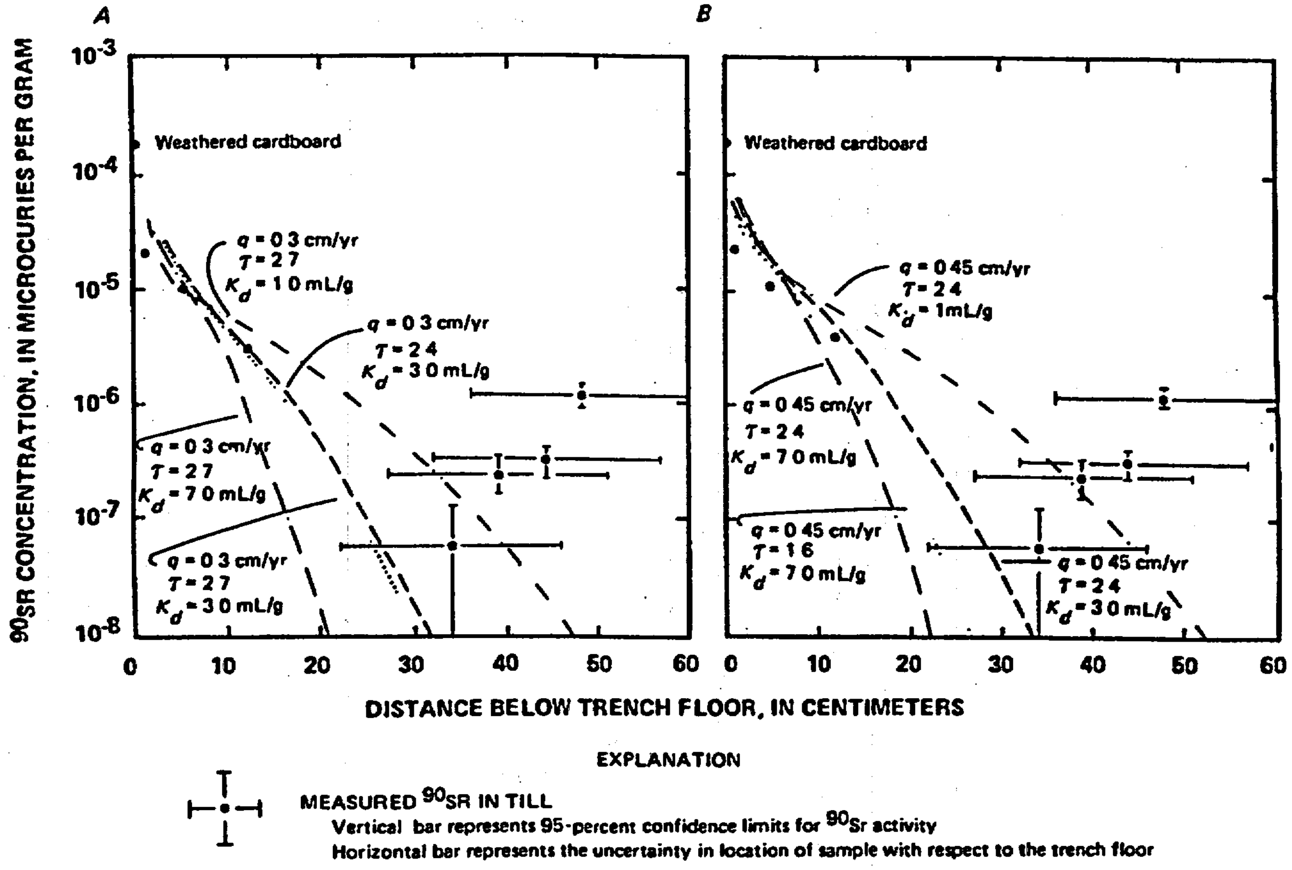


FIGURE 4.6. Comparison of Observed and Calculated ^{90}Sr Concentrations Beneath Trench 8 in Test Hole 8-2B (from Prudic 1986)

nonlinearity in the measured ^{90}Sr profile. Projections indicate that ^{90}Sr will migrate about 4 m below the trench floor after 100 years and about 6 m after 500 years (Figure 4.7).

4.1.2.3 Carbon-14

Changes were made in the model input to analyze ^{14}C transport that include changing the half-life to 5730 years. Calculation of the distribution and diffusion coefficients is difficult due to the wide range of values that carbon may assume in various organic and inorganic forms. Prudic assumed the ^{14}C to be in the form of bicarbonate and assumed the same diffusion coefficient value as for ^{90}Sr. Prudic (1986) reports that distribution coefficient values for organic ^{14}C are relatively low, ranging from 0.7 to 1.1 mL/g, while inorganic ^{14}C ranged between 3 and 12 mL/g. Prudic assumed a range of between 1 and 3 mL/g. Utilizing specific discharge and tortuosity factor

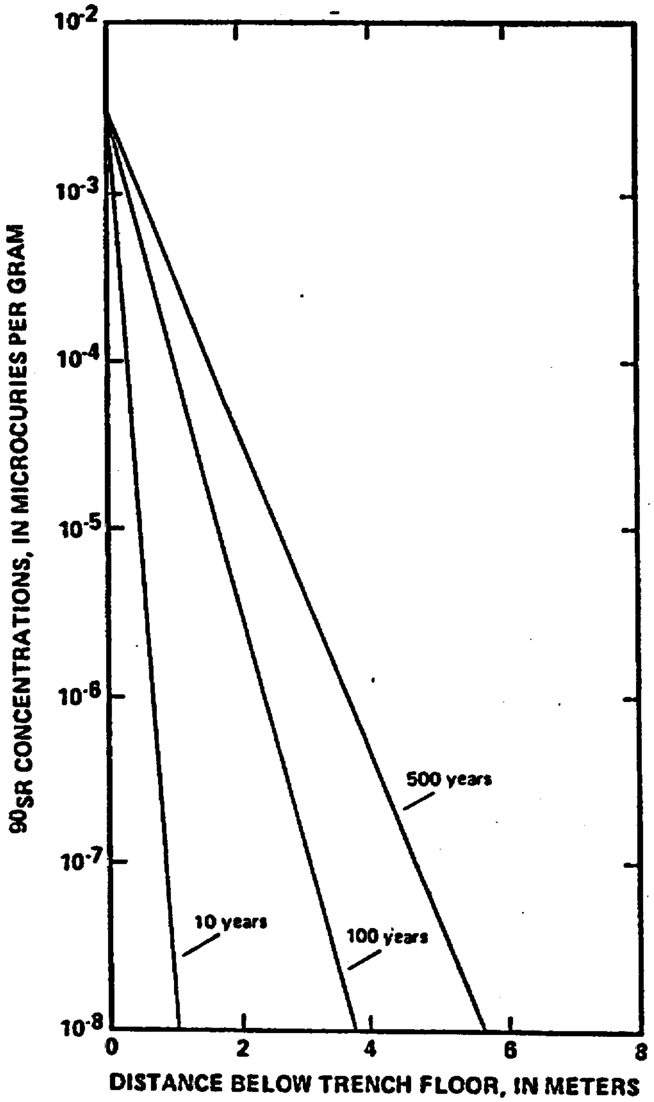


FIGURE 4.7. Predicted ^{90}Sr Concentration in Till Beneath Trench 4 After 10, 100, and 500 Years (from Prudic 1986)

ranges similar to previous applications, projections of ^{14}C movement indicate that between 1500 and 20000 years will be required for a migration of 23 m below the trench floor.

4.2 HYDROGEOLOGIC PERFORMANCE ASSESSMENT

Previous work provided the basis for the hydrogeologic performance assessment of the West Valley site. The following discussion provides a description of the performance objectives used in the assessment, details of the code and underlying assumptions used in the modeling analysis, and results of the assessment for key radionuclides released.

4.2.1 Performance Objectives

The key performance objective as required by a low-level radioactive waste facility license in 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," states that:

> ". . . during operation and after site closure that concentrations of radioactive material which may be released to the general environment in ground water, surface water, air, soil, plants, or animals will not result in any member of the public receiving an annual dose equivalent of 25 millirems (2.5×10^{-4} Sv) to the whole body, 75 millirems (7.5×10^{-4} Sv) to the thyroid, and 25 millirems (2.5×10^{-4} Sv) to any organ of any member of the public."

In this study, the performance assessment considered only the ground-water pathway. We also did not intend that this performance assessment analysis provide the basis for determination of compliance of the West Valley site with the licensing regulations put forth in 10 CFR 61. However, final model results for peak concentrations of the key radionuclides are transformed to dose. Factors used to convert concentration to dose for both the full garden and drinking water scenarios, presented in Table 4.2, are based on dose analysis performed with the GENII code (Napier et al. 1988).

4.2.2 Analysis and Results of Shallow Lateral Pathway Assessment

Prudic's cross-sectional modeling results of ground-water flow in the vicinity of the trenches appear to provide very reasonable information about hydraulic heads and the direction of ground-water flow in the till about the trenches. Much of Prudic's modeling involves comparisons between February 1976 water levels when the trenches were nearly three-quarters full and February 1978 when water was standing in only about the bottom quarter of the trenches. Subsequent modeling of the cross-section was conducted in this study to investigate the flow-system under conditions of very high water levels. Such conditions may exist at the site in the event that the sumps are deactivated when institutional control is lost.

In this study, data sets obtained from Prudic (1981) were modified and analyzed with FEMWATER (Yeh 1987). FEMWATER was developed at Oak Ridge National Laboratory based on the finite element methodology of Reeves and Duguid (1975) and Duguid and Reeves (1976) that Prudic used in his analyses. Some rearrangements of Prudic's data sets were necessary to obtain the proper format for input to

TABLE 4.2. Factors Used to Convert Concentration for Selected Radionuclides to Dose for the Drinking Water and Full Garden Exposure Scenarios

Radionuclide	Drinking Water[(a)]	Full Garden[(b)]
^{3}H	0.000042	0.000089
^{14}C	0.0014	0.041
^{90}Sr	0.088	4.9
^{60}Co	0.0023	0.22
^{137}Cs	0.033	0.064
^{226}Ra	0.7	14
^{232}Th	0.2	9.2
^{235}U	0.019	0.41
^{238}U	0.017	0.17
^{238}Pu	0.24	0.68
^{239}Pu	0.27	7.2
^{241}Am	2.6	0.93

(a) Drinking water scenario - 2 liters per day.
(b) Full garden scenario - ground, external, inhalation uptake, drinking water ingestion, terrestrial foods ingestion, and animal product ingestion. Assumes 300 years of prior irrigation.

FEMWATER. The only change in the hydrologic content of the data sets was to change the ponding depths to raise water levels to the brim of the trenches. The model was operated for a four-layer, isotropic system as depicted in Figure 4.1.

