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Information on the Confinement Capability of the Facility Disposal Area at West Valley, New York

U.S. Nuclear Regulatory Commission

Office of Nuclear Regulatory Research
Office of Nuclear Material Safety and Safeguards

T. J. Nicholson, R. D. Hurt

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ABSTRACT

This report summarizes the previous NRC research studies, NRC licensee source term data and recent DOE site investigations that deal with assessment of the radioactive waste inventory and confinement capability of the Facility Disposal Area (FDA) at West Valley, New York. The radioactive waste inventory for the FDA has a total radioactivity of about 135,000 curies (Ci) and is comprised of H-3 (9,500 Ci), Co-60 (64,000 Ci), SR-90/Y-90 (24,300 Ci), Cs-137/Ba-137m (24,400 Ci), and Pu-241 (13,300 Ci). These wastes are buried in the Lavery Till, a glacial till unit comprised of a clayey silt with very low hydraulic conductivity properties. Recent studies of a tributylphosphate-kerosene plume moving through the shallow ground-water flow system in the FDA indicate a need to better assess the fracture flow components of this system particularly the weathered and fractured Lavery Till unit. The analysis of the deeper ground-water flow system studied by the USGS and NYSGS staffs indicates relatively long pathways and travel times to the accessible environment. Mass wasting, endemic to the glacial-filled valley, contributes to the active slumping in the ravines surrounding the FDA and also need attention.

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I. BACKGROUND

A. HISTORY OF DISPOSAL AREA USE

The Western New York Nuclear Service Center, located about 30 miles south of Buffalo at West Valley, NY (see Figure 1) is the site of a spent fuel reprocessing plant which was operated under a federal license from 1966 to 1972. There are two radioactive waste disposal areas at West Valley, one for wastes that originated in reprocessing operations licensed by the NRC, and one for a variety of commercial low-level wastes mostly generated off-site licensed by New York State. During its commercial life, the site was operated by Nuclear Fuel Services (NFS), owned by the New York State Energy Research and Development Authority, and licensed by the NRC and the New York State Department of Environmental Conservation. In 1972 NFS stopped operation of the reprocessing plant in order to expand its capacity. In 1976 NFS decided to withdraw from reprocessing. The plant was maintained by NFS in a dormant condition until 1982. In 1980 Congress enacted the West Valley Demonstration Project (WVDP) Act, directing the Department of Energy (DOE) to take possession of the site, primarily for the purpose of solidifying the high-level liquid wastes stored at the site. Under the conditions of the WVDP Act, the DOE took possession of the site in February 1982, and the NRC has responsibility for overview of the Department's program for protection of the public's health and safety at West Valley.

The facility disposal area and the state-licensed disposal area lie adjacent to one another, as shown in Figures 2 and 3, and although they share many hydrogeologic characteristics, they have different administrative histories and to some extent contain different types of waste and waste burial techniques. The facility disposal area was used for solid wastes that originated in the NFS reprocessing operation. The state-licensed burial ground was used for disposal of a wide variety of solid radioactive wastes, most of which originated off-site at nuclear reactors, hospitals, research and development facilities, and miscellaneous other sources. The radioactive inventories of the facility disposal area is discussed in Section II of this report.

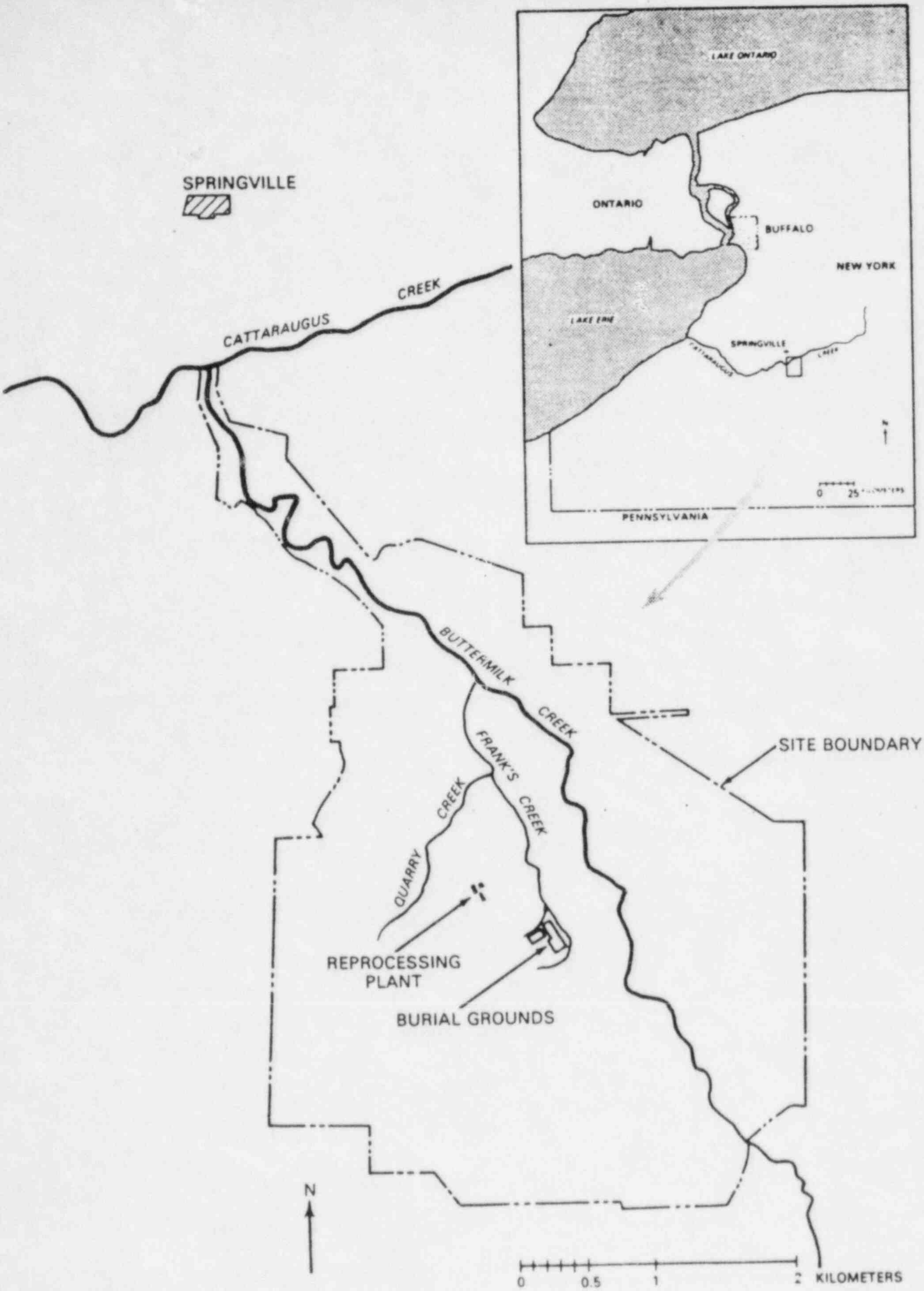

Fig. 1. Location of Western New York Nuclear Service Center

The first disposals in the facility disposal area were in 1966, when the reprocessing plant began to operate. Since the plant closed in 1972, the only wastes disposed by NFS were low activity materials such as resins and sludges from filtering systems. The Department of Energy's prime contractor for the site, West Valley Nuclear Services (WVNS), has continued to dispose of wastes in the facility disposal area. These wastes consist mostly of decontamination residues which must be removed from the defunct reprocessing plant before DOE can solidify the high-level liquid wastes stored on the site, the main purpose of the WVDP. It is also likely that "project wastes", low-level wastes generated during the actual solidification of the high-level wastes, will be disposed in the facility disposal area.

B. HISTORY OF DISPOSAL AREA RESEARCH

Much hydrogeologic research has been performed at the West Valley disposal areas. Site characterization holes were drilled as early as 1961 by the New York State Department of Public Works (the predecessor of the New York State Department of Transportation) and many other holes were drilled during the 1960's and early 1970's by NFS and the New York State Energy Research and Development Authority (and its predecessor, the New York State Atomic and Space Development Authority). These holes were drilled mainly to support construction activities related to the reprocessing plant.

A systematic hydrology research project was started for the state-licensed disposal area in 1975, shortly after the trench water seepage problem was discovered. This research was performed by the New York State Geological Survey (NYSGS) with funding from the Environmental Protection Agency (EPA) and was completed in 1979. The scope of the EPA project was quite broad, covering site geology, ground-water and surface-water flow, trench water buildup and migration, and trench gas migration.

In 1978 an analogous research project for the facility disposal area was started by the NRC, with NYSGS again serving as prime contractor. The NRC project has covered most of the same topics for the facility disposal area as the EPA project did for the state-licensed disposal area, though with more emphasis on geomorphology and glacial stratigraphy. The U. S. Geological Survey (USGS) has

