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Date: January 20, 1999
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RECEIVED

HSWA LANL 6/1/5 '99

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SUBJECT: GROUNDWATER ANNUAL STATUS SUMMARY REPORT FOR FISCAL YEAR 1998

Dear Mr. Young:

Enclosed for your information and comment is the draft version of the *Groundwater Annual Status Summary Report for Fiscal Year 1998*. We plan to incorporate comments in the final version of this report, which will be completed in time for the annual review meeting in March.

I look forward to receiving yours and other Bureau's comments by February 15. Please call me (505) 665-4681 if you have any questions.

Sincerely,

Charles L. Nylander

Charles L. Nylander
Water Quality and Hydrology Group

CN/md

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DRAFT
GROUNDWATER ANNUAL STATUS SUMMARY REPORT
for
FISCAL YEAR 1998

Los Alamos National Laboratory
January 19, 1999

DRAFT
GROUNDWATER ANNUAL STATUS SUMMARY REPORT
for
FISCAL YEAR 1998

Los Alamos National Laboratory
January 19, 1999

FIGURES

TABLES

ACRONYMS

bgs	below ground surface
BMP	best management practice
CDR	Conceptual Design Report
DLM	diffuse layer model
DOE	Department of Energy
DP	Defense Programs (DOE)
DQO	data quality objective
EEG	External Evaluation Group
EES	Earth and Environmental Sciences (Division)
EPA	Environmental Protection Agency
ER	Environmental Restoration
ESH	Environment, Safety, and Health (Division)
ET	evapotranspiration
FEHM	Finite Element Heat and Mass Transfer (code)

FIMAD	Facility for Information Management, Analysis, and Display
GIS	Geographic Information System
GIT	Groundwater Integration Team
GWPMPP	Groundwater Protection Management Program Plan
HE	high explosive
HFO	hydrous ferric oxide
HRMB	Hazardous and Radioactive Materials Bureau (NMED)
HSWA	Hazardous and Solid Waste Amendments (of 1984)
HWPDB	Hydrogeologic Workplan Database
K_d	distribution coefficient
LANL	Los Alamos National Laboratory
MCL	maximum concentration level
MDA	material disposal area
MWIP	Monitoring Well Installation Project
NMED	New Mexico Environment Department
PCB	polychlorinated biphenyl
ppb	parts per billion
ppm	parts per million
PRS	potential release site
QA	quality assurance
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
SAP	sampling and analysis plan
SVOC	semivolatile organic compound
SWSC	Sanitary Wastewater Systems Consolidation
TA	technical area
TAL	target analyte list
TDS	total dissolved solids
VCA	voluntary corrective action
VOC	volatile organic compound

1.0 INTRODUCTION

This is the second Annual Report intended to provide the Department of Energy (DOE), the New Mexico Environment Department (NMED), and other interested stakeholders with a status of the groundwater protection and management activities performed during fiscal year 1998. This report also includes a summary of changes made to the Los Alamos National Laboratory's (LANL's or Laboratory's) conceptual model of the hydrogeologic setting as a result of integrating data collected over the past year and a projection of activities for fiscal year 1999.

This document is intended as an addendum to the Hydrogeologic Workplan. This document is specifically written as a summary-level report and relies on information incorporated by reference.

1.1 Background

The need to prepare this Annual Report comes from commitments made in the Groundwater Protection Management Program Plan (GWPMPP) (LANL, 1996) and the Hydrogeologic Workplan (LANL, 1998). The Laboratory has had groundwater programs in place since 1945. The early programs were focused on the need to develop reliable water supplies. Groundwater quality has been monitored through the environmental surveillance program using existing test wells, water supply wells, and springs. Since the early 1990s, there has been an increased emphasis on understanding the hydrogeologic environment in order to more effectively protect and manage the groundwater resource.

The GWPMPP (approved by DOE in 1996) provides for submittal of an annual groundwater status report to DOE summarizing the status of groundwater protection activities listed in the GWPMPP. The GWPMPP was prepared in response to the DOE requirement to conduct operations in an environmentally safe manner. DOE Order 5400.1: "General Environmental Protection Program" establishes environmental protection requirements, authorities, and responsibilities for all DOE facilities (DOE 1990). The goal of this order is to ensure that operations at DOE facilities comply with all applicable environmental laws and regulations, executive orders, and departmental policies.

The Hydrogeologic Workplan (approved by NMED in 1998) commits the Laboratory to prepare an annual report to summarize the activities of the previous fiscal year and to make recommendations for the current fiscal year activities. The Hydrogeologic Workplan was prepared in response to the NMED request to prepare a hydrogeologic work plan to address the requirements of the Resource Conservation and Recovery Act (RCRA) and the Hazardous and Solid Waste Amendments of 1984 (HSWA) as detailed in the regulations and in the Laboratory's RCRA/HSWA permit. The Hydrogeologic Workplan is the implementing document for the GWPMPP and the Laboratory's institutional commitment to complete a hydrogeologic characterization program. It includes the installation of 32 regional aquifer wells, i.e., the Monitoring Well Installation Project (MWIP), and describes the data collection and analysis activities needed to characterize the hydrogeologic setting of the Laboratory as part of the Pajarito Plateau within the regional context of the Española Basin. The need for characterization of the hydrogeologic setting beyond that already established by studies over the past 50 years has been recognized as a critical step in developing an effective monitoring program and in managing the groundwater resource.

This Annual Report serves as the annual status report for both the GWPMPP and the Hydrogeologic Workplan. Further, this Annual Report serves as the update mechanism for the scope and schedule in the Hydrogeologic Workplan. Specifically, the Hydrogeologic Workplan will not be revised; however, changes to the scope and schedule outlined in the plan will be discussed with NMED in quarterly meetings and at the annual meeting. Those changes for which there is concurrence by all parties will be documented in this Annual Report.

1.2 Summary of FY98 Meetings

Three meetings were held to discuss the groundwater characterization activities that occurred in FY98. The participants of the meetings were Laboratory staff involved in the activities, DOE representatives, and NMED representatives from the bureaus of Hazardous and Radioactive Materials (HRMB), Groundwater Quality, and DOE Oversight. A summary of each meeting and the points of agreement are provided in the following sections.

1.2.1 March 30, 1998 Annual Meeting

The notes from the March 30 Annual Meeting were issued with the final approved Hydrogeologic Workplan (LANL, 1998) on May 22, 1998. The topics covered included the Laboratory's approach to groundwater protection, and presentation of the material in the "Groundwater Annual Status Summary Report FY97." The non-field activities included geologic model development and a discussion of historical water quality data.

The significant field accomplishments included:

- Drilling and sampling of R-9 in Aggregate 1;
- Confirmation of the conceptual model's prediction of recharge through the mesas by Area G performance assessment in Aggregate 2;
- Confirmation of the conceptual model's prediction of recharge through the mesas by chloride and oxygen isotopes at Technical Area (TA) -49 in Aggregate 3;
- Confirmation that perched zones in TA-16 are intermittent and localized, but tracer test showed breakthrough to a spring in 3 months indicating rapid travel times in Aggregate 5.

Proposed FY98 non-field activities included data management improvements, hydrologic modeling of the region (Española basin). Proposed FY98 field activities included drilling R-12 and R-25 and starting R-7.

The agreements and action items resulting from the discussions during the Annual Meeting were:

Agreements

- Schedule

R-12	March 1998
R-25	July 1998
R-7	Oct 1998
2 intermediate wells in Mortandad Canyon	Fall 1998/FY99
R-14	Spring 1999

- Final locations of wells will be reviewed for possible use for compliance wells on well-by-well basis
- Involve state in evaluations for well completion and other changes in scope.

- Intermediate well (or multi-completion in perched zones) decisions will be made as well completion decisions are made and installed usually within one year of regional well completion.
- Analyze for volatile organic compounds (VOCs)/semivolatile organic compounds (SVOCs) when sources are present, not in every sample. Use analysis from four quarters of sampling to define contaminants of concern.
- The data quality objectives (DQOs) will go through iteration when new data is available.
- Provide more detail in the Annual Report.

Action Items

- Schedule South Valley Westbay tour.
- Provide letter to NMED with request and justification to convert intermediate wells in LA Canyon to regional wells

1.2.2 June 29, 1998 Quarterly Meeting

The June 29 Quarterly Meeting is documented in notes issued in a memorandum from Charles Nylander of the Laboratory's Water Quality and Hydrology Group (ESH-18) on July 31, 1998. The agenda included discussion of R-12, R-9, R-25, well installation priorities, TA-16 status, well drilling techniques, and the Annual Report. The geology and hydrology encountered in R-12 was discussed and the sampling was described. The major conclusions drawn from R-12 are: (1) that the perched zone water is geochemically different from perched zones in R-9, therefore the perched zones are laterally limited and probably do not extend beneath the mesas in this part of the Lab; and (2) increased understanding of the hydrologic setting of the regional aquifer in the northeast part of the Laboratory. The static water level is the same in both R-9 and R-12, and it is a different elevation than in the nearby water supply well. The integrated pressures in the water supply well raises the water level elevation by upward gradient.

Considerations for completing R-9 at a deeper total depth were commented on. These include the location close to contaminant sources in Los Alamos Canyon and R-9 is not near existing deep wells (as is R-12), so the deeper information would be new data. Neither R-9 nor R-12 will be completed for another year due to budget constraints. Planned versus actual data collection in the R-9 and R-12 boreholes will be presented in the completion reports. The Hydrogeologic Workplan will be used as the basis of comparison.

Plans for R-25 and expected costs were presented. R-25 will be much deeper than either R-9 or R-12 because the regional aquifer is expected to be at 1300 ft. The Barber drill rig will be used to drill R-25. The estimated cost of the well is $1.4 million if it is single completion or $2.3 million with stainless steel multiple completion.

Moving up R-15 in Mortandad Canyon in place of R-7 was discussed. This re-prioritization would be in response to data needed for the TA-50 Discharge Plan and to public concerns about Mortandad Canyon. There was consensus to move up R-15 at the expense of R-7, even though that will delay the completion of work in Los Alamos/Pueblo Canyon.

Updates of the results of tracer studies in TA-16 were described. Tracer studies suggest that fracture flow controls the contaminant distribution and saturation.

Well drilling techniques were discussed with a focus on reducing the cost of drilling the regional aquifer wells. Examples of well drilling techniques used at the Nevada Test Site were provided based on interviews with Nevada Test Site personnel.

Suggestions were made regarding the Annual Report format. The Annual Report should provide the data that conclusions are based on. Referencing data is acceptable as long as the referenced data is readily accessible.

The major agreements and action items reached in the meeting were:

- Completion of R-9 and R-12 wells will be approximately a year from now; a completion proposal with technical rationale will be presented at a future meeting.
- LANL will produce a comparison of the R-9 planned data collection versus actual data collection.
- R-15 will be drilled starting in October, 1998 and R-7 will be drilled in the spring of FY99.
- NMED HRMB will send comments on the "Groundwater Annual Status Summary Report FY97".

1.2.3 October 27, 1998 Quarterly Meeting

The second Quarterly Meeting was originally scheduled for the end of September but was postponed until the end of October to accommodate the participants' schedules. The notes from the October 27 Quarterly Meeting were distributed as a memo from Charles Nylander, ESH-18, dated December 15, 1998. The agenda for the meeting included discussion of R-25 progress, R-15 status, R-9 and R-12 completion, FY99 drilling plans, modeling task progress, use of existing test wells, results of peer review, status of database, and Annual Report.

R-25 encountered saturated conditions with a static water level at an elevation of 711 ft. This is considerably higher than the regional aquifer was expected, and it is unclear whether this saturation represents the regional aquifer or a perched zone. Core, cuttings, and a water sample from R-25 were field screened for high explosives (HE). The core and cuttings were negative, but the water sample did contain detectable HE. Analytical results from a fixed laboratory are pending.

R-15 is located in Mortandad Canyon. It was started in September with a hollow-stem auger drill rig. The borehole was down to 420 ft where the hollow stem auger drill rig was no longer capable of drilling further. Continued drilling of R-15 will wait until the Barber rig is done at R-25.

The Laboratory's Groundwater Integration Team (GIT) Construction Subcommittee recommended that R-9 be completed as a single screened interval in the regional aquifer. It will be completed in late winter/early spring. No recommendations have been made for R-12, but a multiple completion is contemplated.

Drilling plans for FY99 were described as follows:

DP

- Complete R-25
- Drill and complete R-5 in Pueblo Canyon
- Drill and complete R-31 in Ancho Canyon

ER

- Complete R-15
- Complete R-9
- Install 2 alluvial wells in Pueblo Canyon and 2 alluvial wells in Mortandad Canyon

The GIT Modeling Subcommittee has completed a draft report on regional (Española Basin) flow modeling (see Keating et al., 1998). Plans for FY99 include development of a high-resolution Pajarito Plateau model.

Existing test wells scheduled for plugging and abandonment will each be surveyed with the borehole camera. If a well is structurally sound and could be useful in the characterization or monitoring programs, it may be reworked and kept in service. It will be a well-by-well decision.

A peer review panel, independent of the Laboratory, has been formed to provide an review of the Hydrogeologic Workplan and the MWIP. The first meeting of the review panel was in August and the panel has submitted a report. (*The peer review committee is described in Section 1.3 of this report*).

A comprehensive database to support the groundwater and watershed programs is being developed. A steering committee is in place and a project leader has been hired. This data will be linked to ER data and will be accessible through a web site.

Annual Report is in preparation. It will be submitted to the state on or about January 15. The peer review panel will review the Annual Report before it is submitted to the state.

Major points of agreement from the October 27 Quarterly Meeting were:

- NMED is concerned that intermediate perched groundwater zones are not receiving adequate attention in this groundwater characterization program. LANL has committed to addressing the intermediate perched groundwater zones.
- The completion of R-9 as a single screen in the regional aquifer in the late winter/early spring.
- LANL committed to providing a list of "critical data needs" for modeling at the Annual Meeting in March.
- LANL committed to providing a more detailed presentation of the modeling to NMED in the near future, the date and time to be coordinated with John Young.
- LANL will provide a copy of the External Peer Review Panel Report to NMED and the panel would like to have the participation of NMED.
- LANL committed to have a small group meeting with NMED to discuss the prioritization of the wells in December.

1.3 Independent Peer Review Panel

The GIT formed an External Evaluation Group (EEG) to provide an independent review of the GIT's implementation of the Laboratory's Hydrogeologic Workplan. The EEG consists of six members with diverse technical and professional backgrounds to provide a broad technical and managerial review of the

Laboratory's Hydrogeologic Workplan activities and methods. The GIT plans to add two additional EEG members in FY99 to further strengthen this multi-disciplinary peer review group.

The EEG met August 17 and 18, 1998 at Los Alamos National Laboratory for the first semi-annual review of activities proposed under the Hydrogeologic Workplan. The EEG studied the written document, the "Groundwater Annual Status Summary Report FY97", and the response to a request for information from the NMED. The EEG also listened to a number of introductory and technical presentations, participated in a field trip to view aspects of the geologic setting, and visited a well site where drilling operations were in progress.

The EEG has committed to provide technical review of groundwater characterization activities for the planned 7-year duration of the project. The EEG will meet twice annually, generally in March (associated with the annual meeting) and August. The EEG will review documents and provide requested advice through the year. The EEG has appointed a chairperson (Dr. Robert Charles) that coordinates EEG meetings and serves as the focal point for communication with the EEG.

The EEG consists of the following members:

- Robert Charles, Ph.D.—Dr. Charles has a doctorate in Geology with a specialty in geochemistry. He also has a Master of Arts degree in Organizational Management, and has more than 25 years of experience in his disciplinary areas. Dr. Charles served as Chair of the EEG.
- Jack Powers, P.E.—Mr. Powers is a drilling consultant with more than 45 years of world-wide professional drilling experience.
- John Butler, M.S.—Mr. Butler has a Master of Science degree in Chemistry and 25 years of experience working for federal agencies, international agencies, and private companies. He has specialized in environmental economics since 1980.
- Robert Powell, M.S.—Mr. Powell has a Master of Science degree in Environmental Science and 25 years of experience and 33 groundwater-related publications. Mr. Powell has expertise in the area of low-flow groundwater sampling.
- Elizabeth Anderson, Ph.D.—Dr. Anderson has a doctorate degree in inorganic chemistry and more than 20 years of experience in health and environmental science. Dr. Anderson is a nationally renowned expert on risk assessment and established the major national risk assessment programs at the Environmental Protection Agency.
- David Schafer, M.S.—Mr. Schafer is employed by Geraghty & Miller and has 25 years of experience focused on computer modeling using numerical models, analytic element models, and proprietary analytical models that he has developed.

The major conclusions of the EEG's report, titled "Semi-Annual Report, Groundwater Integration Team External Evaluation Group Los Alamos National Laboratory" (EEG, 1998) are:

- The Hydrogeologic Workplan is thorough and well integrated with other on-going Laboratory programs and Laboratory staff have formed a productive team to accomplish the work.

- Relationships among LANL, DOE, and NMED appear to be improving, but continued frequent, detailed, and consistent communication efforts must be maintained to foster further improvement. Representatives of NMED were requested to attend the next semi-annual meeting.
- Reach a timely agreement with NMED on maximum contaminant levels (MCLs) and alternate contaminant levels.
- Knowledge contaminant transport through the intermediate perched zones will be necessary. Although the focus is on the regional aquifer now, further examination of the intermediate perched zones in the future is recommended.
- The drilling methods and equipment are paramount to obtaining the information necessary to meet the DQOs in the Hydrogeologic Workplan. Although the drilling costs for the first two wells were high, the selected drilling technologies are correct and appropriate. However, the costs should be benchmarked against similar activities.
- Development of a comprehensive database should be a high priority.
- A second drilling crew should be trained and used to relieve the existing 3-person crew.
- Recommend metal fittings for well completion rather than PVC.
- Modeling should be done concurrent with the well drilling/data collection and should be used to inform the decisions of how many more wells and where they are located.

1.4 FY98 Accomplishments

This section is intended to provide a concise list of FY98 groundwater activity accomplishments. Based on the schedule provided in the Hydrogeologic Workplan, three wells that should have been completed in FY98 (R-9, R-12, and R-7) were not. The funding source for these planned wells was the ER Project, but due to decreased funding, these wells could not be started. Section 4 describes the ER Project funded wells that are planned for FY99 based on the expected funding. More detailed descriptions of these activities are contained in the referenced sections.

- Drilled the R-12 borehole in Sandia Canyon to the regional aquifer; collected cuttings, core, and water samples, and completed analyses of collected samples (Aggregate 1, Section 3.2.1)
- Drilled the R-25 borehole near Cañon de Valle, collected cuttings, core, and water samples (Aggregate 5, Section 3.2.5)
- Started the R-15 borehole in Mortandad Canyon (Aggregate 7, Section 3.2.7)
- Installed alluvial wells PAO-2.5, -3, -5N, and -5S
- Updated the FY97 Hydrogeologic Conceptual Model to include new findings (Section 3.1)
- Completed a regional-scale hydrologic model using the Finite Element Heat and Mass Transfer (FEHM) code. This modeling effort is documented in a draft report by Keating et al. (1998).
- Formed an independent peer review panel to provide broad-based, multi-disciplinary assessments of the Hydrogeologic Workplan activities. The results of the first semi-annual peer

review are documented in "Semi-Annual Report, Groundwater Integration Team External Evaluation Group, Los Alamos National Laboratory" (EEG, 1998) (Section 1.3).

- Completed a user needs assessment for the comprehensive groundwater database (Section 2.1).

1.5 Organization of the Annual Report

Both the GWPMPP and the Hydrogeologic Workplan describe data collection and analysis activities. These activities consist of both non-field and field activities. Non-field activities include task such as historical data compilation, data management, and computer modeling. The status of the non-field activities is described in Section 2 of this report. Field activities include some that are regional in scale (e.g. sample all springs) and some that are specific to particular geographic areas, referred to as Aggregates in the Hydrogeologic Workplan. The results of the field activities are presented in Section 3 of this report. Section 4 contains a summary of activities proposed for FY99.

2.0 STATUS OF NON-FIELD ACTIVITIES

2.1 Information Management

This section summarizes progress towards developing a Hydrogeologic Workplan database (HWPDB) in support of the well drilling and sampling activities and data needs described in the Hydrogeologic Workplan. The objective is to develop a database that contains both the analytical and physical groundwater data. These data will include historic data and data collected through the MWIP. While the database will be primarily designed to support modeling efforts conducted as part of the Hydrogeologic Workplan, it will be accessible to all groups involved in the Hydrogeologic Workplan and to State regulators and oversight personnel.

2.1.1 Progress During FY98

Activities identified in the FY97 Groundwater Annual Status Summary Report were accomplished to the degree possible. Most activities described are not finite but rather ongoing efforts to develop and maintain the database, and improve database usability.

2.1.1.1 Budget

A budget describing the tasks and associated costs for developing the HWPDB was developed. The budget development was a cooperative effort between ESH-18, EES, and the ER Field Support Facility. This budget reflects the "end state vision" for the HWPDB. The total dollars required to develop the database were estimated to be $1.7 million. This budget request was submitted to the DOE Los Alamos Area Office in November. No response has been received to date. At present there is very little funding for developing the HWPDB.

2.1.1.2 User Needs Assessment

Harding Lawson Associates performed a User Needs Assessment for the HWPDB. Their findings included the following recommendations:

- Form a steering committee to coordinate ESH/ER efforts. (We have formed the steering committee from ESH and ER representatives.)
- Manage the HWPDB as a separate database from the ER Database
- Use the existing FIMAD GIS system as a foundation for the spatial portion of the HWPDB
- Develop a Data and Records Management Plan
- Identify existing records that should be included in the HWPDB
- Include a plan for sharing information with the public and State personnel

All of the recommendations were adopted. Those requiring action have either been completed and are discussed here or are planned to begin in FY99 assuming appropriate funding has been approved.

2.1.1.3 Project Leader

Effective November 30, 1998, ESH-18 has hired a Project Leader for the HWPDB. The Project Leader's time will be split equally between ESH-18 database support and development of the HWPDB. It will be the Project Leader's responsibility to coordinate with all the participants in the Hydrogeologic Workplan to develop the HWPDB.

2.1.2 FY99 Planned Activities

- Development and formalization of the "end state vision" by the HWPDB Project Leader is planned for FY99.
- Development of a Data and Records Management Plan for the HWPDB by the HWPDB Project Leader is planned for FY99.
- Consensus will be sought by the HWPDB Project Leader on the priorities for loading the various data sets.
- A data repository will be created and loading or linking of existing data and data currently being collected will begin in FY99.

It should be noted that, at the current levels of funding, the HWPDB will never be a comprehensive database.

2.2 Modeling

Groundwater flow and transport modeling has been proposed in the Hydrogeologic Workplan (LANL1997) as a significant component of Laboratory efforts to better understand the geology, hydrology, and geochemistry of the regional aquifer. Long-term goals of both flow and transport modeling include:

1. Support for the MWIP including siting well locations.
2. Integration of stratigraphic, hydrologic, and geochemical data available for the Pajarito Plateau.
3. Testing of hypotheses concerning predominant flow directions, recharge zones, and potential contaminant migration in the regional aquifer.

2.2.1 Progress During FY98

Activities identified in the FY97 Groundwater Annual Status Summary Report were accomplished to the degree possible. Most modeling activities described are not finite but rather ongoing efforts to develop and refine the overall hydrogeologic conceptual model. Table 2.2-1 includes a description of modeling tasks, subtasks, a short synopsis of FY98 status, and future activities. A discussion of FY98 modeling activities and FY99 planned activities follows.

Table 2.2-1. Status of FY98 Non-Field Activities

Task	Subtasks	1998 Status	Future Activities
Develop Geologic Model	Compile and publish drilling and completion data from all significant boreholes.	Completed interim completion reports for R-9 and R-12.	Develop completion reports for alluvial, perched intermediate, and regional aquifer wells as they are installed.
	Perform comprehensive review of 3-dimensional stratigraphy including analytical chemistry and mineralogy necessary to make stratigraphic correlations between boreholes, integrate newly-collected geologic data into structure-contour maps, isopach maps and cross-section	Activities in FY98 were directed at migrating the site-wide 3-D Geologic Model to Stratamodel.	Data from R-9, R-12, R-25, R-15 and other boreholes are being incorporated into cross-sections and structure contour maps.
	Develop 3-dimensional geological database to include surface geology, structural geology, and borehole stratigraphy.	QA performance on migrated model and contact surfaces and isopachs evaluated to provide an internally consistent model of the 3-D stratigraphy	QA of migrated model and incorporation of new drill hole and surface data into model
	Salvage of data from stratigraphic and geochemical analysis of available canyon bottom core samples	ER's Canyons Focus Area will hire a GRA in FY 98 to log these sediments	????
Develop Hydrologic Model	Compile and publish hydraulic characteristic data: Bandelier Tuff - Assemble hydrologic laboratory test results of Bandelier Tuff core from across the Plateau. Evaluate test results for validity. Calculate unsaturated hydraulic properties from moisture retention characteristics. Summarize data by stratigraphic unit and locations. Determination of vadose zone fluxes in Los Alamos mesas using chloride and stable isotope profiles. Analyze soil moisture for chloride mass and isotope ratios. Calculate fluxes from tracer profiles. Hydrologic parameter estimation for the Pajarito Plateau, including in-situ hydraulic testing of wells. Load available hydrologic measurements in 3-dimensional database. Statistically describe zones and regions.	Data on Bandelier Tuff hydraulic characteristics from TA-21 and TA-49 are included in ER RFI reports for those sites. A report was written comparing the chloride profile results from DP mesa and TA-16. Known hydraulic properties of the regional aquifer were incorporated into the regional-scale hydrologic model.	Hydraulic properties of Bandelier Tuff will be evaluated for testing in each characterization borehole. Continue to analyze soil moisture for chloride mass and isotope ratios at regular intervals in each characterization borehole. Use existing and newly collected hydrologic properties of the regional aquifer in plateau-scale model.
	Evaluate Water Quality Data: Consolidate historical water quality data in database and perform trend analysis. Evaluate water quality variations and vertical stratification within the regional aquifer using water samples from supply wells. Pull permanent pump and isolate discrete sample zones (46-ft lengths) in each well using hydraulic packers. Sample with temporary pump.	Completed report on the trend analysis San Ildefonso Pueblo. Made water quality data available via the internet. Zonally sampled new supply wells GR-1, GR-2, GR-3, and GR-4 in Guaje Canyon during 1998 before these wells entered routine service.	Continue trend analysis on the historic data and focus on evaluating trends by drainage basins. Zonally sample water supply wells as the opportunity arises during maintenance.

