Task/Site Work Plan for Operable Unit 1049 Los Alamos Canyon and Pueblo Canyon

Environmental Restoration Project

November 1995

A Department of Energy
Environmental Cleanup Program

Los Alamos
NATIONAL LABORATORY

LA-UR-95-2053

Executive Summary

Purpose

This Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) task/site work plan establishes the technical approach and methodology for environmental investigations of Los Alamos Canyon and Pueblo Canyon, two of the major drainage areas or canyon systems at Los Alamos National Laboratory (the Laboratory). Specifically, this investigation of Los Alamos Canyon and Pueblo Canyon evaluates the potential impacts of Laboratory-derived contaminants within the two canyon systems. The purpose of this investigation is to

- determine the potential for contaminant transport into or within Los Alamos Canyon and Pueblo Canyon watersheds;
- evaluate human health risks and ecological impacts associated with the presence of contaminants;
- refine conceptual models for contaminant transport;
- assess the potential for interconnections between ground water in alluvium, perched intermediate zones, and the main aquifer; and
- assess the projected impact that contaminants may have on off-site receptors and the Rio Grande.

This task/site work plan presents a technical approach that is significantly different from previous RFI work plans that investigated solid waste management units (SWMUs). This task/site work plan deals with the investigation of affected media within the canyon systems rather than the investigation of SWMUs. The technical approach and the sampling and analysis plans are designed to address the broad and far-reaching regulatory requirements contained in the Hazardous and Solid Waste Amendments (HSWA) Permit.

Response to Regulatory Requirements

This task/site work plan satisfies the regulatory requirements of Module VIII, Sections I.5 and Q, tasks 1 through 5, of the HSWA Permit (May 19, 1994), which was issued by the Environmental Protection Agency (EPA) to address contamination problems specific to the Laboratory. The satisfaction of these permit requirements is accomplished by the Laboratory Environmental Restoration (ER) Project. Because this task/site work plan identifies the canyons as ultimate transport pathways for contaminants migrating across and off the Laboratory, a distinction is created between the HSWA requirements for the canyon systems and the HSWA requirements for SWMUs. These canyon pathways cross American Indian, private, and public land and eventually contribute sediments, surface water, and ground water to the Rio Grande. Because the canyons and the associated transport processes are identified as the regulatory focus, the canyon investigations are different from SWMU-based investigations, both from a regulatory and a scientific perspective.

Background

Description of Field Unit 4

Field Unit 4, one of the five major field units in the ER Project, includes three operable units (OUs): OU 1098, OU 1129, and OU 1049. OU 1049 contains 19 canyon systems; two of these, Los Alamos Canyon and Pueblo Canyon, are the focus of this task/site work plan. The canyon systems were grouped for study using four criteria:

- potential for greatest risk to human health and the environment,
- amount of available data,
- presence of known contamination, and
- geographic proximity.

Los Alamos Canyon and Pueblo Canyon comprise about 18 miles of the 110 miles of canyon and drainage systems on property controlled by the Laboratory. Los Alamos Canyon and Pueblo Canyon were selected as the subjects for the first task/site work plan for two reasons: the considerable body of information available concerning the release of contaminants into these canyons and their proximity to populated areas.

Future Task/Site Work Plans

The Los Alamos Canyon and Pueblo Canyon task/site work plan is the first of eight planned task/site work plans. In FY96 an integrating task/site work plan that will act as an "umbrella" or core document will be developed. The additional seven work plans will be prepared in the following few years. These task/site work plans will address the remaining canyon systems of the Pajarito Plateau that may have been affected by Laboratory operations (see Table 1-2 in Chapter 1 of this task/site work plan). The core document, which will incorporate a significant amount of material from Chapters 1 through 5 of this task/site plan, will be used as a tier document for the seven remaining task/site work plans. Each of the seven task/site work plans will have only an introduction, a chapter on the historical background, a short chapter describing the issues concerning the environmental setting of a specific canyon system, and a chapter describing the sampling and analysis plan and the quality assurance project plan. This approach is expected to effectively and efficiently satisfy the permit requirements.

Public Involvement

At the beginning of calendar year 1992, the ER Project established a public involvement effort. The ER Project Office schedules informal and formal meetings with the general public, the neighboring Indian Pueblos, and ER Project advisory groups. The purpose of these meetings is to involve these groups with the ER Project and its goals within the RCRA regulations. Activities undertaken for this task/site work plan include formal interactions with the Pueblos of San Ildefonso, Santa Clara, Cochiti, and Jemez, which have formal accords and agreements with the Department of Energy (DOE) and the Laboratory. (These Indian Pueblos are referred to as the Accord Pueblos in this task/site work plan.) These interactions result in suggested approaches for the task/site work plans. In addition, the ER Project has employed Indian Pueblo members to work on the field characterization teams. The intent of these interactions is to provide avenues for the American Indian perspective to become an integral part of the preparation and execution of the canyons task/site work plans.

Conceptual Model and Technical Approach

One of the significant distinctions of this task/site work plan compared with an RFI SWMU-based work plan is the responsibility to investigate the canyons as an integrated natural system. The canyons that drain the Pajarito Plateau at the Laboratory are geologically and hydrologically diverse. This diversity and wide geographic extent caused the creation of a germane work plan methodology for these studies. This methodology is based on well-defined regulatory and broadly applicable technical issues that apply to the canyons investigations. Therefore, the canyon characterization activities are designed to collect data for a present-day snapshot of risk based on present-day contaminant levels, evaluate the potential impact of contaminant transport into and within the watersheds, and subsequently transition to a long-term monitoring program. The characterization study area is bounded by the western Laboratory border to the Rio Grande, the canyon floors laterally from the stream channel to the modern floodplain deposits, and the stream channel vertically to the deepest ground water bodies affected by regulatorially defined limits of contaminants. The characterization data is used to develop risk scenarios based on Laboratory use, recreational land use, traditional use by American Indians, and residential use at Totavi and Otowi Houses. Risk scenarios based on cumulative or dose release in future generations are recognized as possible products of these investigations but are not explicitly dealt with at this time. Refinement of the regulatory framework would need to provide more detailed guidance before future risk studies could be undertaken. Therefore, the technical approach is based primarily on satisfying the HSWA Module requirements in an efficient and technically defensible manner. To meet these objectives, the following two investigation paths are followed:

- sampling and analysis of surface sediments on the canyon floors to evaluate surface exposure pathways and
- sampling and analysis of surface and ground water to assess the transport pathways and potential impacts on the different zones of saturation.

For example, sediment sampling is largely restricted to post-1943 canyon deposits in both the active channels and the floodplains. Furthermore, task/site work plans will focus on identifying areas *most likely* to contain contaminants, determining the geomorphic settings where the greatest contaminant inventories could occur (post-1943 sediments), and assessing the susceptibility of the contaminants to redistribution in sediments and dust.

Task/site work plans for ground water investigations will also focus on areas most likely to contain contaminants, such as the near-surface alluvial and intermediate perched zone ground waters. Results of these ground water investigations are also used for locating and designing ground water monitoring systems. Studies of the deep unsaturated zone and the main aquifer will be conducted if (1) the intermediate perched zones contain contaminants above maximum concentration limits for drinking water, (2) the data from nearby main aquifer wells indicate the presence of contaminants, or (3) the combined historical data and investigation results suggest that the alluvium, intermediate perched zones, and main aquifer are interconnected.

Sampling and Analysis Strategy

Chapter 7 of this task/site work plan contains the sampling and analysis plans for the first set of investigations to be conducted under this technical approach. The strategy is based on first understanding the nature of the contaminants present. This understanding is gained through a biased sample location selection strategy and broad-based analyses. After the lists of contaminants are defined, subsequent investigation will limit analyses to the limited suite of known contaminants. Because there is high probability that Laboratory-derived contamination is predominantly radioactive and that there are associated radioactive components in virtually all waste streams serving as canyon source terms, the initial sampling strategy relies heavily on the use of remote sensing radiological surveys and geomorphologic mapping to give a broad view of the distribution of contaminants within surface sediments. Discrete sampling points are identified based on radiological screening surveys and geomorphologic features. Locations of new wells are based on known or suspected hydrologic features. In all sampling, the selection criteria for location and analytical content are designed to develop the best possible data set at the most reasonable cost. The iterative portions of the technical approach will allow the investigators to tune the characterization requirements to observed conditions in the field. This approach will ultimately lead to a well-defined and quantitative understanding of the natural systems involved in canyon contaminant fate and transport.

Schedule and Reporting

Annex I of this task/site work plan contains a preliminary schedule for conducting the activities described in the sampling and analysis plans. This schedule is not currently supported by a firm budget commitment from DOE for ER Project activities and is subject to change when the final FY96 budget is determined. However, regardless of the level of the budget, Field Unit 4 personnel plan to conduct a pilot study for one or two of the reaches in Pueblo Canyon during FY96. Information gained from these pilot studies will help refine the manner in which the remaining studies are implemented.

The Laboratory, DOE, EPA, and the stakeholders have not produced a final definition of the types and schedule of reports for the efforts in this task/site work plan. Since the canyons contain no SWMUs, reporting schedules pertinent for HSWA permit modification are not directly applicable. Every effort is directed at creating an efficient schedule and communicative format for reporting the results of canyon investigations. Consistent with the technical approach, any results that indicate the need for an immediate mitigation remedial action will be communicated and initiated.

Structure of the Work Plan

This task/site work plan contains seven chapters, five annexes, and five appendixes, as listed below.

Chapters

Chapter 1 gives a brief introduction to the overall regulatory, operational, and environmental setting.

Chapter 2 provides the historical background for the archaic and modern land uses within the investigation areas, including a discussion of possible contaminant sources based on archival data.

Chapter 3 describes the environmental setting for Los Alamos Canyon and Pueblo Canyon and summarizes available data germane to the current investigation.

Chapter 4 develops the conceptual model for the canyons system and its implications in shaping the overall investigation efforts.

Chapter 5 describes the technical approach that will be followed during execution of this task/site work plan.

Chapter 6 explains the human health and ecological risk assessment considerations and approach for evaluating the data derived from the investigation.

Chapter 7 contains the sampling and analysis plans for the initial characterization efforts in the two canyons and describes more fully the implementation of the reach concept for understanding the natural systems. Elements of the quality assurance project plan are also found in this chapter.

Annexes

Annex I presents a general project management plan for Field Unit 4 along with an implementation schedule for the investigation work.

Annex II contains other elements of the quality assurance project plan, including analytical tables.

Annex III is the overall health and safety plan for Field Unit 4 field operations.

Annex IV is a brief description of the records management plan.

Annex V describes the general public involvement plan for obtaining and maintaining stakeholder interest and communication in canyons investigation activities.

Appendixes

Appendix A contains the fold-out color maps referenced in the text.

Appendix B contains the detailed plant and animal checklists used for ecological evaluations.

Appendix C summarizes the human health risk assessment calculations.

Appendix D describes the various field and laboratory investigation methods likely to be employed.

Appendix E lists the individuals who contributed to this task/site work plan.

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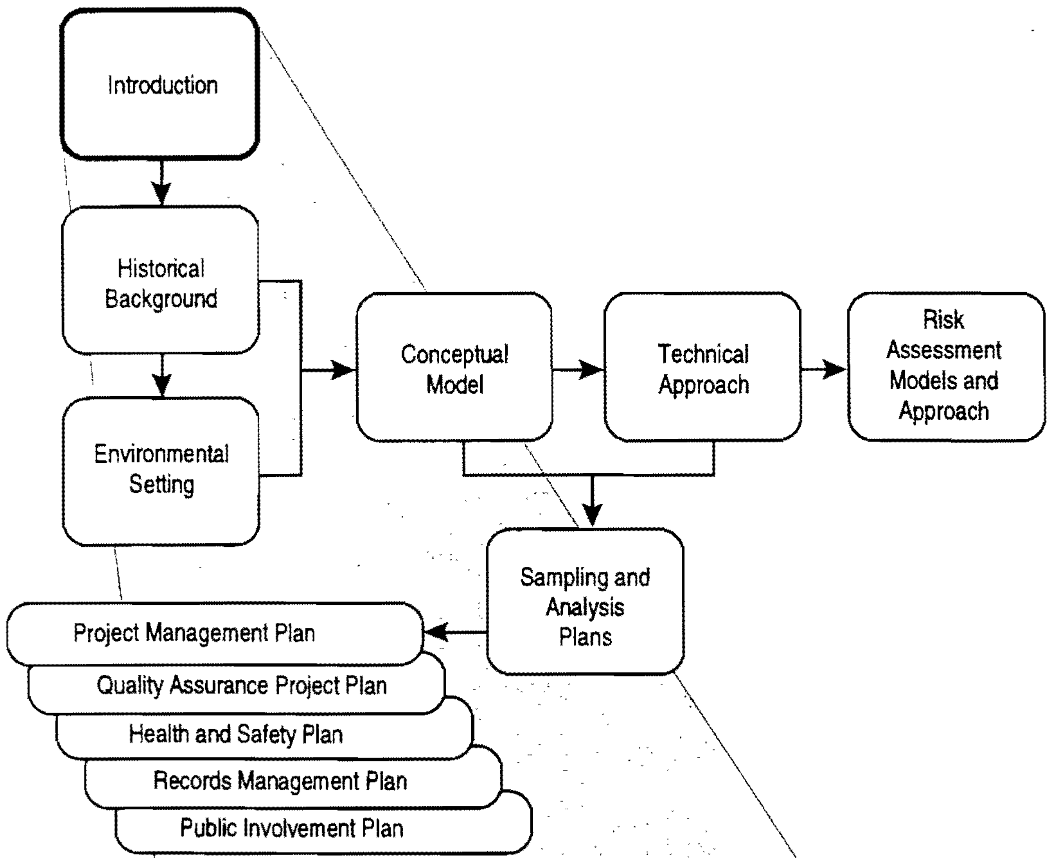
LIST OF ACRONYMS AND ABBREVIATIONS

AC	Acid Canyon
AEC	Atomic Energy Commission
AGGIH	American Conference of Governmental Industrial Hygienists
AOC	area of concern
AP	administrative procedure
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BIA	Bureau of Indian Affairs
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CGI	combustible gas indicator
CMS	corrective measures study
COC	chemical of concern
COPC	chemical of potential concern
CU	University of Colorado
CVAA	cold vapor atomic absorption
dB	decibel
DCG	derived concentration guide
DOE	Department of Energy
DQO	data quality objective
EC	expedited cleanup
EDL	estimated detection limit
EM	Environmental Management
EPA	Environmental Protection Agency
EQL	estimated quantitation limit
ER	Environmental Restoration
ESG	Environmental Surveillance Group
ESH	Environment, Safety, and Health
EST	ecological studies team
FID	flame ionization detector
FIDLER	field instrument for detecting low-energy radiation
FIMAD	Facility for Information Management, Analysis, and Display
FPL	field project leader
FUSRAP	Formerly Utilized Sites Remedial Action Program
GFAA	graphite furnace atomic absorption
GM	Geiger-Müller
GPC	gas proportional counter
GWPMP	Ground Water Protection and Monitoring Plan
H&S	health and safety
HASP	health and safety plan
HEPA	high-efficiency particulate air
HSWA	Hazardous and Solid Waste Amendments
IC	ion chromatography
ICPES	inductively coupled plasma emission spectroscopy
ICPMS	inductively coupled plasma mass spectrometry
IWP	Installation Work Plan
LA	Los Alamos (Canyon)
LANL	Los Alamos National Laboratory
LEHPGe	low-energy, high-purity germanium

LEL	lower explosive limit
LSC	liquid scintillation counting
MCL	maximum contaminant level
MDA	minimum detectable activity
MDA	material disposal area
Myr	million years
NAPL	nonaqueous phase liquid
NEPA	National Environmental Policy Act
NFA	no further action
NIOSH	National Institute for Occupational Health
NMED	New Mexico Environment Department
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity units
OSHA	Occupational Safety and Heath Administration
OU	operable unit
P	Pueblo (Canyon)
PC	Pueblo Canyon
PCB	polychlorinated biphenyl
PID	photoionization detector
PRS	potential release site
PVC	polyvinyl chloride
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
RPF	Records-Processing Facility
RSD	treatment, storage, and disposal
SAL	screening action level
SAP	sampling and analysis plan
SOP	standard operating procedure
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TA	technical area
TD	total depth
TDS	total dissolved solids
TES	threatened, endangered, or sensitive
The Laboratory	Los Alamos National Laboratory
TI/MS	thermal ionization/mass spectrometry
TLD	thermoluminescent dosimeter
TSD	treatment, storage, and disposal
TW	test well
UC	University of California
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USRADS	Ultrasonic Ranging and Data System
UST	underground storage tank
UTL	upper tolerance limit
VCA	voluntary corrective action
VOC	volatile organic compound

Chapter 1



Introduction

- Overview
- HSWA Requirements
- Operable Unit Description
- Document Organization

1.0 INTRODUCTION

1.1 Purpose

This task/site work plan discusses investigations to be conducted in Los Alamos Canyon and Pueblo Canyon as part of the Environmental Restoration (ER) Project for Operable Unit (OU) 1049, the canyons OU at Los Alamos National Laboratory (the Laboratory). The investigation includes evaluation of the effects of past and current releases into tributaries to the canyons; past releases into Acid Canyon, a tributary to Pueblo Canyon; and past and current releases into DP Canyon, a tributary to Los Alamos Canyon.

This is one of eight task/site work plans that will describe ER work for all the canyons that were part of historical operations at the Laboratory or now cross property controlled by the Laboratory. This task/site work plan meets the requirements of the Environmental Protection Agency (EPA) under the Resource Conservation and Recovery Act (RCRA), as amended by the Hazardous and Solid Waste Amendments (HSWA), and related Department of Energy (DOE) orders. Also, it describes the field sampling plans to meet those requirements and other commitments to external stakeholders. This introductory chapter gives a brief summary of regulatory requirements, describes Los Alamos Canyon and Pueblo Canyon, and explains the structure of this task/site work plan.

1.2 Public Participation

Regulations issued pursuant to HSWA address public participation in the corrective action process. In addition, through the Community Involvement and Outreach Office, the Laboratory is providing a variety of opportunities for public participation. These opportunities include meetings held as needed to disseminate information, to discuss significant milestones, and to solicit informal public review of this and the other draft work plans. The ER Project staff will also discuss this work plan at meetings of community organizations. The Community Involvement and Outreach Office also distributes meeting notices and updates the ER Project mailing list, prepares information sheets summarizing completed and future activities, and provides public access to plans, reports, and other ER Project documents. These materials are available for public review between 8:00 a.m. and 5:00 p.m. on Laboratory business days in the Laboratory Community Reading Room at 1350 Central Avenue, Suite 101 in Los Alamos; at the public libraries in Española, Los Alamos, and Santa Fe; and at the San Ildefonso Pueblo Governor's Office.

1.3 Regulatory Requirements Governing the Work Plan

In March 1987 DOE established a national ER Program to address environmental cleanup requirements at its Defense Program facilities nationwide. DOE and the University of California (UC), which operates the Laboratory for DOE, are jointly responsible for implementing the DOE ER Program at the Laboratory. The Laboratory's ER Project is the organization responsible for that implementation, which must satisfy a number of regulatory mandates and meet internal requirements of DOE and the Laboratory.

1.3.1 Resource Conservation and Recovery Act Requirements

The Laboratory's operating permit under RCRA sets forth requirements that are implemented by the ER Project. The RCRA Part B Operating Permit, issued by EPA, and its

HSWA Module VIII (hereafter referred to as the HSWA Module) give specific requirements affecting the conduct of the ER Project (EPA 1990, 1585). The HSWA Module became effective May 23, 1990, and is updated to reflect changes in the status of the operating permit. The most recent update became effective May 19, 1994.

The HSWA Module requires the Laboratory to prepare an installation-wide work plan that contains the programmatic elements of a RCRA facility investigation (RFI) work plan. The Laboratory-wide Installation Work Plan (IWP) (LANL 1995, 49822), which DOE/UC uses to guide and manage the ER Project, meets this requirement. The most recent revision of the IWP was submitted to EPA in February 1995. The IWP describes the DOE ER Program and its history at the Laboratory, describes current Laboratory conditions, identifies the Laboratory's potential release sites (PRSs) and their aggregation into field units, and presents the management and technical approaches for meeting the requirements of the HSWA Module. Relevant information presented in the IWP will be cited but not repeated in this task/site work plan.

The HSWA Module also requires the Laboratory to prepare RFI work plans for specific PRS-based investigations and task/site work plans for the affected media of the canyon systems. Generic guidance for preparing RFI work plans are found in the proposed regulations of Subpart S of 40 CFR 264 (EPA 1990, 31277); specific requirements are described in the HSWA Module. EPA has provided specific guidance in Volume I of the interim final RFI guidance (EPA 1989, 8794). The HSWA Module sets out the scope of the RFI work plan, establishes the expected correspondence between the RFI tasks identified in EPA guidance documents (EPA 1989, 8794) and the equivalent ER Program tasks, and specifies the requirements to be fulfilled. These considerations are summarized in Table 1-1, which has been adapted from the HSWA Module, Section Q. Table 1-1 lists the major RFI tasks and subtasks defined by EPA and shows where in the IWP and in this task/site work plan the required subtasks are discussed.

This task/site work plan fulfills part of the requirements of the HSWA Module, Section I.5: Task/Site Work Plan, Canyon Systems (EPA 1990, 1585). That section calls for one or more task/site work plans for studies to evaluate the potential impact of contaminants from solid waste management units (SWMUs) on the 15 (the Laboratory currently recognizes 19) major drainage areas or canyon systems at the Laboratory. It states that

> The Permittee shall submit one or more Task/Site Workplans for studies to evaluate the 15 major drainage areas or Canyon systems at the facility. These studies must address each system as an integrated unit and evaluate them for potential impacts of contaminants from SWMUs [Solid Waste Management Units]. The plans must address the existence of contamination and the potential for movement or transport to or within Canyon watersheds and interactions with the alluvial aquifers and the main aquifer. The studies shall evaluate the potential for offsite exposure through these pathways including the ground water and possible impacts on the Rio Grande.

This task/site work plan addresses these concerns for Los Alamos Canyon and Pueblo Canyon. Task/site work plans for the remaining canyons and a core plan will be prepared later, with input from EPA, the New Mexico Environment Department, DOE, and the Indian Pueblos of San Ildefonso, Santa Clara, Cochiti, and Jemez, which have formal accords and agreements with DOE and the Laboratory. These four Indian Pueblos are referred to as the "Accord Pueblos" in this work plan.

TABLE 1-1

LOCATION OF DISCUSSIONS OF HSWA MODULE REQUIREMENTS

HSWA Module Requirements	IWP (1995)	Location in Task/Site Work Plan
RFI Task I: Description of Current Conditions		
Facility Background	Chapter 2	Chapters 2 and 3
Nature and Extent of Contamination	Appendices A and B	Chapters 2, 3, and 7
RFI Task II: RFI Workplan		
Data Collection Quality Assurance Plan	Chapter 4	Annex II
Data Management Plan	Chapter 5	Annex IV
Health and Safety Plan	Chapter 6	Annex III
Community Relations Plan (Public Involvement Plan)	Chapter 7	Annex V
RFI Task III: Facility Investigation		
Environmental Setting		Chapter 3
Source Characterization		Chapters 2, 3, 4, and 7
Contamination Characterization		Chapters 2, 3, 4, and 7
Potential Receptor Identification		Chapter 6
RFI Task IV: Investigative Analysis		
Data Analysis		Chapter 6
Protection Standards		Chapter 6
RFI Task V: Reports		
Preliminary and Workplan Progress Draft and Final	The IWP with annual update	Task/Site Work Plan

Sites to be investigated and evaluated by the ER Project are collectively referred to as PRSs. A PRS may be a SWMU or an area of concern (AOC). A SWMU is defined in the HSWA Module as "any discernible unit at which solid wastes have been placed at any time, irrespective of whether the unit was intended for the management of solid or hazardous waste. Such units include any area at or around a facility at which solid wastes have been routinely and systematically released." Radioactive materials and some hazardous substances (as defined under the Comprehensive Environmental Response, Compensation, and Liability Act [CERCLA] and listed in 40 CFR 302 [EPA 1990, 0093]) are not included in the RCRA definitions of solid waste, hazardous waste, and hazardous constituents and are not subject to the provisions of the HSWA Module. However, the IWP (LANL 1995, 49822) indicates that the ER Project will address the potential release of radioactive and hazardous substances not regulated by RCRA. Sites that potentially contain hazardous substances but not hazardous wastes or hazardous constituents as defined by RCRA are called AOCs. The different geologic media of the canyons system—sediments, aquifers, and parent material—are categorized as AOCs.

The investigation of Los Alamos Canyon and Pueblo Canyon is required by the HSWA Module to ensure that the transport of contaminants released into the canyons will not adversely affect human health or the environment either on or off Laboratory property.

1.3.2 CERCLA, NEPA, and DOE Orders

Sections 1.2.1.3 and 1.2.1.4 of the IWP (LANL 1995, 49822) discuss the integration of the RCRA-based ER Project with applicable requirements of CERCLA and the National Environmental Policy Act (NEPA). Additionally, the ER Project will comply with other applicable federal acts, state statutes, and DOE orders and policy statements. Chapter 5 of this task/site work plan discusses further the regulatory basis and requirements for investigation of the canyons system and the implementation of the technical approach for addressing those requirements.

DOE orders applicable to the ER Project are identified in Annex I (Program Management Plan) of the 1993 version of the IWP (LANL 1993, 26077) (all annexes to the 1993 IWP are current with the 1995 IWP update). Compliance with the requirements of these orders is integral to all Laboratory operations and is ensured through the documented policies, planning, auditing, and work review procedures of the Laboratory.

1.3.3 Assessment of Natural Resource Damage

CERCLA Section 120 extends the liability for natural resource damage to federal facilities, which includes the Laboratory. The first part of a natural resource damage assessment is a preassessment screen as described at 43 CFR 11 (Department of the Interior 1993, 43390). The preassessment screen is used to determine whether a full natural resource damage assessment is appropriate and integrated with the CERCLA ecological assessment process for the canyons. RCRA Subpart S also requires that releases from SWMUs not pose a threat to the environment; specific methods to evaluate natural resource damage are currently being discussed by the ER Project and EPA. Information gathered during ecological impact assessment activities in canyons investigations will create a baseline that will be used to assess the damage to natural resources. Any modifications of the general procedure will be described in investigation reports. This procedure is consistent with DOE guidance (DOE 1991, 8641). Natural resource damage assessment is not a direct regulatory requirement under this work plan. If ecological risk assessments are necessary, as required under RCRA and as performed under the CERCLA process, then the environmental impacts or damages will be evaluated through these existing programs. The need to integrate these requirements with natural resource damage assessments will be determined on a site-specific basis by the lead trustee (DOE).

1.4 Environmental Restoration Project Guidance

The IWP (LANL 1995, 49822) specifies the ER Project's technical and managerial approaches for compliance with the HSWA Module and other regulatory obligations.

As illustrated in Table 1-1, the IWP has been prepared and is updated annually in accordance with the requirements of the HSWA Module. The IWP provides overall direction to the ER Project; specific guidance on the preparation of work plans for RFIs conducted under the project; detailed description of the facility (the Laboratory); and programmatic-level plans for data collection quality assurance, data management, health and safety, and public involvement.

Each work plan for PRS-based RFIs deals with the investigation of a specific operable unit and provides (with the guidance of the IWP and in accordance with the requirements of the HSWA Module) detail on the specific operable unit with respect to environmental setting, source and contaminant characterization, and identification of potential receptors. Each PRS-based RFI work plan also details the technical approach to investigation of the operable unit using the general approach of the IWP for guidance and includes operable unit-specific plans for data collection quality assurance, data management, health and safety, and public involvement.

Each PRS-based RFI work plan uses the IWP for both guidance and as a referenceable source of information regarding the history of the Laboratory and its operations. Accordingly, reference is made in the canyons task/site work plans (which are focussed on affected media and AOCs) and in every PRS-based RFI work plan to existing text in the IWP that describes programmatic-level issues and general facility history and status.

The ER Project Quality Assurance Project Plan (QAPP, formerly referred to as the QAPjP) (see Chapter 4 of the IWP [LANL 1995, 49822]) discusses the procedures and methods employed to ensure that environmental data of the desired quality are available for the decision-making process. The QAPP addresses quality objectives for measurement data, as determined by the data quality objectives process, and the sampling and analysis procedures to be implemented to achieve the quality objectives. It discusses the quality control (QC) requirements for the data collection process, including the need to define acceptance criteria for certain QC procedures and samples. It outlines the procedures for quality assurance assessments and response actions. The QAPP also presents the requirements for personnel training; sample handling and custody; and data management, review, validation, and verification. In addition to requirements for measurement data, the QAPP also addresses requirements for using archived and nonmeasurement data. Wherever possible, the appropriate ER Project administrative and quality procedures and standard operating procedures to be used in conducting the investigation are cited in applicable sections of Chapter 4 of the IWP.

1.5 Description of the Canyons Operable Unit

1.5.1 General Setting

Los Alamos County is situated on the Pajarito Plateau, a region 5 to 6 miles wide and 6500 to 7600 ft above sea level, between the 10,500-ft-high Jemez Mountains to the west and the 5500-ft-high Rio Grande Valley to the east (Figure 1-1). The plateau is cut by many deep canyons that run generally west-northwest to east-southeast from the mountains to the Rio Grande. Developments within Los Alamos County include the Los Alamos and White Rock residential areas and the Laboratory technical areas. The Los Alamos townsite and most of the Laboratory technical areas occupy relatively flat mesa tops situated between the canyons. A more in-depth description of the regional geologic and hydrologic setting is found in Chapter 3 of this task/site work plan and in Chapter 2 of the IWP (LANL 1995, 49822).

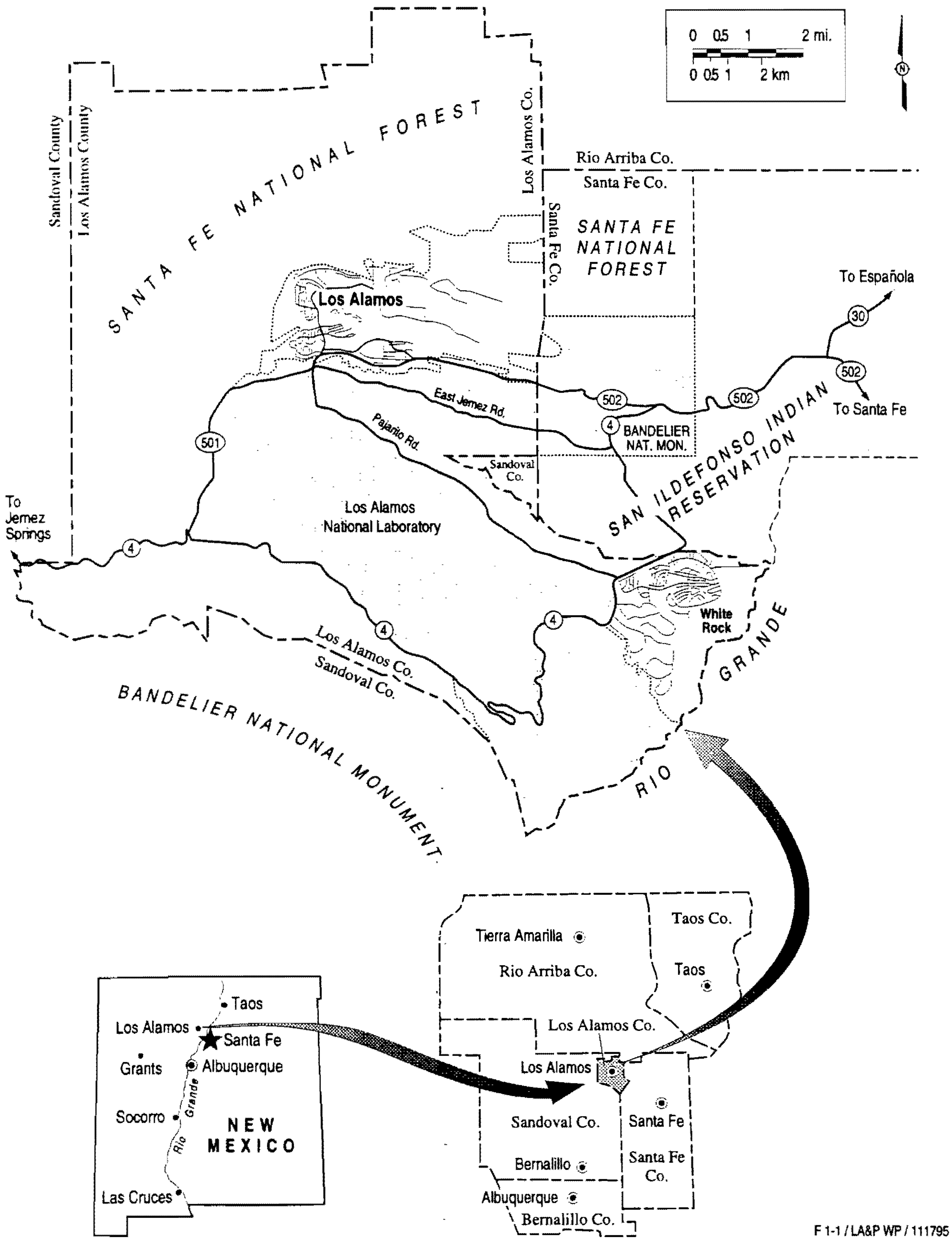


Figure 1-1. Location map of Los Alamos National Laboratory.

Nineteen significant canyon systems drain the surface water from the Laboratory sites located on the Pajarito Plateau (Figure 1-2). Most of the reaches of these canyons within the Laboratory boundaries are ephemeral. Runoff flows naturally but briefly in response to precipitation events, mostly summer thunderstorms and spring snowmelt. During these events the runoff drains rapidly from the mesa tops into these deep canyon systems. Essentially all the surface water discharge that leaves the Laboratory site moves through these canyons and occasionally reaches the Rio Grande. From there the water flows downstream to Cochiti Lake.

Carried by storm event runoff, contamination from mesa-top PRSs has the potential to enter surface water drainages. Runoff-derived contamination entering these canyon drainages is mainly bound to the sediments; more soluble contaminants tend to remain in solution (see Chapter 3 of this task/site work plan). The rate of sediment (affected media) transport by storm events is governed by the energy or carrying power of the specific event. It is expected that given sufficient storm events, over time these sediments will eventually be moved across the Laboratory boundary to the Rio Grande (LANL 1993, 26077).

Environmental monitoring for chemical and radiochemical quality of surface water, ground water, and sediments began with the United States Geological Survey in 1945 (Purtymun 1964, 11822; Purtymun 1975, 11787; Purtymun and Kunkler 1967, 11782; Purtymun 1967, 8987). To date, the Laboratory has continued these investigations. Groups from the Laboratory's Environment, Safety, and Health Division perform environmental monitoring across the Laboratory site and in nearby areas (Environmental Protection Group 1993, 23249).

This task/site work plan addresses potential contaminant contributions from SWMUs (PRSs) located adjacent to Los Alamos Canyon and Pueblo Canyon, which may have resulted in releases into these two canyons. Operable units under investigation and the technical areas (TAs) included in them that may affect (or may have affected) Los Alamos Canyon and Pueblo Canyon include OU 1078 (former TA-1), OU 1079 (former TA-45), OU 1098 (TAs -2 and -41), OU 1100 (TA-53), OU 1106 (TA-21), OU 1111 (TA-62), OU 1114 (TA-3), and OU 1136 (TA-43) (Figure 1-2).

1.5.2 Task/Site Work Plans

The current scheme is to consolidate the studies of these 19 canyon systems into 8 task/site work plans (Table 1-2) and a core document. This consolidation is based on geographic proximity, similarity of discharges and potential resulting contamination, and economic efficiency.

The core task/site work plan is intended to be a tiered document that provides text common to all task/site work plans for the introduction, background (historical) information, environmental setting, conceptual model, technical approach, and risk assessment chapters. The core document is in effect the parent document for the eight task/site work plans. The individual task/site work plans will provide detail specific to the canyon(s) being investigated in the environmental setting and the canyon-specific sampling and analysis plans that are appended to the core document.

Because of scheduling constraints, this Los Alamos Canyon and Pueblo Canyon task/site work plan was developed ahead of the core document. This task/site work plan contains all the sections found in an RFI work plan. The majority of the text in this task/site work plan and the associated knowledge will be used to create the core document. Future canyon-specific task/site work plans will contain only a brief introduction,

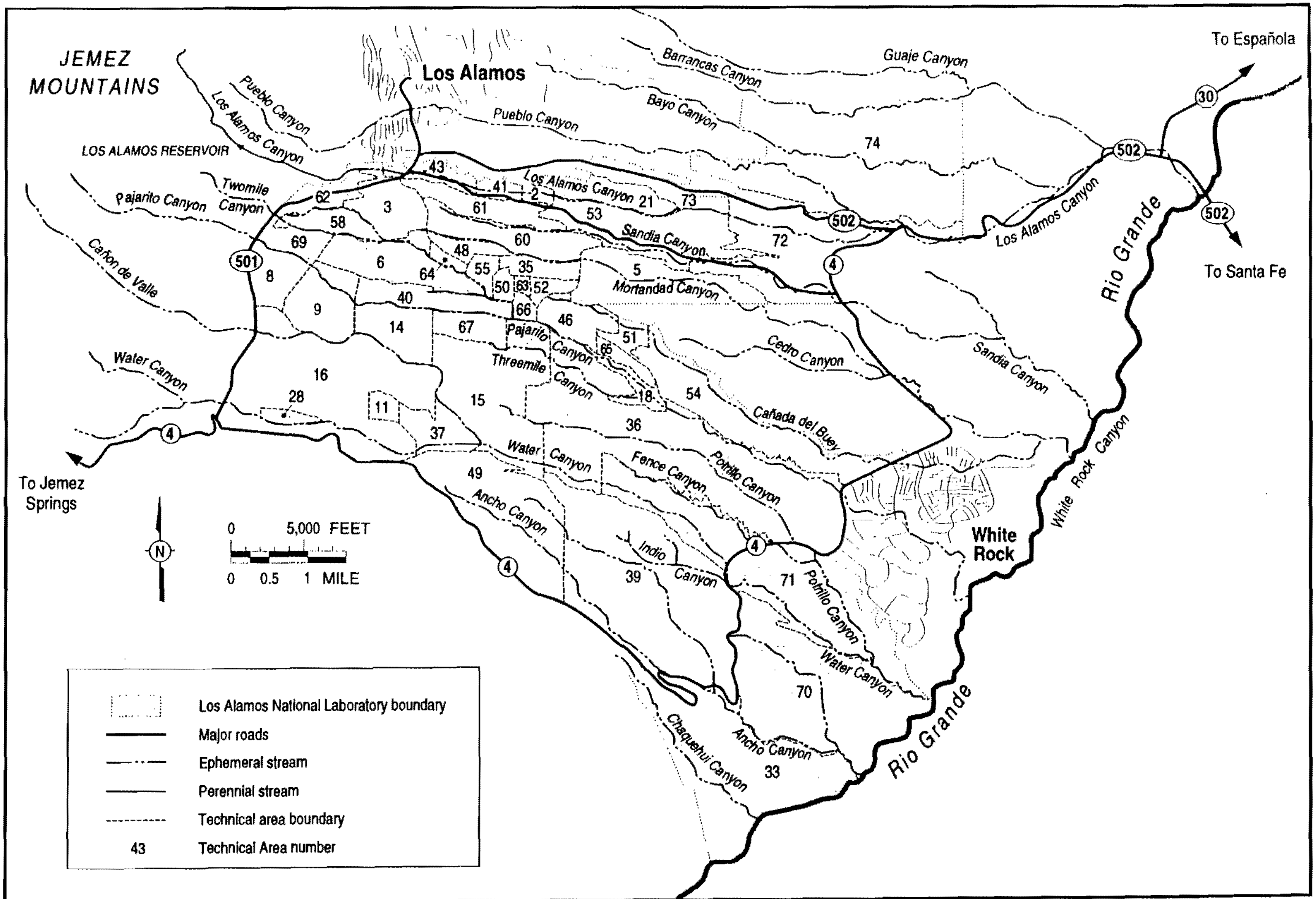


Figure 1-2. Major surface water drainages in the Los Alamos area.

TABLE 1-2

OPERABLE UNIT 1049
CANYONS AND ASSOCIATED OPERABLE UNITS AND TECHNICAL AREAS

Canyon Groups	Associated Technical Areas	Associated Operable Units	Task/Site Work Plan Date[a]
Core Document	N/A[b]	N/A	September 1996
Group 1			November 1995
Los Alamos/DP	Former TA[c]: 1 Current TAs: 0, 2, 3, 21, 41, 43, 53, 62, 72, 73, 74	1071, 1078, 1098, 1100, 1106, 1111, 1114, 1136	
Pueblo/Acid	Former TAs: 1, 45 Current TAs: 0, 72, 73, 74	1071, 1078, 1079, 1100, 1106	
Group 2	Current TAs:		September 1997
Mortandad and Sediment Traps	3, 4, 5, 35, 42, 48, 50, 55, 59	1114, 1129, 1147	
Group 3	Current TAs:		November 1998
Pajarito	6, 7, 8, 9, 14, 18, 22, 23, 36, 40, 46, 50, 51, 54, 65, 66, 67, 69	1093, 1111, 1129, 1130, 1140, 1157	
Twomile	3, 55, 58, 59, 64	1111, 1114, 1129	
Threemile	14, 15, 18, 36, 67	1085, 1086, 1093, 1130	
Group 4	Current TAs:		October 1999
Cañada del Buey	5, 18, 46, 51, 52, 54	1129, 1140, 1148	
Sandia	3, 53, 60, 61, 72	1100, 1114	
Group 5	Current TAs:		April 2000
Guaje	74, residences	1071	
Bayo	0, 10, 74, residences	1071, 1079	
Barrancas	74, residences	1071	
Rendija	0, 74, residences	1071	
Group 6	Current TAs:		October 2001
Water	11, 16, 28, 36, 37, 49, 68, 71	1082, 1086, 1122, 1130, 1132, 1144	
Cañon de Valle	9, 11, 14, 15, 16, 37, 67	1082, 1085, 1086, 1157	
Group 7	Current TAs:		May 2002
Ancho	33, 39, 49	1122, 1132, 1144	
Indio	39, 49, 70	1132, 1144	
Chaquehui	33	1122	
Group 8	Current TAs:		December 2003
Potrillo	14, 15, 36, 67	1085, 1086, 1130	
Fence	36, 68, 70, 71	1122, 1130	

a. Based on budgets
b. N/A = not applicable
c. TA = Technical Area

a short discussion of the canyon's history and environmental setting, and a comprehensive sampling and analysis plan.