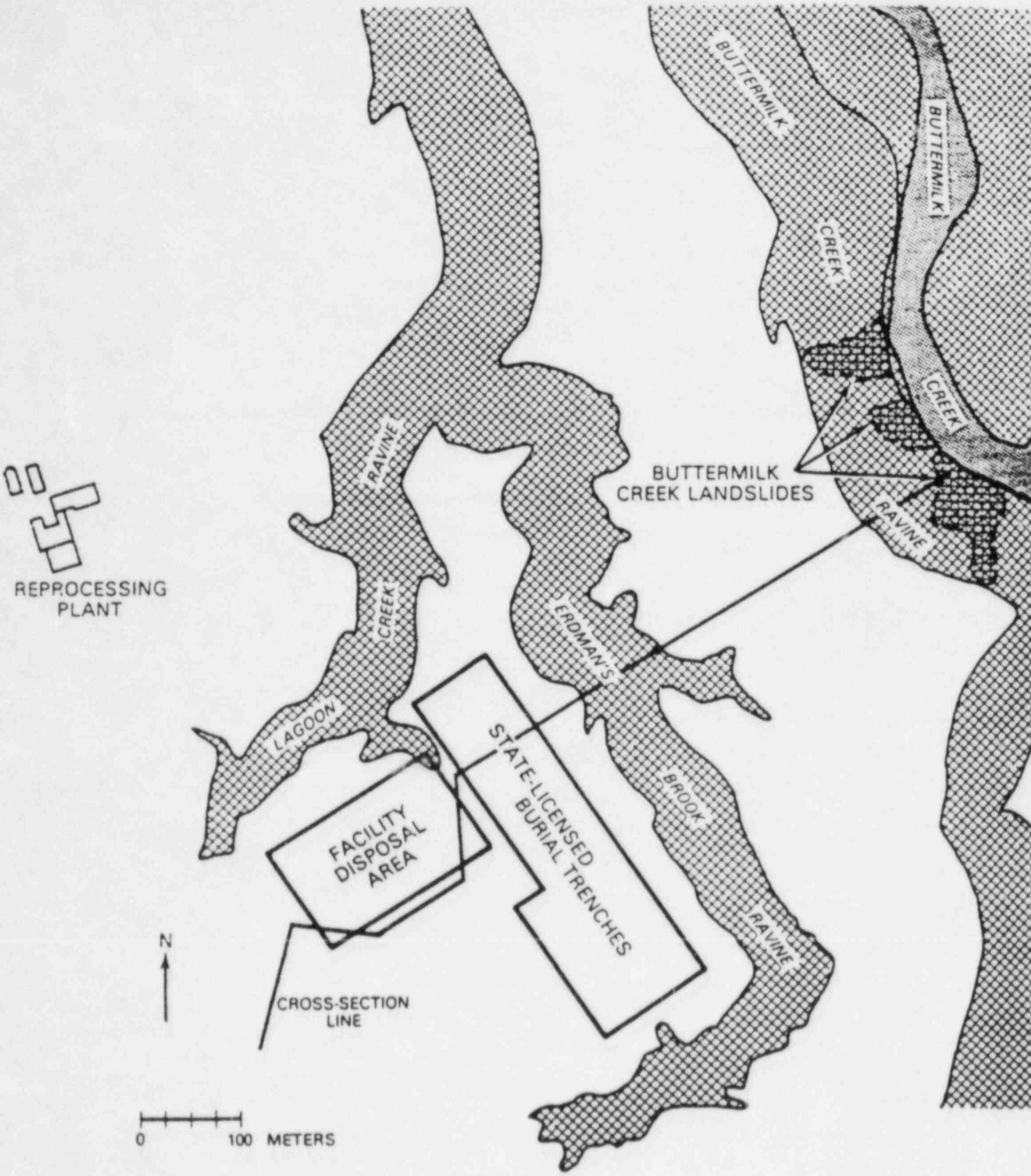

Fig. 2. West Valley Disposal Areas and Nearby Ravines

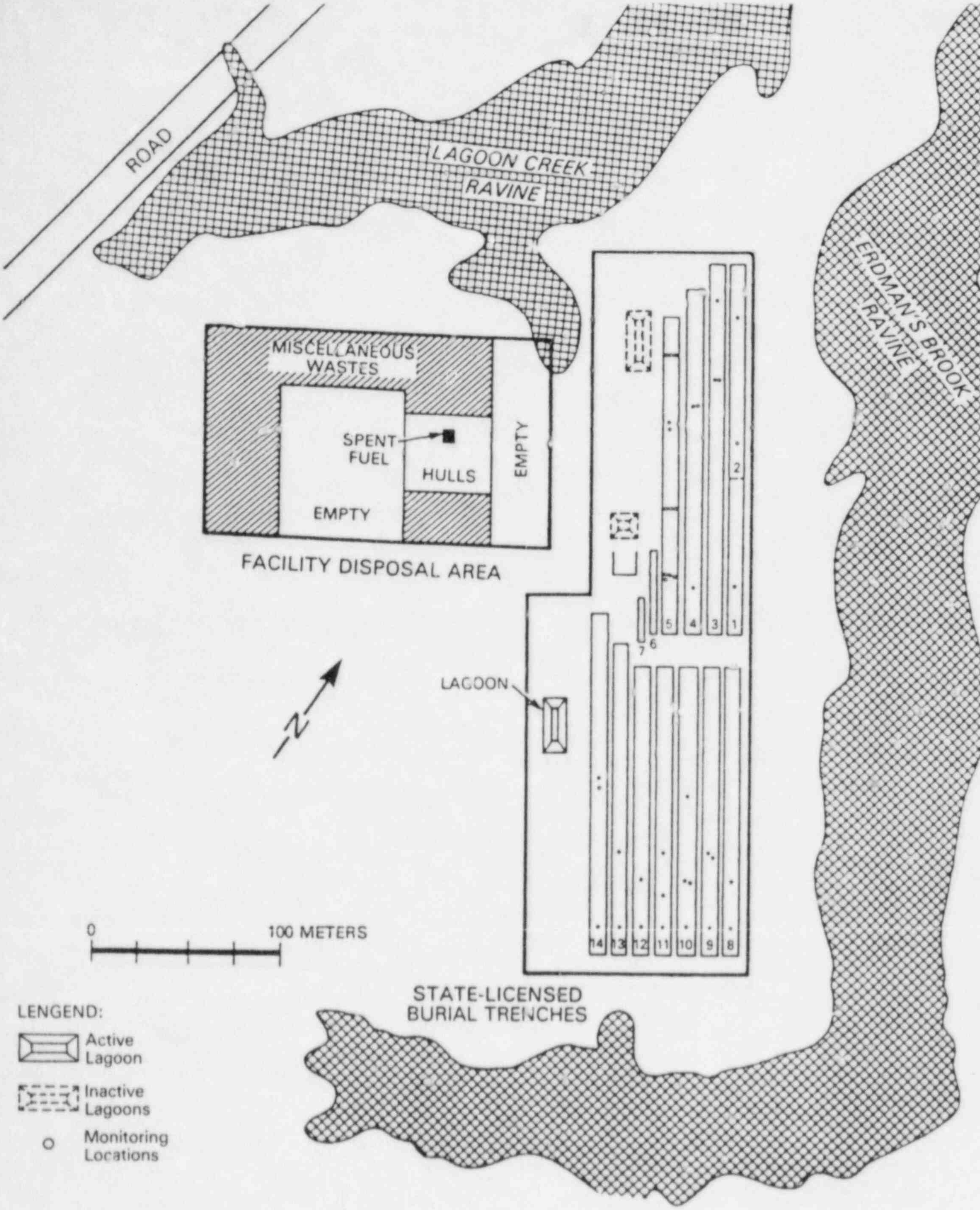

Fig. 3. Details of West Valley Disposal Areas

supported these research efforts in the field of ground-water flow and transport. Most of the geomorphology work has been done by Earth Surface Research, Inc., affiliated with the University of Rhode Island, and is published in Appendix G of NUREG-CR-3782, "Geologic and Hydrologic Research at the Western New York Nuclear Service Center, West Valley, New York Final Report" (see Reference 1). The glacial stratigraphy study included a standardization of both the NRC-funded drilling work and previous site drilling, such as the early foundation borings for the reprocessing plant, and is published in NRC technical reports, NUREG/CR-3207 (see Reference 2) and NUREG/CR-3782. This report summarizes the results of these research projects.

II. RADIOACTIVE SOURCE TERM FOR THE FACILITY DISPOSAL AREA

A. WASTE VOLUMES AND DISPOSAL METHODS

As of 1980, NFS had disposed of 4,300m^3 of waste in the facility disposal area.[12] Approximately 4 percent (185m^3) of this waste was drums of leached hulls and spent fuel hardware. The remainder was composed of a wide variety of low activity solid wastes from the reprocessing plant, including failed equipment, used filters, laboratory wastes, sludge from the low-level waste treatment plant, and degraded organic solvent absorbed in vermiculite. Relatively little is known of the detailed chemical, physical, or radioisotopic characteristics of the wastes. Many of the buried containers were described in the records simply as "waste", with no further identification of contents.

The miscellaneous wastes (i.e., those other than leached hulls or related spent fuel debris) were packaged in several types of containers, including steel drums, wooden crates, and cardboard boxes, and were placed in pits 20 to 30 feet deep. The horizontal dimensions of each pit varied according to the quantity of waste on hand and the dimensions of large waste items such as failed equipment. Most of the pits are about 12 feet wide and 20 to 30 feet long, although a few are much longer. The NRC imposed a technical specification that the top of the waste had to be at least four feet below the top of the undisturbed till. The definition of undisturbed till was not provided but is presently regarded as the weathered/unweathered interface of the Lavery Till. Also the backfill was to be filled and compacted with the unweathered till.

The leached hulls and spent fuel hardware were disposed of somewhat differently than the miscellaneous wastes. They were loosely packaged in 30-gallon steel drums and stacked three abreast in narrow 50-foot deep shafts. As with the other wastes, the NRC imposed a requirement that the top of each stack of hull cans stop at least four feet below the top of the disturbed till. The weathered clay is best identified by its lack of reaction to hydrochloric acid (leached of calcium carbonate), its color (brownish-gray) and its numerous horizontal as well as vertical fractures. Three of the 30-gallon drums normally used for leached hulls contain irradiated, unreprocessed New Production Reactor (NPR) fuel. The cladding on this fuel was badly damaged and the operators decided not to bring it into the reprocessing plant and risk excessive contamination. Instead, the fuel was emplaced in concrete at the bottom of one of the 50-foot-deep leached hull shafts.

Figure 3 illustrates the general location in the facility disposal area of the major source term components. The small dark spot in the right center indicates the location of the NPR fuel and the square boundary lines surrounding the NPR fuel show the location of the leached hulls. The shaded area indicates where the miscellaneous NFS wastes were disposed. The areas labeled "empty" were not used by NFS but have been partly filled with plant wastes since DOE took over the site.

B. FISSION PRODUCT RADIOACTIVITY

The fission products in the facility disposal area can be thought of as divided between the leached hulls, the NPR fuel, and the miscellaneous plant wastes. The great majority (at least 90 percent) of the fission product activity is in the first two categories. Nearly all of the remaining fission product activity is in the form of Sr-90, Cs-137, and H-3.

In the site records listed as reference 12, J.P. Duckworth, the prior NFS site manager, has estimated the quantities of several major isotopes at time of disposal, assuming that the average fuel had been out of the reactor for two years.[12] These records show a total fission product activity of about 144,000 Curies (Ci) at time of disposal, with about 125,000 Ci in the hulls and 19,000 Ci elsewhere. The NPR fuel is not addressed in reference 12, and it is not clear if the 125,000 Ci includes the NPR fuel activity. As discussed further below, the NPR fuel safety evaluation report gives an activity at the time of disposal of about 105,000 Ci, so it is unlikely that the 125,000 Ci value is intended to include the spent fuel.[13]

The radioactivity estimates in the site records were apparently obtained by summing the radioactivity values in the West Valley disposal logs. This is not explicitly stated, but the figures agree with the disposal log sums to within less than 1 percent. The disposal logs were records kept on site of the activities of each batch of disposed wastes. The activities were obtained by measuring the gamma dose rate at the surface of each container with a hand-held counter and converting the dose rate to a radioactivity value with an empirically-derived chart. In the reference 12 site records, the total radioactivity appears to have been partitioned into its major fission product and activation product constituents. The selected fission products were Sr-90, Cs-137, and Ru-106, and their contributions to the total fission product activity were assumed to be 45 percent, 45 percent, and 10 percent, respectively.[12]

In the course of their analysis of the high-level waste supernate, WVNS calculated that the average out-of-reactor time for the fission products was 14.4 years in September 1982[13]. The site records state that the average out-of-reactor time for the wastes at the time they were disposed was two years.[12] The decay time since disposal at the moment of this writing (mid-1985) is about 15 years. Assuming that the isotopic ratios above are correct, the 1985 fission product activity in the facility disposal area would be about 91,000 Ci.

The assumption that 90 percent of the activity in two-year old spent fuel is due to Sr-90 and Cs-137 is questionable. Even for high burnup (33,000 MWD/MTU) PWR fuel, computer calculations with the ORIGEN code show that less than 40 percent of the activity in 2-year old spent fuel is due to these isotopes. The fuel processed at West Valley was of much lower burnup, averaging about 13,000 MWD/MTU for the 228 MTU of power reactor fuel and about 2000 MWD/MTU for the 380 MTU of NPR fuel. The West Valley wastes would be expected to have relatively less of the long-lived fission products like Sr-90 and Cs-137, and more of the shorter-lived isotopes like Ru-106, Ce-144, and Pm-147. The data on the disposed NPR fuel shows that at two years only 21 percent of its activity was due to Sr-90 and Cs-137.

Back-calculating from the results of the chemical analysis of the 8D-2 high-level waste (HLW) tank provides additional confirmation on the relative isotopic abundances[14]. Twelve years before the chemical analysis was performed, which would correspond to an average out-of-reactor time of two years, the Sr-90 and Cs-137 accounted for about 20 percent of the combined activity of the Sr-90, Cs-137, Ru-106, Ce-144, and Pm-147. (ORIGEN calculations for 33,000 MWD/MTU PWR fuel show that these five isotopes provide 87 percent of the activity at one year out of the reactor.) Due to preferential decontamination or dissolution of some elements, the fission products ratios in the HLW may not be identical to those in the leached hulls, but these comparisons give some idea of the extreme conservatism of the assumption that 90 percent of the activity at two years was due to Sr-90 and Cs-137. The various comparisons of isotopic abundances are summarized in Table 1.

Table 1
COMPARISION OF ISOTOPIC ABUNDANCE ESTIMATES
IN TWO-YEAR OLD SPENT FUEL
(Expressed in Percent of Total Activity)

	Sr-90	Cs-137	Ru-106	Ce-144	Pm-147
Site Records	45	45	10	0	0
HLW Analysis	10	10	9	57	14
Disposed NPR	10	11	4	59	15
ORIGEN PWR (33,000 MWD/MTU)	17	24	30	22	7

A more detailed examination of the HLW analysis can provide another estimate of total fission product activity in the hulls.[14] The activities of five major fission products at two years out of the reactor can be obtained by using HLW analysis values and correcting for 13.4 years of decay. These activities are listed in Table 2.

Table 2
FISSION PRODUCT ACTIVITIES
OF HIGH LEVEL WASTE AT TWO YEARS OUT OF REACTOR
(Based on HLW Analysis)

Isotope		Curies x 10^{-6}	% of Total
Sr-90/Y-90		20.8	10
Cs-137/Ba-137m		20.8	10
Ru-106/Rd-106		18.9	9
Ce-144/Pr-144		116.7	57
Pm-147		29.2	14
	Total	206.4	100

Other isotopes were assumed to be of negligible activity at two years. The activity value in Table 2 is the total for the HLW. It remains to relate the fission product contents of the HLW to the fission product contents of the leached hulls. As mentioned earlier, there may be some difference between relative elemental abundances in the HLW and the leached hulls. The hulls are contaminated by fission products that did not dissolve, the HLW by fission products that dissolved but were separated from the product stream by solvent extraction. While there are data showing that some elements are preferentially dissolved or extracted, this paper will assume that this is a second order effect and that the two types of waste have the same relative abundances of radioisotopes.

As discussed in Section II.A.4, the average measured fractional loss of plutonium in the hulls was 0.17 percent of plutonium throughput. This percentage could easily be in error by 25-50 percent, and the question remains of whether the fractional loss for plutonium is the same as the fractional loss for fission products. Nevertheless, this is probably the best estimate available for fractional spent fuel loss in the hulls. Using 0.17 percent as the average fractional spent fuel loss yields a time-of-disposal leached hull fission product activity of 351,000 Ci. If the isotopic distribution of Table 2 is correct, the 1985 fission product activity (not counting tritium) is 50,600 Ci, of which 98 percent is due to Sr-90 and Cs-137.

One way to confirm this value is to consider the fission product activity reported for the disposed NPR fuel.[13] At two years out of the reactor the disposed fuel would have had the isotopic activities listed in Table 3. The burnup of the disposed fuel was 2,600 MWD/MTU, about 30 percent higher than average for the NPR fuel processed at West Valley. So it would cause some overestimation of radioactivity content to assume that all of the NPR fuel had the same isotopic ratios as the disposed fuel. The quantity of spent fuel disposed was 458 kg, compared to the NPR fuel throughput of 380,000 kg. According to site records, the fission product radioactivity of the spent fuel at the time of disposal was 58,000 Ci[13]. If this value is scaled linearly, assuming that all of the NPR fuel had the same isotopics, the total NPR activity at two years would be 48.2×10^6 Ci. Assuming as before that 0.17 percent of the fuel remains in the hulls, the fisson product activity of the NPR hulls would have been about 82,000 Ci at time of disposal.

