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ASSESSMENT of POTENTIAL SHALLOW GROUNDWATER TRANSPORT of RADIONUCLIDES at CRITICAL EXPERIMENT FACILITY, TA-18 LOS ALAMOS NATIONAL LABORATORY

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EXECUTIVE SUMMARY

The purpose of this project was to develop baseline data on radionuclides present in the soil and shallow groundwater in the vicinity of Los Alamos National Laboratory's Los Alamos Critical Experiment Facility and to assess the transport potential for these radionuclides. Four wells were installed to a depth of approximately 25 ft. Soil and groundwater samples were analyzed for various radioisotopes and compared to background or environmental levels. Well data suggest that the area is subject to strong seasonal fluctuations of the water table. Laboratory results indicate that the radioisotopes of concern are at background levels or below detection limits, with sample depths from the surface to about 25 ft.

1.0 INTRODUCTION

1.1 Scope of Work

This document contains the results from work performed by Los Alamos Technical Associates, Inc., (LATA) under Task Order 005 of Subcontract #9-X50-8196N-1 with the Los Alamos National Laboratory (LANL).

The objective of work performed under this task order was to provide technical support to LANL in assessing the potential for transport of radionuclides by shallow groundwater at the Los Alamos Critical Experiment Facility (LACEF) at TA-18 in Pajarito Canyon. The information in this report is to be included in a revised Safety Analysis Report (SAR) for the LACEF. The work involved a survey of existing site facilities and utilities in the vicinity of Kiva 1, geologic and hydrologic investigations, design and installation of four shallow groundwater monitoring wells around the LACEF (generally referred to as the Sheba building), sampling of soil and groundwater (including radiochemical analysis of these samples), compilation of the analytical results, and preparing recommendations for an on-going monitoring program.

This report addresses the concerns of NRC 1.70, Revision 3, Sections 2.4.13.1 through 2.4.13.4, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants," as they pertain to the limited scope of work of this project.

1.2 Facility Description

The location of the LACEF and the monitoring wells is illustrated in *Figure 1-1*. (Approximate utility locations are shown in *Figure 1-2*.) The LACEF will be used to conduct solution criticality experiments related to reactor design. The facility consists of a 6-ft diameter steel caisson (closed at one end), with a stainless steel liner set vertically in the ground. The open end of the caisson is flush with a concrete pad. A steel cover with various experimental fittings is bolted in place during experiments. The caisson is bedded in concrete at a depth of approximately 12 ft, and the annulus between the caisson and the undisturbed soil around it is filled with concrete. A metal building with two doors at opposite ends encloses the concrete pad. The concrete pad measures approximately 20 ft square. The perimeter of the concrete filling the annulus reportedly does not extended beyond the edge of the pad. The primary concern motivating the need for this investigation is the very small potential for leakage of radioactive solutions from the experiment activities into the surrounding soil and groundwater.

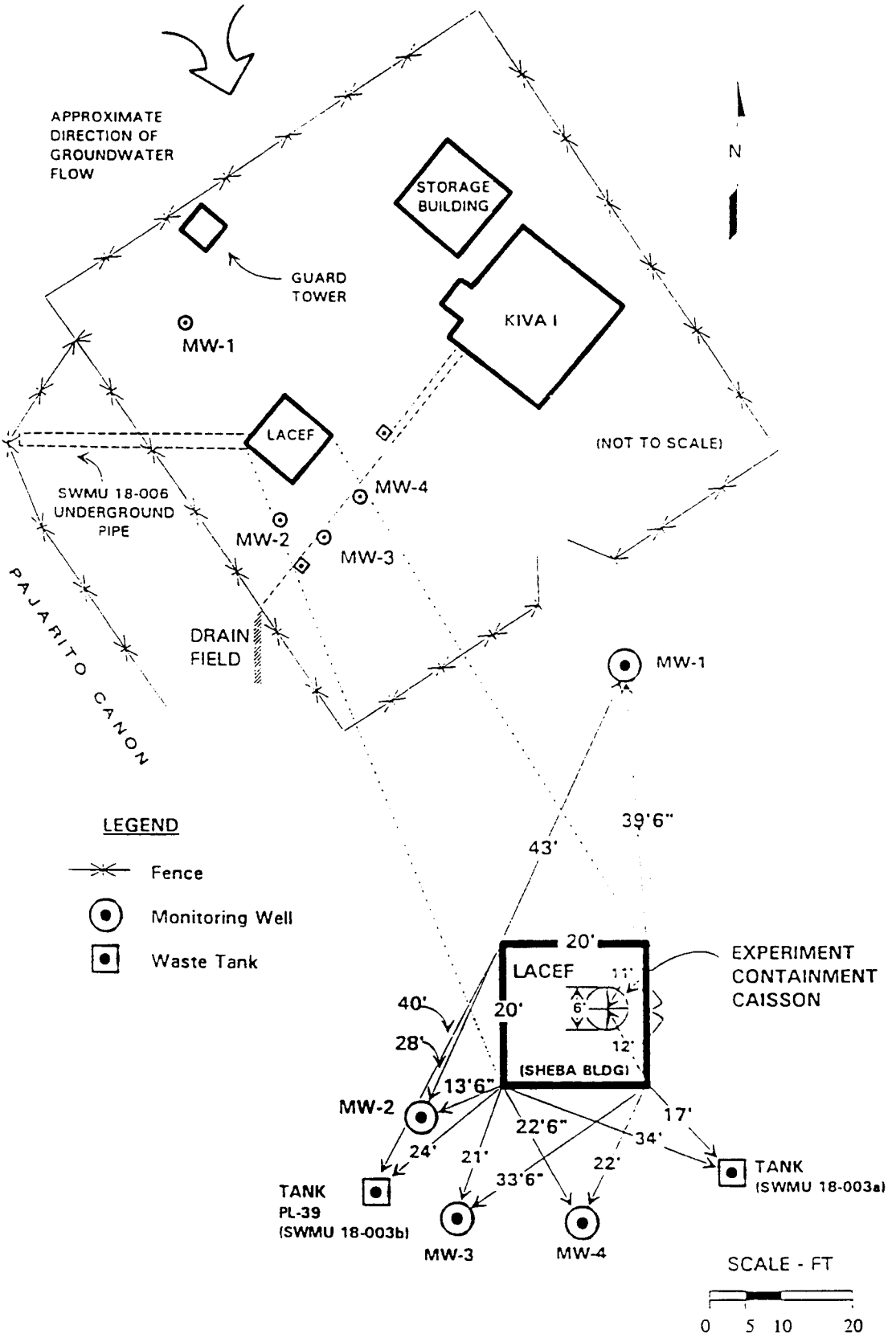
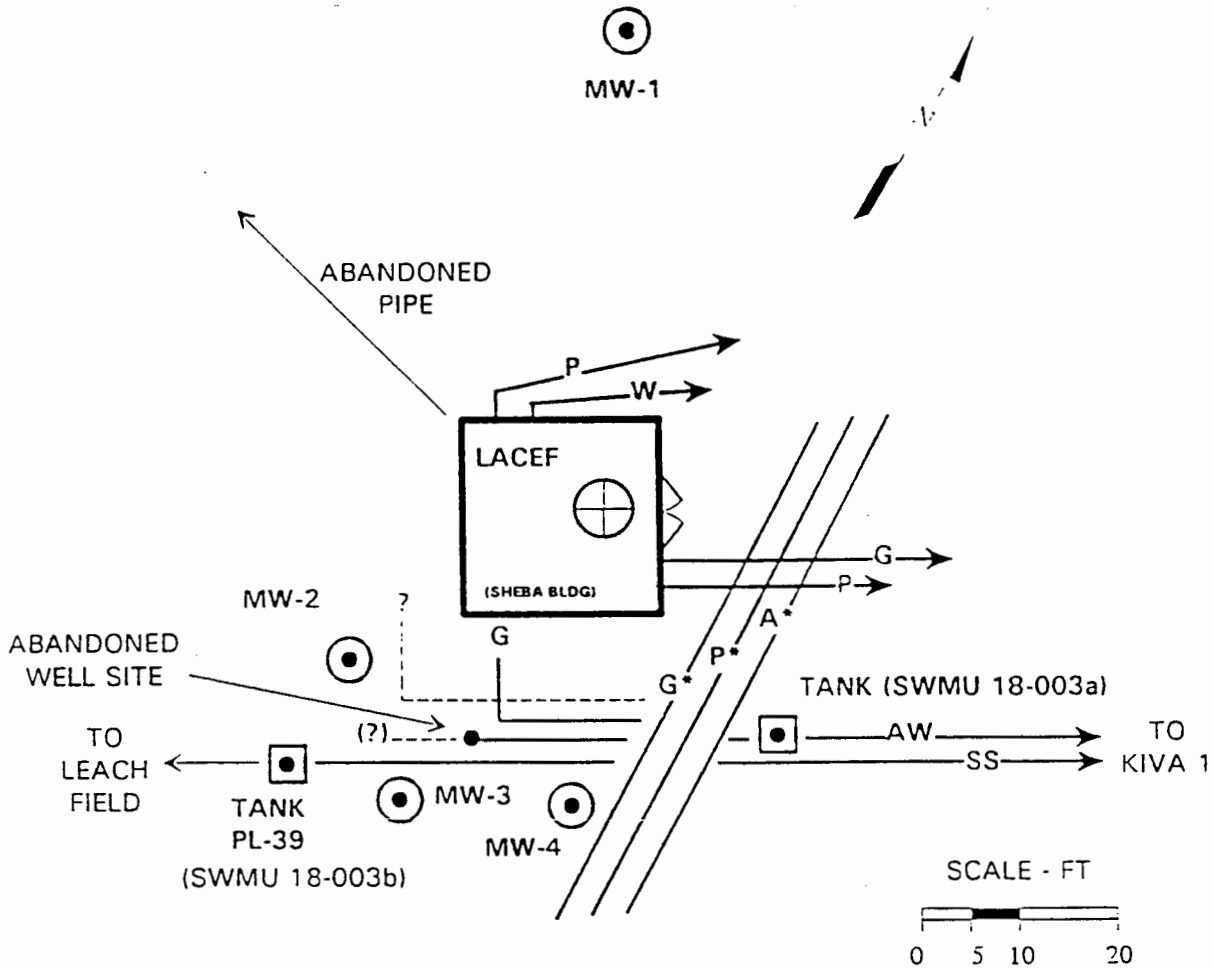


Figure 1-1. Site Plan and Well Location Data



LEGEND

—— AW ——	= abandoned acid water line (vitreous clay pipe)
—— SS ——	= sanitary sewer line
—— P ——	= underground power electric
—— G ——	= gas
—— A ——	= air
—— W ——	= water
------ ? ------	= found, but not identified
----- (?) -----	= (interpolated location)
•	= lines are grouped, exact sequence not determined

(All underground utility locations approximate, as determined by Pan Am World Services, Utilities Division.)

Figure 1-2. Underground Utility Locations Relative to the LACEF Building

Surface structures near the LACEF include an assembly building, Kiva 1, a storage building, and an unused guard tower. Subsurface structures in the vicinity of the LACEF include various utility manholes, a drainline for the sanitary sewer system from Kiva 1, and an inactive underground storage system for an experiment previously conducted at the location of the LACEF.

The site is underlain by alluvial material derived from the Bandelier Tuff, to a thickness of approximately 35 ft. A shallow perched groundwater system is present in the alluvium, with the water table at a depth of approximately 15 ft below the surface at the time of this project. This saturated zone was encountered during construction of the LACEF and is the focus of the groundwater monitoring that was performed by the project.

2.0 AREA DESCRIPTION

2.1 Geological Formations

Los Alamos National Laboratory (LANL) is located on the Pajarito Plateau (*Figures 2-1, 2-2,* and *2-3)*. The volcanic and sedimentary rocks forming the Pajarito Plateau, and its subsurface are made up of the Tesuque Formation, Puye Formation, basaltic rocks of Chino Mesa, Tschicoma Formation, and Bandelier Tuff.

The Tesuque Formation consists of siltstones and sandstones with lenses of clay and conglomerate. Many beds in this formation are permeable and, where saturated, yield water to a well. Some of the beds are relatively impermeable and, thereby, restrict vertical and lateral movement of groundwater within the formation. The upper 1000 ft of this formation consist of coarser sediments which yield larger amounts of water to wells than do the finer sediments that are predominate to the east of the area (Purtymun, 1984).

The Puye Formation is a channel fill deposit consisting of pebbles, cobbles, small boulders, and a poorly consolidated, silty, sandy conglomerate. The formation is highly permeable and, when saturated, yields large amounts of water to wells.

The basaltic rocks of the Chino Mesa consist of a series of basalt flows and interflow breccias. Basalt flows, separated by interflow breccias, are permeable and, when saturated, will yield water. Open joints and cavities in thick basalt flows also yield water. However, steepening of the contours on the surface of the main aquifer along the Rio Grande indicates that thick basalt flows form a barrier to the movement of ground water *(Figure 2-4)*.