Table 2.2-1. Status of FY98 Non-Field Activities (continued)

Task	Subtasks	1998 Status	Future Activities
	Inventory springs on-site and near Lab boundaries by reviewing existing Laboratory and USGS reports for initial inventory. Perform additional field reconnaissance. Supplement with aerial photography where possible. Select springs with discrete discharge points. Install flow and monitoring probes	Tracer tests were completed for selected springs in TA-16. In one test, the tracer traveled from the pond to SWSC spring in 3 months and fracture flow seemed to be controlling tracer.	Continue to obtain field observations from Laboratory and NMED personnel. Continue ER investigations at critical discharge points (particularly TA-16 and TA-18) where there is uncertainty if flow is natural spring-fed or perennial. Continue monitoring of flow and for bromide tracer and other chemical constituents. Analyses of the flow and chemistry time series will be conducted
	Long-term water balance estimates for the Pajarito Plateau. Install stream gages at upstream and downstream boundaries of the Laboratory. Continuously measure ET, precipitation, and groundwater levels.	Data collected in most regional aquifer test wells, and some intermediate and shallow alluvial wells. Stream flow measurements collected from 19 stations. Precipitation data collected from 7 stations and ET data collected from 2 stations.	Water level data will be collected annually. Stream flow gaging stations will be installed at canyon confluences and Laboratory boundaries
	Groundwater flow modeling using the FEHM code	Developed a regional-scale model that incorporated the geologic framework model, had a computational grid, used initial permeability estimates that were informed by data, had steady-state model calibration which resulted in refined permeability estimates, and evaluated conceptual model alternatives, including flow directions and sources of recharge.	Improve calibration of the regional-scale model, incorporate geochemical data and publish conceptual and numerical models. Create a high-resolution Pajarito Plateau-scale model, conduct sensitivity analyses to identify areas of critical data needs, use geostatistics to simulate heterogeneity within hydrostratigraphic units, and incorporate pumping effects/transients
Develop Geochemical Model	Hydrogeochemical and statistical evaluation of solute distributions on the natural surface and groundwaters	Expanded statistical evaluation of solute distributions for LANL background distributions. Incorporated geochemical data from R-9, R-12, and R-25.	Continue hydrochemical analyses of groundwater and surface water to develop representative distributions that can be used in hydrologic modeling.
	Geochemical characteristics of key subsurface geohydrologic units	Characterized hydrochemistries of alluvium, perched intermediate zones, and regional aquifer and associated aquifer material in R-9, R-12, and R-25.	Continue to characterize hydrochemistry of alluvium, perched intermediate zones, and regional aquifer and associated aquifer material from boreholes as they are drilled and completed.
	Geochemical modeling	Performed speciation, mixing, and mineral saturation calculations using MINTEQA2 and PHREEQC for water collected from R-9, R-12, and R-25.	Continue geochemical modeling to understand important processes occurring along groundwater flow paths.

2.2.1.1 Hydrologic Modeling Activities

Regional Aquifer Modeling Activities

A groundwater flow model for the Los Alamos regional aquifer is being developed to compliment the MWIP. The broad goals for this modeling work include (1) integration of geologic and hydrologic data, (2) refinement of our conceptual model for flow in the regional aquifer, and (3) simulation of potential contaminant transport. To date, a hydrostratigraphic framework model and a steady-state flow model of the regional aquifer have been developed. The model has been calibrated to water levels measured in 770 domestic, test, and supply wells under non-pumping conditions.

To accomplish modeling goals, a fluid flow and transport code was developed at LANL called FEHM (Zyvoloski et al., 1996). FEHM has a number of capabilities that will be critical to the success of this project, including simulation of multi-phase flow and reactive-transport. Grid-generating software, also developed at LANL (Trease et al., 1996), facilitates development of complex computational grids that can be used to represent subsurface hydrostratigraphy. The authors of the FEHM code have developed the current version of the code under the software quality assurance (QA) program for the Yucca Mountain Site Characterization Program. Therefore, a QA pedigree has been established, and the code version is tracked using configuration management software (Dash et al., 1997).

The extent of the Los Alamos regional aquifer model approximately corresponds to the structural boundaries of the Española Basin. By extending the flow model well beyond the boundaries of the Pajarito Plateau, the influence of boundary conditions on model results has been minimized. In building the model, a wide range of geologic and hydrogeologic data for the basin was integrated, with the highest priority on detail and accuracy in the vicinity of the Pajarito Plateau. The objective is to build and improve upon previous flow models for the region (e.g. Hearne, 1980; Frenzel, 1995) by increasing the amount of geologic detail incorporated, by using a more finely resolved grid (especially in the vertical direction), and by extending the model boundaries to a more physically-meaningful distance.

At present, the Los Alamos regional aquifer model represents a preliminary steady-state groundwater flow model with physically meaningful boundary conditions and elevation-dependent recharge rates. The lateral boundaries are located as follows: the western edge is defined by topographic divides in the southeast and northern Jemez mountains and the western margin of the Valles Caldera; northern edges are defined by the northernmost extent of the Santa Fe Group; the eastern edge is defined along the drainage divide between the Rio Grande and Rio Pecos; and southern edges are defined along the transition zone between the Española Basin and the Santo Domingo Basin to the south. Most of the lateral boundaries are specified as "no-flow", since they are located either at presumed groundwater divides or in locations where the Santa Fe Group is very thin or absent. Boundaries where water enters or exits the model are along the upper Rio Chama and Rio Grande valleys, along the western margin of the Valles Caldera, and along the Española Basin/Santo Domingo Basin transition zone. The upper boundary represents the water table, which receives recharge at rates constrained by observed rainfall data and elevation dependent ratios of precipitation-to-recharge.

Calibration results demonstrate the ability of the model to reproduce observed heads in the vicinity of LANL and to predict reasonable fluxes across model boundaries. The relative magnitude of fluxes into the model along northern river valleys, out of the model to the south, and towards the Rio Grande in the center compare favorably to values presented in previously published reports. The sensitivity of the model to assumptions about recharge, hydraulic conductivity, and the significance of the Pajarito fault zone has been investigated. Our preliminary conclusions include the following: (1) a steady-state calibration is insensitive to assumptions about the permeability of both the Pajarito fault zone and the "Chaquehui" Formation , and (2) the model is very sensitive to recharge rates and therefore further calibrations may be useful in constraining the range of plausible recharge rates in this area. For a more detailed description of the Los Alamos regional aquifer model and preliminary results, see Keating et al. (1998).

Other Hydrologic Modeling Activities

Smaller-scale modeling efforts were performed or began during FY98 and are intended to ultimately feed into the regional model or subsets of it. These efforts focus more on the unsaturated zone than does the regional model.

TA-54

One modeling activity using data from Area G addressed deep drying within the mesas. Previous studies using natural chloride and stable isotope tracers have indicated that deep evaporation can dry out the mesa subsurface which results in small downward flux rates of liquids (Newman, 1996; Newman et al., 1997). Stauffer and Birdsell (work in progress) modeled topographically driven airflow in mesas and found that air flow through a fracture system can explain the existence of low moisture content/high chloride zones deep within mesas. These dry zones reduce the downward flux rates of liquids in mesas, but the airflow may increase the movement of volatile species.

Development of a hydrologic model for the lower Los Alamos Canyon was started. Activities thus far have focused on developing a representative hydrostratigraphic model for the canyon. The recent stratigraphic and hydrologic results from borehole R-9 have been critical for developing the Los Alamos Canyon hydrostratigraphic framework. The observations of the perched zones and the refined stratigraphy from the R-9 drilling have allowed the development of a more representative conceptual model of the lower part of the canyon, which should translate to better numerical flow models.

2.2.1.2 Geologic Modeling Activities

A revised digital geologic model (FY98 model) has been developed for LANL. This model resolves all inconsistencies that previously resulted in the intersection of stratigraphic surfaces. A major effort was also made to identify the extent of additional pre-Bandelier flow units that could have major impacts on groundwater flow. Top and bottom surfaces were created for four basalt units as well as two quartz latite flows of the Tschicoma Formation. These new units have not yet been incorporated into the model due to surface intersection problems and pending development of appropriate methods to import these discontinuous surfaces into the Stratamodel software package. As these units have a major impact on models of ground water flow, efforts are continuing on resolving outstanding issues and incorporating these data into the model. An interim FY99 model incorporating these units should be available by early January. The new FY98 model is available at FIMAD.

Initial efforts in FY98 were directed toward removing remaining inconsistencies in the FY97 model. The resulting FY98 model is available at FIMAD and was provided to E. Keating for incorporation in an Española Basin (Strata) model. Quantitative predictions of hole stratigraphy were provided for the R-9, R-12, and R-25 wells using both the FY97 and updated FY98 model. Drilling results from the R-9 well confirmed the importance of the deeper basalts (pre-Bandelier) in any hydrogeologic model. New data to help define these deeper units were collected and include: geologic age and rock chemistry data, the geologic map of the White Rock Quadrangle (Dethier, 1997), and drilling results from the MWIP R-series wells, and the GR-series water supply replacement wells in the Guaje well field.

Responsibility was assumed for the Stratamodel software rendition of the 3-D data set in September, in order to facilitate utilization of the model by numeric flow modelers. The project also assumed a major role in development of a "geohydrologic" atlas. For this reason several of the FY98 tasks were delayed including web page development, and data accountability procedures. These tasks will be completed in FY99.

Six subunits are identified, based upon age and chemistry: four basalts and two quartz latite (Tschicoma) flows. The basalt and quartz latite subunits are enclosed within the Puye and Santa Fe units, have irregular shapes, and are limited in geographic extent. For this reason, both top and bottom contacts are identified for these subunits. Unit surface and drill-hole contacts were displayed in 2-dimensional plots as well as 3-D visualizations. The 2-D, geographic plots identified elevations of surface and drill hole contacts for individual units, as well as drill holes that were deep enough to have penetrated the unit, but did not. The 2-D plots were hand contoured by staff geologists to provide the input for creating gridded contact surfaces using Arcinfo software. Analysis of the gridded contact surfaces is currently underway to resolve intersection and other issues. Additional age and chemical analyses that were initiated with FY98 funds will be provided in FY99 with no additional costs to the project; improving the geospatial correlations upon which the contact surfaces are based.

2.2.1.3 Geochemical Modeling Activities

Geochemical modeling was conducted for borehole R-9 using the computer code, MINTEQA2 (Allison et al., 1991) to quantify adsorption of uranium (uranyl) onto hydrous ferric oxide (HFO). The results are briefly discussed here while a more detailed description is provided in the summary for Aggregate 1 FY98 Investigations (Section 3.2.1.1).

Results of the adsorption modeling suggest that, in the lower perched zone, over half of the uranyl present is bound as a surface complex, $SO_2UO_2^+$. The remaining dissolved (non-sorbed) uranium occurs mainly as $UO_2(CO_3)_3^{4-}$ with some $UO_2(CO_3)_2^{2-}$. The model predictions for dissolved uranium are in excellent agreement with the measured values. Uranyl complexation with mobile bicarbonate and carbonate ions in the lower perched zone decreases the amount of adsorption by 41.7 %, which results in uranium concentrations exceeding the proposed EPA MCL of 20 µg/l.

In addition to R-9 geochemical modeling, the PHREEQC code was used to examine barium solubility and speciation in TA-16 springs and the Cañon de Valle alluvial system. The results are briefly described in the summary for Aggregate 5 (Section 3.2.5).

2.2.2 FY99 Planned Activities

2.2.2.1 Hydrologic Modeling FY99 Planned Activities

Continued calibration of the Los Alamos regional aquifer model will be accomplished by simulating transients in the aquifer. Effects of pumping in Los Alamos, Española, and Santa Fe well field and simulate historical trends in water levels will be incorporated into the model. A high resolution sub-model of the regional model for the Pajarito Plateau will also be developed. This will allow more detailed predictions at the LANL site. Finally, transport capabilities will be added to the model, both reactive and non-reactive, in order to test its ability to predict the observed concentrations of major ions (e.g. Na, Ca, Mg) and stable isotopes (e.g. $\delta^{18}O$, δD, ^{14}C) in wells and springs. This analysis is intended to help us refine both the conceptual model and the numerical flow model.

Continued development of the lower Los Alamos Canyon hydrologic model is planned. The focus will be to develop flow models to examine the links between the various aquifers in the lower part of the canyon.

2.2.2.2 Geologic Modeling FY99 Planned Activities

The 3-D Site-wide Stratigraphic model maintenance and enhancement activities planned for FY99 include:

1. Migrate the current 3-D Geologic model to Stratamodel
    - maintain a current model in Stratamodel format,
    - store versions of the model in Stratamodel and Arcinfo format at FIMAD,
    - develop tools/utilities to extract and present information from the model (either format) to support "Atlas" activities, and
    - maintain close communication with modelers to insure that the geologic model is adequate for the numerical modeling tasks.
2. Extend, refine, or create new grids in Stratamodel for specific applications such as detailed studies at MDAs or stream channels.
3. Review and compile existing geologic information, or collect new information as required, to insure that regional extent and/or refinement of the model fulfills modeling requirements.
4. Assume ownership of the regional basin-wide Stratamodel to include:
    - migration of the model and associated data support to the 3-D geologic model team,
    - maintain, adapt, and QA the existing support database, and identify and add new data to the model as necessary, i.e., Precambrian and Paleozoic/Mesozoic surfaces to be provided by E. Keating.
5. Complete incorporation of older basalt and Tschicoma flow units into the model with addition tasks to include:
    - create a repository for associated chemical and age data,
    - QA of the modeled geometry of the units,
    - provide stratigraphic control through age dates of basalt and silicic volcanics, and
    - update and modification of the existing basalt model as new data becomes available from new wells.
6. Develop basic geologic information/data model for the Chaquehui Formation
    - based on characterization of cuttings from new water supply wells, and
    - possible study of equivalent units having surface exposure.

7. Assist in developing a geohydrologic atlas to include as a minimum:
   - spatial distribution of units in 2- and 3-D,
   - geology at the water table,
   - chemical and physical property information or units,
   - sources of data for the model, and
   - a web page describing and illustrating the geology at LANL.

8. Work with the New Mexico Bureau of Mines to produce the Frijoles Geologic Quadrangle from the existing 3-D database.

9. Creation of FY99 3-D stratigraphic model and updating model on a timely basis when required by customers.

10. Integration of hydrologic data into Stratamodel by utilizing geostatistics and other methods of parameter estimation to extend and qualify the data support.

2.2.2.3 Geochemical Modeling FY99 Planned Activities

Continued geochemical modeling of the Los Alamos, Sandia, and Mortandad Canyons will be accomplished by (1) incorporating speciation, mineral saturation index, and adsorption computations using alluvial, perched intermediate, and regional aquifer groundwaters as data input, (2) performing adsorption experiments for key contaminants, e.g., uranium and strontium, (3) validating geochemical modeling using water chemistry data, results of mineralogical analyses, and hydrologic properties of different aquifer materials, and (4) performing risk analyses using geochemical data.

Geochemical modeling of Cañon de Valle perched zones and regional aquifer groundwater will be initiated by (1) incorporating speciation, mineral saturation index, biodegradation and adsorption computations, (2) performing biodegradation experiments for key HE contaminant, e.g., RDX and TNT, (3) validating geochemical modeling using water chemistry data, results of mineralogical analyses, and hydrologic properties of different aquifer materials, and (4) performing risk analyses using geochemical data.

Additional geochemical modeling of barium speciation and solubility will be performed as more water chemistry time-series data is collected at TA-16. A summary of FY98 barium modeling results are included in the discussion of Aggregate 5 (Section 3.2.5).

3.0 STATUS OF FIELD ACTIVITIES

Field activities include both regional and aggregate-specific activities. Regional activities include activities such as plateau-wide sampling of surface or groundwater. Aggregate-specific activities include the installation of wells or other types of activities. Figure 3-1 shows the locations of aggregates. Figure 3-2 shows the locations of the geologic cross section lines that the conceptual model diagrams are based on.

3.1 Regional Field Activities (Aggregate 9)

3.1.1 Aggregate 9 FY98 Investigations

Aggregate 9 (site-wide aggregate) addresses the entire laboratory. It must integrate all available information from field and modeling studies to update the overall hydrologic conceptual model for the Laboratory and the Pajarito Plateau by confirming of hypotheses, expanding on detail, and posing new hypotheses where new data raises questions. Two key focus areas of investigation include:

- Understanding the major recharge locations and pathways for the uppermost aquifer(s), and
- Better quantification of the rate and direction of groundwater flow beneath the Pajarito Plateau.

A number of field investigations and data collection efforts were carried out across the laboratory in FY98. Similar to FY97, field measurements of near-surface hydrologic cycle components and of groundwater levels at various depths were made. The hydrologic sample locations were unchanged from those of FY97 and are listed in Table 3.1-1. The following bullets summarize the types of data collected.

- Surface hydrology data included stream flow measurements at 19 gaging stations.
- Spring discharge measurements were conducted at three springs at TA-16 near the western Laboratory boundary.
- Groundwater levels were continuously recorded at 33 locations using pressure transducers installed in shallow, intermediate, and deep wells.
- Wells in normally dry canyon bottoms were checked for water.
- Precipitation was measured at seven stations.
- Evapotranspiration (ET) was measured at two stations, one near the western boundary at TA-6 and one near the eastern boundary at TA-54.

Decisions were made on number and location of additional gaging stations to provide stream flow measurements and analytical data for tracking contaminant transport through the Laboratory's Watershed Management Plan. The planned expanded stream flow-monitoring network will provide needed information for a plateau-wide water balance study.

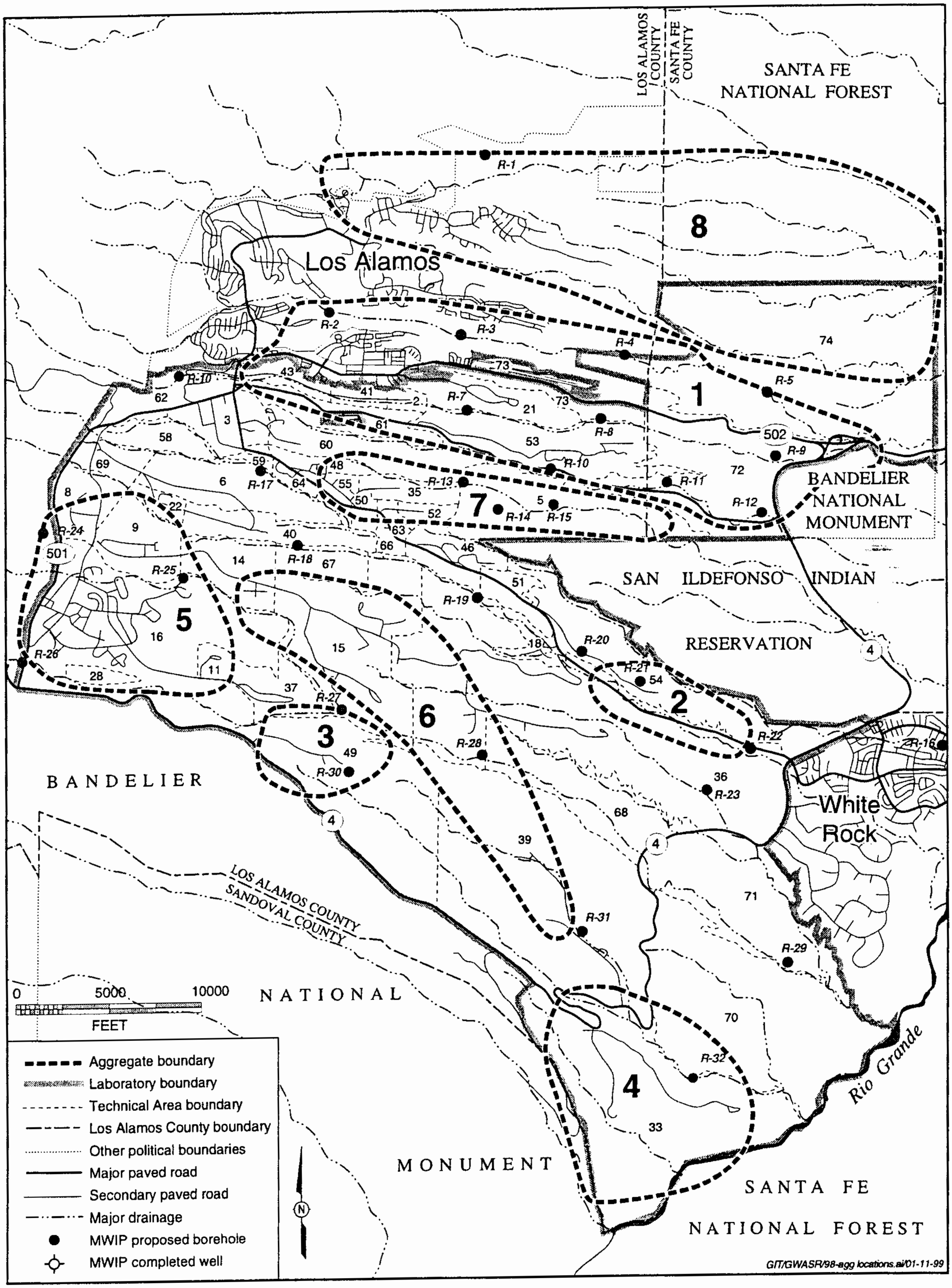

Figure 3-1. Locations of aggregates.

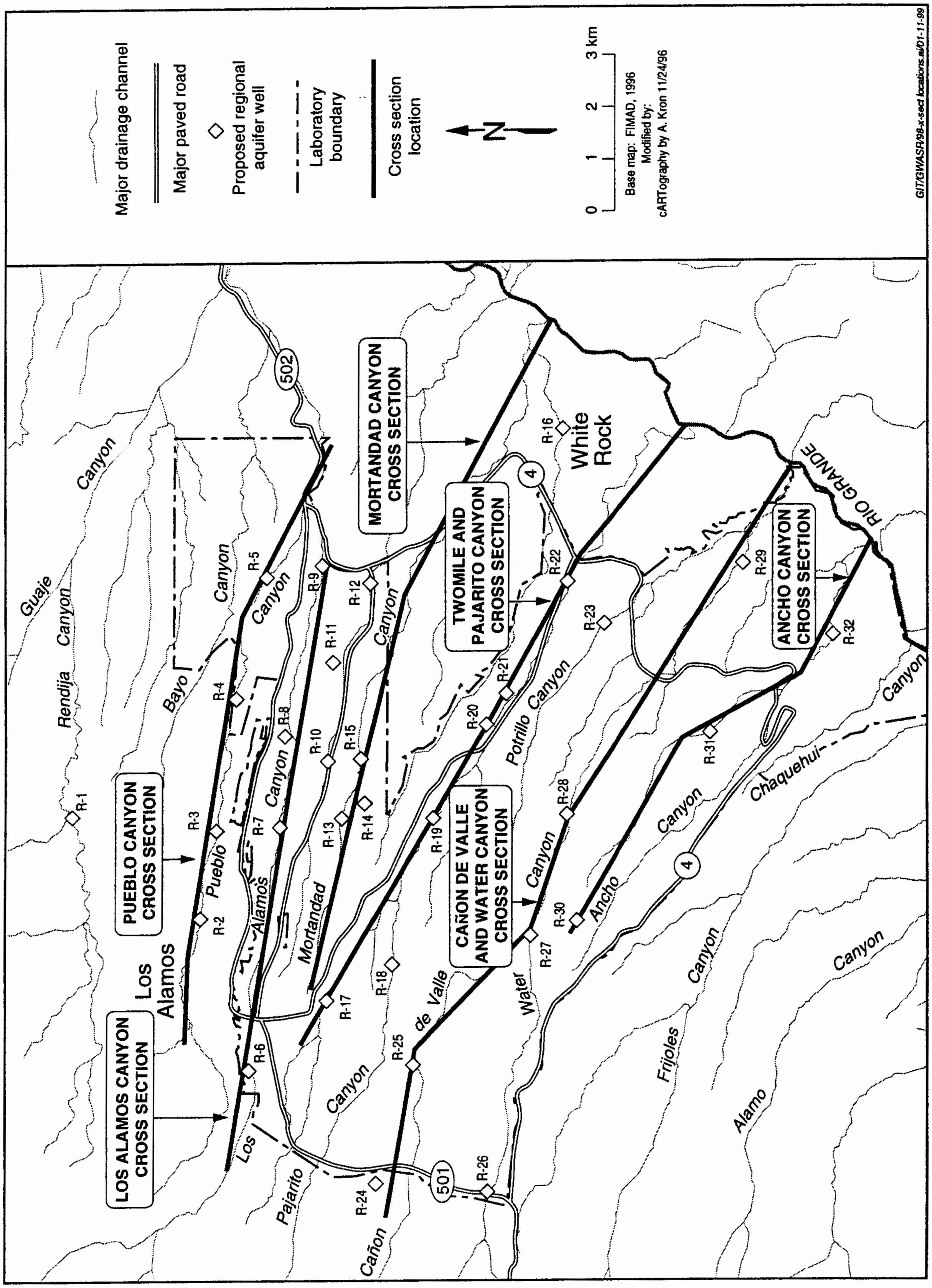

Figure 3-2. Location of geologic cross sections.

Table 3.1-1. Water Budget Hydrologic Data Collected at LANL in 1998

Measurement	Location	Mode
Stream flow (19 stations)	Ancho Canyon	1 gage: Ancho @ SR-4
	Water Canyon	2 gages: Water @ SR-502, Water @ SR-4
	Cañon de Valle	1 gage: Cañon de Valle @ SR-502
	Potrillo Canyon	1 gage: Potrillo @ SR-4
	Pajarito Canyon	3 gages: Pajarito @ SR-502, Pajarito near TA-18, Pajarito @ SR-4
	Cañada del Buey	2 gages: CDB north of TA-54, CDB @ SR-4
	Mortandad Canyon	4 gages: Mortandad @ GS-1, Mortandad above sediment traps, Mortandad below sediment traps, Mortandad @ Laboratory eastern boundary
	Sandia Canyon	1 gage: Sandia @ SR-4
	Los Alamos Canyon	3 gages: LA @ Skating Rink, LA above DP Canyon, LA @ SR-4
	Pueblo Canyon	1 gage: Pueblo @ SR-4
Spring flow (3 stations)	TA-16	3 springs: SWSC line, Burning Ground, Martin
Groundwater levels (33 stations)	Mortandad Canyon Alluvium	12 wells: MCWB-5, MCWB-5.5A, MCWB-5.5B, MCWB-6.2A, MCWB-6.5C, MCWB-6.5E, MCWB-7A, MCWB-7B, MCWB-7.2, MCWB-7.4A, MCWB-7.4B, MCWB-7.7B
	Los Alamos Canyon Alluvium	8 wells: LAO-C, LAO-0.7, LAO-1, LAO-2, LAO-3, LAO-4, LAO-4.5C, LAO-6A
	Intermediate Depth Groundwater and Regional Aquifer	13 wells: LAOI-1.1, LADP-3, LA-1B, TW-1A, TW-2A, TW-1, TW-2, TW-3, TW-4, TW-8, DT-5A, DT-9, DT-10
Precipitation (7 stations)		7 stations: North Community, TA-16, TA-6, TA-49, TA-53, TA-54, TA-74, Pajarito Mountain
Evapotranspiration (2 stations)		2 stations: TA-6, TA-54

New information regarding the complexity of the intermediate perched groundwater systems was provided through the drilling of boreholes R-9 and R-12 and the start of R-25. Detailed findings of R-9 and R-12 are presented in Section 3.2.1 of this report, and will be only generally referenced here. At shallower depths, significant complexities in the near-surface groundwater systems on the western boundary of the Laboratory were indicated by analyses of precipitation and spring discharge data for the RFI investigations at TA-16.