Results for the scenario where water levels rise to the very top of the trenches at an elevation of about 420 m are shown in Figure 4.8. The results seem reasonable in comparison to Prudic's results for the north trenches (Figure 4.2). Water levels several meters higher in the trenches than the February 1976 water levels appear to produce hydraulic heads several meters higher in the till immediately surrounding the trenches. Comparison with Figure 4.2 reveals that the increase in head is distributed within the potential field about the trenches.

Of particular importance for long-term closure of the site is the potential for lateral movement of radionuclides through the weathered, fractured, oxidized till zone located in the upper few meters of the section. Water levels at or near the top of the trenches may provide the necessary driving force to move water through the weathered, fractured till. The modeling results reveal some increase in lateral flow, particularly near the base of the trenches. However, the results seem to indicate that movement

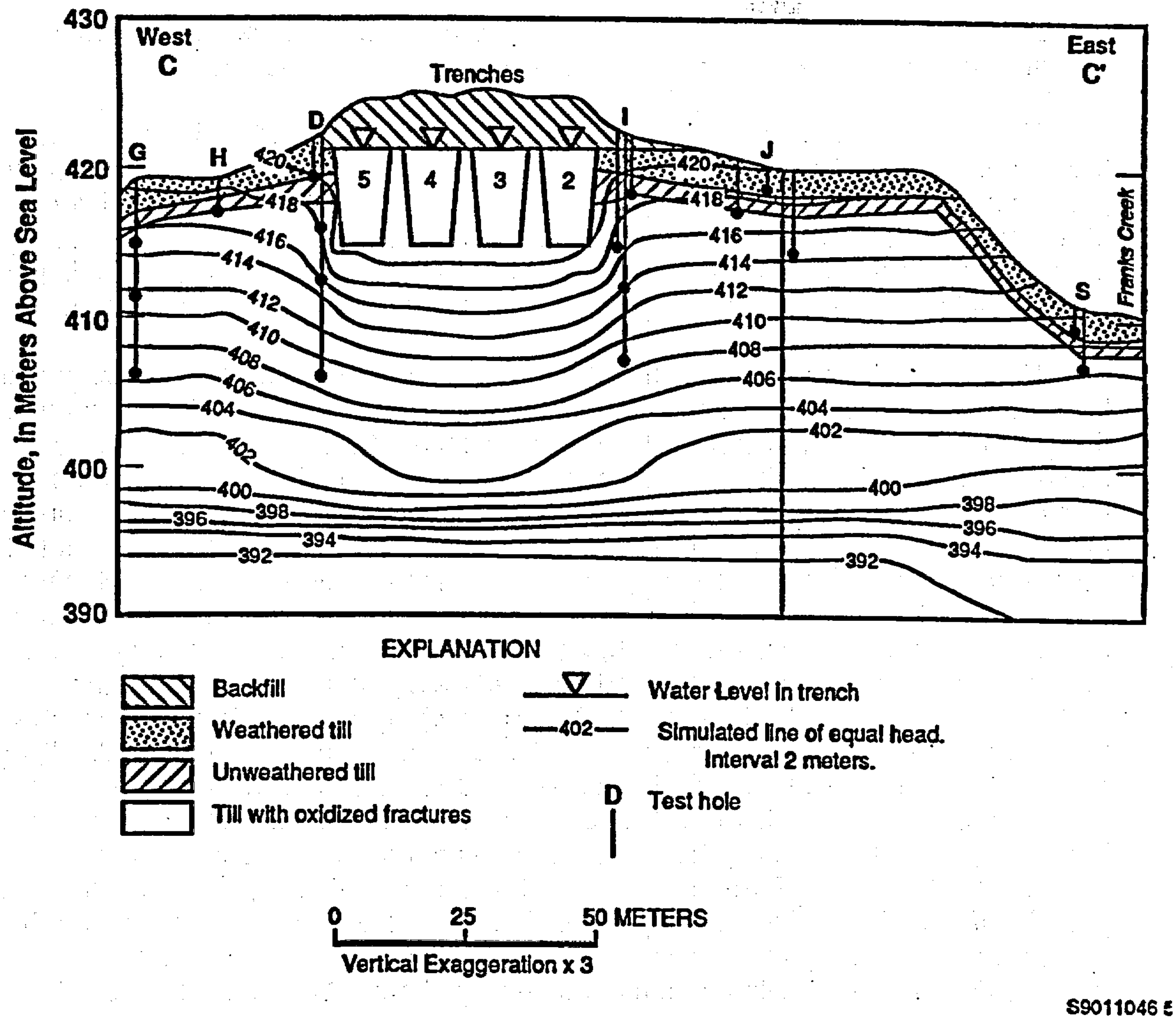


FIGURE 4.8. Vertical Section C-C' Through North Trenches Showing Computer Simulated Distribution of Heads for a Scenario of High Water Levels in the Trench

will still be predominantly downward through the till in the areas adjacent to the trench. Consequently, the hydraulic head gradient does not appear to exist to allow for significant, continuous lateral movement through the weathered, fractured till zone while moving laterally for a short distance to the nearest drainage.

Below the soil cap covering the trenches and above the unweathered till is the fractured, weathered, oxidized till zone where transport of water may occur in a relatively higher hydraulic conductivity zone. This zone is about 2 m deep at about 4 to

5 m below the surface. Surface water coming through the trench cap may move laterally through the surface zone to Frank's Creek to the east of the site.

While hydrologic flow modeling done by Prudic (1986) and in this study indicates the lateral pathway through the fractured till may be attenuated to a large extent by the predominantly vertical gradient within the till, the occurrence of migration of kerosene at the nearby facility burial area would seem to indicate that migration could be significant. To evaluate this pathway, we made conservative estimates of what the impact of the contaminated water overflowing from the trench might be to Frank's Creek.

We first made the assumption that after the period of institutional control water levels in the trenches would rise in the trench covers and would begin to migrate into the shallow weathered, fractured till. We also assumed that infiltration of rainfall would be sufficient to maintain these water levels within each trench. We also made an assumption contrary to the modeling studies done that contaminated water would in fact reach nearby Frank's Creek, and the rate of migration would be equivalent to that derived from the extent of lateral migration of kerosene at the FDA (i.e., 1.38 m/yr). The average travel time within the weathered fractured till to the creek, which is approximately 140 m away from the trenches, would thus be about 100 years. Using the estimated elevation of the trench head for overflowing conditions (420 m), the approximate elevation of Frank's Creek (410 m), and the approximate distance to Frank's Creek from the trenches (140 m), we calculated a hydraulic gradient of 0.07. Using the assumed velocity of 1.38 m/yr and a porosity of 0.3, we can calculate an effective hydraulic conductivity of 1.8 x 10^{-7} cm/s, which is about equivalent to values estimated in previous modeling. Using the approximate length of the trenches (370 m), an approximate thickness of the weathered and fractured till of 2 m, and an estimated porosity of 0.3, the cross-sectional area of flow can be estimated to be about 220 m^2. Multiplying this area by the assumed linear velocity of 1.38 m/yr, we can calculate the average flux of water moving from the trenches to Frank's Creek to be about 300 m^3/yr.

Trench water entering the shallow till system would migrate for approximately 100 years before entering Frank's Creek. During this period, trench water concentrations would be reduced during transport by a number of factors including radioactive decay, diffusion and dispersion within the till, and eventually, dilution by the flow in Frank's Creek. Radioactive decay appears to allow concentrations of many radionuclides to decline to negligible levels. This is particularly true for radionuclides that have an affinity to be absorbed to the till materials. The combination of decay and adsorption eliminate all radionuclides but tritium and ^{14}C.

Table 4.3 provides a summary of the effects of decay and river dilution on maximum measured trench concentrations for tritium and ^{14}C taken from Table 3.3. The concentrations given in column 2 would reflect the effect of decay of maximum concentrations during transport up to the river. For tritium, the decay time would be 100 years;

TABLE 4.3. Summary of Effects of Decay and River Dilution on Maximum Trench Concentrations for Tritium and ^{14}C

Radionuclide	Maximum Concentration (pCi/L)	Decayed Concentration (pCi/L)	Diluted River Concentration (pCi/L)
Tritium			
North Trenches	2.3×10^9	8.1×10^6	2,785
South Trenches	4.3×10^9	1.5×10^7	5,170
Carbon-14			
North Trenches	7.4×10^4	7.3×10^4	75
South Trenches	5.2×10^5	5.1×10^5	176

for ^{14}C, which is assumed to have a retardation factor of about 7, the time was assumed to be 700 years. Concentration of tritium and ^{14}C are further reduced by dilution from Frank's Creek. The average annual flow rate of 875,837 m^3/yr measured in 1977 at a gauging station on Frank's Creek northeast of the site provides a dilution factor of 2920 when compared to the estimated flux through the shallow till of 300 m^3/yr. This dilution reduces the concentration of these radionuclides to levels below regulatory limits (see Table 4.2). Therefore, with the assumed conditions, movement of radionuclides along a lateral flow path through the till does not appear to provide a significant loading to Frank's Creek.

4.2.3 Analysis and Results of Deep Vertical Pathway Assessment

The following section provides a discussion of the transport analysis for the deep vertical pathway. This discussion describes the modeling approach, model selection and design, modeling assumptions with regard to the site hydrogeologic characteristics, physical characteristics and setting of the site trenches, the waste inventory and related radionuclide release, and subsequent transport into the environment to hypothetical offsite wells.

4.2.3.1 Modeling Approach and Model Selection and Design

The transport modeling approach was devised for the site to take advantage of the main attributes of the site conceptual model. Radionuclides were released from the site waste inventory and were transported downward in a vertical streamtube with a cross-sectional area equivalent to the surface areas of all trenches contained within the disposal facility through the total thickness of unweathered till to the underlying lacustrine unit. Once in the lacustrine, radionuclides were transported laterally in a horizontal streamtube defined by the length of the burial trenches and the saturated thickness of the lacustrine unit. The transport was done to hypothetical off-site wells where an assessment of exposure through drinking water and full garden scenarios was made. Because of their physical separation, the north trenches and south trenches were treated separately in this analysis.

The model selected for this analysis, the TRANSS code (Simmons et al. 1986), is designed for one-dimensional, convective transport in a streamtube. This approach is schematically illustrated in Figure 4.9. The code, which incorporates the theory of Simmons (1982) and relates dispersion directly to the variation observed in the travel time from the contaminant source, includes the following features:

- A probability-weighted summation of either the fluxes or concentration is calculated along a streamline with a constant flow velocity determined from the travel time and length of the hydrologic streamline.
- One-dimensional transport is represented along each streamline by an analytical solution of the convective-dispersion equation. (This approach assumes a constant flow velocity, which varies with a local-scale dispersion coefficient.)