The Tschicoma Formation, the major part of the interior mass of the central Jemez Mountains, consists of volcanic flow rocks. This formation has low permeability and retards and restricts groundwater movement. There are limited open joints and interflow breccias within the formation that could yield appreciable amounts of water.

The Bandelier Tuff is a sequence of rhyolite ash flows and pumice, and the tuff itself ranges from non-welded to welded. Bandelier Tuff is above the main groundwater body, but in areas on the flanks of the Sierra de los Valles, small amounts of perched water discharge from springs (Purtymun, 1984).

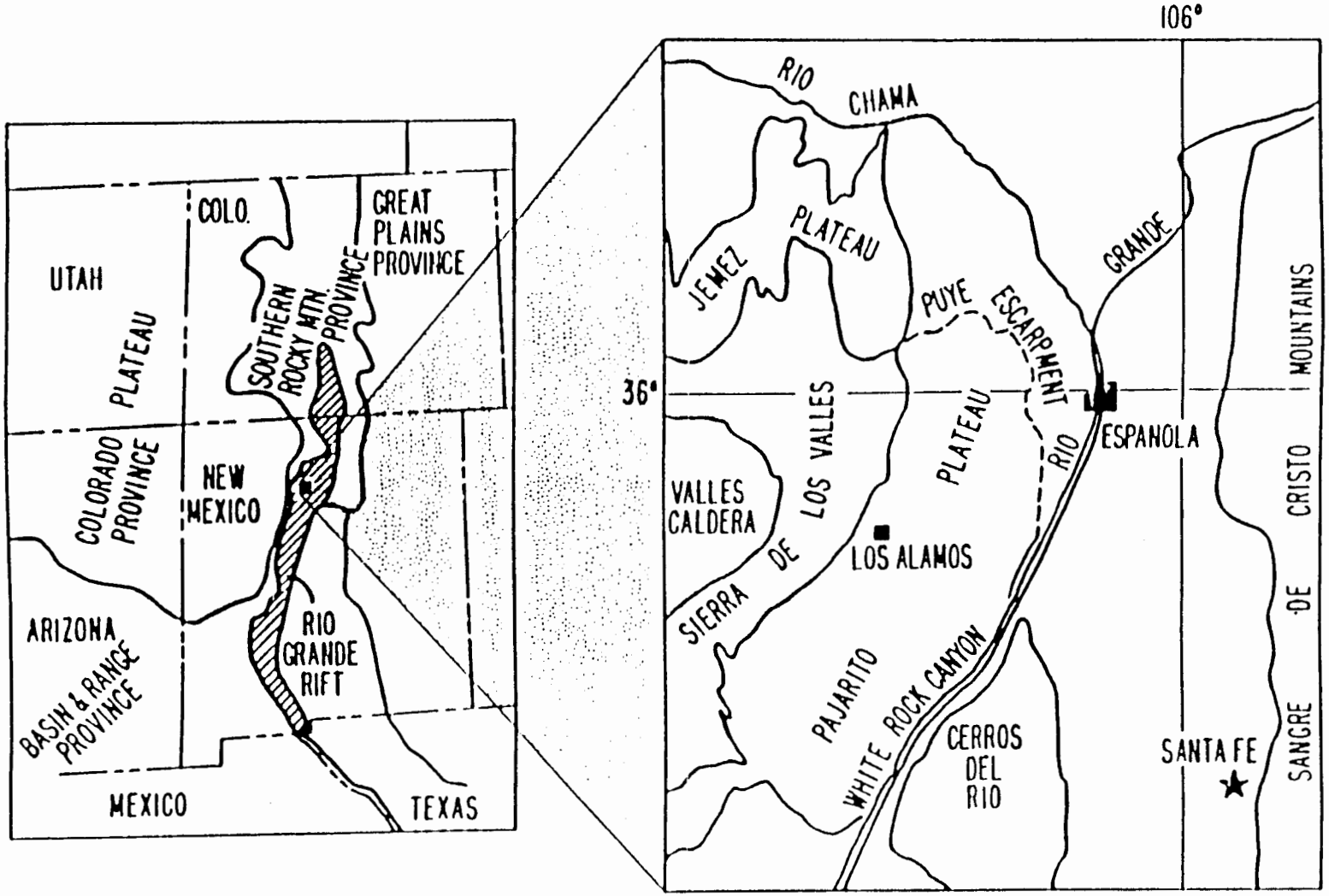


Figure 2-1. Physiographic Features Near Los Alamos (U.S. Department of Energy, 1979, as cited in Devaurs and Purtyman, 1985)

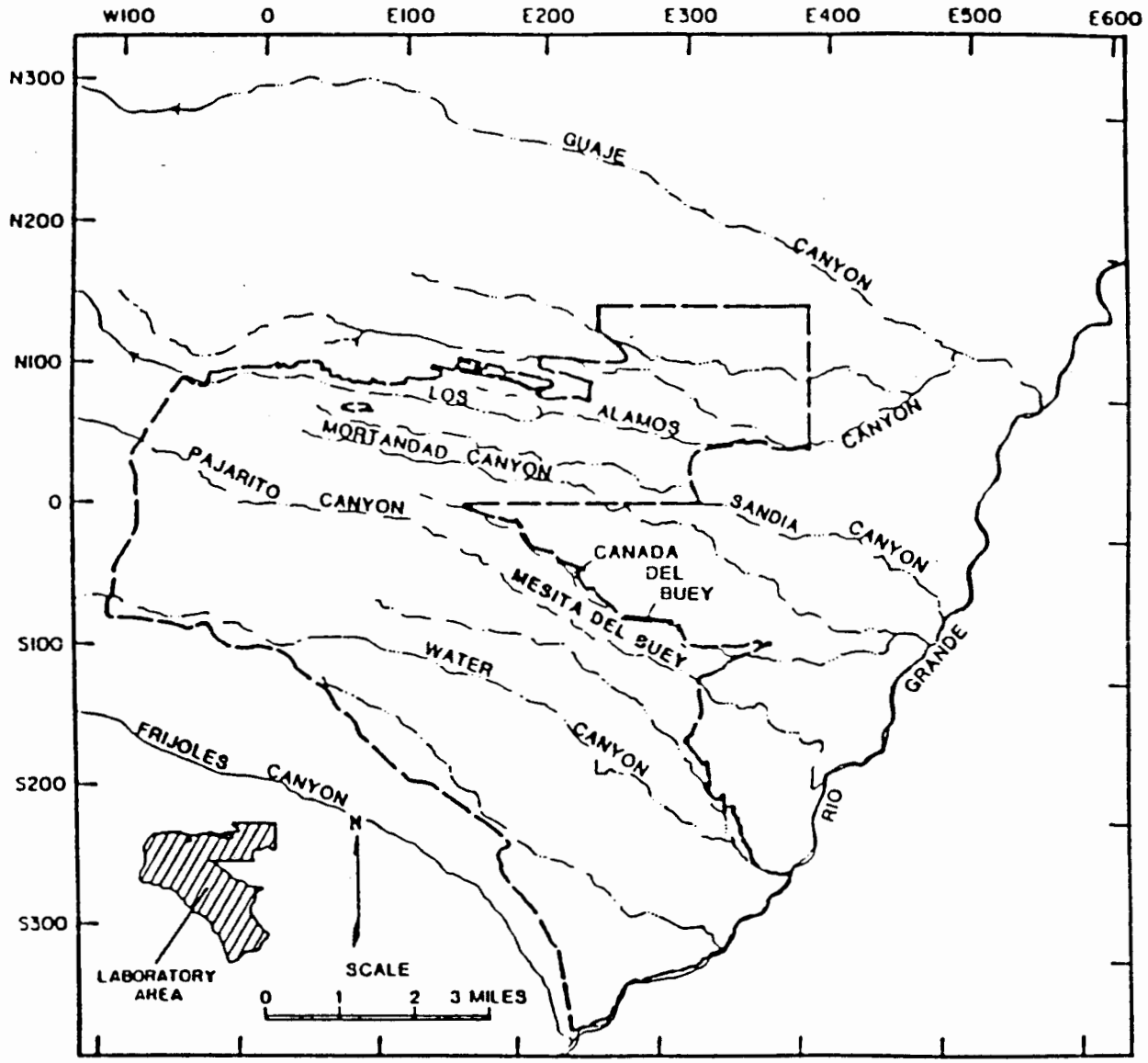


Figure 2-2. Map of Los Alamos Area Showing Various Canyons (Purtymun, 1984)

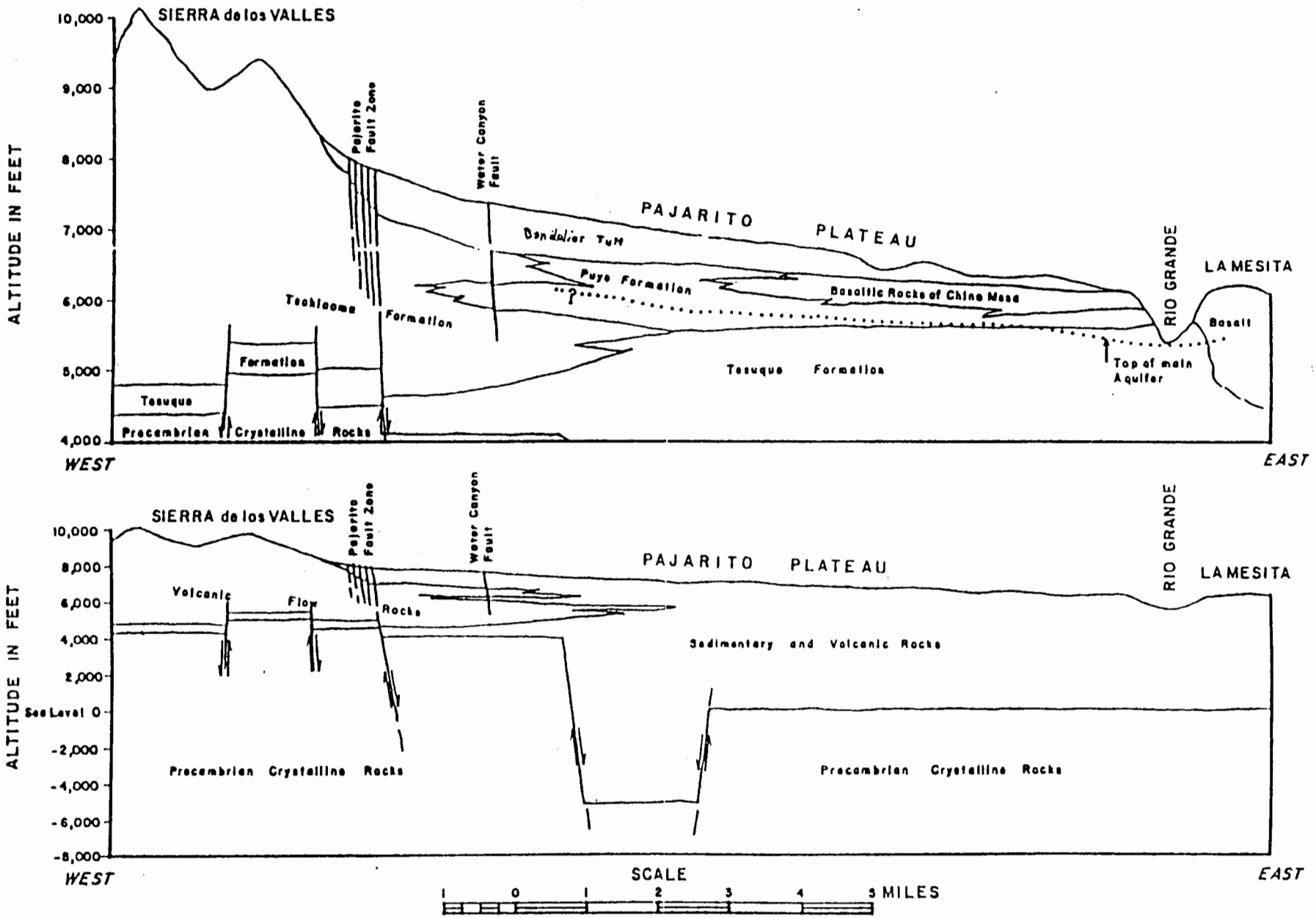


Figure 2-3. Geologic Profile Across the Pajarito Plateau (Purtymun, 1984)

