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INITIAL ASSESSMENT OF THE GROUND WATER MONITORING PROGRAM AT LOS ALAMOS NATIONAL LABORATORY, NEW MEXICO

W.J. Stone

Ground Water Protection and Remediation Bureau

Teri D. Davis

and

Danny Katzman

Hazardous and Radioactive Materials Bureau

NEW MEXICO ENVIRONMENT DEPARTMENT

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INTRODUCTION

SETTING

Los Alamos National Laboratory (LANL) is located west of the Rio Grande in Los Alamos County, 40 mi northwest of Santa Fe (Figure 1). Geologically, it sits on the Pajarito Plateau, an area of deeply dissected Quaternary-aged volcanic deposits and Tertiary fill of the Espanola Basin (Figure 2). The volcanics belong primarily to the Bandelier Tuff, largely rhyolitic ash flows and pumice falls that were derived from the Valles Caldera in the Jemez Mountains to the west. The basin fill is represented by the Puye Conglomerate (fanglomerate, lake clays, basalt flows, and ash and river gravels) and the Tesuque Formation (mostly poorly-consolidated sand and gravel). The average elevation of the resulting finger-like mesas is approximately 7,000 ft. The area is drained by ephemeral and intermittent streams that flow easterly to the Rio Grande, lying some 1,450 ft below the Plateau (Figure 3). Regional ground-water flow is also generally eastward except near the well fields.

BACKGROUND

The Department of Energy (DOE) Oversight Program of the New Mexico Environment Department (NMED) was initiated in October 1990. The Ground Water Protection and Remediation Bureau (GWPRB) and the Hazardous and Radioactive Material Bureau (HRMB) are the two NMED entities responsible for oversight of ground-water issues at the DOE facilities in the state. In the case of Los Alamos National Laboratory, this involves one position in the GWPRB and three positions in the HRMB. These were all staffed in early to mid 1992.

This report satisfies deliverable X.A.B.1, Action No. 8 of the DOE/NMED Agreement in Principle (AIP): "the state will review the current ground-water monitoring system and identify any modifications or improvements needed to meet applicable laws and regulations." Additionally, suggestions are offered regarding the effectiveness of the annual surveillance reports prepared by LANL. Comments herein are meant to be general in scope; detailed, site-specific recommendations are given in reviews of the various Operable Unit work plans as well as in reviews of waste management unit monitoring plans and systems.

This initial evaluation of LANL's ground-water monitoring effort involved three steps. First, the potential sources of ground-water contamination were identified and generally located on maps of the lab. Next, a general conceptual hydrogeologic model for the region was formulated. This model was based on LANL's model, existing hydrogeologic information (largely published), briefings and field trips given by LANL staff, interviews with present and former LANL employees, and independent observations. Finally, the adequacy of the monitoring network was evaluated, based on the location, number, and quality of monitoring sites relative to potential pollution sources and the hydrogeologic system, as well as the quantity and quality of monitoring parameters. Specific activities are documented in the GWPRB's quarterly reports and the HRMB's monthly reports.

POTENTIAL GROUND-WATER POLLUTION SOURCES

DOCUMENTATION

Radioactive and hazardous waste has been generated and disposed of at LANL since the Lab's inception in 1943 (Kelly, 1975). Twenty-three Materials Disposal Areas (A, B, C, D, E, F, G, H, J, K, L, M, N, P, Q, R, S, T, U, V, W, X, and Y; Figure 4) were identified by Rogers (1977). All such sites are considered potential sources of ground-water contamination. Some of these disposal sites have been characterized in considerable detail by previous workers. Kelly (1975) summarized burial conditions and environmental monitoring at eight of these Areas (A, B, C, D, E, F, G and T) in conjunction with an evaluation of monitoring efforts at LANL. Rogers (1977) made an invaluable and exhaustive two-volume compilation of the history and environmental setting of the same Areas covered by Kelly. Volume I includes background (historical) information on the site, the geologic and hydrologic setting, type of waste involved, and the mode of disposal. Volume II consists of Appendices including a list of photos, slides and engineering drawings, the Lab's solid radwaste management policy, the guidelines for disposal pit construction, and records of disposal in Tech Area 54, Area G shafts.

Waste-disposal sites were identified by LANL (DOE, 1987) as part of the Comprehensive Environmental Assessment and Response Program (CEARP), under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund). A Resource Conservation and Recovery Act (**RCRA**) Facility Assessment (**RFA**), conducted by A.T. Kearney (1987) for the Lab, provided additional information on Solid Waste Management Units (**SWMUs**) at LANL. In 1988, a draft SWMU report, providing "reasonably available" information, was submitted to the Environmental Protection Agency (EPA), pursuant to Title 40, Code of Federal Regulations, Part 270.14.d (40 CFR270.14d). The 1988 draft SWMU report was revised by International Technology Corporation under contract to LANL and includes an update on SWMU's identified at the Lab (IT Corporation, 1990). The 1990 report identifies 537 SWMU's located in 50 active and former Technical Areas. As of this writing, the number of potentially contaminated sites recognized is approximately 2,000. Many of these are minor and LANL estimates that 90-95% of these will be handled under Voluntary Corrective Actions or No Further Action proposals.

An additional possible source of ground-water contamination is the historic and current practice of discharging liquid waste (NPDES-permitted) in canyons near the northern boundary of the Lab. According to the latest Surveillance Report (for 1990; Environmental Protection Group, 1992), four areas have received industrial or sanitary effluents: DP-Los Alamos (**DP-LA**), Sandia, Mortandad, and Acid-Pueblo Canyons.

DP-LA Canyon received treated industrial (including radioactive) and sanitary effluent between 1952 and 1984. The effluent, together with natural runoff, resulted in a shallow body of perched ground water in the alluvium of LA Canyon. Sandia Canyon received cooling tower blowdown and treated sanitary effluent from TA-3. The stream in the canyon is perennial for a short distance downstream of the outfall in the upper canyon. No perched ground water has been identified in the alluvium of the lower canyon. Mortandad Canyon receives radioactive liquid waste from TA-50. This maintains a perched ground-water body in the alluvium on the canyon floor. Purtymun (1974) found this water moves at a rate ranging from 59 ft/d in upper reach to 7 ft/d in the lower reach of the canyon. Elevated NO_3, Pu, and tritium (^3H) have been identified in Mortandad Canyon. Acid-Pueblo Canyon received radioactive effluent from 1944 to 1964 and receives treated sanitary effluent from the Los Alamos County Bayo Canyon sewage treatment plant. In 1990, the sewage effluent produced flow in lower Pueblo Canyon and into Los Alamos Canyon for most of the year. However, subsequent sampling in the canyon indicated that Pu values were below detection and ^3H content was at background level, which is very near its detection limit.