The consistency of this value with the total activity estimate obtained from the HLW analysis can be confirmed by comparing the megawatt-days of energy generated by the NPR fuel to the energy generated by all of the fuel processed at West Valley. The energy produced by the NPR portion of the throughput was 773,000 MWD. The energy produced by all of the fuel processed was 2.97 x 10^6 MWD or about 3.84 times the NPR energy. Multiplying 82,000 Ci by 3.84 should yield the approximate total fission product activity in the hulls. This approach gives a value of 315,000 Ci, about 10 percent less than HLW analysis estimate of 351,000 Ci. Such close agreement seems to indicate that either of these values is a better estimate than the value of 125,000 Ci from the site records.

To summarize, it would appear from our present information that the best estimate of time-of-disposal fission product activity in the hulls (temporarily neglecting tritium) is between 300,000 Ci and 350,000 Ci, with about 20 percent of this due to Sr-90 and Cs-137. The best estimate of 1985 activity would be between 48,000 Ci and 51,000 Ci, about 98 percent due to Sr-90 and Cs-137.

Table 3

FISSION PRODUCT ACTIVITIES OF DISPOSED NPR FUEL
AT TWO YEARS OUT OF REACTOR*

Isotope		Curies x 10^{-3}	% of Total
Sr-980/Y-90		6.08	10
Cs-137/Ba-137m		6.42	11
Ru-106/Rd-106		2.56	4
Ce-144/Pr-144		34.04	59
Pm-147		8.43	15
Other		0.56	1
	Total	58.09	100

Estimating the quantity of H-3 in the hulls is a special problem. Compared to Sr-90 and Cs-137, H-3 is a minor fission product, generated in uranium fuel in only small amounts, and if it behaved like most other fission products it would not be a significant contributor to the radioactive inventory of the facility

*See Reference 12.

disposal area. A large fraction of the H-3, however, migrates out of the fuel as it is produced, and in the case of zirconium-clad fuels (which includes essentially all of the fuels processed at West Valley) reacts with the cladding to form zirconium hydride. The hydride is stable enough that it is largely unaffected by head-end reprocessing operations, so whatever fraction of the H-3 was in the cladding at reactor discharge has presumably been disposed with the leached hulls.[16]

Experiments at Oak Ridge National Laboratory indicate that about 50% of the H-3 produced by fission in LWR fuels is retained in the claddding.[15] Most fuel from the NPR was clad in Zircaloy-2, the same as most LWR fuels, so the 50% figure is probably a reasonable estimate for all of the fuel processed at West Valley. Science Applications, Inc. has run the ORIGEN code to calculate the quantity of H-3 that would have been produced in the fuel processed at West Valley, and their calculation, using the 50% cladding retention figure, was that about 26,000 Ci of H-3 were buried with the leached hulls[17]. The 1985 radioactivity estimate is about 9,500 Ci of H-3.

The 1985 fission product activity in the disposed NPR fuel is about 9,000 Ci.[17] Duckworth estimates that the activity in the miscellaneous wastes is about 4 percent of the activity in the hulls.[12] This would add about 2,000 Ci of fission products to the facility disposal area inventory, for a total of about 72,000 Ci of fission products overall.

C. ACTIVATION PRODUCTS

There was a large inventory of activation products, mostly Co-60, buried in the facility disposal area. Naturally-occurring Co-59 tends to be present in small quantities in the stainless steel end fittings of LWR fuel assemblies, and with its large neutron activation cross-section a significant percentage of it is transformed during irradiation into radioactive Co-60, an energetic gamma emitter with a 5.27 year half-life. The site records estimate that there were 173,000 Ci of Co-60 buried in the facility disposal area.[12] If that estimate is accurate, the 1985 Co-60 inventory would be 24,000 Ci.

Estimates of the Co-60 inventory based on the ORIGEN code do not agree with the site records. The ORIGEN code predicts that the quantity of Co-60 present in spent LWR fuel of the type processed at West Valley would range from 2,000 Ci to 5,000 Ci per metric ton of uranium (MTU), with the low Co-60 value corresponding to the lowest burnup LWR fuel processed (about 9,000 MWD/MTU) and the high value corresponding to the highest burnup fuel (about 24,000 MWD/MTU). The NPR fuel did not generally have stainless steel fittings, so it presumably contained little cobalt. The average LWR burnup was about 13,000 MWD/MTU and the LWR throughput was 228 MTU, yielding an ORIGEN-calculated inventory of Co-60 of about 600,000 Ci at reactor discharge, or 460,000 Ci at time of burial (two years after discharge). Not all of the Co-60 in the incoming fuel would have been disposed. Small amounts might have gone into the high-level waste (although the WVNS analysis in 1982 did not report any) and some would still be in the dormant reprocessing plant in the form of scattered bits of fuel hardware and fines, or as general surface contamination. The inventory in the plant is probably small compared to the amount already disposed, though, and in any case the plant wastes removed from the dormant facility are themselves being buried in the facility disposal area by WVNS. Assuming that the Co-60 buried was nearly equal to the Co-60 received, the 1985 inventory of the facility disposal area would be about 64,000 Ci. In the absence of a clearer understanding of how the numbers in the site records were calculated, the 64,000 Ci value should be viewed a more confident estimate.

D. PLUTONIUM

For purposes of discussing the disposal areas, the plutonium can be thought of as divided into two categories: long-lived isotopes that will not decay significantly within a few centuries and short-lived isotopes that may contribute the the near-term radioactive inventory of the facility disposal area. The approximate isotopic characteristics of the plutonium in the leached hulls buried at West Valley are listed in Table 4. The LWR estimates are based on ORIGEN calculations performed by Science Applications, Inc. and the NPR estimates are based on information provided by United Nuclear, Inc.[17, 18]

The long-lived isotopes, Pu-239, Pu-240, and Pu-242 have a total mass of 3.6 kg according to the computer-based estimates of Table 4. This agrees closely with Duckworth's estimate of 3.7 kg of plutonium in the leached hulls, which is not surprising considering that both estimates include the same

Table 4

PLUTONIUM ISOTOPIC CHARACTERISTICS OF LEACHED HULLS*

1. NPR FUEL

Isotope	Yield (%)	1984 Facility Disposal Area Inventory Radioactivity (Ci)	Mass (g)
Pu-238	0.1	10	0.6
Pu-239	88.7	69	1,132
Pu-240	9.4	27	120
Pu-241	1.7	942	9.4
Pu-242	0.1	~0	1.4

2. LWR FUEL

Isotope	Yield (%)	1984 Facility Disposal Area Inventory Radioactivity (Ci)	Mass (g)
Pu-238	0.7	284	17
Pu-239	62.7	102	1,664
Pu-240	22.0	135	598
Pu-241	11.7	13,550	135
Pu-242	2.7	~0	79

assumption about the percentage of the incoming fuel that remained in the leached hulls after dissolution.

The Duckworth estimate was obtained by summing the plutonium losses of the individual campaigns. In the first few NPR campaigns, NFS sampled and analyzed the leached hulls at the AEC's request. The results were consistent enough that NFS was given permission to forego such analysis in future NPR campaigns and instead assume that 0.1 percent of the weight of the leached hulls was heavy metal. The hulls were also sampled and measured for most of the power reactor campaigns. There was no regulatory requirement to do so, but the contractual

*See References 17 and 18.

agreements between NFS and its customers usually stipulated that such a measurement be performed to determine how much plutonium remained in the hulls. This being the purpose of the measurements, the figures may to some extent represent economic compromise as much as objective estimation of the plutonium contents. As a percentage of plutonium throughput, the hull losses reported by Duckworth for individual campaigns range from a low of 0.06 percent to a high of 0.94 percent, with the average being 0.17 percent. The safeguards records of plutonium losses in the hulls agree closely with Duckworth's figures and appear to be based on the same source of data. The 0.17 percent value was used to obtain the mass and radioactivity inventory estimates in Table 4.

The information we have now does not provide much of a basis for judging the validity of the 0.17 percent assumption. Most of the plutonium in the hulls was probably in a minority of the pieces, particularly the ends of the fuel rods, which may have been exposed to acid through only one opening, and crimped pieces of fuel rods, which likewise may not have had their fuel contents completely exposed. It would have been difficult to take a representative sample of the hulls. There was also substantial uncertainty in the chemical analysis. The sampled hulls were not themselves dissolved but were subjected to hydrofluoric acid leaching to remove residual fuel. Plutonium that had migrated into the metallic structure of the hulls may not have been detected. To the extent that a weight percent factor was used in some campaigns instead of a measurement, the question arises as to whether the unmeasured batches were dissolved as completely as the batches on which the factor was based. These considerations justify some conservatism in assigning an uncertainty to the 3.7 kg estimate. On the other hand, there is no special reason to believe that any of the batches of fuel were dissolved less thoroughly than others, and it was certainly in everyone's economic interest to recover as much of the plutonium as possible.

In addition to the leached hulls, there is long-lived plutonium in the NPR fuel and the miscellaneous wastes. The inventory in the NPR fuel has been estimated by isotope generation codes to be about 0.82 kg.[13] All of the plutonium created in the NPR fuel was buried with it, so in this case the undissolved fuel fraction is not an issue, and since DOE routinely uses computer codes to predict the plutonium content of NPR fuel it is safe to assume that the 0.82 kg value is much more accurate then the leached hull plutonium inventory estimate.

Duckworth estimates that there is about 0.4 kg of plutonium distributed among all of the NFS burials other than the hulls and spent fuel.[12] His paper implies that this value may have been obtained by adding the estimated plutonium contents of buried birdcages and resins. It does not appear that his value includes the plutonium that might be present as a minor contaminant in general wastes from the plutonium load-out areas or laboratory. The waste packaging procedures used by NFS were intended to keep the average plutonium level below 1 g per container. The burial logs and records do not indicate how many individual containers from plutonium-contaminated areas were buried; if they did, we could use the 1 g per container limit to establish a reasonable upper bound. There must have been hundreds of packages of plutonium-contaminated solid waste generated during the life of the plant. In addition, there must be some plutonium in the absorbed decontamination solutions and spent solvent. Even with generally low levels of plutonium contamination among these wastes, the total quantity could easily exceed the 0.4 kg estimate.

The safeguards records show a cumulative inventory difference of 10.2 kg of plutonium over the plant's lifetime. This is the difference between input at the accountability tank and measured product output, and does not include measured losses to the high-level waste or hulls. There are, of course, many possible explanations for the inventory difference, principally the errors could occur in measuring its components. But it should be noted that a plutonium loss in miscellaneous trash going to the disposal area significantly higher than Duckworth's estimate of 0.4 kg is not inconsistent with the safeguards records. Considering all of these issues, it would seem that a conservative estimate of plutonium inventory in the miscellaneous waste might be about one kilogram.

Considering all three constituents together--hulls, spent fuel, and miscellaneous--the information we have at present indicates that a conservative estimate of total long-lived plutonium inventory would be about 5.5 kg, with an uncertainty of about 2.0-2.5 kg.

The short-lived plutonium isotopes, those that are not a health concern over long periods of time, are Pu-238 and Pu-241. Table 4 shows that the total plutonium radioactivity is dominated in 1984 by Pu-241, a low-energy beta emitter with a half-life of 14.7 years. The Pu-241 activity of about 14,000 Ci is a significant addition to the fission product and activation product total of about 135,000.

E. SUMMARY OF FACILITY DISPOSAL AREA SOURCE TERM

The overall radioactivity inventory of the facility disposal area is summarized in Table 5 below. The largest 1984 source term component,

Table 5

SUMMARY OF 1984 FACILITY DISPOSAL AREA RADIOACTIVE SOURCE TERM

Isotope	Radioactivity (Ci)	Half-Life (Years)
H-3	9,500	12.3
Co-60	64,000	5.3
Sr-90/Y-90	24,300	29.0
Cs-137/Ba-137M	24,400	30.2
Pu-241	13,300	14.7
Total	135,500	

Co-60, is the shortest lived. Within ten years, the Co-60 inventory will drop below the Sr-90 and Cs-137 inventories. In thirty years, the Sr-90 and Cs-137 alone will comprise the great majority of the radioactivity. To review the physical condition of the major radioisotopes, we believe that (1) the H-3 is bound to the hulls as a zirconium hydride, (2) the Co-60 is mostly contained in the stainless steel end fittings that are randomly distributed among the hull cans, and (3) the Sr-90, Cs-137, and Pu-241 are present mostly in bits of undissolved spent fuel in the leached hulls.

III. GEOLOGY AND HYDROLOGY

A. SITE GEOLOGY

1. STRATIGRAPHY

As of 1985, over 300 boreholes have been drilled on the West Valley site. The majority of the boreholes are shallow (less than 50 meters) and are in the glacial units, with a few drilled to bedrock (shale). Many of the boreholes were drilled to provide specific information for construction activities and were not geologically logged. Therefore, the available stratigraphic data is more limited than the number of holes would indicate. However, there is sufficient information to provide a fairly detailed description of the site's stratigraphy. In general, the stratigraphy is better understood at present than other geologic aspects of the site, such as the hydrogeology and geochemistry.

Under NRC sponsorship, the NYSGS has examined all of the existent drilling records for West Valley and has compiled a standardized log so that data from various boreholes drilled at different times by different parties can be easily compared.[1,2] The USGS, in cooperation with the NYSGS, has also drilled and logged several new boreholes, concentrating in the vicinity of the facility disposal area and in the "North Plateau" area. These new boreholes are either to bedrock (shale) or slightly shallower providing substantial new information about the deeper glacial strata overlying the bedrock. The stratigraphy in the vicinity of the burial grounds is as follows. (Refer to Fig. 4).

1. Alluvium up to 3m thick, removed and replaced by backfill within the burial grounds, but still present in adjacent areas.