1.6 Organization of This Task/Site Work Plan

Following this introductory chapter, Chapter 2 provides background information on Los Alamos Canyon and Pueblo Canyon, including a description and history of the area and of the potential sources of contamination; Chapter 3 describes the environmental setting; Chapter 4 contains the conceptual model of contaminant transport within the two canyons; Chapter 5 describes the technical approach to the investigation and numerical models that may be used to evaluate transport and assess current and potential future exposure and impact; Chapter 6 describes human health and ecological risk and impact assessment considerations; and Chapter 7 contains the field investigation objectives and sampling and analysis plans based on data describing the known nature and extent of contamination.

A list of acronyms precedes Chapter 1. Definitions of unfamiliar terms can be found in the IWP (LANL 1993, 26078) and in the *Glossary of Geology* (Bates and Jackson 1987, 50287).

1.7 Units of Measurement

The units of measurement used in this document are expressed in both English and metric units, depending on which unit is commonly used in the field being discussed. For example, English units are used in text pertaining to engineering, and metric units are often used in discussions of geology, geochemistry, and hydrology. When information is derived from some other published report, the units are consistent with those used in that report.

References for Chapter 1

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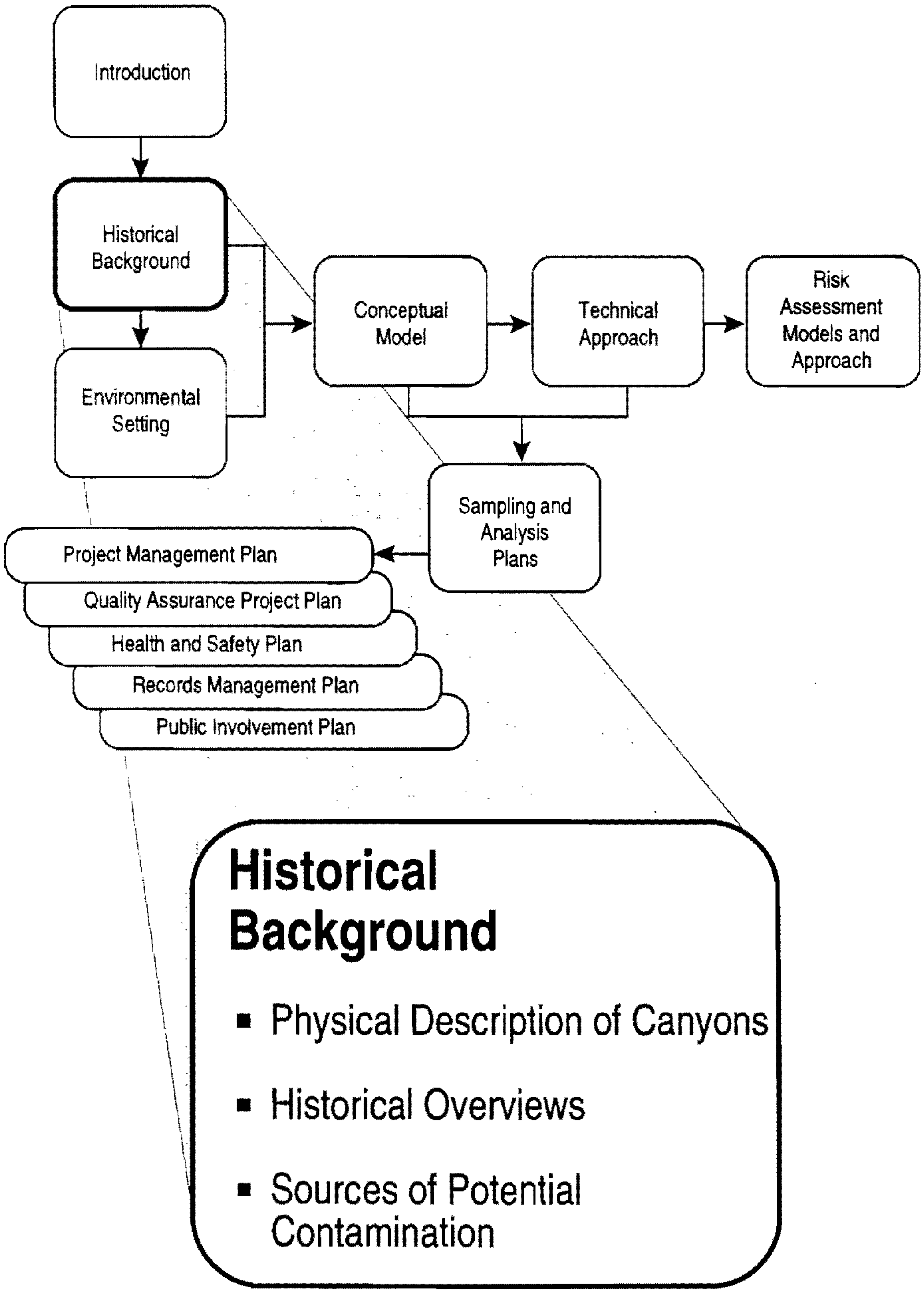
Chapter 2


Introduction
Historical Background
Environmental Setting
Conceptual Model
Technical Approach
Risk Assessment Models and Approach
Sampling and Analysis Plans
Project Management Plan
Quality Assurance Project Plan
Health and Safety Plan
Records Management Plan
Public Involvement Plan
Historical Background
Physical Description of Canyons
Historical Overviews
Sources of Potential Contamination

2.0 HISTORICAL BACKGROUND

This chapter describes the historical uses of the Los Alamos Canyon and Pueblo Canyon systems and adjacent areas, with an emphasis on identifying the sources and nature of potential contamination. This chapter also discusses the known contamination that has been released into the canyons from past and present operations at Los Alamos National Laboratory (the Laboratory).

2.1 Description

Los Alamos Canyon and Pueblo Canyon are part of Field Unit 4 in the Laboratory Environmental Restoration Project. Figure 2-1 shows the locations of Los Alamos Canyon and Pueblo Canyon with respect to the Laboratory, Los Alamos County, and the surrounding area. Figure 2-2 shows the Laboratory technical areas crossed by the two canyons. Figure A-1 in Appendix A of this work plan shows morphologic features of the two canyons.

Los Alamos Canyon originates on US Forest Service land in the Jemez Mountains and extends eastward across the north central part of the Laboratory. It enters San Ildefonso Pueblo land a short distance downstream of its confluence with Pueblo Canyon. Lower Los Alamos Canyon crosses San Ildefonso Pueblo land and discharges to the Rio Grande. Pueblo Canyon also originates on US Forest Service land. It extends across northern Los Alamos County and into the northeastern part of the Laboratory, where it joins Los Alamos Canyon.

Los Alamos Canyon passes through or is adjacent to Laboratory Technical Areas (TAs) -2, -21, -41, -43, -62, -72, and -73; Pueblo Canyon passes through or is adjacent to TA-72 and TA-74 (Figure 2-2).

This work plan addresses potential contaminant contributions from solid waste management units (SWMUs) (potential release sites [PRSs]) located adjacent to Los Alamos Canyon and Pueblo Canyon, which may have resulted in releases into these two canyons. Operable units (OUs) under investigation and the technical areas included in them, which contain (or have contained) SWMUs and/or PRSs and, therefore may affect (or may have affected) Los Alamos Canyon and Pueblo Canyon include the following: OU 1078 (former TA-1); OU 1079 (former TA-45); OU 1098 (TA-2 and TA-41); OU 1100 (TA-53); OU 1106 (TA-21); OU 1111 (TA-62); and OU 1136 (TA-43). See Figure 1-2 in Chapter 1 of this work plan.

Los Alamos Canyon is 600 to 2500 ft wide at the top and varies in depth from 360 to 800 ft; Pueblo Canyon is 500 to 3000 ft wide at the top and varies in depth from 200 to 500 ft. The canyon floors are relatively flat, are filled with alluvium and colluvial soils eroded from the canyon walls, and vary in width from a few tens of feet to 2000 ft. The sides of these canyons are steep and rocky and are partially covered by trees, particularly on the south sides (the north-facing slopes).

Small streams characterized by extremely variable flow are located on the floors of both canyons. Los Alamos Reservoir, situated west of the Laboratory boundary, provides a relatively constant source of surface water to the stream in upper Los Alamos Canyon except during late spring and early summer (after the snow has melted and before summer storms refill the reservoir). No comparable source of water to sustain perennial flow is present in upper Pueblo Canyon. The Los Alamos County sewage treatment plant located between Bayo Canyon and Pueblo Canyon (see Figure 1-2 in Chapter 1 and Figure A-2 in Appendix A of this work plan) releases a substantial flow of treated water into the lower half of Pueblo Canyon, which feeds lower Los Alamos Canyon.

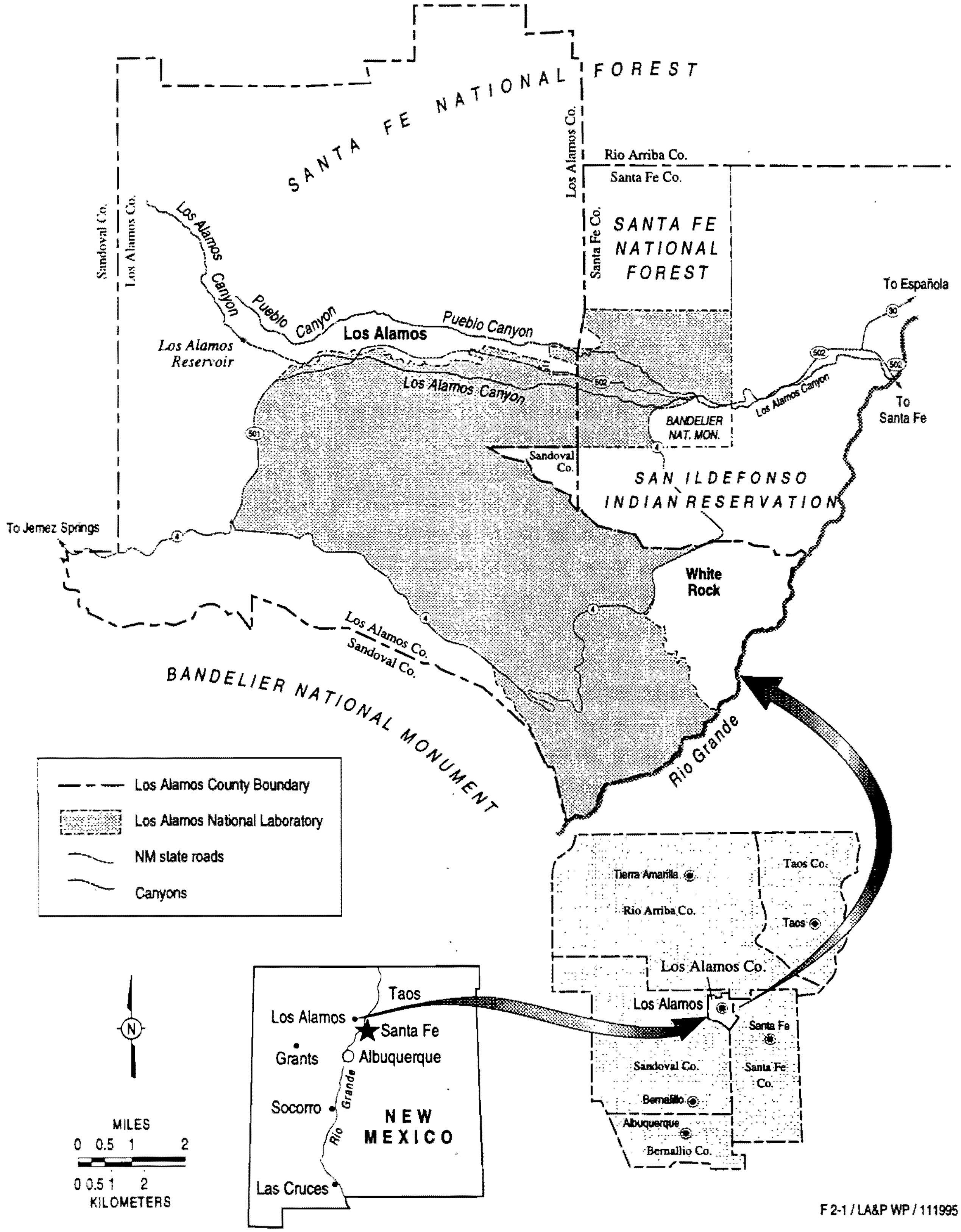


Figure 2-1. Location of Los Alamos Canyon and Pueblo Canyon.

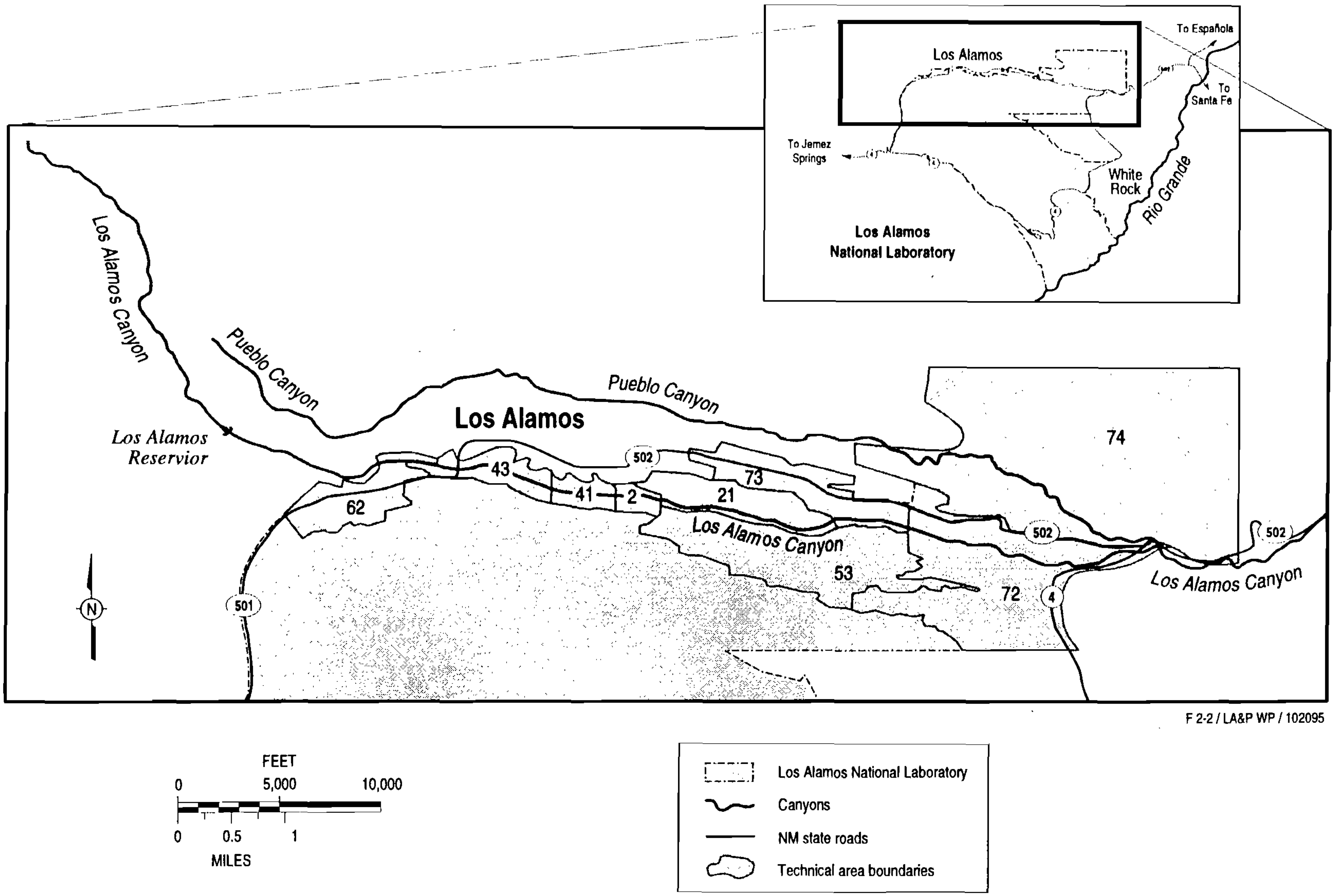


Figure 2-2. Laboratory technical areas adjacent to Los Alamos Canyon and Pueblo Canyon.

2.2 History

2.2.1 Prehistoric Use by American Indians

This section summarizes the cultural resources for the central portion of the Pajarito Plateau and the archaeological survey of those portions of Los Alamos Canyon and Pueblo Canyon that are located on Laboratory property. The sections of Los Alamos Canyon that are located on San Ildefonso Pueblo land have not been surveyed; therefore, they are not included in this summary.

2.2.1.1 Paleo-Indian Culture

The Paleo-Indian Culture (10,000 B.C. to 4000 B.C.) is characterized by small groups of big game hunters who might have followed herds up and down the Rio Grande and made trips to the Pajarito Plateau to procure obsidian and other materials. This period is represented on Laboratory property by occasional surface finds of diagnostic projectile points (dart and/or spear points) made from both local obsidian and exotic (excellent quality, nonlocal) chert.

A portion of one Paleo-Indian projectile point was located in Pueblo Canyon. It probably was lost or discarded during a hunting expedition. Because this projectile point was observed at a multicomponent site (more than one cultural affiliation), it might have been subsequently curated by later inhabitants of the canyon.

Paleo-Indian sites in the Southwest are often revealed by severe erosion. Paleo-Indian sites could have existed in Los Alamos Canyon and Pueblo Canyon, but the sites either have been buried under the sediment that has built up on the canyon floor or have been eroded away.

2.2.1.2 Archaic Culture

The Archaic Culture (4000 B.C. to A.D. 600) is characterized by small groups of people who might have used the Pajarito Plateau for lithic (stone) resource procurement, hunting expeditions, and seasonal exploitation of certain wild plants. This period is represented on Laboratory property by scatters of lithic tools, chipping debris (waste chips produced during stone tool manufacture), and diagnostic projectile points. Little research has been conducted for this period, but buried habitation or burial sites might also be present on Laboratory property.

Large Archaic lithic sites (sites with chipped stone remains) have been found on the mesa tops near Los Alamos Canyon and Pueblo Canyon. Also, Archaic projectile points and point fragments are occasionally found in Los Alamos Canyon and Pueblo Canyon. The projectile points indicate that these canyons were used during the Archaic Culture. The Archaic populations that occupied the mesa-top sites probably used Los Alamos Canyon and Pueblo Canyon for gathering, hunting, and small-scale horticulture (gardening). Four multicomponent sites with Archaic cultural remains have been documented near the Los Alamos Canyon and Pueblo Canyon floors.

2.2.1.3 Prehistoric Indian Pueblo Culture

The prehistoric Indian Pueblo culture, which succeeded the Archaic culture, has traditionally been referred to by archeologists as the Anasazi culture. However, consultation with representatives of the present Indian Pueblos has indicated that this term is not currently applied by the American Indian community to the people they consider their ancestors. The representatives expressed a preference for the term "prehistoric Indian Pueblo culture," and this term is used here in recognition of that preference.

Developmental Period

The Early Developmental Period (A.D. 600 to A.D. 900) is characterized by settled hunter-gatherers living in semi-subterranean pit houses. Some possible locations of pit houses and associated artifacts have been identified on Laboratory property, but identification is tenuous.

The Late Developmental Period (A.D. 900 to A.D. 1100) is characterized by small groups of maize horticulturists who still relied to a great extent on gathering wild plants. Structures at these sites are typically small, adobe, sometimes crude masonry pueblos. Very few sites from this period are located on Laboratory property.

No Developmental Period sites have been recorded in Los Alamos Canyon or Pueblo Canyon.

Coalition Period

The Coalition Period (A.D. 1100 to A.D. 1325) is characterized by maize horticulturists. Early sites are rectangular adobe and masonry structures. Later sites are large masonry-enclosed plaza roomblocks with more than 100 rooms. Most of the ruins recorded on Laboratory property date to this period.

Los Alamos Canyon and Pueblo Canyon contain more sites from the Coalition Period than from any other period. These sites include small to large pueblos (habitation sites), field houses (one- to two-room storage structures), rock shelters (using rock overhangs), cavates (small rooms carved into the canyon cliff faces), garden plots, and artifact scatters. Terraced garden plots, which are often located near pueblos, indicate that at least portions of the canyon floors were used for growing crops.

The numerous Coalition Period sites located in the vicinity of Los Alamos Canyon and Pueblo Canyon indicate that these areas were used extensively during this period. Thirty-eight Coalition Period sites have been documented near the Los Alamos Canyon and Pueblo Canyon floors. Twelve sites and some of the artifacts from another site are transitional between the Coalition and Classic Periods or have components from both periods.

Classic Period

The Classic Period (A.D. 1325 to A.D. 1600) is characterized by intensive maize horticulturists. Prehistoric Indian Pueblo settlements on the Pajarito Plateau are aggregated into three population clusters with outlying one- to two-room field houses. The central site cluster consists of four temporally overlapping sites: Navawi, Otowi, Tsankawi, and Tshirege. Otowi and Tshirege are located on Laboratory property. These ruins were inhabited by the ancestors of the Tewa speakers now living at San Ildefonso Pueblo.

Field houses and a series of garden plots associated with Otowi, which is located in Pueblo Canyon, indicate that the canyon floor was intensely farmed during this period. The Classic Period is surprisingly poorly represented in Los Alamos Canyon.

Undoubtedly, Los Alamos Canyon was used for hunting, gathering, and probably horticulture during the Classic Period; however, little evidence of habitation exists in Los Alamos Canyon compared with the substantial evidence of habitation in Pueblo Canyon. Eleven Classic Period sites and a component of another have been documented near the Los Alamos Canyon and Pueblo Canyon floors.

In addition to the period-affiliated sites noted above, the survey of the canyon floors located six single-component sites and two multicomponent sites with unknown prehistoric Indian Pueblo culture affiliations.

Three Historic Period sites and two multicomponent sites with Historic Period affiliations were documented during this archaeological survey.

2.2.2 Historic Use

The American Indians at San Ildefonso Pueblo claim much of the Pajarito Plateau as their ancestral land and, in fact, have an unsettled American Indian Original Land Claim on file with the US government. Much of the Indian Pueblo history is not written but is handed down orally by the elders through traditional stories. Many of the elders speak of sites on the Pajarito Plateau that are called by traditional names, such as Navawi and Tshirege. The ancient people (or "old ones" as they are sometimes called) came from a lake to the north called Sipophe. These people migrated from the lake to Mesa Verde (in southern Colorado), then to Chaco Canyon (in northwestern New Mexico), and finally into what is now Bandelier National Monument. They used the mesas and the canyons for farming, hunting, gathering food (such as piñon nuts and acorns), and gathering plants for religious and ceremonial purposes (Hewett 1953, 44150). The Keresaw-speaking as well as other Pueblo Indians have ancestral and cultural links to the area.

Today, the Indian Pueblo people use Los Alamos Canyon and Pueblo Canyon as their ancestors did. They use the nearby mesas for hunting and grazing; they make pilgrimages to shrines and sacred sites; they collect plants from the canyons for religious, ceremonial, economic, and medicinal use. When the piñon nuts are abundant, the people gather the crop for consumption. They use some plants to dye wool.

During the westward expansion by pioneers of European origin, much of the Pajarito Plateau, including portions of Los Alamos Canyon, was part of the Ramon Vigil land grant from the King of Spain. In the late 1800s and early 1900s the Pajarito Plateau, including portions of Los Alamos Mesa and what is now called DP Mesa, was used for ranching, farming, and timber production.

From the mid 1840s to the late 1880s the Pajarito Plateau was used mainly as an access route to the Jemez Mountains where the cattle, mining, and lumber industries were expanding. Cattle were later grazed on the plateau itself beginning in the late 1880s. From 1897 until 1903, the Ramon Vigil land grant was used for timber harvest. During that time, the Pajarito Plateau and the newly constructed town of Buckman (on the Rio Grande below the Pajarito Plateau) were connected by railroad. In 1906 the Ramon Vigil land grant was bought by the Ramon Land and Lumber Co. At that time, a sawmill, called the Phillips Mill, was built in Pajarito Canyon.

The land grant was bought in 1914 by Ashley Pond and some Detroit executives who hoped to turn the area into a recreational ranch called The Pajarito Club. The venture failed, and subsequently the grant was purchased by Frank Bond and used as a line camp. In 1917 the Brook Ranch, situated on Los Alamos Mesa, was purchased by

Ashley Pond who established the Los Alamos Ranch School (Foxx and Tierney 1984, 5950). Dr. J. Robert Oppenheimer and General Leslie R. Groves (commanding officer of the Manhattan Project) decided that the Pajarito Plateau was ideal for the final research, design, and assembly facility for the Manhattan Project. Condemnation proceedings for the Los Alamos Ranch School began in November 1942; in February 1943 it closed (Graf 1993, 23251).

2.2.3 Los Alamos National Laboratory Operational Use

Extensive archival searches, examination of aerial photographs, and interviews with many former Laboratory employees have established that the Laboratory has used the land in Los Alamos Canyon and Pueblo Canyon continuously since the mid-1940s.

Use of the canyons system at the Laboratory began at a small branch of Pueblo Canyon known as Acid Canyon where radioactive liquid wastes from Manhattan Engineer District/Atomic Energy Commission operations were discharged between late 1943 or early 1944 and June 1964. Initially, wastes were untreated. A treatment plant (at former TA-45) on the rim of Acid Canyon was constructed and began operation in April 1951 providing chemical treatment (which was developmental for the times) for reduction of radionuclide concentrations. The treatment plant was decommissioned in late 1966, and decontamination work at the site and in Acid Canyon began in 1967. By June 1967, the treatment plant and Acid Canyon were deemed sufficiently free of contamination to be released from Atomic Energy Commission control without restrictions. The treatment plant site and a portion of Pueblo Canyon were transferred to Los Alamos County by quitclaim deed on July 1, 1967 (LANL 1981, 6059). Additional decontamination work was performed in 1982 (see Section 2.5.4 for more details).

Los Alamos Canyon and Pueblo Canyon continue to receive discharges of treated wastewater, both industrial and domestic, to the present day. The history of waste treatment and discharges and the potential contamination resulting from them are discussed in greater detail in this chapter.

These and other uses of the canyons and adjacent mesas, and potential resulting contamination, are discussed further in Sections 2.4 and 2.5.

2.2.4 Current Recreational Use

Los Alamos Canyon is a popular recreational area for local residents. Camping and picnic areas are located near Los Alamos Reservoir, and the reservoir itself is used for fishing and some swimming. The Los Alamos County Ice Rink is located in TA-62 west of TA-43.

In addition to joggers, hikers, and bird watchers who frequent the area, Pueblo Canyon is often visited by those people who are interested in the numerous archeological sites within the canyon.

2.3 Environmental Monitoring

The Environmental Surveillance Group (ESG) at the Laboratory has conducted environmental monitoring in Los Alamos Canyon and Pueblo Canyon since 1966. Results of this monitoring are reported in the Laboratory's annual environmental surveillance reports and other special reports (ESG 1990, 6995; Elder and Knoell 1986, 6670; Montoya 1991, 6997). These reports provide the basis for the following discussion.

During the past several decades, data have been collected from seven alluvial monitoring wells located in Los Alamos Canyon: LAO-C, LAO-1, LAO-2, LAO-3, LAO-4, LAO-4.5, and LAO-5. The results, especially during the last decade, confirm contamination of the shallow alluvial ground water, primarily with low to moderate levels of tritium, ^{137}Cs, and ^{90}Sr (ESG 1990, 6995). The chemical composition of water from these wells is discussed in detail in Section 4.4.3 of the *RFI Work Plan for Operable Unit 1098* (LANL 1993, 21404). These wells and the contamination data are discussed in greater detail in Chapter 3 of this work plan.

Measurable surface sediment contamination by radionuclides has been found within the Los Alamos Canyon creek channel west of the confluence with Pueblo Canyon at state road 4 (LANL 1993, 21404; LANL 1991, 7528; LANL 1991, 7529; LANL 1991, 7680; LANL 1981, 6059). Radionuclide contamination above background levels has been observed in surface sediment samples taken west of TA-41 and in surface sediment and shallow (alluvial) ground water samples taken east of TA-2. These data and the recent Environmental Restoration (ER) Project work (which is the source of the data) are discussed at greater length in Chapter 3 of this work plan. Near-surface, low-level radionuclide releases occurred within TA-2 and TA-21 (LANL 1993, 21404; LANL 1991, 7529); individual sediment samples have shown concentrations (expressed as activities per unit mass of sediment) of ^{137}Cs that exceed the screening action level (SAL) of 4 pCi/g (LANL 1993, 21404). This contamination is attributable primarily to TA-2 but also to TA-21 (LANL 1993, 21404; LANL 1991, 7528; LANL 1991, 7529; LANL 1991, 7680; LANL 1981, 6059).

Previous studies indicate that most radionuclides (excluding ^{90}Sr) are transported on suspended sediments and in the bedload (LANL 1981, 6059). These sediments are transported during storm flows. Therefore, contaminant distributions like those described above may be expected to vary substantially spatially as well as temporally. Additional discussion of the nature of this surface contamination in Los Alamos Canyon is provided in the *RFI Work Plan for Operable Unit 1098* (LANL 1993, 21404) and in Chapter 3 of this work plan.

2.4 Internal Sources of Potential Contamination—Los Alamos Canyon

This section discusses the sources of potential contamination that originated from activities conducted within Los Alamos Canyon. No similar sources exist in Pueblo Canyon. Sources of potential contamination originating from SWMUs on the mesa tops or from other canyons are discussed in Section 2.5. The activities that directly contaminated Los Alamos Canyon occurred at the two technical areas located within the canyon: TA-2 and TA-41. The locations of these technical areas are shown in Figure 2-2.

TA-2 and TA-41 have been used continuously since 1943. TA-2 has housed a series of research nuclear reactors; TA-41 is used for weapons development and long-term studies of weapon subsystems. The most probable contaminants from these activities are radiological and chemical constituents including uranium, plutonium, tritium, ^{90}Sr, ^{137}Cs, other fission products, chromium, mercury, acids, and solvents.

2.4.1 Technical Area 2

TA-2 has been used to house a series of small research reactors (Bunker 1983, 44020). The first three reactors at TA-2, including the first water boiler reactor, were homogeneous, liquid-fueled systems that were operated in succession. They were fueled by aqueous uranyl solutions enriched with ^{235}U. The last of the liquid-fueled reactors was deactivated in 1974.

The first solid-fueled reactor at TA-2 operated from 1946 to 1953 and has since been decommissioned. It was self contained and used plutonium fuel. Since 1956 TA-2 has been the site of the Omega West Reactor that, from 1956 until 1993, generated 8 MW of power from a water-cooled, highly enriched uranium core. The reactor was shut down in 1993, and the fuel rods have been removed.

Soils and sediments near TA-2 have been contaminated with uranium, chromium, ^{137}Cs, ^{90}Sr, mercury, and silver. In addition, plutonium, beryllium, and various fission products may have been deposited (LANL 1993, 21404). Some contaminants may be present throughout extensive areas, whereas others may be very localized. Concentrations at levels above background and possibly above SALs may be present.

An area of residual soil and sediment contamination (up to 1000 pCi/g of ^{137}Cs) is located east of building TA-2-1 (SWMU No. 2-009). The area is covered by 5 to 7 ft of clean, stabilized fill that replaced soil removed during remediation efforts in 1986 as part of Phase I decommissioning of the water boiler reactor. However, not all the contaminated soil was removed from the former leach fields associated with the water boiler reactors because a high water table impeded the cleanup (Elder and Knoell 1986, 6670).

In January 1993 a tritium leak was discovered at the Omega West Reactor. The leak was caused by a broken weld seam on the delay line that connected building TA-2-1 to the primary cooling system surge tank (LANL 1993, 21404). The leak continued to release up to a maximum of 70 gal. per day until March 1993 when the cooling water was drained from the delay line (after the reactor was shut down). Typical concentrations of tritium in the cooling water ranged from 15.7×10^6 to 20.2×10^6 pCi/L. These values are above the Safe Drinking Water Act limits of 20,000 pCi/L. The leak may have existed as early as 1956 but was almost certainly present by 1967, as indicated by tritium activities of 41,000 pCi/L in monitoring well LAO-1 (see Section 3.7). Evidence from current ER Project activities, which are discussed in Section 3.7 of this work plan, supports the conclusion that the dominant source of this tritium was the Omega West Reactor (see Table A-XXXIV in the Formerly Utilized Sites Remedial Action Program [FUSRAP] report [LANL 1981, 6059]). If the release rate and activities mentioned above are extrapolated for these two periods (1956 to 1967 and 1967 to 1993), the cumulative release could have been tens of Curies of tritium. Because of natural decay plus evaporation of tritiated water, probably less than 15 Ci of the released tritium remain. These values represent reasonable upper bounds on the release. One of the objectives of the investigation described in this work plan will be to determine the fate of this tritium and of any other contaminants that also might have been released.

Currently, waste management activities at TA-2 consist primarily of temporary storage of radioactive liquids from periodic deionizer regeneration at the Omega West Reactor. Radioactive liquids are piped to four underground storage tanks: three 1000-gal. tanks and one 170-gal. tank. The liquids are periodically pumped via pipeline or taken by tank truck to the Laboratory waste management facility at TA-50 for treatment. Following treatment, the liquids are discharged into Mortandad Canyon.

2.4.2 Technical Area 41

TA-41 has been used for more than four decades for testing, monitoring, and test assembling of nuclear weapon components; developing weapon subsystems and boosting systems; and conducting long-term studies of critical systems.

Soil and ground water at TA-41 may be primarily contaminated with tritium and possibly by alpha-emitting radionuclides from a sewage treatment plant outfall (SWMU No. 41-002) (National Pollutant Discharge Elimination System [NPDES] number SSS 06s) located at the site (LANL 1993, 21404). According to monitoring data collected by the Laboratory Weapons Engineering Group (ESA-WE), the buildings are contaminated with tritium but not with other radionuclides (Larson 1992, 44022).

TA-41 contains four SWMUs and five areas of concern. The two most important SWMUs are a septic system (SWMU No. 41-001) and a sewage treatment plant (SWMU No. 41-002), which operated from 1951 until 1987. These SWMUs are likely to be contaminated with tritium, plutonium, and uranium (SWMU No. 41-001) and with undifferentiated alpha-, beta-, and gamma-emitting radionuclides (SWMU No. 41-002). Phase I sampling at TA-41 as part of the Resource Conservation and Recovery Act facility investigation (RFI) for OU 1098, will determine whether certain other possible contaminants are present, including other radionuclides (such as ^{137}Cs, ^{60}Co, ^{90}Sr, or ^{99}Tc), semivolatile organic compounds, volatile organic compounds, and metals (especially lead, beryllium, and mercury) (LANL 1993, 21404). The other two SWMUs are a sump (SWMU No. 41-003) and a container storage area (SWMU No. 41-0004). Areas of concern include a diesel tank, an industrial waste tank, storm drains, and a fuel tank of unknown origin.

2.5 External Sources of Potential Contamination

This section presents an overview of the site histories of former TA-1 and former TA-45 (both now part of the Los Alamos townsite), and of TAs -21, -43, and -53. In addition, this section discusses the potential contaminants most likely to have been released from those technical areas into Los Alamos Canyon and Pueblo Canyon. All of those technical areas occupied or occupy mesa tops exclusively except former TA-45, which included Acid Canyon, and TA-21, which includes DP Canyon.

Various contaminants are known (or suspected) to have been discharged into Los Alamos Canyon (from former TA-1, TA-21, and TA-53) and into Pueblo Canyon (from former TA-45 into Acid Canyon). No sources (such as outfalls, discharge lines, and septic tanks) that might have contaminated Los Alamos Canyon have been identified at TA-43 (LANL 1993, 21404).

The following subsections will show that the major suspected contaminants include radionuclides (uranium, plutonium, cesium, strontium, tritium, and americium) and metals. The primary potential impact from these external sources of potential contamination results from the migration of contaminants from Pueblo Canyon and upper Los Alamos Canyon into the downstream parts of both canyons.

Former TA-1, TA -21, former TA-45, and TA-53 are potential sources of contamination in Los Alamos Canyon and Pueblo Canyon through

- direct discharge of contaminants into the canyons (for example, releases through outfalls);
- direct transport from mesa tops into the canyons by mass wasting, wind or water erosion, or subsurface migration; or
- indirect transport into tributary canyons and then into Los Alamos Canyon or Pueblo Canyon.

Only two technical areas contain tributary canyons through which indirect transport could have occurred: TA-21 includes DP Canyon, which feeds Los Alamos Canyon;

former TA-45 included Acid Canyon, which feeds Pueblo Canyon. Both tributary canyons have served as pathways for indirect contaminant transport.

Table 2-1 shows the known and suspected potential contaminants from sources outside the canyons.

TABLE 2-1

EXTERNAL SOURCES OF POTENTIAL CONTAMINATION

Technical Area	Known Potential Contaminants	Suspected Contaminants	Potentially Affected Canyons
Former TA-1	Uranium, plutonium, tritium, ^{137}Cs, fission products, alpha-emitting radionuclides, paint and solvent residues (in cans), chemicals and solvents associated with radionuclides (uranium and plutonium), mercury	Chromium, organic compounds, miscellaneous chemicals, solvents, nonferrous metals	Acid Bailey Los Alamos
TA-21	Uranium, plutonium, americium, actinium, copper, tritium, ^{137}Cs, ^{90}Sr, fission products, cadmium, beryllium, lead, mercury, sodium, fluorine, chlorine, iodine, concentrated ammonium citrate, citric acid, chlorine and nitrogen products, ethylene glycol, phosphoric acid, polychlorinated biphenyls (PCBs), perchlorates, ethers, kerosene, diesel oil, No. 2 fuel oil, benzene, toluene, xylene isomers	Chromium, hydrofluoric acid (liquid and vapors), organics, miscellaneous organic and inorganic chemicals, solvents, corrosive gases, gasoline, ethanol	Los Alamos DP
TA-21 SWMUs	Stored: radionuclides, Freon, acetone, alcohol, waste oil, organics, solvents Released: plutonium, uranium, ^{90}Sr, ^{137}Cs, barium, lanthanum, iodine, tritium, PCBs (in oil), No. 2 fuel oil, kerosene, diesel oil, benzene, toluene, xylene isomers	Released: chromium, gasoline, ethanol, unspecified chemical contaminants and hazardous constituents	Los Alamos DP
TA-21 Outfalls	Uranium, plutonium, tritium, cesium, polonium, actinium, strontium, cadmium, beryllium, lead, mercury, sodium, fluorine, chlorine, iodine, ethylene glycol, phosphoric acid	Beryllium, PCBs (in oil), miscellaneous chemicals, hydrofluoric acid (liquids and vapors), solvents, organics, other unspecified hazardous constituents	Los Alamos DP
TA-21 MDA-T	Plutonium, americium, concentrated ammonium citrate, citric acid, fluorine, chlorine and nitrogen compounds	Lead, mercury, cadmium	Los Alamos DP
TA-43	Tritium, plutonium, fission products, radioactive liquid waste, photographic chemicals including silver	Miscellaneous inorganic and organic compounds	Los Alamos
Former TA-45	Uranium, plutonium, ^{90}Sr, ^{137}Cs, alpha-emitting radionuclides, nitrate, chloride	Chemicals and solvents associated with radionuclides	Acid Pueblo
TA-53	Uranium, plutonium, tritium, ^{22}Na, ^{60}Co, ^{137}Cs, other radionuclides, unspecified scale- and corrosion-control compounds, chemical cleaners, industrial wastes, cadmium, lead, PCBs, Freon, acetone, toluene, ethanol, trichloroethane, trichloroethylene, waste oil, pump oil, gasoline, epoxy resins, organics, solvents, scintillation liquid, photographic chemicals	Miscellaneous inorganic and organic chemicals	Los Alamos
TA-53 Outfalls	Tritium, ^{22}Na, other short-lived radionuclides (probably ^{60}Co), scale- and corrosion-control compounds, chemical cleaners, industrial wastes, other unspecified chemicals	Miscellaneous inorganic and organic chemicals	Los Alamos

2.5.1 Former Technical Area 1

TA-1 was the first technical area at the Laboratory (LANL 1990, 7511). Beginning in November 1942 it housed the theoretical divisions, Laboratory administration, plutonium chemistry, physics research, and other activities. Between 1943 and 1945 much of the theoretical, experimental, and production work to develop the atomic bomb occurred in this main technical area. Beginning in the 1950s those facilities were moved to TA-3. By 1965 TA-1 became inactive, and beginning in 1966 it was decontaminated and demolished in stages. By the late 1960s the US Atomic Energy Commission relinquished TA-1 to Los Alamos County to be used for residential and commercial development (DOE 1987, 8663; DOE 1987, 8664).