CONCERNS/RECOMMENDATIONS

As this is the initial review of the ground-water program at LANL, this report primarily addresses basic concerns regarding potential sources of ground-water contamination:

1. Regarding location of potential sources of ground-water contamination, the 1990 Environmental Surveillance Report contains no map of known disposal areas. Evaluation of monitoring efforts at LANL would be greatly facilitated if the major disposal areas (not individual SWMU's) were generally indicated (along with monitoring sites and water-level contours) on a single map in future Environmental Surveillance Reports. This would likely require a larger plate (preferably at a scale of 1:24,000) folded in a pocket at the back of the report.

2. A biannual update on disposal activity at all these areas should be prepared. Such reports should cover the same topics addressed by Rogers (1977).

3. It is a cause for concern that a large number of the potential sources of contamination are located in the vicinity of high fault/fracture density (Wachs and others, 1988), near cliffs, and in canyon bottoms.

Subsequent assessment reports by the NMED will address site-specific concerns.

CONCEPTUAL HYDROGEOLOGIC MODEL

PREVIOUS WORK

Oversight at LANL is facilitated by the existence of a sizable body of reference materials and the availability of most of them in LANL's Environmental Restoration Program Records Processing Facility in Los Alamos. The citations below are not intended to be exhaustive, but rather to indicate representative important works.

Major sources of geologic information on the Pajarito Plateau include reports by Theis and others (1950), Griggs (1964), Purtymun (1966), Smith and others (1970), Crowe and others (1978), and Kelley (1978). Most of these include mapping. The most detailed (1 inch = 400 ft), and only Lab-wide geologic map is unpublished (Rogers, 1981).

Numerous published works report on various aspects of the hydrologic system associated with the Pajarito Plateau. Many of these reports treat the system strictly from a water-supply point of view (Theis and Conover, 1962; Griggs, 1964; Cushman, 1965; Cooper and Purtymun, 1965; Purtymun and Cooper, 1965, 1969; Cushman and Purtymun, 1975; Purtymun and others, 1980; Purtymun, 1984; Purtymun and Stoker, 1988). The water supply at Los Alamos has been carefully documented in a series of annual reports by Purtymun, and Purtymun and others dating back to 1972 (Purtymun, 1984). Modeling of the ground-water system near Santa Fe by McAda and Wasiolak (1988) includes the Los Alamos area.

Some reports, however, do focus on hydrogeologic considerations in radwaste disposal or monitoring at the Lab (Weir and others, 1962; Weir and Purtymun, 1962; John and others, 1966; Purtymun, 1966, 1973a, b; Devaurs, 1895; Purtymun and others, 1974, 1989; Anonymous, 1990; Penrose and others, 1990; Stoker and others, 1991). The spread of radioactive contamination in specific canyons or Tech Areas was addressed by Baltz and others (1963), Purtymun (1974), Devaurs and Purtymun (1985), Purtymun and Stoker (1987), and Stoker and others (1991).

LANL's CONCEPTUAL MODEL

As many of the reports listed above were done by or for the Lab, they are the basis for LANL's conceptualization of the regional hydrologic system. The key elements, as summarized in the 1990 Surveillance Report, are as follows.

1. Ground water occurs in three situations:

    a) perched water in alluvium in canyons,

    b) perched water in basalts and sedimentary units of the Puye Conglomerate, and

    c) beneath the regional water table in the main aquifer.

2. The alluvium on canyon floors is recharged by surface-water runoff.

3. The main aquifer consists of the Tesuque Formation and the lower parts of the overlying and intertonguing Tschicoma Formation (in the western part of the Pajarito Plateau), and the Tesuque Formation and overlying Puye Conglomerate (in the central and eastern parts of the Pajarito Plateau).

4. Water in the main aquifer is separated from that in the shallow alluvium and other perched systems by 250 - 620 ft of unsaturated tuff and sediments.

5. There is little or no recharge of the main aquifer from the mesas, the shallow alluvium, or other perched ground water.

6. The main aquifer is recharged in the Valles Caldera, west of the Lab.

7. Ground water in the main aquifer flows easterly until discharging to the Rio Grande.

LANL's conceptual hydrogeologic model is shown diagrammatically in Figure 5.

Site specific studies undertaken by the Lab have added to the understanding of the relationship of the complete hydrologic system. For example, the study of Mortandad Canyon by Stoker and others (1991) enhanced the conceptualization of the so-called "shallow alluvium aquifer":

1. Saturation is confined to a relatively thin zone, extending 5 - 20 ft above the contact of the alluvium with the underlying Tshirege Member of the Bandelier Tuff.

2. The area of saturated alluvium extends from the treatment plant (TA-50) outfall SWMU 50-051) to a point approximately 2 miles down canyon.

3. Thickness of the saturated zone decreases towards the canyon margins.

4. Since 1960, the saturated portion of the alluvium aquifer has neither changed significantly in size nor moved down canyon (eastward).

Reportedly, tritium was found at a depth of approximately 200 ft within the Bandelier Tuff. Other radionuclides had apparently moved only a few feet beneath the alluvial aquifer. No organic contaminants were detected above, in, or below the perched water in the alluvium.

CONCERNS/RECOMMENDATIONS

Again, as this is the initial assessment, the focus is on very basic questions. The adequacy of the monitoring network at LANL depends to a very large extent on the accuracy of the conceptual hydrogeologic model upon which it is based. In his evaluation of environmental monitoring at LANL, Kelly (1975) concluded that further hydrogeologic data were needed to design an effective monitoring system. Although some progress has been made in this area, there are still concerns about LANL's conceptual model, the hydrogeologic data base, and the presentation of surveillance information.

1. The recharge area(s) for the main aquifer under the Pajarito Plateau has not been clearly identified. Most RCRA operating permits, closure plans, and annual surveillance reports

state that "major recharge to the main aquifer is from the intermontane basin of the Valles Caldera in the Jemez Mountains west of Los Alamos", following Purtymun (1974). The water-level map published by the Lab does suggest a recharge area to the west. The Pajarito fault zone at the west edge of the plateau could provide a pathway for some of this recharge. However, stable-isotope data suggest that some component of recharge occurs at elevations higher than available in the Jemez Mountains (Goff and Sayer, 1980). The Sangre de Cristo Mountains have been suggested as the site of these higher elevations. Further work is needed on this matter.

2. Maps published by the Lab show that the main aquifer is generally unconfined, except in a wedge-shaped area near the central part of Los Alamos County. Since unconfined conditions suggest connection with the surface (i.e. atmospheric conditions occur at the water table), the common contention in operating permits and work plans, that the Bandelier Tuff is an impermeable barrier to recharge, does not seem to be valid over most of the plateau. Further work is needed to resolve this issue.