2. Lavery Till up to 37m thick northeast of the burial area, thinning to 8m southwest of the burial area. This material was used for backfill and is exposed at the surface within the burial grounds.

    a. Weathered-fractured till exposed in trenches to depth of 3 meters generally but highly variable due to surface activities.

b. Unweathered-fractured till exposed in trenches to depths exceeding 5 meters below land surface.

c. Unweathered-unfractured till, not exposed in trenches but inferred from cores, extends to Kame Deltas or where absent, Lacustrine Beds.

3. Kame Deltas up to 6m thick, variable thicknesses and absent in places.

4. Lacustrine Beds up to 13m thick northeast of the burial area, thinning to 3m under and southwest of the burial area.

5. Kent Till about 1.5m thick southwest of the facility disposal area, thickening to about 25m under the burial areas. Only the deepest exploratory boreholes penetrated this stratum.

6. Basal Gravel about 0.6m thick generally, but not present in all holes. This material may be weathered bedrock.

7. Shale Bedrock as shallow as 13m below the surface at point A in Fig. 4, deepening to 28m at the southwest edge of the facility disposal area, and 65m at approximately the middle of the facility disposal area. The depth to the northeast of this is unknown but presumably greater.

2. WASTE DISPOSAL UNIT GEOLOGY

All of the wastes in the disposal areas are contained entirely within the Lavery Till. The deepest emplacement of wastes was in the 50-foot-deep (17m) leached hull shafts in the facility disposal area. The Lavery Till in that vicinity is believed to be about 30m thick. The shafts and trenches in the disposal areas were backfilled with excavated Lavery Till. It is thus clear that the containment of the wastes depends greatly on the characteristics of the Lavery Till.

Many cores of till have been extracted in or near the disposal areas and subjected to detailed examination. The NYSGS staff and others have also examined the walls of some of the open trenches in the state-licensed disposal area.

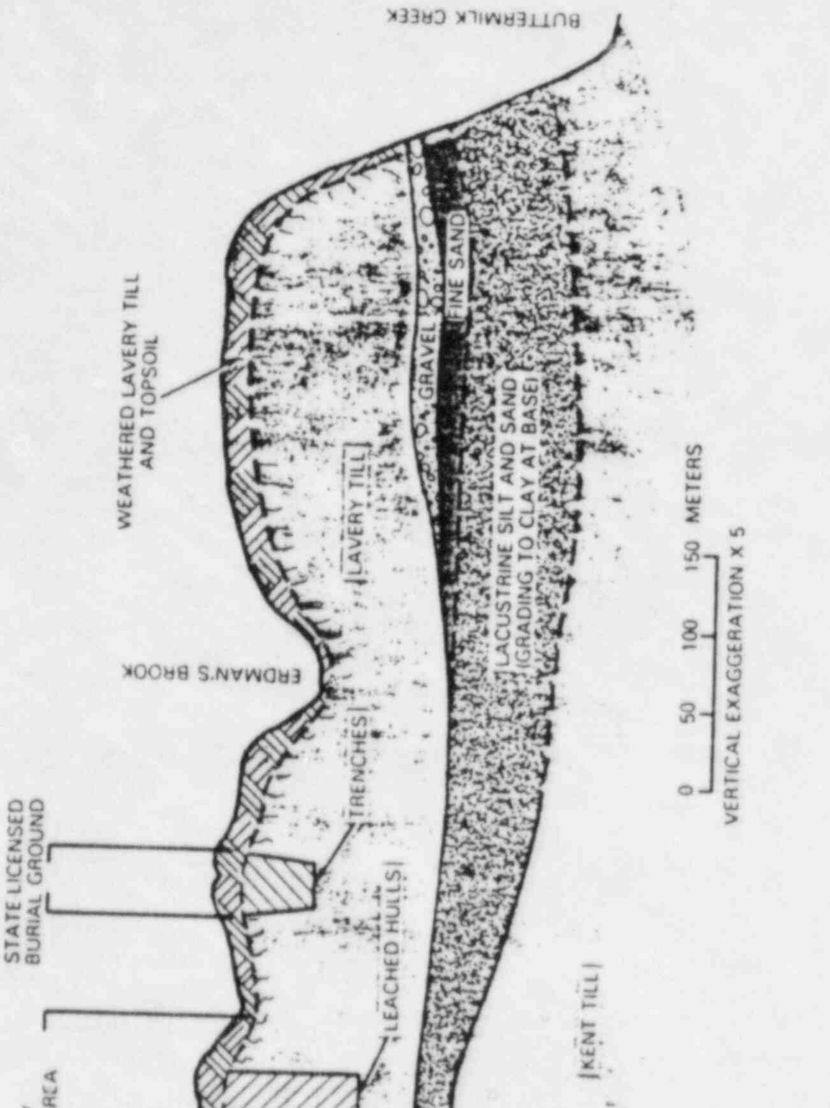

Fig. 4. Geological Cross-Section (from Bergeron et. al.)

The disposal trenches were generally six or seven meters deep and provided a good view of the structure of the upper part of the Lavery Till. Three research trenches (field simulations of the trenches in the state-licensed disposal area) were dug on the opposite side of Erdman's Brook to provide a completely undisturbed site to examine the till.

More recently, (1984 summer field season) NRC research staff and contractors examined recently excavated trenches in the FDA. The weathered zone was observed to contain numerous fractures with a blocky soil structure, brownish-grey in color, and fracture filling of calcium carbonate. The unweathered till was dark grey in color with large vertical fractures in depths exceeding 5 meters and spaced fairly uniformly, approximately 1 meter apart. The indistinct weathered-unweathered interface of the Lavery Till was determined using a hydrochloric acid test, and from clay-filling presence and color observations.

The Lavery Till is a generally homogeneous mixture of clay and silt interspersed with small pebbles. Unoxidized samples of the till are moist and dark gray. Where the till has been exposed to air for any length of time it is light gray, and quite hard and brittle when dry. There is no consistent stratification within the till, although LaFleur has defined three different subfacies, each with a different percentage of pebbles, cobbles, and sand.[2]

Subfacies 1 and 2 constitute most of the volume of the Lavery till, both being clay-silt matrices and differing mainly in their pebble contents.[2] These two subfacies are interfingered with one another throughout the till stratum. Subfacies 3 consists of sand and gravel interspersed with torn wisps of silty clay. This coarse-grained material forms lenticular bodies, usually highly deformed, of a wide variety of sizes and shapes. Most of these "sand pods" are believed to be in the upper part of the till, at depths of 2 to 3.5m.[2] The geomorphic reason for the "sand pods" is that previous sand lenses were contorted when the glacial material was reworked by the succeeding glacial advance/retreat events.

As will be discussed in Section III.B.3, the coarse-grained Subfacies 3 lenses are apparently much more permeable than the rest of the till and there has been some concern that they might provide a quicker pathway for radionuclide migration.

This concern came into focus in 1974, when geologists from the New York State Geological Survey (NYSGS) were observing the progress of a burial in one of the state-licensed trenches. A sandy layer 0.6m thick and almost 20m long was seen near the top of Trench 13. Disposal operations were temporarily suspended while shallow holes were dug with a backhoe to determine the dimensions of the layer. The investigation ultimately revealed an oblong sand lens concave upward, with its edges just under the surface and its center a little more than a meter deep. The lens was about a meter thick at its center and thinned into the surrounding till at its edges. It was about 90m long and 60m wide, and ultimately intersected the tops of the projected locations of Trenches 13-18. (Trench 14 was the last actually dug.)

A concerted effort has been made since then to locate and characterize other sand lenses, and to determine if they are large enough or sufficiently interconnected to provide a preferred migration pathway from the disposal areas. The research trenches were dug specifically for this purpose, and the NYSGS and USGS staffs have collected additional data from boreholes and by examining each burial pit as it is excavated. Many other sandy, Subfacies 3, bodies have been found, though none as large as the Trench 13 lens. Most of the bodies are small, deformed inclusions, better described as "pods" than "lenses", with maximum dimensions generally less than a meter. In 1982 the NYSGS and USGS drilled five clusters of wells around the facility disposal area. Each cluster consisted of three or four holes spaced one or two meters apart. Although several sandy pods were encountered, it was not possible to trace any of them from one hole to another within a cluster.[15] This and other evidence accumulated from the trenches and bore holes indicate that the Subfacies 3 material probably does not form layers or tubes that extend far enough to have a significant effect on the overall containment capability of the Lavery Till. The hydrological properties of the "sand pods", due in part to their partial saturation, are not fully understood. Since, the "sand pods" are of limited extent and are isolated within a clay matrix, their impact on ground-water flow and radionuclide transport is assumed to be highly localized.

Most discussion in the West Valley literature is of the deep, unoxidized Lavery Till. It is important to realize that the upper portion of the till has been exposed to weathering and biological processes that have significantly altered its hydrologic properties. The upper two or three meters of the till are browner in color than the deep till, indicating oxidation of some of the clay minerals.[2] This color change, though always gradual and sometimes quite hard to discern, was apparently used by the NFS burial ground operators to determine the location of the weathered/unweathered boundary, and thus to determine the minimum depth to the top of the buried wastes. The upper two or three meters also contains numerous fractures, root tubes, and mole runs. Some of the fractures extend as deep as five meters, well into the unoxidized till.[19]

B. GEOMORPHIC CONDITIONS

1. GEOMORPHIC STUDIES

Geomorphic studies of the site and environs was not a major aspect of the EPA project at West Valley. The EPA summary report recommended that future work be done on this topic, but did not draw any conclusions specifically about mass wasting or erosion.[8] The subsequent NRC-funded study of the facility disposal area included a substantial geomorphic project,[1] largely at the recommendation of the NYSGS staff members who worked on the EPA study and felt that this area was important. Some of the geomorphology field work sponsored by the NRC was performed by the NYSGS, but most was done by subcontractors from the University of Rhode Island and the Mahoosuc Corp.[5] (The geomorphic subcontractors from these two organizations later formed a new company called Earth Surface Research, which became the subcontractor during the second half of the project.)

The geomorphic study was set up to last a total of five years, with three years of field work scheduled for 1978, 1980, and 1982 and the intervening years being used for data analysis. The first year of work concentrated on studying the general characteristics of Buttermilk Creek, particularly its reach adjacent to the burial grounds (see Figure 2), and on estimating the simple denudation rate in Buttermilk Creek Valley.[1,5] In the second phase, data were collected on some of the Buttermilk tributaries, and quantitative evaluation of the slumping occurring along Buttermilk Creek was started.[4] Phase III continued the examination of the mass wasting processes along Buttermilk Creek, and issues related to stream gravel transport.

The principal conclusions from this work indicated that "yearly autumn storm events or a moderate spring freshet do not substantially alter the bar complexes, although some gravel transport does occur.

Stream discharges of 15-20 cu m/sec appear to be quite common events approximately bi-monthly. These events, while transporting a significant quantity suspended sediment, move only the very fine gravel. As such, they are not bar or channel modifying events. We believe that bar and channel changes are affected only by 40 cu m/sec events and above. A 40 cu m/sec event may be the 1-year return flood, as stated in the Phase II report.

Continued monitoring of landslide movement by slumping and earthflow corroborates earlier (Phase II) estimates of downslope movement of 1.5 cu m/yr. Movement initiated by toe undercutting during Hurricane Frederic, 1979, is continuing. Valley-wall failure appears to occur in a step-wise upslope progression involving, first, failure of lower third of the landslide slope followed by failure of the mid-slope, and then the upper slope to the valley wall rim. At BC-6, failure of the mid-slope area appears to have just been initiated."[1] The geomorphic study ended prematurely with no further work on the tributaries in the vicinity of the low-level trenches or FDA.

2. GEOMORPHIC PROCESSES

a. EROSION

The radioactive wastes at West Valley are buried about 500m southeast of the reprocessing plant in a thick glacial sequence of till, Kame Delta, and lacustrine deposits as illustrated in Figure 2. Buttermilk Creek Valley, in which the entire West Valley site is situated, can be thought of as a bedrock trough that was once almost completely filled with various types of glacially-derived deposits. One of the thickest deposits, in which the waste disposal unit (see Figure 4) is located, is the Lavery Till composed of silty clay interspersed with moderate amounts (5-20%) of sand and gravel.[2] The unweathered Lavery Till has relatively low hydraulic conductivity (on the order of 10^{-8} cm/s), a characteristic that can help minimize ground-water flow and subsequent transport of buried radioactivity.[10] Rainwater and snowmelt run off rapidly, due to the low permeability of the till. This rapid runoff subjects the till to severe erosion.