Numerical modeling of the vadose zone in Mortandad Canyon (Dander 1998) and TA-54 Area G *(see Other Modeling Activities under Section 2.2.1.1)* and of the regional aquifer systems *(see Section 2.2.1.1)* and stratigraphy *(see Section 2.2.1.2)* provides additional insights into the dynamics of water movement on the Pajarito Plateau.

Existing data on construction, use, geology, hydrology, and current status of 25 test wells and test holes on the plateau were compiled. Based on this data, recommendations were made on which wells or holes should be plugged and abandoned and which ones should be left in service. Emphasis for plugging and abandonment recommendations was placed on test holes that present a safety hazard, uncased holes that present a contaminant transport pathway, and wells that have been abandoned but not plugged. It was recommended that 11 test holes and test wells be plugged and abandoned. They are, in order of priority: Alpha Hole (1) and Beta Hole (2) because they are large-diameter dug holes that present a safety hazard; TW-8 (3) because it provides a possible contamination pathway for vapor phase tritium; H-19 (4) because the hole is uncased to 2000 ft and there is insufficient surface casing (10 ft) to prevent surface water or alluvial groundwater from entering the borehole; TW-2B (5) because it is an open hole providing a contamination pathway; Layne-Western (6) because it has been abandoned since 1950; and TH-5 (7), TH-6 (8), DT-5 (9), TH-EGH-LA-1 (10), and H-16 (11) because they are abandoned open holes or partially cased holes that provide a contamination pathway. Emphasis for retaining a well as part of the monitoring network was placed on known construction quality, well history, and the quality of water records. It was recommended that nine test wells be retained as part of the monitoring network: TW-1, TW-1A, TW-2, TW-2A, TW-3, TW-4, DT-5A, DT-9, and DT-10. Engineering, geology, and construction data upon which the recommendations are made are compiled in Purtymun and Swanton (1998 draft in press).

3.1.2 Aggregate 9 Conceptual Model Refinements

Data collected in FY98 provides the basis for all three types of conceptual model development: confirmation, added detail, and questions requiring new hypotheses. A summary follows:

- Examination of detailed hydrographs for the springs at TA-16 provides insights into recharge at the springs, and hence into the subsurface hydrogeologic conceptual model for the near-surface western portion of the Laboratory. In addition, tracer studies at TA-16 indicate relatively direct connections of effluent sources with pathways to these springs. The data suggest that groundwater flow in this area is structurally controlled by surge beds and/or fractured intervals (LANL ER Project 1998a; LANL ER Project 1998b). Spring discharge and groundwater flow at shallower depths (less than 200 ft) evidently occurs as a result of highly channelized flow along discrete zones rather than as discharge from a larger porous media volume. Groundwater flow through fractures has long been recognized at the Water Canyon Gallery, located west of the Laboratory along the flank of the Sierra de los Valles. These analyses suggest the phenomenon extends further east beyond the Pajarito Fault Zone, onto the west side of the Laboratory. Contaminant transport through these systems thus may be rapid and seasonally variable.

- Detailed review of existing data raises the question of whether springs high on the flanks of the Sierra de los Valles may be fed largely or partially by an old source of groundwater as opposed to the presumption that they are sustained by contemporary precipitation.

- Some confirmation of basic stratigraphy and the projections of the 3D model were provided by the drilling of regional boreholes R-12, -25, and -15. These boreholes also provided additional data on the exact nature of the individual strata.

- The intermediate depth perched groundwater zones present on the eastern portion of the Laboratory are more numerous and have more complex flow paths than previously recognized. Both boreholes R-9 and R-12 encountered multiple perched zones within the vadose zone, suggesting the presence of a large number of potential perching layers in all of the stratigraphic units penetrated. The saturated thicknesses of these zones were variable: some of the zones were thin (a few feet thick) while others showed saturated thicknesses greater than anticipated (more than 70 feet). Additionally, the field observations indicate many of the perched horizons are confined with hydraulic pressures of several tens of feet. The cumulated data suggests that delineating the direction or velocity of groundwater flow for all but the largest saturated zones may prove difficult.

- While the tritium data are strong evidence that downward percolation has occurred, other chemical data from the various intermediate perched zones contributes to the growing recognition of complexity of the possible pathways from surface sources. Questions have been raised about possible sources of elevated levels of uranium, oxalate, and nitrate in some of the perched zones. Possible candidates could be Pueblo, Los Alamos, and Mortandad Canyons, but inconsistencies in the data leave numerous questions open at this time.

- A portion of the water moving through the vadose zone may be horizontally displaced for noteworthy distances from the source. Perched water in borehole R-12 may have been impacted by surface sources located on the order of one mile away, based on an initial interpretation of stable nitrogen isotopic analyses. The isotopic data indicates the water contains nitrogen originating from septic sources, most likely sewage effluents. The closest known sewage effluent streams are located approximately three quarters of a mile away in Pueblo Canyon and two miles away in Sandia Canyon.

- Numeric modeling of the vadose zone in Mortandad Canyon suggests oppositely that flow in the unsaturated zone may be predominantly downward; thus lateral flow at lithologic boundaries may not be significant. This conclusion is very dependent on the permeability contrast between lithologic units and the continuity of the units.

- The presence of elevated levels of tritium in the R-9 and R-12 perched zones provides additional evidence for percolation of Laboratory effluents to significant depths (more than 500 feet) in the vadose zone.

- Tritium levels in regional aquifer samples from R-9 and R-12 indicate some recharge of water from the land surface to the regional aquifer in a period of 40 years or less. These findings support earlier test results obtained in old monitoring wells scattered across the Laboratory. Simulations from a numerical modeling study of unsaturated groundwater movement beneath Mortandad Canyon showed water from the shallow perched water table could reach the regional aquifer in approximately ten to one hundred years, depending upon the assumed recharge rate used in the simulations (Dander 1998).

- Upward vertical gradients in the regional aquifer are indicated at R-12, based on initial comparison of static water levels in R-12 with the deeper adjacent municipal well PM-1. If vertical gradients are verified with additional testing, the potential for Laboratory contaminants at the top of the regional aquifer to migrate deeper is much reduced. Upward hydraulic gradients are known to exist in wells approximately 4 miles east of R-12, near the Rio Grande (the old Los Alamos well field). Significant uncertainties exist, however, in our understanding of vertical gradients beneath the Laboratory. Preliminary results from the regional numerical flow modeling indicate minimal vertical gradients (i.e. predominantly horizontal flow) beneath most of the central portion of the Laboratory. The pumping of municipal supply wells may also locally alter the vertical gradients.

- Initial results of the regional modeling suggest that flow beneath the laboratory must be generally eastward, with most recharge coming from the west.

3.1.3 Aggregate 9 FY99 Planned Activities

Monitoring and data collection activities for near-surface hydrologic cycle components and groundwater levels at various depths similar to those conducted in FY98 are planned. Wells located in normally dry canyon bottoms will be monitored and sampled if groundwater is present.

Twenty-two surface water-gaging stations are to be installed in FY99 to provide additional stream flow measurements at canyon confluences and the Laboratory's east and west boundaries. Decisions on the number of stations, design, locations, and sampling plans were made jointly between ER Project personnel and ESH-18 personnel to meet program needs and regulatory requirements. Data from these stations will provide needed information for a plateau-wide water balance study as well as information on contaminant migration in sediments and surface water. This planned activity will be funded through the Watershed Management Program.

A water balance study in Los Alamos Canyon is planned in FY99. Activities are designed to build upon work previously performed by Robert Gray for a master's thesis (Gray, 1997) The scope of the previously completed work included the computation of a water balance for the Los Alamos Canyon watershed using available meteorological and hydrologic data. The water balance results were then used to constrain the recharge and ET parameters for a three-dimensional finite-difference groundwater flow model of the alluvial aquifer in Los Alamos Canyon constructed with the U.S. Geological Survey's MODFLOW code (McDonald and Harbaugh, 1988). A steady-state simulation was calibrated to alluvial head data and transient simulations were conducted to test the model's performance. The results of the modeling were used to quantify infiltration seepage from the alluvial aquifer into the canyon's subsurface strata, a significant source of groundwater recharge to the deeper subsurface that is important because of the implications for the mobilization and migration of LANL-derived contaminants along the groundwater flow paths.

The previous work represents an initial effort restricted in scope because of the limited availability of pertinent hydrologic data (i.e. varying streamflow rates and alluvial hydraulic conductivities) and inherent simplifications imposed on the initial hydrologic conceptual model (i.e. aerial recharge was assumed as the dominant recharge mechanism; homogeneous and isotropic conditions were assumed within the aquifer). The subsequent efforts planned for FY99 are designed to (1) provide additional hydrologic data characterizing the hydraulic properties of the alluvium and the nature of stream-aquifer interaction, and (2) refine the groundwater flow model of the alluvial system. The specific activities planned to address these objectives are:

- perform slug tests on additional ER alluvial wells and analyze previously collected (FY98) slug test data to determine varying hydraulic conductivities of the alluvium
- collect measurements of the water levels in ER alluvial wells on a monthly basis providing data for model calibration
- refine the groundwater flow model by applying updated hydraulic conductivity data and incorporating focused recharge from the streambed based on limited seepage run data previously collected (in 1995) by the United States (US) Geological Survey
- perform multiple detailed seepage run analyses by collecting closely spaced measurements of streamflow rates during peak runoff conditions (i.e. spring snowmelt) and additional discrete runoff events including storm events and during low-flow conditions

The results of these efforts will be to improve the existing alluvial aquifer flow model and quantify the amount of groundwater recharge due to infiltration seepage from the alluvial system in Los Alamos Canyon with a higher degree of confidence than was previously determined. This information will then be available for application to additional groundwater modeling efforts planned by EES-5 to simulate flow conditions in the deeper subsurface. The planned FY99 efforts involve a limited scope of activities designed to permit specific modifications to the pre-existing flow model, thereby enhancing the veracity of it's results. Pre-existing streamflow data will be utilized to quantify focused recharge to the alluvium from the streambed, while the pre-existing water budget results will continue to be used to constrain the aerial recharge and ET rates applied to the rest of the model. The detailed streamflow data, alluvial head data, and slug test data to be collected will be useful for future efforts projected to carry over into FY2000 and directed towards updating and refining the water balance for the Los Alamos Canyon watershed and further refining the flow model of the alluvial system.

3.2 Aggregate-Specific Field Activities

The FY98 investigations that occurred within Aggregates 1-8 are described in the following sections. Figure 3-1 shows the locations of aggregates. Based on the data collected in the investigations, refinements to the conceptual models are presented. A brief description of proposed FY99 activities is also included.

3.2.1 Aggregate 1

Aggregate 1 is bounded on the north by Pueblo Canyon, on the south by Sandia Canyon, on the east by state road NM 4, and to the west by the Jemez Mountains (Figure 3.2-1). Aggregate 1 includes the Los Alamos townsite, and currently active technical areas: TA-21, which is on DP Mesa; TA-43, which is the site of the Los Alamos Medical Center; TA-53, which is the site of the Los Alamos Neutron Science Center; and TA-73, which is the Los Alamos Airport. This aggregate also includes two inactive technical areas (TA-0 and TA-45) where early Laboratory operations took place.

3.2.1.1 Aggregate 1 FY98 Investigations

Borehole R-9

R-9 drilling results were mostly summarized in last year's annual report. Groundwater chemical data, particularly for contaminants, were pending at the time the 1997 annual report was prepared. Therefore, a brief summary of the groundwater zones encountered in R-9 and a summary the water chemical characteristics of these zones is provided below. A more in-depth description of R-9 drilling and testing activities is presented in Broxton et al (1998). Figure 3.2-2 is a completion diagram of R-9 showing water levels and zones where contamination was detected.

- Six zones of saturation were encountered during the drilling of R-9. Two perched groundwater zones were encountered in Cerros del Rio basalt at depths of 180 and 275 ft. The upper zone was confined, and water rose in the hole to 137 ft after the top of the zone was penetrated. The saturated thickness of the upper zone is approximately 45 ft. The second perched zone occurs at the base of the Cerros del Rio basalt and is approximately 7 ft thick. Thin zones of saturation were also encountered in the Puye Formation at depths of 579, 615, and 624 ft. These zones, which are of uncertain origin, occur in transmissive zones intercalated in clay-rich tuffaceous sedimentary deposits. These three zones are confined and appear to be hydraulically connected because water levels rose to a depth of 524 ft after the tops of each of the zones were penetrated. The deepest groundwater zone was encountered at a depth of 688 ft near the top of basalt in the Santa Fe Group. This deep groundwater is unconfined, and it is almost certainly associated with the regional aquifer.

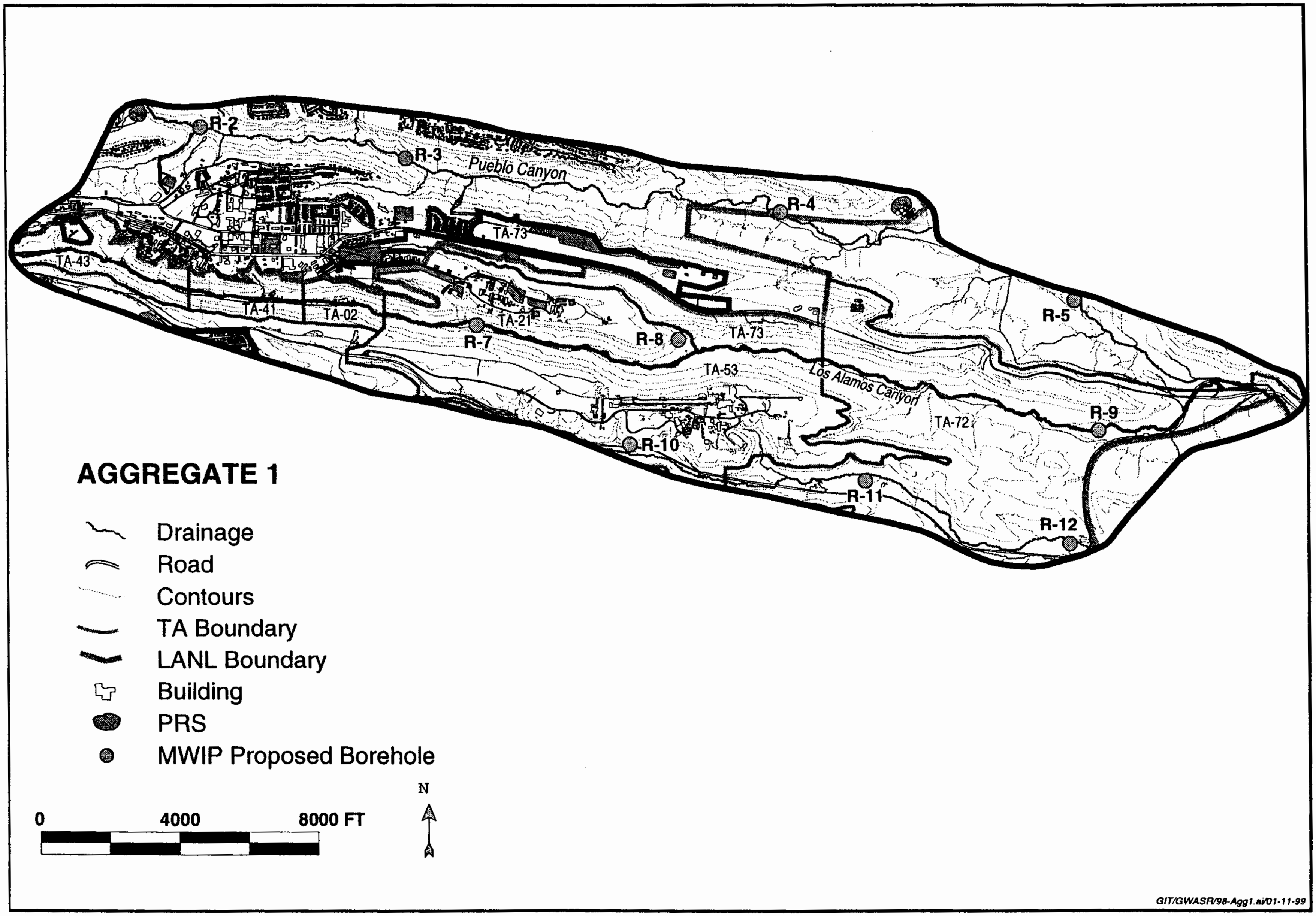

Figure 3.2-1. PRSs and proposed wells in Aggregate 1.

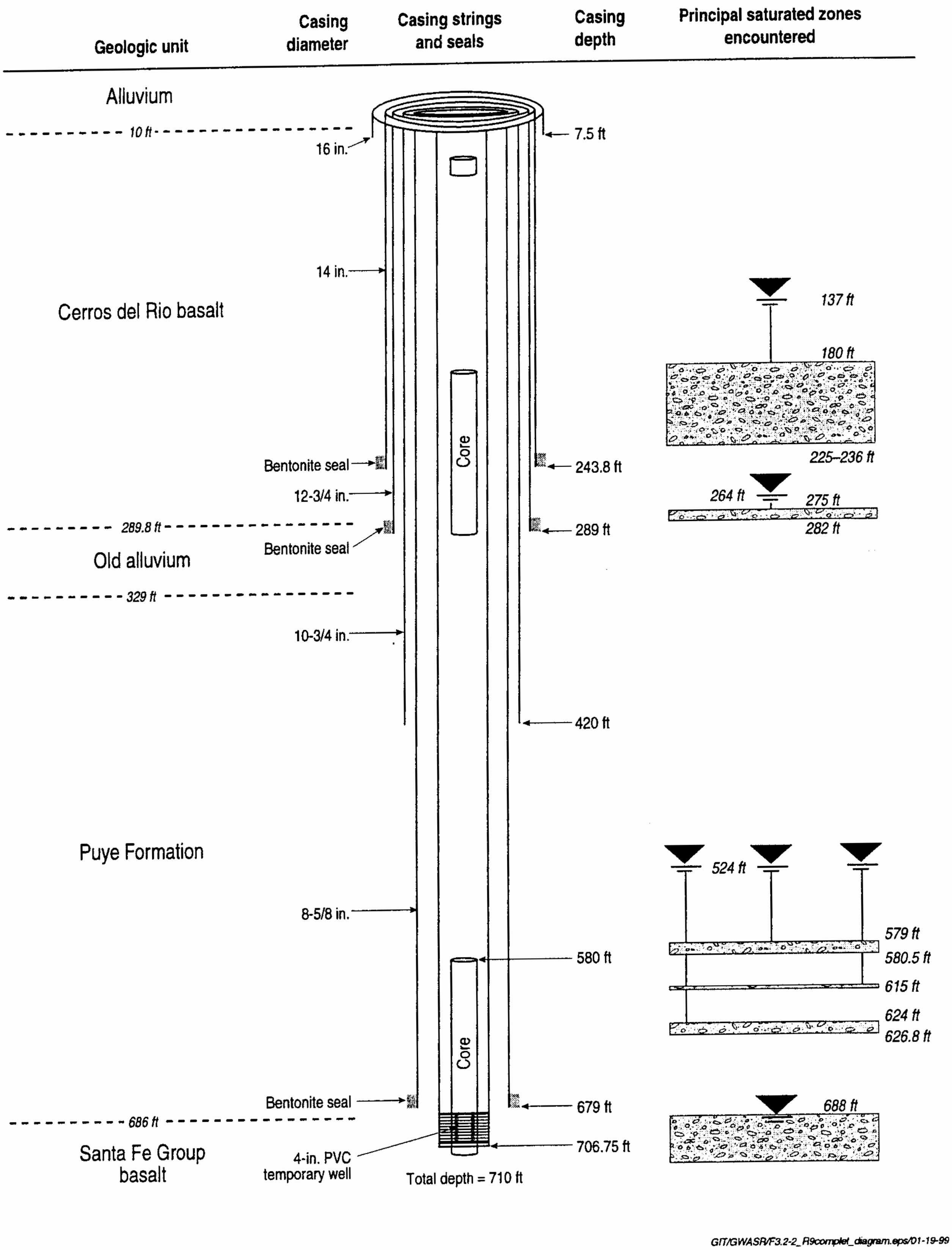

Figure 3.2-2. Configuration of R-9 as of January 30, 1998.

- In R-9, groundwater in the six saturated zones was chemically characterized for major ions, trace elements, dissolved organic carbon, stable isotopes, tritium, and other radionuclides. Groundwater from the uppermost perched zone (180-ft depth) is characterized by a sodium-calcium-chloride-bicarbonate ionic composition with a pH value of 8.30. This zone contains 347 pCi/L tritium (analysis by low-level electrolytic enrichment), which is similar to tritium activities detected in alluvial groundwater within upper Los Alamos Canyon. The perched zone at the base of the Cerros del Rio basalt at a depth of 275 ft is characterized by a sodium-sulfate-bicarbonate ionic composition with a pH value of 8.79. This zone contains 106 pCi/L tritium (low-level electrolytic enrichment) and 48.4 parts per billion (ppb) dissolved uranium. The lower zone in the Cerros del Rio basalt has a higher total dissolved solids (TDS) content (389 parts per million [ppm]) than the upper zone (252 ppm), possibly reflecting a longer groundwater residence time. Composition of groundwater within the Puye Formation varies from a calcium-sodium-bicarbonate to sodium-chloride-bicarbonate type. Tritium activities in groundwater of the Puye Formation range from 2.71 to 30.3 pCi/L. The saturated zone in Santa Fe Group basalt at a depth of 688 ft is characterized by a calcium-sodium-bicarbonate ionic composition with a TDS content of 387 ppm. This groundwater is chemically similar to that in the regional aquifer in wells PM-1 and PM-3. It has a tritium activity of 14.43 pCi/L.

Borehole R-12

Characterization well R-12, located in Sandia Canyon near the eastern boundary of Los Alamos National Laboratory, is the second of approximately 32 wells being installed in the regional aquifer as part of the Laboratory's *Hydrogeologic Workplan* (LANL 1996, 55430). R-12 was funded by the Laboratory's ER Project and is primarily designed to provide water quality and water-level data for potential intermediate-depth perched zones and for the regional aquifer. R-12 is downgradient of multiple contaminant source areas that potentially include release sites in the upper Sandia Canyon, Los Alamos Canyon, and Mortandad Canyon watersheds. R-12 is also sited to provide early warning for contaminants approaching water supply well PM-1 and to provide hydrologic and geologic data that contribute to the understanding of the vadose zone and regional aquifer in this part of the Laboratory. Although located in Sandia Canyon, R-12 is presented as part of the Aggregate 1 discussion because it was installed as part of the Work Plan for Los Alamos Canyon and Pueblo Canyon. A summary of R-12 drilling results is summarized below. A more in-depth description of R-12 drilling and testing activities is presented in Broxton et al. (1998A). Figure 3.2-3 shows the current completion status of R-12.

- R-12 was drilled to a total depth of 847 ft using air-rotary techniques. Drilling methods included downhole percussion hammers and dual-wall casing to drill open hole, a continuous coring system to core open hole, and Holte/Stratex casing advance systems that operated on dual-wall casing and downhole percussion hammers. In descending order, geologic units penetrated in R-12 included alluvium, tephras and volcaniclastic sediments of the Cerro Toledo interval, Otowi Member of the Bandelier Tuff, basaltic rocks of the Cerros del Rio volcanic field, old alluvium, Puye Formation, and basaltic rocks of the Santa Fe Group.

- A perched groundwater system was encountered from depths of 443 to 519 ft in the lower part of the Cerros del Rio basalt and in underlying old alluvium. Groundwater in this zone was confined and the water level stabilized at a depth of 424 ft after the top of the zone was penetrated. The confining layer at the top of this zone apparently is massive basalt, and the lower perching layer is a clay-rich lacustrine deposit. The saturated thickness of this groundwater body is approximately 75 ft, making it one of the thickest intermediate-depth perched groundwater bodies identified yet on the Pajarito Plateau.

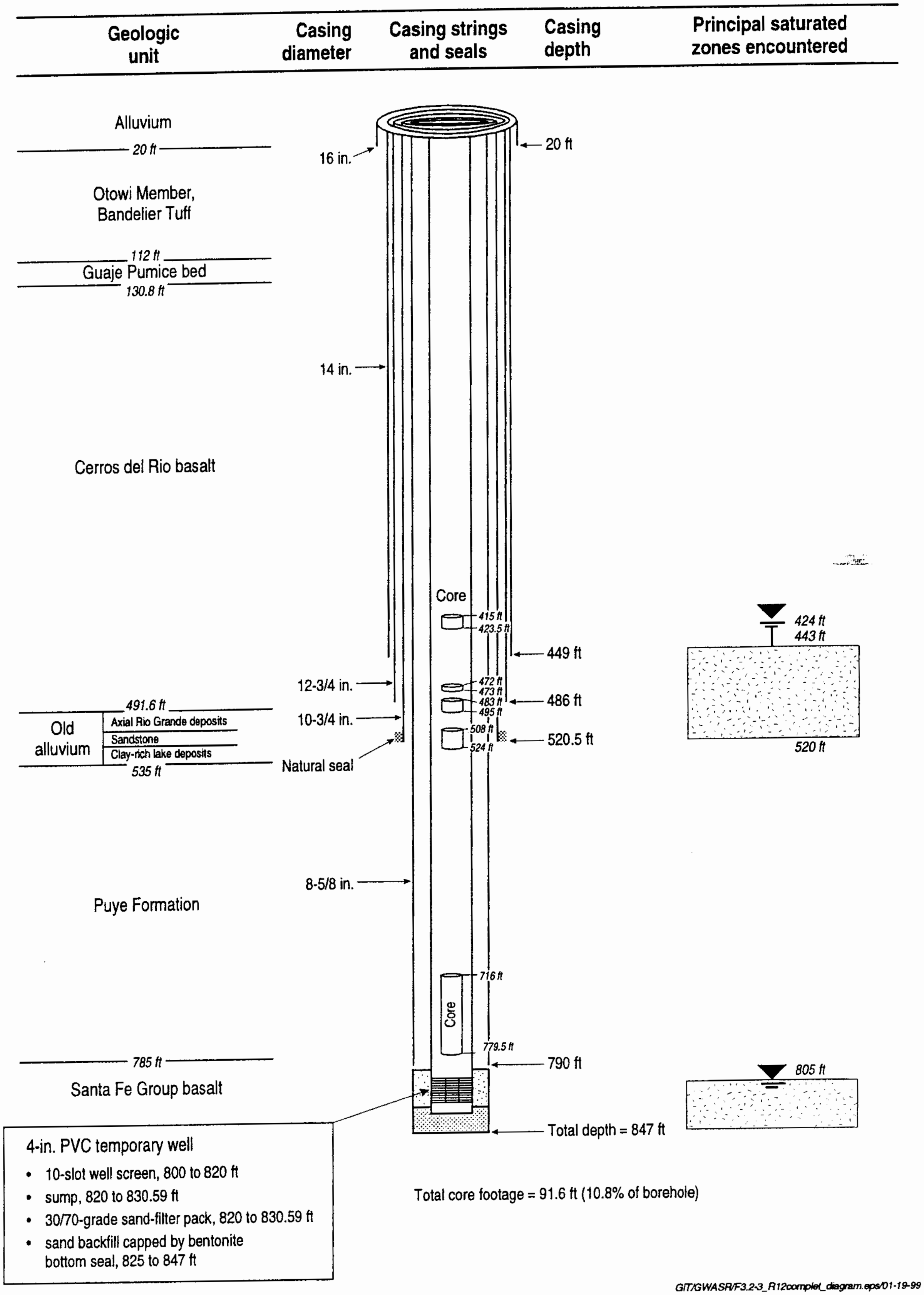

Figure 3.2-3. Configuration of R-12 as of June 10, 1998.