3. Perched water beneath the Bandelier Tuff suggests that there is recharge through the tuff. Various methods of determining recharge (e.g. chloride mass balance, chlorine 36, etc) may prove useful in answering this question.

4. TW-1 is a deep ground-water observation well that shows a 50 ft water mound. TW-1A is completed in perched water above the screened interval of TW-1. The perched water from TW-1A and the alluvial water in this area have similar chemistry, different from that in TW-1. This situation raises questions concerning the effectiveness of the Bandelier Tuff as a barrier to vertical migration and needs to be investigated.

5. If ^3H has penetrated at least 200 ft beneath the alluvium aquifer in Mortandad Canyon, it seems possible that it could ultimately reach the main aquifer.

6. As asked by LANL hydrologists, is 200 ft the true maximum depth of ^3H percolation, or is that merely the deepest it can be detected, owing to dilution? Furthermore, did the ^3H move in the liquid or vapor phase, and which phase is most common at the Lab?

7. What is the cause and fate of disappearing streams in canyons (for example, Potrillo Canyon)? A study of hydrogeologic conditions at such sites (water table depth, thickness/character of the alluvium, etc) would be useful.

8. An alluvial deposit within the Cerro Toledo interval of the Bandelier Tuff, lithologically similar to the Puye Conglomerate, and known informally as the "epiclastic unit", crops out in various places on the plateau. LANL has reported that, where unsaturated, this unit may serve as a capillary barrier to vertical migration of contaminants or recharge, but that it has been observed to be as much as 90% saturated, locally. Of particular concern is an outcrop of the epiclastic unit in a cliff near the confluence of Pueblo and Acid Canyons. In this position it lies down canyon of both the Larry Walkup Center,

which discharges approximately 800,000 gallons of chlorinated water annually, and the decommissioned untreated liquid radwaste facility (SWMU 1-00). Thus, the potential role of the "Epiclastic Unit" as a pathway for contaminant transport should be investigated.

9. The hydraulic properties of all aquifers should be characterized in the field through properly designed pumping tests, using appropriately constructed and placed wells. Such tests should include wells on both sides of major faults in order to better define the role of these structures as conduits, barriers, or inconsequential.

10. Water level maps for the shallow, perched systems should be contoured separately from those for the deep (main) aquifer.

11. An approximate geologic map at the water table should be constructed from available subsurface data, and appropriate hydraulic conductivities should be assigned to each unit in order to show the contaminant-transport capacity across the area.

12. Once such a map is available, modeling of the ground-water flow system should be undertaken. This would be an excellent way of testing the conceptual model, as well as the assumed hydrologic properties of materials underlying the Pajarito Plateau.

13. Eventually, contaminant transport should also be modeled. This could initially be done with hypothetical leaks or spills, then modified for actual excursions. Such models could show directions, rates, and concentrations that might be expected from a most conservative scenario. Results would be ideal for presentations to the public, the Pueblos, etc.

14. No water-level map is provided with the 1990 surveillance report. Such maps normally accompany monitoring reports and provide essential information on the hydrologic system. In fact, it is difficult to interpret water-quality data, let alone evaluate the monitoring network, without such maps. As noted above, page-size versions will probably not suffice; a 1:24,000 map, including major disposal areas and monitoring sites would be ideal (folded in a pocket at the back of the report). If digitized, it should be a simple matter to update such a map for subsequent annual reports.

15. Previously published water-level maps essentially depict pre-development conditions: no impacts of pumping at production wells (i.e. cones of depression) are indicated (Figure 6). Yet, water-level changes (i.e. drawdown values) are regularly given in the annual reports on the water supply at LANL. Modeling by McAda and Wasiolek (1988) predicts significant cones of depression in the future as well. As ground-water flow is toward such depressions, their position and extent are critical to both designing and evaluating the monitoring network. Water-level maps for the Lab should include these features.

16. Water-level maps commonly used for closure plans, RCRA Facility Investigation (RFI)

Work Plans, operating permit applications, etc, all include data collected over 10 years ago at TA-49 in wells DT-5A, DT-9 and DT-10. This gives a false impression of the water level in the southwestern part of the Pajarito Plateau. It is understood that this is, in part, because there is no access port for water-level measurement at these wells. This should be remedied such that water levels can be monitored on a regular basis.

GROUND-WATER MONITORING NETWORK

WELLS/SPRINGS USED

The 1990 Surveillance Report identifies 43 ground-water monitoring wells (Figure 7). Of these, 26 are deep and target the main aquifer, whereas, 17 are shallow and monitor perched water in the alluvium. Of the 26 deep wells, 19 are water-supply wells; the remaining 7 are test wells. The supply wells used for monitoring include 7 in the Guaje well field, 6 in the Los Alamos well field, and 6 in the Pajarito well field. None of the shallow wells are water-supply wells. In addition to these wells, ground water is also monitored by means of 33 springs that primarily discharge along the eastern edge of the plateau in White Rock Canyon.

PARAMETERS MONITORED

Different sites are analyzed for slightly different lists of parameters. According to Appendix G of the 1990 Surveillance Report, springs in White Rock Canyon are monitored for 16 non-radioactive parameters (SiO_2, Ca, Mg, K, Na, CO_3, HCO_3, P, SO_4, Cl, F, NO_3-N, TDS, hardness, pH, specific conductance), 6 radiochemical parameters (^3H, ^{137}Cs, total U, ^{238}Pu, $^{239/240}Pu$, gross gamma) and 20 trace metals (Ag, Al, As, B, Ba, Be, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Sb, Se, Sr, Tl, U, V, Zn). Ground water in supply wells and the water distribution system at LANL is monitored for 6 radiochemical parameters (gross alpha, gross beta, ^3H, ^{238}Pu, $^{239,240}Pu$, and total U), 18 EPA primary/secondary standards (Ag, As, Ba, Cd, Cr, F, Hg, NO_3-N, Pb, Se, Cl, Cu, Fe, Mn, SO_4, Zn, TDS, pH), and 20 other parameters (Al, SiO_2, Ca, Mg, K, Na, CO_3, HCO_3, P, hardness, specific conductance, B, Mo, Sr, V, Be, Ni, Sb, Tl, NO_2-N). Ground waters are also monitored for organic compounds: 68 volatiles, 71 semi-volatiles, 19 pesticides, 2 herbicides, and 4 PCB's.

CONCERNS/RECOMMENDATIONS

1. It is understood that the monitoring plan for the Lab is currently being revised. Inclusion of a table, in both the plan and future surveillance reports, giving sites, parameters monitored and frequency of monitoring, would be most helpful in our oversight effort.