About 10,000 years ago, during the last glacier retreat, ancestral Buttermilk Creek formed its initial channel in the glacial deposits and has progressively cut deeply into the glacial till-filled valley. In the vicinity of the disposal areas, the bed of Buttermilk Creek now lies 45m below its post-glacial elevation. Boothroyd and Timson estimated the simple denundation rate to be 6,600m^3 yr^{-1} which represents the mean annual amount of bedload and suspended-load transported by Buttermilk Creek.[1,4] This figure was obtained by dividing the total volume of valley fill removed to produce the present valley configuration by the number of years Buttermilk Creek has been eroding (i.e., age of the terrace which has been incised), and confirmed by erosional studies of stream gravel movement rates and the measured suspended sediment transport rates in Buttermilk Creek itself, and analysis of sediment deposition rates in two small reservoirs on the West Valley site.[1,4]

Due to the erosion-prone characteristics of the glacial till and the relatively steep gradient of the Buttermilk Creek draining basin, the overall rate of valley erosion is relatively high by present geologic standards. It is reasonable to expect that much, perhaps most, of the glacial till deposits in the valley will be gradually removed over the next several thousand years and that remedial programs to stop this process cannot be expected to be permanent. Much of the glacial material seems to be transported into Buttermilk Creek and its tributaries by broad-front sheetwash erosion of the upland plateaus and slopes.[4] The sheetwash erosion occurs everywhere within the valley, so the total volume moved is large, but viewed on a local scale, it is a slow phenomenon. The depth of till washed away from an average slope in an average year is probably much less than a centimeter, judging from the depth to which the valley has been cut since the glacier retreated (45m maximum in 10,000 years).[1,4] The radioactive wastes are buried sufficiently deep and located such that there are several meters of till cover, so that sheetwash erosion is not likely to affect the wastes for centuries.

b. MASS WASTING

Mass wasting, which is the downslope movement of soil and rock material due to gravitational body stresses, is much more of a short-term problem than sheetwash erosion. Mass wasting, or more specifically, slumping, occurs along the edges of the ravines formed by Buttermilk Creek and its tributaries due to the material properties of the glacial units and slope configurations. The slumping process enhances the erosional processes for ravine incision and widening. Only a small fraction of the area of the drainage basin, being the escarpments of the ravines, is vulnerable to mass wasting at any particular time. But within the vulnerable areas, slumping can occur suddenly and move large volumes of soil creating "landslides " with large individual slump blocks if there is sufficient topographic relief.

The slumping mechanism can be understood in terms of the slope configuration. The till is relatively impermeable, so water runs off rapidly and scours deep, steepening ravines. When a larger-than-average rainstorm occurs, the swollen streams tend to overflow their normal channels and erode the "toes" (base) of the adjacent slopes, and when the "toe" of a slope is removed, the glacial material above it is likely to slump. Most of the downslope movement associated with this slumping occur as a series of individual slump blocks, ranging in size from a few meters to several tens of meters across.[1,4] Typically, as the blocks descend, they break up into smaller pieces, piling up as they reach the bottom of the slope. The next storm flood sweeps away the piled-up debris, recreating an unstable slope condition which generates new slump blocks following slope failure.

The slump blocks on the site are of various sizes and move at various rates. Boothroyd and Timson (see References 2 and 4) have measured and analyzed a large slump block complex on the slopes of the Buttermilk Creek ravine near the disposal areas (see Figure 2). This area is almost 300m in width and has been active for at least 50 years. Its true dimensions are obscured at first glance by the fact that some of the slump blocks are large enough to have patches of trees growing on them, although on closer inspection the eccentric angle of many of the tree trunks reveals the unstable nature of the slope.

In October 1978 Boothroyd and Timson placed 35 markers, mostly 1.5m steel posts, on various parts of the slump block complex and adjoining slopes.[1,4] In July 1980 they returned to resurvey the posts' locations. Fifteen of the posts had disappeared and were assumed buried. The twenty remaining posts had moved downslope an average of 15m, with the fastest moving 32m and the slowest moving

10m.[4] The day-by-day history of movement is not well known. Some of the blocks may creep down the slope at a nearly constant rate, while it is likely that others move in sudden lunges with stationary periods in between.

Based upon these studies, a downslope movement rate of 8m/year (or 15m in slightly less than two years) was estimated.[1,4] This corresponds to a ravine edge backcutting rate of 5-6 m/year, taking into account the steep angle of the slope. No one is certain that 8m/year is a representative movement rate for a longer period of time. It is clear, though, that large floods, by removing the slumped debris at the base of the slope, serve to accelerate the slumping.[4] In September 1979 there was a severe storm associated with Hurricane Frederic estimated as having a recurrence interval of 10 to 20 years. Because of the occurrence of this storm, the movement rate measured during the 1978-1980 period may represent an upper estimate of the annual mass movement.

There are at present no slump blocks on Erdman's Brook or Lagoon Creek (see Figure 2) as active as those of the slump block complex along Buttermilk Creek. The geomorphology of these smaller ravines, however, is generally similar to Buttermilk Creek and the same mass wasting process (i.e. slumping) is apparently the primary mechanism by which these ravines grow.[4] In fact, there are several sections of the ravine walls along Lagoon Creek and Erdman's Brook that are largely unvegetated and appear to have slumped significantly within the last few years. One area along the portion of Lagoon Creek nearest the state-licensed disposal area has been closely studied by the NYSGS staff.[1] Along this slump, called the "North Slope Landslide," the till is currently moving down the slope at a rate of about 0.2m/year, which means that the ravine edge is approaching the disposal areas at a rate of about 0.15m/year.

Whether actively slumping, slowly creeping, or currently stationary, nearly all of the ravine walls in the Buttermilk Creek drainage basin are unstable. Mass wasting is a natural part of the evolution of the valley and while some type of human intervention can slow the process in some areas, it probably cannot be permanently stopped. Future mass movement will be most rapid along the streams that are downcutting most aggressively. Boothroyd and Timson believe that the ravine of upper Erdman's Brook will be relatively stable for the next few decades, while Lagoon Creek, lower Erdman's Brook, and the adjacent portion of

Buttermilk Creek will incise rapidly, making their ravines more subject to slumping.

Most of the disposal areas perimeter is separated from the edges of the ravines by 40-50m of plateau (see Figure 2). If the slumping at the "North Slope Landslide" continues at its present rate, it would be many decades before the edges of the ravines encroach the disposal areas perimeter. The only exception would be at the northeast corner of the facility disposal area where the ravine is very close and local slumping occurs. Unfortunately, no one can be certain that more rapid slumping, akin to that occurring along Buttermilk Creek, will not occur near the disposal areas in the future due to severe storm events and steepened ravines. The Lagoon Creek and Erdman's Brook ravines are shallower than the Buttermilk Creek ravines (about 15m compared to 45m), so even an active slump block may not be as large or cut into the plateau as rapidly as those along Buttermilk Creek. But it is possible that an acceleration of the slumping could begin suddenly at any particular spot, especially in the aftermath of a severe storm. If slumping on the same proportional scale as is presently occurring along Buttermilk Creek were to begin on Lagoon Creek or Erdman's Brook, it could encroach on the order of a meter or two per year. The probability of this happening within the next few years is small, but it would be prudent to take steps to stabilize the nearest slopes as much as possible to protect against a sudden increase in slumping and to minimize any future mass wasting and erosion.

C. GROUND-WATER TRANSPORT

1. HYDRAULIC CONDUCTIVITY AND GROUND-WATER FLOW

The hydraulic conductivity of the unweathered Lavery Till has been measured by the USGS researchers in several locations using several different techniques. Two types of *in situ* slug tests have been performed in 17 different holes around the two disposal areas at depths ranging from four to sixteen meters. Permeameter and consolidation tests have been conducted in the laboratory using core samples from 23 locations.[19,20] All of the hydraulic conductivities measured by the various techniques were on the order of 10^{-8} cm/s, an extremely low value compared to most unconsolidated media. Such a low hydraulic conductivity implies that ground-water transport through the unweathered till is predominately by molecular diffusion rather than by advection.

In contrast to the large number of field measurements taken in the unweathered Lavery Till, only three slug tests were performed by the USGS in the weathered till. One of the tests yielded results as low as the unweathered till, while another indicated that the conductivity of the weathered material is 200 times greater.[19] Prudic concluded that a reasonable estimate for the average hydraulic conductivity of the weathered till, based on the three measurements, would be about 10^{-7} cm/s, or ten times greater than the deeper till. Considering the small number of measurements made and the wide variability of results, this estimate should be regarded as highly uncertain. It is reasonable that the oxidized till, with its desiccation cracks and root tubes, would have a higher conductivity than the unweathered till, and that if the fissures provide the main pathway for the flow of ground water, measurement of the conductivity of the weathered material might yield widely variable results depending on the number, size, and orientation of the cracks near the piezometer. Assuming this is true, and if the ground-water flow through the fractures is the predominant mechanism in the shallow weathered till, Prudic's measured hydraulic conductivities to describe the weathered material may be insufficient since the limited sample tests values may have been low due only to the absence of cracks near certain test piezometers. Recent information on the detection of the Tributyl-Phosphate (TBP) solvent plume indicate the need for hydrologic tests to determine the ground-water flow and transport properties of the shallow weathered till.

Bergeron et. al. conducted laboratory measurements on four samples of weathered till from different locations near the facility disposal area, with results ranging from 2.4×10^{-8} to 1.2×10^{-7} cm/s.[20] These tests seem to indicate that small samples of the oxidized till are approximately as impermeable as the deep till. The effect of fissures on the large-scale hydraulic conductivity of the weathered till cannot be determined from these measurements. The low water content, seasonal drying, and desiccation effects on the weathered till may affect the soil structure to give it lower permeability and an apparent high cohesion.

USGS researchers placed five piezometers in small sand lenses and performed slug tests to measure their hydraulic conductivities.[19] The values obtained ranged from 2×10^{-7} to 2×10^{-5} cm/s, with an average of about 6×10^{-6} cm/s, nearly two orders of magnitude higher than the unweathered till. It is not surprising that the sandy Subfacies 3 material is more conductive than the unoxidized till. Fortunately, the field evidence indicates that the sand lenses are not substantially interconnected, as discussed in Section III.B.2, and thus do not appear to provide a significantly faster migration pathway for the buried wastes. Instead, the sand lenses are considered by Prudic to have the effect of slightly increasing the overall hydraulic conductivity of the unweathered Lavery Till stratum by acting as small, high conductivity pockets within the low conductivity till matrix.[19] The equivalent hydraulic conductivity of the sand lense/unweathered till combination was calculated to be about 4×10^{-8} cm/s based on the average dimensions of the sand lenses.[19]

The USGS used several sets of nested piezometers to determine the hydraulic gradient in the unweathered till.[19] Some of the piezometer data are inconsistent but Prudic concluded that the evidence indicates that the gradient is predominantly downward. Ground water in the unoxidized till can be expected to move essentially straight down 20-25m until it reaches the lacustrine stratum, which may act as a drain for the Lavery Till. The hydraulic conductivity of the lacustrine material is uncertain, and in Prudic's judgement could reasonably be as high as 10^{-2} cm/s or as low as 10^{-6} cm/s. His best estimate is 10^{-4} cm/s. Three piezometers installed by the USGS in the lacustrine unit have shown that at least the lower part of the stratum is saturated, and that there is a small pressure gradient pointing down the incline of the stratum toward Buttermilk Creek (see Fig. 4).[19] These data imply that the quickest migration pathway for ground water to travel from the bottom of one of the disposal trenches to the surface environment would be to move straight down through the Lavery Till and horizontally along the lacustrine layer to its outcropping in the Buttermilk Creek Valley.

The recent solvent plume studies indicate that there may be a shallower pathway. The upper weathered-fractured till may act as a preferential pathway under certain conditions, particularly when the gradient is upward (due to lower density fluids (e.g., solvents)) or horizontal (due to perched-water conditions). The solvent plume extent and behavior indicates that there is an upper hydrogeologic unit characterized by fractures with highly anisotropic hydraulic conductivities that are enhanced by the presence of solvent.

Using the site specific hydraulic conductivities, pressure head gradients, and distances, one can calculate the average time required for ground water to move from the bottom of a disposal pit to the outcropping of the lacustrine stratum along Buttermilk Creek. Prudic has performed these calculations for the state-licensed disposal trenches using the highest and lowest reasonable values of hydraulic conductivity and gradient.[19] Assuming an average thickness of 23m of till beneath the trenches, the time required for water to travel from the bottom of a trench to the top of the lacustrine stratum would be between 300 and 2,300 years. The time required for water to travel 840m along the lacustrine unit to Buttermilk Creek is more difficult to estimate because of the larger uncertainty in the lacustrine's hydraulic conductivity. If Prudic's best estimate of 10^{-4} cm/s for conductivity is used, the travel time would be 500 years, but the time could be as short as five years if the highest reasonable conductivity value is applied.[19] For the deep pathway scenario, and the most conservative estimate of total ground-water travel time from the state-licensed trenches to Buttermilk Creek would thus be a little over 300 years, while Prudic's best estimate is at least 800 years.

The reader should bear two things in mind when considering these travel times. First, they apply to ground water, not radionuclides. The radionuclides do not move faster than the ground water and many, such as Cs-137, are believed to move orders of magnitude more slowly due to chemical sorption. This topic will be discussed in the geochemistry section, II.C.5. Second, these travel times are based on a specific migration scenarios. Radionuclides may move out of the disposal areas by other mechanisms (involving shallow perched water or unsaturated flow, for example) that operate on completely different time scales.

Migration times from the facility disposal area can be computed as well, although the USGS has not done so in its publications. The leached hull shafts in the facility disposal area are deeper than the state-licensed trenches, extending to within 12m of the bottom of the till compared to 23m for the trenches. Therefore the time required for ground water to travel from the bottom of one of the leached hull pits to the lacustrine stratum would be from 150 to 1,100 years if Prudic's figures can be scaled linearly with distance. The leached hull holes are about 100m further up-gradient from Buttermilk Creek than the state-licensed trenches, so there would be an additional migration time for the pathway segment in the lacustrine unit, although considering the extreme uncertainty in the hydraulic conductivity of the lacustrine material it is difficult to determine.