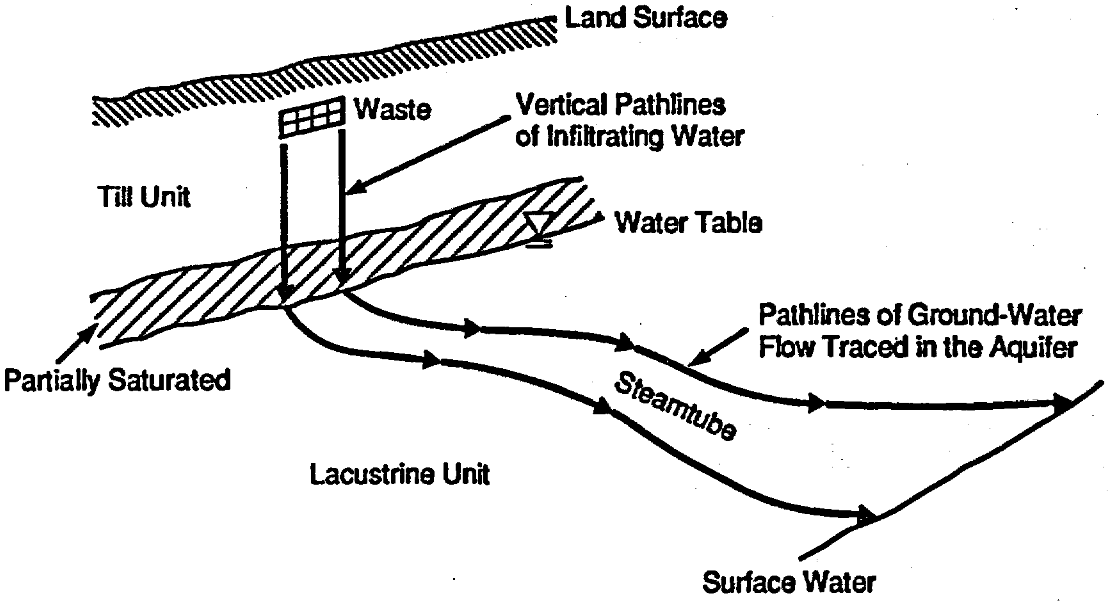


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FIGURE 4.9. Depiction of the Streamtube Approach to Transport Through the Till Zone and Lacustrine Unit as Incorporated Into the TRANSS Code

- Decay of radioactive contaminants is applied both during containment and after leaching from the waste source and entering the hydrologic flow path.

- Retardation of the contaminant migration is based on a fixed distribution coefficient (K_d) for each nuclide.

- The model contains a general empirical description of contaminant release but also includes the choice of three optional release models: 1) a constant fractional release rate, 2) a concentration-limited release rate based on chemical solubility, and 3) an adsorption equilibrium release rate based on the K_d value for the nuclide.

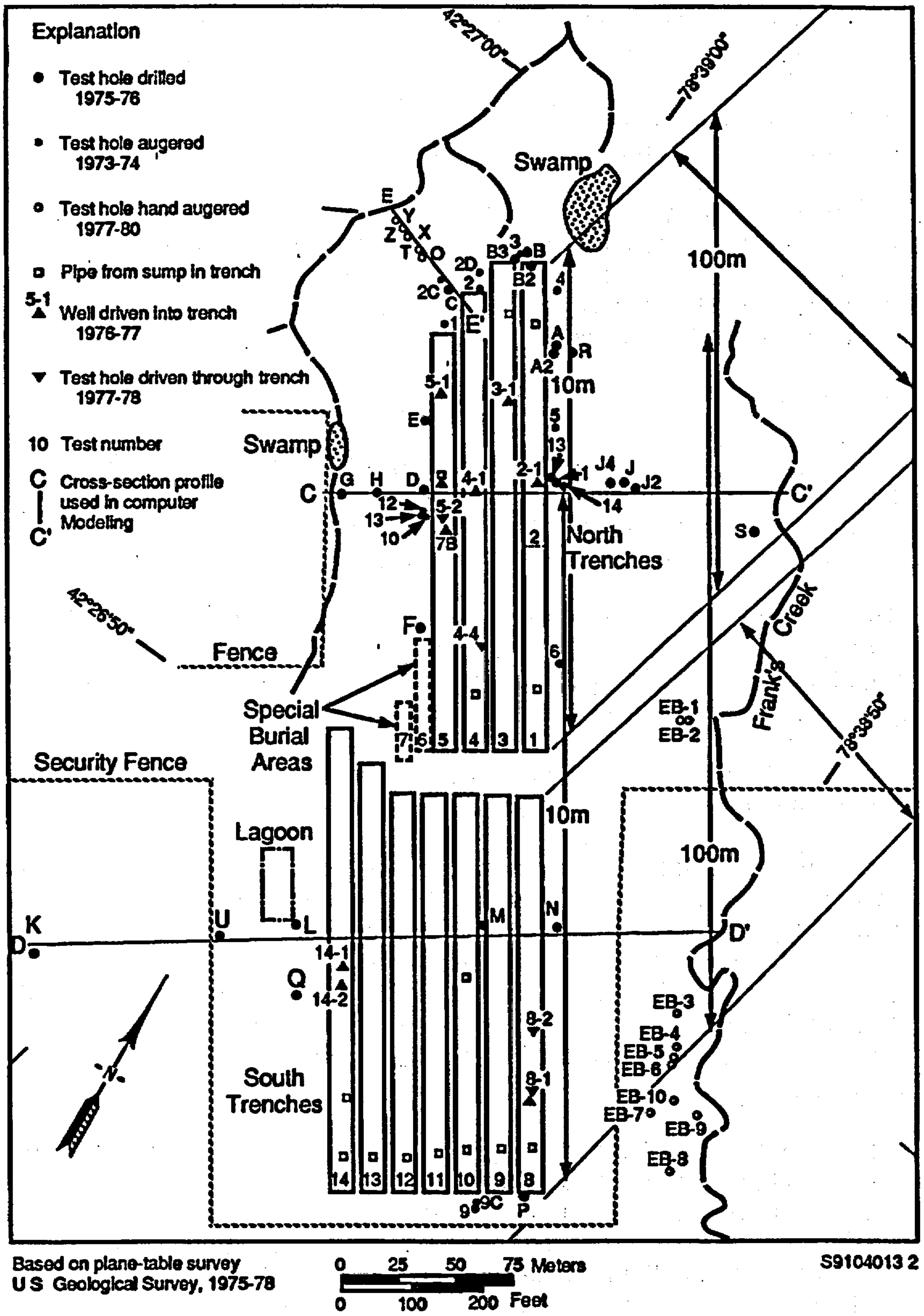
4.2.3.2 Modeling Assumptions and Parameters

Site Characteristics. The site has been divided vertically into two hydrologic zones, the near-surface weathered and fractured till, and the deeper unfractured till. Drainage in the subsurface is generally toward the north-northeast in the lacustrine unit, but flow paths are essentially vertical in the till.

The area of the trenches was computed by measurement of the outlines of the trench boundaries from Smoot (1989). The cumulative area of the trenches receiving net infiltration is approximately 20,282 m^2. Hydrologic and site information (Smoot 1989) includes the water influx and soil properties at West Valley. Net infiltration is approximately 0.023 m/yr. This infiltration rate will be assumed to be constant throughout the year. The porosity was assigned a value of 0.3, and the bulk density of the streamtube material was given a value of 1.8 g/cm^3.

To simulate the deep pathway scenario, two models were constructed, one from the southern trenches to wells 10 m and 100 m from the edge of the trenches in a direction downgradient from the waste site, and one from the northern trenches to wells 10 m and 100 m from the edge of the trenches. A map view of the trenches, wells, and streamtubes is shown in Figure 4.10. Streamlines from several different points along the streamtube in the trench area divide the inventory area. The width of the trenches projected in a direction along the hydraulic gradient was considered to be the streamtube width.

Results of the hydrologic flow modeling provided the basis for the conceptual model used in the TRANSS transport calculations. Figure 4.11 shows a cross-sectional view of the flow path through the unfractured till. Water infiltrating through the burial till moves vertically until it eventually reaches the underlying lacustrine unit, which acts as a drain to the till. The water then travels laterally downgradient to the wells. The average dispersion coefficient was chosen to be the largest found by



Based on plane-table survey
U S Geological Survey, 1975-78

FIGURE 4.10. Streamlines and Streamtubes Used for Transport Modeling

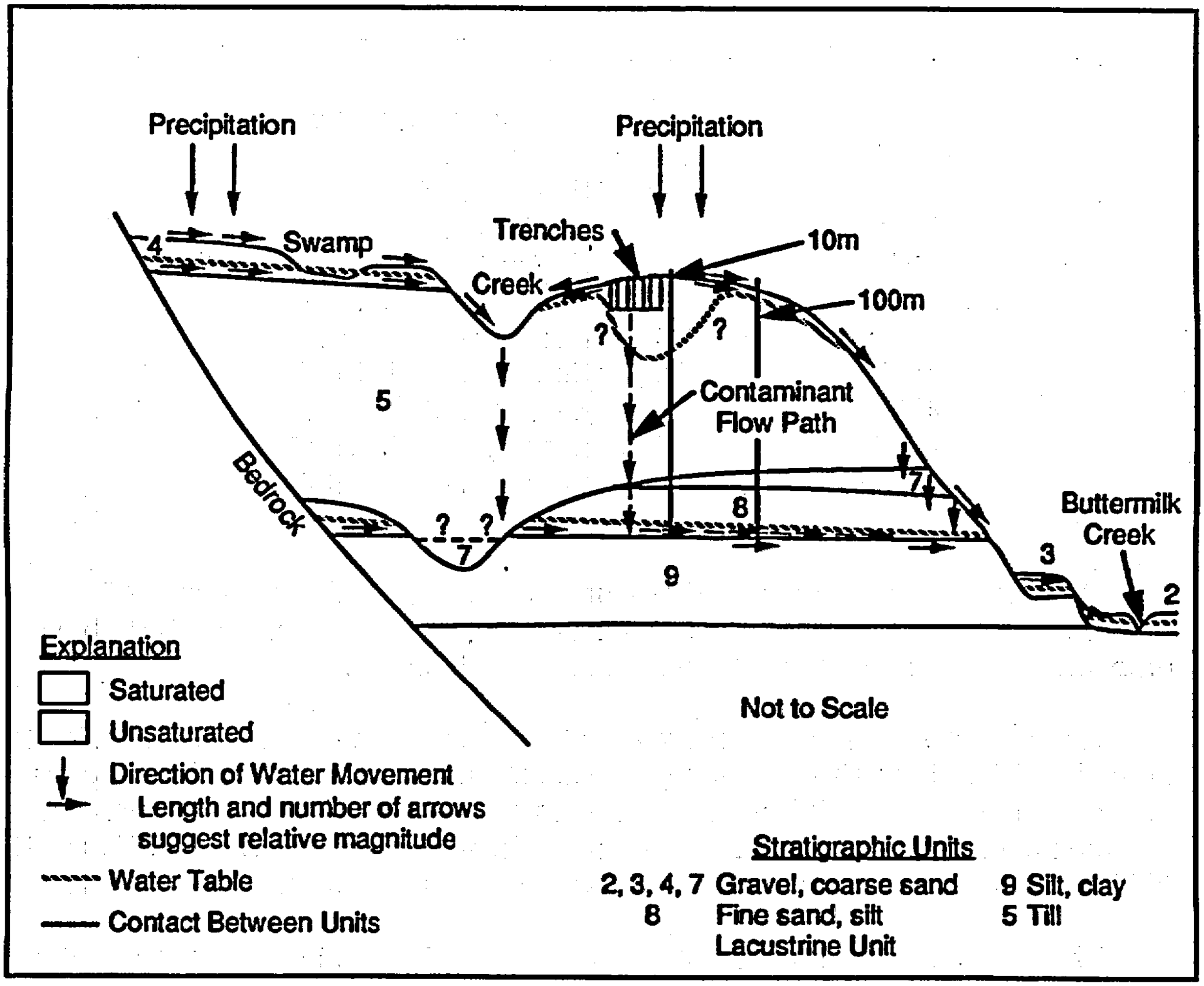


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FIGURE 4.11. Cross-Sectional View of Flow Path Used in Transport Modeling