2. As in all monitoring networks, existing wells are employed where possible because drilling new ones is expensive. However, the large number of water-supply wells used

for monitoring at LANL is a concern. Wells constructed for supply have large screened intervals in order to maximize water production. By contrast, water-level or water-quality wells are usually screened over a narrow interval to provide information for a more discrete portion(s) of the aquifer. Properly constructed monitoring wells should be installed to replace, or at least supplement/verify, data from the supply wells currently used.

3. There are relatively few monitoring wells/sites in view of the size of the area encompassed by the Lab. This may result from the conceptual notion long held by the Lab that, due to the deep water table, and presumed impermeability of the volcanic tuff at the surface, the main aquifer is not at risk and need not be monitored, other than at the supply wells. Not only would more wells better cover the area and, if properly constructed, better monitor the aquifers, but they would provide an excellent test of this hydraulic isolation hypothesis. Lower Los Alamos Canyon is one such area that should have a more extensive monitoring system in place.

4. The density of wells/sites is also unrealistic. There are many wells in some areas and few to none in others. A more uniform spacing of wells is desirable and should be established. New wells should be strategically located with respect to historically contaminated areas of the plateau or to enhance depiction of the water table. A partial solution to this is to not use all wells in the well fields. A representative well should be selected, an alternate designated, and the others ignored, as far as regional surveillance is concerned. This would prevent the misconception that the relatively large of "monitoring wells" actually represents an adequate regional surveillance system.

5. The wells drilled under the Hazardous Solid Waste Amendment (HSWA) permit requirements are not currently included in the Environmental Surveillance network, but should be.

6. As noted above, the map of monitoring wells/sites in the surveillance reports should also show the major disposal areas (not every SWMU) that are being monitored, and contours that represent recent water-level information.

7. The classification of monitoring sites should be reconsidered and standardized. The designation of springs is not consistent; sometimes they are denoted as surface water and sometimes as ground water. Ground water is preferable inasmuch as springs are outcrops of the water table or the potentiometric surface.

8. Spring-sampling stations are inadequately marked in the field. They should be identified by as permanent a monument as possible, to avoid major deviation in a sampling point over time. A written description of sampling points should also be on file.

9. The organization of the surveillance reports is somewhat confusing. The following would be helpful for the oversight effort:

   a) field identification of sites should be the same as maps identification. Site identification numbers, as used on figures and maps, should appear in the first column;

   b) presentation of a summary table with sampling frequency and parameters monitored for each site (water level, major ions, radionuclides, etc; quarterly, annually, etc); and

   c) listing the standards for all parameters, for easy reference. LANL projects, understood to be underway or planned, will greatly enhance our conceptualization of the hydrogeologic system.

SUMMARY

Current monitoring efforts at LANL go far beyond those of just a few years ago, and surveillance reports regularly present more than was previously known. However, a number of general and specific inadequacies are recognized, based on our initial assessment. The following are largely summarized from the sections entitled "Concerns/Recommendations" above. However, **this list is not all inclusive and the concerns/recommendations listed above should be consulted for details**.

1. Potential Contamination Sources

   a) Biannual reports on waste-disposal activities at all sites should be prepared.

   b) General waste-disposal areas (not individual SWMU's) should be shown on maps of monitoring wells/sites, together with the regional water-level contours, so that adequacy of the surveillance network may be better evaluated.

2. Conceptual Hydrogeologic Model

   a) Questions concerning recharge, confined/unconfined conditions of the aquifer, and permeability of the Bandelier Tuff should be resolved. Appropriate tests should be designed and conducted (chloride, isotopes, paired piezometers, pumping tests, etc).

   b) A water-level map, depicting current conditions (drawdown around supply wells), should be included with surveillance reports.

   c) Ground-water flow and contaminant-transport modeling should be undertaken to test LANL's conceptual hydrogeologic model.

3) Ground-Water Monitoring Network

a) The monitoring plan should be revised as soon as possible, focusing on clearly stated objectives.

b) The number and location of monitoring wells should reflect the number and location of major waste disposal areas; this does not mean a well or series of wells is needed at each SWMU, but rather there should be enough wells to intercept any possible contamination.

c) The location of future monitoring wells should be based on the location of the potential sources of contamination, transport pathways, and the regional flow system as indicated by a current water-level map that includes drawdown due to pumping of production wells. Some additional monitoring wells may be needed merely to better depict the water table.

d) New wells should be constructed to monitor discrete hydrologic interval(s) (production wells are screened over too large an interval).

We would be glad to clarify or discuss our position/recommendations on any of the issues addressed herein at any time. Inquiries may be directed to 827-2434 or 665-7130.