For the deep pathway scenario, a conservative estimate of the travel time from the facility disposal area to Buttermilk Creek would thus be about 150 years, with a best estimate of perhaps 700 years if we use Prudic's value of 10^{-4} cm/s for the lacustrine's conductivity. However, the shallow pathway as evident in the solvent plume studies, may be made more rapid. For the shallow pathway created by perched-water conditions, the travel time may be on the order of a few years depending upon the perched-water gradients and the distance between the ravines and disposal area.

2. INFILTRATION OF WATER INTO THE DISPOSAL PITS

In several of the state-licensed trenches the void spaces have filled with water, and there are indications that the same thing may be happening in the facility disposal area. The prospect of further infiltration and the consequences of fluctuations in perched water levels are among the major areas of concern for the shallow pathway for the facility disposal area.

Of the two disposal areas, much more is known about the history of water infiltration in the state-licensed trenches. All of the trenches except the first were equipped with a sump and well system for collecting trench water samples and measuring water levels.[21,22] Water levels have been recorded intermittently since 1966 and continuous water level recorders were maintained on some of the trenches from 1975 to 1979. The most common pattern was for the water level to rise slowly for a few months after each trench was closed and stabilize at a fairly low level, well below the top of the unweathered till. Only Trench 8 (see Figure 3 for the trench numbering system) deviated from this pattern, showing instead an early decrease in level.[13,21] (Apparently most of the trenches accumulated some rain water while they were being filled.)

In 1971 levels in Trenches 3, 4, and 5 began to rise again after two or three years of stability. By early 1973, water had reached the top of the unweathered till, and in March 1975 water broke through the caps on the north end of Trench 4 and the west edge of Trench 5.[8,18,21] (The references disagree about whether the north end of Trench 4 or Trench 3 leaked; in any case, both were nearly full of water.) After the surface leaks were detected, NFS suspended further burials and began to pump the water out of Trenches 2-5. The trench water was placed in temporary holding ponds and eventually decontaminated in the reprocessing plant's waste treatment system. In the summer of 1978, about 1.3m of additional cover was added over Trenches 1-5. Shortly thereafter the water levels rose again, not only in the recapped trenches but in Trenches 11-14 as well. This was the first time that water levels had gone up significantly in the south trenches. The trenches were pumped several more times, most recently in 1981. Since 1981, the water levels have risen gradually in most of the trenches at a rate of a few inches per year except for Trench 14, which is rising at a rate of about one to two feet per year.[25]

There are two explanations, not mutually exclusive, for how water gets into the trenches: (1) infiltration of precipitation through the caps and (2) seepage of ground water through the walls and floors. The evidence is conclusive that percolation is a major contributor and may predominate in certain conditions. The role of ground-water seepage through the walls and floors is still obscure.

Prudic gives several reasons why he considers precipitation as the principal source of the trench water recharge.[19] First, nearly all of the piezometer data indicate that the general pressure head gradient in the till is downward, not lateral. Second, the low hydraulic conductivity of the till would discourage substantial lateral ground-water seepage into the trenches even if there were a horizontal pressure gradient. Third, large cracks that would facilitate infiltration of precipitation are visible and widespread in the trench caps. Fourth, there is evidence that gases respire through these cracks, indicating that they sometimes penetrate the caps. Finally, the record of water level changes in the continuously monitored trenches matches the precipitation record more closely than the variation in well water levels in the surrounding till.

These arguments make a convincing case that precipitation infiltration is filling the trenches and that it will continue to do so until less permeable caps are placed over them. It is not clear, however, that infiltration of precipitation explains all of the trench water data, and in general the contribution of groundwater seepage remains uncertain. Even if infiltration predominates, groundwater seepage may fill the trenches eventually. If this is the case, improvement of the caps, while necessary, would not prevent eventual saturation of the trench materials.

The applicability of these observations to the facility disposal area (FDA) is an important unresolved issue. There were no wells installed into older pits in the facility disposal area, so there is no way at present to measure water levels. However, recent site studies have planned to install monitoring wells into recently excavated trenches which would provide important information on infiltration at the FDA.

The individual disposal pit geometries have small surficial areas with a smaller volume percentage in the disturbed weathered fractured till than the disposal trenches. One reason the trenches overflowed is that they have large horizontal cross-sections and are tilted about 2° on their long axes.[22] Thus precipitation that infiltrates anywhere along the cap tends to accumulate at the low (north) end of the trench. With a comparable rate of infiltration per unit of surface area, the deep, narrow pits in the disposal area should take longer to fill and overflow. On the other hand, an effort was made from the beginning to cap the state-licensed trenches in a way that would minimize infiltration. This effort was obviously not completely successful, but the compaction and mounding of the covering soil probably caused precipitation to run off faster and infiltrate less than would otherwise have been the case. There were no special efforts made to compact the soil over the facility disposal area pits and there are no mounded caps to shed water, so it is plausible that the infiltration rate for the deep pits may be comparable to that for state-licensed trenches or even greater. As discussed in the following section, recent evidence from the solvent plume studies indicates that some of the facility disposal area pits may develop perched water conditions.

The consequences of water getting into the trenches or pits may or may not be severe depending upon the soil properties and conditions, and the waste buried. The low permeability of the till and the downward hydraulic gradient will generally discourage the water from seeping directly back out into the local environment except for abnormally high perched conditions. There is some indication that saturated conditions weaken the trench walls and may encourage wall sloughing and surface subsidence.[23] In addition, excess water in the pits translates into extra leachate for dissolving the radioactive materials. As explained in Section III.C.5, the solubility of the wastes is not well understood, but any waste migration scenario that includes dissolution of radionuclides in ground water is rendered more plausible by the presence of trench water.

The most serious concern, though, is recurrence of the overflow problems of the mid-70's, with trench water rising high enough to leak into the fractured weathered till horizon or actually seep onto the surface. The trench water that leaked in 1975 was only moderately radioactive; only its H-3 levels were substantially above the 10 CFR Part 20 safety standards.[24] Further trench water leakage, however, is not a foreseeable prospect since the state-licensed trenches are continously monitored and pumped out periodically, which indicates that NYSERDA can continue to keep the trench water under control indefinitely. However, the necessity of actively monitoring and pumping the trenches creates a somewhat uncomfortable long-term situation, and there is no provision presently for monitoring or pumping the pits in the facility disposal area except for special holes (SH) #10 and 11 where the solvent originated which are presently being monitored and periodically pumped (see Figure 6).

3. NOVEMBER 1983 SOLVENT DISCOVERY

On November 30, 1983 an organic liquid was discovered in well 82-5A near the northwestern boundary of the facility disposal area (see Figure 5). Well 82-5A was one of several shallow wells around the facility disposal area perimeter installed by the USGS under NRC Research funding for the purpose of characterizing the hydrostratigraphy, measuring ground-water levels, examining recovered cores and water samples for radionuclides, and collecting hydrological data. Of the three individual wells in the 82-5 cluster, 82-5A was the shallowest, being screened at approximately 20 feet below the surface. When the USGS researchers bailed out the well on November 30, they found that it contained several liters of organic fluid, later determined by chemical analysis to be kerosene with a 2% concentration of tributylphosphate (TBP).[26,29] Radiochemical analysis of the kerosene showed that it had a Co-60 concentration of 1.5x10-4 mCi/mL and somewhat lower concentrations of Ru-106, I-129, and the major plutonium isotopes. It contained little Sr-90 or Cs-137. The relative abundances of the isotopes confirms that the organic liquid was spent reprocessing solvent.

The standard method for disposing of degraded solvent was to pour it into carbon steel tanks filled with vermiculite, thus converting it to a "solid" form. The records show that several of these tanks were buried in two sections of the facility disposal area (FDA), as illustrated in Figure 5.

Approximately two dozen exploratory holes were drilled in rapid fashion by West Valley Nuclear Service Co. (WVNS) in the vicinity of well 82-5A to determine the extent of the contamination.[29] The data collected from these preliminary holes was difficult to interpret. The WVNS staff measured the Co-60 dose rates in some holes and the total gamma activity in others.[26] They also "smelled" the soil for a kerosene odor as the holes were being drilled. Whenever kerosene was noticed, radioactivity was also detected, although the reverse was not always true. The pattern of detected contamination did not correspond to a conventional wide-front plume. In some cases, contamination was found in two holes a few feet apart, but not in a third hole located directly between the other two. Additional holes were drilled in the vicinity of the nearest burial pits believed to contain large quantities of solvent (in the northernmost of the two major solvent areas shown in Figure 5). The data from these preliminary holes was also confusing, with contamination found in some holes but not all, with no clear pattern apparent.

Subsequent investigations by DOE contractors in consultation with NRC Research staff and consultants, and review of FDA burial records have identified locations of burial holes containing or possibly containing solvents (see Figure 6). The following hypothetical scenarios listing the subsequent mechanisms from the April 1985 DOE contractor report (see Reference 29) appears to accurately represent the existing data base,

(1) "The tanks were breached by corrosion.

(2) Either poor cap construction or settlements caused by the failure of the tanks resulted in crack development in the trench cap which permitted surface runoff infiltration. The lack of cap compaction observed in