- The regional water table was encountered at a depth of 805 ft in fractured basalt of the Santa Fe Group. The water is unconfined and occurs at the same elevation as at R-9, located approximately 1 km to the north. The elevation of the water table in R-12 is approximately 62 ft lower than the static water level in nearby supply well PM-1 under nonpumping conditions.

- Groundwater samples were collected from the perched zone at depths of 443, 464, and 495 ft. These samples were chemically characterized with respect to major ions, trace elements, dissolved organic carbon, stable isotopes, tritium, and other radionuclides. Groundwater compositions are similar for the samples collected at depths of 443 and 495 ft, but the groundwater sampled at 464 ft has a distinctive chemistry.

- Groundwater from the perched zone is dominantly a calcium-sodium-bicarbonate-chloride type as represented by the samples collected at depths of 443 and 495 ft. There is also a sodium-calcium-chloride-sulfate-bicarbonate groundwater at a depth of 464 ft. Groundwater from the depths of 443 and 495 ft was found to contain 249.3 to 254.7 pCi/L tritium (analysis by low-level electrolytic enrichment), 31.5 to 33.4 ppm chloride, <0.02 to 0.26 ppm ammonium, 4.9 to 5.5 ppm nitrate, and 2.46 to 2.51 ppb uranium. Groundwater from the depth of 464 ft was found to contain 208.1 pCi/L tritium, 200 ppm chloride, 13.5 ppm ammonium, 0.21 ppm nitrate, and 2.04 ppb uranium.

- Groundwater at the top of the regional saturated zone is a calcium-sodium-bicarbonate type with a TDS content of 386 ppm. The major cation and anion chemistry of this water is similar to groundwater in supply wells PM-1 and PM-3. The tritium activity in the regional saturated zone is 46.9 pCi/L.

Alluvial Groundwater Investigations

Four alluvial wells were installed in middle and lower Pueblo Canyon during FY98. These alluvial wells, which included PAO-2.5, PAO-3, PAO-5N, and PAO-5S, were installed by hollow stem auger. Figures 3.2-4 and 3.2-5 show the locations of these wells. Some information for each of these wells is given below. A more in-depth description of these wells is provided in Gray (1998).

- Alluvial well PAO-2.5 is located in middle Pueblo Canyon, approximately 12,350 ft west of the Los Alamos County Bayo Sewage Treatment Plant. The purpose of this well is to determine groundwater chemistry and monitor groundwater quality upgradient of discharges from the Los Alamos County Bayo Sewage Treatment Plant; determine continuity of alluvial groundwater in middle Pueblo Canyon; provide water level information for water balance analyses; provide alluvial groundwater chemistry data to assess potential source of recharge to intermediate-depth perched groundwater zone(s). The stratigraphy encountered included alluvial sediments (0–7.7 ft below ground surface [bgs]) and the Otowi Member of the Bandelier Tuff (7.7–13.9 ft bgs). The water level was 3.8 ft bgs during drilling of initial borehole, but the well was dry after installation.

- Alluvial well PAO-3 is located in middle Pueblo Canyon, approximately 5,200 ft west of the Los Alamos County Bayo Sewage Treatment Plant. The purpose of this well is to determine groundwater chemistry and monitor groundwater quality upgradient of discharges from the Los Alamos County Bayo Sewage Treatment Plant; determine continuity of alluvial groundwater in middle Pueblo Canyon; provide water level information for water balance analyses; provide alluvial groundwater chemistry data to assess potential source of recharge to intermediate-depth perched groundwater zone(s). The stratigraphy encountered included alluvial sediments (0–10.8 ft bgs) and the Otowi Member of the Bandelier Tuff (10.8–17.5 ft bgs). The water level was 6 ft bgs during drilling of initial borehole, but the well went dry after bailing during attempted development activities.

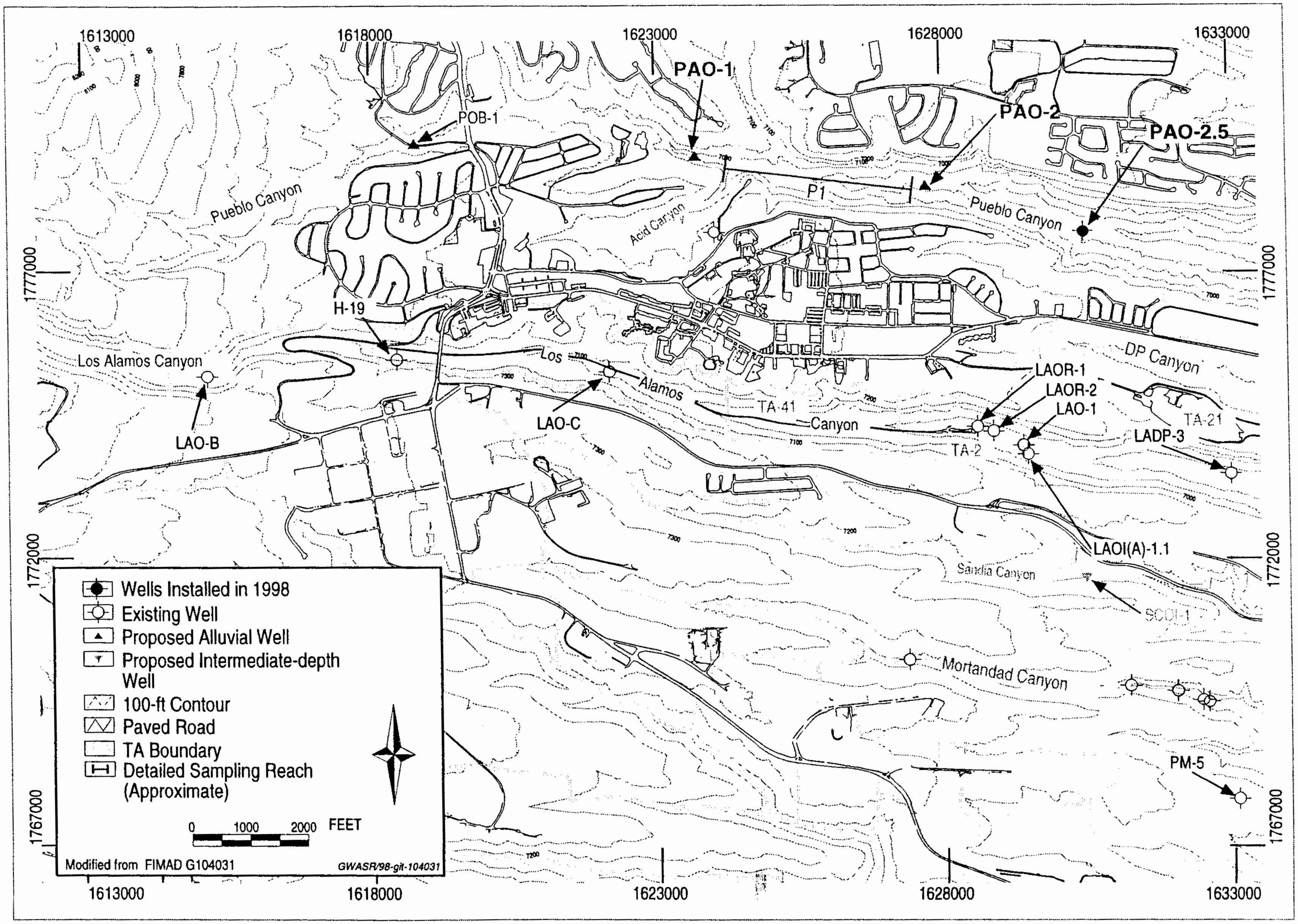

Figure 3.2-4. Wells installed in 1998 and other proposed well locations: western Los Alamos and Pueblo Canyons.

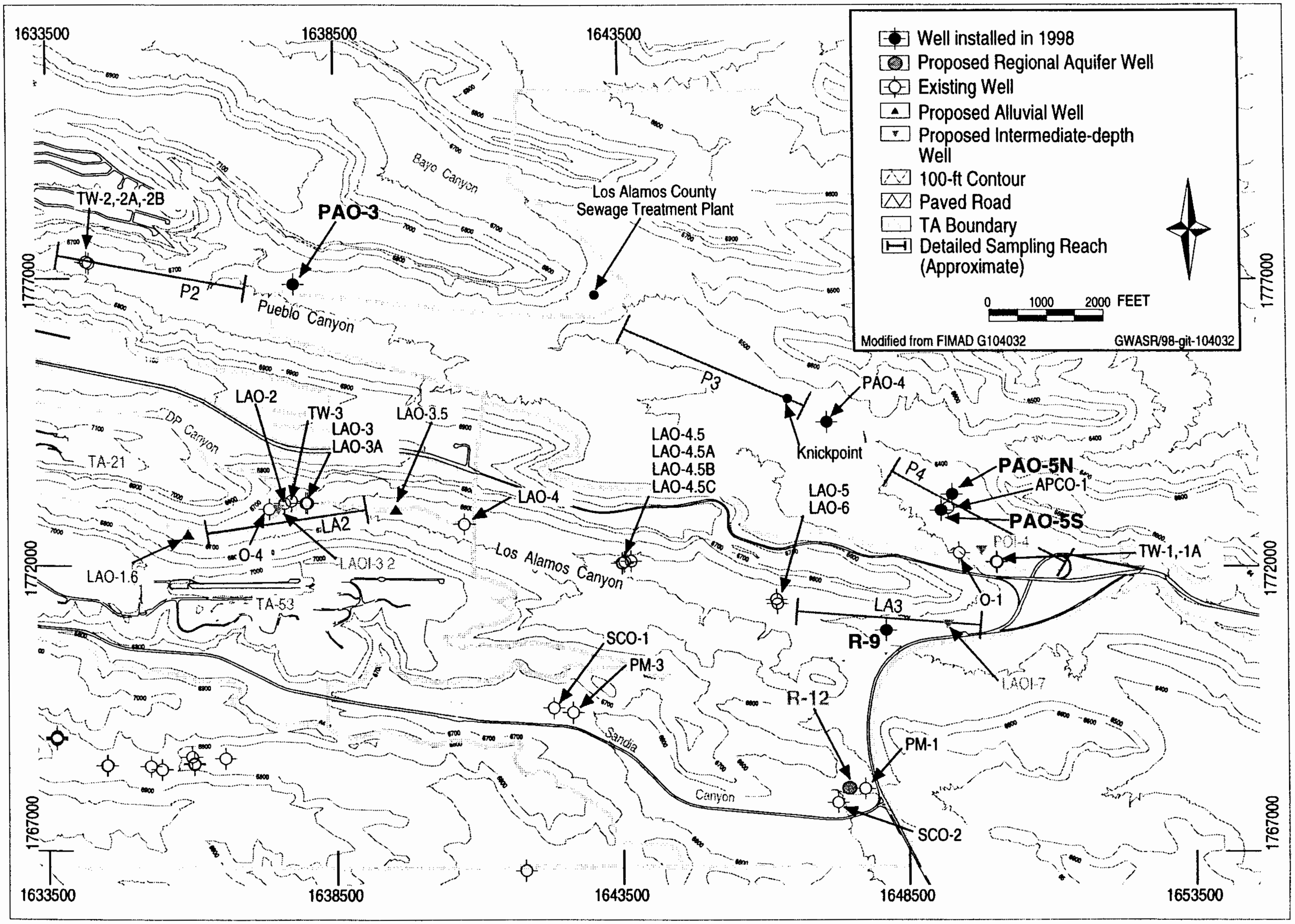

Figure 3.2-5. Wells installed in 1998 and other proposed well locations: central Los Alamos and Pueblo Canyons.

- Alluvial well PAO-5S is located in lower Pueblo Canyon, approximately 800 ft north-northwest of the Otowi-1 supply well, and approximately 1800 ft northwest of the White Rock "Y". The purpose of this well is to determine groundwater chemistry; monitor groundwater quality upgradient of San Ildefonso Pueblo (identify alluvial groundwater impacts from discharges from the Los Alamos County Bayo Sewage Treatment Plant); provide water level information for water balance analyses; provide alluvial groundwater chemistry data to assess potential source of recharge to intermediate-depth perched groundwater zone(s); determine lateral extent of alluvial sediments from a borehole transect that includes wells PAO-5N and APCO-1. The stratigraphy encountered included alluvial sediments (0–5.3 ft bgs) and the Puye Formation (5.3–20 ft bgs). The water level was 7 ft bgs during drilling and well development.

- Alluvial well PAO-5N is located in lower Pueblo Canyon, approximately 170 ft north-northeast of well PAO-5S, approximately 950 ft north-northwest of the Otowi-1 supply well, and approximately 1700 ft northwest of the White Rock "Y". The purpose of this well is to determine groundwater chemistry; monitor groundwater quality upgradient of San Ildefonso Pueblo; provide water level information for water balance analyses; provide alluvial groundwater chemistry data to assess potential source of recharge to intermediate-depth perched groundwater zone(s); determine lateral extent of alluvial sediments from a borehole transect that includes wells PAO-5S and APCO-1. The stratigraphy encountered included alluvial sediments (0–18.0 ft bgs) and the Puye Formation (18.0–22.5 ft bgs). The water level was 7 ft bgs during drilling and well development.

Airport Landfill (TA-73)

The ER Project has been investigating a former municipal landfill near the Los Alamos airport since 1994. This investigation has spanned multiple media and potential contaminants, which resulted in a large database (approximately 64,000 records) of environmental chemical information for this landfill. The RCRA facility investigation (RFI) report submitted to NMED in FY98 presented data for this project, which included statistical evaluations of chemical distributions of contaminants. The RFI report also provided a detailed discussion and information on the nature and extent of contamination and presented qualitative information on contaminant fate and transport. Other information included in the RFI report consisted of calculations of human health risk, developed a site-specific screening-level ecological risk assessment, and mostly importantly documented these findings in an appropriate and technically defensible report. There was no transport modeling of these data in the RFI report, but the conceptual model suggests that vapor phase transport of organic chemicals could be a potential pathway of contaminants to groundwater. The conceptual model also suggested that infiltration of precipitation through the waste into the vadose zone was not a likely groundwater transport pathway. Further action at the airport landfill was recommended to mitigate areas of surface contamination and potential human exposure to landfill gasses.

TA-21 Activities (Submitted by G. McMath and J. Jones)

Material Disposal Area (MDA) B, Potential Release Site (PRS) 21-015

The sampling and analysis plan (SAP) for PRS 21-015 was submitted to the NMED on September 10, 1998 to fulfill the FY98 Work Schedule Commitment. Field work consisted of geophysical surveys, radiological surveys, surface sampling, drilling, and geodetic surveys.

Geophysical surveys were conducted to determine the approximate locations and dimensions of the disposal trenches. Results of geophysical surveys were used to assist in determining final borehole locations around the perimeter of the trenches. Surface samples were collected along the southwestern, western, and northern edges of MDA B.

Seven boreholes were drilled to a depth range between 64 to 82 ft bgs. The boreholes were angled between 40° and 50° from the vertical to drill beneath the disposal trenches. Soil samples are being analyzed for SVOCs, target analyte list (TAL) metals, gamma spectroscopy (cesium-137), isotopic americium, isotopic plutonium, isotopic uranium, strontium-90, and tritium. Soil gas samples are being analyzed for organic constituents.

MDA U, PRS 21-017 (a, b, and c)

The SAP for PRS 21-017 (a–c) was submitted to the NMED on September 28, 1998 to fulfill the FY98 Work Schedule Commitment. Field work consisted of radiological surveys, surface sampling, drilling, and geodetic surveys.

Surface samples were collected along the down gradient slope north and northeast of the beds. Seven vertical boreholes were drilled to approximately 75 ft bgs. Boreholes were drilled within the trenches and around the perimeter of the trenches. Soil samples are being analyzed for SVOCs, TAL metals, gamma spectroscopy (cesium-137 and actinium-227), isotopic americium, isotopic plutonium, isotopic uranium, strontium-90, and tritium. Soil gas samples are being analyzed for VOCs.

PRS 21-024(i), Former Septic Tank and Outfall

Field work consisted of installation of best management practices (BMPs) around the septic tank and removal of contaminated soil from the outfall area.

BMPs around the septic tank were upgraded by installing a temporary roof over the top of the septic tank and placing straw bales and sand bags around the perimeter to prevent storm water run on. Approximately 60 cubic yards of soil were removed from the outfall and placed in roll-off bins. The bins will be taken to TA-54 for burial upon finalization of the transportation manifests.

PRS 21-011(k), Outfall

BMPs were upgraded at PRS 21-011(k). A new sand bag berm was built at the top of the slope to prevent storm water run on and straw bales were installed at the base of the slope in the flow dissipation area. New mulch was placed on the outfall area.

DP Canyon (TA-21)

Quarterly groundwater sampling was conducted in DP Canyon at alluvial monitoring wells LAUZ-1 and LAUZ-2 (Locations 21-01811 and 21-01812, respectively) and DP Spring (Location 21-01854). The 2nd, 3rd and 4th quarter samples were collected during FY98. The sampling was conducted in fulfillment of the SAP that is being implemented as an addendum to the Work Plan for Los Alamos Canyon and Pueblo Canyon. Filtered samples from these locations were analyzed, at a minimum, for isotopic plutonium, isotopic uranium, strontium-90, cesium-137, tritium, and TAL metals. Unfiltered samples were analyzed, at a minimum, for isotopic plutonium, isotopic uranium, strontium-90, cesium-137, tritium, TAL metals, pesticides and polychlorinated biphenyls, SVOCs, and VOCs.

Analytical results from these sampling events indicate that only strontium-90 was detected at activities exceeding the NMED MCL for drinking water (8 pCi/L).

Upper Sandia Canyon

The first phase of an investigation of upper Sandia Canyon was completed in FY98. The investigation is being managed by the Remedial Actions Focus Area with the technical lead provided by the Canyons Focus Area. The first phase of the investigation involved mapping of the upper canyon (Reaches S-1 and S-2) and analysis of 72 sediment samples collected from the volumetrically important geomorphic units identified during the mapping process. Validated results of the first phase of sampling are pending.

Aggregate 1 Geochemistry Findings

Distribution of Oxalate in Surface Waters, Groundwaters, and Soils, Los Alamos National Laboratory and Surrounding Areas (P. Longmire and D. Counce, 11/30/98)

Oxalate has been identified in groundwater in borehole R-9, upper Los Alamos Canyon (Broxton et al., 1998). The origin(s) and distribution of oxalate at R-9 and elsewhere around the Laboratory have been investigated. This preliminary report provides a summary of oxalate distributions in soils, surface water, and groundwater at the Laboratory and surrounding areas.

Approximately 195 groundwater samples, 23 surface water samples and nine background soil samples have been analyzed for anions including oxalate. Groundwater samples were collected from 1996 through 1998 and surface water and soil samples were collected in 1998. In addition, groundwater samples have been analyzed for major cations, trace elements, and trace metals as part of the LANL background water investigation. Surface water samples were collected from the Rio Grande, Mortandad Canyon, upper Sandia Canyon, Pajarito Canyon, DP Canyon, Acid Canyon, Pueblo Canyon, and upper Los Alamos Canyon. Groundwater samples were collected from the following locations: Los Alamos Canyon (alluvium, perched intermediate zones, and regional aquifer), Guaje Canyon (regional aquifer), Sandia Canyon (perched intermediate zone[s] and regional aquifer), Mortandad Canyon (alluvium and regional aquifer), White Rock Canyon springs (perched intermediate zones and regional aquifer), and LANL background springs (perched intermediate zones and regional aquifer) located west and north of the Laboratory.

Oxalate is an organic acid that occurs naturally under specific oxidation-reduction conditions. It is also produced for metal extraction processing for industrial uses. In natural systems, oxalate is formed from the oxidation of carbohydrates (CH_2O) present in organic-rich soils and, in turn, it can eventually oxidize to CO_2 gas. Oxalate is stable under reducing conditions typical of wetlands, bays (Thurman, 1985), oil-field brines, O-horizon soils, and organic-rich soils found in the southeastern USA (Fox and Comerford, 1990). Above a pH value of 4.2, oxalate is stable as $C_2O_4^{2-}$ (Drever, 1988), which is mobile in groundwater and surface water under near-neutral pH conditions. Oxalate precipitates from solution forming minerals with divalent metals including calcium, magnesium, and the uranyl cation, UO_2^{2+}. The oxalate anion can be an excellent tracer under oxidizing conditions due to its mobility in aqueous systems.

Oxalate was used at former TA-1 (LA 1100 report, 1947) and TA-21 in the processing uranyl oxalate ($UO_2C_2O_4$) and plutonium oxalate ($Pu[C_2O_4]_2$ and $Pu_2[C_2O_4]_3$). The solubility of $UO_2C_2O_4$ is approximately 5,000 mg/L. Waste solutions containing uranium and oxalate probably were discharged into upper Los Alamos Canyon and DP Canyon since the 1940s. Discharges containing oxalate, nitrate, chloride, and sulfate may have migrated to the top of the regional aquifer at borehole R-9.

Concentrations of oxalate within soil extracts, surface water samples, and groundwater samples were determined by ion chromatography at EES-1. The detection limit for oxalate using ion chromatography is 0.02 mg/L or ppm. Analytical precision of Dionex ion chromatograph is better than 5%. Both non-acidified filtered and non-filtered water samples were collected for oxalate analysis. Soil samples were dried for 12 hours at 100°C prior to leaching. For the soil samples, 75 ml of deionized water were added to 75 g dry soil forming a 1:1 water-soil slurry. The slurry was shaken for 24 hours on a rotary mixer and filtered prior to chemical analysis.

Only eight groundwater samples contained measurable oxalate, which were collected from borehole R-9 in 1997 and 1998. These included four filtered and four non-filtered samples collected from perched intermediate zones (275, 615, and 624 ft) and the regional aquifer (688 ft). Concentrations of oxalate in R-9 groundwater range from 0.30 to 3.03 ppm (Broxton et al., 1998). The remaining 186 groundwater samples did not contain measurable oxalate. These samples are representative of both background and Laboratory-effluent waters.

Eight of the nine background soil samples did not contain oxalate. One wet top soil sample collected from a grassland area near the ski hill road and state road NM 501 intersection, however, contained 0.5 ppm oxalate.

None of the surface water samples contained oxalate.

Base on these results, it is strongly suggestive that the oxalate measured in groundwaters encountered at borehole R-9 is Laboratory derived. Naturally produced oxalate would occur more ubiquitously at Los Alamos and surrounding areas than what is currently observed. In addition, oxalate occurs with uranium in groundwater samples collected from borehole R-9 (Broxton et al., 1998). Co-location of uranium and oxalate is consistent with the fact that at former TA-1, in the early 1940s, natural uranium ore was initially digested in nitric acid and precipitated as uranyl oxalate prior to forming U_3O_8 (LA-1100, 1947). Residual uranium and oxalate were discharged to upper Los Alamos Canyon, based on sampling results for perched intermediate groundwater and the regional aquifer (R-9). In addition, oxalate and other anions were present in R-9 core samples leached with deionized water (Broxton et al., 1998). Occurrence of oxalate in the core samples varies with depth. This suggests that multiple flow paths may exist and changes in vertical recharge with time may have occurred in upper Los Alamos Canyon.

Geochemical Modeling Predictions of Uranium Mobility in the Regional Aquifer Los Alamos National Laboratory (P. Longmire, 11/30/98)

Geochemical modeling was conducted for borehole R-9 using the computer code, MINTEQA2 (Allison et al., 1991) to quantify adsorption of uranium (uranyl) onto hydrous ferric oxide (HFO). In the past, surface complexation modeling of uranium and other solutes has not been performed on groundwaters and aquifer materials found at LANL. These simulations should improve our understanding of how natural solutes and contaminants (actinides and fission products) adsorb onto solids. Adsorption is the dominant process influencing the fate and transport of both trace natural solutes and contaminants in groundwater. Desorption processes can also be evaluated through both experimental investigations and surface complexation modeling. Adsorption modeling can be applied to evaluating intrinsic remediation and risk analysis.

Groundwater was encountered in a lower perched zone (275 ft depth) within the basalt at borehole R-9. This perched groundwater has a pH of 8.8 and is characterized by a sodium-bicarbonate ionic composition (Broxton et al. 1998). Suspended uranium concentrations are 112 µg/l (0.112 mg/kg) in this perched zone (Broxton et al. 1998). Dissolved uranium concentrations of 48.4 µg/l (0.0484 milligram/liter) were also observed. The proposed Environmental Protection Agency (EPA) MCL for uranium in drinking water is 20 µg/l. Background concentrations of dissolved uranium at Los Alamos are typically less than 1 µg/l within basalt. Uranyl forms strong (soluble) complexes with bicarbonate and carbonate under alkaline pH conditions (Langmuir, 1997). Uranium was analyzed by inductively coupled plasma mass spectrometry (ICPMS) at CST-7.

Adsorption processes for uranium can be represented by measuring or calculating a distribution coefficient (K_d). The K_d is the amount of species (uranium) sorbed per mass of sorbent (typically silts, clays, or oxides within the aquifer) divided by concentration of solute (uranium) in solution (Langmuir, 1997). Higher K_d values correspond to increasing sorption onto solid materials or lower mobility in aqueous solution. For the lower perched zone in R-9, a calculated K_d for uranium is 0.112 (mg/kg)/0.0484 (mg/l), which is equal to 2.3 l/kg. This low K_d value implies that uranium (uranyl) is mobile under alkaline and oxidizing conditions characteristic of the lower perched zone.

The diffuse layer model (DLM) was selected to quantify adsorption of the uranyl cation (UO_2^{2+}) onto HFO. HFO may occur as surface coatings present on basaltic glass and clay minerals identified in core samples collected from R-9. The DLM considers solution speciation and aqueous ion activities. The DLM is more rigorous than the Kd model because it includes sorbent (solid material) properties such as surface area and concentration, and groundwater composition such as pH and solute concentration. The model uses the electric double-layer theory that assumes that the positive or negative surface charge of a sorbent, in this case HFO, in contact with solution generates an electrostatic potential that declines rapidly away from the sorbent surface (Langmuir, 1997). The potential is the same at the zero (sorbent surface) and d (solution) planes.