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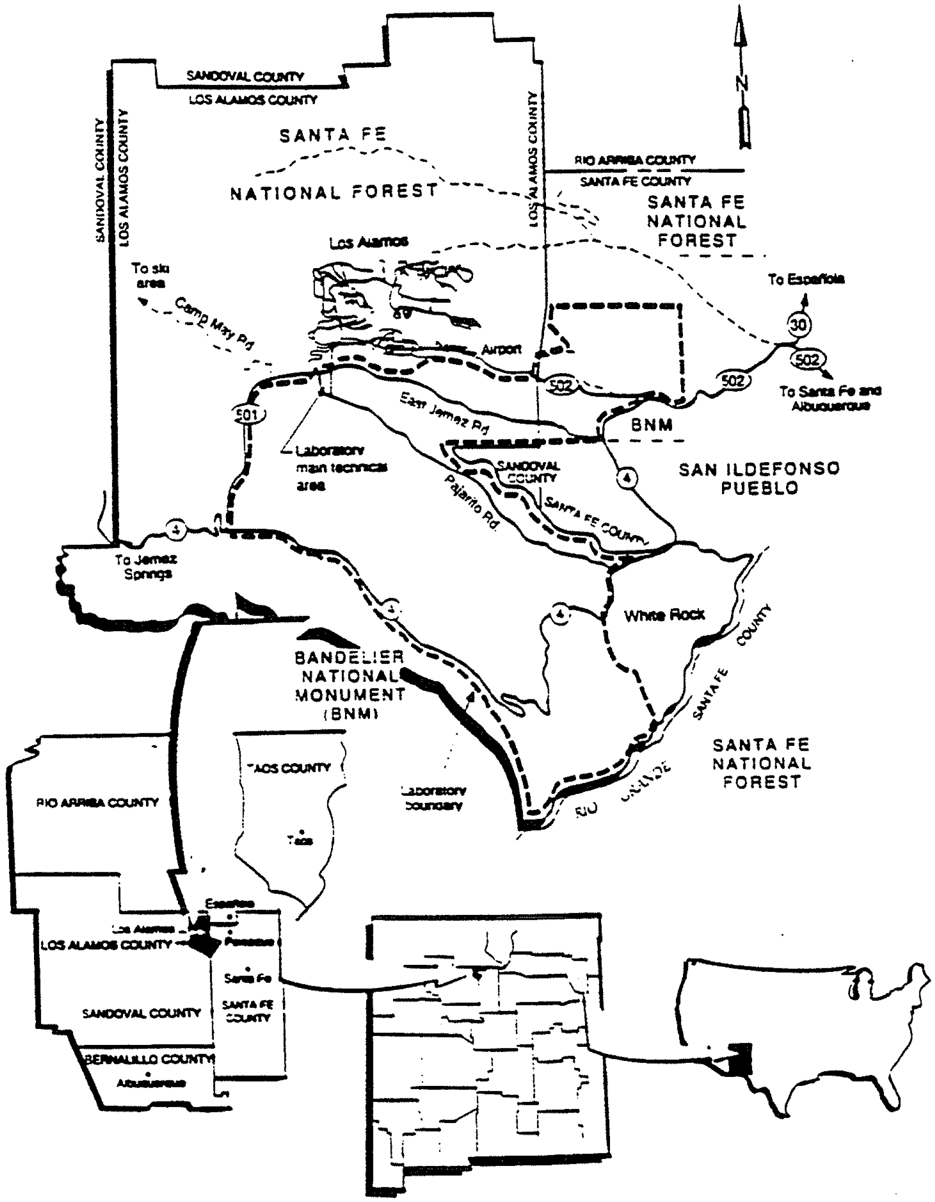
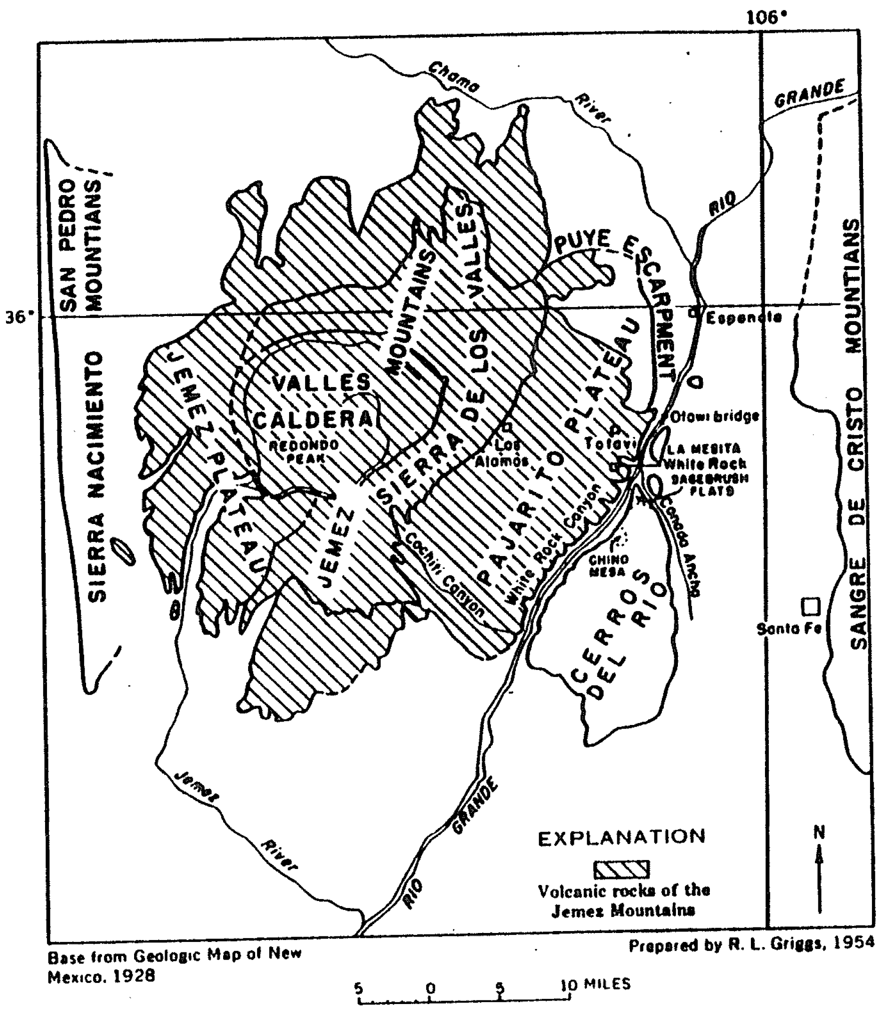
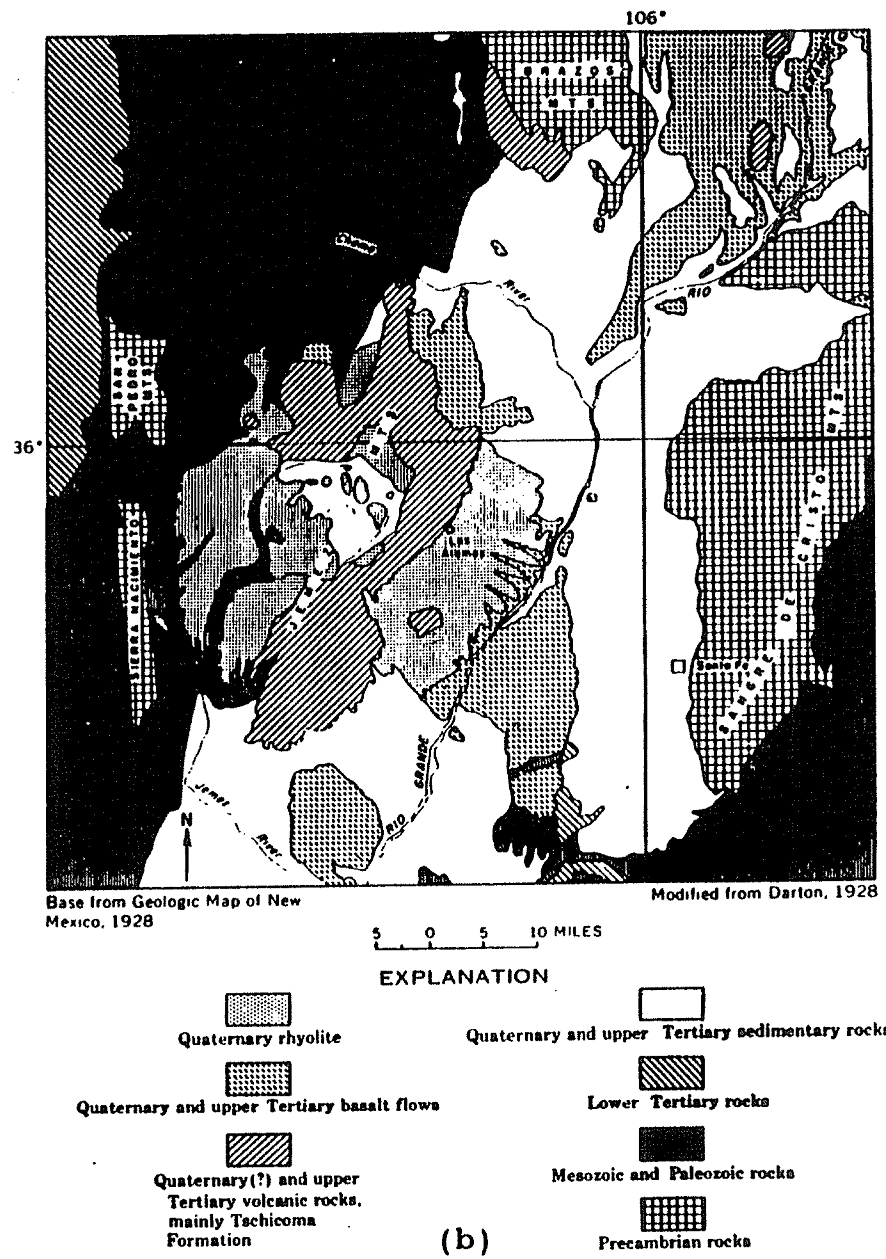