Prudic (1986) at 59 cm^2/yr for tritium and about 47 cm^2/yr for ^{14}C in the till. The average bulk density and porosity was also taken from Prudic (1986) to be 1.8 g/cm^3 and 0.30, respectively. Retardation factors indicate the amount of retardation of the radionuclide, and are computed from

$$R = 1 + (\text{bulk density} / \text{porosity}) * K_d. \tag{4.2}$$

Table 4.4 shows the retardation values used in the transport simulations for the north and south trenches. Based on these figures, the only radionuclides not held

TABLE 4.4. Selected Retardation Factors for Various Radionuclides

Radionuclide	R	Comments or Source
^{3}H	1	Conservative; moves with water
^{137}Cs	292	Prudic 1986
^{60}Co	6	Prudic 1986
^{90}Sr	43	Prudic 1986
^{14}C	7	Prudic 1986
^{226}Ra	1168	Bergeron et al. 1987
^{241}Am	>1200	Routson et al. 1987
^{238}Pu	338	Bergeron et al. 1987
^{239}Pu	338	Bergeron et al. 1987
^{235}U	7.	Bergeron et al., 1987
^{232}Th	219	Bergeron et al., 1987

essentially immobile as a result of retardation by adsorption are ^{3}H and ^{14}C. Cesium-137 along with ^{235}U, ^{60}Co, ^{226}Ra, ^{241}Am, ^{238}Pu, ^{239}Pu, and ^{232}Th, have been dropped from further consideration in model development.

A period of 14 years was allowed for the inventory to decay corresponding to the operational life of the site before any release to the environment. This is important only for the inventory of ^{3}H (53,272 Ci). With a half-life of 12.3 years, approximately half the inventory will have decayed before release is allowed. The half-life of ^{14}C (5730 years) is so long as to make the reduction in inventory (212 Ci) insignificant.

The areas over which net infiltration contributed to the total flux through the waste were calculated to be 9313 m^2 and 16386 m^2, respectively. The waste was considered to be concentrated at the bottom of the trenches, which were an average of 6 m deep. Travel from the bottom of the trenches to the lacustrine unit took place over a distance of 23 m with travel times of 300 to 2300 years (Prudic 1986). The shorter time was used as a conservative estimate, which was based on a specific flux of 2.3 cm/yr, a hydraulic conductivity of 6.0×10^{-8} cm/s, and an effective porosity of 0.3.

The areas used for the streamtubes in the TRANSS runs of the north and south trenches are 2038 m^2 and 1727 m^2, respectively. Migration of the waste was assumed to take place equally along the entire width of the streamtube. The widths of the streamtubes for the north and south trenches were computed to be 198 and 172.7 m, respectively. The velocity of water in the lacustrine unit was determined to be 1.68 m/yr based on a hydraulic conductivity of 1.0×10^{-4} cm/s and a hydraulic gradient of 0.014 (Prudic 1986).

Trench Configuration and Waste Inventory. Information characterizing inventory was gathered for trenches 1 through 11 from Prudic (1986). Trenches 12, 13, and 14 were not studied in detail. Information characterizing waste containment breakdown was compiled for trenches 8 through 14. Trenches 1 through 7 were not studied in detail. Only general information on volume, operational life, and location were given for all trenches in the Prudic (1986) and Kelleher and Michael (1973) reports. The information from the studies were assumed to be indicative of the types and amounts of waste being shipped to West Valley over the operational life of the site. To determine a generalized inventory and waste containment distribution for undocumented trenches, an average trench volume and inventory was compiled. From this an inventory and waste containment distribution was derived, based on documented trenches. The waste containment distribution was assumed to be that of the average trench, and the inventory of each undocumented trench was corrected for the difference in volume from the average trench. A similar method was used to approximate the waste containment breakdown for trenches with no information available. A summary of the estimated inventory for the West Valley site is provided in Table 4.5.

The chemical or physical form (metal, liquid, etc.) of the inventory can vary widely for each radionuclide in the trench. No attempts have been made in compiling the inventory to break out parts of the radionuclide inventory that would possibly have a significant effect on the availability and/or release of that radionuclide to the environment. Tritium, for example, was shipped to West Valley mostly as liquid tritium oxide (T_2O) or targets. However, forms of tritium exist that have a very low release rate as a consequence of their chemical form. Luminous paint containing tritium is assumed to be nonleachable. No information on the possible presence of forms of tritium other than as targets or as byproducts of other wastes was provided.

Solubilities of the different radionuclides depend on the chemical form taken. Little chemical information exists describing radionuclide valences, oxidation states, complexation, etc., to apply solubility information. Therefore, uncertainty exists in the solubility controls applied in the conceptual model. Carbon-14 was determined to be solubility controlled, and passed the screening process described in a later section. A maximum ^{14}C value determined from the trench sumps was used as a limiting solubility, even though it is several orders of magnitude below the theoretical maximum solubility of carbon in water. Additional chemical parameters unknown at this time are assumed to be the source of the lower solubility in the trench leachates.

Waste Containment Characteristics. Of all the different waste containment structures shipped to the West Valley site, three either contained the bulk of the waste or provided an environmental barrier similar to the waste containment actually used. Secondary waste containment structures within the primary waste containment may or may not be present; a conservative assumption of no secondary waste containment to the primary containment structure was made. These waste containment structures are described in Section 2.3.2.

TABLE 4.5. West Valley Trench Inventory

Trench Number	Total Activity (Ci)	Waste Volume (m**3)	Waste Stream Breakdown Total H-3 (Ci)	Waste Stream Breakdown Metal	Waste Stream Breakdown Concrete	Waste Stream Breakdown Boxes, wood, etc.	Waste Stream Breakdown Total C-14	Waste Stream Breakdown Metal	Waste Stream Breakdown Concrete	Waste Stream Breakdown Boxes, wood, etc.
1	4,120	1,560.0	17.2	10.43	0.62	6.11	1	0.61	0.04	0.36
2	2,200	3,240.0	8.1	4.92	0.29	2.88		0.00	0.00	0.00
3	17,100	5,620.0	674.4	410.04	24.28	240.09	5	3.04	0.18	1.78
4	67,100	7,770.0	2,719.5	1,653.46	97.90	968.14	7.77	4.72	0.28	2.77
5	92,900	7,880.0	11,032.0	6,707.46	397.15	3,927.39	3	1.82	0.11	1.07
6	10,200	2.1								
7	1,570	70.0								
8	38,700	7,150.0	15,730.0	7,550.40	314.60	7,865.00	35.035	16.82	0.70	17.52
9	34,200	4,920.0	7,872.0	4,565.76	236.16	3,070.08	17.712	10.27	0.53	6.91
10	54,900	5,170.0	31,537.0	16,399.24	315.37	14,822.39	33.088	17.21	0.33	15.55
11	53,500	5,180.0	36,260.0	22,481.20	362.60	13,416.20	341.88	211.97	3.42	126.50
12	11,200	5,490.0	12,078.0	8,454.60	362.34	3,261.06	53.802	37.66	1.61	14.53
13	9,400	5,820.0	12,804.0	8,578.68	1,024.32	3,201.00	57.036	38.21	4.56	14.26
14	12,300	4,720.0	10,384.0	7,164.96	726.88	2,492.16	46.256	31.92	3.24	11.10
Totals	409,390.00	64,592.1	141,116.16	83,981.15	3,862.51	53,272.50	601.58	374.25	15.00	212.33

TABLE 4.5. (contd)

Trench Number	Total Activity (Ci)	Waste Volume (m**3)	Waste Stream Breakdown Total Co-60	Metal	Concrete	Boxes, wood, etc.	Waste Stream Breakdown Total Sr-90	Metal	Concrete	Boxes, wood, etc.
1	4,120	1,560.0	34.32	20.87	1.24	12.22	0	0.00	0.00	0.00
2	2,200	3,240.0	158.78	96.53	5.72	56.52	0	0.00	0.00	0.00
3	17,100	5,620.0	2,990.20	1,818.04	107.65	1,064.51	0	0.00	0.00	0.00
4	67,100	7,770.0	170.94	103.93	6.15	60.85	15,763.00	0.00	0.00	0.00
5	92,900	7,880.0	46,492.00	28,267.14	1,673.71	16,551.15	0	0.00	0.00	0.00
6	10,200	2.1	10,290.00							
7	1,570	70.0	252.00							
8	38,700	7,150.0	12,870.00	6,177.60	257.40	6,435.00	0	0.00	0.00	0.00
9	34,200	4,920.0	137.76	79.90	4.13	53.73	0	0.00	0.00	0.00
10	54,900	5,170.0	1,809.50	940.94	18.10	850.46	0	0.00	0.00	0.00
11	53,500	5,180.0	264.16	163.79	2.64	97.75	0	0.00	0.00	0.00
12	11,200	5,490.0	8,784.00	6,148.80	263.52	2,371.68	0	0.00	0.00	0.00
13	9,400	5,820.0	9,312.00	6,239.04	744.96	2,328.00	0	0.00	0.00	0.00
14	12,300	4,720.0	7,552.00	5,210.88	528.64	1,812.48	15,763.00	0.00	0.00	0.00
Totals	409,390.00	64,592.1	101,117.66	55,267.45	3,613.85	31,694.35	15,763.00	0.00	0.00	0.00

TABLE 4.5. (contd)