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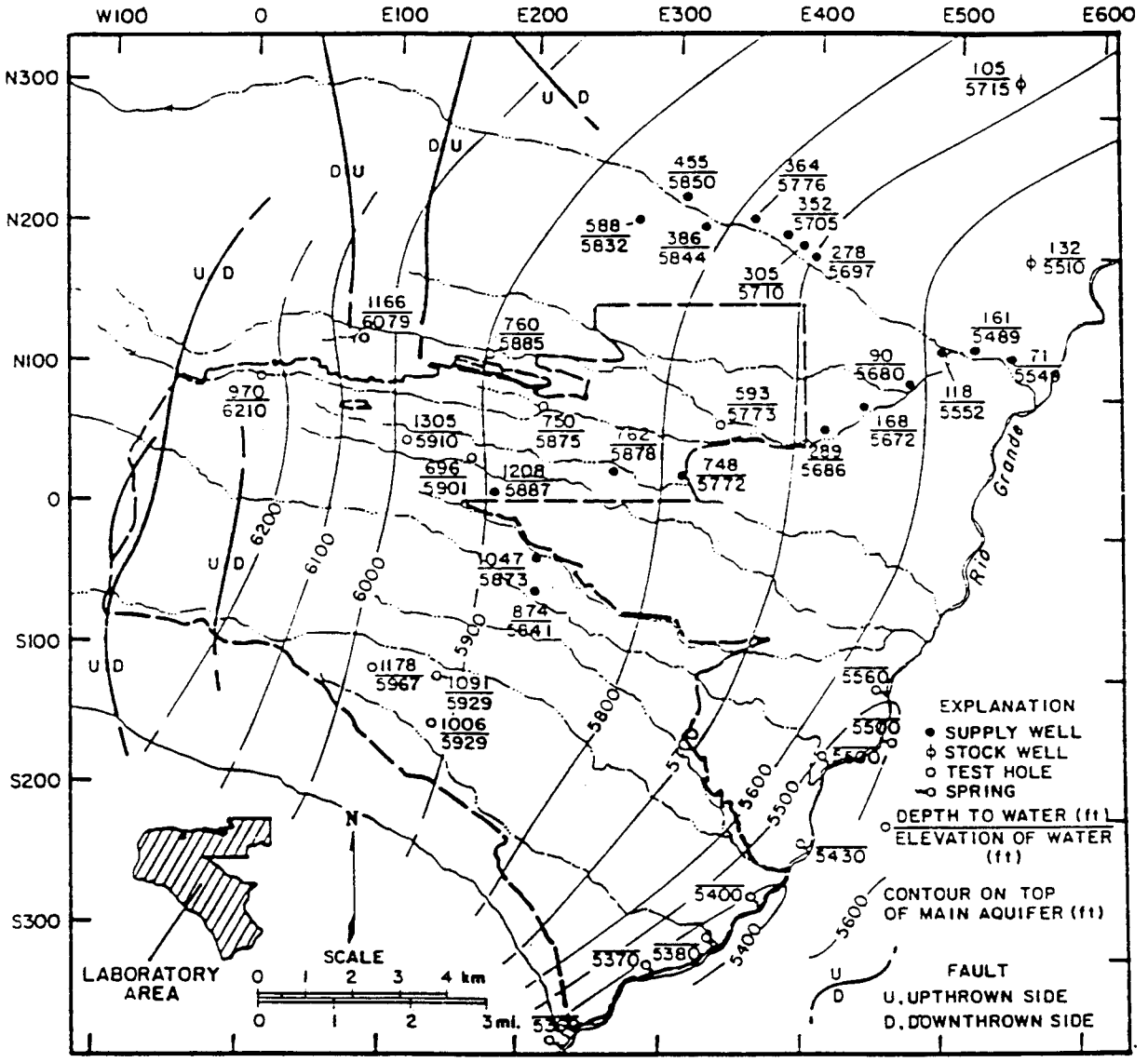


Figure 2-4. Generalized Contours on the Surface of the Main Aquifer (Purtymun, 1984)

2.1.1 Regional and Local Groundwater Aquifers

Groundwater in the Los Alamos area occurs primarily in three modes: shallow perched zones in alluvium in canyons, perched water zones at depth, and the main aquifer.

Alluvium has been deposited by intermittent stream flows in Los Alamos area canyons. These alluvium deposits range from 1-30 m thick. The alluvium deposits are very permeable in contrast to the underlaying volcanic units. Shallow alluvial groundwater aquifers result from the infiltration of water into the alluvium deposits where the downward movement of water is obstructed by less permeable units. As the water in these aquifers moves down gradient, it is depleted by evapotranspiration and movement into underlying volcanic sediments (Purtymun, 1977).

Perched water occurs in conglomerate and basalts beneath the alluvium in two areas. The first is a limited area about 40 m in the mid-reach of Pueblo Canyon. The second area is about 50-70 m beneath the surface near the confluence of the lower Pueblo and Los Alamos Canyon. This area has one discharge point, Basalt Spring in Los Alamos Canyon (Environmental Surveillance, 1987).

The main aquifer is isolated from alluvial and perched waters by approximately 110-190 m of dry tuff and volcanic sediments. Extensive earlier studies have shown that there is little hydrologic connection or potential for recharge to the main aquifer from alluvial or perched water aquifers (Devaurs and Purtymun, 1985).

The only aquifer in the area capable of providing municipal and industrial water supply is the main aquifer of the Los Alamos area. The main aquifer rises westward from the Rio Grande within the Tesuque Formation and moves into the lower part of the Puye Formation beneath the central and western part of the plateau *(Figure 2-3)* (Purtymun, 1984). The thickness of the aquifer is unknown; however the Rio Grande Depression contains over 15,000 ft of volcanic rocks and sediments that overlie the Precambrian crystalline rocks. These volcanic rocks and sediments are a potential aquifer. The saturated basin fill of the Valles Caldera recharges the main aquifer in sediments of the Tesuque Formation. The water in the aquifer moves eastward from the major recharge area in the Valles Caldera toward the Rio Grande, where a portion of the water is discharged into the river through seeps and springs. Minor amounts of recharge can occur in the mountains which flank deep canyons containing perennial streams. Intermittent streams which are cut into canyons in the plateau add little, if any, recharge to the main aquifer. The age of the water in the eastern edge of the main aquifer is dated by C-14 radiometric methods as greater than 1,400 yr (Purtymun, 1984).

The hydraulic gradient of the aquifer averages about 60 ft/mi in the Puye Formation and increases to about 100 ft/mi as water enters the less permeable sediments along the eastern edge of the Tesuque Formation.

2.1.2 Hydrology of the Pajarito Canyon Area

TA-18 is located in Pajarito Canyon. The canyon has a large drainage area that heads on the flanks of the Sierra de Los Valles to the west of the Pajarito Plateau. The alluvium in this canyon is derived from Bandelier Tuff and the Tschicoma Formation. It is composed of silts and clays, sand and gravels, and large boulders. The alluvium varies in thickness and is underlain by Bandelier Tuff (Devaurs and Purtymun, 1985). The stream following in this canyon is perennial on the flanks of the mountains across the western half of the plateau and intermittent across the eastern half of the plateau where it passes through TA-18 to the Rio Grande. There are several large borrow pits in the eastern section of the canyon where gravels and sands were once removed. These pits fill with water when there is a large volume of surface runoff in the canyon.

A study was performed (Devaurs, 1985) to determine if there were perched aquifers below Mesita del Buey (located in the mesa immediately north of Pajarito Canyon) between the mesa top and the upper surface of the main aquifer. It was determined by data collected during construction of two supply wells (wells PM-2 and PM-4) drilled into the main aquifer at Mesita de Buey that there were no perched water aquifers below it. Three test holes, two in Pajarito canyon (wells denominated "T" series), and one in Area G (test hole ST-1), were completed dry into the basalts *(Figure 2-5)* (Devaurs, 1985). Seven test holes (PCO and PCM series,) were completed through the alluvium into the top of the tuff. In spring of 1985, precipitation was estimated to be 8.3 in., compared to a 2.6 in. average over a 30-yr period (Bowen, 1985). Surface runoff was very high, and water was found in four test holes (PCO-1 to 4) in the alluvium. During construction of these four test holes, it was noted that cuttings from the underlaying tuff packed against the auger were dry, indicating little infiltration of water from the alluvium into the underlaying tuff. The remaining three test holes, drilled at the flanks of the canyon to a depth of 60-127 ft, were dry. The test holes drilling results document that perched water in Pajarito Canyon is confined to the alluvium in the stream channel and does not extend to the flank of the canyon (Devaurs and Purtymun, 1985).

2.2 Groundwater Use in the Pajarito Well Field

The well field in the area of TA-18 is the Pajarito Field, which consists of wells PM-1 through PM-5. Wells PM-1 and PM-3 supply the community of White Rock. Water from wells PM-2, PM-4, and PM-5 can also be used to supply White Rock, or the output can be lifted vertically through two booster stations (about 800 ft) into the LANL or the Los Alamos community area. Wells PM-1, PM-2, and PM-3 in the Pajarito Field produced 11,010 x 10^6 gal for the period of 1965-1982. *Table 2-1* contains production data from the

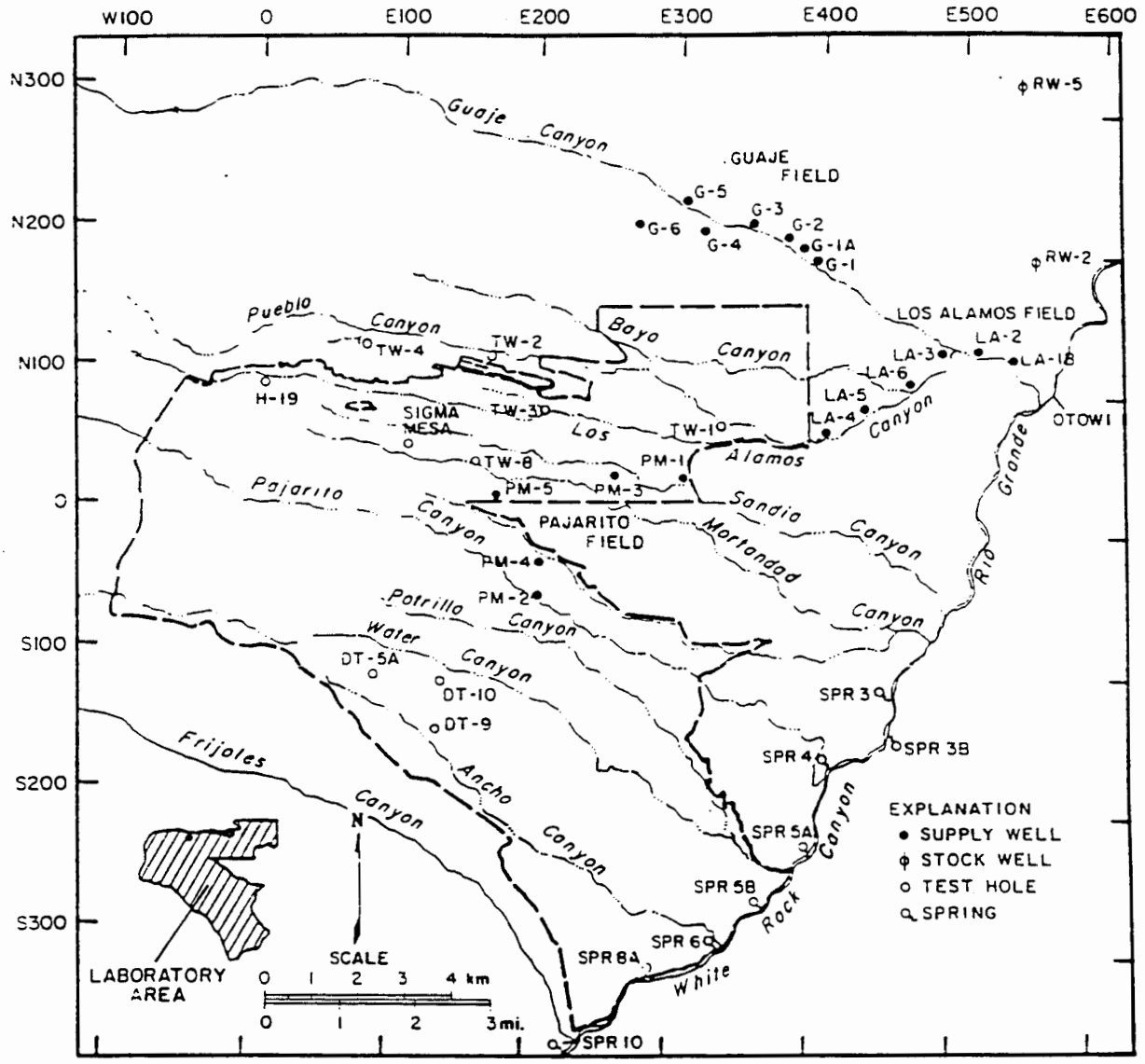


Figure 2-5. Location of Wells and Springs in the Los Alamos Area (Purtymun, 1984)

TABLE 2-1

TOTAL PRODUCTION FROM THE PAJARITO WELL FIELD BETWEEN 1947-82*

Well Number	Pumpage (10^6 gal)	Field Production (%)
PM-1	1,593	14
PM-2	5,863	53
PM-3	3,478	32
PM-4	76	1
PM-5	---	---
Total	11,010	100

* Purtymun, 1984

Pajarito well field and other well fields of the Los Alamos area. The wells in the Pajarito Field penetrated the main aquifer in the lower part of the Puye and Tesuque Formations. The saturated thickness of the Puye Formation in the Pajarito Field ranges from 50-535 ft, with an average thickness of 270 ft. The saturated thickness of the Tesuque formation ranges from 890-1700 ft, with an average thickness of 1470 ft. The average pumping rate is 1215 gpm, and the average specific capacity is 31 gpm/ft of drawdown or an average drawdown of 40 ft (Purtymun, 1984). Rate of movement of water in the combined thickness of 1740 ft of Puye and Tesuque Formations in the Pajarito Field is 95 ft/yr (Purtymun, 1984). *Table 2-2* contains average hydrologic characteristics of the Pajarito Field and other fields in the main aquifer for the Los Alamos area. Other data of note concerning the main aquifer are shown in *Figures 2-6, 2-7, and 2-8*.