Results of the adsorption modeling simulation using the DLM suggest that, in the lower perched zone, 57.5 % of uranyl (64 µg/l sorbed uranium) is bound as a surface complex, $SO_2UO_2^+$, where SO_2 represents a weak sorption surface site on HFO. Dissolved (non sorbed) uranium is predicted to occur both as $UO_2(CO_3)_2^{2-}$ at 5.1% (7 µg/l) and as $UO_2(CO_3)_3^{4-}$ at 36.6% (41 µg/l). The model simulation predicts 48 µg/l of dissolved uranium at a pH value of 9. This is in excellent agreement with the measured dissolved uranium (48.4 µg/l) at pH 8.8. Uranyl complexation with bicarbonate and carbonate in the lower perched zone decreases the amount of adsorption by 41.7 %, which results in uranium concentrations exceeding the proposed EPA MCL of 20 µg/l.

Nitrogen Isotopes in Borehole R-9

Discussion pending.

3.2.1.2 Aggregate 1 Conceptual Model Refinement

The following bulleted items represent specific refinements to the hydrogeologic model resulting from extensive data collection in Aggregate 1 during FY98 (Figures 3.2-6 and 3.2-7). Specific refinements are as follows:

- Based on R-9 and R-12 drilling, the Puye Formation is finer grained than expected based on lithologic logs of existing wells in the area. The upper Puye Formation consists primarily of siltstone and sandstone.

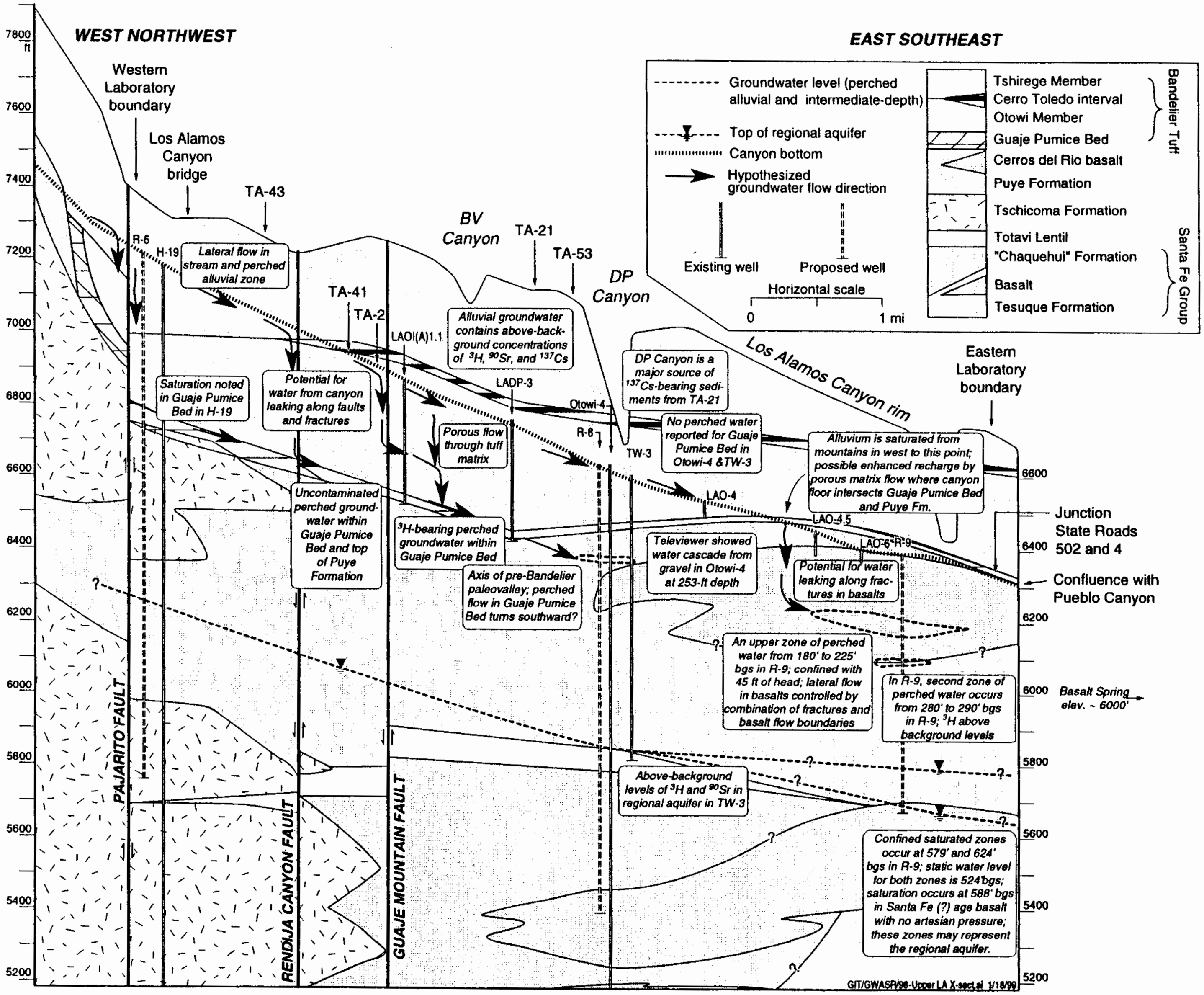

Figure 3.2-6. Schematic cross section showing conceptual model, R-9 results, and proposed regional aquifer wells for upper Los Alamos Canyon.

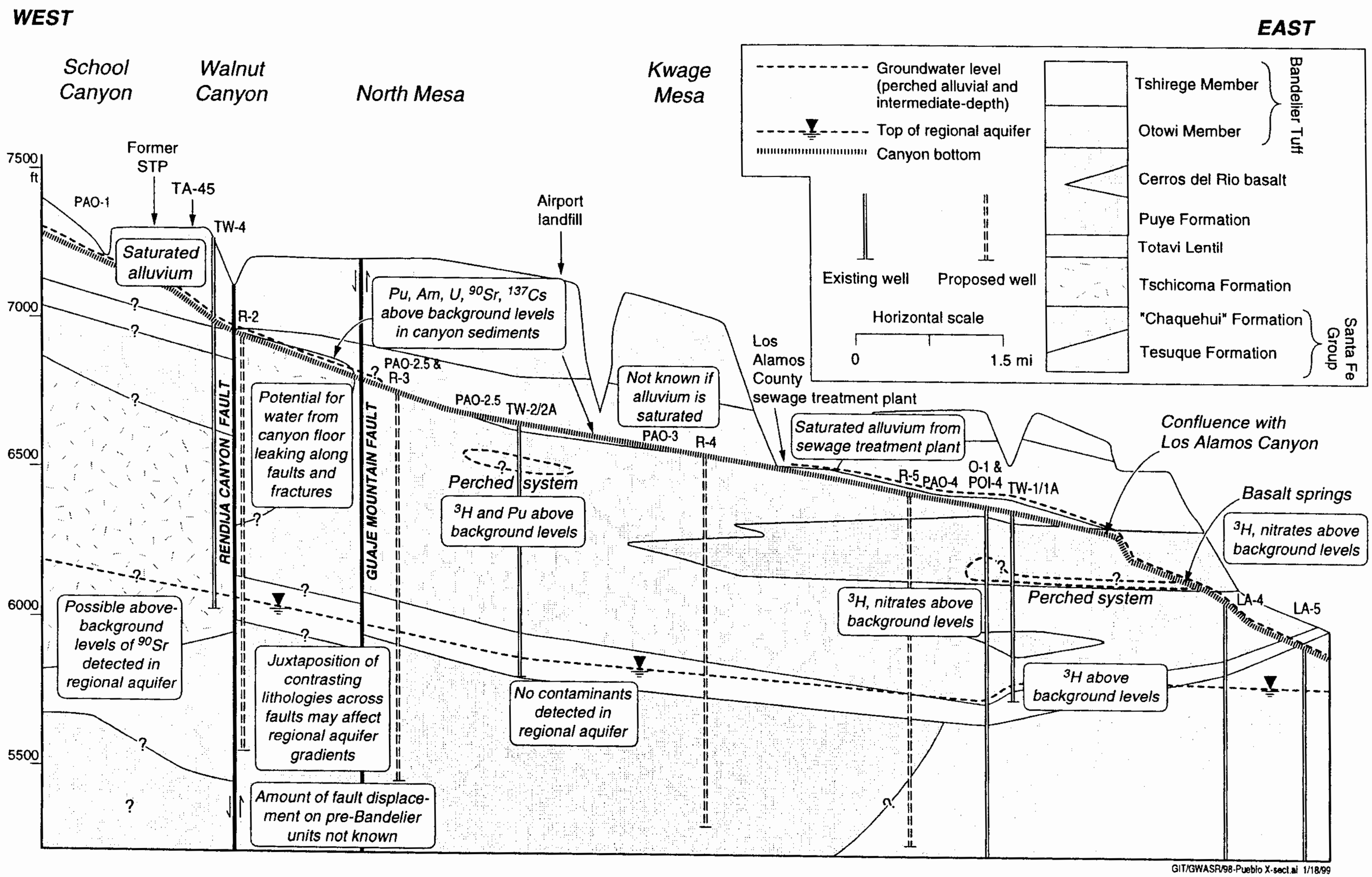

Figure 3.2-7. Schematic cross section showing conceptual model and proposed regional aquifer wells for Pueblo Canyon.

- The lower part of the Puye Formation is composed of a thick sequence of diagenetically altered, reworked tuffaceous sandstone and conglomerate that can be correlated between R-9 and R-12. Pervasive diagenesis of the tuffaceous sedimentary deposits resulted from the alteration of volcanic glass to clay minerals. Similar "tuffs" were assigned to the top of the Santa Fe Group in well PM-1, but the dacitic nature of these deposits indicate they are part of the Puye Formation.

- The axial facies of the Puye Formation (Totavi Lentil) was expected in R-9 and R-12 based on lithologic logs of existing wells in the area; however, these deposits were not present.

- The top of the Santa Fe Group in R-9 and R-12 is represented by a basalt flow with a minimum eruption age of 8.45 to 8.63 million years. This basalt correlates with basalts in the upper part of the Santa Fe Group in PM-1.

- Basaltic rocks of the Cerros del Rio volcanic field are 25% thicker in R-12 than in R-9. Also, the basalt sequence in R-12 contains four flow units that are separated by well-defined contacts. These flow units are correlated with four flow units in R-9.

- Fractures probably provide the saturated porosity for the perched zones in basalt in R-9 an R-12.

- In R-9 and R-12, the depth of the top of the regional water table is 28 to 99 ft lower than what was predicted based on water levels in nearby water supply wells and water-level maps for the regional aquifer. The higher static water levels in nearby water supply wells are probably due to their long screen lengths, which create a composite hydraulic head for each well. The higher static water levels for the supply wells suggest that a higher hydraulic head occurs at deeper levels of the regional aquifer than those penetrated by R-12 and R-9 and that upward gradients may exist in the regional aquifer in this part of the Pajarito Plateau.

- Groundwater from the top of the regional aquifer in R-9 and R-12 is characterized by a calcium-sodium-bicarbonate ionic composition. This groundwater is chemically similar to regional aquifer water in wells PM-1 and PM-3. The tritium activity in these groundwaters ranges from 14.43 to 46.9 pCi/L. These tritium activities suggest the presence of a component of groundwater that is less than 50 years old.

3.2.1.4 Aggregate 1 FY99 Planned Activities

- R-9 will be completed in FY99 following installation of ER borehole R-15 in Mortandad Canyon. Following discussions between the GIT and the NMED, a decision was made to complete well R-9 as a single completion well at the top of the regional aquifer. This completion strategy will allow the characterization of water quality at the top regional groundwater system at the eastern Laboratory boundary.

- Borehole R-5 in Pueblo Canyon is currently scheduled for drilling and completion in FY99.

- Two alluvial wells, PAO-1 and PAO-2, will be installed in the western part of Pueblo Canyon. PAO-1 will be located west of the confluence and will provide background information. PAO-2 will be located east of the confluence between Pueblo Canyon and Acid Canyon and will provide alluvial water quality data downgradient of contaminant release sites in the headwaters of Acid Canyon.

- The GIT will examine the possibility of installing a west to east transect of three multi-port wells in the upper 500 to 700 ft of the regional aquifer to collect information on the vertical distributions of hydraulic head across the Laboratory. R-12, R-5, R-15, and R-31 are considered candidates for the deep multi-port well in the eastern part of the Laboratory.

- Borehole R-12, located 1 km south of R-9, currently contains a temporary casing and will not be completed as a monitoring well in FY99.

3.2.2 Aggregate 2

Aggregate 2 is located in the east-central portion of the Laboratory and encompasses the technical areas where chemical and radioactive waste management are routine operations. The general boundaries of the aggregate are Pajarito Canyon on the south, Cañada del Buey to the north, TA-18 and TA-51 to the west, and the Laboratory boundary along state road NM 4 to the east (Figure 3.2-8).

3.2.2.1 Aggregate 2 FY98 Investigations

TA-18

- Groundwater activities at TA-18 during FY98 included quarterly sampling of alluvial wells for investigating possible VOC contamination near a septic system. Eight quarters of data indicate no detections of VOCs. The tank will be removed as part of a voluntary corrective action (VCA) plan.
- Although mentioned in the FY98 planned activities in last year's groundwater summary, no background alluvial well was drilled in Threemile Canyon above TA-18.
- The water budget planned for Pajarito and Threemile Canyons was postponed. This may be taken up as part of the Work Plan for Pajarito Canyon.
- A Workplan for Pajarito Canyon was prepared during FY98. The plan was approved by DOE in August and sent to NMED in September for review. Development of the work plan was coordinated with TA-18 investigations.

TA-54

- Vegetative cover measurements were made at MDA G to assist in future surface water budget determinations.
- Water vapor flux from MDA G was measured using Lidar to quantify spatial variability in evapotranspiration and assist in future surface water budget determinations. Lidar measurements are anticipated to continue in FY99.
- The ER Project continued pore gas monitoring at TA-54, MDAs L and G.
- Waste Management personnel monitored subsurface moisture using neutron probe measurements. Moisture monitoring holes include five vertical holes and two vertical access tubes in pits, which are monitored every other month. Eight additional holes are monitored annually. Three pits now have horizontal holes installed: two holes under pit 15, four holes under pit 38, and three holes under pit 39. These horizontal holes will be monitored in FY99.
- Waste Management personnel measured subsurface VOC concentrations in four boreholes instrumented with FLUTe (SEAMist) positive pressure sampling membranes.

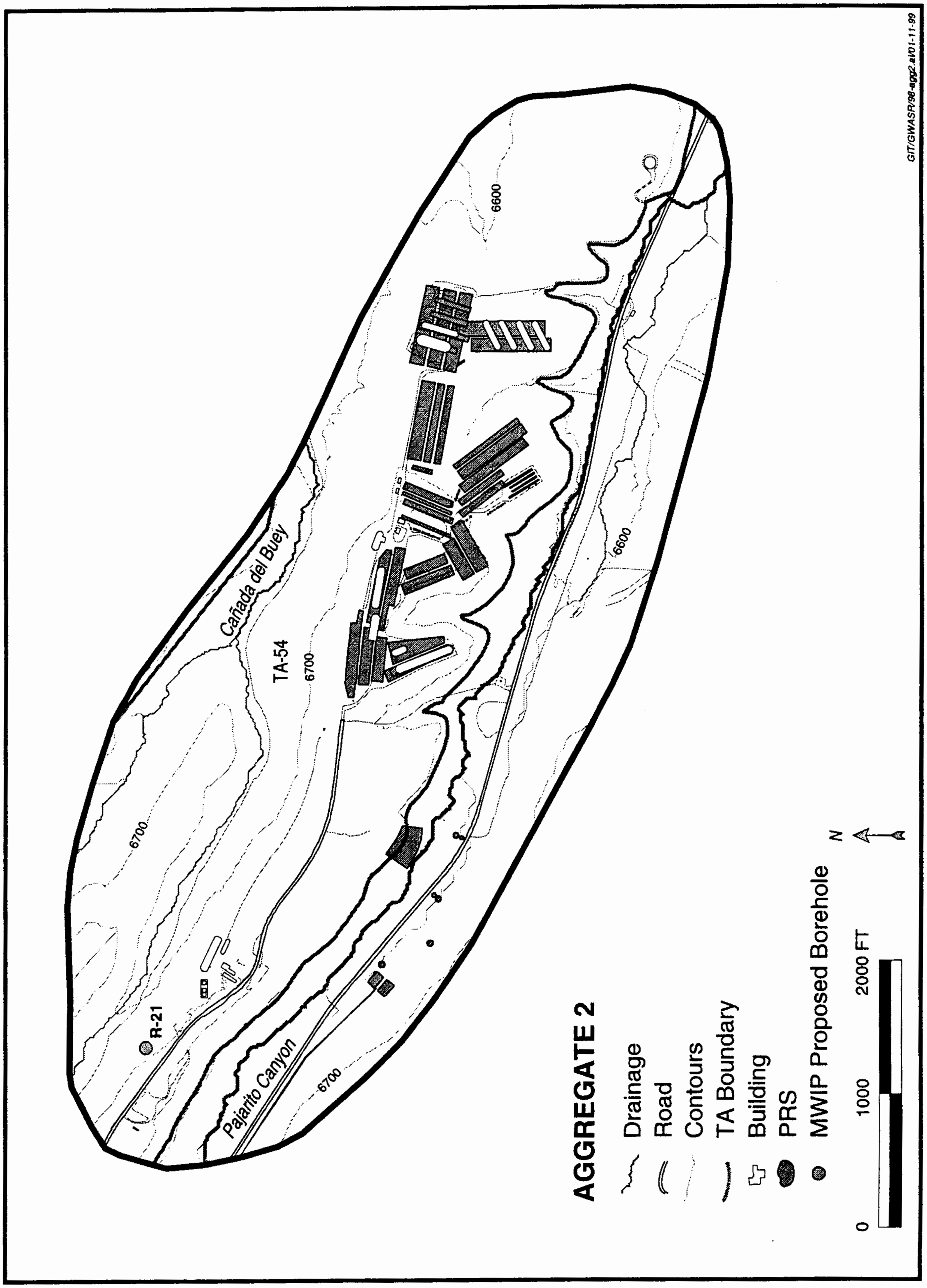

Figure 3.2-8. PRSs and proposed wells in Aggregate 2.

- Air pressure data collection continued to evaluate how barometric pressure moves through the mesa. This study is directed at evaluating how tritium and VOC migration occurs within the mesa at MDA G. In situ measurement of CO_2 also was made within the mesa.

- Measurements continued on the Pilot Extraction Study Plan at MDA L. The purpose is to evaluate the potential for long-term passive vapor extraction within the mesa to remove the VOC plume.

3.2.2.2 Aggregate 2 Conceptual Model Refinement

The conceptual model is shown on Figure 3.2-9.

TA-18

Activities at TA-18 resulted in no conceptual model refinements.

TA-54

Activities at TA-54 resulted in no conceptual model refinements.

3.2.2.3 Aggregate 2 FY99 Planned Activities

TA-18

- The septic tank will be removed as part of a VCA plan.

TA-54

- Pore gas monitoring and neutron probe measurements will continue. Some boreholes will be instrumented for moisture monitoring, and for vapor and moisture sample collection. Horizontal holes under pits will be reentered and evaluated.

- Shallow isotope and chemical profiles (stable isotopes and chloride) will be measured to determine patterns of infiltration.

- Further vegetative cover measurements will be made.

- Lidar water vapor flux measurements will continue.

- In order to evaluate effects of asphalt pads on moisture buildup and infiltration, horizontal trenches with neutron access will be installed at a depth of about 1 meter prior to placing an asphalt pad over pit 7. The trenches will include ports for VOC sampling. Thermocouples will also be installed for temperature measurements.

- Air pressure monitoring will continue.

- Modeling and other work for the Pilot Extraction Study Plan will be finalized. A design for a passive vapor extraction system will be prepared.

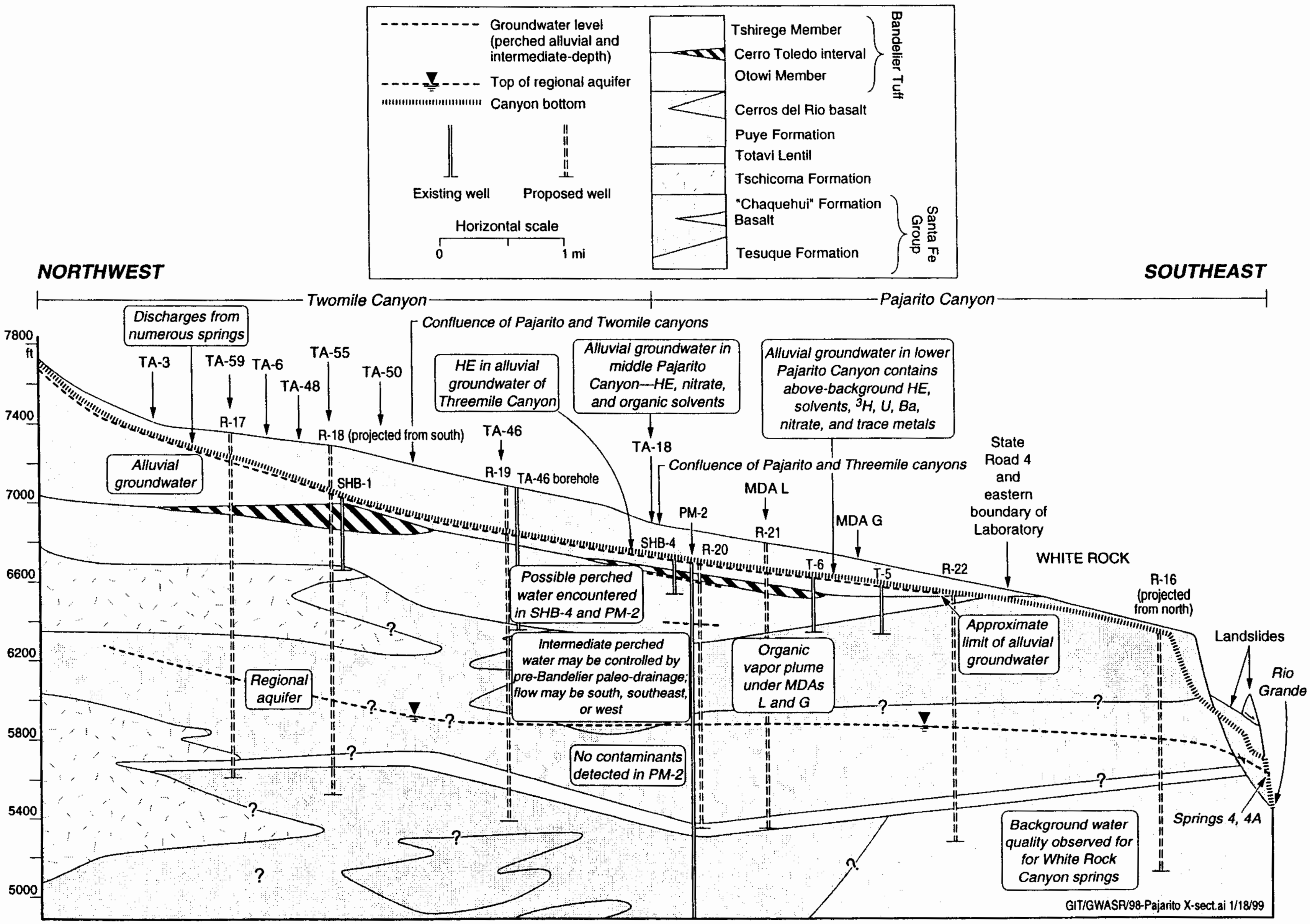

Figure 3.2-9. Schematic cross section showing conceptual model and proposed regional aquifer wells for Pajarito and Twomile canyons.

3.2.3 Aggregate 3

Aggregate 3 is located in the south central portion of the Laboratory and consists of TA-49 on Frijoles Mesa. Aggregate 3 is bounded by Water Canyon on the north, state road NM 4 on the south, TA-39 is the east boundary, and TA-16 is on the west (Figure 3.2-10).

3.2.3.1 Aggregate 3 FY98 Investigations

- MDA AB, Area 2 has a large subsurface inventory of plutonium as well as other metals. An asphalt pad was placed over Area 2 to improve isolation of surface contamination. The pad caused near-surface moisture contents to rise to saturated or near saturated conditions. To address this problem and dry the site out, a stabilization plan was submitted to NMED for implementing the asphalt pad removal interim measure and BMPs. A moisture-monitoring plan for Area 2 was also submitted to NMED for implementation in FY99.

- The asphalt pad at MDA AB, Area 2 was completely removed as described in the stabilization plan. Removal of the pad should eventually improve evapotranspiration conditions at the site. A radiological survey was conducted on the exposed materials, but no material was removed. A clean cover of crushed tuff was applied along with topsoil and gravel mulch. A surface water diversion trench was installed upslope from Area 2 and the site was regraded as part of BMP activities.

- Corehole 2 was logged to 500 ft with a neutron probe for volumetric moisture determination. Other holes in the vicinity of Area 2 were also logged. Preliminary results indicate that the Corehole 2 moisture profile is generally wetter at depth (e.g., 35% at 180 ft) than is typical for profiles measured in boreholes away from the asphalt pad. Corehole 2 has had standing water in the past, but it is not clear whether the standing water and elevated moisture content are artifacts of the borehole construction or representative of conditions under the asphalt pad. The hole was permanently plugged after the profile was taken.

3.2.3.2 Aggregate 3 Conceptual Model Refinements

FY98 activities focused on stabilization activities thus, there are no new changes to the conceptual model. The conceptual model is shown in Figure 3.2-11.

3.2.3.3 Aggregate 3 FY99 Planned Activities

- The objective of FY99 activities is to bound vertical contaminant migration potential. To achieve this objective, a vertical hole will be drilled through an unused shaft and characterized for hydrogeologic properties. In addition, an angled directional borehole will be drilled underneath Area 2 to examine the current vertical extent of contamination. This hole will also be used for various monitoring activities. Finally, an interflow monitoring trench will be installed to assess the impact that lateral flow might have on contaminant mobility at Area 2.

3.2.4 Aggregate 4

Aggregate 4 includes TA-33, TA-39, Ancho Canyon, Indio Canyon, and Chaquehui Canyon which are located in the southwest part of the Laboratory (Figure 3.2-12). Laboratory facilities and operations occurred on the mesa top at TA-33 and within a canyon setting at TA-39. Ancho and Chaquehui canyons are the principal watershed systems in this aggregate.