Figure 2-3 shows the location of former TA-1 relative to Los Alamos Canyon.

2.5.1.1 Direct Disposal into Los Alamos Canyon and Acid Canyon

Numerous outfalls discharged from the former TA-1 septic system, drain lines, and an industrial laundry facility; outfalls were located in Bailey Canyon, Acid Canyon (via pipeline to the north to former TA-45; not shown on the figure), and Hillsides 137, 138, and 140 of Los Alamos Canyon (Figure 2-3). Sanitary waste was collected by three sanitary systems that discharged outside former TA-1. Some outlying buildings used separate septic tanks to handle their sanitary waste. These tanks discharged into Los Alamos Canyon.

Many buildings in former TA-1 were served by drain lines that discharged directly into outfalls. These drain lines are of two types: building drains and storm drains. Several of these drain lines discharged directly into Los Alamos Canyon, whereas others released storm water on the ground around the building they served. Septic Tank 268 was located northwest of Building TU, which it served. A line from the septic tank led to an outfall, which was located in the drainage of a side canyon of Los Alamos Canyon northwest of the tank. Records indicate that when Building TU was removed in 1964, the septic tank was also removed. The outfall for Septic Tank 138 was located east of Building Y and discharged over the rim of Los Alamos Canyon. This outfall area is known as Hillside 138. When the tank was removed, it was found to be free of radioactive contamination.

Landfills were located in the vicinity of the former Bailey Bridge in Bailey Canyon. Some of the outfalls and landfills/dumps are known to have contained mercury, uranium, plutonium, paint and solvent cans, and other unspecified chemicals and solvents, and are suspected to contain dispersed chromium from a cooling tower (LANL 1990, 7511). Four hillside disposal sites are located adjacent to former TA-1 alongside Los Alamos Canyon. Types of waste consist primarily of construction debris, empty paint or solvent cans, and large fragments of scrap metal. The construction debris probably originated from the decontamination and decommissioning of former TA-1 (LANL 1992, 43454).

2.5.1.2 Mesa-Top Contamination

The septic system and the acid waste lines received radionuclides, solvents, and other chemicals from general operations at former TA-1. Production and research incinerators were also located in former TA-1; no releases are known to have occurred from them (LANL 1992, 43454). There is no reason to believe that any indirect releases on the mesa top at former TA-1 migrated into Los Alamos Canyon.

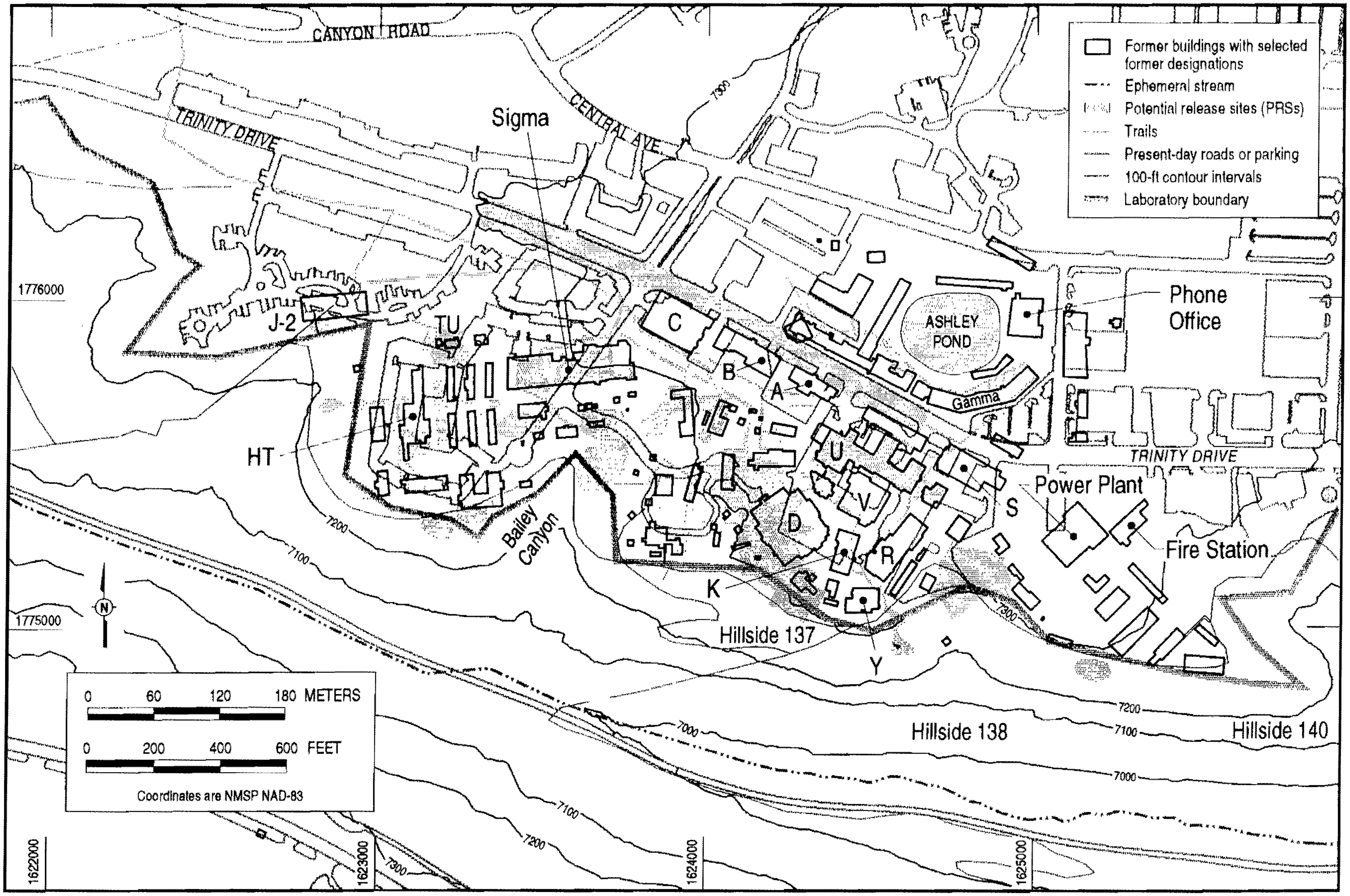


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Figure 2-3. Location of former TA-1 relative to Los Alamos Canyon.

2.5.2 Technical Area 21

The *TA-21 Operable Unit RFI Work Plan for Environmental Restoration* (LANL 1991, 7528; LANL 1991, 7529; LANL 1991, 7680) and the phase report for TA-21 (LANL 1993, 20976), from which the following discussion is abstracted, describe in detail the SWMUs at TA-21.

The Laboratory's Chemistry Division was created in 1943 and was given the responsibility for purifying plutonium received from other production facilities. In September 1945 these operations were transferred to new facilities in the DP West and DP East areas of TA-21 (see Figure 2-4).

The purpose of DP West was to prepare plutonium metal and alloys from the nitrate solution provided by other production facilities. The preparation involved several stages of acid dissolution and chemical precipitation to separate the plutonium and other valuable actinide elements from the nitrate feedstock. The facility also performed research and development work on new purification techniques to increase the efficiency of the separation processes (Christensen and Maraman 1969, 4779). Research was also conducted on reprocessing waste to further enhance recovery.

DP East began operation in September 1945 in buildings TA-21-151, -152, and -153; building TA-21-155 was built in 1949. These facilities were dedicated to the processing of polonium and actinium and the production of initiators for nuclear weapons. Building TA-21-209 was built in 1964 to house research in high-temperature and actinide chemistry. Building TA-21-155 currently houses the Tritium Systems Test Assembly for research and development related to deuterium and tritium handling for fusion reactors.

The major contributors to waste streams at TA-21 were the plutonium-processing activities. As a result of the process chemistry, hazardous constituents are also likely to be part of the waste stream. The SWMUs at TA-21 include the following:

- deep liquid releases, such as seepage pits and absorption beds, into which plutonium-bearing liquids were discharged;
- near-surface liquid releases, such as surface discharges from septic systems, that may have contained industrial liquid wastes;
- subsurface solid waste disposal areas, such as material disposal areas, where contaminated equipment, industrial materials, stabilized process residues, and radioactive or hazardous wastes were buried in shallow trenches or isolated shafts; and
- surface contamination areas where limited quantities of contaminants were released, such as stack release fallout and surface spills.

The potential contaminants at TA-21 include actinide elements (such as actinium, uranium, plutonium, and americium); fission products (such as ^{90}Sr and ^{137}Cs); acids; solvents; polychlorinated biphenyls; other organic and inorganic compounds; and heavy metals. These contaminants are summarized in Table 2-1.

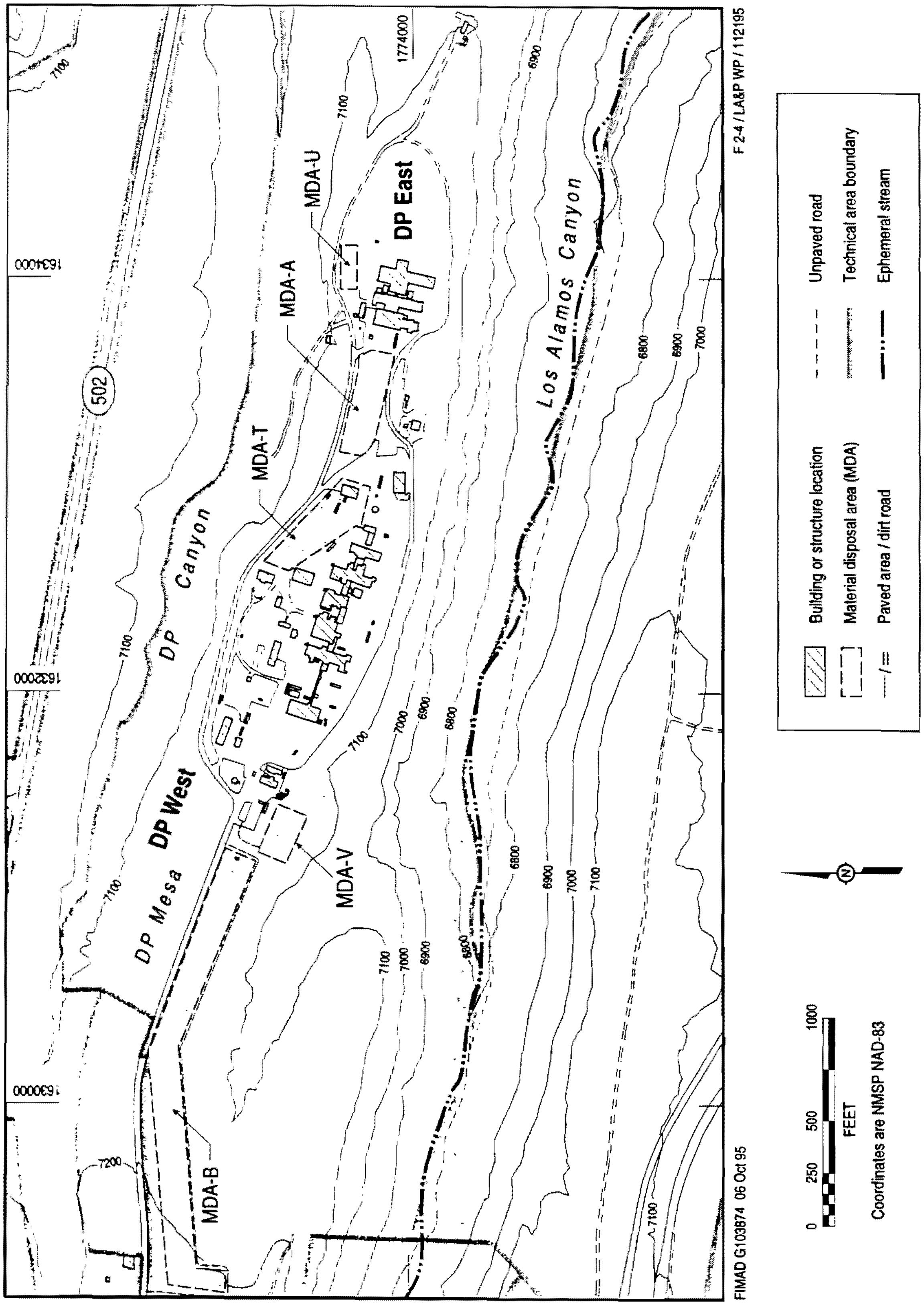


Figure 2-4. Major features of TA-21 relative to Los Alamos Canyon.

2.5.2.1 Direct Disposal into Los Alamos Canyon

Numerous outfalls discharged from the septic system, drain lines, laundry facility, material disposal areas, treatment plants, and seepage pits at TA-21. For example, in the early period of operations at TA-21, a separate sewer system was not available (LANL 1991, 7528; LANL 1991, 7529; LANL 1991, 7680). Sanitary waste was mixed with liquid waste from floor drains and laboratory sinks, and with cooling tower blowdown water. Drain lines from the various buildings carried this waste to the mesa edge or to septic tanks, which then discharged overflow to the mesa edge. These lines, which terminated in outfalls on the mesa edge, were not intended to discharge contaminated waste; however, occasionally they did so when contaminated material was washed down floor drains or laboratory sink drains.

Most outfalls were abandoned in 1966 when the sewage treatment plant at the east end of DP Mesa was built. Some drain lines discharging cooling tower blowdown water are still in operation and have NPDES permits (LANL 1991, 21557).

The TA-21 Operable Unit RFI Work Plan for Environmental Restoration (currently OU 1106) suggests that some debris from the destruction or remodeling of buildings at TA-21 was pushed over the edge of the mesa south of material disposal area (MDA) -V (see Figure 2-4) (LANL 1991, 7528; LANL 1991, 7529; LANL 1991, 7680).

2.5.2.2 Mesa-Top Contamination

Surface overflow and subsurface migration have been documented for MDA-T, although the quantities of contaminants released were not specified in the SWMU report (LANL 1990, 7511).

2.5.2.3 Disposal into DP Canyon

Releases of radionuclides from Area T are known to have occurred on the mesa top and into DP Canyon. Ongoing studies by Field Unit 1 personnel indicate high concentrations of ^{137}Cs are associated with outfall PRS No. 21-011(k).

Personnel from Field Unit 1 in the Laboratory ER Project are investigating the environmental impacts of discharges into DP Canyon. The analytical results from those investigations have been considered in preparing the sampling plans for Los Alamos Canyon.

Chemistry of surface water in DP Canyon is discussed in Section 3.7.3 in Chapter 3 of this work plan.

2.5.3 Technical Area 43

TA-43 was established in 1953 with the opening of the Health Research Laboratory building where Health Division conducted biomedical and industrial hygiene research. Emphasis was placed on the assessment of health effects as a result of radiation exposure from materials associated with weapons and energy production. When the occupational health building (TA-59-1) was completed in 1966, industrial hygiene activities were suspended at TA-43 (LANL 1990, 7511).

Currently TA-43 is used for biomedical research. The research is a mixture of basic and applied programs to study the mechanisms of energy production and to assess the health effects of radiation and the materials associated with energy production. These studies are conducted at the molecular, cellular, and organism level.

Radioactive materials are used in the research. Occasional work with human pathogens is conducted in a biocontainment laboratory. Spills involving radioactive material have been recorded at TA-43 (DOE 1987, 8663; DOE 1987, 8664).

Table 2-1 shows the known and suspected potential contaminants from TA-43 (LANL 1990, 7511).

2.5.3.1 Direct Disposal into Los Alamos Canyon

No releases of wastes from TA-43 directly into Los Alamos Canyon have been documented, and no potential sources (such as outfalls, discharge lines, and septic tanks) have been identified that may have affected Los Alamos Canyon (LANL 1990, 7511). Discharges from TA-43 directly into Los Alamos Canyon are precipitation runoff only. The industrial pipelines that carry wastes across Los Alamos Canyon for treatment at TA-50 could be sources of contamination only if they leak.

2.5.3.2 Mesa-Top Contamination

Sanitary and industrial waste lines shown on Figure 2-5 received radionuclides, photographic chemicals, solvents, and other chemicals from general operations at TA-43. An incinerator is also located at TA-43, but it has no history of contaminant release. Storage areas currently classified as SWMUs contain radioactive liquid waste, unspecified inorganic and organic compounds, and photographic chemicals (including silver) in approved and monitored containers (LANL 1990, 7511).

2.5.4 Former Technical Area 45

TA-45 was the site of the first radioactive liquid waste treatment facility at the Laboratory (LANL 1981, 6059; LANL 1992, 7668). It was located northwest of the intersection of Canyon Road and Central Avenue in the Los Alamos townsite (Figure 2-6). The treatment facility was operated from April 1951 through June 1964 when all industrial wastes began to be routed to a new treatment facility. Before the treatment facility was constructed, untreated radioactive liquid wastes were released in this area (SWMU No. 1-002 in former TA-1; see Figure 2-6). Several radiation surveys of the structures at former TA-45 were completed after the treatment facility ceased to operate in 1964 and before decontamination and decommissioning began in October 1966.

The structures associated with former TA-45 included a waste treatment facility and laboratory, a vehicle decontamination facility, a sewage lift station, and a transformer station. Beginning in 1966, all buildings were demolished, the debris was removed, the former waste lines were removed, and contaminated surface soil was excavated. The area was released to Los Alamos County in 1967. Further remedial decontamination was conducted in 1982 under the FUSRAP (LANL 1981, 6059).

The area of former TA-45 is currently being investigated under the *RFI Work Plan for Operable Unit 1079* (LANL 1992, 7668) from which this discussion of original contaminant sources and current conditions was derived. Known contaminants at former TA-45 include uranium, plutonium, ^{90}Sr, ^{137}Cs, and gross-alpha radiation. Data on non-radioactive chemical contamination indicate that nitrates and chlorides were released (LANL 1981, 6059). Suspected contaminants include chemicals and solvents associated with the radionuclides.

Table 2-1 lists the known and suspected potential contaminants from former TA-45. (LANL 1992, 7668).

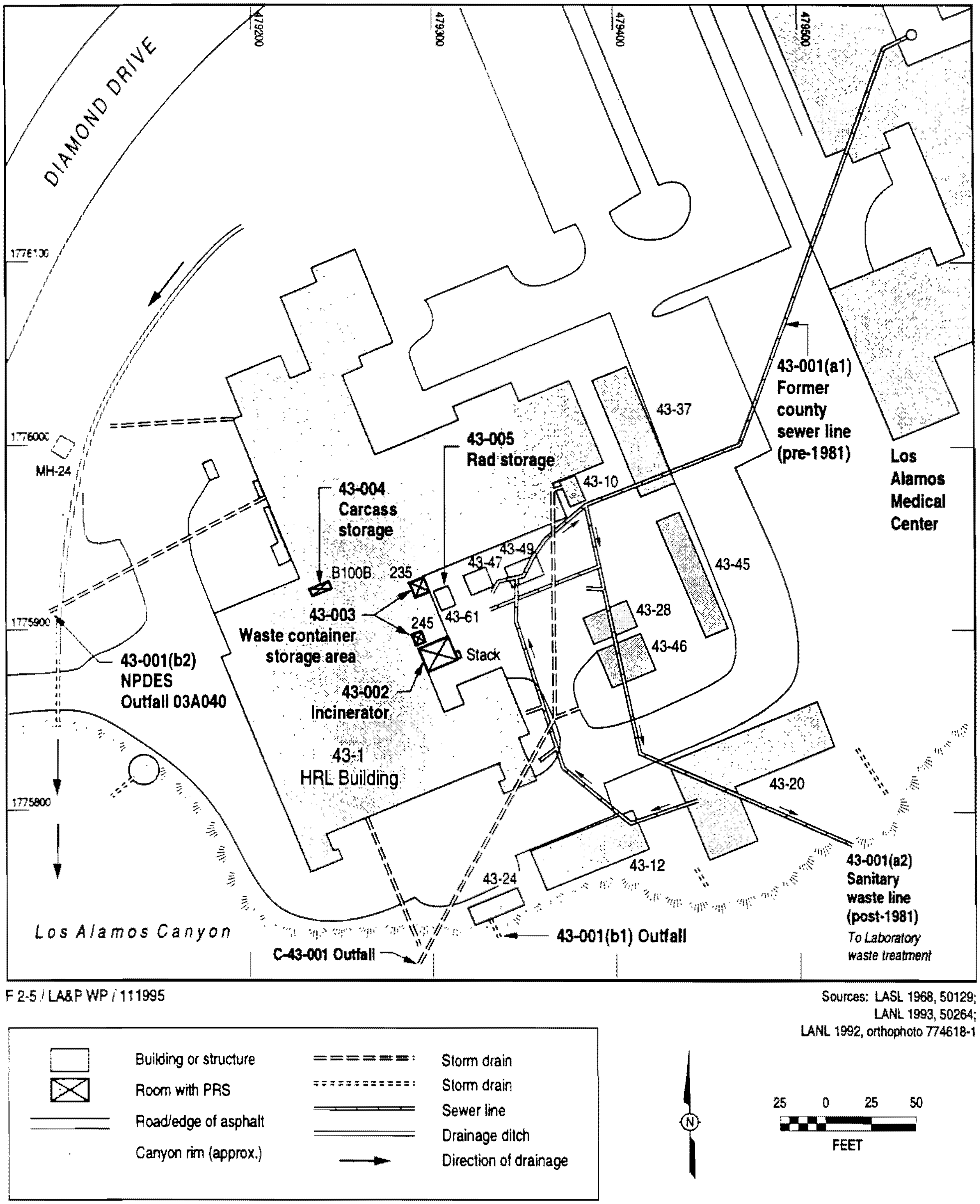
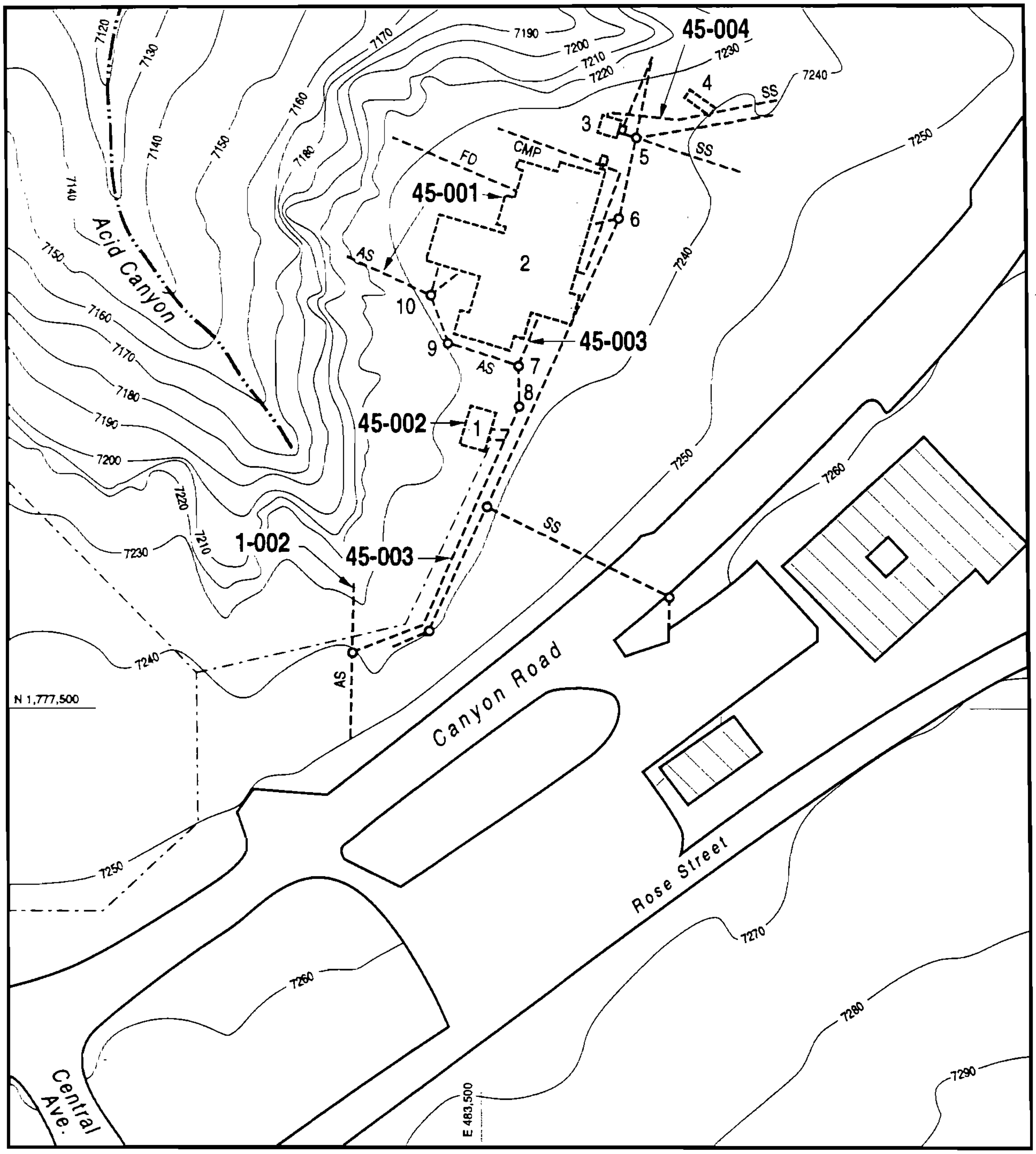


Figure 2-5. Locations of potential release sites in TA-43.



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LANL 1990, 7511; AEC 1963, 2057; Los Alamos County 1986, 2102; Los Alamos County 1986, 2103; LASL 1961, 2092; LASL 1955, 2093; LASL 1962, 2094

(solid box)	Existing building or structure	(dash-dot line)	Intermittent stream
(dashed box)	Former TA-45 building or structure	AS	Acid sewer line
(dashed line)	Former pipeline	SS	Storm sewer line
(dash-dot line)	Fence	FD	Floor drain
		CMP	Corrugated metal pipe

N

0 50 100 FEET

Figure 2-6. Locations of potential release sites in former TA-45.

2.5.4.1 Direct Disposal into Pueblo Canyon

Releases of radionuclides from former TA-45 occurred on the mesa top and into Acid Canyon; radionuclides were not released directly into Pueblo Canyon but rather into Acid Canyon, a short tributary of Pueblo Canyon.

2.5.4.2 Direct Disposal into Acid Canyon

The predominant sources of contamination at former TA-45 appear to have been outfalls from

- radioactive liquid waste line (SWMU No. 1-002 in former TA-1), which released untreated waste generated by Laboratory operations into Acid Canyon from 1943 until the radioactive liquid waste treatment facility was constructed in 1951 at former TA-45 and
- the treated waste line from the radioactive liquid waste treatment facility at former TA-45, which discharged onto the cliffs above Acid Canyon.

Much of the contamination released at former TA-45 remained in the immediate area of the radioactive liquid waste treatment facility and in Acid Canyon below the facility site. The remedial actions taken in 1966 during decontamination and decommissioning and in 1982 as part of the FUSRAP removed much of this contamination. However, some radionuclides from these releases migrated downstream in Acid Canyon, adsorbed to sediments, and are being transported down Pueblo Canyon and Los Alamos Canyon, primarily with suspended sediments and bedload (LANL 1981, 6059). The level of contamination in sediments generally decreases as the distance from the original source increases.

Sediments in the stream channels of Los Alamos Canyon and Pueblo Canyon were sampled under the FUSRAP in the late 1970s. A comprehensive report on these activities was issued in 1981 (LANL 1981, 6059). Samples were collected at regular intervals along canyon transects and included sediments from active channels, inactive channels, and banks. In lower Pueblo Canyon and lower Los Alamos Canyon, the predominant radionuclide present above background level was ^{239}Pu; however, uranium, ^{90}Sr, and ^{137}Cs were also present at levels above background.

Independent estimates of the mass of plutonium released are within the same order of magnitude, but significantly different. Estimates based on the arithmetic means of measured plutonium (reported as ^{239}Pu) content in sediments and inferred volumes of sediment in Acid Canyon and Pueblo Canyon (LANL 1992, 7668) indicate that releases from the two outfalls into Acid Canyon resulted in the deposition of 7.9 ± 3.8 g of plutonium. Estimates based on effluent volume and concentration from the older, untreated radioactive waste line indicate that approximately 1.9 g of plutonium (150 mCi) was released (LANL 1981, 6059; LANL 1992, 7668). Although the outfall from the treatment facility discharged for a longer time, it appears to have released substantially smaller quantities of plutonium into Acid Canyon (26.9 mCi or 0.34 g).

The FUSRAP report (LANL 1981, 6059) includes an estimated release based on the geometric mean of values of the measured plutonium content in sediments of ~250 mCi (~3.2 g), much closer to the estimate based on effluent volume and concentration (~2.2 g). The use of a geometric mean to represent the central tendency of data is often justified in the case of environmental samples, the contaminant concentrations of which are often log-nomally distributed. In addition to the uncertainties in the estimates of total plutonium release, there are uncertainties in the isotopic content of the various releases; therefore, precise estimates may be very difficult to make.

Uranium, ^{90}Sr, ^{137}Cs, and some tritium were also released from the two radioactive waste lines (LANL 1981, 6059; LANL 1992, 7668). However, the data from the postremediation survey conducted under FUSRAP suggest that strontium and cesium activities on-site and in Acid Canyon are below 1.0 pCi/g. These values were well below the FUSRAP action levels (100 pCi/g and 80 pCi/g above background, respectively), and current SALs (4 pCi/g and 5.9 pCi/g, respectively) (LANL 1994, 34756). The highest concentrations of plutonium continue to be found in sediments located directly below the former radioactive waste discharge points. Contamination along the channel of Acid Canyon includes concentrations of ^{90}Sr and ^{137}Cs of several pCi/g, still below FUSRAP action levels but closer to current SALs. Migration of these contaminants and plutonium from Acid Canyon to Pueblo Canyon and ultimately into Los Alamos Canyon is the primary source of potential future impacts on areas located downstream.

2.5.4.3 Mesa-Top Contamination

At the time of closure in 1966, radiation monitoring indicated no contamination at the transformer and sewage lift station or in the sanitary manholes at TA-45. The vehicle decontamination facility and waste treatment facilities were contaminated, as were the industrial waste lines that fed wastes into the treatment facility and the manholes along those lines. Most of this contamination was removed during either the decontamination and decommissioning in 1966 or the FUSRAP activities in 1982 (LANL 1992, 7668). These decontamination activities included removal of part of the cliff face around the outfalls. Further cleanup of former TA-45 may be undertaken as part of the remedial activities for OU 1079 (LANL 1981, 6059; LANL 1992, 7668). The contamination from former TA-45 remaining in Acid Canyon and Pueblo Canyon consists of material released into Acid Canyon during the period from 1943 to 1951 when untreated wastes were discharge and during the period from 1951 to 1964 when treated wastes were discharged onto the cliffs at Acid Canyon.

2.5.5 Technical Area 53 (Clinton P. Anderson Meson Physics Facility)

TA-53 houses a proton accelerator used for basic research, isotope production, radiochemistry, solid-state physics research, and the development of new accelerator technology (LANL 1990, 7511). The area also houses a variety of support facilities for the accelerator including shops, warehouses, trailers for instruments and data logging, offices, and accelerator research facilities. The southern end of TA-53 has been developed for use by the Strategic Defense Initiative. The technical area includes part of former TA-20, which was used by the Manhattan Project between 1944 and 1948 to perform tests related to the development of initiators for nuclear devices. These tests used high explosives and small amounts of radioactive and hazardous materials (LANL 1994, 34756). SWMUs in TA-53 include waste storage areas, a lagoon system, a holding tank, a bead blaster, a disposal pit, underground storage tanks, aboveground storage tanks and sumps, a boneyard (scrap metal and equipment that is no longer controlled property), a bermed area, localized soil contamination, leaking transformers, drains, and outfalls (LANL 1990, 7511).

Table 2-1 lists the known and suspected contaminants from TA-53 (LANL 1990, 7511). Figure 2-7 shows the location of TA-53 relative to Los Alamos Canyon.

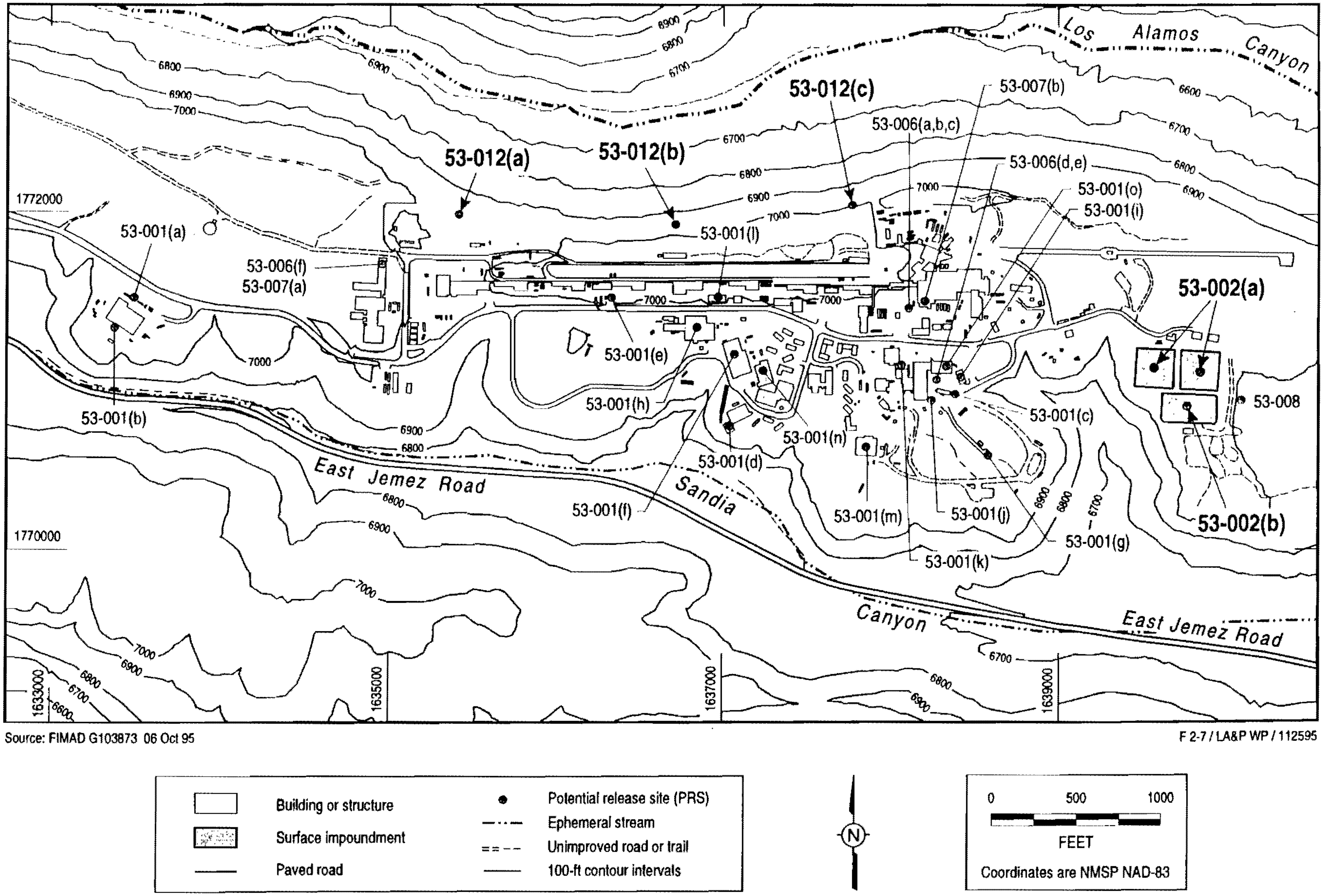

Figure 2-7. Location of TA-53 relative to Los Alamos Canyon.

2.5.5.1 Direct Disposal into Los Alamos Canyon

Known and potential discharges into Los Alamos Canyon come from the drains and outfalls (SWMU Nos. 53-012[a through c]) and from waste-treatment lagoons (SWMU Nos. 53-002[a and b]) (LANL 1990, 7511). The drain lines to the outfalls serve cooling towers for the injector, the acceleration area, and the beam stop. The SWMU report (LANL 1990, 7511) indicates that 140,000 gal. of water per day was discharged into Los Alamos Canyon when the facility was in full operation. It is not known whether radionuclides (from potential leakage from heat exchangers or neutron activation products) released in this cooling water reached the stream in Los Alamos Canyon.

Two of the lagoons contain only sanitary waste (SWMU No. 53-002[a]) and discharge from an outfall permitted under NPDES (number 095). The third lagoon (SWMU No. 53-002[b]) receives radioactive waste and does not have an outfall. The sludge has never been removed from these lagoons. The SWMU report states that all sludge samples from the lagoons indicate contamination with a variety of short-lived radionuclides (with half-lives less than six years and most less than three years) and tritium.

2.5.5.2 Mesa-Top Contamination

Most of the other types of SWMUs at TA-53 have the potential to release contaminants into Los Alamos Canyon, although that potential should be reduced by remedial activities conducted by Field Unit 2. The SWMU report (LANL 1990, 7511) lists the likely contaminants in each SWMU type and provides the basis for the following discussion.

Waste storage areas (SWMU No. 53-001) contain (or have contained) solvents (in liquid form and absorbed on rags), contaminated oils, Freon and other organic chemicals, low-level radioactive waste, photographic chemicals, epoxy resins, solid wastes, lead, cadmium, and radionuclide-contaminated oil mixed with vermiculite.

The underground storage tanks (SWMU No. 53-006) contain (or have contained) resins or water contaminated with short-lived radionuclides and possibly contaminated with acids and organic chemicals. The aboveground storage tanks (SWMU No. 53-007) contain mixed waste, solvents, and organic chemicals (including some carcinogens). However, the SWMU report is not specific. The boneyard (SWMU No. 53-008) contains locked trailers, drums, steel shielding blocks, concrete, radioactively contaminated or activated equipment, and general debris. Radionuclides are the expected contaminants. Other SWMU types are not known to have released any contaminants, or they have been remedied by prior actions (LANL 1990, 7511).

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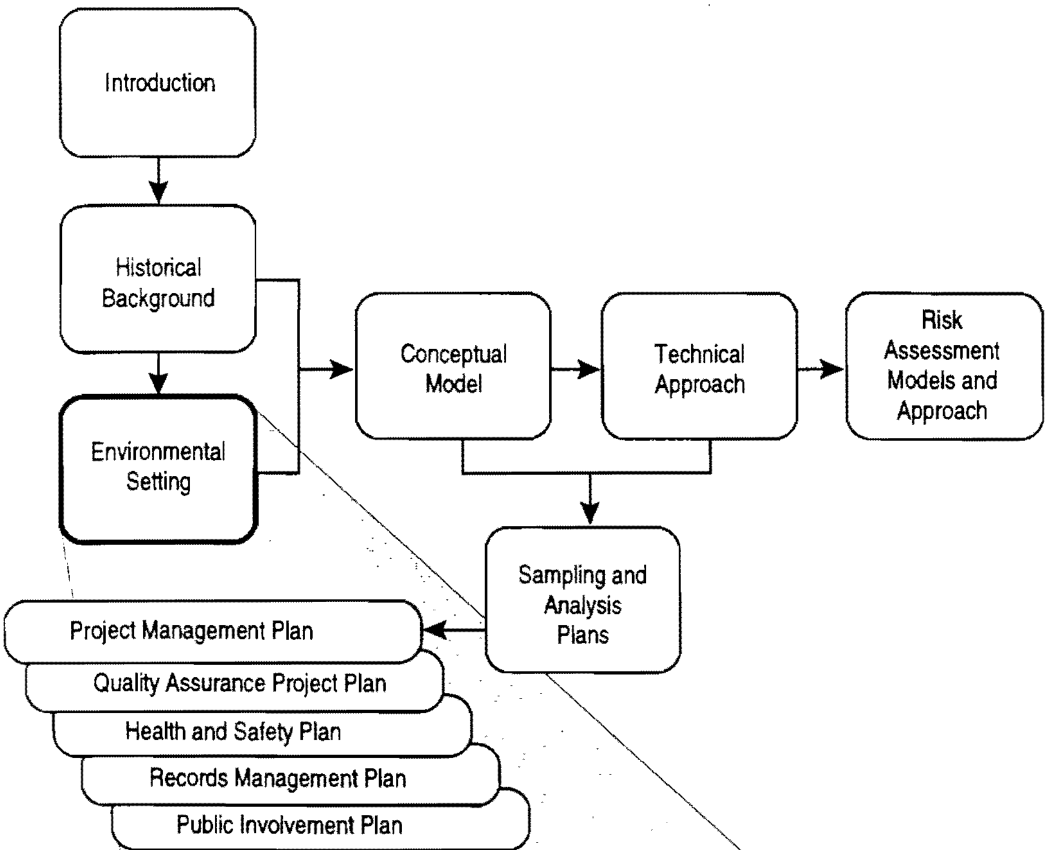
Chapter 3



Environmental Setting

- Environmental Overview
- Geology, Hydrology, and Hydrogeology
- Geochemistry
- Biological Setting

3.0 ENVIRONMENTAL SETTING

This chapter describes the environmental setting of Los Alamos Canyon and Pueblo Canyon. The regional environmental setting of Los Alamos National Laboratory (the Laboratory) is discussed in Chapter 2 of the Installation Work Plan (IWP) (LANL 1995, 49822). This chapter summarizes existing information relevant to the characterization of these two canyons. This chapter also identifies additional information needed for expanding the conceptual understanding of the environmental processes occurring within Los Alamos Canyon and Pueblo Canyon and assessing the magnitude and importance of potential exposure pathways within the two canyons.