Trench Number	Total Activity (Ci)	Waste Volume (m**3)	Waste Stream Breakdown Total Cs-137	Metal	Concrete	Boxes, wood, etc.	Waste Stream Breakdown Total Ra-226	Metal	Concrete	Boxes wood, etc.
1	4,120	1,560.0		0.00	0.00	0.00		0.000	0.000	0.000
2	2,200	3,240.0		0.00	0.00	0.00	0.2	0.122	0.007	0.071
3	17,100	5,620.0		0.00	0.00	0.00	0.5	0.304	0.018	0.178
4	67,100	7,770.0	3.03	1.84	0.11	1.08	1.63	0.991	0.059	0.580
5	92,900	7,880.0	0.102	0.06	0.00	0.04	0.44128	0.268	0.016	0.157
6	10,205	2.1								
7	1,570	70.0								
8	38,700	7,150.0	1	0.48	0.02	0.50	1.6445	0.789	0.033	0.822
9	34,200	4,920.0	8.856	5.14	0.27	3.45	0.6137	0.008	0.005	0.005
10	54,900	5,170.0	3	1.55	0.03	1.41	0.003	0.002	0.000	0.001
11	53,500	5,180.0	3	1.86	0.03	1.11	0.9842	0.610	0.010	0.364
12	11,200	5,490.0	2.745	1.92	0.08	0.74	0.6839	0.423	0.018	0.163
13	9,405	5,820.0	2.91	1.95	0.23	0.73	0.6402	0.429	0.051	0.160
14	12,300	4,720.0	2.36	1.63	0.17	0.57	0.5192	0.358	0.036	0.125
Totals	409,395.00	64,592.1	27.00	16.44	0.94	9.62	7.18	4.30	0.25	2.63

TABLE 4.5. (contd)

Trench Number	Total Activity (Ci)	Waste Volume (m**3)	Waste Stream Breakdown: Total Am-241	Metal	Concrete	Boxes wood, etc.	Waste Stream Breakdown: Total Pu-238	Metal	Concrete	Boxes, wood, etc.
1	4,120	1,560.0		0.00	0.00	0.00		0.00	0.00	0.00
2	2,200	3,240.0		0.00	0.00	0.00		0.00	0.00	0.00
3	17,100	5,620.0		0.00	0.00	0.00	4.048	2.46	0.15	1.44
4	67,100	7,770.0		0.00	0.00	0.00		0.00	0.00	0.00
5	92,900	7,880.0		0.00	0.00	0.00	133.96	81.45	4.82	47.69
6	10,200	2.1								
7	1,570	70.0								
8	38,700	7,150.0	1.5	0.72	0.03	0.75	221.65	106.39	4.43	110.83
9	34,200	4,920.0	4.92	2.85	0.15	1.92	103.32	59.93	3.10	40.29
10	54,900	5,170.0	3.98	2.07	0.04	1.87	878.9	457.03	6.79	415.08
11	53,500	5,180.0	6.734	4.18	0.07	2.49	393.68	244.08	3.94	145.66
12	11,200	5,490.0	4.6116	3.23	0.14	1.25	340.38	238.27	10.21	91.90
13	9,400	5,820.0	4.888	3.27	0.39	1.22	360.84	241.76	20.87	98.21
14	12,300	4,720.0	3.9648	2.74	0.28	0.95	292.64	201.92	20.48	70.23
Totals	409,390.00	64,592.1	30.60	19.06	1.09	10.45	2,729.42	1,633.29	84.79	1,011.34

TABLE 4.5. (contd)

Trench Number	Total Activity (Ci)	Waste Volume (m**3)	Waste Stream Breakdown				Waste Stream Breakdown			
			Total Pu-239	Metal	Concrete	Boxes wood, etc.	Total U-235	Metal	Concrete	Boxes wood, etc.
1	4,120	1,560.0		0.00	0.00	0.00	0.006084	0.004	0.000	0.002
2	2,200	3,240.0	0.5500	0.33	0.02	0.20	0.0013932	0.001	0.000	0.000
3	17,100	5,620.0	6.182	3.76	0.22	2.20	0.00382	0.002	0.000	0.001
4	67,100	7,770.0	29.52	17.95	1.06	10.51	0.01789	0.010	0.001	0.006
5	92,900	7,880.0	18.124	11.02	0.65	6.45	0.006698	0.004	0.000	0.002
6	10,200	2.1								
7	1,570	70.0					0.00063			
8	38,700	7,150.0	27.885	13.38	0.56	13.94	0.027	0.013	0.001	0.014
9	34,200	4,920.0	5.984	3.42	0.18	2.30	0.007872	0.005	0.000	0.003
10	54,900	5,170.0	3.0775	2.02	0.04	1.82	0.0047	0.002	0.000	0.002
11	53,500	5,180.0	0.00215	0.04	0.00	0.02	0.0119	0.007	0.000	0.004
12	11,200	5,490.0	40.677	28.65	1.20	10.02	0.009333	0.007	0.000	0.003
13	9,400	5,820.0	42.485	28.47	3.40	10.62	0.009894	0.007	0.001	0.002
14	12,300	4,720.0	34.456	23.77	2.41	8.27	0.008824	0.006	0.001	0.002
Totals	409,390.00	64,592.1	209.12	132.22	9.74	67.16	0.11	0.07	0.00	0.04

TABLE 4.5. (contd)

Trench Number	Total Activity (Ci)	Waste Volume (m**3)	Waste Stream Breakdown Total Th-232	Metal	Concrete	Boxes wood, etc.
1	4,120	1,560.0	0.0312	0.019	0.001	0.011
2	2,200	3,240.0		0.000	0.000	0.000
3	17,100	5,620.0	0.000992	0.005	0.000	0.003
4	67,100	7,770.0		0.000	0.000	0.000
5	92,900	7,880.0	0.26	0.158	0.009	0.093
6	10,200	2.1				
7	1,570	70.0				
8	38,700	7,150.0	0.3716	0.178	0.007	0.186
9	34,200	4,920.0	0.028	0.016	0.001	0.011
10	54,900	5,170.0	0.0129	0.007	0.000	0.006
11	53,500	5,100.0	0.0512	0.032	0.001	0.019
12	11,200	5,490.0	0.1098	0.077	0.003	0.038
13	9,400	5,820.0	0.1164	0.078	0.009	0.029
14	12,300	4,720.0	0.0944	0.065	0.007	0.023
Totals	409,390.00	64,592.1	1.08	0.64	0.04	0.41

The initial competency of the waste containment structures was determined by the method of placement in the trench. All of the steel drums were assumed to be rolled or dropped into the trench, and thus suffered a 15% denting and/or breakage rate (MacKenzie et al. 1984). Fiberboard boxes, wood, plastic bags, and other simple waste containment structures were assumed not to be a barrier to the environment regardless of the emplacement method.

The competence of the waste containment structures over time was determined by corrosion rates of the waste containment. MacKenzie et al. (1984) reports steel drum corrosion rates and expected lifetimes of waste containment structures in a soil environment similar to that of West Valley. The expected lifetime of a steel drum is 86 years, and a steel liner 215 years. Cardboard and wooden boxes do not have the ability to protect radionuclides from the environment. For the expected transport time of the radionuclides existing in the trenches (with the exception of ^3H), waste containment competency does not seriously affect eventual transport to off-site wells.

In addition, little is known of the waste forms other than the general makeup of the container (metal, concrete, wood, etc.) or placement, so release scenarios would be speculative regarding the retardation or attenuation of radionuclides by the waste containment structure. Therefore, the conservative assumption has been made to disregard the effects of waste containment structures and release the total inventory of radionuclides to the trench environment at the end of the operational life of the site. Radioactive decay, however, is still allowed to attenuate the inventory present in the trenches prior to release.

4.2.2.3 Modeling Results

Transport simulations were made for radionuclides in the trenches at West Valley for waste entering the unfractured zone at the bottoms of the trenches. The modeling assumptions discussed in Section 4.3.4 were used to model radionuclide transport and resulting concentrations of radionuclides reaching wells offsite. Travel times and concentration levels are discussed individually for each radionuclide.

Tritium. Because tritium is a conservative species and travels with the water, it moves without attenuation or retardation through the subsurface. Tritium concentrations resulting from a release of tritium consisting of the maximum observed tritium concentration in trench water multiplied by the assumed infiltration rate of 2.3 cm/yr are presented in Figures 4.12 and 4.13. Figure 4.12 represents predicted concentrations at a hypothetical well located approximately 10 m and 100 m downgradient of the north trenches; Figure 4.13 represents predicted concentrations at a hypothetical well located approximately 10 m and 100 m downgradient of the south trenches. In both cases, the transport through the unweathered till in combination with the short half-life of tritium reduces the concentration of tritium to relatively low levels. Peak concentration at 10 m downgradient from the north trenches is about 4 pCi/L respectively after

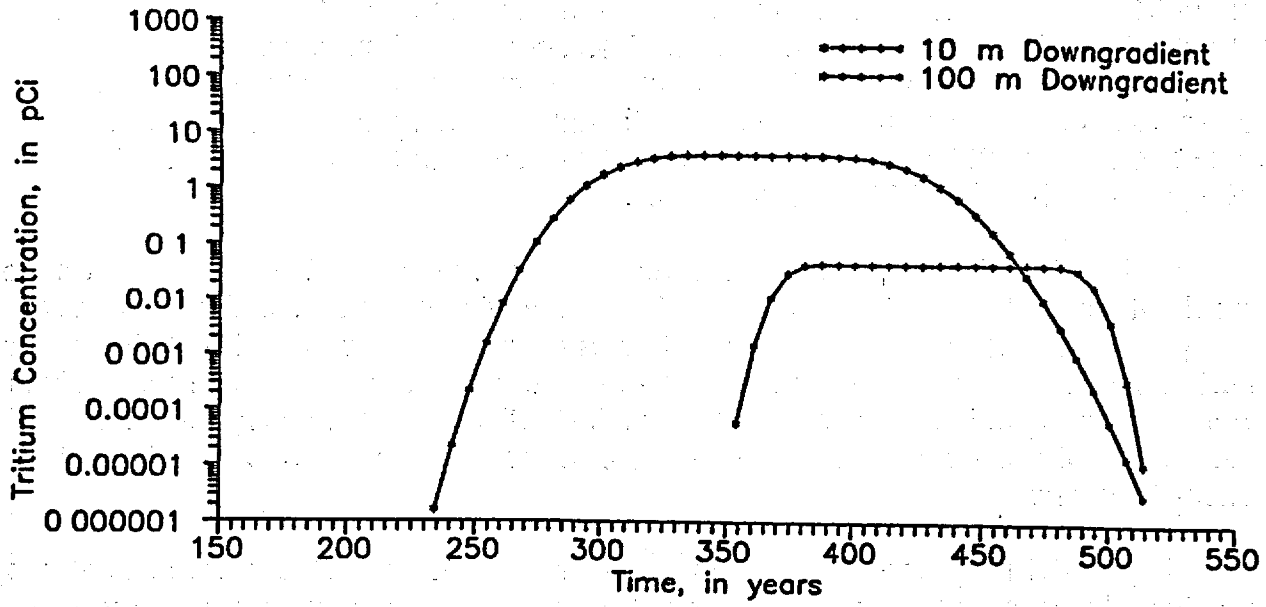

FIGURE 4.12. Tritium Concentrations at a Hypothetical Well Located Approximately 10 m and 100 m Downgradient (Northeast) of the North Trenches