Figure 1. Location of LANL (Environmental Protection Group, 1992).



(a)



(b)

Figure 2. Regional setting of LANL;
a) physiography, b) geology
(Griggs,1964).

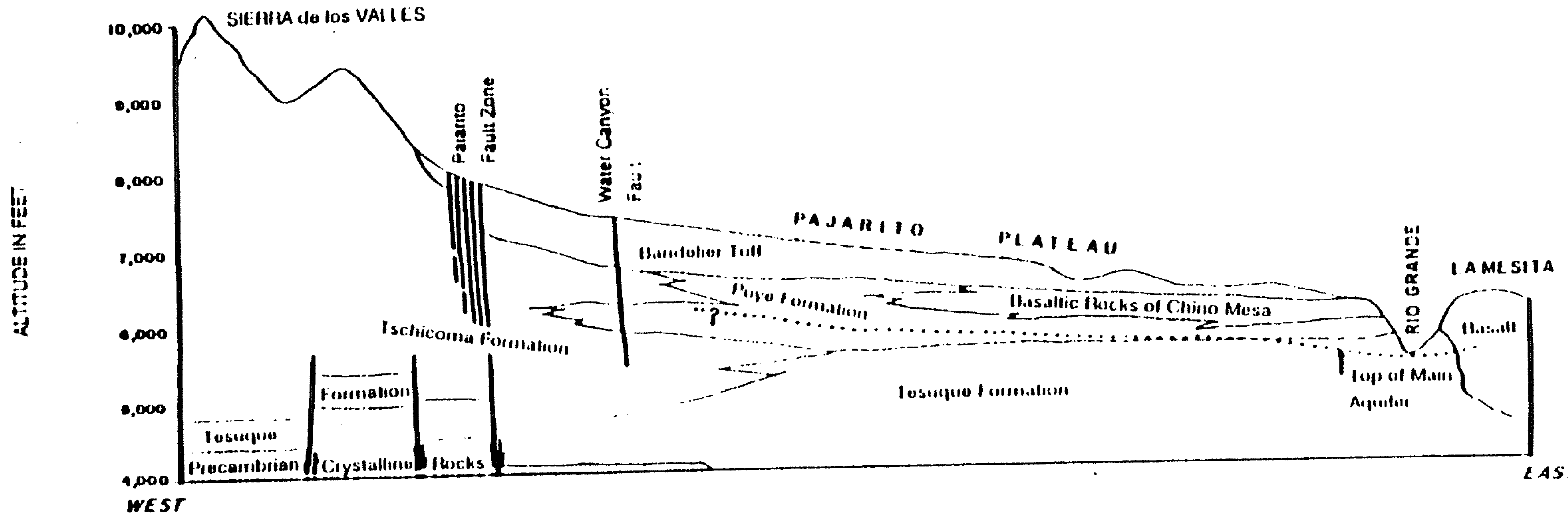


Figure 3. Geologic cross section of the Pajarito Plateau (Purtymun and Stoker, 1988).