TABLE 2-2

AVERAGE HYDROLOGIC CHARACTERISTICS OF THE MAIN AQUIFER IN THE LOS ALAMOS AREA*

	Saturated Thickness (ft)	Rate (gpm)	Specific Capacity (gpm/ft)	Field Coefficient of Permeability (gpd/ft^2)	Transmissivity (10^3 gpd/ft)
Los Alamos Field (Tesuque Formation)	1350	365	4.5	5.6	8.4
Guaje Field (Tesuque Formation and interbedded basalt)	1410	376	5.8	8.2	11.6
Pajarito Field (Tesuque Formation and Puye Conglomerate)	1740	1215	31	53	94
Test Hole TW-4 (Tschicoma Formation)	40	2.8	0.6	18	0.7
Test Holes DT-5A, -9, and -10 (Tesuque Formation and Puye Conglomerate)	490	82	15	83	36
Test Holes TW-1, -2, -3, and 8 (Puye Conglomerate)	60	7.9	2.1	98	4.3

* Purtymun, 1984

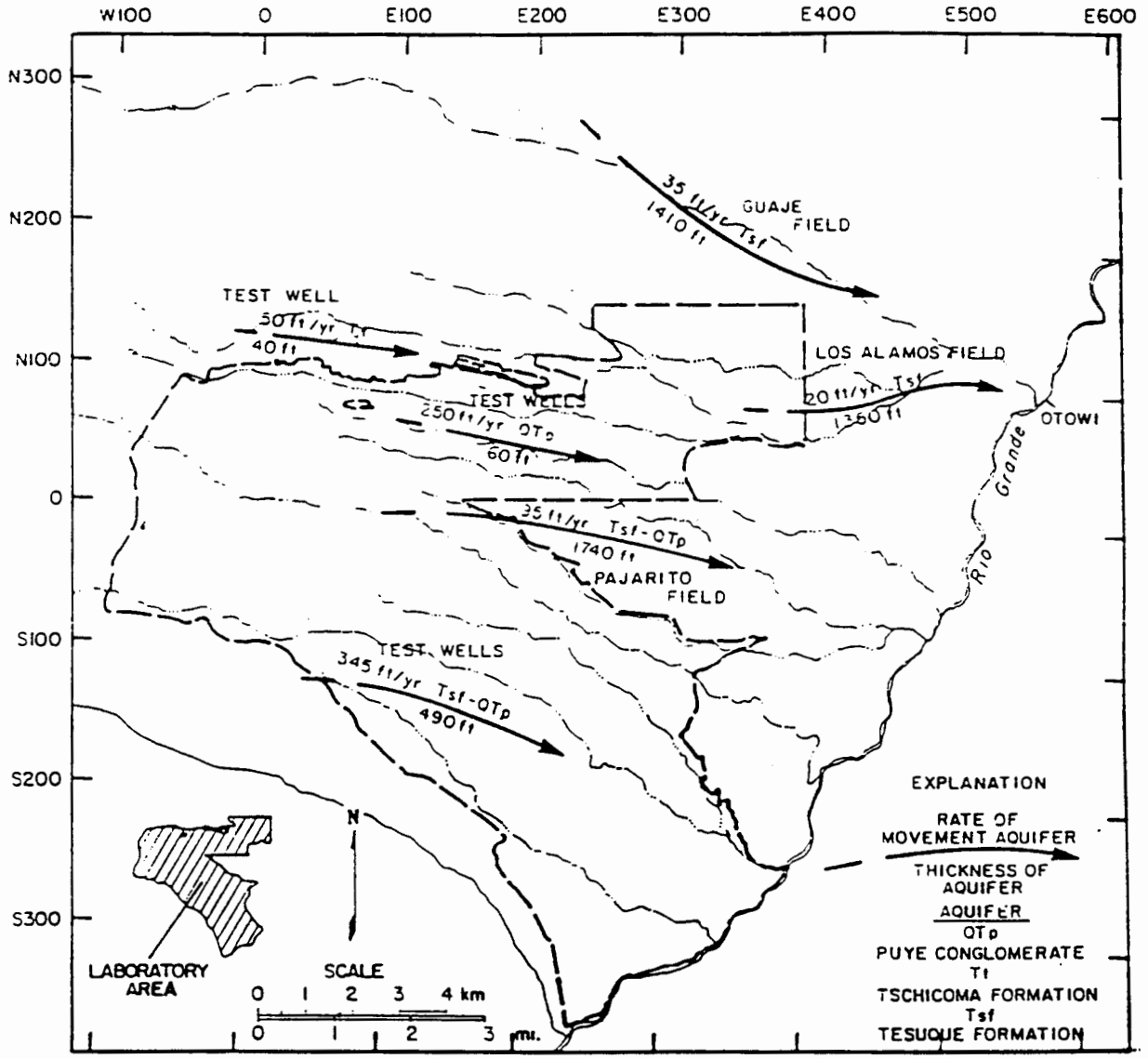


Figure 2-6. Rate of Movement of Water in the Main Aquifer (Purtymun, 1984)

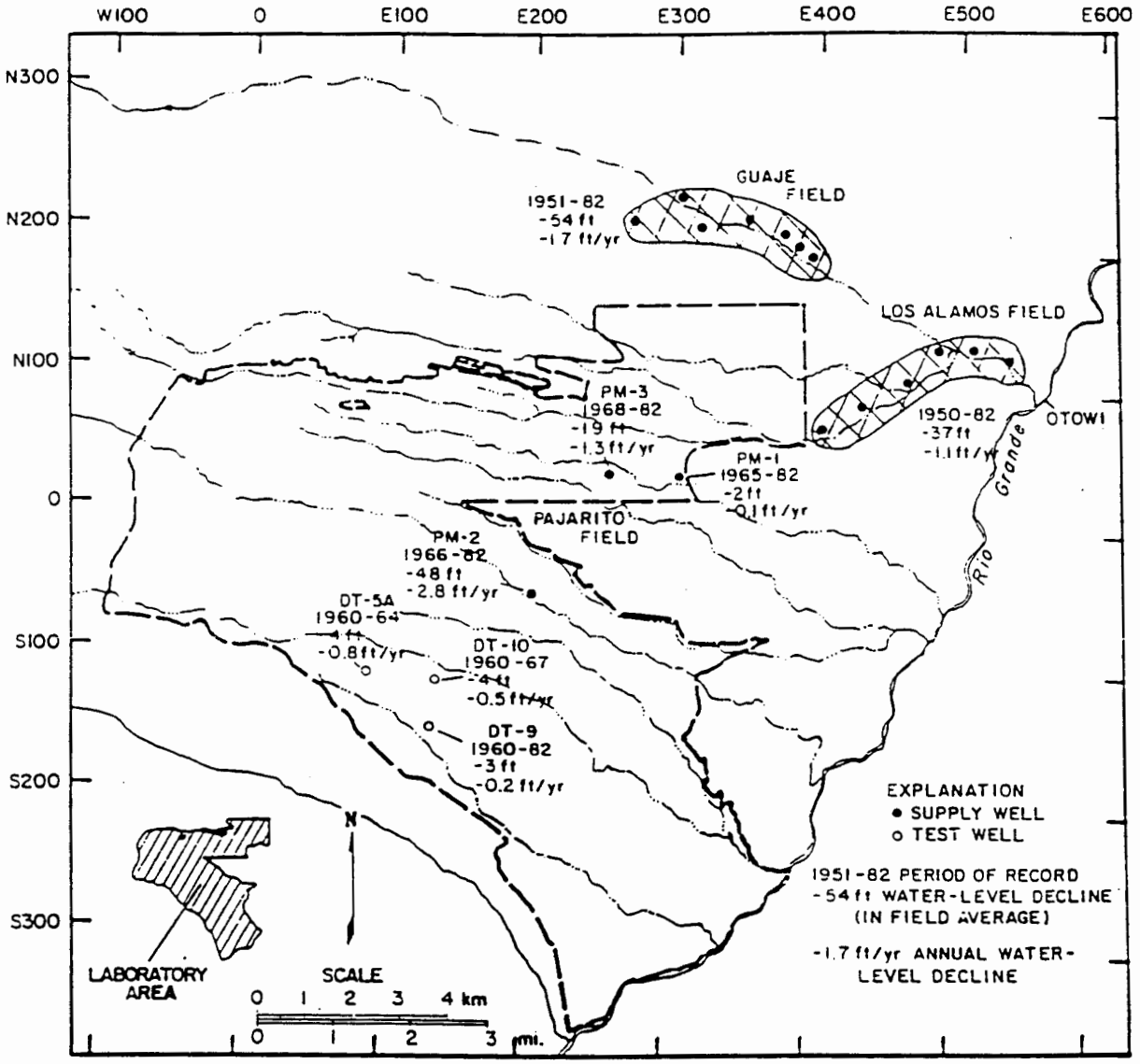


Figure 2-7. Water Level Declines in Various Wells (Purtymun, 1984)

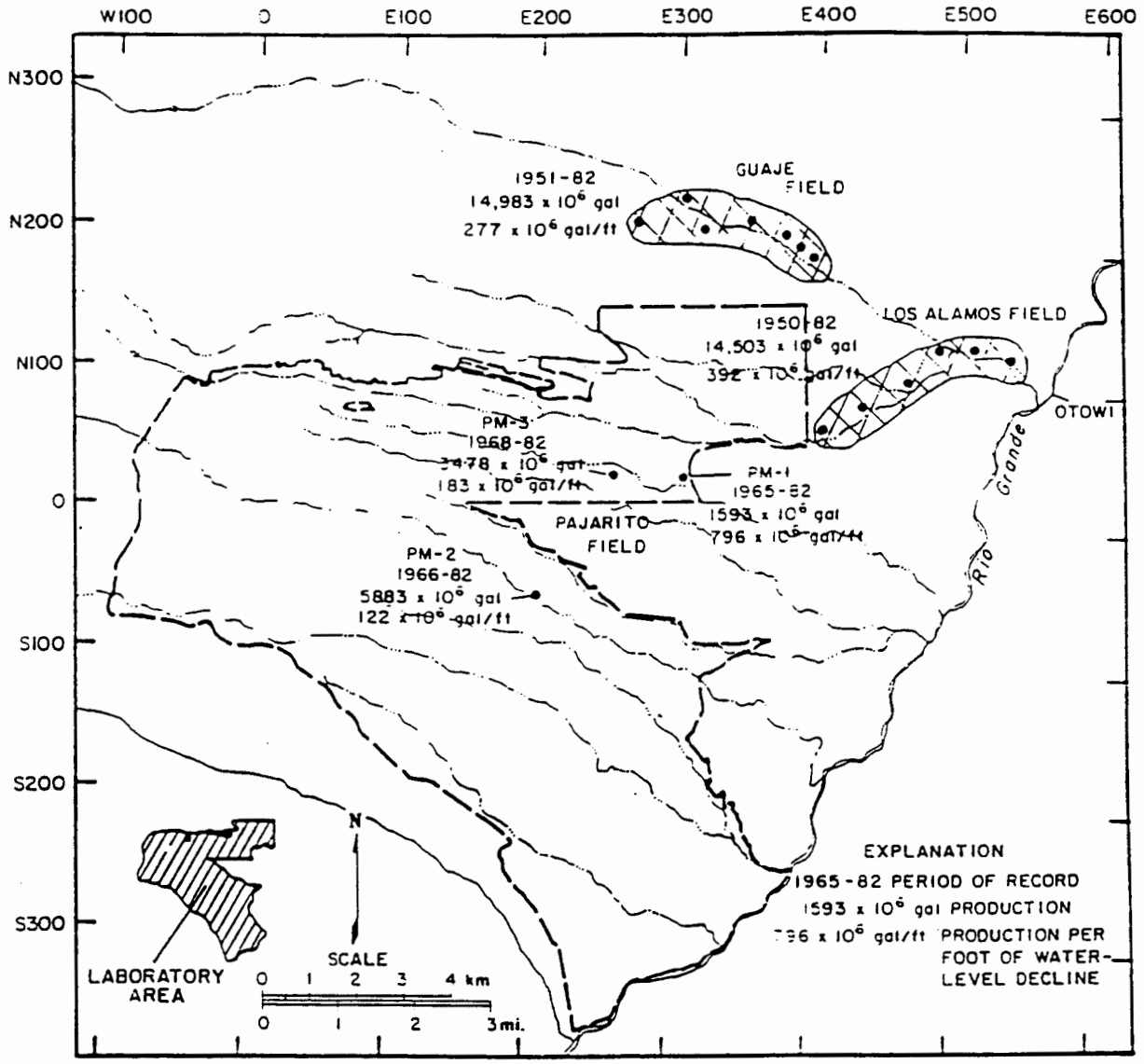


Figure 2-8. Water Level Declines Related to Production (Purtymun, 1984)

3.0 SITE INVESTIGATIONS AT TA-18

3.1 Site Geology

The LACEF building is situated on an alluvial pediment within Pajarito Canyon. While none of the monitoring wells constructed fully penetrated the alluvium, its depth probably does not exceed 35 ft in this area based on field observations. The alluvium is deposited as canyon fill, bounded on both sides by cliffs of Bandelier Tuff. Cuttings and split spoon samples indicated that the alluvium was derived from the Bandelier Tuff; no cobbles other than tuff were found. A general cross section through the Kiva 1 area is shown in *Figure 3-1*.