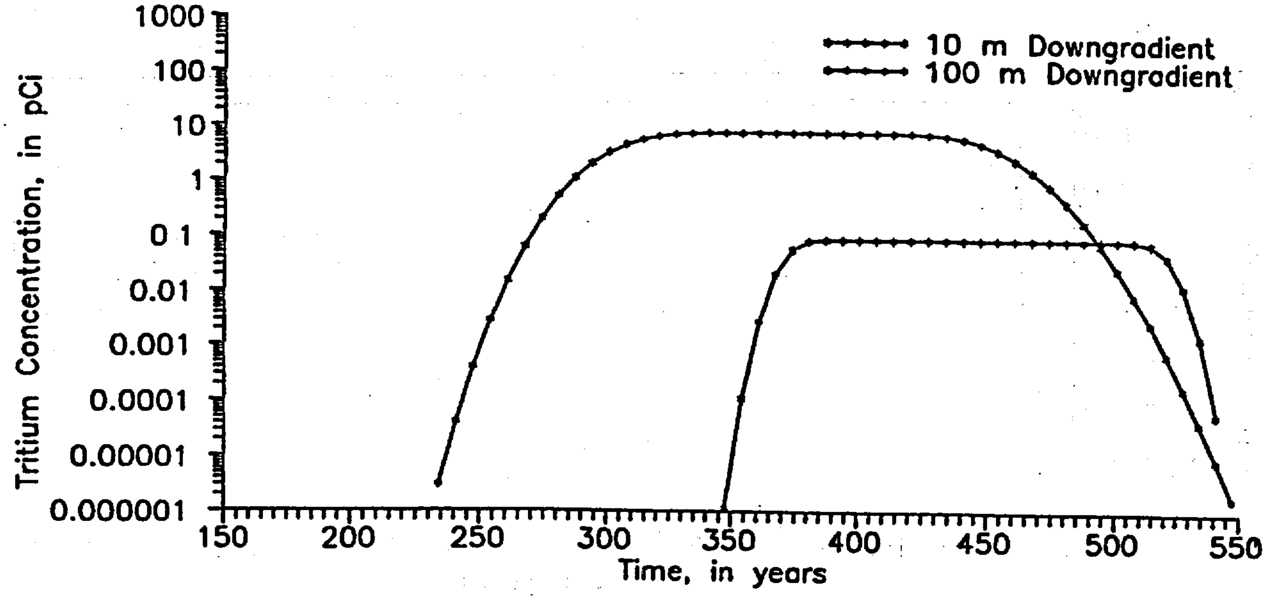

FIGURE 4.13. Tritium Concentrations at a Hypothetical Well Located Approximately 10 m and 100 m Downgradient (Northeast) of the South Trenches

about 310 years. Peak concentration at 100 m downgradient of the trenches reach about 0.046 pCi/L after about 370 years. Peak concentrations decline after 410 years at 10 m and about 500 yr at 100 m. Peak concentrations 10 m and 100 m downgradient of the south trenches rise to about 7.4 pCi/L after 310 years and 0.086 pCi/L after 370 years respectively. Peak concentrations decline after 450 years at 10 m and 530 years at 100 m.

Carbon 14. For ^{14}C, solubility controls are a more important limiting factor on the resultant concentration at a distant well than distribution coefficients. From chemical analyses of leachate waters in the trenches, a maximum value of 74,000 pCi/L for the north trenches and 520,000 pCi/L for the south trenches was obtained. These values were used in combination with the assumed infiltration rate of 2.3 cm/yr to determine the release of ^{14}C from the inventory and the subsequent transport to hypothetical offsite locations.

Figure 4.14 represents predicted concentrations at a hypothetical well located approximately 10 m and 100 m downgradient of the north trenches; Figure 4.15 represents predicted concentrations at a hypothetical well located approximately 10 m and 100 m downgradient of the south trenches. In both cases, the transport through the unweathered till in combination with the long half-life of ^{14}C reduces the concentration of

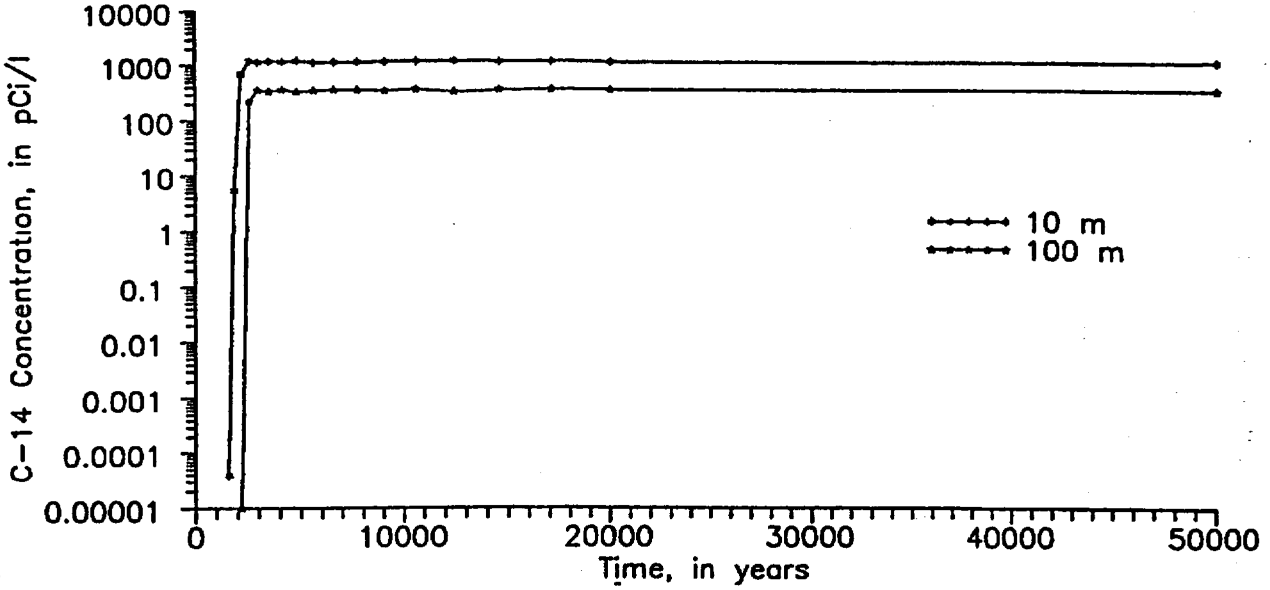

FIGURE 4.14. Carbon-14 Concentrations at a Hypothetical Well Located Approximately 10 m and 100 m Downgradient (Northeast) of the North Trenches

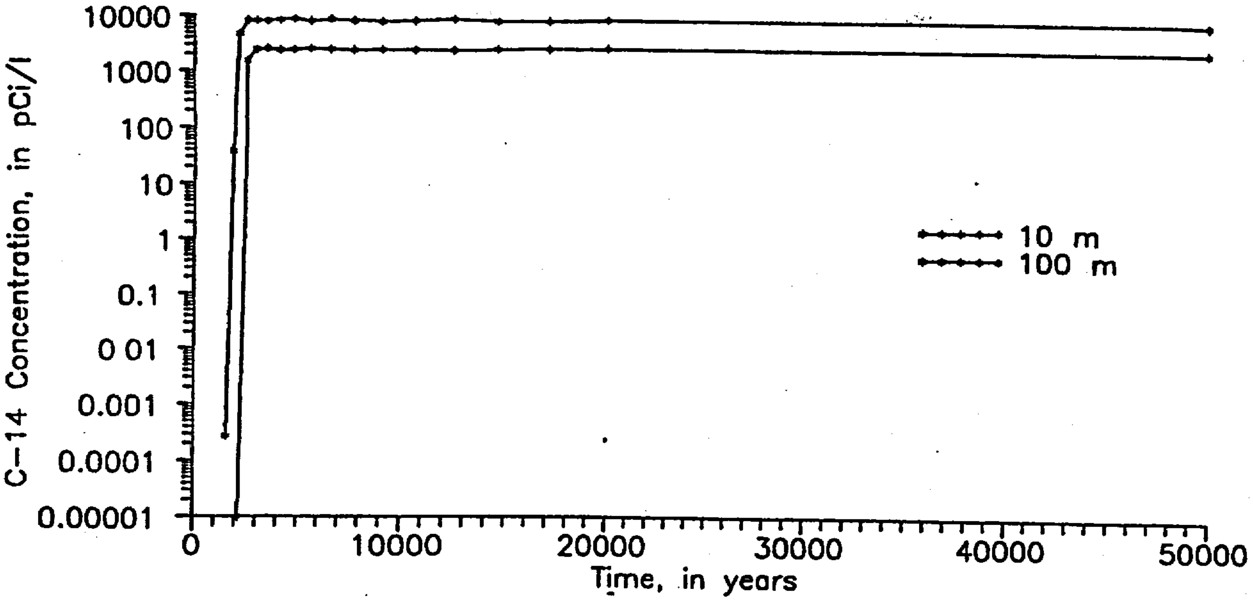

FIGURE 4.15. Carbon-14 Concentrations at a Hypothetical Well Located Approximately 10 m and 100 m Downgradient (Northeast) of the South Trenches

tritium to less significant levels. Peak concentration at 10 m downgradient from the north trenches is about 1660 pCi/L, respectively after about 310 years. Peak concentration at 100 m downgradient of the trenches reach about 418 pCi/L after about 370 years. Peak concentrations 10 m and 100m downgradient of the south trenches rise to about 11680 pCi/L after 310 years and 2940 pCi/L after 370 years, respectively. In both cases, these peak concentrations are sustained by the inventory and long half life for tens of thousands of years.

5.0 DISCUSSION OF PERFORMANCE ASSESSMENT RESULTS

This section of the report discusses the results of the simulated releases with the stated performance objectives and conclusions on the uncertainties associated with the overall site performance assessment results.

5.1 COMPARISON OF RESULTS WITH PERFORMANCE OBJECTIVES

The results in the performance assessment suggests that tritium and ^{14}C would be the only radionuclides released from the West Valley site in any significant concentrations. To date, radionuclide migration has been limited to less than 3 m from the trenches at West Valley.

As stated earlier, this performance assessment analysis was not intended to provide a definitive judgment of compliance of the West Valley site with the licensing regulations put forth in 10 CFR 61. No dose calculations were performed to assess site performance with regard to regulatory limits. For the sake of comparison, however, we did make a comparison of peak concentrations of the key radionuclides from the model results to dose equivalent concentrations that would be consistent with the regulatory limit of 25 mrem/yr whole body dose. A comparison of peak concentrations from the transport modeling results and the relevant dose equivalent concentrations is given in Table 5.1.