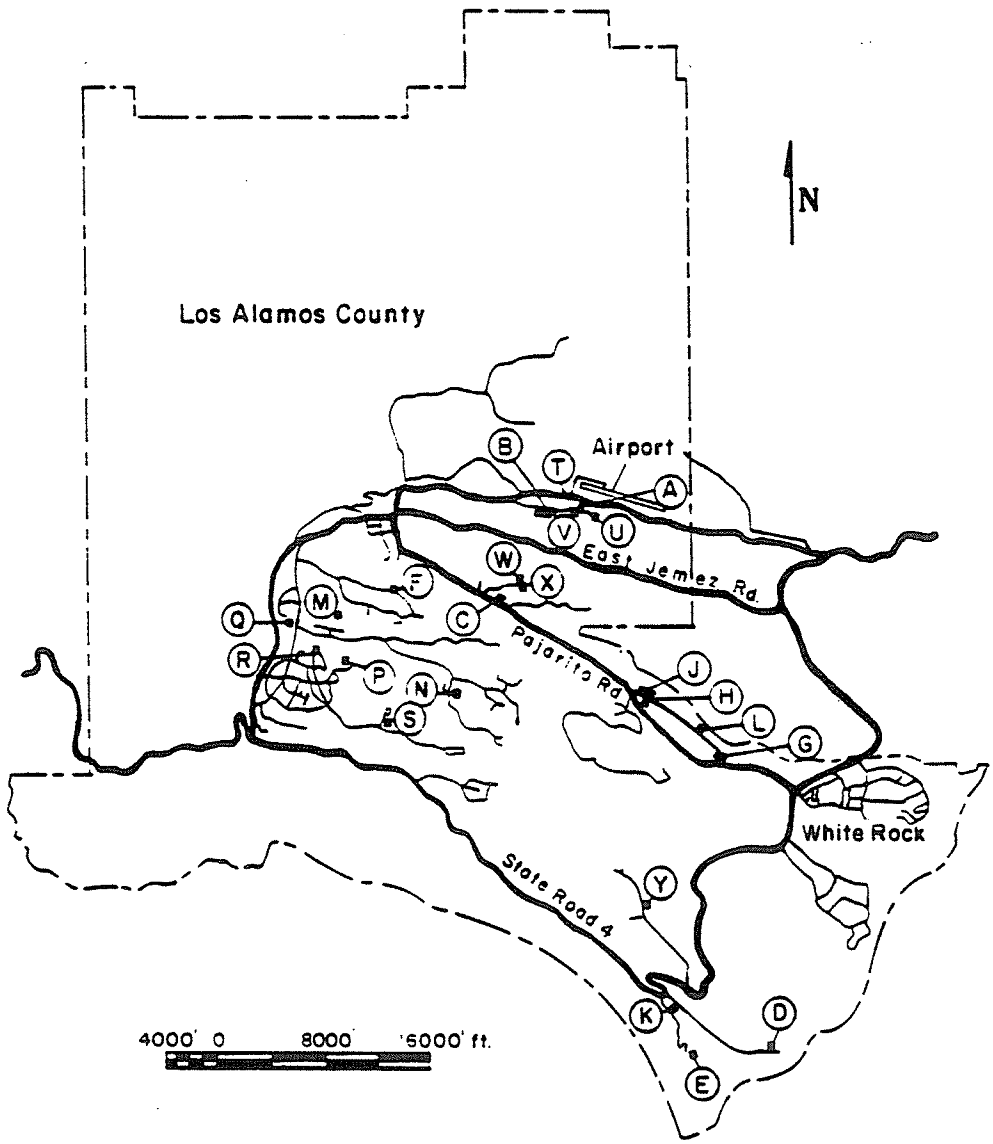


Figure 4. Location of major waste-disposal sites (Rogers, 1977).

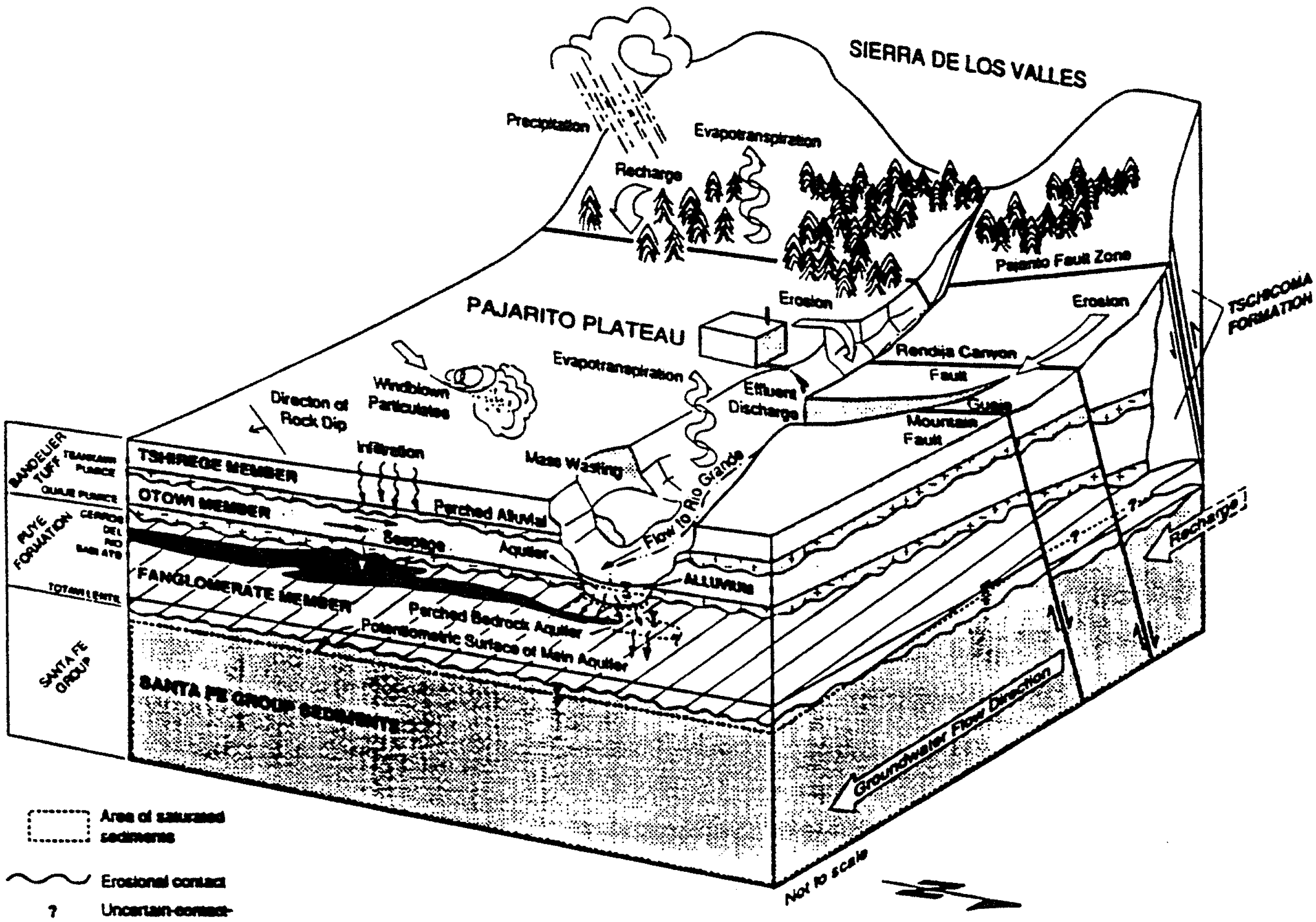


Figure 5. LANL's conceptual hydrogeologic model (Aldrich, 1992).