This chapter provides the technical basis for the conceptual model described in Chapter 4 of this work plan. Chapters 2, 3, and 4 were then used to develop the specific field sampling plans presented in Chapter 7 of this work plan.

3.1 Location and Topography

The locations of Los Alamos Canyon and Pueblo Canyon are shown in Figures 2-1 and 2-2 (in Chapter 2 of this work plan). The west-to-east slope of the Pajarito Plateau, into which the two canyons are incised, results in surface drainage patterns on the mesa tops that are generally oriented to the east, north, and south and feed into the two canyons.

The drainage area of Los Alamos Canyon and Pueblo Canyon extends from the topographic divide on the Sierra de Los Valles (to the west) eastward to the Rio Grande. During the summer, storm-water runoff occasionally reaches the Rio Grande. Pueblo Canyon has a drainage area of approximately 8.4 sq mi and a channel length of 9.8 mi (McLin 1992, 12014). Los Alamos Canyon has a drainage area of 10.4 sq mi and a channel length of 12.3 mi west of its confluence with Pueblo Canyon. Lower Los Alamos Canyon has an additional channel length of 4.5 mi above its confluence with the Rio Grande. The major drainages of Bayo Canyon and Guaje Canyon join Los Alamos Canyon above its confluence with the Rio Grande. These canyons are not addressed here but will be investigated separately in future canyon studies.

The floor of Los Alamos Canyon drops from an elevation of approximately 7500 ft at Los Alamos Reservoir to just below 6300 ft at its confluence with Pueblo Canyon. Just east of this junction the channel drops abruptly 300 ft near the boundary between the Laboratory and San Ildefonso Pueblo land. From there the channel drops gradually to its confluence with the Rio Grande at an elevation of approximately 5500 ft. The elevation of Pueblo Canyon drops from approximately 7400 ft at the western edge of the Pajarito Plateau to approximately 6950 ft at the mouth of Acid Canyon to just below 6300 ft at its confluence with Los Alamos Canyon. Steeper stretches of the canyons occur where they cut through rocks of the Tschicoma Formation and partly of the Tshirege Member of the Bandelier Tuff (see Section 3.4.1). In Los Alamos Canyon, steeper stretches also occur where it cuts through the Cerros del Rio Basalts.

Los Alamos Canyon varies in depth from 900 ft in the Sierra de Los Valles to approximately 400 ft at Pueblo Canyon; it is about 600 ft deep at the Rio Grande. The depth of Pueblo Canyon varies from approximately 200 ft in the Sierra de Los Valles to approximately 400 ft at its confluence with Los Alamos Canyon.

3.2 Climate

The climate in Los Alamos Canyon and Pueblo Canyon influences soil development (Birkeland 1984, 44019) and the transport of contaminants in surface and subsurface environments. The speed, frequency, direction, and stability of the wind can influence the airborne transport of contaminants; the form, frequency, intensity, and evaporation potential of precipitation can strongly influence surface water runoff and infiltration within the canyons.

Los Alamos County has a semiarid, temperate, mountain climate, as summarized in Chapter 2 of the IWP (LANL 1995, 49822) and discussed in detail by Bowen (1990, 6899).

3.2.1 Winds

The Laboratory operates and maintains four meteorological stations; none are located in the canyons. One of these stations, the East Gate station, located between Los Alamos Canyon and Pueblo Canyon, has provided data continuously since 1987 (Bowen 1990, 6899).

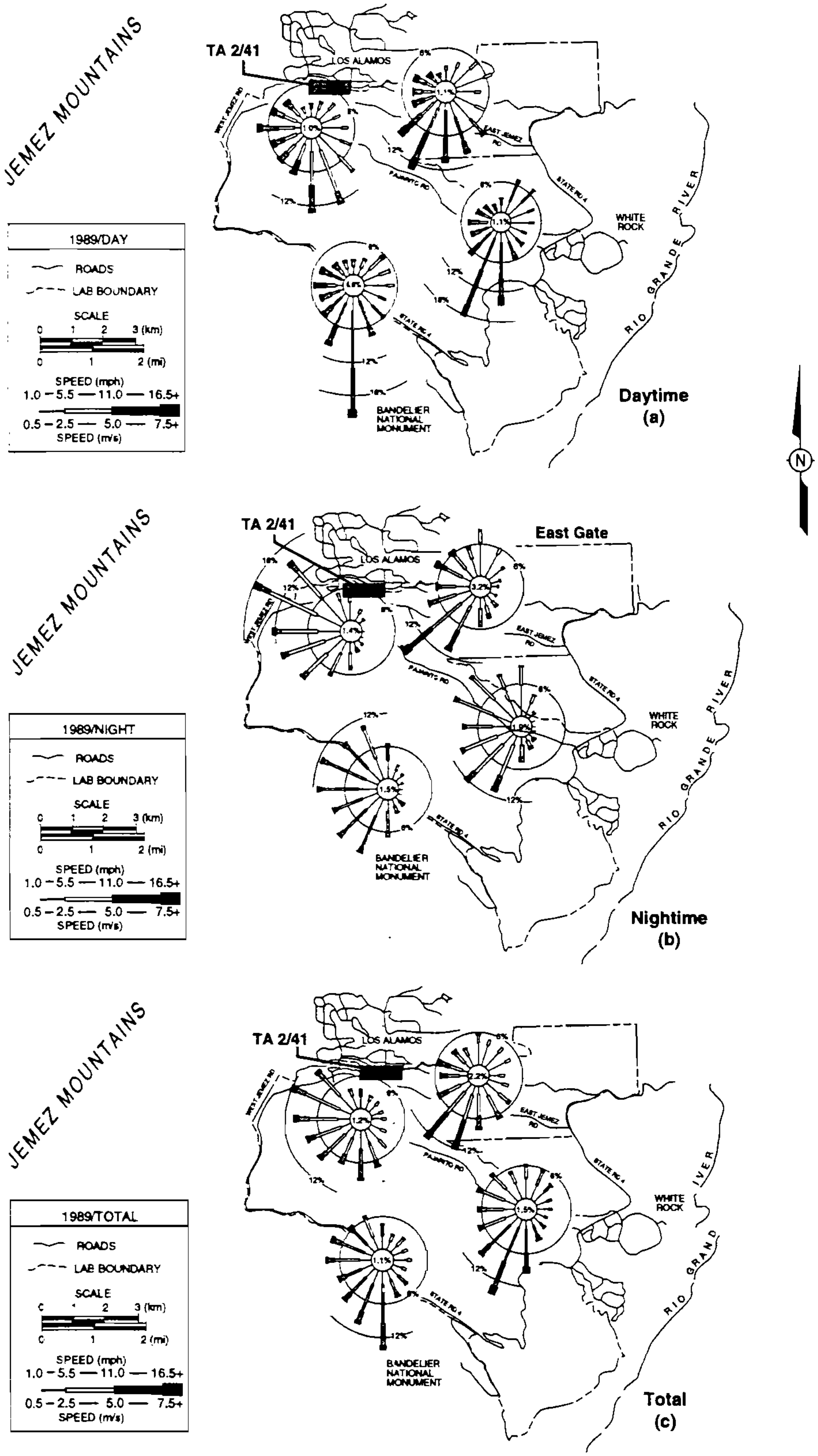
Surface winds measured at the East Gate station are generally light, with strong winds often occurring in the spring. The predominant direction for all winds is from the south and southwest (Environmental Protection Group 1994, 35363). These data imply that any airborne contaminants within Los Alamos Canyon and Pueblo Canyon would be dispersed primarily toward the northern and eastern boundaries of the Laboratory and over the eastern portion of the Los Alamos townsite. As shown in Figure 3-1, during 1989 wind speeds registered at the East Gate station were less than 5.5 mph 38% of the time and greater than 11 mph 21% of the time. The prevailing winds on the mesa tops provide information on the transport of airborne constituents after they have reached that elevation; however, conditions in the canyons may be quite different from those on the mesa tops. Thus, the transport of airborne contaminants within the canyons may follow a different pattern. A diurnal pattern of wind movement has been deduced from regular observations. During the day the winds tend to blow up-canyon from the east; at night the winds tend to blow down-canyon from the west. Shear winds have also been noted across the canyons.

3.2.2 Precipitation

The average annual precipitation in Los Alamos Canyon and Pueblo Canyon varies from 13 to 23 in. (Environmental Protection Group 1994, 35363). Approximately 50% of the precipitation on the Pajarito Plateau occurs during brief, intense thunderstorms in July and August, which often cause significant surface water runoff. The prevalence of short, intense storms indicates that surface erosion and surface water transport are potential mechanisms for the movement of surface contaminants in Los Alamos Canyon and Pueblo Canyon particularly during the summer months. Approximately 20% of the normal annual precipitation occurs as snowfall in December, January, and February; the remaining 30% is distributed throughout the other seven months of the year.

3.3 Sediments and Soils

This section discusses sediments and soils within Los Alamos Canyon and Pueblo Canyon, including soils and sediments on the canyon floors, soils on the canyon walls, and past sediment sampling investigations.



Source: Environmental Protection Group 1990, 6995

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Figure 3-1. Wind roses at Laboratory stations during 1989.

3.3.1 Erosional Deposits

Erosional deposits within Los Alamos Canyon and Pueblo Canyon consist mainly of alluvium, colluvium, and landslide deposits. Erosion within these two canyons occurs by the following mechanisms:

- wind transport,
- rockfall, landslides, debris flows, and colluvial shedding from the canyon walls;
- runoff into and within Los Alamos Canyon and Pueblo Canyon; and
- water transport within the streams in Los Alamos Canyon and Pueblo Canyon.

Processes and rates of erosion and deposition of the soils and sediments on the mesa tops and in the canyons are not well understood; the erosion rate of the Bandelier Tuff is not well established and may be highly variable, areally and temporally. The cliff-forming units of the tuff appear to be eroded primarily by spalling of large blocks of rock, which results in lateral retreat of the cliff face. This process appears to predominate over vertical incision (downcutting) by surface runoff. The rates of erosion are expected to depend on slope steepness, orientation, and vegetation patterns and probably vary widely.

The bottoms of Los Alamos Canyon and Pueblo Canyon are underlain by thick deposits of alluvium interbedded with colluvium and other mass wasting deposits. These deposits constitute both the matrix for ground water and storage areas for contaminants. The history and characteristics of these deposits, including their age, thickness, and residence times, have important implications for understanding variations in the alluvial ground water and the length of time that contaminants will remain in the canyons.

Sediments in Los Alamos Canyon range up to at least 78 ft thick, as measured in boreholes in the canyon floor. These sediments range in texture from coarse, bouldery, dacite-rich gravels deposited during floods to fine sands, silts, and clays deposited when stream channels overflow. The deeper sediments are quite old, as indicated by the presence of the approximately 50,000- to 60,000-year-old El Cajete pumice at a depth of 29 to 52 ft in borehole LADP-3, near the base of the alluvium (Broxton et al. 1995, 50119). The presence of this pumice indicates that alluvium has probably been present in the canyons for tens of thousands of years; therefore, some present-day sedimentary deposits and associated contaminants could also remain in place for at least that long. However, in some areas alluvium is completely absent, and the streams flow across bedrock. The most significant such area is located at the confluence of Pueblo Canyon and Los Alamos Canyon, where the streams flow across Cerros del Rio basalt until they reach the falls above Basalt Spring.

The alluvial history is relevant for understanding the distribution and potential future fate of contaminants contained within the alluvial system. The recent alluvial history of the canyons on the Pajarito Plateau is complex—some sediments within the stream channels are mobilized during every flood and others adjacent to or deeper beneath the channels are progressively buried and remain stable for long periods. For example, a 13-ft-deep trench excavated in Cabra Canyon, a tributary to Rendija Canyon immediately north of the Los Alamos townsite, revealed cycles of alternating sediment deposition and channel incision for the last 6000 years (Gardner et al. 1990, 48813). In Cabra Canyon there has been a net accumulation of sediment over this period, although sediment deposition was interrupted by at least three episodes when channels incised at least 3 to 6 ft and transported previously stored sediment. In DP Canyon, a tributary to Los Alamos Canyon on the north side of Technical Area (TA) -21, up to 6 ft of sediment has been locally deposited since 1943. These young sediments in DP Canyon have been partially excavated by renewed channel incision (Reneau 1995, 50143). In many canyons on the Pajarito Plateau, including Los Alamos Canyon and Pueblo Canyon, the burial of the bases of young trees indicates that up to a foot or more of historic (post-1943) sediment deposition on floodplains or low terraces (banks) is common. Erosion of these deposits and the associated contaminants is probably caused by the lateral cutting of streams during large floods.

Some geomorphic data are available for the young sediments in Los Alamos Canyon and Pueblo Canyon from several recent studies. Historic sediment deposition sites have been mapped in detail along both canyons as part of environmental surveillance activities (Graf 1995, 48851). This mapping was conducted to allow more accurate inventories of contaminants and to guide future sampling efforts; it will help in the design of field sampling plans for this investigation. A geomorphic study of DP Mesa and DP Canyon was also completed recently (Reneau 1995, 50143).

A geomorphic map of TA-2, TA-41, and vicinity was also made to aid in the interpretation of sediment data for Operable Unit (OU) 1098 (Drakos and Inoue 1994, 48850). Examination of sediment and soil development by Drakos and Inoue (1994, 48850) indicate that the low-elevation geomorphic surfaces along that part of the floor of Los Alamos Canyon are underlain by sediment deposited in the last several decades, several hundred years, or (in some cases) several thousand years. Additional data on the age of Los Alamos Canyon sediments were obtained through radiocarbon dating of alluvium and colluvium at background sites near the upstream and downstream boundaries of the Laboratory (Longmire et al. 1995, 48818). These measurements indicate that sediments beneath low-lying surfaces near the active stream channel were deposited primarily within the last 3000 years.

Mass wasting processes are potentially important because they can move large volumes of material from the canyon walls to the canyon floors. In part, they create a geologic hazard in the canyon floors. Records for the last four decades indicate that fences in the canyon at TA-2 have been damaged by one boulder weighing 300 pounds or more every two years on average (McLin 1993, 50127). Because few contaminants are present on the walls of Los Alamos Canyon and Pueblo Canyon, mass wasting is probably not an important contaminant transport pathway except possibly for a few sites near mesa edges, such as the Los Alamos Airport landfill above Pueblo Canyon (TA-73) and material disposal area V at TA-21 (Reneau 1995, 50143). Such sites will be investigated as part of the Resource Conservation and Recovery Act (RCRA) facility investigations (RFIs) for other operable units. An additional potential consequence of mass wasting is the burial of contaminated sediments in the canyon floors by debris derived from the canyon walls, including massive rockfalls. Such burial of alluvium by rockfall debris would tend to reduce the ability of the streams to erode and transport the sediment and locally increase the residence times of contaminated sediment in the canyon floors.

3.3.2 Soils

Soils on the Pajarito Plateau were initially mapped and described by Nyhan et al. (1978, 5702) and are discussed in Chapter 2 of the IWP (LANL 1995, 49822). The Nyhan study included only DOE-controlled lands and certain United States (US) Forest Service lands within Los Alamos County. It did not address large portions of Pueblo Canyon within the Los Alamos townsite or Pueblo Canyon or Los Alamos Canyon east of the Los Alamos County line.

The soils were formed in a semiarid climate and were derived from chemical, biological, and physical weathering of the Bandelier Tuff and the Tschicoma Formation with contributions from eolian deposits and airfall pumice deposits (Nyhan et al. 1978, 5702). Figure 3-2 shows the distribution and designations of surface soils in upper Los Alamos Canyon.

The soils on the slopes between the mesa tops and canyon floors have been mapped as mostly steep rock outcrops consisting of approximately 90% bedrock outcrop and patches of shallow, undeveloped soils (Nyhan et al. 1978, 5702). Soils mapped in Los Alamos Canyon and Pueblo Canyon are generally poorly developed and are designated as Hackroy-rock outcrop complex, gravelly loamy sand, and Typic Ustorthents rock outcrop complex. These complexes consist of deep, well-drained soils that have weathered from dacites of the Tschicoma Formation near the heads of the canyons and from the Otowi Member and Tshirege Member of the Bandelier Tuff in the middle and lower portions of the canyons (Nyhan et al. 1978, 5702). The surface layers of the Typic Ustorthents and Hackroy-rock outcrop complex are generally a pale brown stony or gravelly, sandy loam approximately 5 to 55 cm thick. The substratum is approximately 150 cm thick and generally consists of a very pale brown or light gray gravelly, loamy sand or sand. The Typic Ustorthents and Hackroy-rock outcrop complex have moderate to very high permeability and very low available water capacities; the clay content is also low.

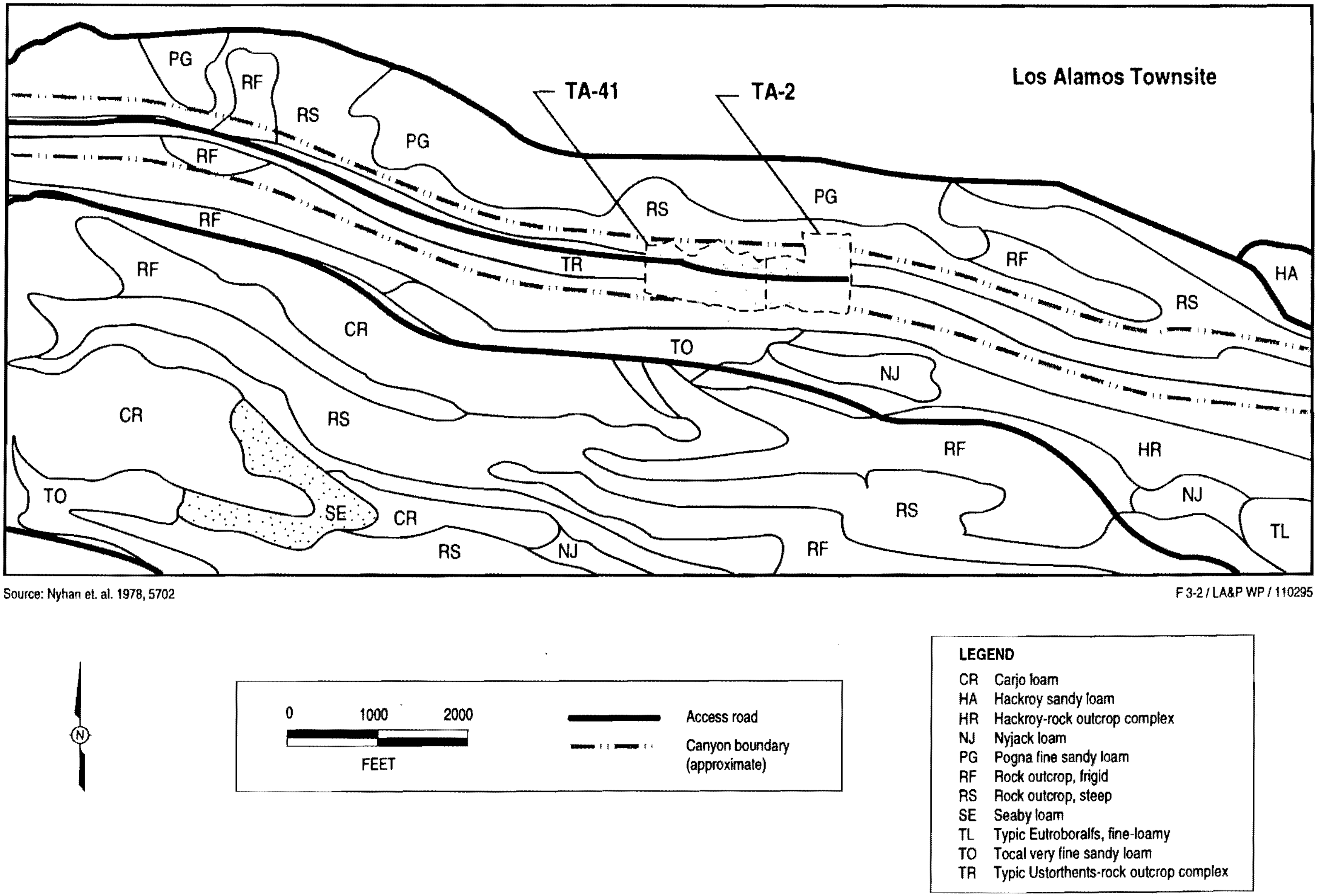
In Los Alamos Canyon and Pueblo Canyon, alluvium underlies the Typic Ustorthents and Hackroy-rock outcrop complex and consists of boulders, gravel, sand, silt, and clay. The alluvium varies in thickness and is underlain by either the Tshirege Member or the Otowi Member of the Bandelier Tuff or the Tschicoma Formation (as in Pueblo Canyon near Acid Canyon) (Nyhan et al. 1978, 5702).

Although the soil classifications of Nyhan et al. (1978, 5702) are adequate for most Laboratory-wide uses, they do not provide all the hydrogeochemical parameters required to determine the local potential for erosion and the potential sedimentary or solute transport of contaminants within Los Alamos Canyon and Pueblo Canyon. Hydrogeochemical parameters typically required to assess potential sedimentary and solute transport of contaminants include organic carbon content, porosity and bulk density, distribution coefficients, retardation factors, and cation exchange capacities.

Estimates of soil erosion by surface water transport, contaminant concentrations, and the available contaminant source inventories in the soil and sediments within Los Alamos Canyon and Pueblo Canyon help assess the importance of sediment transport of contaminants. Lane et al. (1985, 6604) provide methods to estimate these parameters. The test case modeling and evaluations in that study were performed for the Los Alamos Canyon and Pueblo Canyon watersheds using data developed for the Formerly Utilized Sites Remedial Action Program (FUSRAP) study (LANL 1981, 6059).

3.3.3 Previous Sediment Sampling

Environmental data on soils, sediments, surface waters, and ground waters have been collected at the Laboratory and published since 1945. Until 1949 these data were gathered almost exclusively in Los Alamos Canyon and Pueblo Canyon. The United States Geological Survey (USGS) monitored the effects of releases of radioactive effluents and conducted geohydrological studies in the Laboratory area for the Atomic Energy Commission (AEC) from 1949 through 1971.



Source: Nyhan et. al. 1978, 5702

Figure 3-2. Soils map of Los Alamos Canyon and surrounding area.

Results of these studies are available in a series of reports and publications (references compiled by Bennett [1990, 7507]). Starting in 1970 the Laboratory initiated a formal environmental monitoring program. That monitoring program, which is required by DOE Order 5400.1 (DOE 1988, 0075), continues under the direction of the Laboratory's Environment, Safety, and Health (ESH) Division.

Since 1971, surveillance and monitoring data have been published annually by the Laboratory in a formal report. The annual reports through 1989 contained data collected in the previous year. Since 1989, these reports have contained data collected two years previously. Earlier reports cited the data compilers as authors. Much of the data used in this section was taken directly from those reports. For brevity, annual reports of surveillance data are cited hereafter as Environmental Surveillance Group (ESG) and the date or date range of the annual surveillance report(s) containing the data used, for example (ESG 1971–1995).

3.3.3.1 Environmental Surveillance Program

Sediments in Los Alamos Canyon and Pueblo Canyon are sampled as part of the Laboratory-wide routine environmental monitoring program. Locations of the existing sediment sampling stations in Los Alamos Canyon and its tributary, DP Canyon, and Pueblo Canyon and its tributary, Acid Canyon, are shown in Figure 3-3. In the 1950s the USGS established sediment stations in Los Alamos Canyon from the Los Alamos Canyon bridge to the Rio Grande, which were sampled at irregular intervals until approximately 1970 and have been sampled annually since then.

Sediment stations were also established by the USGS in Acid Canyon and Pueblo Canyon and have been sampled regularly since 1954. The number of stations was reduced substantially after active discharges were discontinued in the early 1960s. The frequency of sampling declined through the 1980s, and presently the stations in the monitoring network are sampled annually.

Table 3-1 lists the radionuclide concentrations in sediments collected from Los Alamos Canyon and DP Canyon between 1980 and 1992. The samples were collected at 11 of the locations shown in Figure 3-3. These data are also presented in Figures 3-4 and 3-5, where concentrations and activities are plotted as a function of sample location in Los Alamos Canyon and its tributary, DP Canyon. These data indicate an increase (relative to background levels) in radionuclide content (^{137}Cs, ^{238}Pu, ^{239,240}Pu, and ^{241}Am) of sediments downstream from TA-2 and TA-41. (Note that the isotopes ^{239}Pu and ^{240}Pu are difficult to distinguish by normal alpha spectrometric methods because the energies of the alpha emissions are very close. Therefore, plutonium activities reported as ^{239}Pu, ^{240}Pu, or ^{239,240}Pu are effectively the sum of the two isotopes, unless specifically stated to be otherwise.)

Because most downstream sampling stations include inputs from both Los Alamos Canyon and DP Canyon, data for DP Canyon help identify the contributions from areas adjacent to Los Alamos Canyon, such as TA-21, which also borders DP Canyon. The ESG reported that the plutonium activity in the active channel of upper Los Alamos Canyon (west of state road 4) varied seasonally by location. The existing sediment data (Table 3-1) indicate that ^{90}Sr exceeds background levels measured in Los Alamos Canyon at the bridge (LANL 1981, 6059) but are below regional background levels (Figure 3-4). Figures 3-4 and 3-5 show average concentrations of radionuclides in sediments in Los Alamos Canyon and the tributary, DP Canyon, in the sampling years 1984 through 1988.

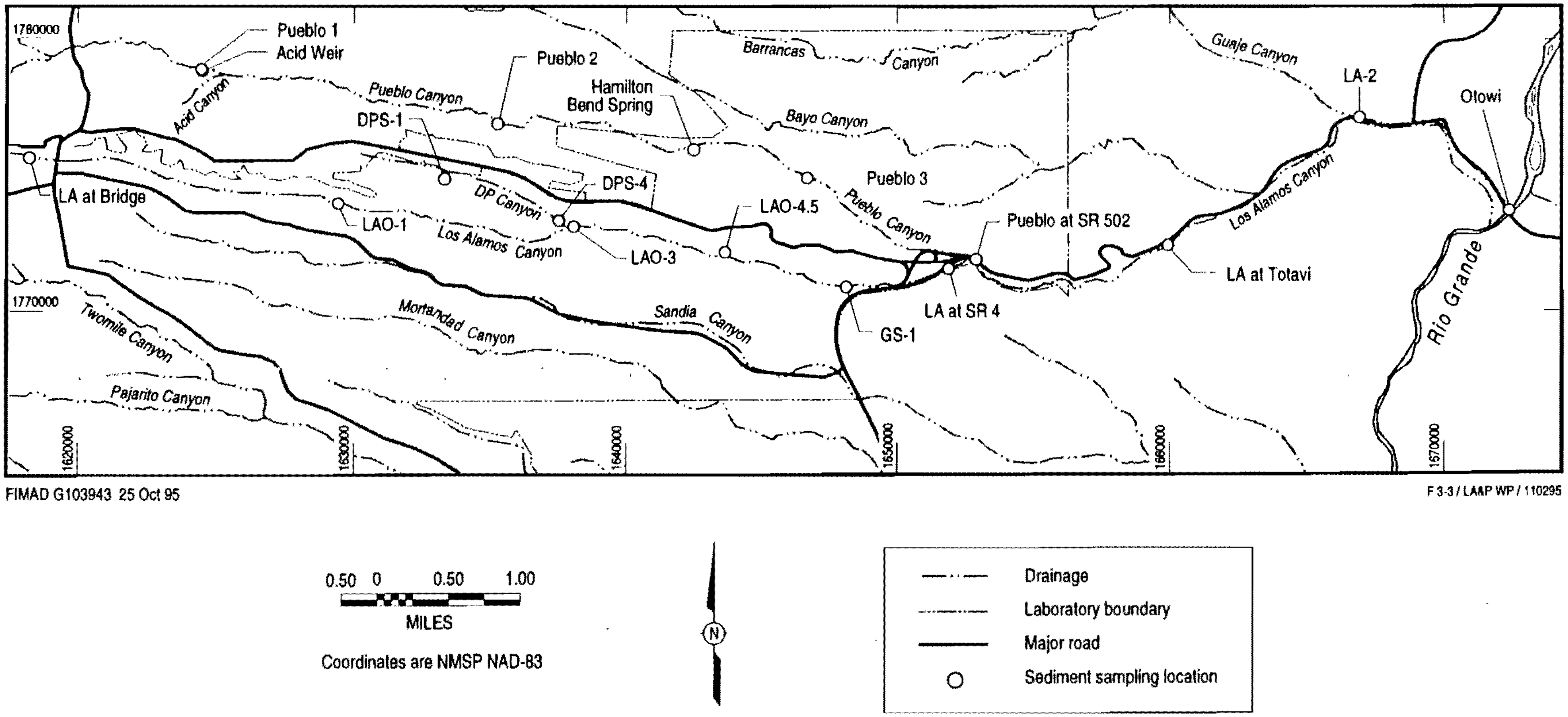


Figure 3-3. Sediment sampling locations in DP Canyon, Pueblo Canyon, and Los Alamos Canyon.

TABLE 3-1

SUMMARY OF RADIOCHEMICAL ANALYSES OF SEDIMENTS IN LOS ALAMOS CANYON AND DP CANYON 1980–1992[a]

Location	^{90}Sr (pCi/g)	^{137}Cs (pCi/g)	Total U (μg/g)	^{238}Pu (pCi/g)	^{239,240}Pu (pCi/g)	^{241}Am (pCi/g)[b]
DPS[c]-1	4.4 ± 5.7	7.5 ± 9.2	8.6 ± 18	0.75 ± 1.0	2.0 ± 2.7	6.3 ± 11
DPS-4	1.3 ± 0.8	8.6 ± 7.1	2.5 ± 1.0	0.092 ± 0.059	0.31 ± 0.15	1.1 ± 1.4
Los Alamos @ Bridge	0.13 ± 0.19	0.16 ± 0.11	2.4 ± 0.75	0.029 ± 0.10	0.0051 ± 0.0092	−0.11 ± 0.44
Los Alamos @ LAO-1	0.42 ± 0.38	3.0 ± 4.3	2.9 ± 1.3	0.068 ± 0.089	0.38 ± 0.29	0.37 ± 0.65
Los Alamos @ GS-1	0.16 ± 0.17	0.39 ± 0.59	2.8 ± 0.94	0.0054 ± 0.0065	0.69 ± 1.1	0.20 ± 0.51
Los Alamos @ LAO-3	0.40 ± 0.32	2.4 ± 2.6	3.1 ± 2.9	0.031 ± 0.026	0.22 ± 0.14	0.33 ± 0.46
Los Alamos @ LAO-4.5	0.53 ± 0.42	5.1 ± 7.6	3.6 ± 1.1	0.091 ± 0.092	0.45 ± 0.44	0.41 ± 1.3
Los Alamos @ SR 4	0.43 ± 0.37	2.9 ± 2.2	2.8 ± 1.1	0.047 ± 0.037	0.24 ± 0.21	0.62 ± 0.73
Los Alamos @ Totavi	0.23 ± 0.22	1.3 ± 2.2	3.1 ± 1.0	0.015 ± 0.018	0.25 ± 0.27	−0.24 ± 1.0
Los Alamos @ LA-2	0.46 ± 0.88	0.46 ± 0.43	2.4 ± 0.78	0.0067 ± 0.0074	0.22 ± 0.27	0.28 ± 0.76
Los Alamos @ Otowi	0.18 ± 0.19	0.39 ± 0.38	2.2 ± 0.66	0.0081 ± 0.011	0.14 ± 0.15	−0.25 ± 0.82

a. Values reported are mean ± one standard deviation.
b. Most values for ^{241}Am are strongly skewed by data from 1987.
c. DPS means DP Canyon surface water station.

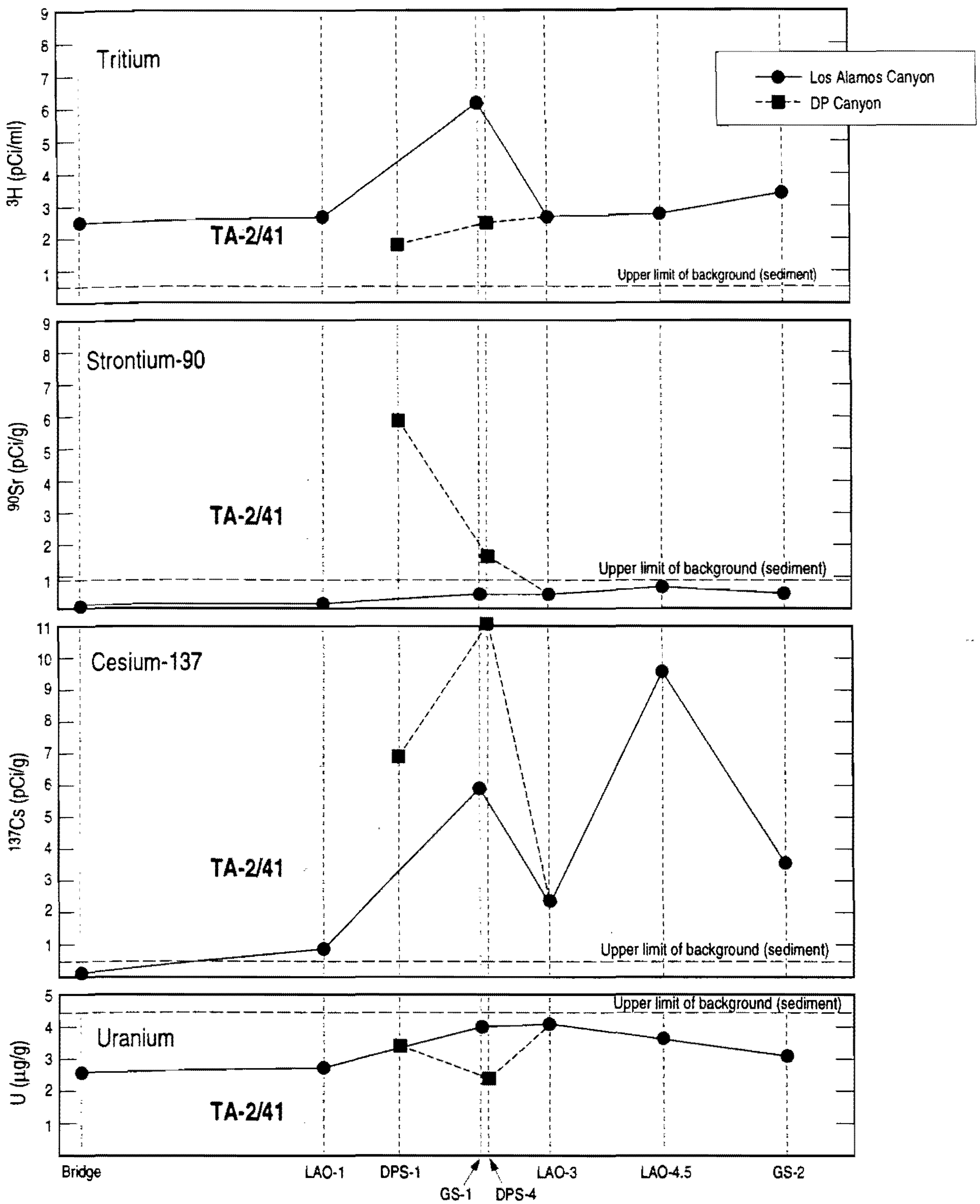
(ESG 1981–1994)

3.3.3.2 Geomorphic Studies

A geomorphic study completed in 1991 (Graf 1993, 23251; Graf 1995, 48851) provides a historic perspective to evaluate the contributions of plutonium from Los Alamos Canyon to the Rio Grande. The study used historic aerial photography and hydrologic data to evaluate the movement and deposition of sediment over time. Several conclusions were made regarding the regional balance of deposited plutonium in the sediment from 1948 to 1985, accounting for both worldwide fallout and the Laboratory contribution from Los Alamos Canyon to the northern Rio Grande.

- Worldwide fallout accounts for more than 90% of the plutonium in the Rio Grande system; the Laboratory contributes slightly less than 10%.
- It is estimated that approximately half the total plutonium in the Rio Grande system resides in sediment along the Rio Grande; the remaining is stored in sediments in the Elephant Butte Reservoir.
- Most of the Laboratory contributions remain in storage along the Rio Grande between the mouth of Los Alamos Canyon and Peña Blanca (just downstream from Cochiti Dam). Since 1973 the downstream movement has ended in Cochiti Reservoir.

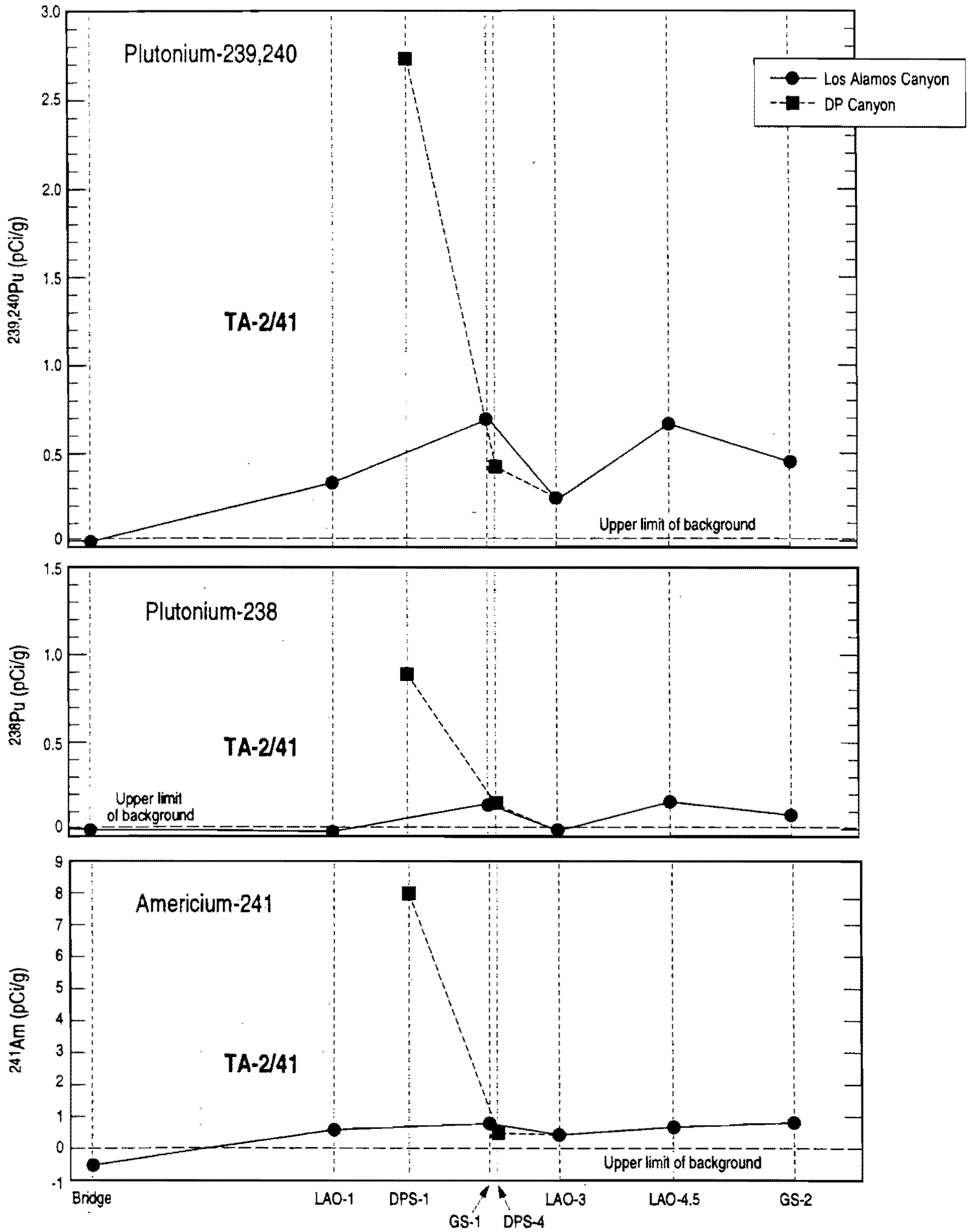
The geomorphic study identified locations where sediments had been deposited during specific periods. A sediment sample was collected from a floodplain near



Sources: ESG 1985, 6610; ESG 1986, 6626; ESG 1987, 6678; ESG 1988, 6877; ESG 1989, 6894

F 3-4 / LA&P WP / 112495

Figure 3-4. Data from sediment samples collected in Los Alamos Canyon and DP Canyon.



Sources: ESG 1985, 6610; ESG 1986, 6626; ESG 1987, 6678; ESG 1988, 6877; ESG 1989, 6894

F 3-5 / LA&P WP / 111895

Figure 3-5. Data from sediment samples collected in Los Alamos Canyon and DP Canyon.

Buckman (near Cañada Ancha and east of the mouth of Sandia Canyon; see Figure 1-2 in Chapter 1 of this work plan) that was hydrologically active between 1941 and 1968. The sample was collected specifically for the analysis of plutonium isotopes by high-sensitivity mass spectrometry. The ratio of ^{239}Pu to ^{240}Pu in the sample indicated that the plutonium consisted of an equal mixture of worldwide fallout and Laboratory-produced material transported through Acid Canyon, Pueblo Canyon, and Los Alamos Canyon. The total activity of the two plutonium isotopes (0.017 pCi/g) was less than the average value for fallout in northern New Mexico (0.023 pCi/g) (Purtymun et al. 1987, 6687). Thus, only the isotopic ratio, not an elevated concentration, identified the contribution as being from historic Laboratory releases.