The alluvium was sampled at regular intervals during drilling to a maximum sample depth of 27 ft. It consists of a mixture of sandy clays, clays, sands, and clayey sands, generally reddish brown in color. Tuff cobbles are commonly found within the strata, and are usually rounded to sub-rounded, indicative of stream bed conditions. The sandy layers range from poorly sorted to well sorted. While no clear marker beds or layers were found, the general picture from all the wells indicates a highly variable, interbraided series of sandy to clayey lenses from a few inches to a foot or more in thickness, that are horizontally discontinuous. A stratigraphic profile of a typical well section is shown in *Figure 3-2*. The varied nature of the stratigraphy indicates that seasonal rises of the water table may be locally confined within the alluvium, leading to variable hydraulic conductivity and travel times within the aquifer as a whole.

The shallow water table in the alluvium appears to be highly seasonal. First signs of water were found at about 10-12 ft in each well, but these zones were unsaturated. The first saturated zones found were generally at about 20 ft. After completion and development of the wells, the static water level in the wells averaged about 15 ft below the surface. In fact, personnel at the site confirmed that during construction for the containment caisson the excavation had water in it when it approached 15 ft in depth and that the sides kept sloughing and enlarging the hole. Witnesses to the construction said that much more concrete was placed around the caisson than had been planned because of this sloughing. LANL personnel onsite also said that there is often water seeping into the basement of the administration building for TA-18, located about 400 m downgradient from the LACEF, especially in years of heavy spring runoff. This appears to indicate that annual changes of 5 ft or more in the water table may occur.

3.2 Well Construction

The basic purpose of drilling and sampling the wells was to define existing concentrations of radionuclides (i.e., of the kind that might be accidentally released during operation of the LACEF) in the soil

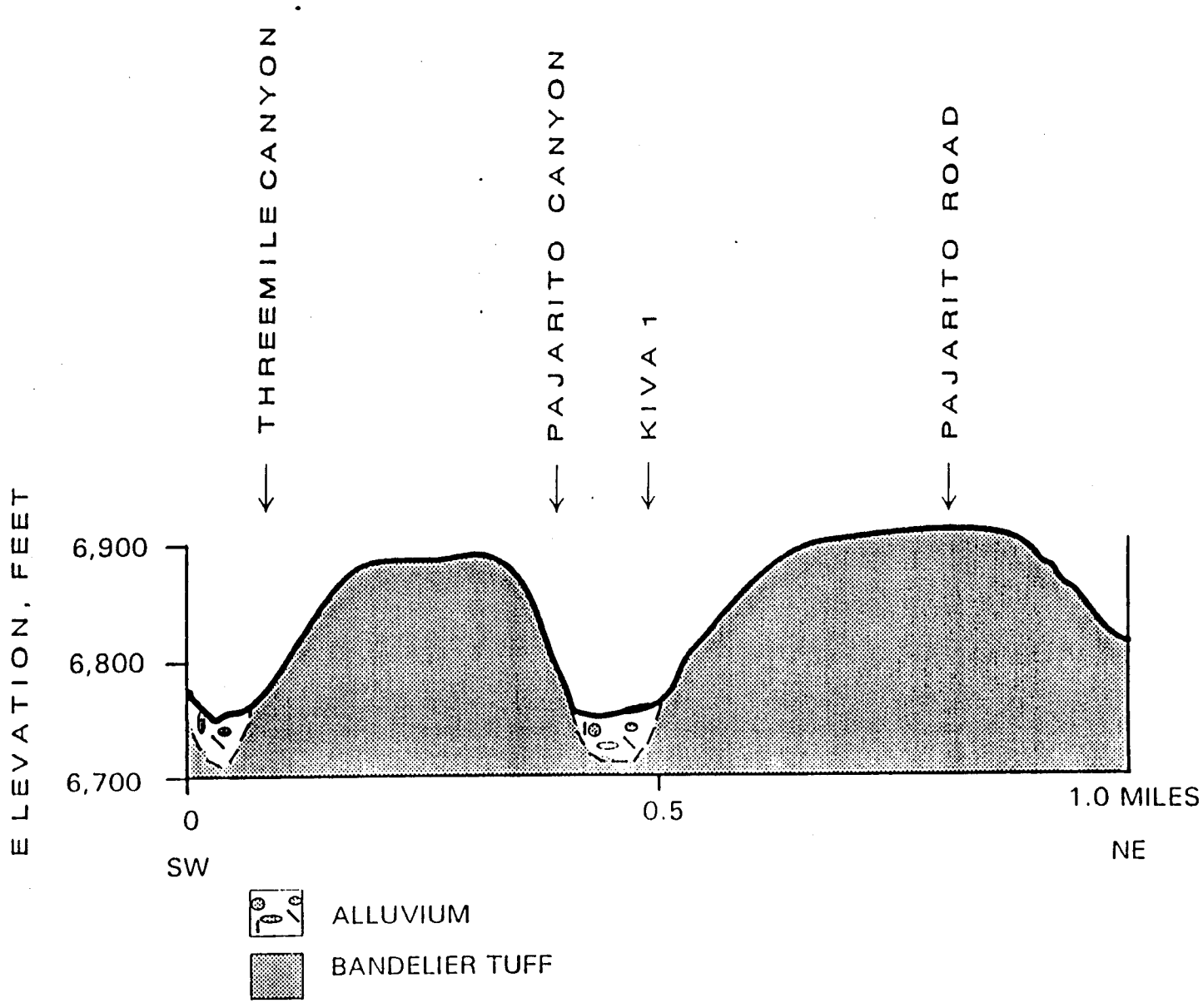
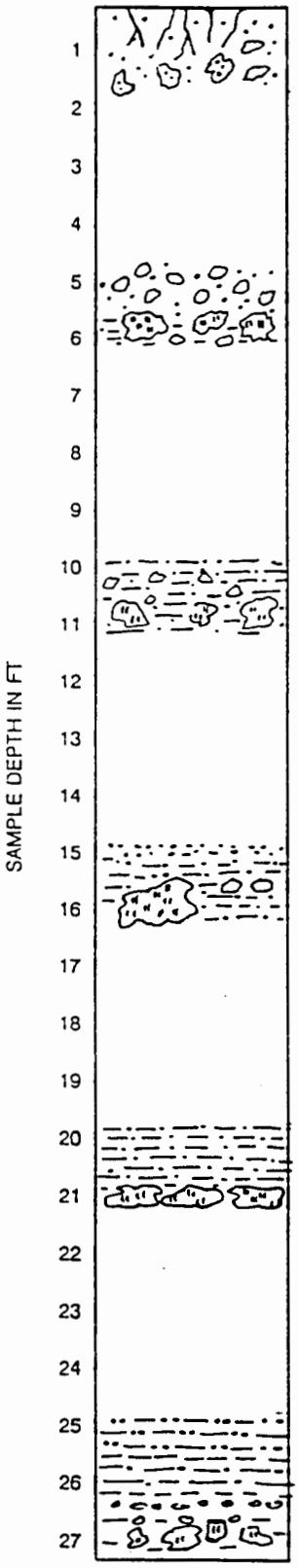


Figure 3-1. Generalized Cross Section Through the Kiva 1 Area



Dark brown sandy loam with subrounded cobbles and pebbles up to 1.5." Organic material present (roots). Tuff shards scarce. Moisture present but not cohesive. Probably fill dirt.

From 5' to 5.5' coarse sand with sub-rounded to rounded cobbles to 1" in size. Fairly dry material with virtually no clay. From 5.5' to 6.5' light brown coarse sand with large welded tuff subrounded cobbles. More clay present in this section.

From 10' to 10.5' reddish brown saturated sandy clay with subrounded cobbles to 2." From 10.5' to 11.5' coarse clayey sand with large tuff (welded) shards. This section has moisture present but not saturated.

From 15' to 16.5' coarse sand with minor clay layers, and layers of saturated clayey sand. Sand is poorly sorted. Large fragment of tuff present; some rounded cobbles present <1.5." Sample very moist except were tuff occurs.

From 20' to 21' fairly well sorted sandy clay, reddish brown in color, very saturated. From 21' to 21.5' clayey sand with tuff fragments ± 2." Clays here grade to red-purple.

From 25' to 25.5' reddish brown saturated clayey sand. From 25.5' to 26' is a lens of yellow-brown sandy clay. From 26' to 27' is a reddish brown clayey sand with rounded to subrounded cobbles of welded tuff. The 2' section was saturated.

Figure 3-2. Descriptive Cross Section of Well MW-3

and groundwater around the LACEF, and to place wells that can be used for monitoring groundwater during operation of the LACEF. The actual well locations are shown in Figure 1-1. Well MW-1 was sited up gradient to establish a baseline for soils and for groundwater arriving at the LACEF site, while the remaining three wells were placed in what was judged to be the optimal pattern for detecting any releases down gradient from the LACEF.

The drilling and well construction presented no problems, although the initial location for MW-3 resulted in intercepting a vitreous clay pipe at about 5 ft. A split spoon sampler was driven through the pipe just below the 5 ft level. At this point the well was abandoned for safety and further analytical purposes. However, it was decided to include the sample for analysis. It was later determined that this was an abandoned acid waste line from a holding tank servicing Kiva 1, designated as SWMU 18-003a under LANL's RCRA plan. Utilities drawings provided prior to drilling made no mention of the line, although research after the pipe was found turned up older drawings that did show it (Section 4.3.1).

The drilling was done with an 8 in. hollow stem auger string with a top drive rig. All holes were split spoon sampled every 5 ft with a 24 in. length spoon. Cuttings were contained in plastic bags until analyses were performed. All wells were drilled to a depth of 25 ft. Completion consisted of placing a 20 ft joint of 2 in. PVC screen to the bottom of the hole, with 2 in PVC casing to the surface. The casing and screen were thoroughly steam cleaned prior to use. The annulus was filed to within 3 ft of the surface with 10/20 silica sand and then the casing was grouted in place. A cylindrical metal well head with a cast iron cover was placed in the wet grout and set flush with the ground. A concrete collar about 2.5 ft in diameter was formed around each well head for protection against damage and water infiltration. Lockable expansion-type well plugs were placed in the top of the casing after completion. The wells were developed with a hand pump after completion, with all water contained in drums. A typical as-built well diagram is shown in *Figure 3-3*. *Figure 3-4* shows a perspective view of the wells relative to the experiment caisson.

3.3 Sampling Approach

To obtain the necessary soil samples, a split spoon sampler was driven ahead of the auger every 5 ft. The spoon was then retrieved and opened. Prior to the sample being handled, a health physics technician monitored each sample. The sample was then photographed and described before being thoroughly mixed and sieved. A 500 mℓ sample bottle was filled for each sample interval. A separate sample of river bank soil was taken on the east side of the Rio Grande about 100 m upstream from the Otowi Bridge, as an environmentally distinct control. Duplicate samples were assigned with individual sample numbers as a laboratory quality control measure.