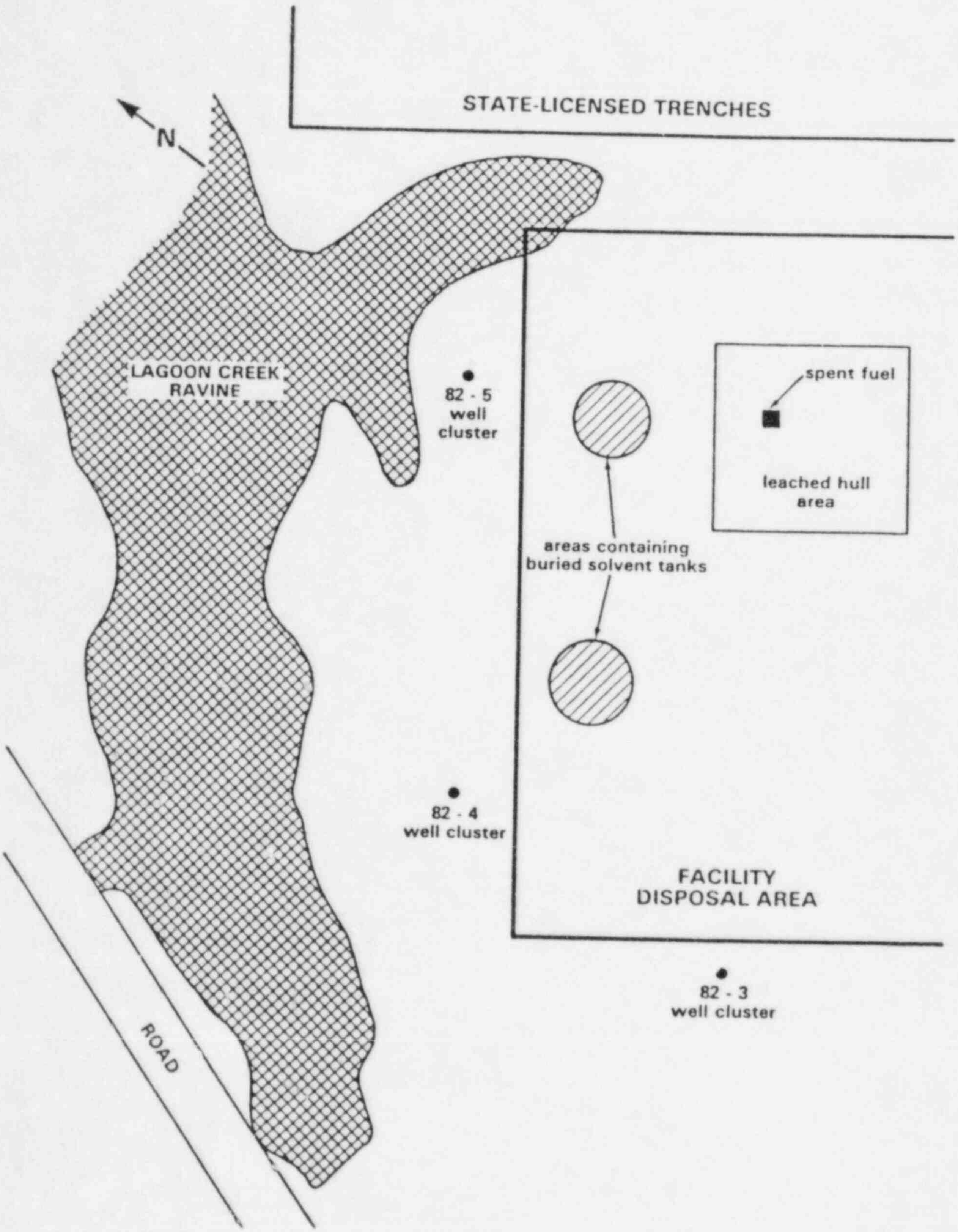

Fig. 5. Location of Disposed Solvent

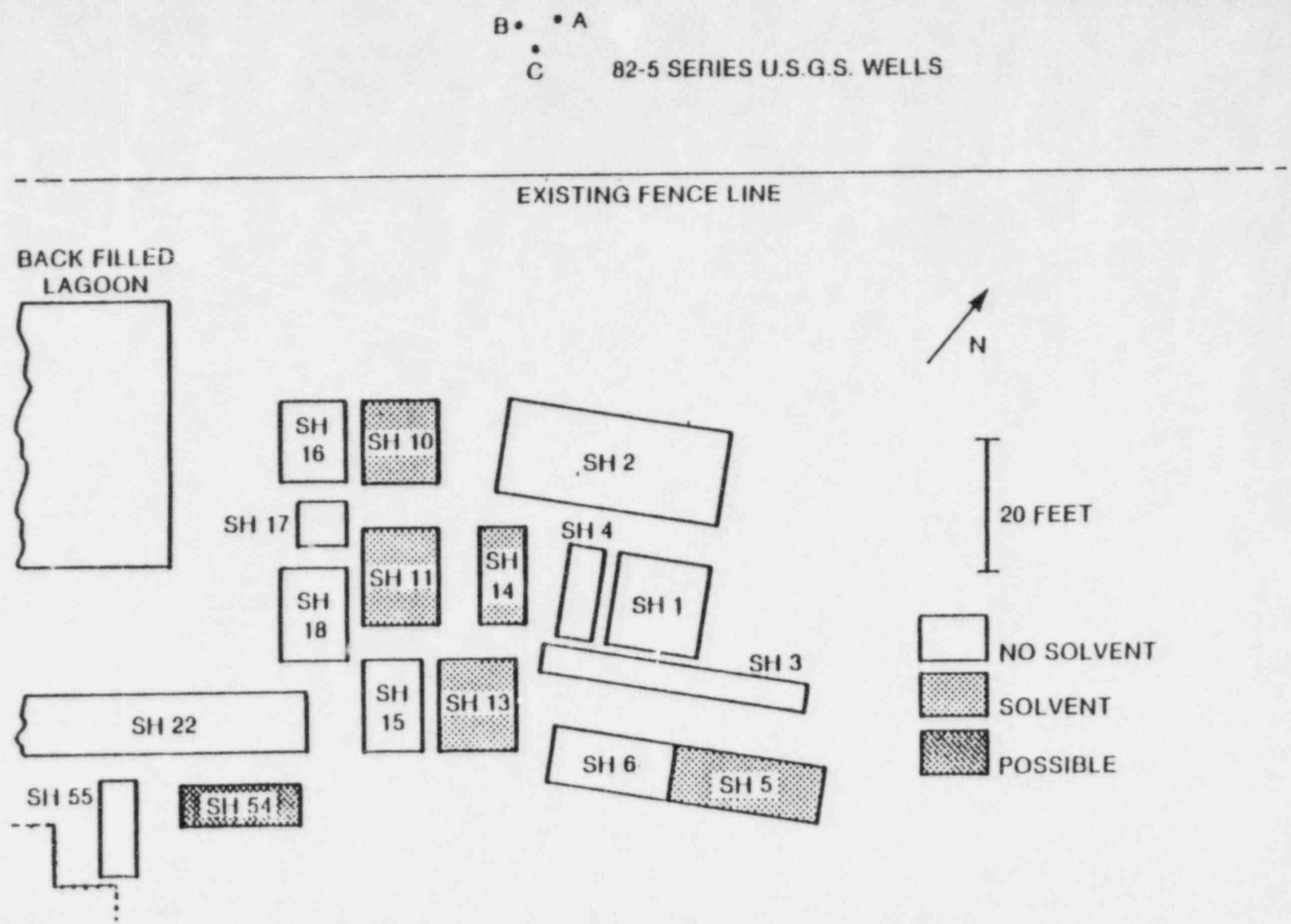

Fig. 6. Location of Disposal Holes Containing or Possibly Containing Solvents (After West Valley Nuclear Services Co., 1985)

all the Phase I drill holes and the voids encountered in 84-I-4 and 4A support this hypothesis.

(3) As the trench filled with water, the contaminated kerosene floated on its surface, eventually reached the weathered till zone, and subsequently the "disturbed" zone of the till. The observation of uniform activity in boring 84-I-3 (which penetrated a burial cap) fits this hypothesis.

(4) The kerosene migrated laterally through the weathered and "disturbed" zones, both of which are dry and contain numerous discontinuities. The dryness of these two zones may even have accelerated flow as a result of capillary or "wicking" action on movement of slugs of water such as those which were associated with rapid fluctuations in the kerosene levels in monitoring wells during a recent thaw.

(5) Once the contaminated kerosene left its water platform in the trench, it migrated downward and away from the SH-10 and SH-11 burial. The decrease in activity with depth in the holes adjacent to the burial supports this hypothesis. The random locations where kerosene was and was not encountered in the drill holes suggest that this migration takes place along preferred pathways.

(6) The downward migration was stopped when the contamination reached the much less permeable and more saturated unweathered till. When it reached this barrier, the contaminated kerosene moved along the interface and collected in depressions such as the one which appears to exist between borings B84-5 and B84-8.

(7) The material which collected in the depressions migrated downward by molecular diffusion, which may have been accelerated by alteration of the clay microfabric."[29]

This closely reflects the NRC Staff analysis at the time of the plume's discovery which was as follows:

1. If the contamination data obtained from the holes drilled by WVNS are reliable, the contamination does not form a conventional plume, but

an irregular, usually narrow, series of fingers and branches. This suggests that the solvent may be moving primarily along the fractures in the weathered till.

2. The vertical extent of the contamination is mostly limited to the weathered/unweathered till interface about three meters below the surface.

3. The holes drilled by WVNS around the burial pits indicate that the backfill covering the wastes was not well compacted and that the pits in question are probably saturated with water. That being the case, it is plausible that the carbon steel tanks have corroded and that the pit water has mingled with the solvent-soaked vermiculite. Any solvent displaced from the vermiculite by pit water (assuming that the solvent was fully absorbed in the first place) would float to the top of the saturated part of the burial pit since kerosene is less dense than water.

4. Once solvent gets into the weathered soil layer, it can move quickly. The archived cores show that there was no contamination at the site of well 82-5A in the fall of 1982. In fact, when a metal tape was inserted down the well in mid-October 1983, the last water level measurement before the bail-out when the kerosene was discovered on November 30, 1983, no kerosene was observed or smelled on the measuring tape.[26] The field technician was not expecting to find kerosene, of course, so the absence of an observation during the tape-down measurement does not firmly prove that solvent had not reached well 82-5A. But the available evidence indicates that solvent, or perhaps any liquid, is able to move rapidly at times in the shallow soil zone.

On the basis of this preliminary data, it was difficult to be certain how the radioactive solvent migrated to the vicinity of well 82-5A. Therefore, the NRC developed a technical assistance contract with Oak Ridge National Laboratory (ORNL) to determine what additional information was needed to fully explain the solvent leak. The ORNL scientists using NRC staff and DOE site information finished their investigation which was submitted to the NRC as a progress report entitled, "Plan for Diagnosing the Solvent Contamination of the West Valley Facility Disposal Area," October 1984 (see Reference 30). The recommendations in the October 1984 ORNL "Diagnostic Plan" (see Section 7. "Conclusions and Recommendations." of Reference 30) were discussed with the DOE staff, their contractors, New York State officials, and NRC staff. Additional wells were installed to identify the extent of the solvent plume, and to better assess its source and transport mechanism (see Figure 7). The present DOE program recognizes the uncertainties of characterizing and fully understanding the plume's extent and transport mechanisms and therefore presently monitors the boreholes for both water and solvent levels, and takes daily surface water samples when stream flow occurs in the vicinity of the FDA[29] (see Figure 8).

4. GEOCHEMISTRY AND RADIONUCLIDE MOBILITY

If there were no substantial concerns or uncertainties about the hydrogeologic properties and transport mechanisms of the West Valley disposal areas, it would perhaps be unnecessary to expend much effort studying waste solubility and local geochemistry. After all, if there is no possibility of the ground water itself travelling from the waste pits to the accessible environment during the next few centuries, it would greatly limit the amount of radioactivity to migrate except by molecular diffusion, and would limit the need for assessing the sorptive properties of the soil and ground water. If, on the other hand, there is a possibility that contaminated ground water may reach the accessible environment, the issues of waste solubility, ground-water chemistry, and waste/soil interactions become important. For example, occasional seepage of pit water into the weathered till zone may not present a significant hazard depending on how much radioactivity is dissolved in the pit water (remember that all of the radioactivity not associated with the solvent tank was initially in a solid form) or on how much of the dissolved radioactivity is removed by the clay minerals in the till as the water migrates.

Relatively little work has been done by the NRC on the issues of solubility or geochemistry at the West Valley facility disposal area. A large study was done on radionuclide transport in Cattaraugus Creek that addressed the behavior of the low-level radioactive effluents from the reprocessing plant.[27,28] The data

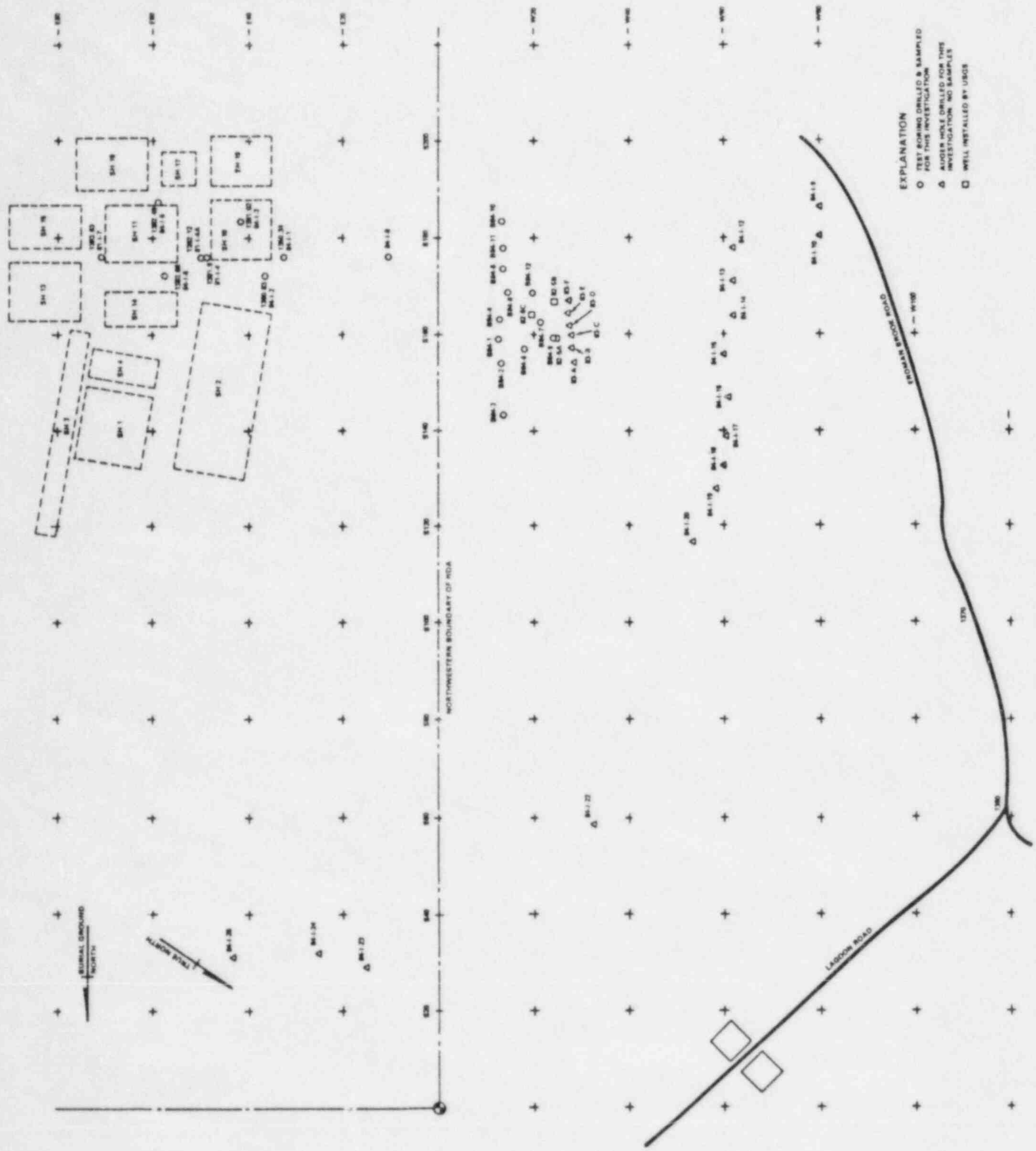

Figure 7. Plot Plan Showing Location of Borings and Disposal Trenches (After West Valley Nuclear Services Co., 1985)