For the assumed simulated conditions, tritium levels are well below regulatory limits. For ^{14}C, predicted peak concentrations meet the 25-mrem dose limit using the drinking water only exposure scenario but exceed the limit for full garden scenario. The limit was exceeded at both the 10-m and 100-m locations downgradient of the trenches.

5.2 UNCERTAINTIES IN PERFORMANCE ASSESSMENT ANALYSIS

Simulated concentrations of radionuclides (tritium and ^{14}C) predicted in this study for the deep vertical pathway have many inherent uncertainties that need to be considered. These uncertainties can be categorized into two basic areas: 1) the area of ground-water movement within the burial till medium and in the underlying lacustrine unit and 2) the area related to the release and transport of radionuclides from the waste inventory. Discussion of the uncertainties in these two areas is summarized below.

TABLE 5.1. Equivalent Doses from Modeled Peak Concentrations for Tritium and ^{14}C

			Tritium			Carbon-14		
				Estimated Dose (mrem/yr)			Estimated Dose (mrem/yr)	
	Downgradient Distance (m)	Time of Peak Arrival (years)	Peak Concentration (pCi/L)	DW Only	Whole Body	Peak Concentration (pci/L)	DW Only	Whole Body
North Trenches								
	10	310	4	1.6E-4	3.6E-4	1,660	2.3	68.1
	100	370	0.046	1.9E-7	4.1E-6	418	0.6	17.1
South Trenches								
	10	2,170	7.4	3.1E-4	6.6E-4	11,680	16.6	478.9
	100	2,590	0.086	3.6E-6	7.6E-6	2,940	4.1	120.5

5.2.1 Ground-Water Movement

5.2.1.1 Burial Till Medium

The flow system at the West Valley site within the burial till medium is characterized as having two interrelated hydrogeologic units: 1) a shallow fractured, weathered till within the top 1 to 2 m, and 2) a deeper unweathered till. The gradation between the two units is typically fairly rapid over a meter or two where the level of fracturing and degree of weathering decreases with depth.

In the shallow fractured, weathered system, the conceptual model of the site indicates that flow is generally lateral away from the burial area towards nearby streams. However, little physical evidence is available at the site to indicate what the degree of this migration can be under a variety of trench conditions. Modeling by Prudic (1986) would seem to support that the fractures and weathering have enhanced the hydraulic properties of the shallow till by a factor of 10. Prudic also provided some simulation results that would indicate that even under conditions where the trenches become filled with leachate that trench water would not migrate all the way to nearby streams. These model results showed that water originating from the trench would migrate laterally some distance before eventually migrating downward into the underlying unweathered till. Little direct evidence has been observed to refute this position other than the experience of kerosene migration at the nearby FDA. This evidence would seem to suggest that lateral migration through this shallow till unit can be rapid and far greater than could be estimated using the results of the Prudic work. However, other factors related to the fluid properties (i.e., kerosene) could aid in explaining the discrepancies.

Within the deeper till, the conceptual model indicates that ground water moves very slowly (a few centimeters per year) in a vertical direction to an underlying lacustrine unit. This is substantiated by the combination of measurement of hydraulic head and laboratory testing of till cores. However, the behavior of water movement in and around sand and silt lenses and pods found within the till matrix and the effect of these features on the overall flow system is not well understood. These lenses vary in shape, size, and degree of saturation. Characterization efforts have suggested that they represented disconnected units that do not have much effect in short circuiting or enhancing horizontal or vertical water movement. Although the distribution and continuity or connectivity of these units has not been completely verified, the matrix of the till is accepted as the unit that dominates the flow system, and the impact of these lenses and pods on the water travel time and radionuclide migration through the till is minimal.

In this analysis, we used the most conservative estimate of travel time through the till [i.e., 300 years multiplied by a retardation factor of 7 (2100 years)] as the basis for the transport analysis. With this travel time estimate, predicted ^{14}C concentrations offsite exceed regulatory limits. To evaluate the sensitivity of this parameter on predicted concentrations, we examine the effect of the range of travel times proposed by Prudic (1986), 2100 to 16,100 years. Results of this evaluation at 10 m downgradient of the north trenches, summarized in Figure 5.1, indicate the overall sensitivity of this parameter. For the longest travel time estimates, predicted concentrations are reduced by a factor of about 5.5 from the effect of increased decay. This would reduce the predicted concentrations from the north trenches well below regulatory limits but would do little to reduce predicted concentrations from the south trenches below the same limits.

5.2.1.2 Underlying Lacustrine Unit

The lacustrine unit below the burial till medium is characterized as being a sandy unit that increases in silt content with depth. The base of the unit has been found to contained varved clays. Because the downward water flux through the till is far less than the water-transmitting capability of the lacustrine unit, upper parts of the units are partially saturated. Based on limited borehole data, only the bottom 1 to 2 m of the unit appear to be saturated.

In the analysis done for this study, the delay in water movement and radionuclide transport through the partially saturated upper part of the lacustrine unit was not considered. To date, the flow system of the lacustrine unit is not well understood. Within the upper parts of the lacustrine, the sands are not entirely unsaturated. Silty parts of the unit have been found to be saturated. However, no laboratory measurements

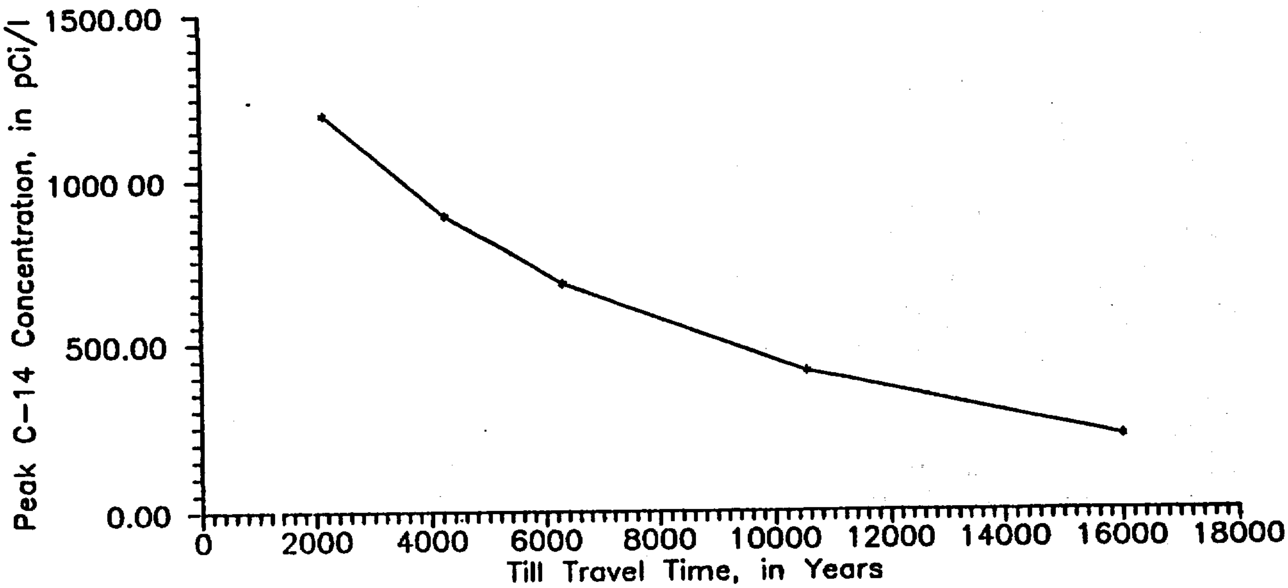

FIGURE 5.1. Sensitivity of Predicted Peak ^{14}C Concentrations to Changes in the Till Travel Time

have been performed to indicate what the actual range of hydraulic properties (i.e., saturated and unsaturated hydraulic conductivity, storage, and porosity) might be for this unit.

If we make an assumption that the water travel time through the unsaturated part of the lacustrine unit can be approximated with a unit gradient approach, the travel time can be estimated with the following equation:

$$TT = L\theta_p/q \qquad (5.1)$$

where L = length of the soil column
θ = residual water content
q = the assumed steady-state flux

If we assume a soil column length of 20 m, a residual water content between 5 and 10%, and a steady state flux equivalent to the infiltration through the till, 2.3 cm/yr, travel time through the lacustrine unit can be estimated to be between 45 and 90 years. Based on the travel time sensitivity analysis illustrated in Figure 5.1, we postulate that while this additional time will have an impact in the final predicted results, the effect would not be expected to have a significant impact on the overall analysis.

Below the upper unsaturated parts of the lacustrine is the saturated base of the unit. Although this part of the unit is known to be saturated and probably composed of increasingly siltier sand and varved clays, the exact nature and regional continuity of the sediments are not well understood. The data in these areas are limited and the range of hydraulic properties, like the upper part of the unit, have not been measured. Even the direction of movement within the unit cannot be considered very reliable because it is based on three wells that are widely spaced regionally. However, previous analysis of rates of water movement through this unit have relied primarily on conservative assumptions and professional judgment. The hydraulic gradients measured in the three wells that are completed were also assumed to be valid. In the final analysis, this part of the flow and transport, when compared to the much longer flow system estimated for the till, is expected to have little impact on overall performance assessment results other than the dilution it offers.

5.2.2 Radionuclide Release and Transport Analysis

5.2.2.1 The Use of Leachate Concentrations in Source-Term Release

The radionuclide release rate is the most sensitive parameter in the overall performance assessment. For the ^{14}C transport analysis, the radionuclide release rate to the flow system relied on measured trench water concentrations for initial conditions. Experimental data on solubility for these radionuclides are generally not directly available for the West Valley site other than what can be inferred from direct measurements in trench leachate. The use of this information was based on the assumption that, because the trenches have historically had water in contact with the waste forms over a number of years, the measured concentrations of radionuclides in the trench leachate could possibly reflect reasonable solubility limits for the radionuclides in question. However, the validity of this assumption is not known in the context of the performance period. It is conceivable that these concentrations could continue to increase with time as waste forms continue to degrade or become compromised in the future. The use of the maximum measured concentration for ^{14}C in the trench leachate was an attempt to add additional conservatism to the overall analysis. We acknowledge that if these concentrations are not valid and continue to increase or decrease, the results of this performance assessment will need to be reevaluated.

Model results change linearly with changes in solubility controlling concentration. For the range of measured concentrations of ^{14}C in leachate for all trenches, the release concentrations range from 2100 pCi/L in trench 1 to 520,000 pCi/L in trench 8. Considering this range, predicted concentrations of ^{14}C from individual trenches using the same release and transport scenario could potentially range over three orders of magnitude.