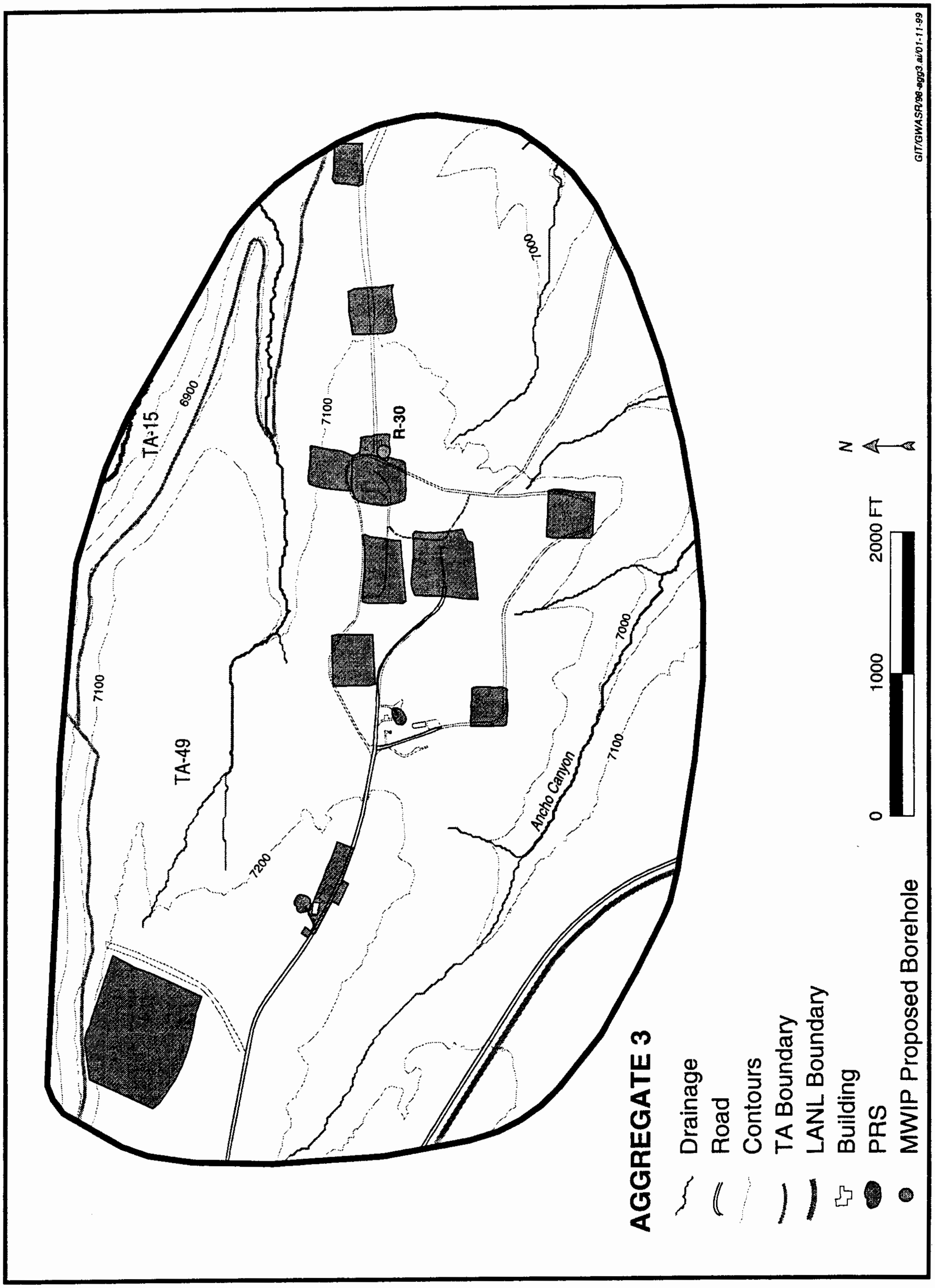

Figure 3.2-10. PRSs and proposed wells in Aggregate 3.

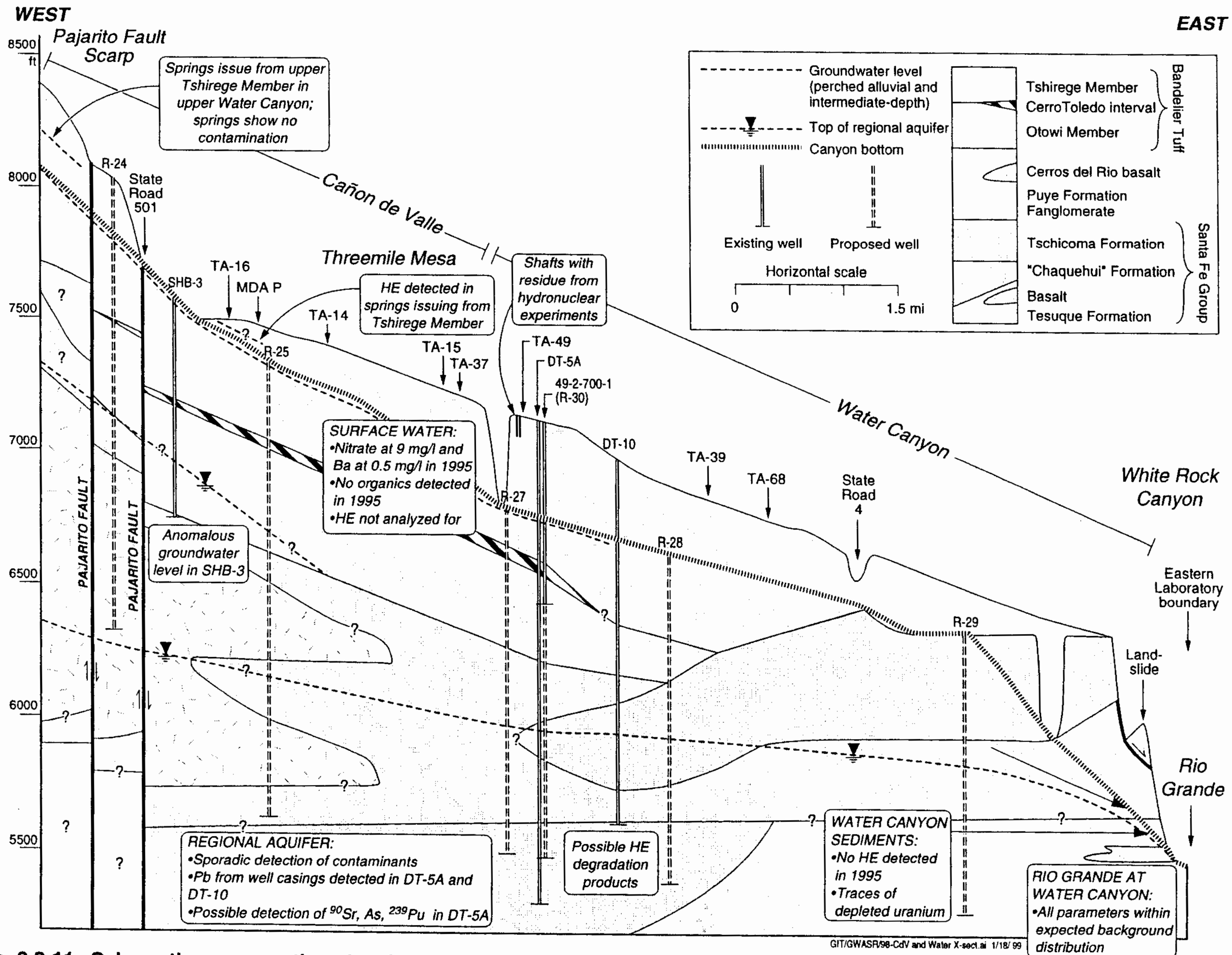

Figure 3.2-11. Schematic cross section showing conceptual model and proposed regional aquifer wells for Cañon de Valle and Water Canyon.

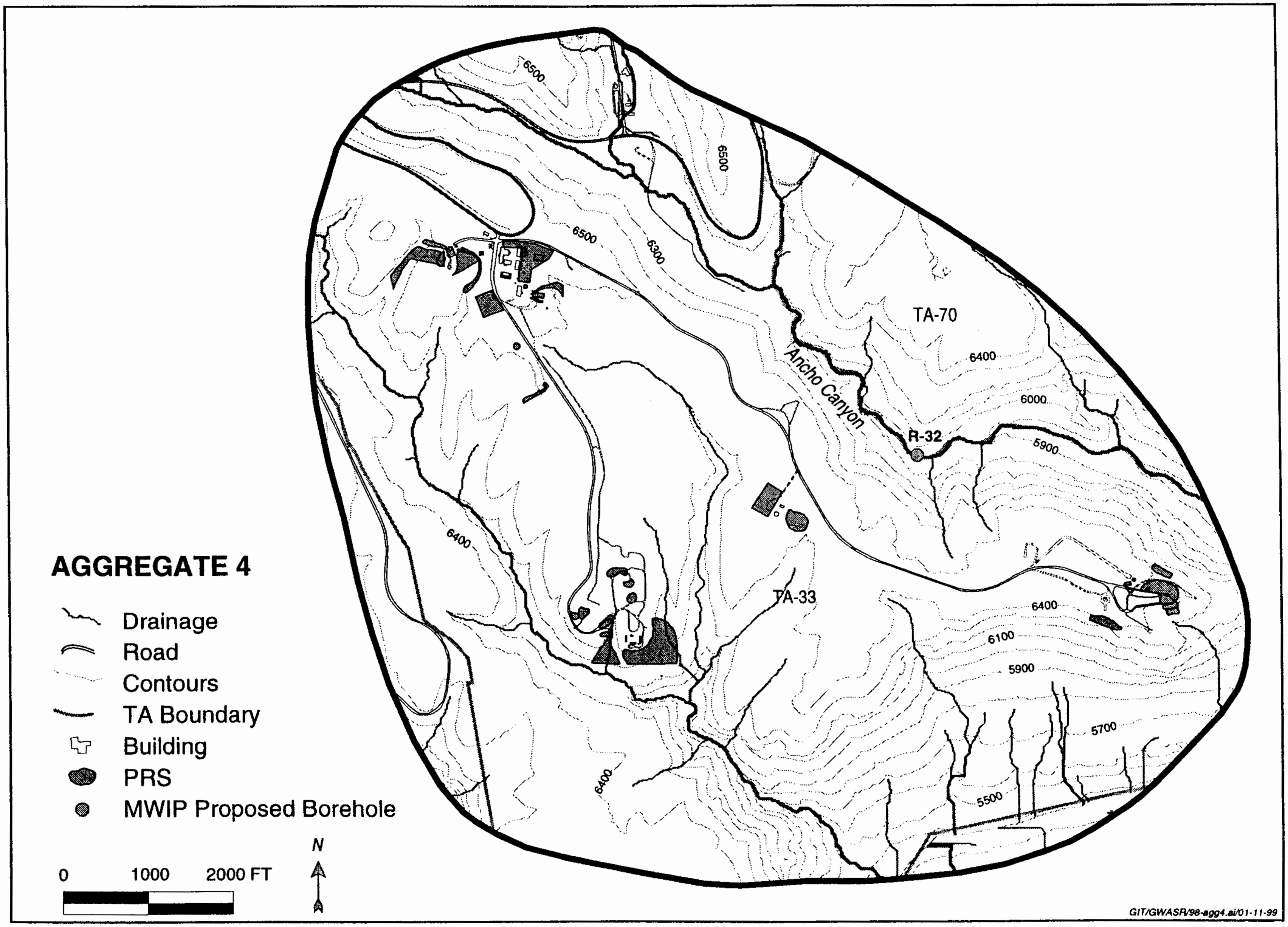

Figure 3.2-12. PRSs and proposed wells in Aggregate 4.

3.2.4.1 Aggregate 4 FY98 Investigations

Two rounds of water level measurements were conducted in 5 monitoring wells completed in canyon bottom alluvium near MDA Y located in the northern branch of Ancho Canyon at TA-39. The first round was completed on December 17, 1997 and the second round was completed on June 30, 1998. During the December round of measurements all of the wells were dry. During the June round all of the wells were dry except one (well DM-6) that had approximately 0.15 ft of water.

Water samples from Ancho Spring were collected November 11, 1997 and September 29, 1998 and analyzed for HE residual compounds, amongst other constituents. No HE compounds were detected.

3.2.4.2 Aggregate 4 Conceptual Model Refinement

The conceptual model for Aggregate 4 is shown on Figure 3.2-13; however, no conceptual model changes stem from work in 1998. The water level measurements in FY98 demonstrate the general absence of shallow groundwater in the northern branch of Ancho Canyon. Thin zones of saturation apparently develop in the alluvium for limited periods of time, likely after periods of heavy local precipitation or snowmelt. Stream gaging in the main branch of Ancho Canyon near SR-4 (approximately one mile downstream of the TA-39 wells) shows streamflow only a few days per year. The absence of any sustained streamflow or effluent discharges indicates the alluvium throughout Aggregate 4 probably is dry but for a few days or weeks per year.

Analyses in 1996, 1997, and 1998 have failed to confirm earlier detections of HE compounds in Ancho Spring. In 1995, three HE compounds were detected in Environmental Surveillance samples of the spring: RDX (23 µg/L), HMX (4.9 µg/L), 2-4-Dinitrotoluene (0.18 µg/L). The lack of HE confirmation indicates the earlier results were more likely due to the pick up of surficial contamination where the spring issues, rather than from contamination of the groundwater system feeding the spring.

3.2.4.3 Aggregate 4 FY99 Planned Activities

The drilling of DP-funded borehole R-31 in Ancho Canyon will commence in FY99. It will provide site-wide characterization information in an area of the Laboratory that the subsurface is largely unexplored. Among other items, R-31 will provide key information about the presence of a possible perched groundwater system (that ultimately feeds water to Ancho Spring) and its associated water quality.

3.2.5 Aggregate 5

Aggregate 5 is bounded on the south by Water Canyon and on the north by the boundary of TA-9. Cañon de Valle is a tributary to Water Canyon; they join at the east end of TA-16 and form the eastern boundary of Aggregate 5. The western boundary of Aggregate 5 is formed by state road NM 501 (Figure 3.2-14).

3.2.5.1 Aggregate 5 FY98 Investigations

- An RFI report (LANL ER Project, 1998a) and Corrective Measures Study Plan (LANL ER Project, 1998b) for the 260 outfall were submitted to NMED. Findings are briefly discussed in section 3.2.5.2 below.
- The bromide tracer test is continuing. Results so far support a hydrologic connection between the 260 outfall and Sanitary Wastewater Systems Consolidation (SWSC) spring. There may also be a connection to Burning Ground Spring, but the data are not as clear as for SWSC spring.

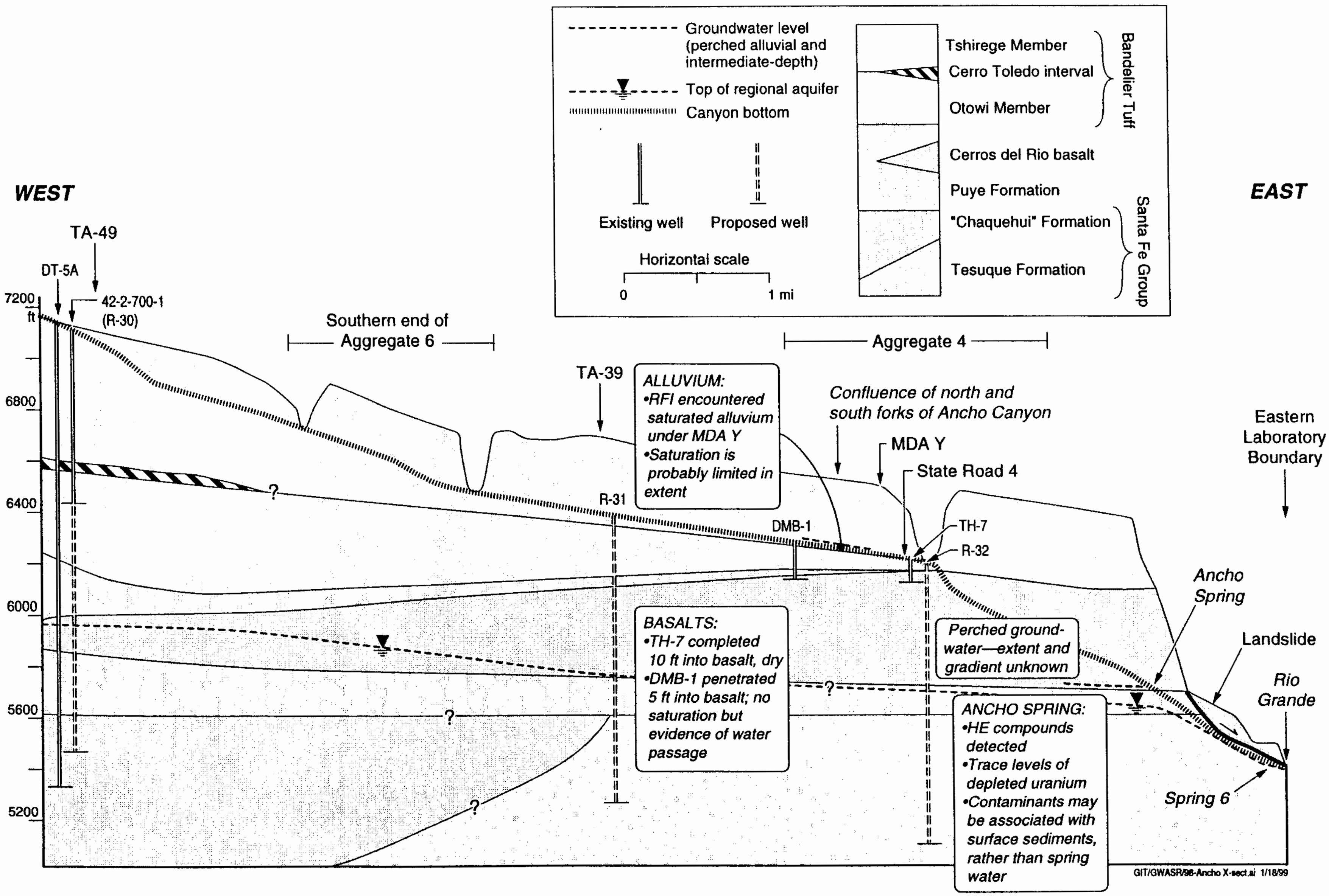

Figure 3.2-13. Schematic cross section showing conceptual model and proposed regional aquifer wells for Ancho Canyon.

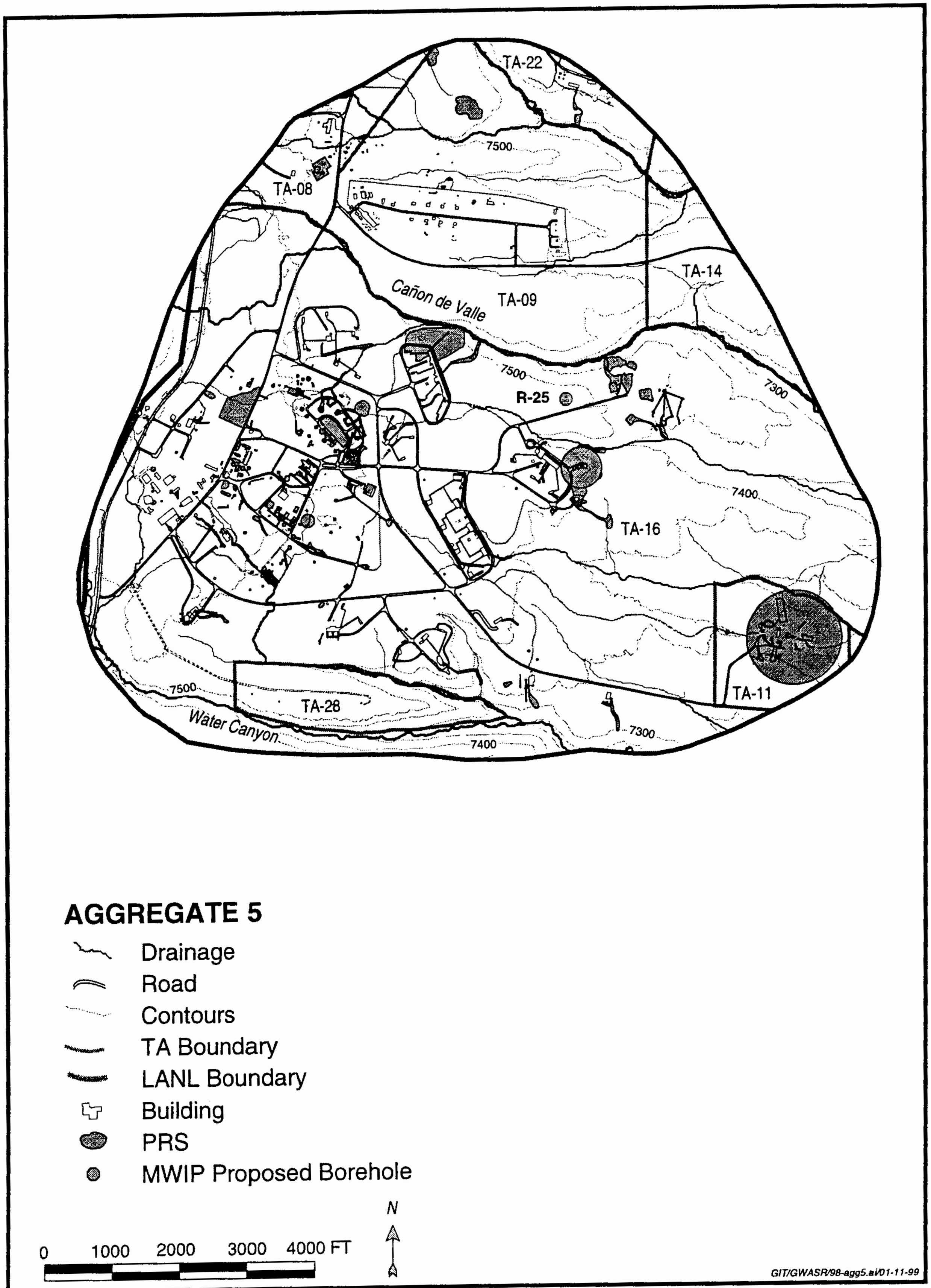

Figure 3.2-14. PRSs and proposed wells in Aggregate 5.

- Quarterly sampling for contaminants and major cations and anions in the springs and alluvial aquifer, and water level measurements in the Cañon de Valle wells were performed.

- Geochemical modeling results using PHREEQC suggesting barite supersaturation in Cañon de Valle springs and alluvial waters were confirmed by the presence of barite ($BaSO_4$) in sediment samples. In addition, the PHREEQC results and sediment analyses suggest that witherite ($BaCO_3$) precipitation and dissolution may control some of the temporal and spatial variability in dissolved barium concentrations in Cañon de Valle alluvial waters.

- Four boreholes were drilled to 100–200 ft depths on the TA-16 mesa to look for contaminants and the saturated systems that feed the springs. Transient saturated zones were encountered in borehole 2669 (near the 90s line pond) and 2665 (near Martin spring). No permanent saturation was encountered. These boreholes were completed as monitoring wells. The other two dry holes were cased with PVC without screens to be used as neutron probe moisture holes.

3.2.5.2 Aggregate 5 Conceptual Model Refinements

The conceptual model for Aggregate 5 is shown on Figure 3.2-11.

- Data collection continues to support the conceptual model described in the RFI report. Namely, that thin perennial saturated ribbons in the mesa feed the three springs. In addition, transient saturated zones may also recharge the springs and transport contaminants. The importance of transient saturation in the tuff and soil zone is indicated by the bromide tracer results, the presence of transient saturation in four boreholes (the two mentioned above and two of the holes in the 260 outfall drainage) and by the presence of interflow at the new burn pad. The disappearance of the Cañon de Valle alluvial groundwater downstream from MDA P suggests that this groundwater may recharge a deeper groundwater system. This is consistent with the observation of HE in the Otowi-Puye saturated zone in borehole R-25.

- Differences in the geochemistry and flow rate data between Martin and the Cañon de Valle springs suggest there may be an additional contaminant source (other than the 260 outfall) that feeds the Martin spring system. This source (or sources) has not been identified. In addition, the presence of barium and HE in the alluvial groundwater up-canyon from the 260 drainage suggest that additional contaminant sources may exist upstream from 260. Possible candidates include MDA R and the former silver outfall.

3.2.5.3 Aggregate 5 FY99 Planned Activities

- Completion of R-25 as a multi-port well.

- A data collection effort in Cañon de Valle will be implemented to evaluate water and contaminant mass balance. This activity will provide information on contaminant inventory, help to define possible remediation options, and may explain the presence of HE that was found in R-25 early in FY99.

possible remediation options, and may explain the presence of HE that was found in R-25 early in FY99.

- A stable isotope ($\delta^{18}O$, δD) tracer study will examine residence times of spring waters.
- Additional investigation of Martin Canyon hydrology will include drilling of at least one alluvial well.
- Finally, an interim measure will be implemented to remove highly contaminated material around the 260 outfall drainage. As part of the implementation plan, soils and tuff will be monitored for the bromide tracer. This will provide useful information for interpreting tracer behavior at TA-16.

3.2.6 Aggregate 6

Aggregate 6 is located in the south-central portion of the Laboratory and encompasses the technical areas where testing with HE and open detonation/open burning are part of routine operations. The general boundaries of the aggregate are Water Canyon on the south, Potrillo Canyon on the north, the Rio Grande to the east, and the Laboratory boundary along the Sierra de los Valles to the west (Figure 3.2-15).

3.2.6.1 Aggregate 6 FY98 Investigations

No studies were planned for or conducted in TA-15, TA-36 or TA-39 during FY98. However, numerous investigations were carried out at TA-16, in conjunction with the Phase II RFI study for the 260 Outfall (Anonymous, 1998). Activities included soil borings in the outfall and drainage areas, installation of wells in the alluvium of Cañon de Valle, sampling and tracer studies of area springs, sampling of water and sediment in Cañon de Valle and construction of 200-ft-deep mesa-top wells to intersect saturation that feeds the springs.

3.2.6.2 Aggregate 6 Conceptual Model Refinement

Figure 3.2-11 shows the general conceptual hydrogeologic model for aggregate 6 in cross section. The Phase II RCRA investigations associated with the 260 Outfall confirm the existing conceptual model in general, but show it to be very complex in detail. Contaminant transport in the Bandelier Tuff is strongly controlled by fractures and the presence of surge beds between units. Thus, there is much uncertainty regarding the location and extent of perched saturated zones.

3.2.6.3 Aggregate 6 FY99 Planned Activities

Additional information is needed to help us better understand conditions in the vicinity of R-25. Plans call for drilling regional well R-28 in FY99 and R-27 in FY00. However, depending on the ultimate findings at R-25, R-27 may be moved ahead of R-28 and possibly other regional wells in the schedule.

3.2.7 Aggregate 7

Aggregate 7 is located in the central part of the Laboratory and contains both canyon-bottom and mesa-top waste disposal sites. The aggregate includes portions of TA-35, TA-48, TA-50 and TA-55 on Pajarito Mesa as well as the adjacent Mortandad Canyon and its major tributary, Ten Site Canyon (Figure 3.2-16).