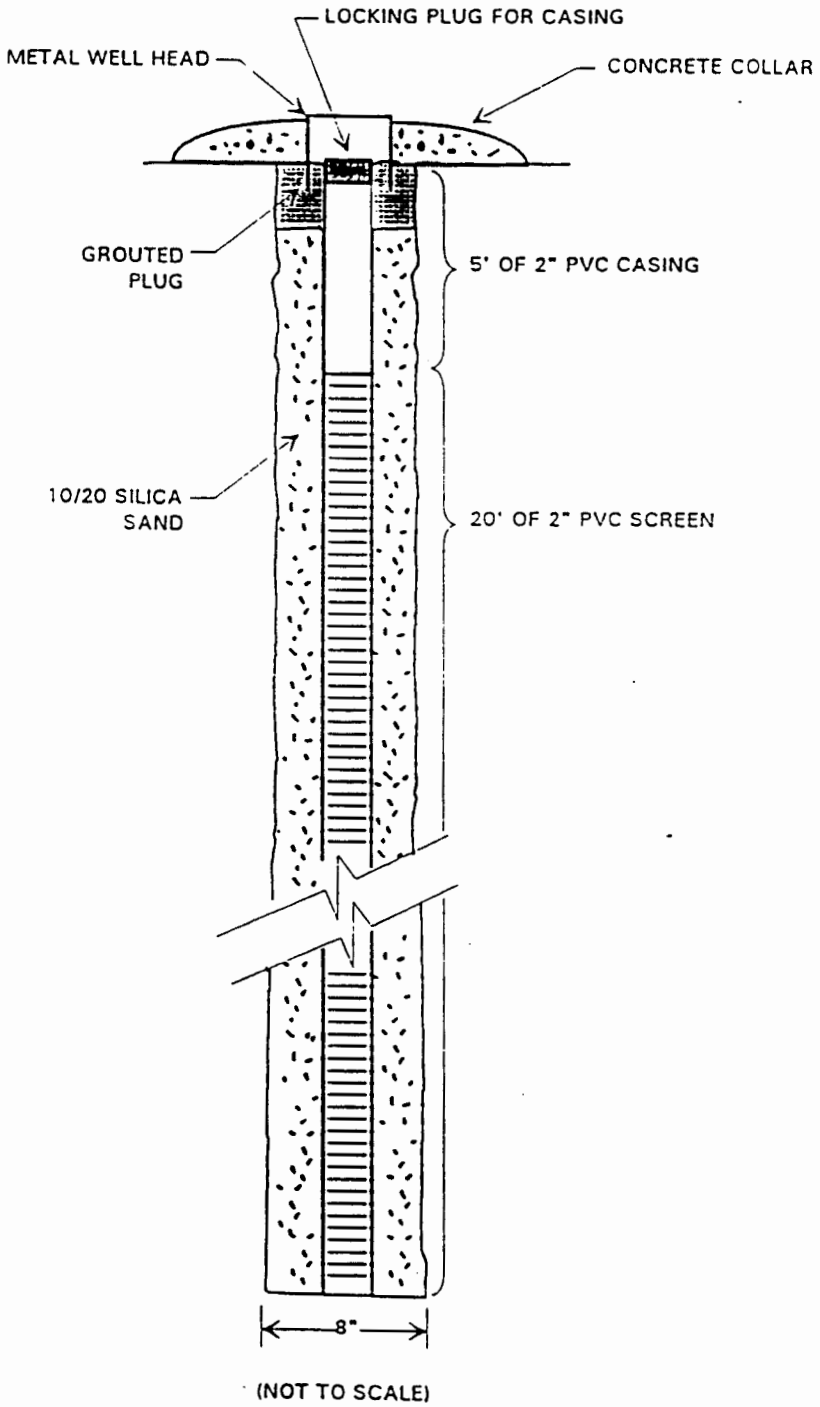


Figure 3-3. Typical Well Construction Details

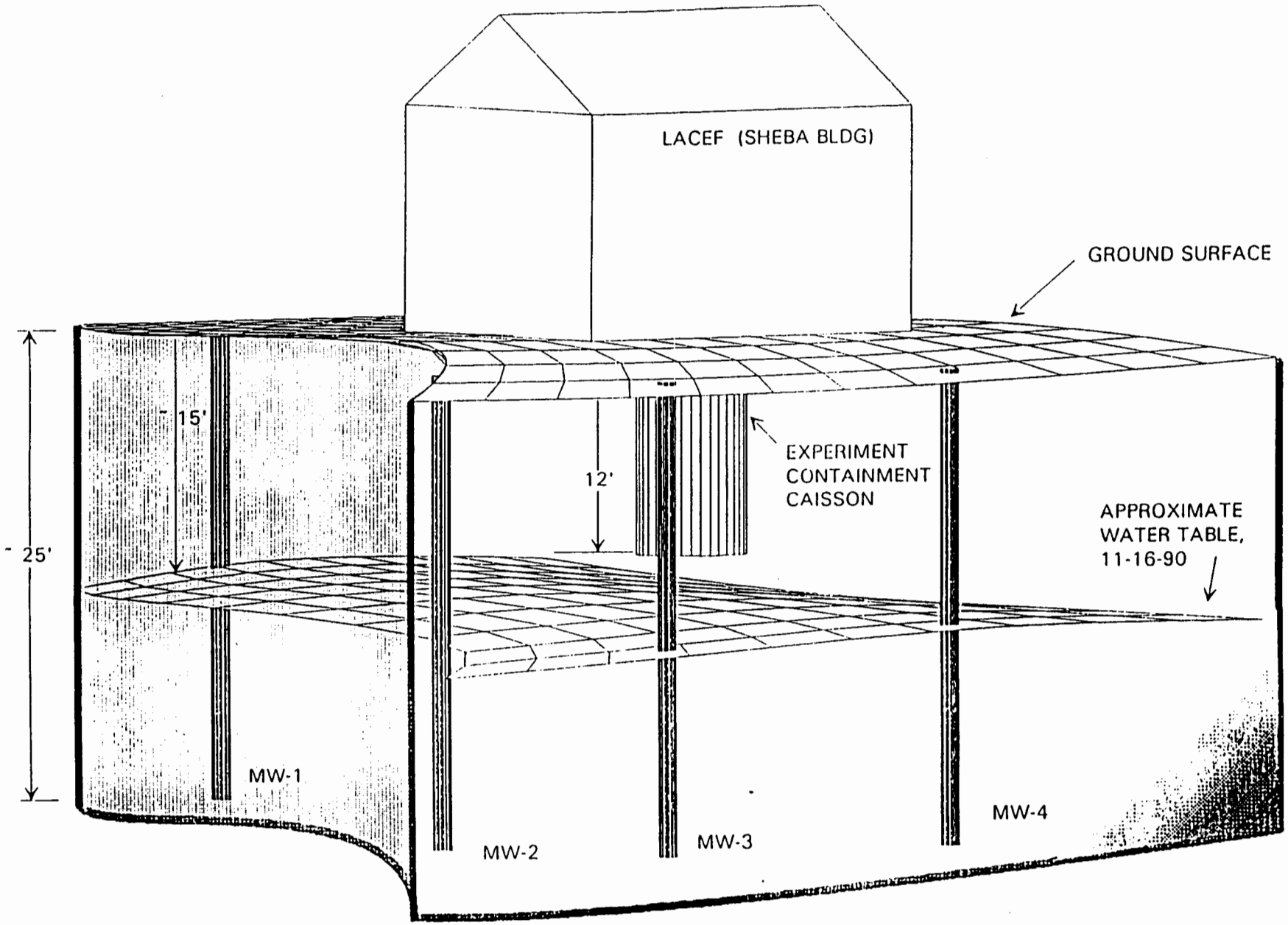


Figure 3-4. Isometric View of LACEF and Monitoring Wells, looking approximately upgradient

Water samples of 1ℓ size were collected about two weeks after well completion. Prior to sampling, the wells were bailed to help clear the sediment remaining after completion. Because some turbidity remained, the samples were filtered prior to lab analysis. In addition to one regular sample from each well, a split sample and a sample of distilled water were submitted as laboratory quality control checks.

All samples were taken to Controls for Environmental Pollution (CEP), Inc., Santa Fe, NM, for analysis of isotopic uranium, cesium, and strontium. Water samples were also analyzed for tritium. Results of the analyses can be found in Section 4.3.

4.0 ACCIDENT EFFECTS

4.1 Probable Accident Scenario

The LACEF was designed to handle liquid criticality experiments contained within the steel caisson. Radioactive materials within the caisson itself have virtually no chance of migrating to the groundwater if the caisson remains structurally sound. This leaves, however, two probable accident scenarios. If the caisson has developed a fracture, a spill of radioactive liquids within the caisson may release radionuclides into the concrete surrounding the caisson. Potential migration of radioactive material through the concrete was not examined in this study.

The second scenario involves a spill outside the caisson itself during placement of liquid into the caisson. Radionuclides in that case could enter the soil, migrate downward and outward, and possibly intercept the highly seasonal water table in the vicinity.

4.2 Potential Pathways of Groundwater Contamination

There are two potential pathways of contamination of significance in the vicinity of the LACEF facility. Spilled material on the surface could be washed into Pajarito Creek, located about 100 m southwest of the LACEF with subsequent recharge to groundwater. However, the stream bed has been channelized through the area of TA-18 with earthen berms between the buildings and the stream channel, forming a barrier to surface transport. Additionally, the stream is intermittent and usually dry except for period of peak runoff in the spring and early summer. Therefore, although Pajarito Canyon eventually discharges into the Rio Grande below White Rock, it is considered very unlikely that any surface transport of radionuclides into the watercourse would occur. The approximate water table surface for the existing conditions is shown in Figure 3-4.

The second potential pathway of a spill would be introduction into the subsurface or downward migration through the soil, intercepting the shallow, perched water table present in the canyon alluvium. The seasonal nature of the water table makes this pathway more likely than runoff contamination in Pajarito Creek. Although definitive tests to determine the precise axis of flow of the shallow groundwater through the alluvial aquifer were beyond the scope of this project, wells MW-2, MW-3, and MW-4 were located to intercept groundwater flow past the LACEF from the most likely directions of transport. As was discussed earlier, other studies have shown that there is no hydraulic connection between the perched canyon aquifers and the main aquifer supplying municipal uses. There are no wells drawing from the alluvial aquifer downgradient from the LACEF. Therefore, any accidental release of radionuclides allowed to reach the perched aquifer should have no measurable effect on any downgradient groundwater users.

4.3 Geochemical Characteristics of Soil and Water

This part of the investigation consists of analysis to determine the concentration of radionuclides (^{137}Cs, ^{90}Sr, ^{234}U, ^{235}U, ^{238}U, and for water, H_3) in soil and water that have the potential to be transported, sorbed, and dispersed by the hydrogeologic environment.

For the purpose of this discussion radionuclide concentrations measured in well MW-1 will be referred to as the "on-site background level." This well is located hydrologically up gradient from the LACEF facility and represents the groundwater composition before exposure to the LACEF facility. Radionuclide concentrations measured in the environmental background sample will be referred to as the "off-site background level." This sample was collected near the Otowi Bridge in an alluvial terrace.

4.3.1 Soil Analyses

Radionuclide concentrations for ^{137}Cs, ^{90}Sr, ^{234}U, ^{235}U, and ^{238}U in soil are shown in *Table 4-1*. Analytical results at or near the detection limits may not be actual concentrations.

Concentrations of ^{137}Cs are uniform in the four wells with concentration decreasing slightly with depth but averaging 0.015 pCi/g. This variation may be due to the concentration of cesium cations in the clay-rich top soil, since the ^{137}Cs cation is firmly fixed by clay minerals. Compared to the concentration of ^{137}Cs in the environmental background sample, the concentration of ^{137}Cs in the wells is at background levels. *Figure 4-1* shows radionuclide concentrations as a function of depth.

Concentrations of ^{90}Sr decrease slightly with depth (0.15 pCi/g) in MW-1 and MW-2, and increase in MW-3 and MW-4. This variation can be a signature of the heterogeneity of the alluvium (see Figure 3-2). In spite of the variation, ^{90}Sr concentrations in MW-2, 3, and 4 are similar to the on-site background level (MW-1), and all but one measurement is similar to the off-site background level. Colloidal and clay fractions strongly sorb ^{90}Sr, and therefore it is easily retarded in an environment such as the one in this investigation.