5.2.2.2 Geochemical Behavior of Carbon-14

In this analysis, we have assumed that all forms of ^{14}C (organic and inorganic) has the same geochemical behavior. The validity of these conservative assumption is unknown given the limited amount of geochemical information on the ^{14}C in the inventory. In the case of ^{14}C, it is generally known that the form of carbon originates from a variety of sources, including organic wastes, such as pesticides, solvents, resin materials, and biological wastes, and inorganic wastes such as activated charcoal filters. The approach used in this study, which assumes minimal adsorption and retardation, in all probability presents an overly conservative case for transport. The range of geochemical behavior in the context these complexities is the subject of much uncertainty and certainly would need to fully evaluated in a licensing situation.

To evaluate the sensitivity of model results to changes in the affinity of ^{14}C to adsorb to the site sediments,we examined the effect of retardation on model results.

Figure 5.2 presents the relationship of predicted peak ^{14}C concentrations down-gradient of the north trenches over the measured range of distribution coefficients presented in Prudic (1986). This range, from 0.7 mL/g to 12 mL/g, translates to retardation factors ranging from 5.25 to 73.8. The effect of increased adsorption is to delay the arrival time and increase the effect of radioactive decay. Over the range of measure adsorption, predicted peak ^{14}C concentration are reduced by a factor of about 13.

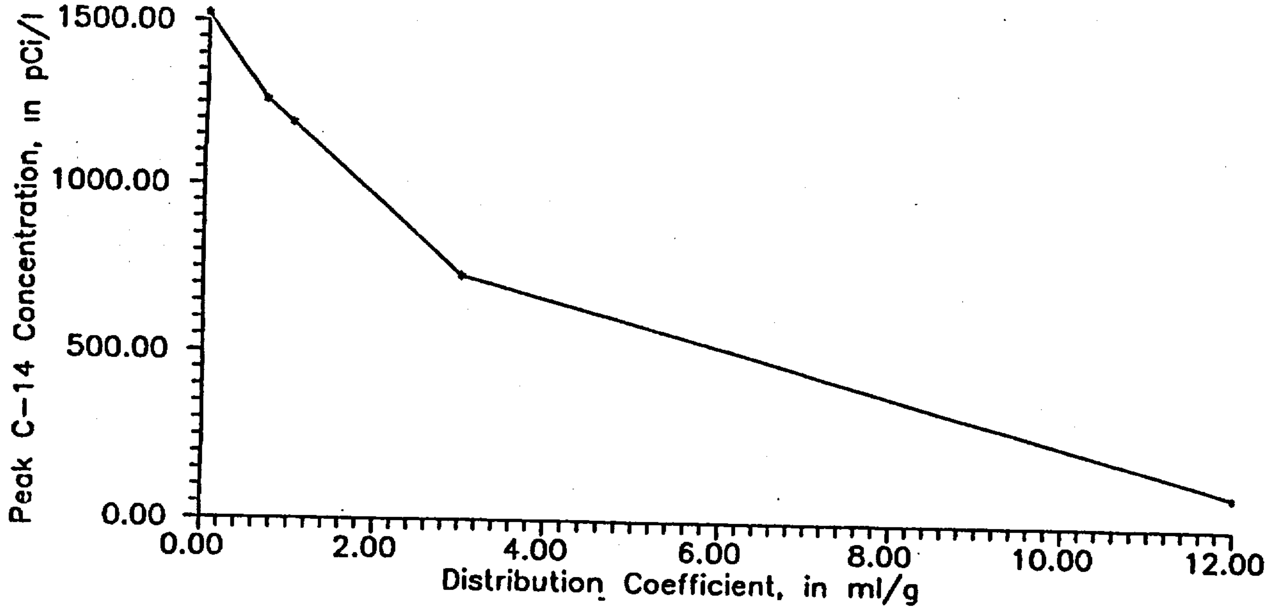

FIGURE 5.2. Sensitivity of Predicted Peak ^{14}C Concentrations to Changes in the Distribution Coefficient

6.0 SUMMARY AND CONCLUSIONS

Results and conclusions of the hydrogeologic performance assessment of the commercial site near West Valley, New York are as follows:

- Two primary ground-water pathways exists at the West Valley site. One pathway is found in the top 1 to 2 m of burial medium where overflowing trench water can potentially migrate laterally through fractured and weathered till to nearby surface water drainages. Another pathway is a deep vertical pathway where trench leachate can migrate vertically downward through unweathered till and laterally within ground water to offsite locations in a more permeable lacustrine unit.

- Though this and previous modeling done indicate the lateral pathway through the fractured till eventually moves downward before reaching nearby streams, the occurrence of migration of kerosene at the nearby facility burial area would seem to indicate that migration could be significant. To evaluate this pathway, we made conservative estimates of what the impact of the contaminated water overflowing from the trench might be to Frank's Creek. Using trench leachate concentrations and conservative estimates of travel time to nearby Frank's Creek, we evaluated what key radionuclides could be released from the site. With exception of Tritium and ^{14}C, the effects of decay and adsorption eliminated the majority of radionuclides in the inventory. The combined effect of decay and dilution offered by the annual average flow of Frank's Creek reduces levels of tritium and ^{14}C to below regulatory concern.

- Within the deep pathway, tritium and ^{14}C would be the only radionuclides released from the West Valley site in any significant concentrations. To date, radionuclide migration has been limited to less than 3 m from the trenches at West Valley. Tritium levels are well below regulatory limits. For ^{14}C, predicted peak concentrations meet the NRC limit for a 25 mrem dose using the drinking-water-only exposure scenario but exceed the limit for the full garden scenario. The limit was exceeded at both the 10-m and 100-m locations down-gradient of the trenches.

- Within the unweathered till, ground water moves very slowly (a few cm/yr) in a vertical direction to an underlying lacustrine unit. Although the distribution and continuity or connectivity of partially saturated and fully saturated sand and silt lenses and pods found in the till has not been completely verified, the matrix of the till is generally accepted as the unit which dominates the flow system, and the impact of more permeable lenses and pods on the water movement and radionuclide migration through the till is minimal.

- In this analysis, the delay in water movement and radionuclide transport through the partially saturated upper part of the lacustrine unit was not considered. To date, the flow system of the lacustrine unit is not well understood. The travel time through the lacustrine unit was conservatively estimated to be between 45 and 90 years. Based on the travel time sensitivity analyses, we postulate that while this additional time will have an impact in the final predicted results for ^{14}C, the effect would not be expected to have a significant impact on the overall analysis.

- The exact nature and regional continuity of the saturated base of the lacustrine sediments is not well understood. Data in these areas are limited and the range of hydraulic properties, like the upper part of the unit, have not been measured. Even the direction of movement within the unit cannot be considered very reliable because it is based on three wells that are widely spaced regionally. However, in the final analysis, this part of the flow and transport, when compared to the much longer flow system estimated for the till, is expected to have little impact on overall performance assessment results other than the dilution it offers.

- The release rate of ^{14}C from the individual trenches is the most sensitive parameter in the overall performance assessment. For this analysis, the release rate to the flow system is estimated from maximum measured trench water concentrations and the estimated infiltration rate. Experimental data on solubility for these radionuclides are generally not directly available for the West Valley site other than what can be inferred from direct measurements in trench leachate. The use of this information was based on the assumption that, because the trenches have historically had water in contact with the waste over a number of years, the measured concentrations of radionuclides in the trench leachate could possibly reflect reasonable solubility limits for the radionuclides in question. However, the validity of this assumption is not known in the context of the performance period. We acknowledge that if these concentrations continue to increase or decrease that the results of this performance assessment would not be valid and would need to be reevaluated.

- Once released to the flow system, we have assumed that all forms of ^{14}C (organic and inorganic) have the same geochemical behavior. The validity of this conservative assumption is unknown given the limited amount of geochemical information on the ^{14}C in the inventory. It is generally known that the ^{14}C can originate from a variety of sources, including organic wastes such as pesticides, solvents, resin materials, and biological wastes and inorganic wastes such as activated charcoal filters. The approach used in this study, which assumes minimal adsorption and retardation, in all probability presents an overly conservative case for transport. The range of geochemical behavior in the context of these complexities is the subject of much uncertainty and certainly would need to fully evaluated in a licensing situation.

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(See instructions on the reverse)

1 REPORT NUMBER (Assigned by NRC Add Vol , Supp , Rev , and Addendum Numbers, if any)
NUREG/CR-5737
PNL-7688

2 TITLE AND SUBTITLE
Hydrogeologic Performance Assessment Analysis of the Commercial Low-Level Radioactive Waste Disposal Facility near West Valley, New York

3 DATE REPORT PUBLISHED

MONTH	YEAR
June	1991

4 FIN OR GRANT NUMBER
B2485

5 AUTHOR(S)
M. P. Bergeron, J. L. Smoot, M. L. Kemner, W. E. Cronin

6 TYPE OF REPORT
Technical

7 PERIOD COVERED *(Inclusive Dates)*

8 PERFORMING ORGANIZATION – NAME AND ADDRESS *(If NRC, provide Division, Office or Region U S Nuclear Regulatory Commission, and mailing address, if contractor provide name and mailing address.)*

Pacific Northwest Laboratory
Richland, WA 99352

9 SPONSORING ORGANIZATION – NAME AND ADDRESS *(If NRC type "Same as above" If contractor provide NRC Division, Office or Region, U S Nuclear Regulatory Commission and mailing address)*

Division of Low-Level Waste Management and Decommissioning
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555

10 SUPPLEMENTARY NOTES
Prepared for U.S. NRC under contract DE-AC06-76RLO 1830

11 ABSTRACT *(200 words or less)*

A hydrogeologic performance assessment of the commercial low-level waste site near West Valley, New York, was performed for two pathways: a shallow lateral pathway where trench water can potentially migrate laterally through fractured and weathered till to nearby streams and a deep vertical pathway where leachate can migrate downward through unweathered till and laterally offsite in a lacustrine unit. Along the shallow pathway, little physical site evidence is available to indicate what the degree of lateral migration can be. Past modeling showed that overflowing trench water would migrate laterally some distance before migrating downward into the unweathered till. If water did reach a nearby stream, calculations show that decay, adsorption, and stream dilution would reduce leachate concentration to acceptable levels. Within the deep pathway, tritium and carbon-14 were the only radionuclides released in any significant concentrations. Predicted tritium levels are well below regulatory limits; however, predicted peak ^{14}C concentrations, while meeting the 25 mrem/yr limit using the drinking-water-only exposure scenario, exceed the limit for full garden scenario. Site information on ^{14}C release rates and geochemical behavior has considerable uncertainty and would need to be more fully evaluated in a licensing situation.

12 KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report)*

Performance Assessment
Ground-Water Models
Low-Level Waste Disposal
Radioactive Waste
Hydrogeology
West Valley LLW Site
Radionuclide Transport
Pathway Analysis

13 AVAILABILITY STATEMENT
unlimited

14 SECURITY CLASSIFICATION
(This Page)
unclassified
(This Report)
unclassified

15 NUMBER OF PAGES

16 PRICE