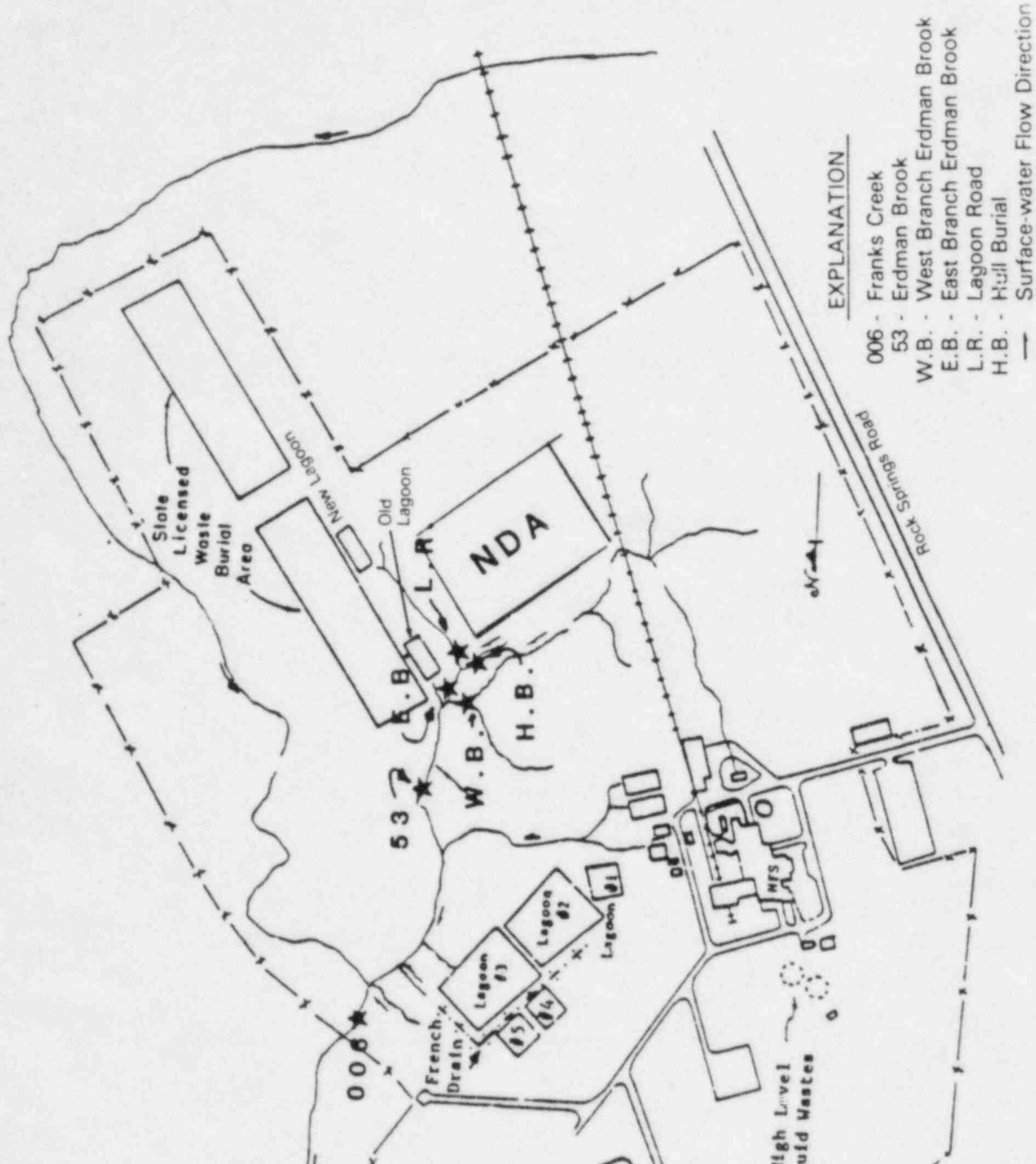

Figure 8. Location of Daily Sampling Stations (After West Valley Nuclear Services Co., 1985)

obtained during the Cattaraugus Creek study may be pertinent to the mobility of the buried wastes to the extent, hopefully minimal, that they ever reach the local surface environment. EPA sponsored studies of the chemistry and radioactivity content of the water in the state-licensed trenches[19,24]. Some of that data may be applicable to the facility disposal area, although much of it probably is not because of the greatly different types of waste in the two burial grounds. Very little is known of the solubilities of the wastes in the facility disposal area. It seems likely that the leached hulls, the largest component of the radioactive source term, would be resistant to leaching, but we have little direct evidence.

Brookhaven National Laboratory (BNL) researchers investigated the isotopic-sorptive properties of the West Valley Lavery Till using laboratory batch sorption tests with trench water used as the liquid phase (see Reference 31).

The sediment characterization of the unweathered till included:

(1) particle size distribution,
(2) surface area,
(3) mineralogy,
(4) extractable iron content,
(5) organic carbon,
(6) carbonate content, and
(7) cation exchange properties.

The Lavery Till particle size distribution is that of a clayey silt. The average soil surface area for bulk material using the ethylene glycol (EG) technique was 22.7 (m^2/g) with a range of 21.8 to 30.5 (cm^2/g).[31]

The BNL qualitative mineralogical analysis of the West Valley till (Lavery Till) sample listed the following minerals for each size fraction:

Table 6

WEST VALLEY TILL MINERALOGICAL ANALYSIS*
(Hole A2 27-28 ft)

Sand Fraction >63μm	Quartz Mica ("illite") Calcite Dolomite Feldspars
Silt Fraction 62.5-4μm	Quartz Mica ("illite") Calcite Dolomite Feldspars
Clay Fraction <4μm	Quartz Mica ("illite") Kaolinite Mixed Layer Clays (minor)

For the Lavery Till, the carbonate content by wt. % is 14.2, the organic iron content by wt. % is 1.7, and the extractable iron content by wt. % is 0.35. The cation exchange data for the West Valley till as determined by the BNL researchers[31] were:

	Ground	Bulk
CEC_T (pH 8.2)	8.3	7.4
CEC_T (pH 4.5)	7.0	6.1
ΔpH	1.3	1.3 (difference due to Ph)
CEC_{Sr}	2.8	4.1

The batch sorption test data shown in Table 7 indicates that solution conditions can have a significant effect on the isotope sorption coefficients. Table 8 indicates whether the soil and/or water composition variation affect the sorption

*See Reference 31.

Table 7

SORPTION COEFFICIENTS FOR TRENCH WATER AND SOIL
FROM WEST VALLEY, NEW YORK, DISPOSAL SITE
(Soil and Water Pretreatment)*

	K_d (mL/g)[a]			
	Solution Condition			
	Oxic		Anoxic	
	Soil Condition			
Radionuclide	Ultrasonic Disaggregated	Ground 100-200 Mesh Fraction	Ultrasonic Disaggregated	Ground 100-200 Mesh Fraction
^{152}Eu	4300±500	3700±600	600±60	2100±200
^{241}Am	4700±60	4000±600	415±60	1000±150
^{85}Sr	31.9±0.2	25±2	6.9±0.4	7.4±0.2
^{134}Cs	200±9	100±30	49±6	260±7
^{137}Cs	195±10	100±30	48±5	260±7
^{60}Co	2.3±0.2	1.8±0.1	1	5±1

Trench Water: West Valley, New York, disposal site, Trench 2-1A (WV-40), collected anoxically November 1977

Soil: West Valley, New York, disposal site Unweathered till, Test Hole A2 (WV-A2) collected July 1975

Solution/Soil Ratio: 20 mL/g

Reaction Containers: Screw cap, septum sealed, glass test tubes

Equilibration Time: 100 hours

Anoxic: Original materials maintained in an argon atmosphere

Oxic: Trench water was exposed to air to precipitate ferric hydroxide. Samples for K_d determination were prepared from the solution after the precipitate was removed by filtration.

[a] K_d is reported as an average ± one standard deviation of observed results.

*See Reference 31.

Table 7 show that Eu sorption is affecteu by differences in water chemistry (oxic versus anoxic) for both the ground-sieved sediment (100-200 mesh), and the ultrasonicated material. Yes responses in Table 8 are recorded for the comparisons in the anoxic and oxic columns. However, under oxic conditions, the sediment variation (100-200 mesh versus ultrasonicated) produces no significant variation in the observed K_d. A no response appears for the comparison in the last column in Table 8.

Table 8

DOES SOIL AND WATER COMPOSITION VARIATION AFFECT K_D RESULTS FOR TRENCH WATER AND SOIL FROM WEST VALLEY, NEW YORK, DISPOSAL SITE?*

	Comparing K_d Results for:			
	Soil Compositions With		Water Compositions With	
Radionuclide	Anoxic Water	Oxic Water	Ground 100-200 Mesh Soil Fraction	Bulk Soil Ultrasonically Disaggregated
^{152}Eu	YES	YES	YES	NO
^{241}Am	YES	YES	YES	NO
^{85}Sr	YES	YES	NO	NO
^{134}Cs	YES	YES	YES	YES
^{137}Cs	YES	YES	YES	YES
^{60}Co	YES	YES	YES	YES

Trench Water: West Valley, New York, disposal site, Trench 2-1A (WV-40), collected anoxically November 1977

Soil: West VAlley, New York, disposal site Unweathered till, Test Hole A2 (WV-A2) collected July 1975

*See Reference 31, and also Table 7.

coefficients. The BNL conclusions on the relationship of sorptive properties of the Lavery Till to radionuclide transport is:

"If the magnitude of the K_d results are considered, some general predictions can be made concerning migration and retention of the radionuclides. For example, Eu and Am sorption in the West Valley system is affected by soil changes under anoxic conditions, but unaffected under oxic conditions, (Table 7). This would indicate that the soil variation is important in controlling sorption around the immediate trench vicinity. However, as the waters move away from the immediate trench vicinity, Am and Eu sorption would be expected to increase due to the chemical regime change. As migration continues, the changes in water chemistry are important in terms of Eu and Am retention."[31]

In light of the possibility that infiltration of water into the pits and trenches may be difficult to completely control (barring installation of a comprehensive monitoring and pumping system) and the consequent possibility that contaminated water may occasionally seep into the weathered soil layer or onto the surface, it would be advisable to improve our understanding of solubility and geochemistry matters. To this end a project has been initiated with Oak Ridge National Laboratory (ORNL) to develop a research plan for obtaining all of the essential information on these and any other topics related to the migration of radioactivity from the facility disposal area.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. GEOMORPHIC CONDITIONS

1. Geomorphic studies at the West Valley site have identified active slope instability conditions caused by erosion and mass wasting phenomena endemic to the glacial till deposits. The extent and rate of these geomorphic processes have been estimated along Buttermilk Creek but not in the vicinity of the disposal areas.

2. The active slumping occurring along Buttermilk Creek should be considered a long-term process that is not presently affecting the geomorphic stability of the disposal areas.

3. The ravines surrounding the disposal areas are subject to active slumping and erosion. The slumping and erosion near the disposal areas could result in shortened ground-water pathways, or possible natural exhumation of the disposed waste. To ensure against this risk, geotechnical studies should begin as soon as possible to characterize these processes in order to develop suitable remedial action and its early implementation.

4. For any remedial action selected, care should be taken that the long-term stability of the site is not sacrificed for short-term protective measures.

B. GROUND-WATER TRANSPORT

1. The most important unresolved hydrologic issue is the behavior of the shallow ground-water flow system and pathways. The rate at which water enters the disposal pits through infiltration and percolation is an important issue in understanding the driving mechanism of this shallow flow system, and its relation to the deeper flow system which needs to be determined.

2. Experience with earthen caps has shown that they are prone to leakage which increases with time. The emplacement of engineered caps, and the design and construction of a surface drainage system are essential for limiting this infiltration.

3. The extent of the shallow ground-water flow system recharge areas needs to be determined. This includes analysis of its relationship to the deeper ground-water flow system and pathways, and the determination of possible lateral flow and transport pathways as related to the weathered and fractured Lavery Till unit.

4. If there is significant lateral ground-water recharge to the shallow pathway, it would be necessary to devise engineering measures to curtail this subsurface flow into the disposal trenches.

5. The TBP-solvent plume studies identified the need to better assess the fracture flow components of the shallow ground-water flow system. Hydraulic conductivity values for the weathered and fractured Lavery Till may be underestimated. Also the presence of a hydrocarbon solvent (kerosene) may further increase these values. Therefore, the hydraulic and geochemical properties of the weathered and fractured Lavery Till unit need to be assessed, and ground-water gradients need to be measured prior to a ground-water transport analysis of this shallow pathway. Plans for corrective action and the weighing of alternatives would be based upon this analysis.

6. The accomplished USGS studies of the deeper flow system and transport pathways indicate that below the weathered and fractured Lavery Till unit, the ground-water flow system has downward flow gradients, and extremely slow ground-water velocities. This would indicate that for the deeper flow system, transport can be characterized as being molecular diffussion dominated. Environmental isotopes (e.g., tritium (^{3}H), carbon 14 (^{14}C), and oxygen 18 (^{18}O) and deuterium (^{2}H)) and ground-water chemistry studies should be conducted to confirm this, and to better understand the relationship between the shallow and deeper flow systems.

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12. SUPPLEMENTARY NOTES

13. ABSTRACT (200 words or less)

This report summarizes the previous NRC research studies, NRC licensee source term data and recent DOE site investigations that deal with assessment of the radioactive waste inventory and confinement capability of the Facility Disposal Area (FDA) at West Valley, New York. The radioactive waste inventory for the FDA has a total radioactivity of about 135,000 curies (Ci) and is comprised of H-3 (9,500 Ci), Co-60 (64,000 Ci), SR-90/Y-90 (24,300 Ci), Cs-137/Ba-137m (24,400 Ci), and Pu-241 (13,300 Ci). These wastes are buried in the Lavery Till, a glacial till unit comprised of a clayey silt with very low hydraulic conductivity properties. Recent studies of a tributylphosphate-kerosene plume moving through the shallow ground-water flow system in the FDA indicate a need to better assess the fracture flow components of this system particularly the weathered and fractured Lavery Till unit. The analysis of the deeper ground-water flow system studied by the USGS and NYSGS staffs indicates relatively long pathways and travel times to the accessible environment. Mass wasting, endemic to the glacial-filled valley, contributes to the active slumping in the ravines surrounding the FDA and also need attention.

14. DOCUMENT ANALYSIS – a. KEYWORDS/DESCRIPTORS

ground-water flow
radioactive waste disposal
ground-water transport
ground-water plumes
glacial hydrogeology
geomorphic processes
geochemistry and radionuclide mobility

b. IDENTIFIERS/OPEN-ENDED TERMS

15. AVAILABILITY STATEMENT: unlimited

16. SECURITY CLASSIFICATION
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18. PRICE