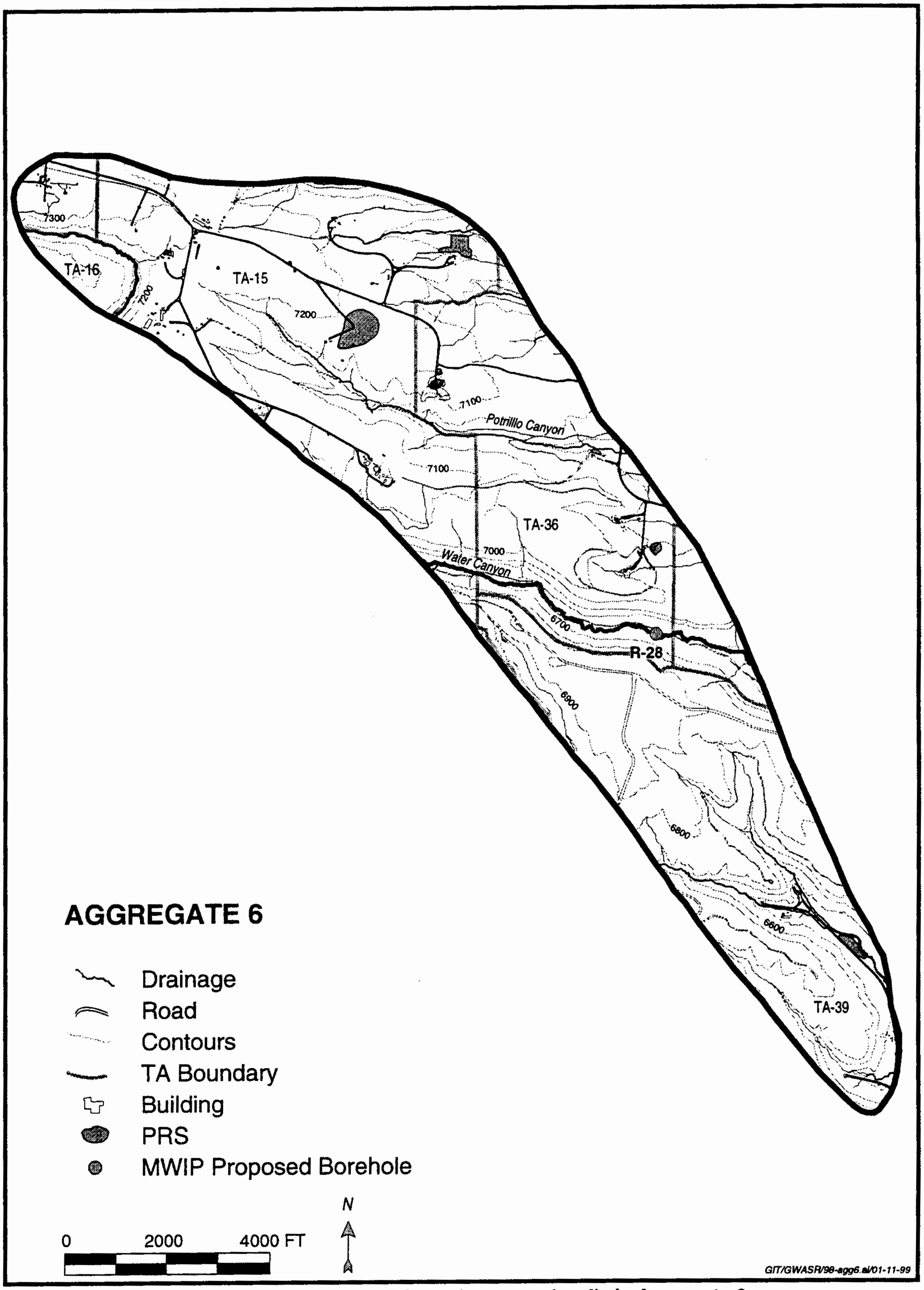

Figure 3.2-15. PRSs and proposed wells in Aggregate 6.

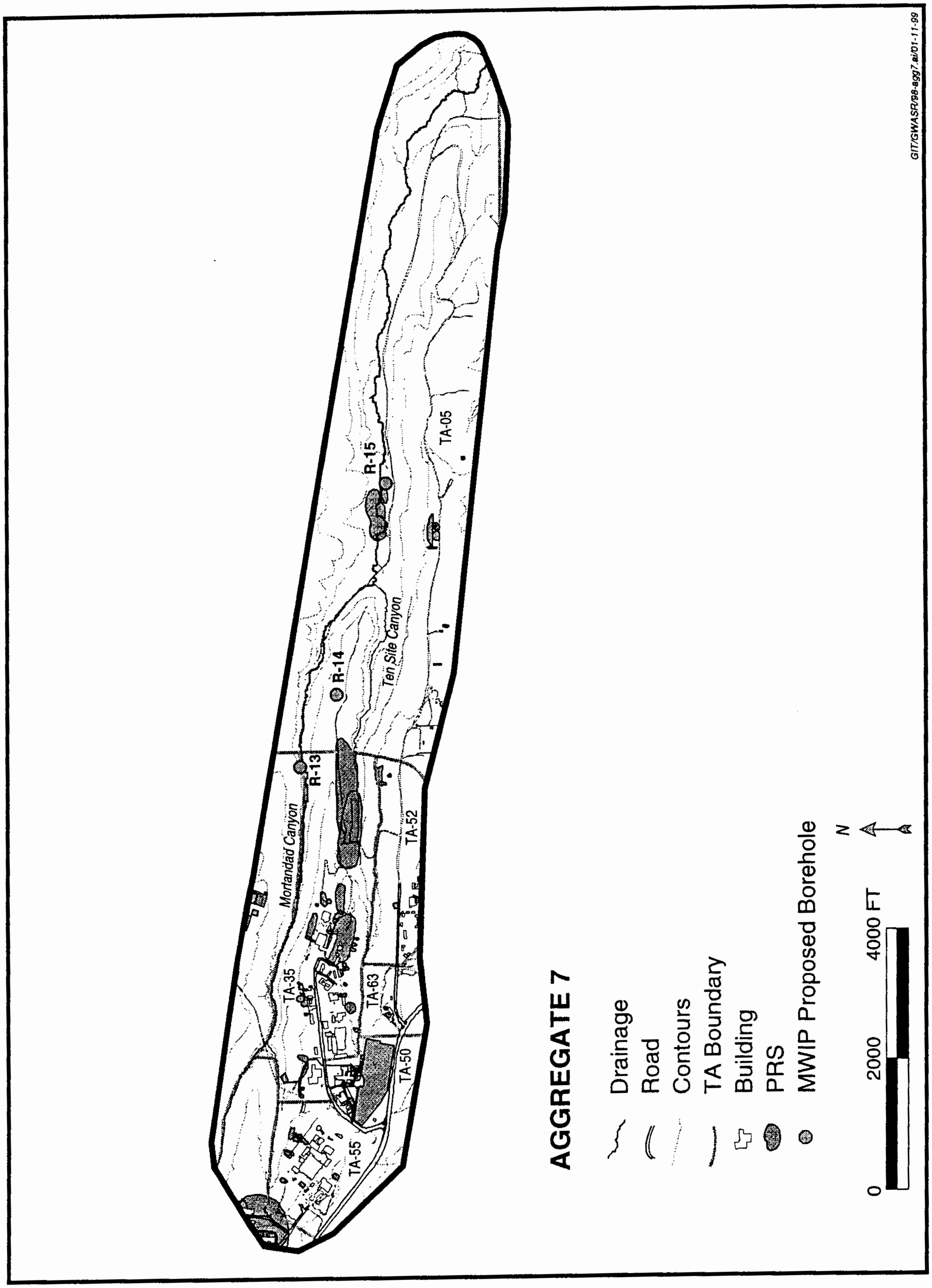

Figure 3.2-16. PRSs and proposed wells in Aggregate 7.

3.2.7.1 Aggregate 7 FY98 Investigations

Unsaturated flow beneath Mortandad Canyon was modeled by Dander (1998) as part of his master's thesis. This study was conducted to develop an understanding of the unsaturated hydrologic behavior below the canyon floor. The main goal of this study was to evaluate the hypothetical performance of the vadose zone above the water table. Numerical simulations of unsaturated groundwater flow at the site were conducted using the Finite Element Heat and Mass Transfer (FEHM) code. A two-dimensional cross-section along the canyon's axis was used to model flow between an alluvial groundwater system and the regional aquifer approximately 300 m below. Using recharge estimated from a water budget developed in 1967, the simulations showed waters from the perched water table reaching the regional aquifer in 13.8 years, much faster than previously thought. Additionally, simulations indicate that saturation is occurring in the Guaje pumice bed and that the Tshirege Unit 1B is near saturation. Lithologic boundaries between the eight lithologic units represented in the model play an important role in flow and solute transport within the system (though the values of permeability are uncertain for some units). A component of horizontal flow is shown to occur in three thin zones above capillary barriers; however, vertical flow dominates the system. Other simulations were conducted to examine the effects of changing system parameters such as varying recharge inputs, varying the distribution of recharge, and bypassing fast-path fractured basalt of uncertain extent and properties. In general, the travel time to the regional aquifer varies inversely with recharge rate. Thus doubling the recharge rate will halve the travel time. System sensitivity was also explored by changing model parameters with respect to size and types of grids and domains, and the presence of dipping stratigraphy.

The investigation of sediments in Mortandad Canyon was initiated in FY98 with the collection of samples for full-suite analysis (in FY99) from three reaches: E-1, M-1, and M-2. Selection of sample-collection sites was based on geomorphologic mapping and radiological field measurements. Results of full-suite analyses were not provided in FY98.

The main ground-water investigation in FY98 was that associated with regional well R-15. Plans called for installing R-15 in two phases: (1) drilling by hollow-stem auger through the Cerro Toledo interval in FY98 and (2) completing the well by air-rotary methods in FY99. Phase 1 was successfully completed in FY98. The 8-in. hole not only penetrated the Cerro Toledo, but extended well into the Otowi Member of the Bandelier Tuff to a depth of 420 ft, an impressive achievement for augering. The lower part of the hole was then backfilled and the upper part reamed to a 20-in. diameter so that 16-in. surface casing could be set to a depth of 125 ft.

R-15 hole was continuously cored over the 420-ft length, except in the alluvium. Geologic units penetrated in Phase 1 drilling operations include, in descending order, alluvium, unit 1g of the Tshirege Member of the Bandelier Tuff, volcaniclastic sediments and tephras of the Cerro Toledo interval, and the Otowi Member of the Bandelier Tuff (Table 3.2-1).

Subsamples of the core were taken for analysis of moisture content, hydraulic properties and chemistry. More specifically, 86 samples were taken for moisture content determination, 60 samples were preserved for hydraulic-property measurement and 47 samples were collected for geochemical analysis during Phase 1 at R-15.

Twenty-three samples of core from R-15 were submitted for chemical and radiochemical analysis. These include one sample of the alluvium, five samples of unit 1g of the Tshirege Member of the Bandelier Tuff, two samples of the Tsankawi Pumice Bed, seven samples of the Cerro Toledo interval and eight samples of the Otowi Member of the Bandelier Tuff. Analytes for the chemical analyses include RCRA metals, anions and percent organic carbon. Samples taken for radiochemistry are being analyzed for strontium-90, cesium-137, uranium isotopes, plutonium isotopes, americium-241, gross alpha, gross beta and gross gamma. Ten samples of soil water extracted from core will be analyzed for stable isotopes of oxygen and hydrogen and fourteen soil-water samples will be analyzed for tritium content. Results of these various analyses are not yet available.

Table 3.2-1. Geologic Units Penetrated in Phase 1 at R-15.

Geologic Unit	Predicted Depth (ft) of Basal Contact	Actual Depth (ft) of Basal Contact	Description
Alluvium	20	16.5	Fine silt and sand
Tshirege Member, Bandelier Tuff	57	65	Nonwelded vitric ignimbrite
Tsankawi Pumice Bed	60	68	Stratified pumice fall deposited
Cerro Toledo interval	130	120	Stratified sands and gravels to 105 ft, silt and fine sand below
Otowi Member, Bandelier Tuff	410	420 +	Nonwelded vitric ignimbrite; distinctive pink oxidation at top of unit (120 to 140 ft depth), gray to white below.
Guaje Pumice Bed	490	Not drilled yet	Phase 1 drilling ended at a depth of 420 ft in the Otowi Member.

3.2.7.2 Aggregate 7 Conceptual Model Refinement

Figure 3.2-17 depicts the general conceptual hydrogeologic model for aggregate 7 in cross section. Soil-water modeling and Phase 1 drilling at R-15 contributed some interesting refinements to this conceptual model.

Modeling of unsaturated flow in Mortandad Canyon contributes a significant hydrologic refinement to the conceptual model. Travel time to the regional aquifer may be faster than previously thought; as short as ten years. Flow in the unsaturated zone may be predominantly downward; thus lateral flow at lithologic boundaries may not be significant. This conclusion is very dependent on the permeability contrast between lithologic units and the continuity of the units. If true, this would indicate that the place to look for contaminants would be beneath the upper reach of Mortandad Canyon.

For the water budget used, simulations showed perched water reaches the regional aquifer in approximately 14 years, much faster than previously thought. Additional work on the water budget is needed.

As shown in Table 3.2-1, drilling at R-15 essentially confirmed the existing geologic conceptual model. That is, not only are the expected stratigraphic units present, but their depths and thicknesses are more or less as predicted.

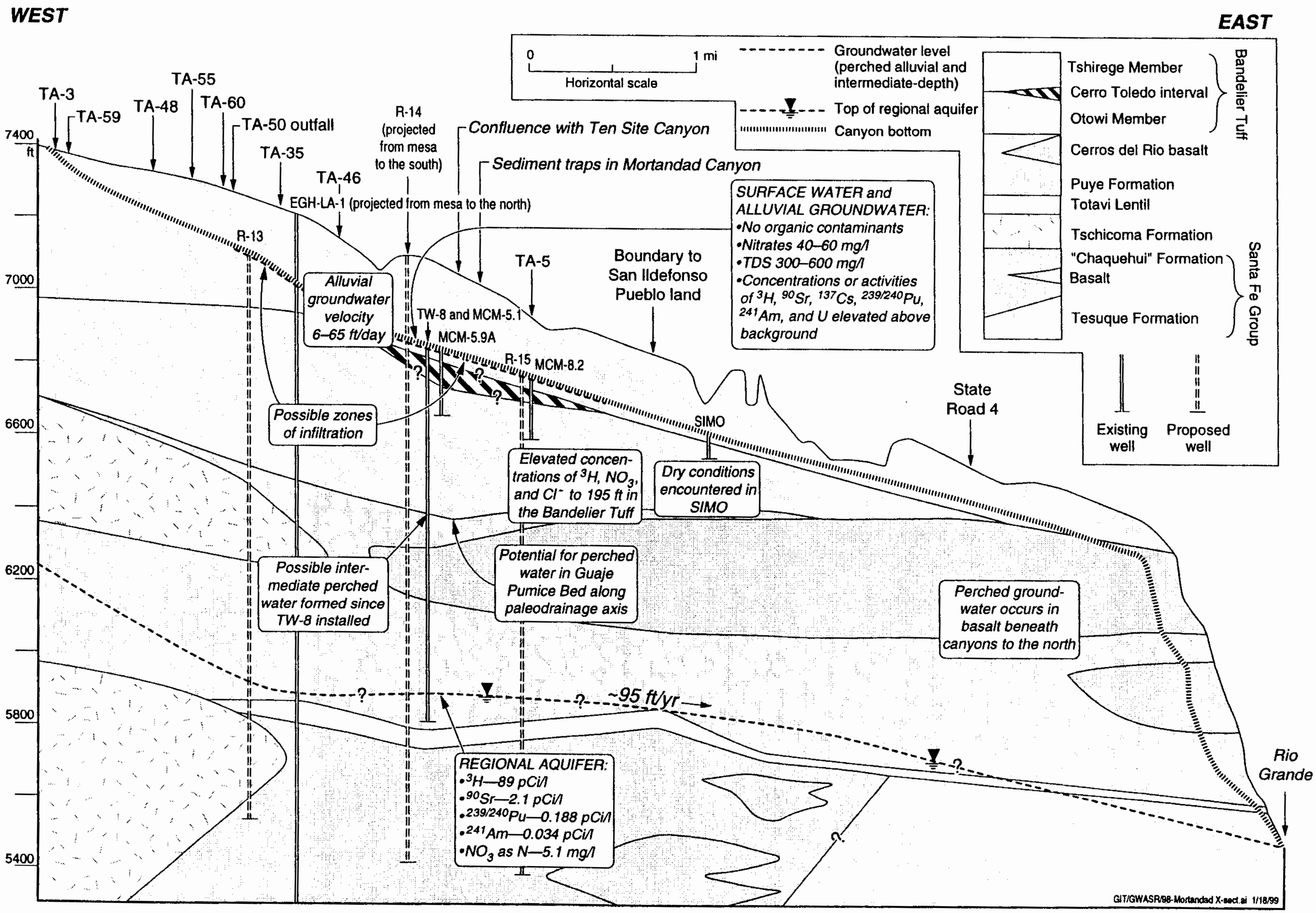

Figure 3.2-17. Schematic cross section showing conceptual model and proposed regional aquifer wells for Mortandad Canyon.

Observations at R-15 provide another hydrologic refinement of the conceptual model. Perched water was expected in the Cerro Toledo Interval. Although no saturation was encountered in that or any other unit during Phase 1 drilling, elevated moisture content was observed in two intervals. Whereas measured values average 10–20% in most of the bore, moisture content was determined to be 40% at the base of unit 1g of the Tshirege Member of the Bandelier Tuff and 50% in the middle of the Cerro Toledo Interval. These intervals may have been previously saturated but later drained to the observed moisture contents. Alternatively, the elevated moisture values may merely represent a slug of downward-moving water from some recharge event that did not result in saturation. These observations suggest that, although the Cerro Toledo is in an optimal position for recharge at R-15, saturation is ephemeral and short-lived, occurring only after sufficient recharge events.

3.2.7.3 Aggregate 7 FY99 Planned Activities

Phase 2 of the R-15 installation will occur in FY99. This will involve drilling with the Barber rig, which will be moved in when operations at R-25 permit. During this phase, saturation and hydrochemistry of the deeper units will be investigated.

Two alluvial wells, MCO 0.6 and MCO 7.2, were scheduled for installation in Mortandad Canyon to provide further information on alluvial groundwater. MCO-0.6 is scheduled for installation near the head of Mortandad Canyon. MCO 7.2 was installed below the sediment traps in early FY99.

3.2.8 Aggregate 8

Aggregate 8 encompasses the area north of Pueblo Canyon and includes Bayo Canyon, Barrancas Canyon, Rendija Canyon, and Guaje Canyon (Figure 3.2-18). These canyons are relatively little affected by Laboratory operations, but may be sources of recharge for groundwater in the northern portion of the Laboratory. Aggregate 8 includes former TA-10 and parts of TA-74 in Bayo Canyon and Barrancas Canyon, respectively. There are also PRSs on Los Alamos County land in Rendija Canyon.

3.2.8.1 Aggregate 8 FY97 and FY98 Investigations

Between September 1997 and March 1998, four new municipal water supply wells were drilled and completed in Guaje Canyon as part of the Guaje Well Replacement Project. These new wells, named GR-1, GR-2, GR-3, and GR-4, are located adjacent to existing wells in the Guaje well field. This well field is on US Forest Service land in Guaje Canyon near the Rendija Canyon confluence. These new wells will replace seven aging wells that were placed into service between 1950 and 1964. Five of these old wells will be plugged and abandoned in accordance with New Mexico State Engineer Office rules and regulations during FY 1999. The sixth well, G-1A, will be retained as a backup municipal water supply well. The seventh well has been transferred to the ESH-18 for use as an observation well. All of the four new wells were drilled to 2,000 ft below land surface and completed similarity. This completion includes 16-in.-diameter production casings and screens fabricated from 304-stainless steel. The louvered, Roscoe-Moss production screens have 0.375-in. thick walls and 0.050-in. slot openings. The annular spacing in the 26-in.-diameter boreholes are filled with spherical, 98% pure quartz sand filter packs.

A great deal of new data has been collected during the construction of these replacement wells. These data include sample drill cuttings collected every ten feet, a complete suite of geophysical logs, constant rate and step-drawdown pump tests utilizing fully penetrating observation wells, spinner logs, and zonal water quality sampling. These data will be analyzed during FY99 and a special Guaje well field report will be issued summarizing important information.

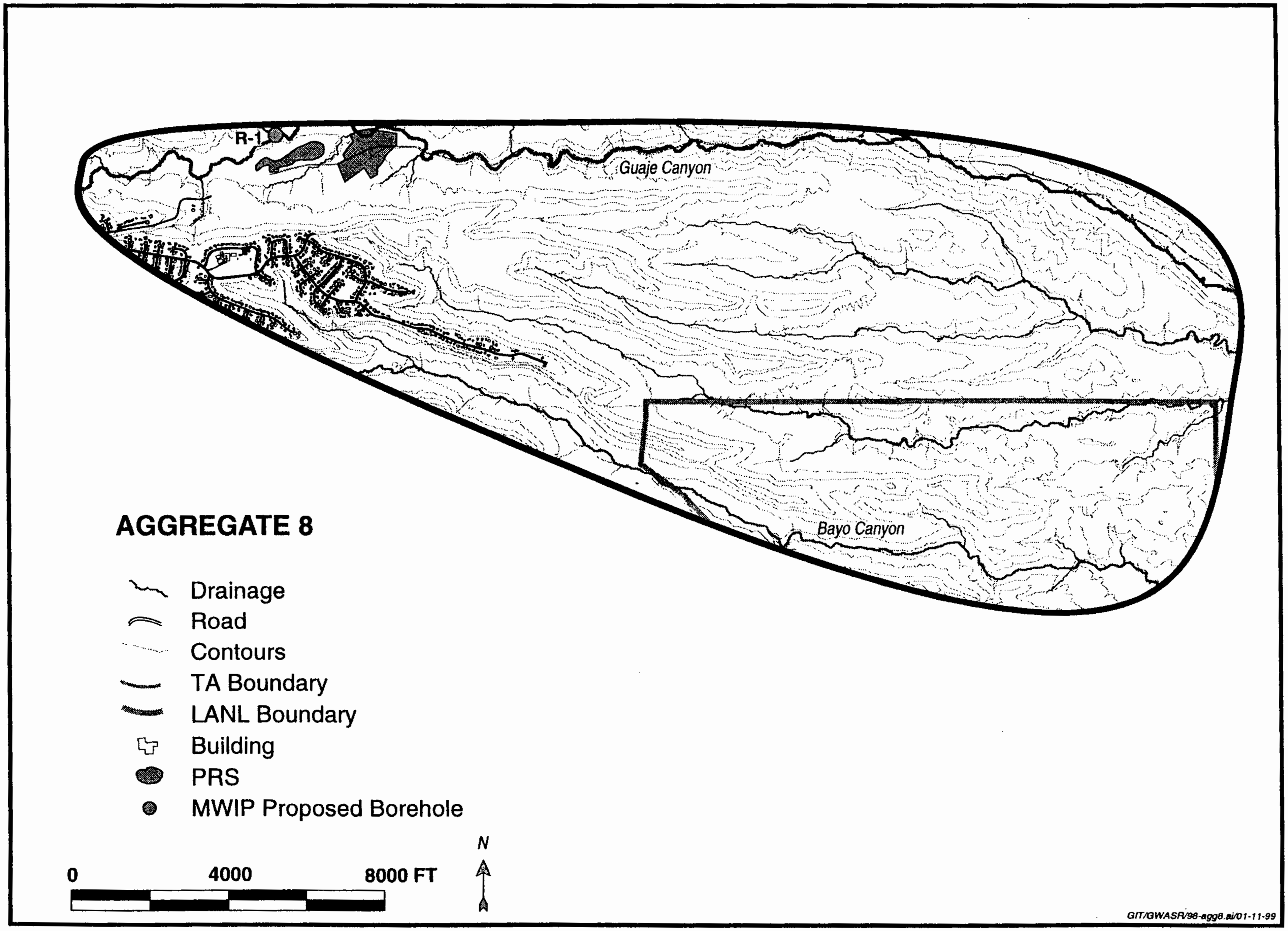

Figure 3.2-18. PRSs and proposed wells in Aggregate 8.

Ownership of the water supply system, including all production wells, distribution lines, storage tanks, pump stations, chlorination units, and most of the water rights, was transferred to Los Alamos County by DOE during the summer of 1998.

3.2.8.2 Aggregate 8 Conceptual Model Refinement

All of the new Guaje replacement wells penetrate portions of the Puye Formation before encountering the underlying Santa Fe Group sediments. Spinner log tests confirm that the upper portions of the regional aquifer (i.e., the Chaquehui formation and interbedded basalts) account for more than 95% of well yields, while the lower Tesuque Formation accounts for less than 5% of yields. Although pump tests will not provide hydraulic conductivity values for individual water-bearing zones within the Santa Fe Group sediments, they do provide a qualitative interpretation for the vertical distribution of hydraulic conductivities. Preliminary analyses confirm that the Chaquehui formation has an important influence on flow and recharge in the regional aquifer. Preliminary analysis of the geological logs also shows the stratigraphy is similar to the original Guaje wells.

3.2.8.3 Aggregate 8 FY99 Planned Activities

Project activities remaining to be completed include the following: (1) completion of all pump test analyses; (2) completion of summary report; (3) development of an optimization and management model for operation of Guaje well field; and (4) conversion of well G-3 to an observation well. Final project tasks include installation of pumps in new wells, construction of well houses, and abandonment of existing wells.

4.0 SUMMARY OF FY99 PLANNED ACTIVITIES

This section summarizes the planned activities for FY99 that are discussed in Section 3.0. The activities are described as either non-field or field activities.

4.1 Non-Field Activities

Non-field activities fall into one of three categories: project management, information management, and modeling. The planned activities for each category are listed below.

Project Management

- Hold GIT meetings on a bi-weekly basis, or as often as necessary to respond to program activities.
- Collect stakeholder input and regulatory direction in four quarterly meetings with DOE and NMED representatives.
- Ensure external program review by the EEG in two meetings and review of documents as necessary.
- Implement EEG recommendations as described in the EEG Action Plan (Nylander, 1999).
- Based on EEG recommendations, make efforts to reach consensus with NMED on two issues in FY99: 1) approach for continued investigations when contamination is detected in a regional aquifer well and 2) establishing the basis for groundwater quality limits. Initial discussions of proposed approaches for both of these issues will be discussed at the Quarterly Meeting (February 3, 1999) and preliminary drafts of the approaches will be included in the final version of this Annual Report for discussion at the Annual Meeting in March, 1999.

Information Management

- Development and formalization of the "end state vision" by the HWPDB Project Leader.
- Development of a "Data and Records Management Plan" for the HWPDB by the HWPDB Project Leader.
- Consensus will be sought by the HWPDB Project Leader on the priorities for loading various data sets.
- A data repository will be created and loading or linking of existing data and new data will begin in FY99.

<u>Modeling</u>

- Continued calibration of the Los Alamos regional aquifer model will be accomplished by simulating transients in the aquifer.
- A high resolution sub-model of the regional model with transport capabilities for the Pajarito Plateau will be developed.

- Continued development of the lower Los Alamos Canyon hydrologic model will be accomplished by incorporating newly generated data.