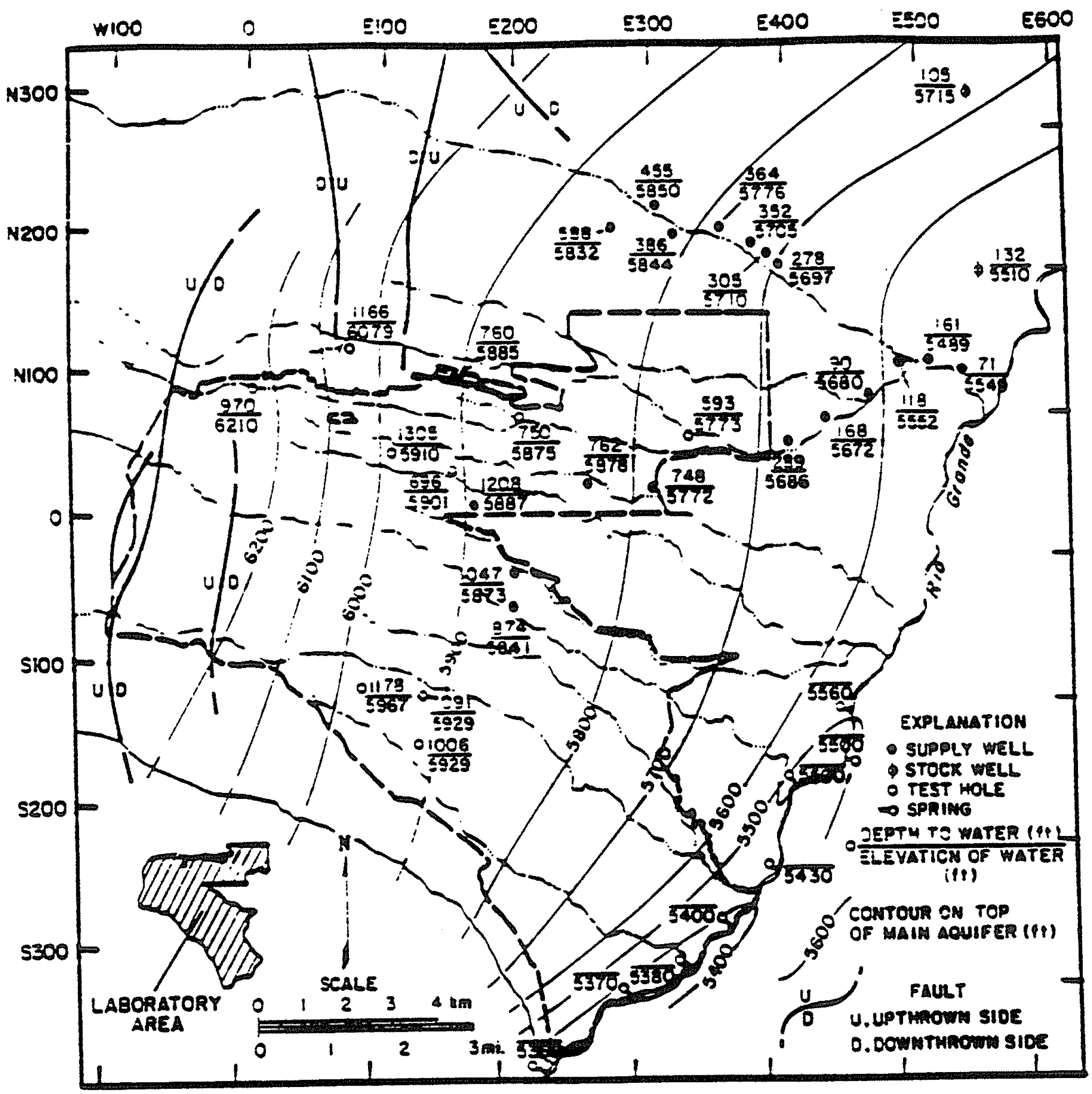


Figure 6. Pre-development water-level map of LANL (Purtymun and Stoker, 1988).

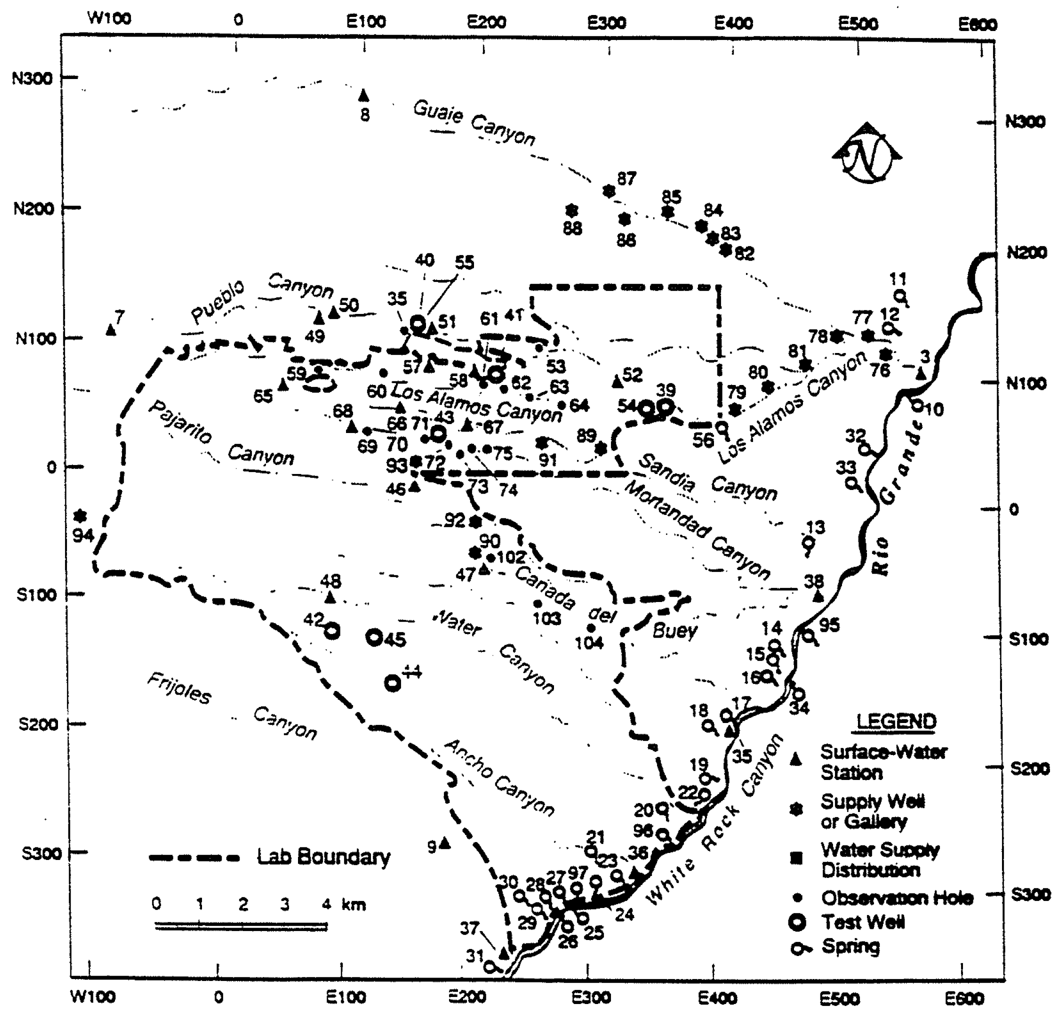


Figure 7. Water sampling sites at LANL (Environmental Protection Group, 1992).