Figure 3-6 shows the 13-year trend of concentrations (as activities) of total plutonium in samples taken from four stream channel locations extending eastward from Acid Canyon through Pueblo Canyon and Los Alamos Canyon to the Rio Grande. The concentrations show no systematic variations over time, although samples collected from individual stations can show significant year-to-year variability. The causes of the variability are unknown. However, it is possible that concentrations return to the trend-line values after variation because the larger inventories of plutonium in out-of-channel sediments are moved into the channels by erosion during large storms, thus re-supplying contaminated sediments at the channel sampling locations.

In later work, Graf (1995, 48851) assembled measured plutonium concentrations at several locations throughout the Los Alamos Canyon system (including Pueblo Canyon). Mean concentrations (Figure 3-7) show that plutonium concentrations in sediments generally decline by about two orders of magnitude from the historic source in Acid Canyon to the Rio Grande.

3.3.3.3 FUSRAP Study

The first significant amount of radioactivity released from the Laboratory was discharged as untreated wastewater into the areas of Acid Canyon, Pueblo Canyon, and Los Alamos Canyon in late 1943 or early 1944 (LANL 1981, 6059). The releases into Acid Canyon and Pueblo Canyon as treated wastewater (after 1951) continued until 1964 as described in Chapter 2 of this work plan; releases into Los Alamos Canyon as treated wastewater continue to the present.

In the late 1970s the DOE conducted activities under the FUSRAP to evaluate and remedy the effects of contamination by Laboratory operations in and adjacent to Acid Canyon, Pueblo Canyon, and Los Alamos Canyon (LANL 1981, 6059). The FUSRAP focused remedial action on locations at and beneath the untreated effluent discharge point at Acid Canyon (used from 1943 through April 1951) and the radioactive liquid waste treatment plant constructed at that location (former TA-45 used from June 1951 until June 1964). In 1982 some additional remediation (soil removal) was carried out at those locations (Gunderson et al. 1983, 6411).

Former TA-45 and portions of Acid Canyon have been investigated further within the Environmental Restoration (ER) Project. In 1993 field sampling was conducted in OU 1079. The results of that investigation will be used to interpret data gathered from the downstream canyon areas during this investigation.

The FUSRAP study involved the collection of samples for analysis of radionuclides from approximately 300 locations in Los Alamos Canyon and Pueblo Canyon. The sampling effort included many sediment transects across the stream channels and onto the adjacent banks (floodplain and terrace deposits) to provide a basis for

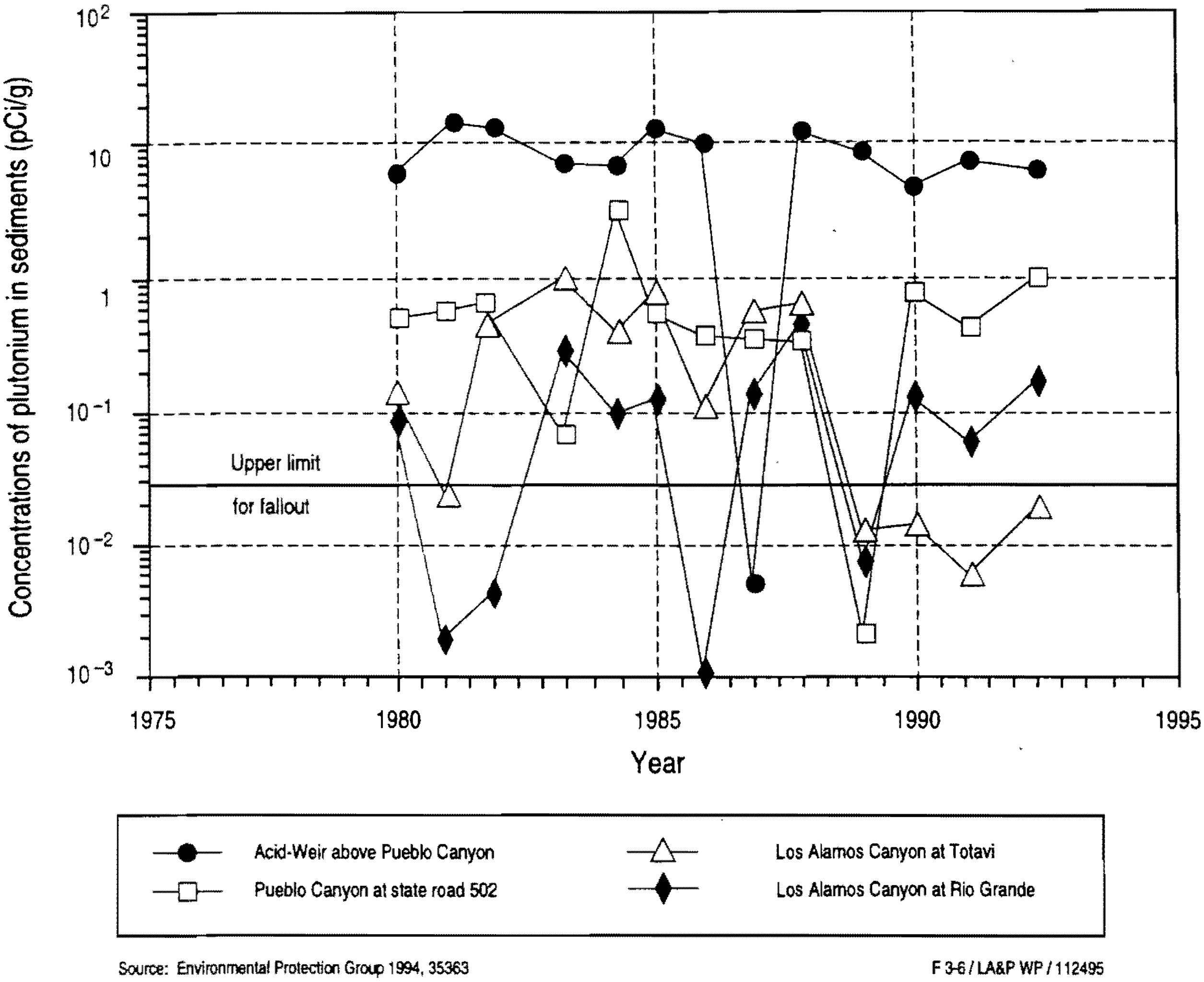
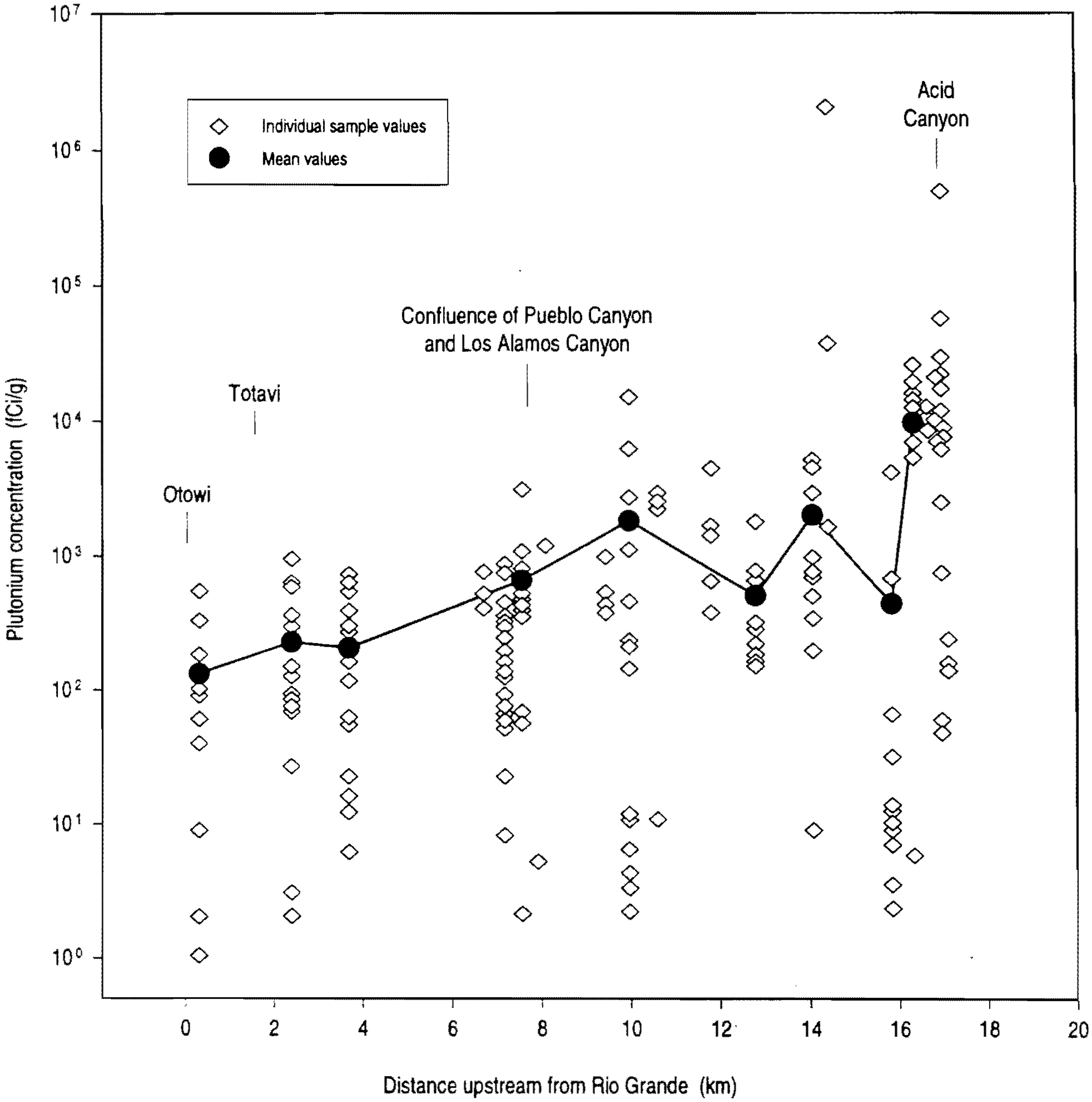


Figure 3-6. Total plutonium concentrations in sediments.



Source: Graf 1995, 48851

F 3-7 / LA&P WP / 110295

Figure 3-7. Relationship between downstream distance and plutonium concentration for bedload sediments throughout the Los Alamos Canyon system.

estimating hydrologically active and inactive inventories of contaminants. Figure 3-8 summarizes the ^{239}Pu concentrations (^{239}Pu is the predominant isotope present) found in the FUSRAP studies in transects in five reaches from the former discharge point down Pueblo Canyon to the Rio Grande. The following results are specifically relevant to this investigation (LANL 1981, 6059).

- Plutonium is present at levels above background in all the channels and banks from the discharge points in Acid Canyon, through middle and lower Pueblo Canyon, and in lower Los Alamos Canyon.
- Plutonium activities in the channels and banks generally decline with increasing distance from the discharge points.
- The banks have higher plutonium activity than the channels in given intervals, except at the source where the outfall channel has highest plutonium activities (Figure 3-8).

Within the Los Alamos Canyon and Pueblo Canyon segments, the affected areas are between approximately 7.5 and 115 ft wide and have a total length of approximately 10.9 mi.

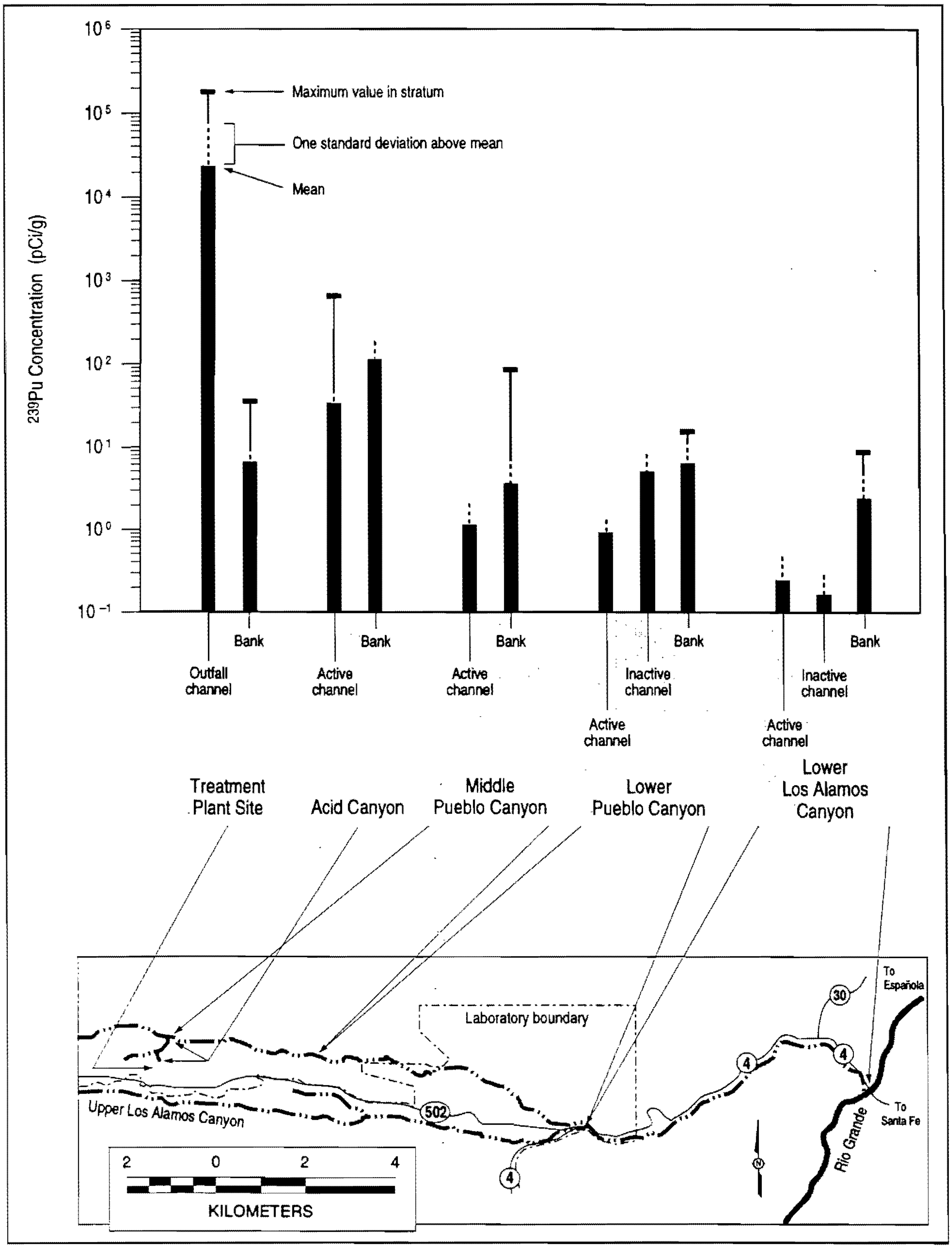
The ^{239}Pu inventories in Acid Canyon, Pueblo Canyon, and lower Los Alamos Canyon (Figure 3-9) were estimated as the product of the average radioactivity in the channels and banks of each segment and the estimated mass of affected sediments and soils. These estimates were derived from measured physical dimensions and average densities (LANL 1981, 6059).

Most of the plutonium inventory was found to be associated with the banks and inactive channels that accumulate finer-grained sediments having larger surface areas per unit mass than coarser-grained materials. This distribution could be due to a number of factors. Sediments with the highest levels of contaminants (deposited between 1944 and 1970) may have been stored in the banks and inactive channels, which are less often inundated than the active channels. Also, the finer grained bank sediments may contain higher concentrations of plutonium than the coarser grained channel sediments (Graf 1993, 23251; Graf 1995, 48851).

Approximately 67% of the total plutonium inventory was found in lower Pueblo Canyon. This large proportion results in part from the large area and the volume of inactive channel deposits. The plutonium concentrations are lower there than further upstream, but the valley is wider; increases in channel width and decreases in channel gradient have lead to extensive deposition of young sediments.

In addition to ^{239}Pu, the transuranic radioactive isotopes present include ^{238}Pu, ^{240}Pu, and ^{241}Am (LANL 1981, 6059). Other radionuclides with activities significantly above background included ^{90}Sr, ^{137}Cs, and total uranium. Data for these constituents are summarized in Table 3-2 (LANL 1981, 6059).

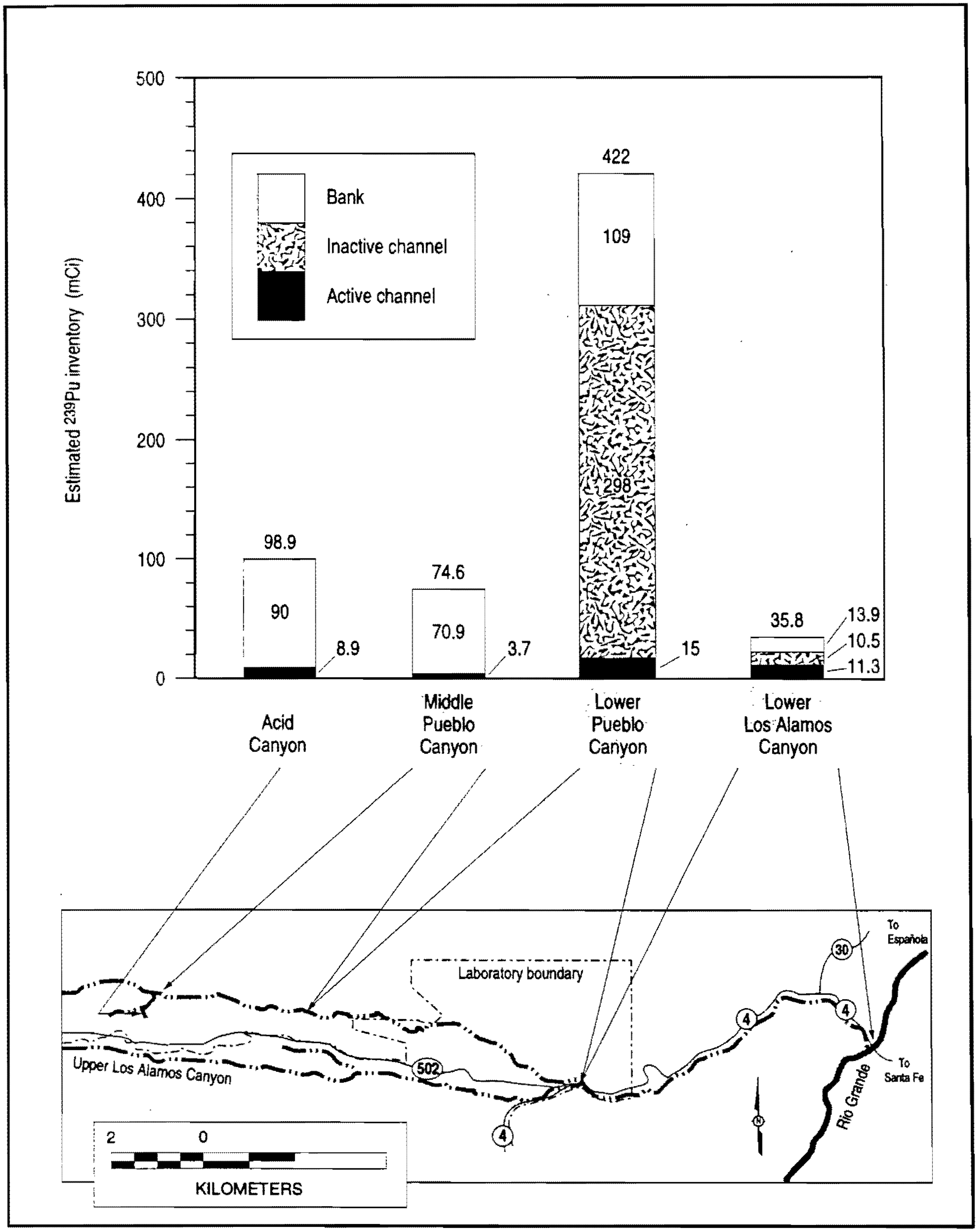
The total estimated inventory of ^{239}Pu in Acid Canyon, Pueblo Canyon, and Los Alamos Canyon (based on the arithmetic means of area, thickness, and activity) is 630 ± 300 mCi (95% confidence interval) or 7.9 ± 3.8 g (LANL 1981, 6059). Based on detailed geomorphic mapping and the FUSRAP plutonium data, Graf has estimated a revised plutonium inventory in Pueblo Canyon of ~1000 mCi (~12.5 g) (Graf 1995, 48851), which is consistent with the previous estimates. However, the FUSRAP report cited estimated releases into Pueblo Canyon of approximately 1.9 g of plutonium in untreated waste and another 0.34 g from the treatment plant at former TA-45. The estimate of untreated waste is considerably less precise than the estimate for the



Source: LANL 1981, 6059

F 3-8 / LA&P WP / 110295

Figure 3-8. Plutonium concentrations in sediments of Pueblo Canyon and lower Los Alamos Canyon.



Source: LANL 1981, 6059

F 4.3-6 / LA&PUEBLO WP / 110295

Figure 3-9. Estimated inventory of ^{239}Pu on soils and sediments by location.

TABLE 3-2

SUMMARY OF DATA ON RADIONUCLIDE CONCENTRATIONS AND INVENTORY

Stratum	Treatment plant site (former TA-45) Subsurface	Treatment plant site (former TA-45) Surface	Acid Canyon Surface	Middle Pueblo Canyon	Lower Pueblo Canyon	Lower Los Alamos Canyon	Northern New Mexico Background Concentrations
Radioactivity Concentrations ($x \pm s$)[a]							
^{239}Pu (pCi/g)							0.008 ± 0.010
Maximum in stratum	35	163000	630	88	15.5	9.3	
Average in active channel	6.3 ± 10.6		31 ± 29	1.1 ± 1.1	0.9 ± 0.5	0.24 ± 0.26	
Average in inactive channel			—	—	5.1 ± 3.6	0.15 ± 0.18	
Average in banks		21000 ± 49000	110 ± 75	3.5 ± 4.0	6.4 ± 5.8	2.3 ± 3.0	
Other Isotopes							
Concentration increment above background							
^{90}Sr (pCi/g)	0.1–10 (range)	0.5–230 (range)	1.0 ± 1.4	NS[b]	NS	NS	0.25 ± 0.27
^{137}Cs (pCi/g)	0–3 (range)	0.1–180 (range)	1.9 ± 4	NS	NS	0.27 ± 0.18	0.32 ± 0.30
Uranium (pCi/g)	1–36 (range)	1–600 (range)	1.3 ± 1	NS	1.1 ± 0.6	2.0 ± 0.6	0.8 ± 1.3
^{239}Pu Inventory Estimate							
Stratum inventory (mCi, $x \pm 2s_x$)[c]			98.9 ± 52	74.6 ± 83.4	422 ± 281	34.8 ± 19.9	
Percent of total (%)			15.7	11.8	66.8	5.7	
Distribution in stratum							
Active channel (%)			9	5	4	32	
Inactive channel (%)			—	—	70	29	
Bank (%)			91	95	26	39	
Physical Characteristics							
Channel length (m)			750	3250	6050	7400	
Average width (m)			2.3	15	33	35	
Area with greater than background concentration (m^2)	~3500	~500	~1750	~50000	~200000	~26000	

a. s denotes the standard deviation of the data population; in this particular table, the numerical value of $x \pm s$ may be taken to represent the confidence interval on the mean with at least 95% confidence.
b. NS means no significant difference.
c. s_x denotes the standard error of the calculated estimate; in this row $\pm 2s_x$ may be taken as an approximate 95% confidence interval of the estimate.

(LANL 1981, 6059)

treatment plant because no actual measurements were made of the radionuclide content or the quantity of untreated waste. Another 32 mCi (0.40 g) of ^{239}Pu was released into DP Canyon from TA-21 (LANL 1981, 6059). The uncertainties are large; therefore, it is difficult to resolve the discrepancy between the two estimates (less than 3 g vs. approximately 8 g).

Data from other studies suggest that at least 75% of the plutonium released into DP Canyon between 1950 and 1977 has been transported into lower Los Alamos Canyon above the Rio Grande (LANL 1981, 6059). Such an interpretation is tentative because DP Canyon and Los Alamos Canyon have not been characterized as extensively as Pueblo Canyon.

These results indicate that radionuclide contaminant levels are commonly above regional background levels in Los Alamos Canyon and Pueblo Canyon, although a few sampling locations showed levels at background. The distribution of sediment contamination is highly discontinuous and may be seasonally variable. Evaluation of sediment flux in response to large runoff events in the 1970s and 1980s suggests that radionuclides have been redistributed between the major canyon reaches during the 18 to 19 years since the FUSRAP data were collected (the late 1970s). The effluent from the Los Alamos County sewage treatment plant has also transported radionuclides, as indicated by surveys in the 1990s. These studies are discussed in greater detail in Section 3.5.1. Despite this transport, measured levels of total plutonium in stream sediments have not changed significantly since 1980, as shown in Figure 3-6.

3.4 Geology

Section 2.5 of the IWP discusses the regional setting and general geology of the Pajarito Plateau (LANL 1995, 49822). The following discussion pertains to the geology in Pueblo Canyon and upper Los Alamos Canyon within the Laboratory boundaries.

3.4.1 Stratigraphy

Los Alamos Canyon and Pueblo Canyon lie on the east flank of the Jemez volcanic field and the active west margin of the Española basin of the Rio Grande rift (Figure 3-10). The bedrock units that crop out on the floors of these canyons are listed below in ascending order.

1. The Santa Fe Group (4 to 21 Myr [million years]) (Manley 1979, 11714)
2. The Tschicoma Formation (2.53 to 6.7 Myr) (Dalrymple et al. 1967, 49924)
3. The Puye Formation (1.7 to 4 Myr) (Turbeville et al. 1989, 21587; Spell et al. 1990, 21586)

   Interstratified volcanic rocks including the Tschicoma Formation on the west (2 to 7 Myr) and the Cerros del Rio basalts on the east (2 to 3 Myr) (Gardner and Goff 1984, 44021)
4. The Otowi Member of the Bandelier Tuff (1.613 ± 0.011 Myr) (Izett and Obradovich 1994, 48817)
5. Epiclastic sediments and tephras of the Cerro Toledo interval

   The age of this unit is bracketed by the ages of the Otowi Member (1.613 Myr) and the Tshirege Member (1.223 Myr) of the Bandelier Tuff.
6. The Tshirege Member of the Bandelier Tuff (1.223 ± 0.018 Myr) (Izett and Obradovich 1994, 48817)

A geologic map showing the distribution of these bedrock units in Los Alamos Canyon and Pueblo Canyon is shown in Figure 3-11. Bedrock geologic maps for the Pajarito Plateau and surrounding areas have been published by Smith et al. (1970, 9752) and

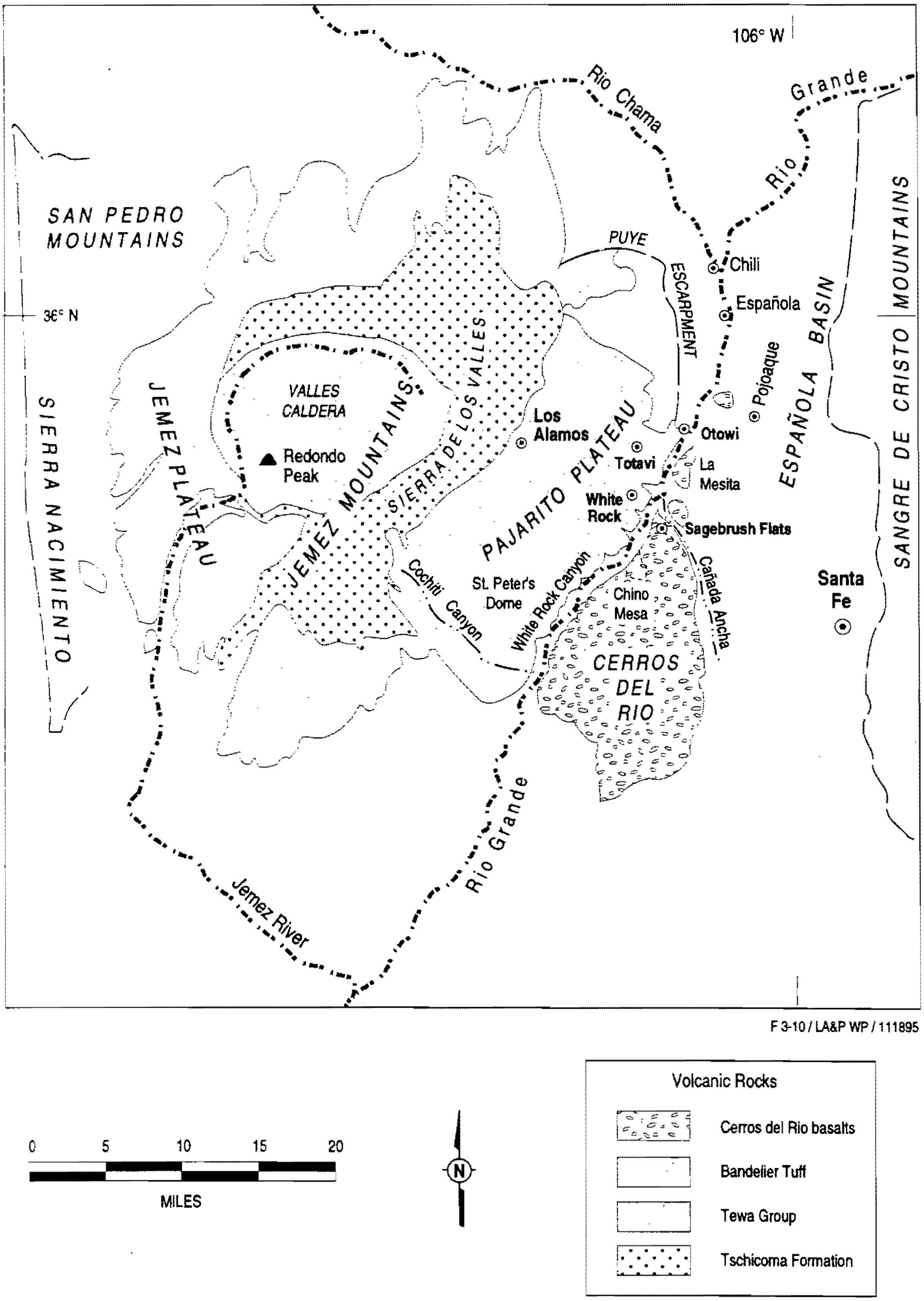


Figure 3-10. General geographic location, topographic features, and simplified geologic units in the vicinity of Los Alamos.

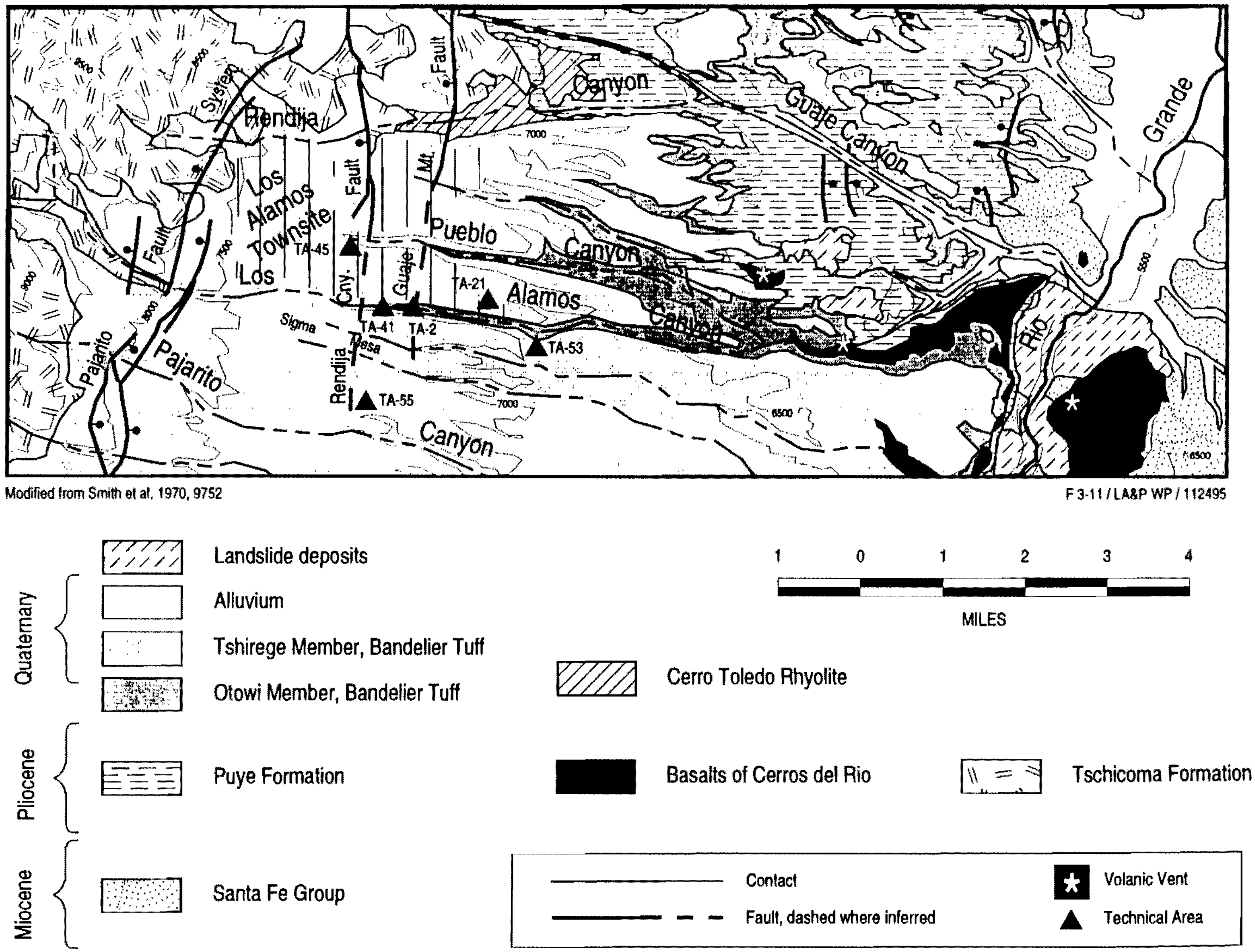


Figure 3-11. Distribution of bedrock units in Los Alamos Canyon and Pueblo Canyon.

Griggs (1964, 8795). Figure 3-12 illustrates the thicknesses of the major bedrock units in the vicinity of upper Los Alamos Canyon by lithologic logs of three wells.

3.4.1.1 Santa Fe Group

Rocks of the Santa Fe Group crop out in lower Los Alamos Canyon east of Totavi (Figure 3-10) near the mouth of Guaje Canyon (Figure 3-11). They consist predominantly of gray to tan to pale orange arkosic fluvial sandstone, siltstone, and conglomerate with subordinate eolian deposits, ash beds, and lacustrine rocks. Galusha and Blick (1971, 21526) subdivided the Santa Fe Group into formations and members based on geologic mapping and faunal assemblages of late Tertiary mammals. Manley (1979, 11714) refined their stratigraphy based on additional mapping and dates on interbedded volcanic ash layers, lava flows, and dikes. The description herein follows the nomenclature of Galusha and Blick (1971, 21526) as modified by Manley (1979, 11714).

In the vicinity of the Pajarito Plateau, the Santa Fe Group consists of, in ascending order, the Tesuque Formation and the overlying Chamita Formation. The Tesuque Formation contains clastic rocks derived primarily from Precambrian basement and Tertiary volcanic sources to the east and northeast of the Española Basin and has an age range of about 7 to 21 Myr (Manley 1979, 11714; Cavazza 1989, 21501). The Tesuque Formation exposure nearest to the Laboratory occurs at the base of the Jemez volcanic field on the east side of St. Peter's Dome and on the west edge of the Pajarito fault zone on the southwest Pajarito Plateau (see Figure 3-10). This exposure is overlain by 13-Myr-old rhyolite tuff of the Keres Group (an older group of volcanic rocks exposed in the southern Jemez Mountains) (Gardner 1985, 48812) and is interbedded with 16.5-Myr-old basalt (Goff et al. 1990, 21574). The Tesuque Formation, located farther northeast in the Pojoaque area, has interbedded tephra that is 9 to 14 Myr old (Manley 1979, 11714). To the north in the Chili Quadrangle the Tesuque Formation is cut by dikes and interbedded with basalt flows that are approximately 9 to 12 Myr old (Dethier and Manley 1985, 21506). Cavazza (1989, 21501) states that the aggregate thickness of the Tesuque Formation is greater than 2000 m and shows the unit thickening to the west.

The Chamita Formation is considered by some geologists to be representative of axial deposits of an ancestral Rio Grande rift. Chamita deposits thicken toward the west side of the Española Basin and overlie and interfinger with the Tesuque Formation. Older Chamita deposits are seldom exposed because they are generally covered by volcanic rocks of the Jemez Mountains and Pajarito Plateau. Nonetheless, Aldrich and Dethier (1990, 49681) imply that the Chamita Formation north of the Pajarito Plateau may be as old as 12 Myr. Paleomagnetic data in the area limit the Chamita Formation to an age range of 4.5 to 6 Myr (MacFadden 1977, 21569); tephra dates by Manley (1979, 11714) support a younger age of about 5 Myr for at least part of the formation. Chamita Formation deposits are similar in appearance to Tesuque Formation deposits, but the former contains a larger proportion of Paleozoic limestone cobbles in its conglomerate layers (Dethier and Manley 1985, 21506). Upper layers of the Chamita Formation may contain cobbles of Jemez volcanic rocks, primarily andesites and dacites. However, because of similarities of appearance, obvious time overlaps, and interfingering relations, differentiating between Chamita and Tesuque deposits is often difficult.

Griggs (1964, 8795) stated that the Tesuque Formation is the Santa Fe Group that is exposed around the flanks of the Pajarito Plateau and intersected by water wells in the Los Alamos area. This stratigraphic assignment was continued by Purtymun and

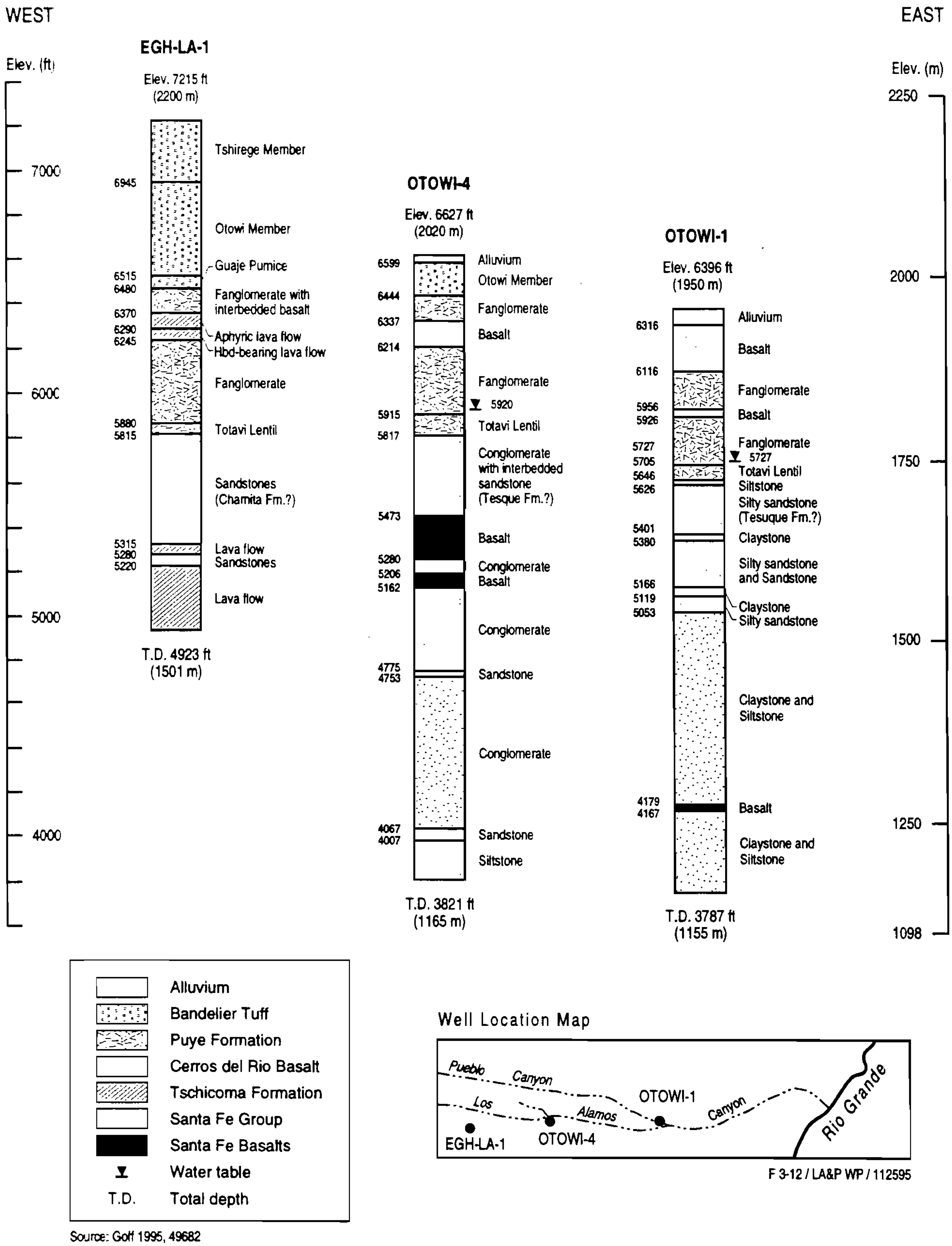


Figure 3-12. Lithologic logs for three wells in upper Los Alamos Canyon.