- Integration of hydrologic data into Stratamodel by utilizing geostatistics and other methods of parameter estimation to extend and qualify the data support and assist in developing a geohydrologic atlas.

- Migrate the current 3-D geologic model to Stratamodel and create FY99 3-D stratigraphic model by updating model with new data and completing the incorporation of basalt and Tschicoma flow units and the Chaquehui Formation into the model.

- Extend, refine, or create new grids in Stratamodel for specific applications such as detailed studies at MDAs or stream channels.

- Work with the New Mexico Bureau of Mines to produce the Frijoles Geologic Quadrangle from the existing 3-D database.

- Continued geochemical modeling of Los Alamos, Sandia, and Mortandad Canyons.

- Geochemical modeling of Cañon de Valle perched zones and regional aquifer.

- Additional geochemical modeling of barium speciation and solubility with water quality data from TA-16.

4.2 Field Activities

FY99 field activities are summarized by aggregate.

Site-Wide (Aggregate 9) FY99 Planned Activities

- Continued monitoring and data collection activities for near-surface hydrologic cycle components and groundwater levels at various depths.

- A water balance study in Los Alamos Canyon.

- Installation of gaging stations at canyon confluences and the Laboratory boundaries. This planned activity will provide water balance information for the hydrogeologic conceptual model, but will be funded through the Watershed Management Program.

<u>Aggregate 1 FY99 Planned Activities</u>

- R-9 will be completed as a single completion well at the top of the regional aquifer.

- Borehole R-5 in Pueblo Canyon is currently scheduled for drilling and completion.

- Two alluvial wells, PAO-1 and PAO-2, will be installed in the western part of Pueblo Canyon.

- The GIT will examine the possibility of using R-12, R-5, R-15, or R-31 in a west to east transect of three multi-port wells in the upper 500 to 700 ft of the regional aquifer.

Aggregate 2 FY99 Planned Activities

- The TA-18 septic tank will be removed as part of a VCA plan.
- TA-54 pore gas monitoring and neutron probe measurements will continue.
- Shallow isotope and chemical profiles (stable isotopes and chloride) will be measured to determine patterns of infiltration at TA-54.
- Further vegetative cover measurements will be made at TA-54.
- Lidar water vapor flux measurements will continue at TA-54.
- Neutron access tubes will be installed at a depth of about 1 meter prior to placing an asphalt pad over pit 7 at TA-54.
- Air pressure monitoring will continue in TA-54.
- Modeling and other work for the TA-54 Pilot Extraction Study Plan will be finalized. A design for a passive vapor extraction system will be prepared.

Aggregate 3 FY99 Planned Activities

- Area 2 investigations include drilling a vertical hole through an unused shaft, drilling an angled directional borehole underneath Area 2, and installing an interflow monitoring trench in order to define the extent of vertical contamination.

Aggregate 4 FY99 Planned Activities

- Drill borehole R-31 in Ancho Canyon.

Aggregate 5 FY99 Planned Activities

- Complete of R-25 as a multi-port well.
- Conduct a water and contaminant mass balance data collection effort in Cañon de Valle.
- Conduct a stable isotope ($\delta^{18}O$, δD) tracer study to examine residence times of spring waters.
- Drill at least one alluvial well in Martin Canyon to investigate the hydrology.
- Implement an interim measure to remove highly contaminated material around the 260 outfall drainage.

Aggregate 6 FY99 Planned Activities

- Plans call for drilling regional well R-28 in FY99 and R-27 in FY00. However, depending on the ultimate findings at R-25, R-27 may be moved ahead of R-28 and possibly other regional wells in the schedule.

Aggregate 7 FY99 Planned Activities

- Complete phase 2 of the R-15 borehole installation involving drilling with the Barber rig to investigate saturation and hydrochemistry of the deeper units.
- Install two alluvial wells, MCO 0.6 and MCO 7.2, in Mortandad Canyon.

Aggregate 8 FY99 Planned Activities

- Complete Guaje water supply wells pump test analyses.
- Complete Guaje water supply wells summary report.
- Develop an optimization and management model for operation of the Guaje well field.
- Convert water supply well G-3 to an observation well.

4.3 MWIP Borehole Status

A summary of the MWIP borehole installation activities and well completion status is provided here in tabular form to consolidate the information provided throughout this report. Table 4.3-1 captures FY98 changes in installation scheduling as published in the Hydrogeologic Workplan (LANL 1998) and provides the status of drilling activities and decisions on well completion.

Table 4.3-1. Status of MWIP Proposed Boreholes

Borehole	Original Start Date	Current Start Date	FY98 Status	Funding Source	Status of Installed Boreholes/Rationale of Proposed Boreholes
R-9	FY98	FY97	Borehole drilled, well completion scheduled in FY99	ER	Borehole R-9 has been installed at the eastern Laboratory boundary in Los Alamos Canyon, but not yet completed as a single-completion monitoring well. It was designed to provide water-quality and water-level data for potential intermediate perched zones and for the regional aquifer downgradient of Aggregate 1. Borehole R-9 encountered two perched intermediate saturated zones at 180 and 275 ft. Additionally, three separate saturated zones (579, 615, and 624 ft) were encountered above the regional aquifer (688ft). The stratigraphic, hydrologic, and geochemical description of R-9 is included in Section 3.2.1.1.
R-12	FY98	FY98	Borehole drilled, well completion scheduled in FY00	ER	Borehole R-12 has been installed at the eastern Laboratory boundary in Sandia Canyon, but not yet completed as a monitoring well. It was designed to provide water-quality and water-level data for potential intermediate perched zones and for the regional aquifer downgradient of Aggregate 1. Due to the proximity of R-12 to R-9, PM-1 and O-1 which provided stratigraphic information, it was not continuously cored. R-12 serves as a water-supply protection well for PM-1. Sandia Canyon has received treated effluents from Laboratory operations (TA-3, TA-53, TA-60, and TA-61) though no contaminants have been detected in nearby water supply well PM-1. Intermediate perched zone groundwater was encountered at a depth of 443 ft and the zone is about 75 ft thick. The stratigraphic, hydrologic, and geochemical description of R-12 is included in Section 3.2.1.1.
R-25	FY98	FY98	Borehole started in FY98, well completion scheduled in FY99	NWT	Borehole R-25 has been partially installed as a multipurpose borehole located adjacent to MDA P in Aggregate 5. Core collected from this borehole will support site-wide studies of the hydrogeologic framework because it is located in a largely uncharacterized area in the southwest part of the Laboratory. It was not continuously cored. This hole will provide critical information about the depth to the regional aquifer for this area. R-25 will also provide water-quality data for intermediate perched zones and the regional aquifer downgradient from MDA P and from other release sites further west in the Canon de Valle watershed. Springs issuing from the upper Bandelier Tuff in this area are contaminated with high explosives, nitrate, and Ba. R-25 is part of a southeasterly traverse of reference wells that includes R-28 and R-32 and a north-south traverse that includes R-6.
R-15	FY00	FY99	Started with hollow-stem auger in early FY99, completion with Barber drill rig in Spring, 1999, after completion of R-25	ER	Borehole R-15 has been partially installed in Mortandad Canyon downstream from active and inactive outfalls at TA-5, TA-35, TA-48, TA-50, TA-52, TA-55, and TA-60. The presence of intermediate perched zones within Aggregate 7 will be investigated and, if present, characterized. Characterization data from R-15 are critical for supporting the TA-50 Discharge Plan and for addressing citizens concerns about releases in Mortandad Canyon. R-15 may replace TW-8 completed in 1960. The location of R-15 is described in the ER Mortandad Canyon Workplan (LANL, 1997).
R-5	FY00	FY99	Planned	NWT	R-5 is planned for installation in lower Pueblo between the Los Alamos County Sewage Treatment Plant and water supply well O-1 and nearby test wells TW-1 and TW-1A. Laboratory surveillance data (EPG 1995, EPG 1996) show the presence of NO_3 (TW-1, TW-1A, TW-2A), $^{239,240}Pu$ (TW-2A), and ^{137}Cs (TW-1A) at various concentrations and activities below MCLs, except for NO_3 (23 mg/l NO_3-N; MCL NO_3-N = 10 mg/l). R-5 will provide a monitoring point between the sewage treatment plant and wells TW-1, TW-1A, and O-1. R-5 will also provide information on whether a recharge mound occurs below the canyon floor and is responsible for the anomalously-high regional aquifer water levels in TW-1. R-5 could serve as a replacement well for TW-1 drilled by cable tool in 1950.

Table 4.3-1. Status of MWIP Proposed Boreholes (continued)

Borehole	Original Start Date	Current Start Date	FY98 Status	Funding Source	Status of Installed Boreholes/Rationale of Proposed Boreholes
R-27	FY00	FY00	Suggested re-prioritization by NMED	ER	R-27 is planned for installation at the confluence of Water Canyon and Cañon de Valle to characterize baseline water quality in intermediate perched zones and in the regional aquifer groundwater upgradient of Aggregate 3. High explosives were detected in water from borehole R-25. R-27 also will provide baseline information on the geology, hydrology, and water quality for the poorly-characterized south-central part of the Laboratory. These data will be used in conjunction with data from R-28 and R-30 to optimize placement of monitoring wells in the vicinity of Aggregates 3, 5, and 6. A more detailed analysis of well placement in Water Canyon and Canon de Valle will be included in the ER sample and analysis plan to be prepared by FY-00.
R-31	FY01	FY99	Planned to start after completion of R-15	NWT	Site-wide characterization borehole R-31 is planned for installation downgradient of open burning/open detonation sites in Aggregate 6 and upgradient of firing sites in Aggregate 4. The primary objective of this borehole is to provide water-quality data for potential intermediate perched zones and for the regional aquifer. This is a part of the Laboratory with no well control and data from this borehole is critical to the modeling activities. This borehole will contribute to the optimization of long-term monitoring wells for Aggregates 4 and 6 by placing better constraints on the geometry of the regional aquifer in this area.
R-7	FY98	FY99	Funding delay	ER	R-7 is planned for installation in upper Los Alamos Canyon to provide water-quality and water-level measurements for the intermediate perched zones and the regional aquifer in an area of Los Alamos Canyon that is in close proximity to release sites of contaminated effluent (TA-2 and TA-21). R-7 is located between existing boreholes LADP-3 and LAOI(A)1.1 in Los Alamos Canyon. These existing boreholes, and H-19 located west of Los Alamos Canyon bridge, penetrated a 5- to 22-ft thick perched intermediate zone. The water-quality data suggest that the perched zone is recharged both by infiltration from overlying alluvium and by recharge sources in the mountains to the west. R-7 is sited in this area of suspected recharge and will provide information about stratigraphic and structural controls on infiltration. Also, R-7 will penetrate the full extent of saturation at the top of the Puye Formation and identify deeper intermediate perched zones beneath Los Alamos Canyon. Hydrologic and geologic properties of pre-Bandelier units in R-7 will be used for ER Project assessments of mesatop sites at TA-21, TA-53, and TA-73.
R-22	FY98	FY98	Funding delay	ER	R-22 is planned for installation near the southeastern Laboratory boundary in Pajarito Canyon to provide water-quality and water-level data for potential intermediate perched zones and for the regional aquifer downgradient of Aggregate 2. Aggregate 2 includes MDA L and MDA G. In addition, this location is downgradient of numerous other Laboratory technical areas which released high explosives, radionuclides, organic solvents, and inorganic solutes. Large springs (e.g. Pajarito Spring) discharge from basalts in lower Pajarito Canyon into White Rock Canyon. Water-quality characteristics will be compared for R-22 and the springs to evaluate whether these groundwater-bearing zones are hydrologically connected.
R-18	FY99	FY99	Funding delay	ER	R-18 is planned for installation above the confluence of Pajarito and Twomile Canyons to provide information about intermediate perched zone groundwater, depth to the regional aquifer, and water quality of perched zones and the regional aquifer in the poorly-characterized west-central part of the Laboratory. It is located downstream from Laboratory release sites at TAs 8, 9 14, 22, 40, and 69, but is in an area that has not been characterized for either groundwater or contaminants. The occurrence of surface flow through most of the year indicates perched alluvial groundwater is present in this part of the canyon.

Table 4.3-1. Status of MWIP Proposed Boreholes (continued)

Borehole	Original Start Date	Current Start Date	FY98 Status	Funding Source	Status of Installed Boreholes/Rationale of Proposed Boreholes
R-3	FY99	FY99	Funding delay	ER	R-3 is planned for installation in upper Pueblo Canyon to provide water quality information for potential intermediate perched zones and for the regional aquifer beneath upper Pueblo Canyon downgradient of former TA-45. In the past, natural surface water flow in Pueblo Canyon was augmented by Laboratory releases and by effluent from the former sewage waste-water treatment plant in upper Pueblo Canyon. Because of the augmented surface flow, upper Pueblo Canyon may have been a source of recharge to intermediate perched zones and the regional aquifer. The available data suggest that mobile contaminants associated with former TA-45 (^{3}H, ^{90}Sr, and NO_3) are present in a groundwater plume that extends at least 1.75 mi down Pueblo Canyon and may extend further. Additional mapping of intermediate perched zones and characterization of water quality is needed to assess the nature of groundwater contamination in upper Pueblo Canyon.
R-2	FY00	FY00	Planned	NWT	R-2 is planned for installation near the confluence of Acid Canyon and Pueblo Canyon within Los Alamos townsite. Laboratory surveillance data collected at nearby mesa-top borehole TW-4 indicate the presence of ^{90}Sr (6.2 pCi/l, MCL = 8 pCi/l) in the regional aquifer (EPG 1996). This remediated area (former TA-45) has documented releases of Am, Pu, NO_3, U, and other contaminants to alluvial groundwater in Acid and Pueblo Canyons in the late 1940's and early 1950's. R-2 is sited in Pueblo Canyon and is downgradient of the Rendija Canyon fault. Recharge contaminated from past releases may be reaching intermediate perched zones and the regional aquifer along this fault. Analyses of core and water samples collected from R-2 will be used to evaluate the fault as a preferential groundwater pathway. R-2 could replace TW-4 drilled by cable tool in 1950.
R-8	FY00	FY00	Planned	NWT	R-8 is planned for installation near the confluence of Los Alamos Canyon and DP Canyon as a water-supply protection well for Otowi-4. When in service, Otowi-4 will provide ~25% of the water supply to Los Alamos County including the Laboratory. Laboratory surveillance data indicated the presence of ^{3}H (~50 pCi/l) and ^{90}Sr (35 pCi/l) in TW-3 located ~300 ft northeast of Otowi-4. Los Alamos Canyon has a long history of facility releases with contaminants detected in alluvial groundwater (^{3}H, ^{90}Sr , ^{137}Cs) and in an intermediate perched zone in the Guaje Pumice Bed (^{3}H). These perched zones may provide recharge to the regional aquifer. DP Canyon contains radionuclides released from the north side of TA-21. R-8 could be used as a replacement well for TW-3 drilled by cable tool in 1949.
R-10	FY00	FY00	Planned	ER	R-10 is planned for installation in upper Sandia Canyon to provide water quality information for a potential intermediate perched zone in the Guaje Pumice Bed. The large intermediate perched zone in Los Alamos Canyon is located in this horizon and contains significant ^{3}H. This perched zone appears to be largely confined to the area beneath Los Alamos Canyon west of TA-21 (the Guaje Pumice Bed was not saturated in boreholes 21-2523 and LADP-4 north of Los Alamos Canyon), but structure contour maps (Broxton and Reneau 1996; Davis et al. 1996) suggest that the gradient of the perching layer changes in the vicinity of R-7 and R-10, and water perched in this zone will move southward along the axis of a large pre-Bandelier paleo-drainage. R-10 is designed to investigate the southward extension of this perched system from the Los Alamos Canyon area.
R-28	FY01	FY01	Planned	NWT	R-28 is planned for installation as a multipurpose borehole in the middle reach of Water Canyon. This borehole will provide water quality information for potential intermediate perched zones and for the regional aquifer beneath potential release sites in Aggregate 6, and it will provide information for optimizing the placement of monitoring wells in this part of the Laboratory. R-28 is presently scheduled to be completed as a type 3 well, but the option is preserved to advance these boreholes to a total depth 4000 ft and to include multiple completions of the well if funding agencies decide further characterization of regional aquifer groundwater resources is required.

Table 4.3-1. Status of MWIP Proposed Boreholes (continued)

Borehole	Original Start Date	Current Start Date	FY98 Status	Funding Source	Status of Installed Boreholes/Rationale of Proposed Boreholes
R-32	FY01	FY01	Planned	NWT	R-32 is planned for installation west of Ancho Spring in lower Ancho Canyon. This borehole is designed to provide baseline information on the geology, hydrology, and water quality for the poorly studied southeastern boundary of the Laboratory. It is located within Aggregate 4 and will provide water-quality and water-level data for intermediate perched zones and the regional aquifer in this area. Water-quality data for R-32 will compared to similar data for springs in White Rock Canyon to identify potential groundwater flow paths near the Rio Grande. Water samples from Ancho Spring contain high explosives and depleted U which probably originated from firing sites in Aggregates 4 or 6.
R-1	FY01	FY01	Planned	NWT	R-1 is planned for installation as a multipurpose borehole located north of Aggregate 1 in Rendija Canyon. R-1 is sited along the northward projection of Purtymun's (1995) mid-Miocene high-permeability zone at the top of the Santa Fe Group, and this borehole could significantly extend the known northern limit of this important water-supply feature. This borehole is presently scheduled to be completed as a Type 3 well, but the option is preserved to advance the boreholes for these wells to a total depth 4000 ft and to include multiple completions of the wells if funding agencies decide further characterization of regional aquifer groundwater resources is required. Water-level and water-quality data from this borehole will be used to test hypotheses concerning possible recharge to the regional aquifer from the north. R-1 is part of a north-south traverse of reference wells that includes R-14 and R-28.
R-4	FY01	FY01	Planned	ER	R-4 is planned for installation to provide water-quality and water-level information for potential intermediate perched zones and for the regional aquifer beneath middle Pueblo Canyon. R-4 will provide information about the downgradient extent of groundwater contamination from former TA-45. This borehole is located between TW-1A and TW-2A, both of which were completed in intermediate perched zones containing contaminant levels that are above background levels. R-4 will place constraints on the lateral extent of the perched zone(s) and identify deeper perched zones within the Puye Formation and basalts in middle Pueblo Canyon near the northern Laboratory boundary. R-4 will also characterize groundwater water quality upgradient of the county's Bayo Sewage Treatment Plant.
R-13	FY01	FY01	Planned	ER	R-13 is planned for installation to provide water-quality and water-level data for potential intermediate perched zones and for the regional aquifer within Aggregate 7. Laboratory surveillance data collected in Mortandad Canyon show elevated concentrations or activities of NO_3, ^{3}H, ^{90}Sr, ^{137}Cs, $^{239,240}Pu$, ^{241}Am, and U in ephemeral surface water and in alluvial groundwater. Vertical migration of ^{3}H beneath the canyon floor has been documented by Stoker et al (1991).
R-19	FY01	FY01	Planned	ER	R-19 is planned for installation to provide information about intermediate perched zone groundwater, depth to the regional aquifer, and water quality in the poorly-characterized central part of the Laboratory. R-19 provides downgradient water-quality data for release sites in upper Pajarito Canyon and upgradient data for TA-18. R-19 will help constrain the location of the axis of the south-draining pre-Bandelier paleo-drainage which trends through this area.
R-20	FY02	FY02	Planned	NWT	R-20, water-supply protection well for PM-2, is planned for installation in lower Pajarito Canyon southwest MDA L and MDA G at TA-54. MDA L has an organic vapor plume(s) consisting of 1,1,1-TCA, TCE, CCl_4, that has migrated to a depth at least 500 ft within basalts under the Bandelier Tuff. R-20 is sited between PM-2 and MDA L. Alluvial groundwater within lower Pajarito Canyon contains above background activities of solvents, high explosives, ^{3}H, NO_3, and U, all which are below MCLs. Intermediate perched zones may occur within the Bandelier Tuff, based on drilling logs for PM-2, and within basalts.

Table 4.3-1. Status of MWIP Proposed Boreholes (continued)

Borehole	Original Start Date	Current Start Date	FY98 Status	Funding Source	Status of Installed Boreholes/Rationale of Proposed Boreholes
R-14	FY02	FY02	Planned	NWT	R-14 is planned for installation as a water-supply protection well for PM-5. Previous investigations and surveillance data show that surface water and alluvial groundwater in Mortandad Canyon contain ^{3}H, Pu, and NO_3 released from the Laboratory's liquid radioactive waste treatment plant at TA-50. Elevated activities of ^{3}H occurs in core samples collected 100-200 ft below the canyon floor (Stoker et al. 1991). Sampling of Test Well 8 confirmed the presence of ^{3}H (89 pCi/l), ^{90}Sr (2.1 pCi/l), $^{239,240}Pu$ (0.188 pCi/l), ^{241}Am (0.034 pCi/l), and NO_3 (as N, 5.1 mg/l) in the regional aquifer beneath Mortandad Canyon (EPG 1996). R-14 will provide information about the radius of influence of pumping from PM-5, and it's location will be optimized to detect the migration of contaminants from Mortandad Canyon towards the water supply well. R-14 is part of a southeasterly traverse of reference wells that includes R-6 and R-16 and a north-south traverse that includes R-1 and R-28.
R-17	FY02	FY02	Planned	ER	R-17, a major tributary to Pajarito Canyon, is planned for installation to provide information about intermediate perched zones, depth to the regional aquifer, and water quality of intermediate perched zones and the regional aquifer in the poorly-characterized northwest part of the Laboratory. It is located downstream from Laboratory release sites at TAs 3, 6, 58, 59, 62, and 69, but is in an area that has not been characterized for either groundwater or contaminants. R-17 will also provide upgradient water quality information for Aggregate 7.
R-23	FY02	FY02	Planned	ER	R-23, located near the southeastern Laboratory boundary, is planned for installation to provide water-quality and water-level data for potential intermediate perched zones and for the regional aquifer downgradient of active firing sites in Potrillo Canyon. R-23 is sited within a hydrological sink, a broad area of infiltration on the canyon floor that typically marks the easternmost occurrence of surface water flow in this canyon. R-23 will evaluate the hydrological sink as a possible recharge zone for perched groundwater and for the regional aquifer.
R-24	FY02	FY02	Planned	NWT	R-24 is planned for installation near the trace of the Pajarito fault system west of Aggregate 5. This borehole will provide water-quality and water-level data for intermediate perched zones and the regional aquifer on the upthrown block of a major spray of the Pajarito fault system. The location and occurrence of perched water and water level data for the regional aquifer, when compared with similar data from R-25 and R-26 on the downthrown block, will be used to evaluate the influence of the Pajarito fault system on the regional piezometric surface and provide information about its role as a recharge zone. R-24 will be used to establish boundary conditions on the western side of the Laboratory for numerical models of groundwater flow. Water-quality data from intermediate perched zone and regional groundwater in R-24 will define background conditions upgradient from the Laboratory, and in particular for Aggregate 5. These background geochemical data will be used to define potential impacts on groundwater from Laboratory facilities and to provide input data for geochemical and hydrological modeling of different groundwater systems.
R-26	FY02	FY02	Planned	NWT	R-26 is planned for installation near the trace of the Pajarito fault system near the southwest corner of the Laboratory. This borehole will provide water-quality and water-level data for perched systems and the regional aquifer on the downthrown block of the Pajarito fault system. Numerous springs, including the large Water Canyon Gallery, issue from the Bandelier Tuff in Water Canyon. The location and occurrence of perched water and water level data for the regional aquifer, when compared with similar data from R-24 and R-25 on the downthrown and upthrown blocks, respectively, will be used to evaluate the influence of the Pajarito fault system on the regional piezometric surface and provide information about its role as a recharge zone. Water-quality data from intermediate perched zone and regional groundwater in R-26 will define background conditions in a large wet canyon upgradient from the Laboratory, and in particular for Aggregate 5. These background geochemical data will be used to define potential impacts on groundwater from Laboratory facilities and to provide input data for geochemical and hydrological modeling of different groundwater systems.

Table 4.3-1. Status of MWIP Proposed Boreholes (continued)

Borehole	Original Start Date	Current Start Date	FY98 Status	Funding Source	Status of Installed Boreholes/Rationale of Proposed Boreholes
R-21	FY02	FY02	Planned	ER	R-21 is planned for installation to evaluate and monitor hydrologic and geochemical conditions in the regional aquifer beneath MDA L. The ER Project has detected dense non-aqueous phase vapors beneath MDA L; these organic vapors have migrated through fractures in the Bandelier Tuff and the underlying basalts to a depth of 500 ft.
R-30	FY02	FY02	Planned	ER	R-30 is planned to deepen borehole 49-2-700-1 in Aggregate 3 from the current depth of 700 ft to approximately 1600 ft. This borehole will determine water quality in intermediate perched zones and in the regional aquifer beneath MDA AB, which was used for underground hydronuclear experiments.
R-6	FY03	FY03	Planned	NWT	R-6, planned for installation in upper Los Alamos Canyon, is designed to provide baseline information about the geology, hydrology, and water quality for the western boundary of the Laboratory. This borehole will determine background water quality for intermediate perched zones and the regional aquifer upgradient of Aggregate 1. It also will provide information about the depth to the regional aquifer for the western part the Laboratory, and contribute to the construction of accurate groundwater maps for placing monitoring wells in this part of the Laboratory. R-6 is part of a southeasterly traverse of reference wells that includes R-14 and R-16 and a north-south traverse that includes R-25.
R-11	FY03	FY03	Planned	NWT	R-11, planned for installation as a water-supply protection well for PM-3, is located in middle Sandia Canyon east of the TA-72 firing range. PM-3 is downgradient from source terms with a long history of releases at TA-53 and TA-21. R-11 is located between PM-3 and the potential release sites. R-11 will also provide information about groundwater gradients near PM-3, which has water levels that are anomalously high compared to elevations expected from regional water level maps.
R-29	FY03	FY03	Planned	NWT	R-29 is planned for installation in lower Water Canyon. It will provide information about the depth to the regional aquifer in a poorly-characterized area, and the water-level data will be used to optimize the placement of downgradient monitoring wells along the eastern Laboratory boundary. Water-quality data from perched and regional groundwaters in R-29 will be compared to similar data for springs in White Rock Canyon to identify potential groundwater flow paths near the Rio Grande.
R-16	FY03	FY03	Planned	NWT	R-16, planned for installation in White Rock, will provide baseline information on the geology, hydrology, and water quality for a large uncharacterized area between the eastern boundary of the Laboratory and the Rio Grande. Numerous springs in White Rock Canyon probably represent discharge points for intermediate perched zones and the regional aquifer based on significant differences in major ion chemistry and stable isotopes. R-16 will determine background water quality for intermediate perched zones and the regional aquifer between the Laboratory and the Rio Grande, provide information about the depth to the regional aquifer for the eastern part the Laboratory, and clarify the relationship between springs in White Rock Canyon and various groundwater zones. R-16 is part of a southeasterly traverse of reference wells that includes R-6 and R-14.

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