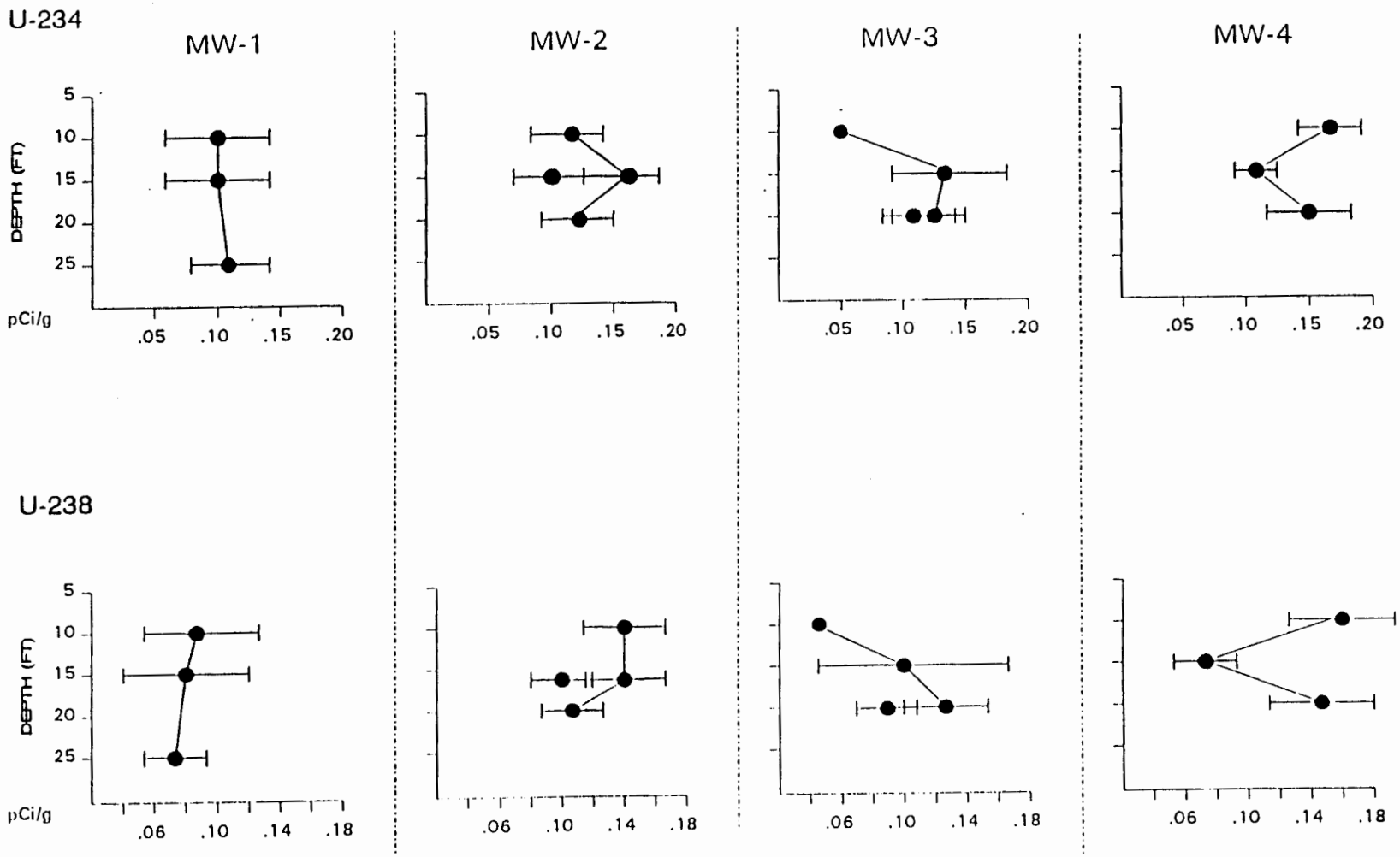
Concentrations of ^{234}U and ^{238}U vary with depth in the four wells, with a range of 0.05-0.17 pCi/g. The concentration of ^{234}U and ^{238}U is slightly higher in the down gradient wells than in either the on-site up gradient well or the off-site background samples. The slightly higher concentration of the sample collected in the abandoned hole may be attributable to the waste products flushed from the tank designated SWMU 18-003a (Section 3.2). ^{235}U concentrations were less than the detection limit of 0.05 pCi/g in all samples.

TABLE 4-1

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES (pCi/g)

Well Number	Well Depth (ft)	Element				
		^{137}Cs[a]	^{90}Sr[b]	^{234}U[c]	^{235}U[c]	^{238}U[c]
MW-1	10.0-11.25	<0.05	0.35 ± 0.09	0.10 ± 0.03	<0.05	0.10 ± 0.02
	15.0-16.75	<0.03	0.17 ± 0.07	0.10 ± 0.03	<0.05	0.08 ± 0.03
	25.0-27.0	<0.03	0.16 ± 0.08	0.11 ± 0.03	<0.05	0.07 ± 0.02
MW-2	10.0-11.5	<0.06	0.13 ± 0.06	0.13 ± 0.03	<0.05	0.14 ± 0.03
	15.0-16.25	<0.05	<0.05	0.10 ± 0.03	<0.05	0.10 ± 0.02
	15.0-16.25	<0.02	<0.05	0.16 ± 0.03	<0.05	0.14 ± 0.03
	20.0-21.5	<0.04	<0.05	0.12 ± 0.03	<0.05	0.11 ± 0.02
MW-3	10.0-11.25	<0.04	0.15 ± 0.08	<0.05	<0.05	<0.05
	15.0-16.25	<0.03	0.48 ± 0.09	0.14 ± 0.05	<0.05	0.11 ± 0.06
	20.0-21.5	<0.02	0.27 ± 0.09	0.11 ± 0.03	<0.05	0.13 ± 0.03
	20.0-21.5	<0.03	0.12 ± 0.07	0.12 ± 0.03	<0.05	0.09 ± 0.02
MW-4	10.0-11.25	<0.04	0.13 ± 0.06	0.17 ± 0.03	<0.05	0.16 ± 0.03
	15.0-16.5	<0.03	0.25 ± 0.07	0.10 ± 0.02	<0.05	0.07 ± 0.02
	20.0-21.0	<0.03	0.22 ± 0.08	0.15 ± 0.03	<0.05	0.15 ± 0.03
AH[d]	5.0-6.5	<0.03	0.14 ± 0.12	3.11 ± 0.15	0.10 ± 0.03	1.56 ± 0.11
Background[e]		0.04 ± 0.03	0.21 ± 0.08	0.09 ± 0.03	<0.05	0.07 ± 0.03

a. Equipment used on these samples had a minimum detection limit of 0.1 pCi/g.
b. Equipment used on these samples had a minimum detection limit of 0.03 pCi/g.
c. Equipment used on these samples had a minimum detection limit of 0.05 pCi/g.
d. An abandoned hole (AH) was also tested.
e. Sample was collected at the Otowi Bridge area.

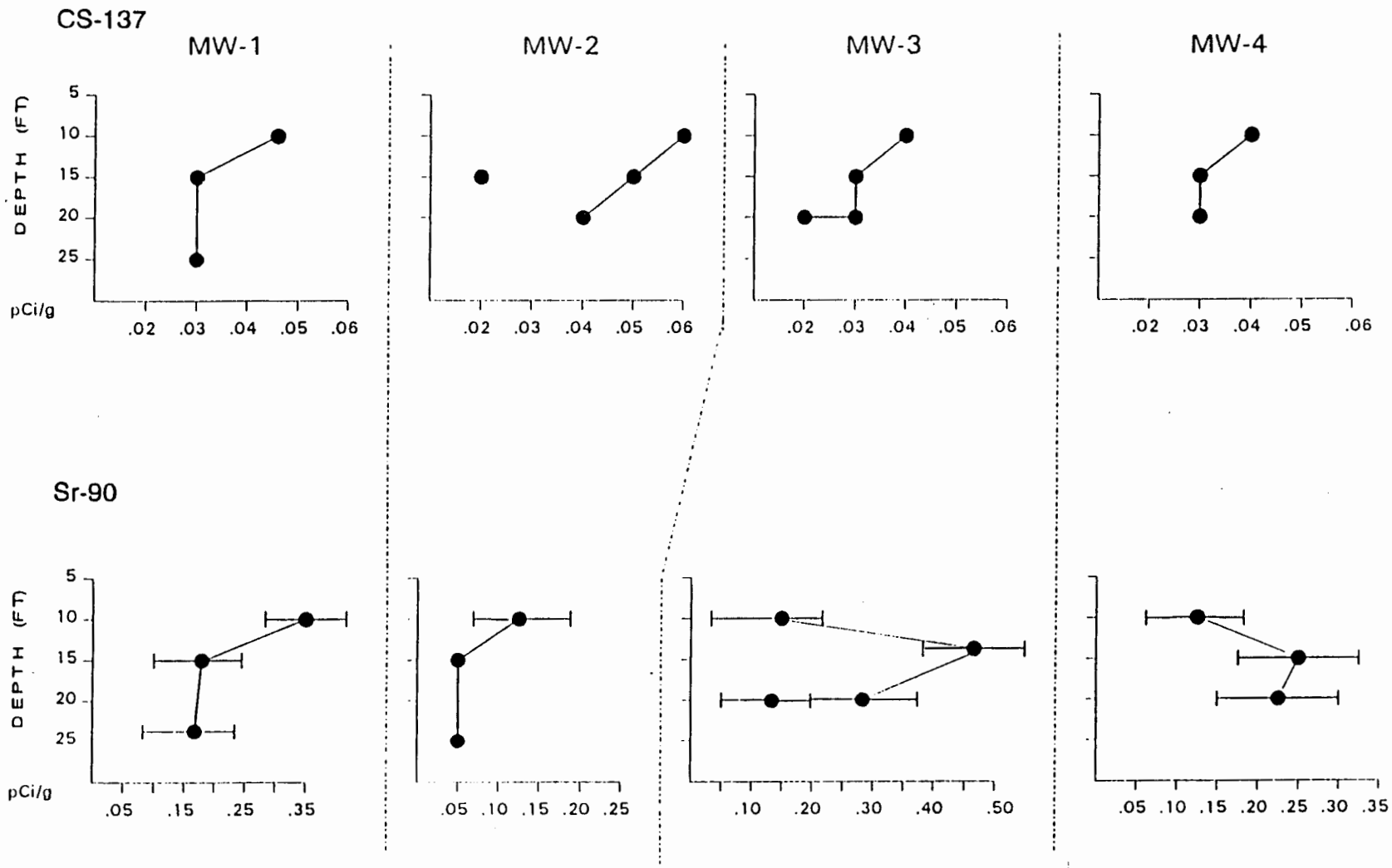


● = ANALYTICAL RESULT (Two dots at same depth indicate duplicate samples.)

⊢⊣ = ERROR LIMITS

Note: Dot locations are representative only. See Table 4-1 for actual concentration values.

Figure 4-1. Radionuclide Concentrations in Soil (continues)



● = ANALYTICAL RESULT (Two dots at same depth indicate duplicate samples.)

⊢⊣ = ERROR LIMITS

Note: Dot locations are representative only. See Table 4-1 for actual concentration values.

Figure 4-1. Radionuclide Concentrations in Soil (continued)

4.3.2 Water Analyses

Analytical results for ^{137}Cs, ^{90}Sr, H_3, ^{234}U, ^{235}U, and ^{238}U, and in water (*Table 4-2*) indicate that all concentrations are below detection limits.

TABLE 4-2

RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLES*

Element	pCi/liter
^{137}Cs	<5.0
^{90}Sr	<0.5
H_3	<500.0
^{234}U	<0.6
^{235}U	<0.6
^{238}U	<0.6

* Samples were taken from MW-1, MW-2, MW-3, MW-4, and a background sample of distilled water. Split samples were done on water from MW-3 and MW-4.

4.3.3 Geochemical Conclusions

The radionuclide concentrations measured in both soil and water were either below detection limits or within background levels in the down gradient wells. This indicates that previous activities in the vicinity of the LACEF have had no impact in the down gradient hydrogeologic environment. The elevated uranium concentrations in the soil samples found in the down gradient wells may be due to the SWMU located immediately up gradient from these wells. Further studies would be needed to determine the ion-exchange (sorption) and dispersion characteristics of the aquifer.

4.4 Hydraulic Conductivity, Hydraulic Gradient, and Transport Rates

The well data shown in ***Table 4-3*** allow for estimating the rate of transport of any isotope introduced into the groundwater as a result of experiment activities with the LACEF. Table 4-3 lists the data gathered on the four wells.

TABLE 4-3

MONITORING WELLS DATA AS OF NOVEMBER 16, 1990

Well Number	Total Depth (ft)	Dept to Water Level (ft)	Well Head Δ Elevation (ft)	Water Level Δ Elevation (ft)	Hydraulic Conductivity K (ft/day)
MW-1	25.42	14.50	0.0 *	0.0 *	0.021
MW-2	26.50	16.00	-0.42	-1.08	0.021
MW-3	26.50	15.83	-0.50	-0.83	0.012
MW-4	26.08	14.83	-0.25	-0.08	0.035

* MW-1 was used as the elevation reference.