Johansen (1974, 11835) and Abeele et al. (1981, 6273) in their studies for the Laboratory. However, C. Potzick from the Laboratory (see Purtymun 1995, 45344, Table XVII-B) identified the uppermost Santa Fe Group beneath Sigma Mesa (see Figure 3-10) as the Chamita Formation. Similar interpretations were proposed by Turbeville et al. (1989, 21587) based on their examination of deposits in Guaje Canyon and lower Los Alamos Canyon. Griggs (1964, 8795, Fig. 9) shows two distinct Santa Fe Group rock types in the stratigraphic sections of five deep water wells in Guaje Canyon. According to present criteria, the upper unit would appear to be the Chamita Formation. In the Guaje Canyon area, the Chamita Formation is apparently 200 to 250 m thick; beneath Sigma Mesa it is at least 180 m thick.

Griggs (1964, 8795) and Purtymun and Johansen (1974, 11835) show many Cerros del Rio basalt flows and flow breccias interbedded with Santa Fe Group deposits, particularly near the east side of the Pajarito Plateau. Farther west Potzick has identified only dacitic and andesitic flows, possibly of the Polvadera Group (1.9- to 7-Myr-old dacitic lavas that make up the Sierra de los Valles) interbedded in the Santa Fe Group. None of these volcanic units have been dated; therefore, the ages of the Chamita and Tesuque deposits beneath the Pajarito Plateau are unknown.

3.4.1.2 Tschicoma Formation

The Tschicoma Formation of the Polvadera Group makes up the rugged highlands west of Los Alamos and is exposed extensively throughout the headwaters of Los Alamos Canyon and Pueblo Canyon. The Tschicoma Formation has been penetrated by wells in the western part of the Pajarito Plateau and is exposed as a small inlier on the floor of Pueblo Canyon downstream from TA-45.

The Tschicoma Formation consists of numerous thick lava flows derived from a series of overlapping dome complexes that predate the Bandelier Tuff. Ignimbrites and ash deposits are also present, but they are volumetrically important only in distal exposures of the Tschicoma Formation. The formation is thickest (up to 2500 ft) in the area of the drainage divide, but flow units are lenticular and thicknesses are highly variable. The Tschicoma Formation thins eastward beneath the Bandelier Tuff on the Pajarito Plateau and interfingers with the Puye Formation with which it is penecontemporaneous.

Tschicoma lava flows range in composition from andesite to low-silica rhyolite. The rocks are mainly gray to purplish gray, but in places they are reddish brown. Jointing is pronounced, and the bottoms of flows are commonly marked by blocky breccia. The flows commonly are devitrified and have a stony appearance; however, chilled glassy margins are present at the tops and bottoms of some flows.

Radiometric ages for the Tschicoma Formation range between 3.7 and 6.7 Myr (Dalrymple et al. 1967, 49924). Turbeville et al. (1989, 21587) report an age of 2.53 Myr for a Tschicoma ignimbrite intercalated in the Puye Formation. In the northern part of the Jemez volcanic field, the age is further bracketed by the underlying Lobato Basalt (7.4 Myr) and the overlying El Rechuelos rhyolite (2.0 Myr) (Turbeville et al. 1989, 21587).

3.4.1.3 Totavi Formation

The Totavi Formation (referred to until recently as the Totavi Lentil, as shown in Figure 3-12) is exposed at Totavi and areas to the east in lower Los Alamos Canyon. The Totavi Formation overlies the Chamita Formation and is a coarse, poorly consolidated conglomerate containing cobbles and boulders composed primarily of quartzite, granite, and pegmatite. Griggs (1964, 8795) described these deposits as the Totavi Lentil, which is defined as the basal unit of the Puye Formation (described in Section 3.4.1.4) based on conformable bed relations with overlying fanglomerate layers. However, the rock types of the cobbles and the arkosic sandy matrix support the argument that these deposits are more akin to the Chamita Formation than to the Puye Formation. Turbeville et al. (1989, 21587) assigned Totavi deposits formational rank because of their unique rock types and depositional environments compared with overlying and underlying units. A consensus exists among present workers that the Totavi Formation represents ancestral Rio Grande channel gravels; therefore, it would be expected to be unconformable with the finer grained sediments of the Chamita Formation beneath.

The Totavi Formation is intersected by no fewer than nine of the water wells and test holes in the Los Alamos area that were studied by Griggs (1964, 8795). The unit apparently thickens in a northwest direction beneath the Pajarito Plateau. Totavi deposits are 20 m thick beneath Sigma Mesa and nearly 30 m thick beneath Pueblo Canyon. Few dates exist to determine the age of the Totavi Formation. A fission track age of 2.9 Myr was obtained by Manley (1979, 11714) from an ash bed in the lower part of the Puye Formation. In lower Los Alamos Canyon the Totavi Formation is overlain by lacustrine beds and a Cerros del Rio basalt flow and pillow-palagonite complex dated at 2.4 Myr. Turbeville et al. (1989, 21587) argue that the Puye Formation is probably no older than 3.5 Myr. Therefore, the Totavi deposits were probably laid down between 2.4 and 3.5 Myr ago. According to Griggs (1964, 8795, p. 31), the Totavi Formation deposits are interbedded between two dacite flows of the Tschicoma Formation beneath Los Alamos Canyon, which suggests that localized deposits could be dated.

3.4.1.4 Puye Formation

The Puye Formation crops out in Pueblo Canyon in the vicinity of the Los Alamos County sewage treatment plant and throughout lower Los Alamos Canyon east of the confluence with Pueblo Canyon. The Puye Formation is an extensive volcanogenic alluvial fan complex shed eastward from the Tschicoma volcanic center of the Polvadera Group. The Puye Formation was described by Griggs (1964, 8795) and mapped by Griggs and by Smith et al. (1970, 9752). The unit is well exposed north of Los Alamos Canyon and is intersected by all the deep water wells in the northern Pajarito Plateau (Dransfield and Gardner 1985, 6612).

The Puye Formation is distributed over an area of 200 km^2 and contains approximately 15 km^3 of volcaniclastic material deposited primarily between 1.9 and 3.5 Myr ago. Because Puye Formation deposits are penecontemporaneous with the Tschicoma Formation, they may be as old as 7 Myr and as young as 1.5 Myr. Most of the Puye Formation conglomerates contain cobbles of dacitic to andesitic composition in a volcanic sand matrix. At least 25 ash beds of dacitic to rhyolitic composition are interbedded within the fanglomerates (Turbeville et al. 1989, 21587). Basaltic ash beds and lacustrine deposits are common on the east side of the deposit. The fanglomerates display considerable lateral variation and are complex, intertonguing mixtures of stream flow, sheet flow, debris flow, block and ash flow, pumice fall, and ignimbrite deposits. Maximum thickness is about 220 m in Pueblo Canyon (Griggs 1964, 8795) but the formation thins to 15 m in the Chili Quadrangle north of the Pajarito Plateau (Dethier and Manley 1985, 21506). The Puye Formation is 183 m thick beneath Sigma Mesa. Interbedded Tschicoma dacite and andesite flows and Cerros del Rio basalt flows are common. The former relations are best observed in water wells on the western side of the Pajarito Plateau, whereas the latter relations are well exposed in White Rock Canyon (see Figure 3-10).

3.4.1.5 Cerros del Rio Basalts

Basaltic flows, breccias, and scoria of the Cerros del Rio volcanic field occur in the subsurface beneath much of the Pajarito Plateau (Dransfield and Gardner 1985, 6612) and crop out in Los Alamos Canyon east of the confluence with Pueblo Canyon (see Figure 3-11) (Griggs 1964, 8795). These volcanic rocks are associated with the Cerros del Rio basalt field, which lies east of the Rio Grande. Rocks from this Pliocene-to-Pleistocene volcanic field have been dated at 2.0 to 4.6 Myr (Gardner et al. 1986, 21527).

3.4.1.6 Otowi Member of the Bandelier Tuff

The Otowi Member (see Figure 3-13 in Section 3.4.1.8) is exposed extensively throughout Pueblo Canyon below the confluence with Acid Canyon and also crops out in Los Alamos Canyon from TA-41 eastward to the confluence with Pueblo Canyon (see Figure 3-11). The Otowi Member is the lower member of the Bandelier Tuff (Griggs 1964, 8795; Smith and Bailey 1966, 9752; Bailey et al. 1969, 21498; Smith et al. 1970, 9752). It was erupted from a caldera coincident with the younger Valles Caldera (Self et al. 1986, 21579) 1.613 Myr ago (Izett and Obradovich 1994, 48817). The Otowi Member is made up of porous, nonwelded, vitric ignimbrite in the middle and lower reaches of Los Alamos Canyon and Pueblo Canyon. This poorly indurated tuff crops out in shallow drainages that incise gentle colluvial-covered slopes extending from the base of the canyon walls to the canyon floor.

The Guaje Pumice Bed occurs at the base of the Otowi Member and consists of sorted pumice fragments whose mean size varies stratigraphically and geographically from 0.8 to 1.6 in. Borehole LADP-4 in DP Canyon (see Figure 3-3 for the location of DP Canyon) penetrated 280 ft of the Otowi Member, including 28 ft of the basal Guaje Pumice Bed (Broxton et al. 1995, 50119). This thickness is about average for the Otowi Member in Los Alamos Canyon and Pueblo Canyon.

The Otowi Member consists of light gray to orange pumice lapilli supported by a white to tan ashy matrix (Broxton et al. 1995, 50119; Broxton et al. 1995, 50121; Goff 1995, 49682). The matrix is made up of glass shards, broken pumice fragments, phenocrysts, and fragments of nonvesiculated perlite. Shards are glassy and show no evidence of either post-emplacement high-temperature devitrification or subsequent low-temperature diagenetic alteration. Pumice lapilli typically make up 10 to 30% of the tuff and range from 0.2 to 2.4 in. in diameter. Pumices are larger (up to 8 in.) and more abundant (approximately 40% of the rock) at the top of the unit, which has a distinct orange coloration. The color is due either to the oxidation of iron by escaping vapors as the ash-flow sheet cooled or to incipient weathering of the top of the unit before deposition of overlying units.

3.4.1.7 Cerro Toledo Interval

The Cerro Toledo interval is an informal name given to a sequence of epiclastic sediments and tephras of mixed provenance that lie between the two members of the Bandelier Tuff—the Otowi Member and the overlying Tshirege Member (Broxton et al. 1995, 50121; Goff 1995, 49682). Outcrops of the Cerro Toledo interval deposits can generally be seen wherever the top of the Otowi Member is exposed. This unit contains deposits normally assigned to the Cerro Toledo rhyolite as described by Smith et al. (1970, 9752), and it includes well-stratified tuffaceous sandstones and siltstones and subordinate primary ash-fall and pumice-fall deposits (Stix et al. 1988, 49680; Heiken et al. 1986, 48638). The Cerro Toledo interval also contains intercalated reworked volcaniclastic sediments not normally assigned to the Cerro Toledo rhyolite. These deposits include poorly sorted sands, gravels, cobbles, and boulders derived from lava flows of the Tschicoma Formation. The Cerro Toledo interval is approximately 9 to 36 ft thick at TA-21 (see Figure 3-11) and approximately 45 ft thick in upper Pueblo Canyon. The occurrence of the Cerro Toledo interval is widespread; however, predicting its presence and thickness is difficult because of the reworking by fluvial processes. The Cerro Toledo interval forms the bedrock floor of Los Alamos Canyon near TA-41.

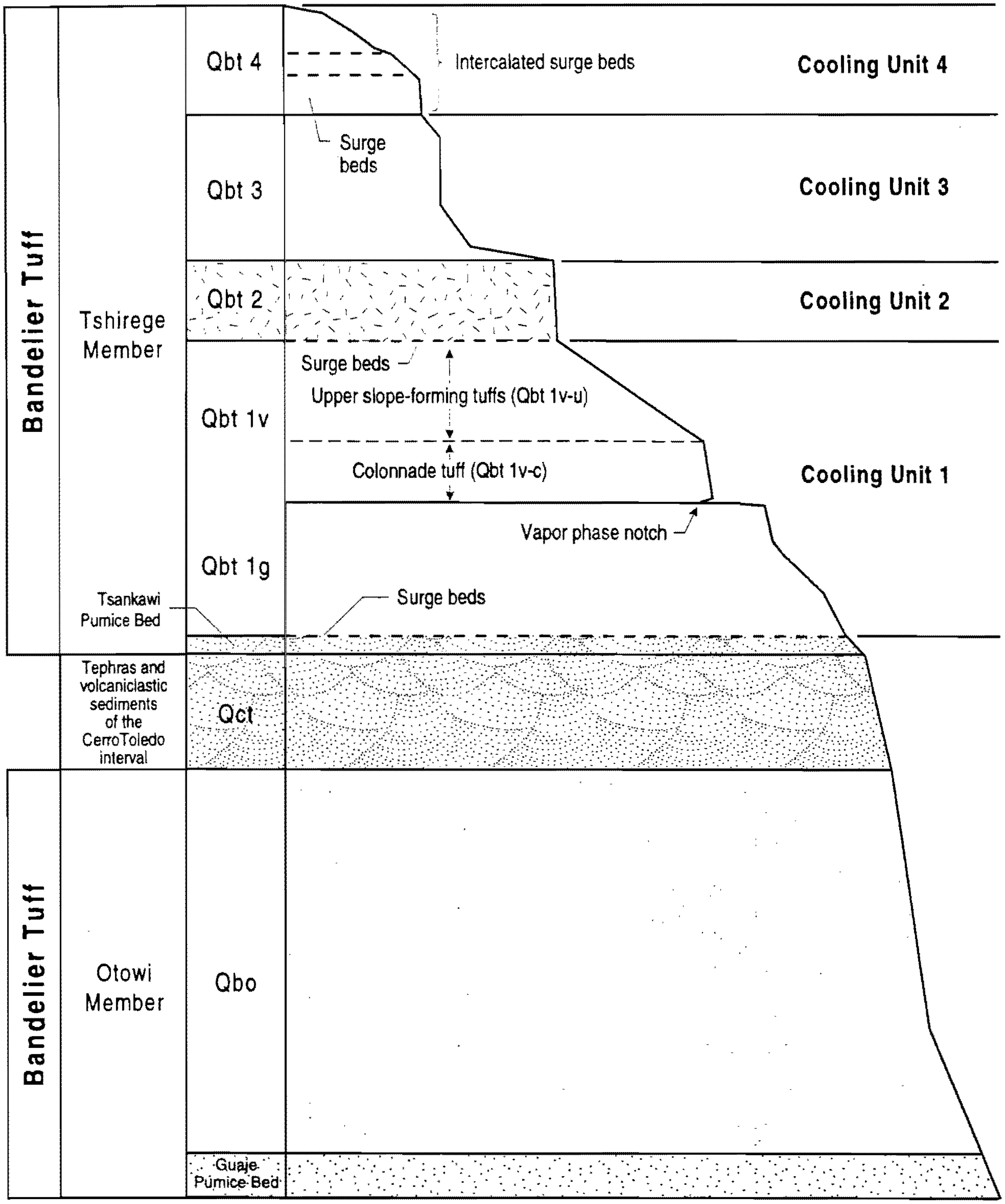
The predominant rock types found in many outcrops in the Cerro Toledo interval are rhyolitic tuffaceous sediments and tephras (Stix et al. 1988, 49680; Heiken et al. 1986, 48638; Broxton et al. 1995, 50121; Goff 1995, 49682). The tuffaceous sediments are the reworked equivalents of Cerro Toledo rhyolite tephras that erupted from the Cerro Toledo and Rabbit Mountain rhyolite domes located in the Sierra de Los Valles (see Figure 3-10). Primary pumice-fall and ash-fall deposits are found in some locations. The pumice falls tend to form the most porous and permeable horizons within the Cerro Toledo interval, and locally they may provide important pathways for moisture transport in the vadose zone. Clast-supported gravel, cobble, and boulder deposits made up of porphyritic dacite derived from the Tschicoma Formation are interbedded with the tuffaceous rocks. The coarse dacitic deposits are typically 1 to 4 ft thick and generally occur as overlapping lenticular paleochannels up to 3 ft deep (Broxton et al. 1995, 50121; Goff 1995, 49682).

The proportions of tuffaceous to dacitic detritus that comprise the Cerro Toledo interval vary from location to location across the Pajarito Plateau. Cerro Toledo deposits exposed at TA-41 are predominantly tuffaceous, whereas rocks at this stratigraphic horizon in lower DP Canyon and in the subsurface at TA-55 (see Figure 3-11) consist primarily of coarse dacitic detritus derived from the Tschicoma Formation and include only subordinate amounts of interbedded tuffaceous detritus (Goff 1995, 49682; Gardner et al. 1993, 12582).

3.4.1.8 Tshirege Member of the Bandelier Tuff

The Tshirege Member is the upper member of the Bandelier Tuff (Griggs 1964, 8795; Smith and Bailey 1966, 9752; Bailey et al. 1969, 21498; Smith et al. 1970, 9752). It was erupted from the Valles Caldera approximately 1.223 Myr ago (Izett and Obradovich 1994, 48817). The Tshirege Member is a multiple-flow, ash-flow sheet that forms the prominent cliffs in Los Alamos Canyon and Pueblo Canyon, and the bedrock floor in Los Alamos Canyon west of TA-41. The Tshirege Member is a compound cooling unit whose physical properties vary vertically and horizontally (Smith and Bailey 1966, 9752; Broxton et al. 1995, 50121). Variations in physical properties result from zonal patterns of welding and crystallization determined by emplacement temperature, thickness, gas content, and composition (Smith 1960, 48819; Smith 1960, 48820). The Tshirege Member is approximately 330 ft thick near TA-21. Figure 3-13 shows a stratigraphic section of the rock types of the Tshirege Member.

Previous workers identified mappable subunits in the Tshirege Member of the Bandelier Tuff based on a combination of surface-weathering patterns, welding features, and crystallization characteristics (Baltz et al. 1963, 8402; Weir and Purtymun 1962, 11890;



Source: Broxton and Reneau 1995, 49726

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Figure 3-13. Nomenclature of the Bandelier Tuff.

Crowe et al. 1978, 5720; Vaniman and Wohletz 1990, 21589; Vaniman 1991, 9995). As a result, there is confusion caused by the inconsistent use of unit names for the Tshirege Member. In part, the confusion arises because different criteria were used by different workers to identify the units. But equally important, the differences in nomenclature arose because the internal stratigraphy of the Tshirege Member varies laterally as a function of distance from its caldera source. In this work plan, the nomenclature of Broxton and Reneau (1995, 49726) is used to describe units of the Tshirege Member.

The Tsankawi Pumice Bed is the basal pumice-fall deposit of the Tshirege Member of the Bandelier Tuff. This pumice bed is 29 to 37 in. thick where it is exposed; the thickness may be different where the pumice bed is not exposed. This pumice-fall deposit consists of two subunits, each one having normally graded bedding. The lower subunit is 24 to 29 in. thick and contains equant angular to subangular clast-supported pumice lapilli up to 2.4 in. in diameter. A 1- to 2.8-in.-thick ash bed overlies the lower pumice bed. The upper subunit is 5 to 6 in. thick and consists of clast-supported pumice lapilli that grade upward into a coarse ash bed at the top of the unit. Pumices in the Tsankawi Pumice Bed are rhyolitic and contain approximately 5% phenocrysts, consisting of sanidine and quartz. Subordinate (less than 5%) hornblende-rich dacitic pumice fragments are also present (Broxton et al. 1995, 50121).

The following descriptions of the Tshirege Member of the Bandelier Tuff are taken from Broxton et al. (1995, 50121).

Unit 1g is the lowermost unit in the thick ignimbrite deposit of the Tshirege Member. This unit is poorly indurated but nonetheless forms steep cliffs because a resistant bench near the top of the unit forms a protective cap over the softer underlying tuffs. Unit 1g is a porous, nonwelded, poorly sorted, vitric ignimbrite. A thin (4 to 10 in.) pumice-poor surge deposit is commonly found at the base of this unit.

Unit 1v forms a combination of cliff-like and sloping outcrops composed of porous, nonwelded, devitrified ignimbrite. The base of this unit is a thin, horizontal zone of preferential weathering that marks the abrupt transition from vitric tuffs below to devitrified tuffs above; this feature forms a widespread mappable marker horizon (locally termed the vapor-phase notch) throughout the Pajarito Plateau. The lower part of unit 1v is a resistant orange brown colonnade tuff that has distinctive columnar jointing. The colonnade tuff is overlain by a distinctive white band of slope-forming tuffs. The tuffs of unit 1v are commonly nonwelded and have an open, porous structure.

Unit 2 forms a distinctive, medium brown, vertical cliff that stands out in marked contrast to the slope-forming, lighter colored tuffs above and below. This unit is the zone of greatest welding in the Tshirege Member, and the degree of welding increases upward through the unit. Because of its greater degree of welding, unit 2 is typically nonporous and probably has a low permeability relative to the other units of the Tshirege Member. Vapor-phase alteration is extensive in this unit. Purple gray, unconsolidated, porous, crystal-rich, nonwelded tuff underlies the broad, gently sloping bench developed on top of unit 2. This nonwelded tuff forms soft, white outcrops that weather into low, rounded mounds; the nonwelded tuff grades upward into unit 3.

Unit 3 is a nonwelded to partially welded, vapor-phase-altered ignimbrite, which forms the uppermost cliff-forming unit above TA-2 and TA-41.

Unit 4 is a partially welded to densely welded ignimbrite characterized by small, sparse pumices and numerous intercalated surge deposits. This unit is exposed on the mesa tops in the western part of the Laboratory but does not intersect the floors of Los Alamos Canyon and Pueblo Canyon except in the Sierra de Los Valles.

3.4.2 Mineralogy

No mineralogical data exist for rocks below the Otowi Member of the Bandelier Tuff.

Bulk-tuff mineralogy of the Bandelier Tuff varies as a function of stratigraphic position (Broxton et al. 1995, 50121). The Bandelier and Cerro Toledo interval tuffs are characteristically composed of glass + feldspar + quartz ± cristobalite ± tridymite. Minor constituents include smectite, hornblende, mica, magnetite/maghemite, hematite, calcite, and kaolinite.

Volcanic glass is the major constituent (greater than 60%) of the Otowi Member of the Bandelier Tuff, the tuffs of the Cerro Toledo interval, and unit 1g of the Tshirege Member of the Bandelier Tuff. The volcanic glass occurs as pumices and is found in the shardy matrix. Quartz and sanidine feldspar are the other two major constituents of the glassy tuffs; these crystalline phases occur as phenocrysts and as relatively minor devitrification products in the fine ash. The volcanic glass is unaltered in thin section, and the absence of significant amounts of alteration minerals, such as clays and zeolites, strongly suggests that these tuffs have had limited contact with ground water since their deposition. In borehole LAOI(A)-1.1, 9 to 32% smectite was detected in the upper part of the Otowi Member. Zones relatively rich in smectite have not been found in other boreholes penetrating the Otowi Member. These zones may represent either translocated clays or alteration of glass in a recharge zone beneath the canyon floor.

Volcanic glass disappears abruptly at the top of unit 1g in the Tshirege Member of the Bandelier Tuff. Above unit 1g, the Tshirege Member consists primarily of feldspar + quartz + cristobalite + tridymite. The amounts of cristobalite and tridymite vary inversely reflecting different degrees of *in situ* devitrification and vapor-phase alteration in the upper tuff units.

Smectite, maghemite, and hematite occur in small amounts (less than 2%) throughout the Bandelier Tuff. These three trace minerals are important because they have sorptive capacities for certain radionuclides and could provide natural barriers to their migration. Smectites are highly selective for adsorbing cationic radionuclides (Grim 1968, 48814). Magnetite and its alteration products (such as hematite) have an affinity for uranium and actinide species through surface complexation (Allard and Beall 1979, 48810; Allard et al. 1982, 48811; Hsi and Langmuir 1985, 48816; Ho and Miller 1986, 48815). Although these minerals occur in small quantities, they are disseminated throughout the stratigraphic sequence. Their combined abundance, small grain size, and large surface area per unit volume provide increased sorptive capacity relative to the bulk rock.

3.4.3 Geological Structure

The Pajarito Fault system, which forms the western margin of the Española Basin, has had Holocene movement and historic seismicity (Gardner and House 1987, 6682; Gardner et al. 1990, 48813). This system is characterized by normal faults that commonly cross each other along the length of the fault and show down-to-the-east movement. The fault system forms a series of prominent fault scarps west of the Laboratory (see Figure 3-11). These scarps decrease in size northward to Los Alamos Canyon, where the fault system becomes less well defined.

In addition to the main traces of the Pajarito Fault system, other faults are exposed in Los Alamos County. The Rendija Canyon fault is a normal oblique-slip fault with north/south orientation; it crosses Pueblo Canyon near its confluence with Acid Canyon and

Los Alamos Canyon in the vicinity of TA-41. The Guaje Mountain fault has been projected as far south as TA-55, about one mile south of TA-2 and TA-41 (Figure 3-14), although clear stratigraphic offset has not been recognized south of Bayo Canyon, the canyon parallel to Pueblo Canyon on the north (see Figure 3-3). The fault projection passes directly beneath TA-2. The Rendija Canyon fault and the Guaje Mountain fault are exposed north of Los Alamos Canyon as zones of gouge and breccia up to several meters wide with visible offset of stratigraphic horizons. Both faults have down-to-the-west displacements. Detailed analysis of fracture density, distribution, and size in the vicinity of these faults may help identify and locate tectonic fracture zones within Los Alamos Canyon and Pueblo Canyon that could be potential pathways for infiltrating water.

Dransfield and Gardner (1985, 6612) integrated a variety of data to produce structure contour maps and paleogeologic maps of the pre-Bandelier-Tuff surface beneath the Pajarito Plateau. Their maps reveal that subsurface rock units are cut by a series of down-to-the-west normal faults. The overlying Bandelier Tuff is not obviously displaced by these buried faults south of Los Alamos Canyon, showing that most displacements predated deposition at least in these uppermost ash-flow units. Displacement on the Guaje Mountain fault and the Rendija Canyon fault decreases south of Los Alamos Canyon, and discrete faults are replaced by wide zones of intense brecciation and fracturing superimposed on the network of cooling joints in the Bandelier Tuff (Vaniman and Wohletz 1990, 21589).

3.4.4 Seismicity and Volcanism

Los Alamos Canyon and Pueblo Canyon lie within a region dominated by Late Cenozoic volcanic and tectonic activity. Volcanism began in the Jemez Mountains volcanic field more than 13 Myr ago and has continued without a significant hiatus into the Late Quaternary Period (Gardner et al. 1986, 21527).

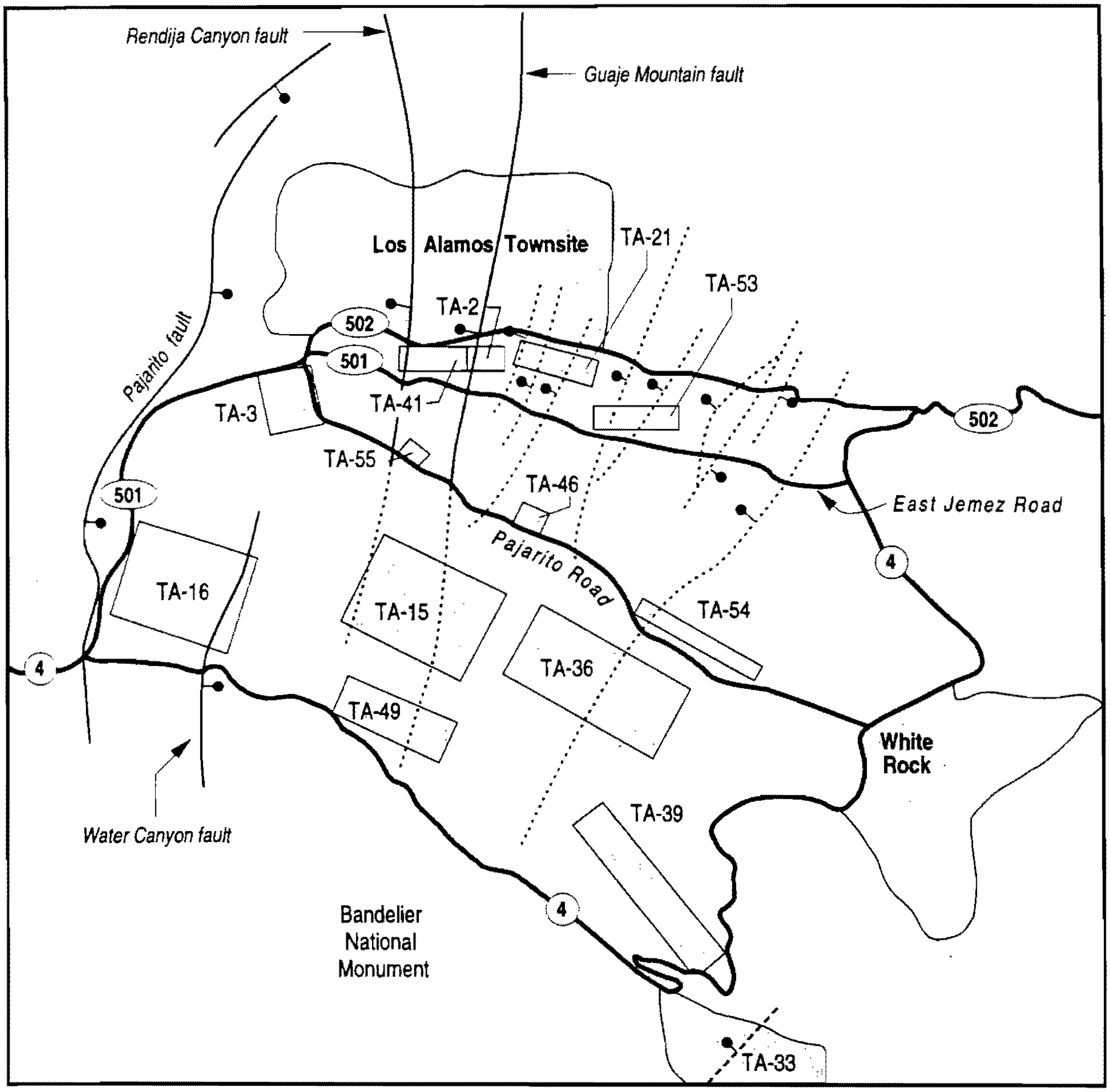
Given the long history of spatially focused, continuous volcanic activity, future volcanism may be expected in the region. Examination of the area's tectonic history suggests that future volcanism is most likely to occur either in the Valles Caldera or tens of kilometers north of Los Alamos Canyon and Pueblo Canyon (Gardner and Goff 1984, 44021; Gardner 1985, 48812; Self et al. 1986, 21579).

3.5 Hydrology

The water that flows through Los Alamos Canyon and Pueblo Canyon is used by wildlife, livestock, and humans and therefore constitutes a significant transport pathway to these potential receptors. Studies of both surface water described in this section and ground water described in Section 3.6 will provide information required to assess the importance of these transport pathways and to improve the understanding of surface water transport and transport through the unsaturated and saturated zones within Los Alamos Canyon and Pueblo Canyon.

Surface water flows provide the primary mechanism for redistributing and transporting contaminants that remain from early Laboratory operations and discharges from currently operating facilities. The hydrology of Los Alamos Canyon and Pueblo Canyon are thoroughly discussed in Section 2.5.2 of the IWP (LANL 1995, 49822). The discussion here elaborates on surface water as a contaminant transport pathway.

Surface water occurs in Pueblo Canyon as ephemeral runoff from precipitation and as effluent discharge from the Los Alamos County sewage treatment plant (Figure A-2 in Appendix A of this work plan). Surface water occurs in Los Alamos Canyon as



Sources: Dransfield and Gardner 1985, 6612;
Gardner and House 1987, 6682

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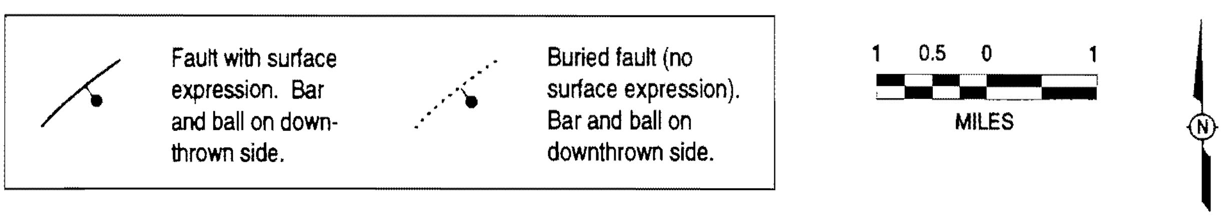


Figure 3-14. Locations of major faults at selected Laboratory technical areas.

perennial flow only in the upper reaches west of Los Alamos Reservoir and in the major tributaries (see Figure A-1 in Appendix A) on US Forest Service land west of the Laboratory boundary.

Flow from spring snowmelt extends down to the confluence with the Rio Grande for several days approximately one out of every two years. For most of the year, the only surface flow in lower Los Alamos Canyon results from discharge from the Los Alamos County sewage treatment plant. This flow combines with perennial flow from Basalt Spring on San Ildefonso Pueblo land just east of the Laboratory boundary (see Figure A-2 in Appendix A), and extends to the Rio Grande.

The predominant mechanisms that affect mobilization of contaminants in Los Alamos Canyon and Pueblo Canyon are sediment transport, contaminant dissolution/desorption, runoff, infiltration, and percolation. Aspects of surface hydrology that are relevant to potentially contaminated areas include

- areas and pathways of surface water runoff and sediment deposition;
- rates of soil erosion, contaminant dissolution/desorption, transport, and sedimentation;
- locations and sizes of areas of disturbed and undisturbed surface soils;
- relationships between infiltration and runoff;
- presence and effectiveness of adsorptive media in retarding infiltration of water-borne contaminants; and
- fate of infiltrating water.

3.5.1 Normal Seasonal Runoff

Runoff from summer storms on the Pajarito Plateau typically reaches a maximum discharge in less than 2 hours after rainfall ceases and generally has a duration of less than 24 hours (Purtymun et al. 1990, 6992). The high discharge rate that is sometimes observed results in large masses of suspended and bedload sediments being carried for long distances, occasionally to the Rio Grande. The most extensive studies of thunderstorm runoff in the Los Alamos Canyon/Pueblo Canyon system were conducted in DP Canyon (see Figure A-2 in Appendix A of this work plan for the location of DP Canyon). In 1967, 23 runoff events were measured. These events carried a total of 88,000 kg of sediments in 36,800 m^3 of water (Purtymun and Johansen 1974, 11835).

Spring snowmelt occurs at a low discharge rate during a period of several weeks to several months. In most years the release of snowmelt water from Los Alamos Reservoir results in nearly continuous surface water flow in Los Alamos Canyon between the western Laboratory boundary and the vicinity of TA-2 (see Figure 3-15). Snowmelt flow occasionally reaches the Rio Grande. For example, between 1975 and 1986 snowmelt reached the Rio Grande a total of 205 days during five of those years, averaging approximately 41 days per year or approximately 4.7% of the total number of days in the 12-year period.

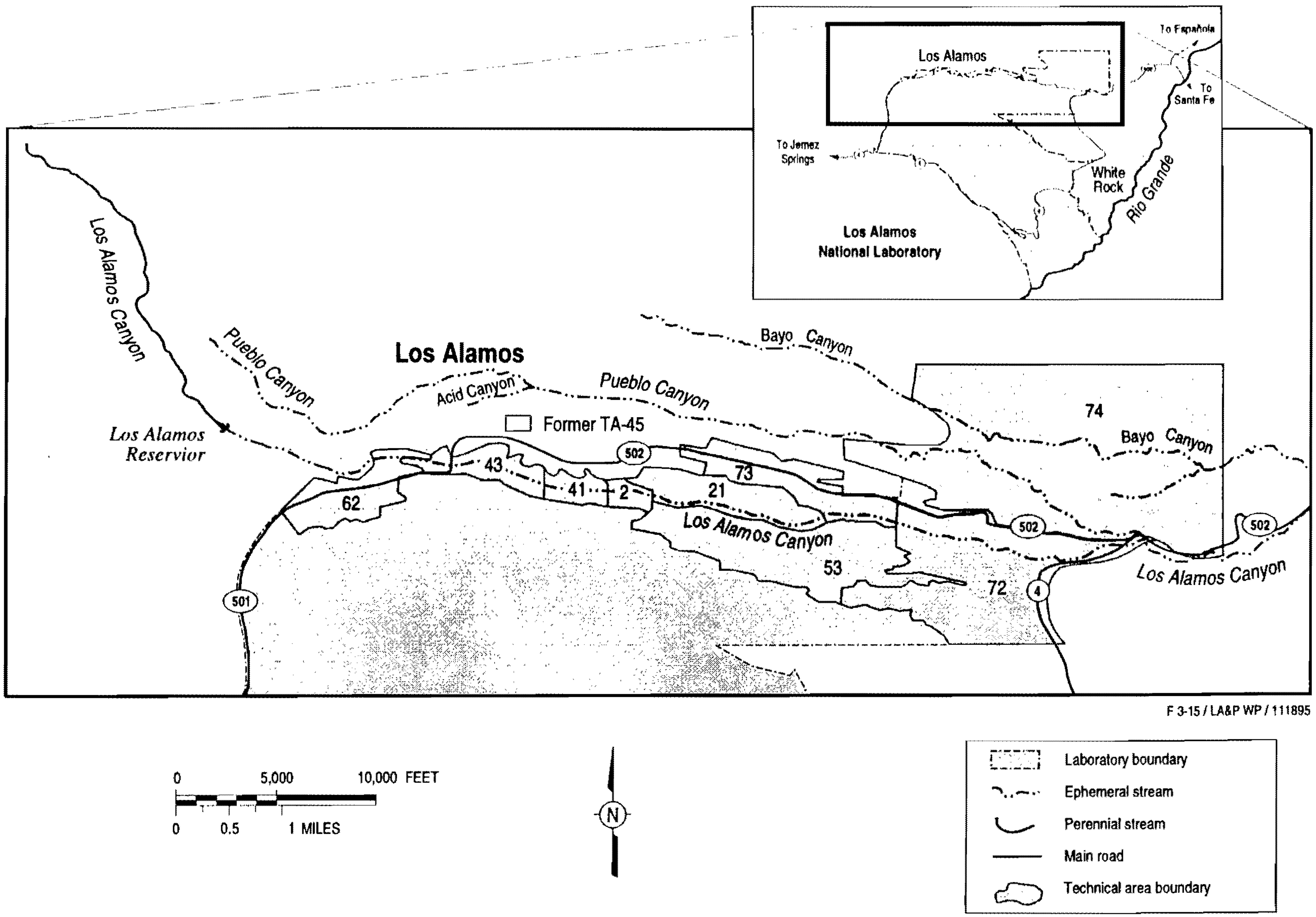


Figure 3-15. Laboratory technical areas adjacent to Los Alamos Canyon and Pueblo Canyon.

A detailed study was conducted in Los Alamos Canyon and Pueblo Canyon between 1975 and 1986, which measured snowmelt runoff from seven events (Purtymun et al. 1990, 6992). A major conclusion from the study was that most of the plutonium that is moved by runoff and reaches the Rio Grande is transported with the sediments. At the mouth of Los Alamos Canyon approximately 57% of the plutonium was associated with suspended sediments and 40% with bedload sediments; 3% was in solution. In five of the seven events in the study, water reached the Rio Grande carrying a total of approximately 600 μCi of plutonium.

The flow of effluent from the Los Alamos County sewage treatment plant provides a significant sediment transport mechanism. Increased effluent from the plant starting in 1990 results in flow through the lower part of Pueblo Canyon into lower Los Alamos Canyon during most of the year. This flow transports some of the contaminated sediments from Pueblo Canyon into Los Alamos Canyon on San Ildefonso Pueblo land. The amounts of plutonium transported were estimated at approximately 3 to 4 mCi in 1990 and 4 to 6 mCi in 1991 (Environmental Protection Group 1992, 7004; Environmental Protection Group 1993, 23249). These annual amounts are roughly 20 to 30 times the amount carried from Pueblo Canyon into Los Alamos Canyon during four spring runoff events measured in 1975, 1979, 1985, and 1986 (Apt and Lee 1976, 5559; ESG 1980, 5961; ESG 1986, 6626; ESG 1987, 6678). Concentrations in the effluent-supported flow were comparable in 1992, although no transport estimate was made (Environmental Protection Group 1994, 35363).

In surface water samples collected in Los Alamos Canyon near TA-2 and TA-41, concentrations of tritium, ^{137}Cs, ^{90}Sr, natural and enriched uranium, ^{238}Pu, ^{239}Pu, ^{240}Pu, and ^{241}Am are commonly above natural background or regional fallout levels observed at Los Alamos Reservoir (LANL 1993, 21404). Surface water samples collected in DP Canyon also show elevated levels of these contaminants, which indicates that detectable contaminant transport from TA-21 has occurred (LANL 1993, 21404).

In sediment samples collected in Pueblo Canyon at the confluence with Acid Canyon, concentrations of the contaminants listed above, as well as some trace metals, are elevated above natural background or regional fallout levels. Activities of plutonium at the confluence of Acid Canyon with Pueblo Canyon are higher than those found in upper Los Alamos Canyon. Activities of tritium in soil and sediment moisture are generally lower in Pueblo Canyon than in Los Alamos Canyon (Environmental Protection Group 1992, 7004).

3.5.2 Flooding Potential

The climate and topography in the region of the Laboratory are conducive to short-term, high-intensity storms and rapid associated runoff. The Environmental Protection Agency (EPA) requires by virtue of the location standards for treatment, storage, and disposal (TSD) facilities and TSD permitting requirements under RCRA (at 40 CFR 264.18[b] and 40 CFR 270.14 [b] [11] [iii] respectively) (EPA 1994, 50122; EPA 1994, 50116) that the potential impacts on Laboratory facilities be evaluated for floods that might result from these storms. The Laboratory recently performed an evaluation of the estimated 100-year storms and resultant floodplain elevations for the watersheds that drain the Laboratory area (McLin 1992, 12014). For this study, researchers used the US Army Corps of Engineers computer-based flood hydrograph packages, HEC-1 (Army Corps of Engineers 1990, 44017) and HEC-2 (Army Corps of Engineers 1990, 44018), to perform the floodplain hydrologic simulations. A six-hour storm was modeled for Los Alamos Canyon. Parameter inputs (such as precipitation, surface runoff, and initial soil moisture content) were selected to represent a reasonable worst-case scenario and thus present a conservative estimate of a 100-year flood in Los Alamos Canyon (McLin 1992, 12014).

3.5.3 Infiltration

The primary mechanism of contaminant transfer between the surface and the underlying aquifers is infiltration of surface water carrying colloidal and dissolved contaminants. The following surface water infiltration pathways occur within Los Alamos Canyon and Pueblo Canyon:

- native or disturbed soils,
- unconsolidated alluvium,
- Bandelier Tuff,
- faults and fracture systems, and
- cooling joints.

Surface water is hydraulically connected to the alluvium in parts of Los Alamos Canyon (see Section 2.5 of the IWP [LANL 1995, 49822]) (Environmental Protection Group 1992, 7004). The alluvium in Los Alamos Canyon extends eastward from Los Alamos Reservoir to observation well LAO-5 west of state road 4. Portions of the alluvium in this reach are seasonally saturated; the extent of the saturated reach varies with the volume of surface water flow. The alluvium is perennially saturated in lower Los Alamos Canyon from Basalt Spring to the Rio Grande. Ground water is also present in the alluvium in some areas of Pueblo Canyon. The perennially saturated portion of the alluvium in Pueblo Canyon extends at least from the Los Alamos County sewage treatment plant downstream to the confluence with Los Alamos Canyon.

3.6 Hydrogeology

This section discusses the hydrology of the unsaturated zone beneath the alluvium and the saturated zones of the alluvium in Los Alamos Canyon and Pueblo Canyon; the intermediate perched ground water zones in the Guaje Pumice Bed, Cerros del Rio basalt, and Puye Formation; and the deep or main aquifer in the Santa Fe Group.

Ground water pathways in Los Alamos Canyon and Pueblo Canyon are important because of the shallow depth of the alluvium, the presence of intermediate perched zones (in the Guaje Pumice at the base of the Otowi Member of the Bandelier Tuff, the Puye Formation, and potentially the Cerros del Rio basalts), and the past and present discharges into the two canyons. These discharges include

- former TA-1;
- the inactive sewage treatment plant at TA-41;
- the cooling water system for the Omega West Reactor;
- outfalls at TAs -2, -21, and -53 within Los Alamos Canyon;
- Los Alamos County sewage treatment plant; and

- outfalls from former TA-45 into Acid Canyon, which drains into Pueblo Canyon.

The potential for significant infiltration exists, given the presence of coarse-grained sediments in Los Alamos Canyon and Pueblo Canyon. Special low-detection-limit (0.1 pCi/L) measurements of tritium have recently confirmed the presence of some recent recharge to the main aquifer in several locations in both canyons. In addition to tritium, other contaminants have been documented in the alluvium and in intermediate perched zones in Los Alamos Canyon and Pueblo Canyon. Potential receptors include water users located downgradient: wildlife, livestock, and wetland plants and animals. Potential exposure points include springs, seeps, gaining streams, and pumping wells.

3.6.1 Unsaturated Zone

Understanding the hydrogeologic properties of the unsaturated zone within the Otowi Member of the Bandelier Tuff in Los Alamos Canyon and Pueblo Canyon is important because the unsaturated zone encompasses both potential secondary barriers and conduits for the movement of liquid discharges. These discharges originate from the potential release sites at former TA-45 (into Acid Canyon) and TAs -2, -21, -41, and -53 and from the Los Alamos County sewage treatment plant and migrate through the alluvium. Features of the unsaturated tuff relevant to contaminant transport (Kearl et al. 1986, 8414) that may be considered during investigations include the following:

- physical properties (density, porosity, and specific gravity);
- geohydrologic properties (saturated and unsaturated permeabilities, conductivities, and moisture characteristic curves);
- properties of fractures and joints (frequency, orientation, degree of interconnectedness, and filling materials);
- properties of mapping unit contacts or paleosurfaces (flow paths or barriers);
- geochemical properties (specific surface area, ion exchange capacity, retardation factors, and mineralogy); and
- depth to ground water.

The significance of natural fracture systems as potential zones of recharge within Los Alamos Canyon and Pueblo Canyon, including the Guaje Mountain fault zone and the Rendija Canyon fault zone (see Section 3.4.3), will be evaluated in these investigations (see Chapter 7 of this work plan). The lateral variability of potentially permeable zones (such as cooling fractures and fault zones) may need further evaluation.

The movement of water through the unsaturated zone has been clearly demonstrated in some locations at the Laboratory. A recent study of Mortandad Canyon (see Figure 1-2 in Chapter 1 of this work plan) concludes that moisture containing tritium from Laboratory effluents has migrated vertically at least 200 ft beneath the canyon floor (Stoker et al. 1991, 7530).

Studies in Los Alamos Canyon (and it's tributary, DP Canyon) suggest vertical migration there as well. Borehole LADP-4 was drilled in DP Canyon to investigate whether subsurface contaminants from the industrial areas of TA-21 have migrated northward toward DP Canyon. The borehole penetrated alluvium on the canyon floor and the following bedrock units: the Tshirege Member of the Bandelier Tuff (including the Tsankawi Pumice Bed); fluvial sediments of the Cerro Toledo interval; the Otowi Member of the Bandelier Tuff (including the Guaje Pumice Bed); and fluvial sandstones, gravels, and conglomerates of the Puye Formation. Although no saturated zones were observed, tritium contamination was found in this borehole. Preliminary laboratory analysis indicates tritium concentrations in the moisture of 13,200 ± 1100 pCi/L at a depth of 158.6 to 160.1 ft in a moist zone associated with the contact between unit 1v and unit 1g of the Tshirege Member (Broxton et al. 1995, 50119). The tritium probably came from discharges from one of the two radioactive liquid-waste treatment facilities that had operated at TA-21. In the 1960s concentrations of tritium in surface waters in DP Canyon were typically in the hundreds of thousands of pCi/L (LANL 1981, 6059).

Hydrogeologic properties of Bandelier Tuff (such as bulk density, porosity, permeability, moisture content, hydraulic conductivity, and moisture characteristic curves) are required to model contaminant movement. Geochemical data (including multiparameter adsorption properties, particle surface area, vadose zone chemistry, water chemistry, and mineralogical characteristics) may be required for geochemical and solute transport modeling. Most of the available data have been obtained on cores collected from boreholes. A limited amount of data on *in situ* properties are available but only from the vicinity of the TA-54 waste disposal facilities on Mesita del Buey. In addition, the influence of fractures and secondary minerals that line the fractures is not known.

Approximately 30 cores of the Otowi Member of the Bandelier Tuff have been analyzed in detail for hydrologic properties. Most of these cores came from boreholes in Los Alamos Canyon, Mortandad Canyon, Sandia Canyon, and Potrillo Canyon (see Figure 1-2 in Chapter 1 of this work plan for the locations of these canyons). No unsaturated hydrologic properties have been measured for the units underlying the Bandelier Tuff, namely the Cerros del Rio basalts, the Puye Formation, and the Santa Fe Group. Some geochemical and hydrologic data from these hydrogeologic units will be required to evaluate contaminant migration pathways especially in lower Pueblo Canyon and lower Los Alamos Canyon.

Hydrologic data from core samples are summarized in Table 3-3 (Rogers and Gallaher 1995, 48845). The following discussion summarizes the limited information that exists on the properties of the Otowi Member of the Bandelier Tuff (the unit immediately underlying the alluvium in upper Los Alamos Canyon and Pueblo Canyon).

3.6.1.1 Porosity

The rocks of the Bandelier Tuff tend to have relatively high porosities, ranging from 30 to 63 vol % on tuff samples collected within the Laboratory boundaries. Porosity values are lower in more densely welded tuff (see Section 2.5.2 of the IWP [LANL 1995, 49822]). The effective porosity (interconnected or fluid accessible porosity) ranges from 18 to 52 vol % (Stephens and Associates 1991, 27618; Stoker et al. 1991, 7530).

3.6.1.2 Moisture Content

Moisture content of the Otowi Member of the Bandelier Tuff has been measured in three boreholes (one borehole in Sandia Canyon and two boreholes in Mortandad Canyon) to assess the movement of water through the unsaturated zone. The moisture content of the Otowi Member in these boreholes is moderate to high, generally

TABLE 3-3

HYDRAULIC PROPERTIES OF ALLUVIUM AND BANDELIER TUFF[a]

Property	Alluvium	Tshirege	Tsankawi	Otowi
b. ρ_b (g/cm^3)	1.42 ± 0.17 (9)	1.23 ± 0.16 (89)	1.25 ± 0.19 (20)	1.18 ± 0.096 (32)
c. θ_{sat} (%)	43.3 ±4.3 (8)	48.9 ± 6.0 (89)	49.0 ± 9.8 (19)	46.9 ± 5.26 (32)
d. S(%)	46.8 ±28.9 (8)	35.6 ± 23.8 (86)	46.8 ± 28.4 (19)	33.0 ± 9.9 (31)
e. K_{sat} (cm/sec)	4.4 X10-4 (2)	3.2 X10-4 (67)	1.3 X10-3 (10)	6.3 X 10-4 (25)
f. log K_{sat}	−3.64 (2)	−3.85 ± .50 (67)	−3.25 ± 0.70 (10)	−3.57 ± 0.49 (25)
g. θ_r (%)	3.8 (2)	2.1 ± 2.7 (52)	1.7 ± 2.7 (9)	2.6 ± 2.7 (21)
h. α (1/cm)	0.385 (2)	0.120 ± 0.033 (52)	0.187 ± 0.194 (9)	0.0066 ± 0.0030 (21)
i. N	1.558 (2)	1.759 ± 0.341 (52)	1.481 ± 0.246 (9)	1.711 ± 0.218 (21)

a. Figures are mean values ± one standard deviation with the number of observations in parentheses (Rogers and Gallaher 1995, 48845).
b. ρ_b = grain density
c. θ_{sat} = effective porosity
d. S = saturation
e. K_{sat} = saturated hydraulic conductivity
f. log K_{sat} = logarithm to the base ten of saturated hydraulic conductivity
g. θ_r = residual saturation
h. α = a constant (units 1/cm) used in calculating residual water content
i. N = curve-fitting parameter for moisture retention curves (van Genuchten 1980, 49927)

ranging from 20 to 40 vol % (Stephens and Associates 1991, 27618; Stoker et al. 1991, 7530). These values are considerably higher than those typically reported for the mesa tops and in some cases approach full saturation (Weir and Purtymun 1962, 11890; Section 2.5.2 of the IWP [LANL 1995, 49822]). Results of this investigation suggest that greater infiltration of water occurs in the canyon floors than through the mesa tops.

3.6.1.3 Hydraulic Conductivity

Hydraulic conductivity is a measure of the potential for fluid flow within a porous solid material. Saturated cores of the Otowi Member of the Bandelier Tuff have hydraulic conductivities that range from 8.3×10^{-6} to 7.8×10^{-3} cm/s. The hydraulic conductivity of unsaturated Bandelier Tuff varies with moisture content and has values two to five orders of magnitude lower than those for saturated tuff (5.6×10^{-8} to 5.6×10^{-11} cm/s for welded tuff and 3.1×10^{-6} to 3.3×10^{-9} cm/s for nonwelded tuff) (Stoker et al. 1991, 7530).

One of the key relationships describing the movement of water in unsaturated porous media is the characteristic curve, which relates water content of the solid phase to suction, tension, or negative pressure head. The moisture characteristic curve is also used to determine the relative hydraulic conductivity so that flux values can be calculated for water contents below full saturation.

Numerous moisture characteristic curves have been determined on crushed Bandelier Tuff. A limited amount of *in situ* moisture characteristic data are available, particularly for the low water contents generally found in the Bandelier Tuff (Abeele 1984, 6520). Further study of hydrologic properties may be needed to resolve transport issues in Los Alamos Canyon and Pueblo Canyon.

3.6.2 Alluvial Ground Water

Surface water infiltration creates a saturated zone in the alluvium of Los Alamos Canyon and Pueblo Canyon within the Laboratory boundaries (see Section 2.5.2 of the IWP [LANL 1995, 49822]). Surface water infiltrates through the alluvium, and downward movement continues into the Otowi Member of the Bandelier Tuff. Partial depletion by evapotranspiration and movement into the underlying geologic formations controls the size and depth of the alluvial saturated zone.

The alluvium in Pueblo Canyon has not been extensively characterized. The discussion here is drawn from Purtymun's (1995, 45344) description of the alluvial sediment and some aspects of the hydrology of the alluvial system. Unlike other canyons heading on the Jemez Mountains, Pueblo Canyon has no springs to create a stream flow. Natural surface flow exists only in the upper part of the canyon, near Acid Canyon, and it is intermittent. The Pueblo and Central sewage treatment plants (Figure A-2 in Appendix A of this work plan) provided recharge to the alluvium in the canyon during the period of their operation, as does the currently operating Los Alamos County sewage treatment plant. The effluent from the Los Alamos County sewage treatment plant maintains stream flow from approximately the location of Hamilton Bend Spring to state road 502 (see Figure A-2 for location). Recharge to Hamilton Bend Spring and Otowi Seep was believed to be from the effluent of the earlier Pueblo and Central sewage treatment plants. The downgradient and lateral extent of saturation in the alluvium is largely unknown.

Extensive portions of Los Alamos Canyon are characterized by saturated conditions in the alluvium. This part of the hydrologic system is most significant in evaluating potential contaminant releases. Saturated thicknesses of the alluvium in Los Alamos Canyon and Pueblo Canyon vary throughout the year; they are greatest in the spring and summer when recharge reaches its peak. The saturated thickness of the alluvium in Los Alamos Canyon varies from a few feet to approximately 25 ft (Environmental Protection Group 1992, 7004).

The alluvium in upper Los Alamos Canyon extends eastward from its upper reaches near Los Alamos Reservoir to just west of state road 4. It is recharged by infiltration from the drainage channel of the reservoir during most of the year. Water levels decline in the winter when runoff is at a minimum (LANL 1995, 49822). Contaminants in soil, sediments, and surface water enter the alluvium and migrate downgradient at different rates due to adsorption and precipitation reactions. This saturated alluvium is of interest because of the following issues.

- Contaminated surface water that recharges alluvium may be stored in the canyon system and be available for uptake by plants or available locally at discharge points downgradient for consumption by animals (see Appendix K of the IWP [LANL 1993, 26078]).
- The alluvial ground water that recharges the underlying Bandelier Tuff may contaminate the perched intermediate zones and the much deeper main aquifer within the Santa Fe Group (especially along the Guaje Mountain fault zone and the Rendija Canyon fault zone).

Alluvial ground water flow within upper Los Alamos Canyon is expected to be rapid because of the coarse-grained texture of the alluvium. Hydraulic conductivity measurements from nine slug tests conducted by the ESG gave an average value of

3.2×10^{-4} ft/s (with a range from 3.8×10^{-5} to 7.9×10^{-4} ft/s) (Gallaher 1995, 49679). The average rate of ground water movement in the alluvium is highly variable and depends on local conditions. At TA-2 alluvial ground water was observed to move several hundred feet per day based on tritium concentrations associated with past leaks from the delay line at the Omega West Reactor (LANL 1993, 21404). Alluvial ground water in upper Los Alamos Canyon flows to the east at an average rate of 900 ft/yr (Gallaher 1995, 49679).

The alluvium in lower Los Alamos Canyon is probably saturated from about the location of Basalt Spring to the Rio Grande. This inference is based on the observation of stream flow through most of this reach, the presence of seeps at the mouth of Los Alamos Canyon, and saturated zones noted in several Bureau of Indian Affairs monitoring wells and drive points. No systematic observations or studies of alluvial ground water in lower Los Alamos Canyon have been made to date.

3.6.3 Intermediate Perched Zones

Saturated conditions are known to be present at depths intermediate between the alluvial aquifer and the main aquifer. Within Los Alamos Canyon and Pueblo Canyon, two or more zones have been identified as discussed below.

3.6.3.1 Guaje Pumice Bed

ER Project personnel drilled three geologic characterization boreholes (LADP-3, LADP-4, and LAOI(A)-1.1), which revealed the local presence of an intermediate-depth zone of saturation within and perhaps below the Guaje Pumice Bed in Los Alamos Canyon. Boreholes LADP-3 and LADP-4 were drilled in the autumn of 1993 as part of the RFI for OU 1106 (Broxton et al. 1995, 50119), and borehole LAOI(A)-1.1 was drilled in the autumn of 1994 as part of the RFI for OU 1098 (LANL 1993, 21404).

Boreholes LADP-3 and LAOI(A)-1.1 penetrated slope-derived colluvium and stream-derived alluvium on the canyon floor before entering bedrock (Broxton et al. 1995, 50119). Bedrock units penetrated by borehole LADP-3 included the Otowi Member of the Bandelier Tuff, the Guaje Pumice Bed, and gravels of the Puye Formation. This borehole encountered two perched water zones. The upper zone is part of the alluvium in Los Alamos Canyon. Moisture data show that this unit is divided into two distinct zones of saturation. In borehole LADP-3, an intermediate-depth perched water zone was encountered in the Guaje Pumice Bed at a depth of 325 ft. In borehole LAOI(A)-1.1, a similar perched water zone was encountered in the Guaje Pumice Bed at a depth of 295 ft. Borehole LADP-4, drilled north of TA-21 in DP Canyon, encountered no comparable intermediate perched zone.

Test well (TW) H-19, which was drilled in 1949, penetrated alluvium; the Tshirege, Otowi, and Guaje Members of the Bandelier Tuff; the Tschicoma Formation; the Puye Formation; and Santa Fe Group (Purtymun 1995, 45344). One 20-ft interval in the Guaje Pumice Bed was reported in the logs to be saturated. However, that borehole was abandoned, and there is no way to verify the present saturated condition or to sample the ground water.

3.6.3.2 Cerros del Rio Basalts and Puye Formation

Intermediate perched zones occur in the conglomerates and basalts beneath the alluvium in portions of Los Alamos Canyon, Pueblo Canyon, and Sandia Canyon

(LANL 1995, 49822). These systems occur at depths of less than 350 ft between TA-2 and the confluence of DP Canyon with Los Alamos Canyon. A chemically distinct perched water zone was noted at a depth of 317 ft in the uppermost portion of the Puye Formation in borehole LAOI(A)-1.1. Perched water is found at a depth of 117 ft in TW-2A in the middle reach of Pueblo Canyon and at approximately 253 ft in supply well Otowi-4 in the middle reach of Los Alamos Canyon (Purtymun and Stoker 1988, 6879). The perching may be caused by a 5- to 10-ft-thick clay layer in the upper fanglomerate section of the Puye Formation.

TW-1A was drilled to a depth of 225 ft and penetrated an intermediate perched zone within the Cerros del Rio basalts in Pueblo Canyon. Water infiltrating from the alluvium recharges perched water in the Cerros del Rio basalt interbedded with the Puye Formation under middle and lower Pueblo Canyon (LANL 1981, 6059). This body of perched ground water occurs at depths of 121 ft in TW-2A in middle Pueblo Canyon and at depths of about 160 to 230 ft in TW-1A in lower Pueblo Canyon.

Within the fractured basalts and the Puye Formation, ground water movement is probably to the east/southeast. Some of this ground water discharges at Basalt Spring in lower Los Alamos Canyon about 0.6 mi below its confluence with Pueblo Canyon.

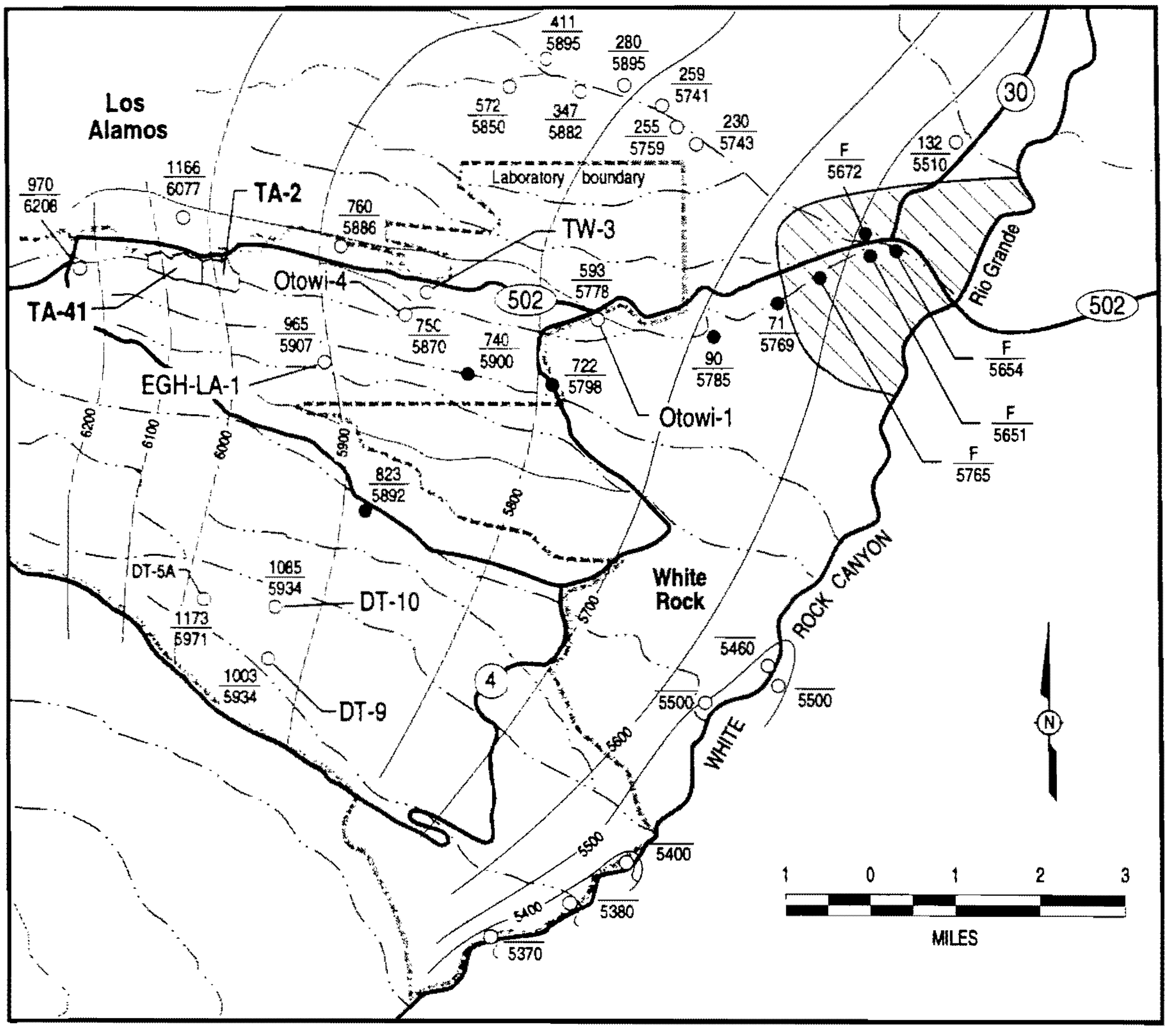
This perched water is monitored by ground water samples collected from TW-1A and from the discharge at Basalt Spring in lower Los Alamos Canyon. Nonradioactive contaminants (including chloride and nitrate) have been detected in water samples collected from Basalt Spring (see Section 3.7.3.3) (Environmental Protection Group 1994, 35363). The most likely source of these contaminants is the Los Alamos County sewage treatment plant. More recently, low-detection-limit measurements of tritium and ^{14}C have shown the presence of Laboratory contaminants in samples of the intermediate perched zone ground water collected from TW-1A and Basalt Spring.

3.6.4 Main Aquifer

The main aquifer occurs in the sediments of the Santa Fe Group at a depth of approximately 800 ft below the floor of Los Alamos Canyon in TW-3 and in supply well Otowi 4 (Figure 3-12), both located at the confluence of DP Canyon with Los Alamos Canyon (at the east end of TA-21).

Ground-water-level measurements taken in deep observation wells located on the Pajarito Plateau indicate that the elevation of the potentiometric surface of the main aquifer rises westward from the Rio Grande through the Santa Fe Group and the lower part of the volcanic and sedimentary rock units beneath the central and western part of the Pajarito Plateau (Purtymun and Johansen 1974, 11835) (Figure 3-16). The hydraulic gradient indicates that ground water moves eastward toward the Rio Grande, where part of it discharges into the Rio Grande through seeps and springs (LANL 1995, 49822; Purtymun et al. 1980, 6048).

The primary recharge area to the main aquifer is apparently located to the west in the flanks of the Sierra de los Valles, but neither the locations nor the major mechanisms of recharge are known. Recharge to the main aquifer may occur within Los Alamos Canyon in areas where bedrock units such as the Otowi Member of the Bandelier Tuff, Guaje Pumice Bed, Puye Formation, and the Santa Fe Group consist of coarse-grained materials. Coarse-grained materials are found especially in lower Los Alamos Canyon. Fractured Cerros del Rio basalt may also provide recharge pathways. Other possible zones of recharge include the Guaje Mountain, Rendija Canyon, and Pajarito fault zones, and possibly the other fault zones.



Source: Purtymun and Johanson 1974, 11835

F 3-16 / LA&P WP / 11 2595

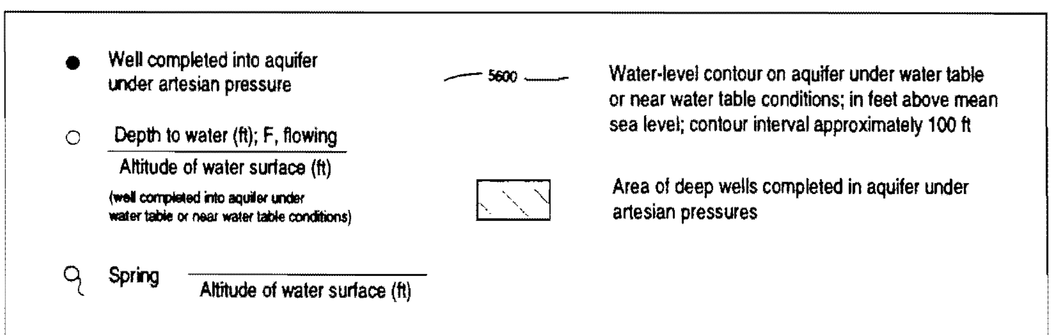


Figure 3-16. Generalized water-level contours and piezometric surface contours of the main aquifer.

The Rendija Canyon fault zone extends across upper Pueblo Canyon and upper Los Alamos Canyon. The Guaje Mountain fault zone may occur in these canyons as a zone of higher fracture density, although no fault offset is demonstrable. Such zones may provide potential recharge paths to the intermediate perched zones and main aquifers.

The age of the main aquifer ground water has been estimated using ^{14}C and ^{3}H dating; results of analyses are presented in Section 3.7.6.2 (Table 3-19). Age estimates vary widely from a few tens of years using ^{3}H techniques to over 40,000 years using ^{14}C techniques. Research continues on determining the actual age and causes for the present wide disparity in estimates of age.

The hydraulic gradient of the main aquifer beneath upper Los Alamos Canyon is approximately 120 ft/mi (0.0227 ft/ft) under static or nonpumping conditions, based on the generalized water level contour map (Purtymun and Johansen 1974, 11835) (Figure 3-16). Movement of ground water is perpendicular to the potentiometric surface in isotropic unfractured rock.

The estimated average velocity of the ground water flow in the main aquifer beneath upper Los Alamos Canyon (calculated using average thickness and permeability values) is 40 to 60 ft per year (Purtymun and Stoker 1988, 6879).

3.7 Surface Water and Ground Water Chemistry and Contaminant Occurrence

This section presents a summary of water-quality data and a detailed discussion of the hydrochemistry of surface water and ground water within the alluvium, Guaje Pumice Bed, Puye Formation, and the Santa Fe Group (main aquifer). Water-quality data consisting of major ions, trace elements, radionuclides, organic compounds, and stable isotopes have been collected for nearly fifty years at the Laboratory. This section also identifies additional information and data needs related to expanding the conceptual understanding of environmental processes occurring within Los Alamos Canyon and Pueblo Canyon and assessing the magnitude and importance of transport pathways and potential exposure pathways within these two canyons.

3.7.1 Previous Sampling and Investigations

Since 1945, water-quality data, primarily on unfiltered surface waters and ground waters, have been collected and published. The USGS monitored the effects of releases of radioactive effluents and conducted geohydrological studies in the Los Alamos area for the AEC from 1949 through 1969. Results of these studies are available in a series of reports and publications (references compiled for use in the ER Project in Bennett [1990, 7507]). Starting in 1970, the Laboratory initiated a formal environmental monitoring program. This monitoring program, which is required by DOE Order 5400.1 (DOE 1988, 0075), continues under the direction of the Laboratory's ESH Division. Five decades of environmental monitoring and numerous hydrologic studies conducted by the USGS, the Laboratory, and other researchers will be supplemented by new data collected under this work plan to characterize significant hydrochemical processes operating in the canyons system.

Since 1971, surveillance and monitoring data have been published annually by the Laboratory in a formal report. The annual reports through 1989 contained data collected in the previous year. Since 1989, the reports have contained data collected two years previously. Earlier reports cited the data compilers as authors. Much of the data used in this section was taken directly from those reports. For brevity, annual reports of surveillance data are cited hereafter as ESG and the date or date range of the annual report(s) containing the data used, for example (ESG 1971–1995).

3.7.2 Geochemical Data Requirements

Existing water-quality data show that tritium, chloride, nitrate, ^{90}Sr, and other contaminants of concern occur in both surface waters and ground waters in Los Alamos Canyon and Pueblo Canyon (ESG 1971–1995). The potential for receptors to be exposed to contaminants drives the need for improved understanding of contaminant transport pathways through the unsaturated and saturated zones within Los Alamos Canyon and Pueblo Canyon. Geochemical and water-quality studies described in this section provide information on contaminant occurrence.

The predominant hydrochemical mechanisms affecting mobilization and transport of contaminants in Los Alamos Canyon and Pueblo Canyon are precipitation/dissolution and adsorption/desorption reactions and possibly colloidal transport, specifically

- sorption of contaminants on surface sediments that are dispersed during surface water runoff and sediment deposition,
- effectiveness of adsorptive geological media in retarding movement of contaminants in the subsurface,
- chemical precipitation and dissolution of contaminants in discrete phases, and
- rate of movement of infiltrating water.

Important geochemical data needed for impact assessment include the following: chemical analyses of surface waters and ground waters (for dissolved and suspended constituents); mineralogical composition of different aquifer materials and surface sediments; and retardation factors or adsorption capacities of different aquifer materials and surface sediments for americium, cesium, plutonium, strontium, and uranium.

3.7.3 Surface Water

3.7.3.1 Upper Los Alamos Canyon

Several locations have been sampled in Los Alamos Canyon, DP Canyon, and Pueblo Canyon since the mid 1940s. Results of chemical analyses of different species, generally gathered on unfiltered water samples, are tabulated in Laboratory reports (LANL 1981 6059; ESG 1971–1995; references to pre-1990 reports compiled in Bennett [1990, 7507]). These species include major ions (calcium, sodium, magnesium, potassium, chloride, sulfate, fluoride, and bicarbonate); radionuclides (tritium, ^{90}Sr, ^{137}Cs, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, ^{234}U, ^{235}U, ^{238}U, and gross-alpha and -beta); and trace elements. A summary of these investigations is presented in this section. Location of surface water sampling stations discussed herein are shown in Figure A-2 in Appendix A of this work plan.

A surface water sampling station is located west of the Laboratory boundary in Los Alamos Canyon (near Los Alamos Reservoir). It is intended to measure background levels of potential contaminants. Measurements at this station indicate that radionuclide activities are near regional fallout levels (except tritium) and that concentrations of individual major ions (calcium, sodium, magnesium, potassium, chloride, sulfate, and bicarbonate) are commonly less than 20 mg/L, as shown in Table 3-4. Silica, in the form of $H_4SiO_4^0$, is the predominant dissolved species in these background surface waters as a result of the dissolution of soluble silica present in the Bandelier Tuff. The pH values of background surface water range from slightly acidic (6.8) to alkaline (8.1) (ESG 1971–1995), and the pH is controlled by CO_2 gas dissolved in the solution, which exchanges with CO_2 gas in the atmosphere. Background surface waters are a calcium-sodium-bicarbonate type with total dissolved solids (TDS) concentrations generally less than 150 mg/L (ESG 1971–1995).

Downstream from Los Alamos Reservoir, concentrations of major ions (in particular, sodium and chloride) increase in the surface water as a result of dissolution of road salt and discharge of treated water from facilities in and adjacent to upper Los Alamos Canyon (Table 3-5). Location of the transects sampled in 1994 and 1995 during the RFI for OU 1098 are shown in Figure A-2 in Appendix A of this work plan. Discharges from former TA-1 and TAs -2, -21, -41, and -53 are the primary anthropogenic sources influencing surface water chemistry in upper Los Alamos Canyon west of state road 4.

Results of surface water sampling in DP Canyon (north and east of TA-21) at DPS-1 and DPS-4 (see Figure A-2 in Appendix A) conducted between 1967 and 1994 indicated elevated activities of radionuclides in the following order (Table 3-6): tritium, ^{137}Cs, ^{90}Sr, ^{238}Pu, ^{239}Pu, and ^{241}Am. Two other surface water stations, DPS-2 and DPS-3, were sampled from 1967–1971 but are not listed in Table 3-6 because of the short term of the monitoring at those stations. Levels of gross-alpha and -beta radiation were also elevated. The sources for this radioactivity are releases from TA-21. Intermittent surface water within DP Canyon flows to the east and southeast to the confluence with Los Alamos Canyon.

Activities of ^{90}Sr in DP Canyon, shown in Figure 3-17, decrease downstream in DP Canyon and have generally decreased with time at a given location. Total uranium concentrations during the period 1967 to 1992 (Table 3-6) ranged between 0.1 and 108 µg/L. Activities of all these radionuclides have decreased over time (Table 3-6), which suggests that the radionuclides have been dispersed within DP Canyon and Los Alamos Canyon.

Concentrations of major and minor ions in surface water, listed in Tables 3-7 A and B, are elevated above background (as measured at Los Alamos Reservoir) in DP Canyon. From 1962 to 1975, the measured values for major anions spanned the following ranges: fluoride from 2.3 to 32 mg/L, chloride from 45 to 410 mg/L, and nitrate (as NO_3) from 18 to 381 mg/L. Treated sewage and laboratory effluents from TA-21 were discharged into DP Canyon from 1945 through 1975, which accounts for the elevated concentrations of these solutes (LANL 1981, 6059). More recent analyses of surface water collected from DP Canyon (Table 3-7A) show reduced concentrations of major ions and nitrates due to cessation of discharges from TA-21. Between 1962 and 1975, the pH values of surface water in DP Canyon ranged from 6.5 to 10.7 (Table 3-7A) which, compared with the pH values of 6.6 to 9.3 measured more recently (Table 3-7B), suggests that near neutral to alkaline solutions were discharged from TA-21.

TABLE 3-4

BACKGROUND WATER QUALITY DATA FROM LOS ALAMOS RESERVOIR

Element/Parameter	Value
pH (field)	8.1
Total dissolved solids (mg/L)	181
Radiochemical (pCi/L)	
^{3}H[a]	300 (300)[b]
^{90}Sr	N/A[c]
^{137}Cs	2.9 (1.1)
^{238}Pu	0.004 (0.016)
$^{239,240}Pu$	0.018 (0.014)
^{241}Am	N/A
Gross-alpha	1 (0)
Gross-beta	4 (1)
Gross-gamma	110 (90)
Major Constituents (mg/L)	
SiO_2	39
Ca	8
Mg	2.6
K	3
Na	6
Cl	6
F	0.2
CO_3	<5
HCO_3	29
PO_4-P	0.0
SO_4	5
NO_3-N	<0.04
CN	<0.01
Trace Metals (mg/L)	
Ag	<0.0006
Al	0.14
As	<0.0020
B	<0.020
Ba	0.0158
Be	<0.0010
Cd	<0.0020
Cr	<0.0050
Co	<0.0020
Cu	<0.002
Fe	0.14
Hg	<0.0001
Total uranium (µg/L)	<0.6

a. Tritium as tritiated water in moisture distilled from sample
b. Radioactivity counting uncertainties (+/– 1 standard deviation) are shown in parentheses.
c. N/A means analysis not performed, lost, or not completed.

(Environmental Protection Group 1994, 35363)

TABLE 3-5

CHEMISTRY OF SURFACE WATER AT TRANSECTS IN TA-2 AND TA-41, UPPER LOS ALAMOS CANYON[a]

Sample No.	Transect	Date	Al mg/L	As mg/L	B mg/L	Ba mg/L	Br mg/L	Ca mg/L	Cd mg/L	Cl mg/L	Cr mg/L	Cs mg/L
PP94-102	Transect 1	10/19/94	2.81	0.0003	0.016	0.05	0.04	12.0	<0.0005	50.1	<0.002	<0.002
PP94-105	Transect 2	10/20/94	2.14	0.0010	0.010	0.04	0.04	11.3	<0.0005	52.8	<0.002	0.002
PP94-106	Transect 3	10/20/94	1.62	0.0005	0.016	0.05	0.03	13.3	<0.0005	51.5	<0.002	<0.002
PP94-108	Transect 4	10/24/94	1.00	0.0007	0.012	0.04	0.03	12.9	<0.0005	48.0	0.003	0.002
PP94-112	Transect 5	10/26/94	1.27	0.0007	0.011	0.04	0.03	13.2	<0.0005	47.5	0.003	<0.002
LAC95-6	Transect 1	01/25/95	0.27	<0.002	0.011	0.03	<0.02	10.2	<0.002	52.7	<0.002	<0.002
LAC95-7	Transect 2	01/25/95	0.32	<0.002	0.012	0.04	0.02	13.0	<0.002	62.7	<0.002	<0.002
LAC95-11	Transect 3	02/13/95	0.47	0.0004	0.007	0.05	<0.02	16.4	<0.0002	134	<0.002	<0.002
LAC95-12	Transect 4	02/16/95	1.27	0.0005	0.010	0.05	0.03	17.3	<0.0002	115	<0.002	<0.002
LAC95-10	Transect 3	02/13/95	0.51	0.0004	0.008	0.05	<0.02	15.9	<0.0002	135	<0.002	<0.002
LAC95-28	Transect 1	05/10/95	0.07	<0.002	<0.01	0.02	<0.05	8.11	<0.0002	20.4	<0.002	<0.002
LAC95-29	Transect 2	05/15/95	1.56	<0.002	<0.01	0.03	<0.05	8.30	<0.0002	20.9	<0.002	<0.002
LAC95-30	Transect 3	05/16/95	0.08	<0.002	<0.01	0.03	<0.05	8.22	<0.0002	19.2	<0.002	<0.002
LAC95-34	Transect 4	05/17/95	1.26	<0.002	<0.01	0.03	<0.05	8.21	<0.0002	18.5	0.002	<0.002
LAC95-35	Transect 5	05/17/95	0.07	<0.002	<0.01	0.02	<0.05	7.98	<0.0002	19.0	<0.002	0.002
LAC95-38	Transect 1	05/10/95	0.14	<0.002	<0.01	0.03	<0.05	8.67	<0.0002	20.4	<0.002	<0.002

Transect	Cu mg/L	F mg/L	Fe mg/L	HCO_3 mg/L	K mg/L	Li mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Na mg/L	NH_4 mg/L	Ni mg/L
Transect 1	0.006	0.11	0.95	64.9	4.07	<0.01	3.25	0.02	0.004	40.9	0.19	0.004
Transect 2	0.003	0.12	0.99	67.1	3.87	<0.01	2.94	0.14	0.004	44.0	0.09	<0.002
Transect 3	0.008	0.13	0.73	67.9	4.10	<0.01	3.10	<0.01	0.004	41.7	0.14	0.002
Transect 4	0.007	0.13	0.42	69.6	3.85	<0.01	3.02	<0.01	0.005	40.2	0.11	0.003
Transect 5	0.006	0.15	0.56	69.5	3.89	<0.01	2.98	<0.01	0.010	39.2	0.07	<0.002
Transect 1	<0.002	0.14	0.09	58.9	2.67	<0.01	2.22	<0.01	0.002	44.1	0.05	<0.002
Transect 2	<0.002	0.13	0.09	60.8	3.16	<0.01	2.67	<0.01	<0.002	46.6	0.05	<0.002
Transect 3	0.015	0.10	0.20	56.5	4.44	<0.01	3.57	<0.01	0.002	83.6	0.05	<0.002
Transect 4	0.005	0.11	0.55	55.0	4.25	<0.01	3.90	<0.01	0.003	69.4	0.04	<0.002
Transect 3	0.015	0.11	0.20	56.6	4.46	<0.01	3.42	<0.01	0.002	85.0	0.05	<0.002
Transect 1	<0.002	0.07	0.01	31.0	2.22	<0.01	2.35	<0.01	<0.002	12.9	0.10	<0.002
Transect 2	0.002	0.08	0.59	29.8	2.29	<0.01	2.44	<0.01	<0.002	13.5	0.14	0.002
Transect 3	<0.002	0.07	0.04	30.5	2.16	<0.01	2.44	0.02	<0.002	13.9	0.08	<0.002
Transect 4	<0.002	0.08	0.51	30.6	2.21	<0.01	2.46	0.02	<0.002	13.9	0.06	<0.002
Transect 5	0.005	0.08	0.01	30.7	2.22	<0.01	2.26	<0.01	<0.002	13.2	0.06	<0.002
Transect 1	0.002	0.08	0.07	30.8	2.16	<0.01	2.56	0.02	<0.002	14.1	0.05	<0.002

a. The following chemical constituents are not shown because they are below the detection limits as indicated: Ag (<0.0005 mg/L), Be (<0.002 mg/L), Hg (<0.0002 mg/L), I (<0.01 mg/L), S_2O_3 (<0.01 mg/L), Ti (<0.002 mg/L), Se (<0.002 mg/L).