The hydraulic gradient (total head difference/length) is quite shallow. Calculating the hydraulic conductivity (K) from the results of a modified slug test yields a mean value of 0.022 ft/day (0.007 m/day). While this value falls within the expected range of K values of 0.001 to 0.10 m/day for clay, sand, and gravel mixes (Bouwer, 1976), it should be considered only an approximation. Because of the multitude of factors not studied in this project (e.g., sorption rates, seasoned water table changes), the hydraulic conductivity calculated is only an order of magnitude approximation. More extensive well tests would be necessary to give a precise number to the hydraulic conductivity.

The scope of work involved here did not include examination of any of the vertical components of radionuclide migration or long-term pumping tests necessary for calculation of the volume rate of flow for this perched aquifer. Longer-term monitoring data, transport modeling, and additional aquifer testing would develop a more complete picture of the annual behavior of the aquifer.

5.0 MONITORING

5.1 General Considerations

The variability of the alluvium and the highly seasonal nature of the perched aquifer are the most important considerations in designing a functional, long-term monitoring plan for the LACEF site. Other than the results of this project, there is little data available to predict the overall behavior of the perched aquifer. The results in this report give a close estimate of the conditions in the aquifer at the time the data were gathered, but this should be viewed as a "snapshot" rather than the overall picture. Data gathered at different times of year can be expected to vary considerably. The measured effective hydraulic conductivity, or K, is a function of the depth of the water table and the transmissivity of the individual lenses comprising the alluvial aquifer. The depth of the water table is dependent on the annual weather cycle, which can be expected to vary too, depending on both snow pack levels and summer precipitation in the upper Pajarito Canyon drainage area, and the volume and duration of runoff.

Monitoring the behavior of this alluvial aquifer over time, rather than at just one point in time, will help in developing a model for the dynamic nature of the shallow groundwater aquifer. This model, in turn, will assist in more accurate prediction of contaminant release transport times at any time of year. In fact, modeling may result in recommendations for the timing of operations to allow maximum mitigation of any potential accident release. This information would be very valuable, not only for the Pajarito Canyon area, but also for operations concerned with groundwater contamination in canyon aquifers elsewhere in LANL's areas of responsibility.

5.2 Recommended Monitoring Plan

Options are available for long-term monitoring at TA-18. The minimum level of effort recommended is a regular program of static water level measurement and rate-of-rise tests. These tests and measurements should be done at least bi-weekly during the spring and summer and monthly in fall and winter. K values should be calculated and data tabulated to chart seasonal fluctuations.

Because of the highly variable behavior of groundwater, more extensive testing and experimentation should be carefully considered. Recommended options include

- design and execution of more precise aquifer tests to derive a more accurate number for hydraulic conductivity, and calculation of additional groundwater parameters and coefficients.

- laboratory testing to determine sorption coefficients for the specific soils found at the LACEF site relative to the radionuclides of concern.

- drilling of more wells in a pattern at the site to allow development of injection well tests using tracer elements and direct measurement of some of the calculated parameters.

- additional exploratory drilling to determine the exact profile of the alluvium in the vicinity of TA-18.

- more frequent (or constant) monitoring during and immediately following conduction of experiments at the LACEF.

6.0 REFERENCES

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APPENDIX: CALCULATION METHOD AND DRAWDOWN DATA

A.1 Calculation Method for Hydraulic Conductivity

Because of the geometry and nature of the constructed wells, it was decided to use a modified slug test or "rate-of-rise test" to approximate the hydraulic conductivity of the perched aquifer.

The basic data were gathered using an electric well sounder to measure the static water level in each well after several undisturbed days. The wells were then rapidly bailed with a hand bailer to lower the water level as much and as fast as possible. The water level rise was measured at set time increments.

The calculation method used was developed by Bouwer (1976). The well geometry is shown in Figure 3-3. The equation is

$$K = \frac{r_c^2 \ln (R_e / r_w)}{2L_e} \frac{1}{t} \ln \frac{y_o}{y_t}$$

where

- K = hydraulic conductivity,
- R_e = effective radial distance over which the head is dissipated,
- r_w = radial distance between well center and undisturbed aquifer,
- L_e = height of screened section through which groundwater enters,
- y_o = y at time (zero),
- y_t = y at time (t), and
- t = time since y_o.

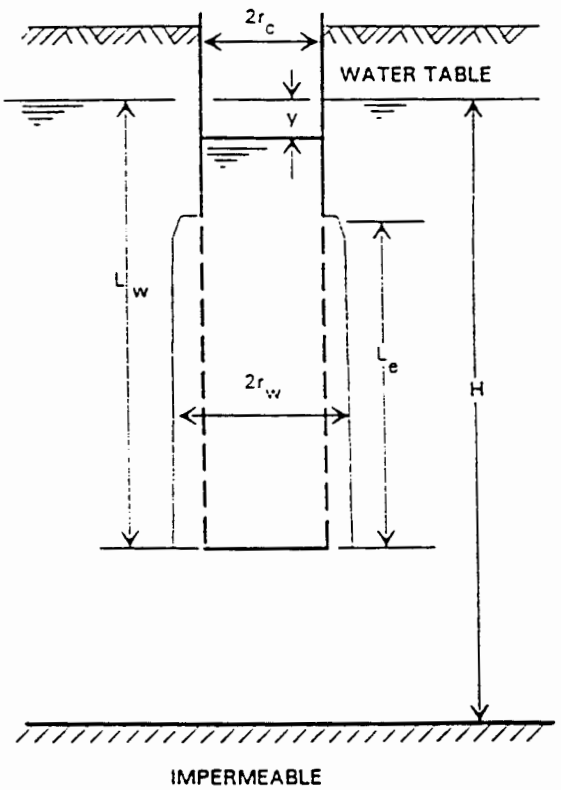
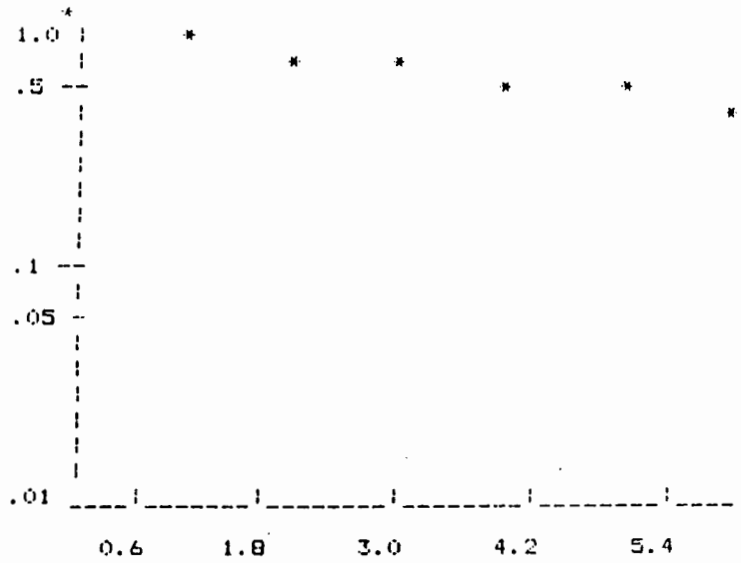


Figure A-1. Well Geometry Used in Calculations

A.2 Plots of Drawdown Data from Slug Tests

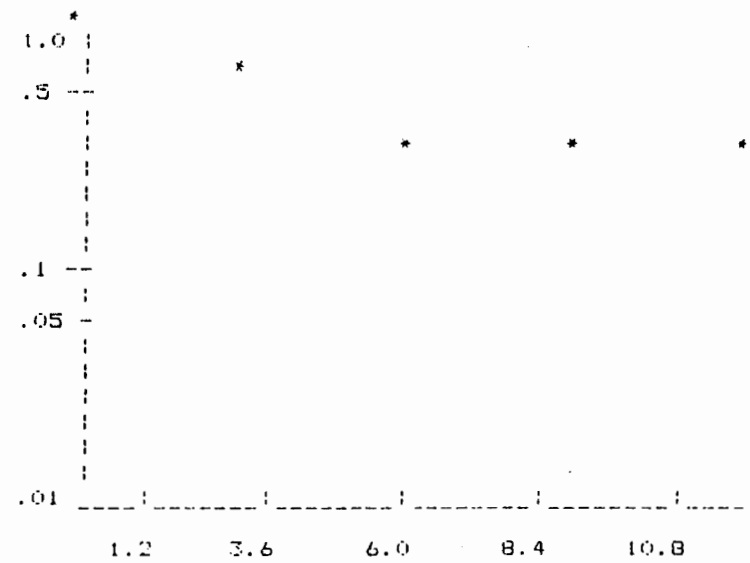
The printouts in this section show a semi-logarithmic plot and accompanying data from the well tests (Thompson, 1987).



REGRESSION COEFFICIENT = -.9954867

Test Results for MW-1 TEST DATA

TIME (seconds)	WATER LEVEL (feet)	DRAWDOWN (feet)	H/HO
0	17.33	2.83	1
60	16.83	2.33	.8233216
120	16.58	2.08	.7349823
180	16.25	1.75	.6183745



REGRESSION COEFFICIENT = -1

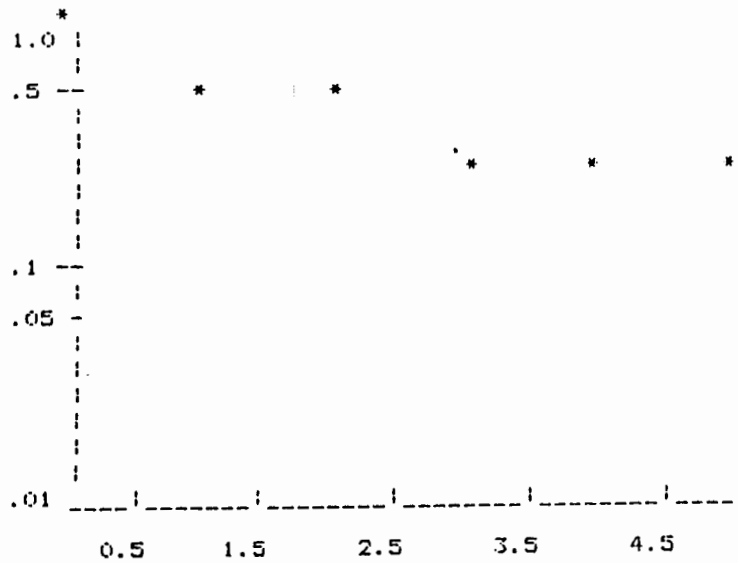
Test Results for MW-2 TEST DATA

TIME (seconds)	WATER LEVEL (feet)	DRAWDOWN (feet)	H/HO
0	18	2.00	1
180	17.17	1.17	.585

X AXIS:
TIME, min

Y AXIS:
LOG(H/HO)

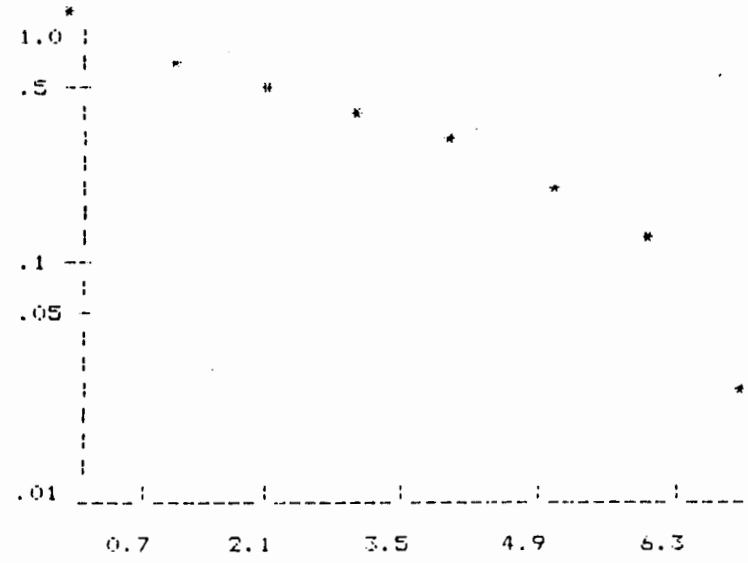
Figure A-2. Plots of Well Drawdown Data (continues)



REGRESSION COEFFICIENT = -.9476515

Test Results for MW-3 TEST DATA

TIME (seconds)	WATER LEVEL (feet)	DRAWDOWN (feet)	H/HO
0	16.58	0.75	1
60	16.17	0.34	.4533332
120	16.17	0.34	.4533332
180	16	0.17	.2266666



REGRESSION COEFFICIENT = -.9984602

Test Results for MW-4 TEST DATA

TIME (seconds)	WATER LEVEL (feet)	DRAWDOWN (feet)	H/HO
0	17.83	3.00	1
60	17	2.17	.7233333
120	16.5	1.67	.5566667
180	16	1.17	.39

X AXIS:
TIME, min

Y AXIS:
LOG(H/HO)

Figure A-2. Plots of Well Drawdown Data (concluded)