TABLE 3-5 (continued)

CHEMISTRY OF SURFACE WATER AT TRANSECTS IN TA-2 AND TA-41, UPPER LOS ALAMOS CANYON

Transect	NO_2 mg/L	NO_3 mg/L	Pb mg/L	pH (lab)	PO_4 mg/L	Rb mg/L	Sb mg/L	SiO_2 mg/L	SiO_4 mg/L	Sr mg/L	V mg/L	Zn mg/L	TDS mg/L	^3H mg/L
Transect 1	<0.02	0.57	<0.002	6.82	<0.05	0.008	<0.0002	42.8	6.94	0.09	0.011	0.02	229.9	77.2
Transect 2	<0.02	0.33	<0.002	7.06	<0.05	0.007	<0.0002	44.9	6.97	0.09	0.012	0.01	237.9	85.6
Transect 3	<0.02	0.40	<0.002	7.17	<0.05	0.007	<0.0002	41.3	7.08	0.09	0.011	0.01	233.2	93.5
Transect 4	<0.02	0.50	<0.002	7.21	<0.05	0.007	<0.0002	39.8	6.57	0.09	0.010	0.02	226.3	368
Transect 5	<0.02	0.33	0.002	7.37	<0.05	0.005	<0.0002	42.2	6.62	0.09	0.011	0.02	227.7	421
Transect 1	<0.02	<0.02	<0.002	7.58	<0.05	0.004	<0.002	29.5	6.43	0.07	0.007	<0.01	207.4	76
Transect 2	<0.02	0.26	<0.002	7.46	<0.05	0.005	<0.002	31.9	6.81	0.08	0.007	<0.01	228.6	63.8
Transect 3	<0.02	<0.02	<0.002	7.55	<0.05	0.005	<0.0002	28.9	8.12	0.12	N/A	<0.01	336.6	142
Transect 4	<0.02	<0.02	0.002	7.30	0.06	0.006	<0.0002	28.2	7.86	0.11	N/A	<0.01	303.2	109
Transect 3	<0.02	<0.02	<0.002	7.43	<0.05	0.005	<0.0002	26.1	8.06	0.11	<0.01	<0.01	356.6	144
Transect 1	<0.02	<0.05	<0.002	7.48	<0.1	0.004	<0.002	30.0	5.33	0.06	<0.002	<0.01	112.6	92.6
Transect 2	0.16	1.04	<0.002	6.96	<0.1	0.005	<0.002	35.5	5.23	0.06	<0.002	<0.01	121.6	76.6
Transect 3	<0.02	<0.05	<0.002	7.18	<0.1	0.004	<0.002	30.2	5.38	0.08	0.002	0.02	112.4	73.4
Transect 4	<0.02	<0.05	<0.002	7.33	<0.1	0.006	<0.002	34.7	5.33	0.07	0.002	0.03	117.9	67
Transect 5	<0.02	0.26	<0.002	7.19	<0.1	0.005	<0.002	30.4	5.40	0.06	<0.002	<0.01	111.7	89.4
Transect 1	<0.02	<0.05	<0.002	7.27	<0.1	0.005	<0.002	30.8	5.74	0.08	0.002	0.02	115.7	79.8

(LANL 1994, 34756; LANL 1993, 21404; LANL 1993, 23240)

3.7.3.2 Pueblo Canyon

Stream flow in Pueblo Canyon consists in part of ephemeral flow from snowmelt and rain. However, this flow has historically been dominated by anthropogenic contributions from effluents discharged from former TA-1, former TA-45, former sewage treatment plants (Pueblo and Central), and the present Los Alamos County sewage treatment plant.

Since the late 1940s, sewage was treated at and discharged from three different treatment plants in Pueblo Canyon (shown in Figure A-2 in Appendix A of this work plan) (LANL 1981, 6059).

The oldest plant was the Pueblo sewage treatment plant, whose annual discharges typically ranged from 375,000 m^3 to 875,000 m^3. The Central sewage treatment plant operated from the late 1940s until 1966 when operation was transferred to the Los Alamos County sewage treatment plant. Until 1954, the annual discharges from the Central sewage treatment plant ranged from 70,000 m^3 to 760,000 m^3. In 1954, part of the effluent was pumped to the power plant for use as cooling water, and the releases into Pueblo Canyon decreased. Between 1954 and 1966, the discharges ranged between 75,000 m^3/yr and 150,000 m^3/yr. The Pueblo sewage treatment plant began operation in the 1950s and continued until 1990 when all sewage treatment was transferred to the Los Alamos County sewage treatment plant. The Los Alamos County sewage treatment plant began operation in 1963 and continues to the present day. Annual discharges from the Los Alamos County sewage treatment plant are approximately 900,000 m^3. More detailed information regarding discharges from these treatment plants is contained in the FUSRAP report (LANL 1981, 6059).

TABLE 3-6

RADIOCHEMICAL QUALITY OF SURFACE WATER IN DP CANYON, UPPER LOS ALAMOS CANYON

Element/Parameter	1967	1968	1969	1970	1971	1972	1973	1974
DPS[a]-1								
^{3}H (pCi/L)	540000	20000	430000	402222	356000	396100	310000	11000
^{90}Sr (pCi/L)	28600	11360	800	568	716	—[b]	—	—
^{137}Cs (pCi/L)	34000	13400	3490	692	1200	<350	260	48
Total uranium (μg/L)	—	—	—	—	2.3	7.1	0.1	3.1
^{238}Pu (pCi/L)	3.87	4.25	5.55	0.81	1.16	0.32	2.91	0.17
^{239}Pu (pCi/L)	76.1	28.8	9.1	2.2	2.07	5.68	10.1	0.27
^{241}Am (pCi/L)	1.29	4.52	3.58	1.19	0.6	0.33	—	—
Gross-alpha (pCi/L)	63	34	14	7	22	13	12	10
Gross-beta (pCi/L)	51700	14300	2060	1200	1390	2470	460	670

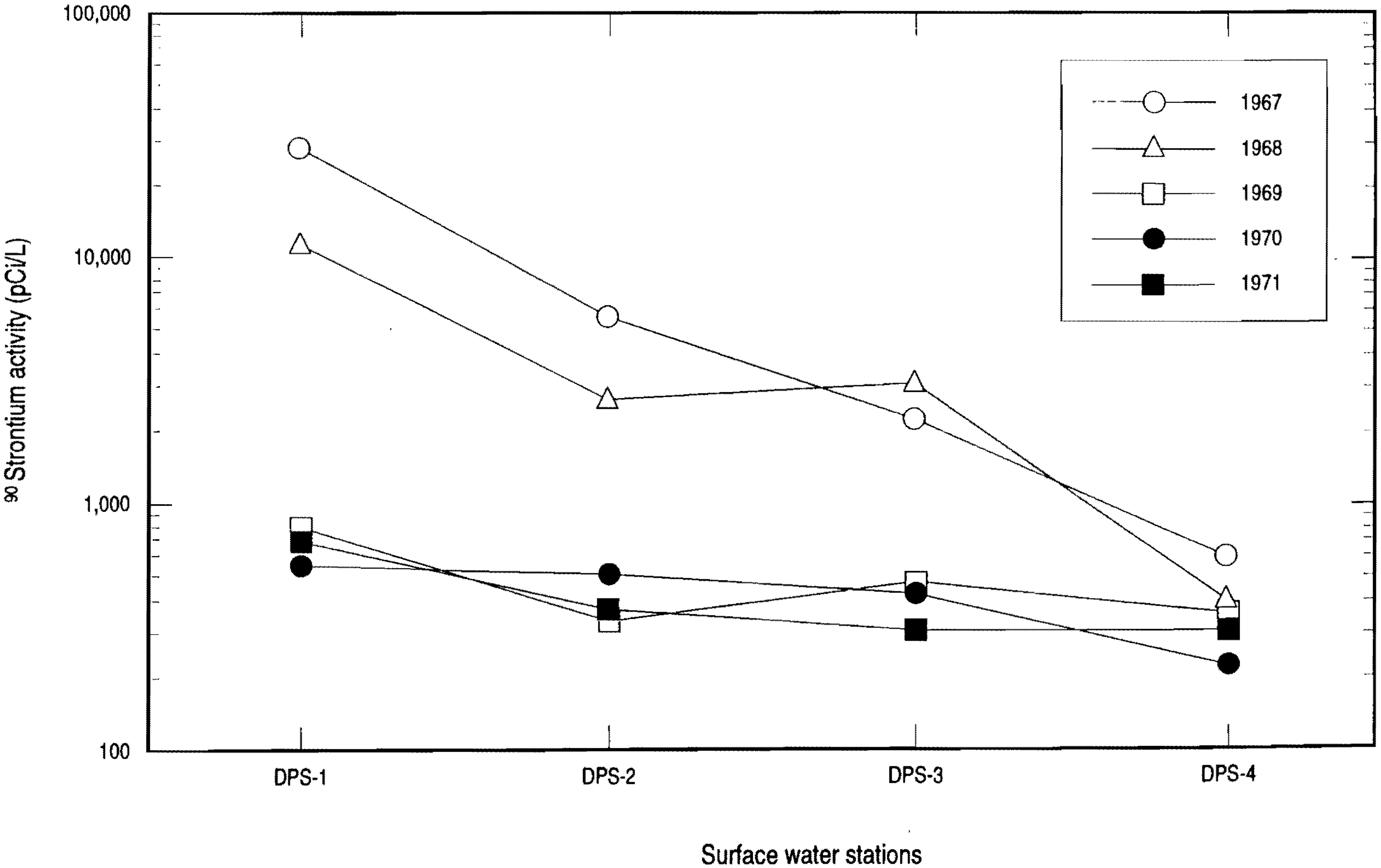
	1975	1977	1986	1988	1989	1991	1992
^{3}H (pCi/L)	19000	130000	900	700	1200	Dry	800
^{90}Sr (pCi/L)	—	—	—	—	—	Dry	19.6
^{137}Cs (pCi/L)	12	0	35.5	43	0	Dry	44.8
Total uranium (μg/L)	6.9	108	0.75	1	1	Dry	2.2
^{238}Pu (pCi/L)	0.27	0.69	0.035	0	0	Dry	0
^{239}Pu (pCi/L)	0.57	1.67	—	—	—	Dry	0.182
^{241}Am (pCi/L)	—	—	—	—	—	Dry	0.3
Gross-alpha (pCi/L)	25	106	—	—	—	Dry	1
Gross-beta (pCi/L)	500	3870	—	—	—	Dry	40

Element/Parameter	1967	1968	1969	1970	1971	1972	1973	1974
DPS-4								
^{3}H (pCi/L)	410000	476000	346000	162000	103000	172000	51000	23000
^{90}Sr (pCi/L)	632	435	380	233	315	—	—	—
^{137}Cs (pCi/L)	<240	<240	<240	<240	<300	<50	<350	<50
Total uranium (μg/L)	—	—	—	—	0.6	3.3	0.4	0.9
^{238}Pu (pCi/L)	0.13	0.09	0.44	0.13	0.11	0.11	0.04	0.94
^{239}Pu (pCi/L)	0.14	0.08	0.52	0.21	0.13	0.27	0.11	0.39
^{241}Am (pCi/L)	<0.05	0.08	0.35	0.2	0.08	0.25	—	—
Gross-alpha (pCi/L)	2	6	2	1	3	2	2	5
Gross-beta (pCi/L)	1800	625	418	457	370	609	215	500

	1975	1977	1986	1988	1989	1991
^{3}H (pCi/L)	46000	43000	3300	1100	Dry	Dry
^{90}Sr (pCi/L)	—	—	—	—	Dry	Dry
^{137}Cs (pCi/L)	<50	93	0	0	Dry	Dry
Total uranium (μg/L)	1.3	6.8	1	1	Dry	Dry
^{238}Pu (pCi/L)	0.02	0.03	0.012	0	Dry	Dry
^{239}Pu (pCi/L)	<0.05	0.15	—	—	Dry	Dry
^{241}Am (pCi/L)	—	—	—	—	Dry	Dry
Gross-alpha (pCi/L)	3	0	—	—	Dry	Dry
Gross-beta (pCi/L)	—	763	—	—	Dry	Dry

a. DPS means DP Canyon surface water station.
b. — means not analyzed.

(LANL 1981, 6059; ESG 1971–1995; Environmental Protection Group 1992, 7004)



Source: LANL 1981, 6059

F 3-17 / LA&P WP / 110295

Figure 3-17. Strontium activities in surface water in DP Canyon.

TABLE 3-7A

CHEMICAL QUALITY OF SURFACE WATER IN DP CANYON, UPPER LOS ALAMOS CANYON[a]

Station	Year	No. of Analyses	Na	Cl	F	NO_3	TDS[b]	pH
DPS[c]-1	1967	2	630	410	9.5	104	1740	9.7
	1968	3	670	215	23.0	381	1950	10.1
	1969	2	375	92	32.0	53	1100	10.7
	1970	5	241	140	6.0	118	878	9.6
	1971	4	233	76	4.7	62	893	9.3
	1972	3	206	137	2.5	88	932	7.9
	1973	3	180	46	8.9	198	1097	7.9
	1974	2	148	46	5.6	92	456	8.0
	1975	2	176	65	2.3	260	816	8.9
DPS-2	1967	1	290	75	8.0	140	669	8.5
	1968	2	250	65	9.4	101	746	9.4
	1969	2	282	103	12.0	26	716	9.8
	1970	2	188	85	13.0	48	714	9.1
	1971	1	68	88	3.7	35	642	8.2
DPS-3	1967	1	310	85	10.0	28	799	8.8
	1968	2	325	88	16.0	150	676	9.1
	1969	2	293	75	12.0	31	409	9.0
	1970	3	200	93	10.0	84	814	9.3
DPS-4	1962	2	143	134	15.0	40	771	7.4
	1963	2	132	113	13.0	41	743	7.5
	1964	3	109	106	5.6	57	734	7.8
	1965	2	110	109	15.0	40	656	7.8
	1966	—[d]	—	—	—	—	—	—
	1967	2	253	103	7.7	145	757	7.9
	1968	2	200	85	6.2	—	607	8.1
	1969	2	198	60	5.0	35	390	8.0
	1970	4	103	45	11.0	18	464	8.5
	1971	4	113	47	5.0	36	531	7.8
	1972	3	214	58	4.1	30	493	8.0
	1973	4	115	75	4.2	34	540	7.8
	1974	2	96	45	2.7	32	247	7.7
	1975	2	107	47	2.9	295	479	7.6

a. Average of a number of analyses in mg/L, except pH (units)
b. TDS = total dissolved solids
c. DPS means DP Canyon surface water station.
d. — means not analyzed.

(LANL 1981, 6059)

TABLE 3-7B

CHEMICAL QUALITY OF SURFACE WATER IN DP CANYON, UPPER LOS ALAMOS CANYON[a]

Sample No.	Location Description	Date	Na	Cl	F	NO_3	TDS[b]	pH
PP-1	DP Spring	5/30/90	72	39.5	1.88	5.78	330.2	7.51
PP-2	DP Spring	8/10/90	50.6	24.7	1.73	3.41	282.7	7.42
PP-3	TA-21 sewage treatment plant	8/10/90	104	38.1	1.25	153	525.7	7.40
PP-4	DP Site, Cold Spring	9/6/90	49.1	21.1	1.69	2.45	258.9	7.87
PP93-28	DP Spring	5/??/93	71.5	82.2	1.14	14.5	330.9	6.55
PP93-29	DP Site, Location 21-1575	6/23/93	67.6	68.8	1.31	14.6	331.7	6.80
PP93-30	DP Site, Location 21-1575	7/23/93	60.2	55.6	1.26	10.5	305.9	7.06
PP93-32	DP Site, Location 21-1575	10/6/93	49.7	38.4	1.41	3.03	269.1	6.69
PP94-45	DP Spring	4/14/94	63.4	107	1.05	6.39	324.0	6.90
PP94-46	DP Canyon, 100 m up from PP94-45	4/14/94	65.2	104	0.55	3.65	319.1	7.00
PP94-47	DP Canyon, 200 m up from PP94-46	4/14/94	75.2	98.8	0.62	0.28	370.8	8.06
PP94-48	DP Canyon, below sewage outfall	4/14/94	52.3	14.3	1.05	<0.02	228.8	6.79
PP94-49	K of C drainage	4/14/94	70.4	94.6	0.25	0.07	349.4	9.34
DP95-1	DP Spring	1995	64.0	93.1	1.12	0.61	300.1	7.2

a. Single sample analyses in mg/L, except pH (units)
b. TDS = total dissolved solids

(Environmental Protection Group 1993, 23249; Environmental Protection Group 1994, 35363; Environmental Protection Group 1995, 50285)

Several surface water monitoring stations in Pueblo Canyon are shown in Figure A-2 in Appendix A. Results of previous water-quality sampling have shown that the industrial and sanitary effluents were alkaline and contained elevated concentrations of major ions (Table 3-8). Urban runoff and chlorinated water discharged from the swimming pool at Los Alamos High School also contributed to increases in major ion concentrations in surface water in Pueblo Canyon. The chemical quality of surface water collected at monitoring station Pueblo 3 reflects a contribution from treated sewage discharged from the Pueblo, Central, and Los Alamos County sewage treatment plants (LANL 1981, 6059). Surface water in lower Pueblo Canyon is a mixed-ion (sodium-chloride-nitrate) type.

Activities of tritium, ^{90}Sr, ^{137}Cs, ^{238}Pu, and ^{239}Pu measured in Pueblo Canyon generally decrease downstream from the original point of wastewater discharge in Acid Canyon. Surface water samples have been collected at Acid Weir in Acid Canyon (just above the confluence with Pueblo Canyon) and at other stations downstream to the monitoring station Pueblo 3. Table 3-9 shows the results of radiochemical analyses of surface water collected at stations Acid Weir, Pueblo 1, Pueblo 2, and Pueblo 3 from 1970 to 1975.

Results of studies to date indicate that residual contamination from past discharges at former TA-45, present as radionuclides sorbed onto sediments, is transported downstream on resuspended sediments during storm events. This process increases the inventory of radionuclides in sediments in Pueblo Canyon and lower Los Alamos Canyon (LANL 1981, 6059).

TABLE 3-8

HISTORICAL CHEMICAL QUALITY OF SURFACE WATER IN THE PUEBLO CANYON DRAINAGE SYSTEM[a]

Location	Year	No. of Analyses	Na	Cl	F	NO_3	TDS[b]	pH
Acid Weir	1953	9	—[c]	29	4.1	157	435	—
	1954	10	—	37	5.2	242	545	—
	1955	6	—	36	5.2	304	640	—
	1956	10	—	32	5.7	50	583	8.6
	1957	3	72	23	3.8	36	345	7.9
	1958	6	66	25	5.1	23	350	8.1
	1959	3	87	45	4.0	26	400	8.3
	1960	1	85	44	3.9	16	335	8.6
	1961	1	78	29	2.0	29	420	8.5
	1962	2	94	39	2.2	26	400	9.4
	1963	2	72	24	2.0	13	356	8.3
	1965	1	38	14	1.7	4	246	7.6
	1970	2	98	165	1.7	4	437	7.7
	1971	1	41	52	0.9	4	276	7.1
	1972	2	86	73	1.9	4	305	7.4
	1973	2	68	41	0.9	5	326	7.4
	1974	2	80	89	0.8	7	316	7.4
	1975	2	59	50	0.7	26	324	7.7
Pueblo 1	1953	9	—	31	2.2	61	350	—
	1954	11	—	30	2.4	77	360	—
	1955	6	—	32	3.3	153	470	—
	1956	8	—	35	2.5	14	445	8.0
	1957	6	65	24	2.3	38	275	7.5
	1958	12	56	24	1.6	30	280	7.5
	1959	5	62	26	1.4	35	320	7.4
	1961	1	45	16	1.0	22	340	7.7
	1962	2	70	28	1.6	53	403	6.9
	1963	2	60	33	2.0	35	348	7.2
	1970	2	80	40	1.4	44	374	7.0
	1971	1	82	28	1.0	57	376	7.0
	1972	2	75	41	3.3	53	416	7.1
	1973	2	75	33	6.0	16	430	7.3
	1974	2	78	45	1.0	32	426	7.6
	1975	2	61	39	0.7	42	362	7.3

a. Average of a number of analyses in mg/L, except pH (units)
b. TDS = total dissolved solids
c. — means not analyzed.

TABLE 3-8 (continued)

HISTORICAL CHEMICAL QUALITY OF SURFACE WATER IN THE PUEBLO CANYON DRAINAGE SYSTEM[a]

Location	Year	No. of Analyses	Na	Cl	F	NO_3	TDS[b]	pH
Pueblo 2	1953	8	—[c]	32	1.2	42	305	—
	1954	9	—	32	1.2	60	310	—
	1955	2	—	34	2.5	64	360	—
	1956	9	—	34	2.4	26	494	8.2
	1957	4	63	27	2.3	25	280	7.6
	1958	12	64	27	1.7	24	265	7.8
	1959	5	72	31	1.5	35	325	7.3
	1961	1	38	12	1.0	13	294	7.8
	1962	1	61	25	1.2	30	325	7.2
	1963	3	71	30	1.5	40	398	7.5
	1964	2	84	31	2.0	40	390	7.5
	1970	2	81	44	1.3	22	402	7.5
	1971	1	72	28	0.6	26	330	7.3
	1972	2	73	39	3.3	31	363	7.7
	1973	2	59	36	4.8	18	344	7.6
	1974	2	86	44	1.0	22	387	7.5
	1975	2	64	38	0.6	36	225	7.2
Pueblo 3	1957	1	48	18	2.0	20	210	7.9
	1958	7	51	22	1.4	22	215	7.6
	1959	5	71	32	1.6	20	310	7.4
	1961	2	59	17	0.7	18	465	7.7
	1963	1	65	28	2.0	9	362	7.5
	1964	2	115	47	2.0	22	455	7.8
	1970	2	84	22	1.0	61	376	7.0
	1971	1	74	26	1.2	66	416	6.9
	1972	2	76	39	3.3	44	385	7.3
	1973	2	78	35	5.7	66	453	7.1
	1974	2	92	54	1.1	31	434	7.5
	1975	2	72	36	0.8	48	380	7.2

a. Average of a number of analyses in mg/L, except pH (units)
b. TDS = total dissolved solids
c. — means not analyzed.

(LANL 1981, 6059)

TABLE 3-9

RADIOCHEMICAL QUALITY OF SURFACE WATER IN THE PUEBLO CANYON DRAINAGE SYSTEM[a]

Location	Year	No. of Analyses	Gross-Alpha	Gross-Beta	^{238}Pu	^{239}Pu	^{137}Cs	^{3}H	Total U (μg/L)
Acid Weir	1970	2	2	225	<0.05	0.27	—[b]	3000	0.6
	1971	1	6	52	0.18	7.9	<300	1600	2.3
	1972	2	2	132	<0.05	0.42	<300	1200	1.7
	1973	2	5	86	<0.05	0.20	<300	1400	<0.4
	1974	4	3	140	<0.05	1.4	<100	1000	1.2
	1975	3	2	61	<0.05	<0.05	—	2300	1.3
Pueblo 1	1970	2	<1	21	<0.05	<0.05	—	<500	0.8
	1971	1	<1	16	0.07	0.08	<300	<500	<0.4
	1972	2	<1	8	0.11	0.09	<350	<500	1.4
	1973	2	<1	21	0.09	0.33	<300	3000	<0.4
	1974	4	2	24	<0.05	<0.05	<100	<500	0.8
	1975	3	1	11	<0.05	<0.05	—	1500	—
Pueblo 2	1970	2	<1	20	<0.05	0.06	—	<500	0.8
	1971	1	<1	9	0.07	1.02	<300	<500	0.4
	1972	2	1	14	<0.05	0.11	<350	<500	1.4
	1973	2	1	14	0.10	0.70	<300	<500	<0.4
	1974	4	2	17	<0.05	0.12	<100	<500	0.7
	1975	3	1	17	<0.05	0.34	—	<500	0.8
Pueblo 3	1970	2	<1	11	<0.05	<0.05	—	<500	0.7
	1971	1	1	6	0.06	<0.05	350	<500	<0.4
	1972	2	<1	20	0.05	0.08	<350	<500	1.6
	1973	2	<1	14	0.05	0.21	<300	<500	<0.4
	1974	4	1	17	0.10	<0.05	<100	<500	0.6
	1975	3	1	19	0.10	<0.05	—	<500	2.3

a. Average of a number of analyses in pCi/L
b. — means not analyzed.

(LANL 1981, 6059)

3.7.3.3 Lower Los Alamos Canyon

Stream flow in lower Los Alamos Canyon consists in part of discharges from Basalt Spring (see Figure A-2 in Appendix A) and ephemeral flow from snowmelt and rain. However, this flow has historically been dominated by anthropogenic contributions from effluents discharged from former TA-1, former TA-45, and the Pueblo and Central sewage treatment plants. Current Laboratory discharges come from TAs -2, -21, -41, and -53. Since 1990, increased discharge from the Los Alamos County sewage treatment plant has maintained almost continuous flow through lower Pueblo Canyon and into Los Alamos Canyon.

Several surface water monitoring stations in lower Los Alamos Canyon are shown in Figure A-2 in Appendix A. Monitoring data for surface water in lower Los Alamos Canyon at Basalt Spring are summarized in Tables 3-10 A, B, and C. The pH of surface waters is near neutral to slightly alkaline, and the concentrations of several major ions are elevated above background (see Table 3-4) at some locations. Activities of measured radionuclides (tritium, ^{90}Sr, ^{137}Cs, ^{238}Pu, and ^{239}Pu) in unfiltered water samples generally decrease downstream.

3.7.4 Alluvial Ground Water

3.7.4.1 Upper Los Alamos Canyon

In upper Los Alamos Canyon, the quality of ground water in the alluvium is monitored by 17 shallow observation wells. The locations of these wells are shown in Figure A-2 in Appendix A of this work plan; information regarding the construction of the wells is described by Purtymun (1995, 45344). Twelve of these wells were installed as early as 1966 as part of the Laboratory's surveillance program; the other five were installed at TA-2 and TA-41 in 1994 for the ER Project.

The alluvial ground water is a sodium-calcium-bicarbonate type with an average TDS concentration of approximately 125 mg/L. Observation well LAO-B serves as a background well for upper Los Alamos Canyon and is located near the western boundary of the Laboratory (see Figure A-2 in Appendix A). Concentrations of chloride are less than 10 mg/L, similar to chloride concentrations in Los Alamos Reservoir. Activities of tritium measured at observation well LAO-B are less than 65 pCi/L, which is within the range of rainfall and snowmelt (Adams et al. 1995, 47192). Tritium, in the form of tritiated water is a mobile species in ground water and is expected to migrate at the same rate as ground water in the alluvium and other saturated zones. Tritium has a half-life of 12.33 years. Its residence time in the alluvium is expected to be less than that of ^{90}Sr and ^{137}Cs, which are adsorbed (chemically retarded) to a much greater extent than tritium.

Observation well LAO-C, located west of TA-41, serves as a background well for TA-2 and TA-41. Water from LAO-C contains higher concentrations of contaminants than water from LAO-B.

Downgradient from TA-2 and TA-41, the measured concentrations (as activities) of tritium, ^{137}Cs, ^{90}Sr, natural and enriched uranium, ^{238}Pu, ^{239,240}Pu, ^{241}Am, and the concentrations of major cations and anions, and some trace metals generally are above the natural background or regional fallout levels observed at Los Alamos Reservoir (Table 3-4). Figures 3-18 through 3-26 show selected results of chemical analyses of ground water in upper Los Alamos Canyon, as reported annually by the ESG.

TABLE 3-10A

HISTORICAL CHEMICAL QUALITY OF WATER LOWER LOS ALAMOS CANYON AT BASALT SPRING[a]

Year	No. of Analyses	Na	Cl	F	NO_3	TDS[b]
1951	1	—[c]	16	0.5	8	220
1952	4	—	15	0.4	13	215
1953	3	—	16	0.4	10	198
1954	3	—	16	0.4	15	195
1955	2	—	16	0.5	12	198
1956	18	17	17	0.6	18	212
1957	3	16	13	0.5	14	191
1958	6	13	13	0.6	11	169
1959	5	14	15	0.4	10	190
1960	2	15	13	0.5	8	175
1961	1	14	14	0.5	8	174
1962	2	20	17	0.8	13	256
1963	2	24	20	1.2	13	198
1964	1	20	20	0.8	13	229
1965	2	10	14	0.8	13	197
1967	1	25	15	0.3	13	150
1968	1	24	14	0.6	13	168
1969	2	24	14	0.3	9	207
1971	2	15	11	0.6	13	220
1972	2	19	14	0.4	10	197
1973	2	15	14	0.9	10	263
1974	2	16	17	0.7	11	206
1975	2	13	15	0.6	10	209

a. Average of a number of analyses in mg/L
b. TDS = total dissolved solids
c. — means not analyzed.

TABLE 3-10B

CHEMICAL QUALITY OF WATER LOWER LOS ALAMOS CANYON AT BASALT SPRING METAL-ION ANALYSES 1971 AND 1972[a]

Metal Ion	In Solution	Particulates
Cadmium	1.7	0.29
Beryllium	<0.25	<0.25
Lead	<1.0	1.4
Mercury	<0.02	0.03

a. Average of a number of analyses in μg/L

TABLE 3-10C

HISTORICAL RADIOCHEMICAL QUALITY OF SURFACE WATER LOWER LOS ALAMOS CANYON AT BASALT SPRING 1967 THROUGH 1975[a]

Year	No. of Analyses	Gross-Alpha	Gross-Beta	^{238}Pu	^{239}Pu	^{137}Cs	^{3}H	Total U (μg/L)
1967	1	1	4	<0.05	<0.05	—[b]	—	0.4
1968	2	<1	4	<0.05	<0.05	—	—	0.7
1969	1	<1	3	<0.05	<0.05	—	—	1.6
1970	1	<1	5	<0.05	<0.05	—	—	0.4
1971	2	1	2	<0.05	<0.05	—	<1000	1.6
1972	2	<1	4	<0.05	<0.05	<350	<1000	3.0
1973	2	<1	2	<0.05	<0.05	<300	<1000	<0.4
1974	4	<1	4	<0.05	<0.05	<300	<1000	—
1975	3	1	7	<0.05	<0.05	—	1300	1.2

a. Average of a number of analyses in pCi/L, except as noted
b. — means not analyzed.

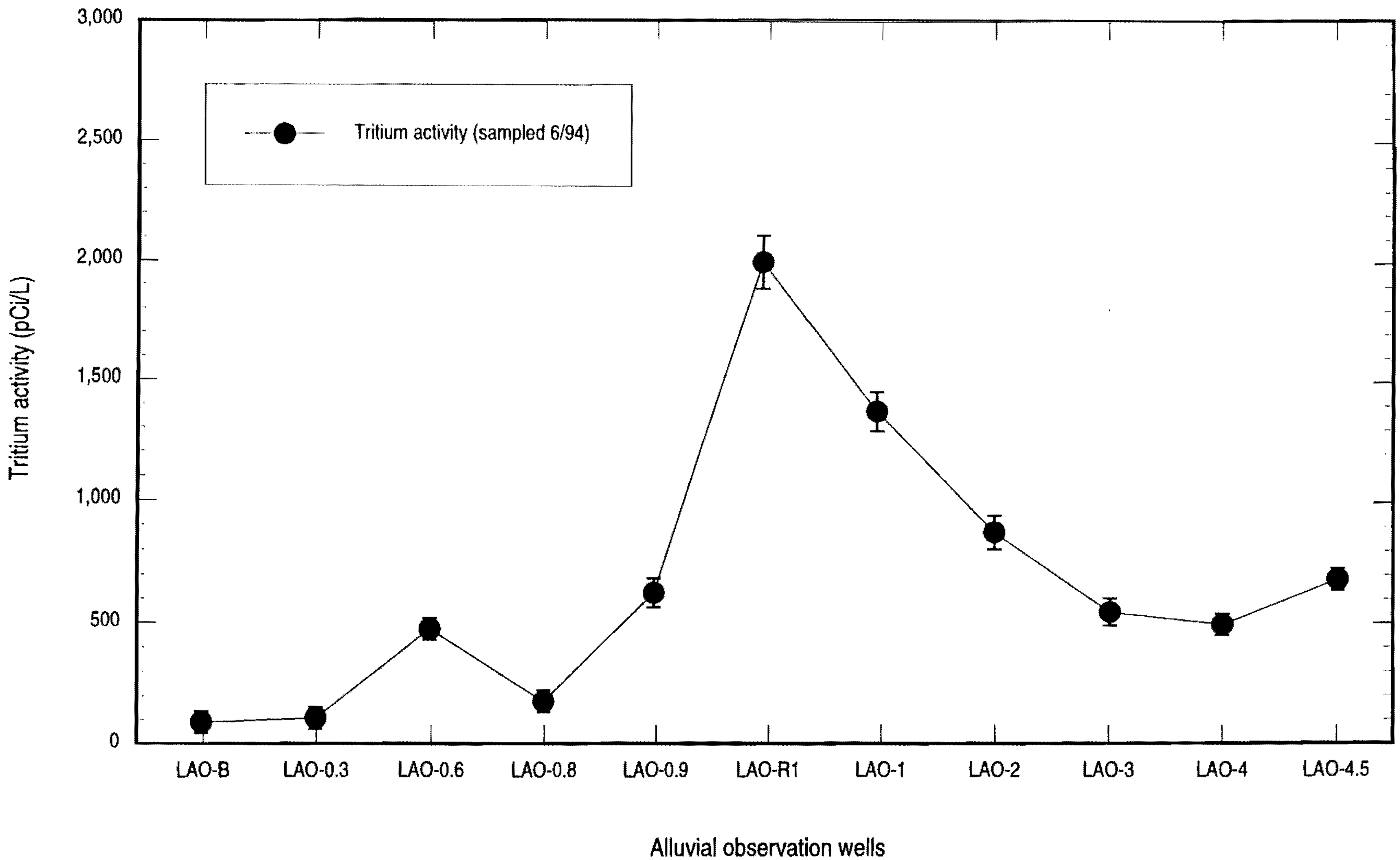
(LANL 1981, 6059)

Tritium activities have been above background (relative to observation well LAO-B) in all wells downgradient from LAO-C and well above background in two alluvial observation wells (LAO-R1 and LAO-1) immediately downgradient from TA-2 (ESG 1966–1994). Tritium activities at observation well LAO-1 (at the eastern boundary of TA-2) generally showed the highest tritium activities during the 1980s and early 1990s (Figure 3-19). Releases of tritium resulted from a leak in the cooling water system delay line at the Omega West Reactor, which is discussed in Chapter 2 of this work plan. Tritium activities fluctuate in observation wells farther downgradient (LAO-2, LAO-3, LAO-4, and LAO-4.5). Results of analyses for radionuclides in alluvial observations wells in Los Alamos Canyon through 1975 are listed in Table 3-10C.

Facilities at TA-21 have discharged tritium into Los Alamos Canyon via DP Canyon. During the mid-1960s, tritium activities were as high as 475,000 pCi/L in water from observation well LAO-2 (in Los Alamos Canyon above the confluence in DP Canyon), probably the result of a leaking tritiated water tank at the tritium facility at TA-21 (LANL 1981, 6059). Tritium activities in observation well LAO-2 have decreased since the 1960s (Table 3-11). Elevated activities of tritium have been documented by the ESG (1970–1994) in ground water samples collected from observation wells LAO-3, LAO-4, LAO-4.5, LAO-5, and LAO-6.

Activities of ^{90}Sr in alluvial ground water are shown in Figures 3-20 and 3-21. The highest activities of ^{90}Sr occur in ground water samples collected from observation wells LAO-1, LAO-2, and LAO-3, which implies that TA-2 and TA-21 are contaminant sources for ^{90}Sr. Higher activities of ^{90}Sr were observed in the middle to late 1970s and early 1980s; activities of this radionuclide decreased slightly in the early 1990s compared with earlier values.

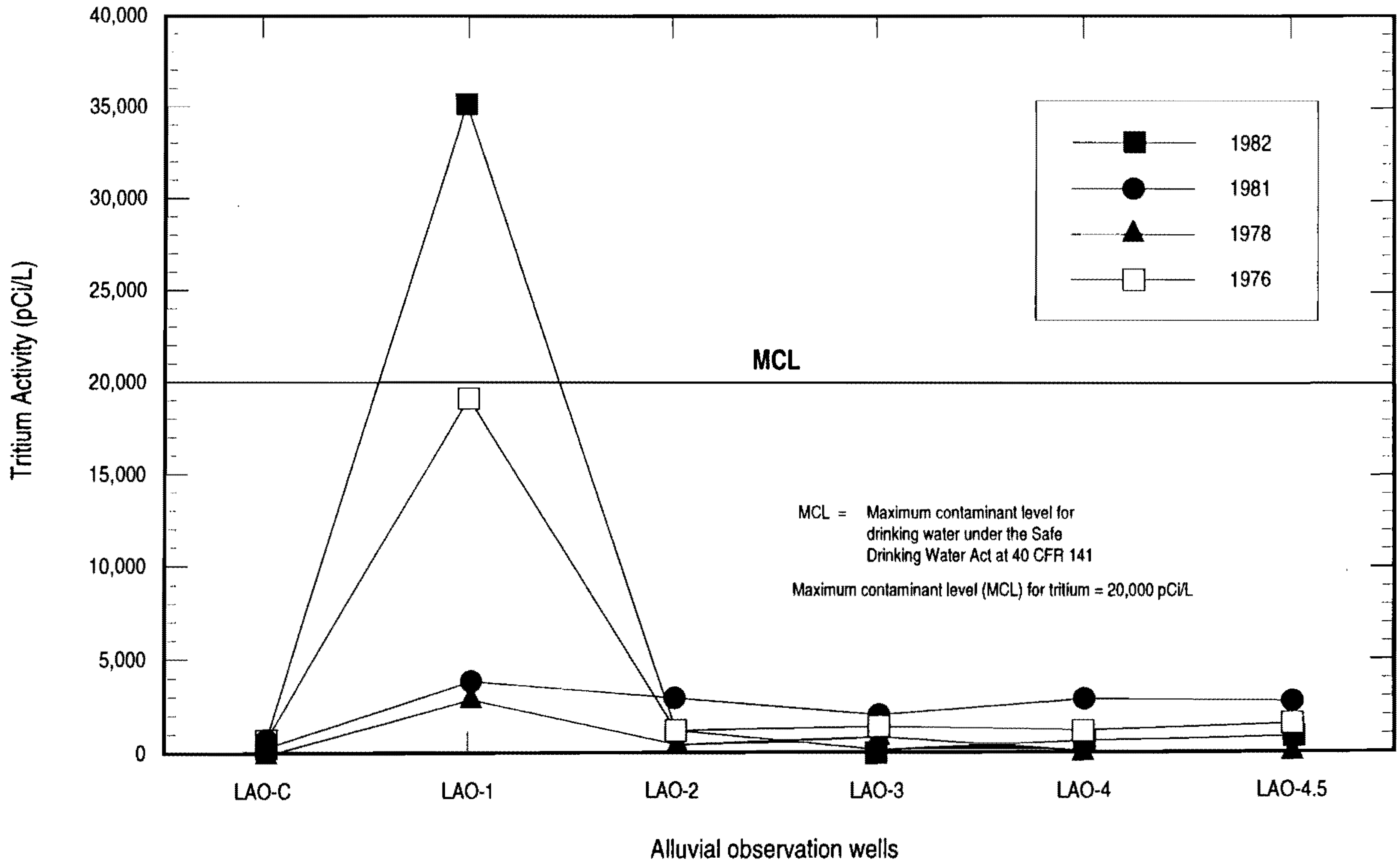
Concentrations of nitrate fluctuate along the ground water flow path in the alluvium downgradient from observation well LAO-C (Figures 3-22 and 3-23). Past discharges



Source: Kennedy et al. 1971, 4800

F 3-18 / LA&P WP / 112495

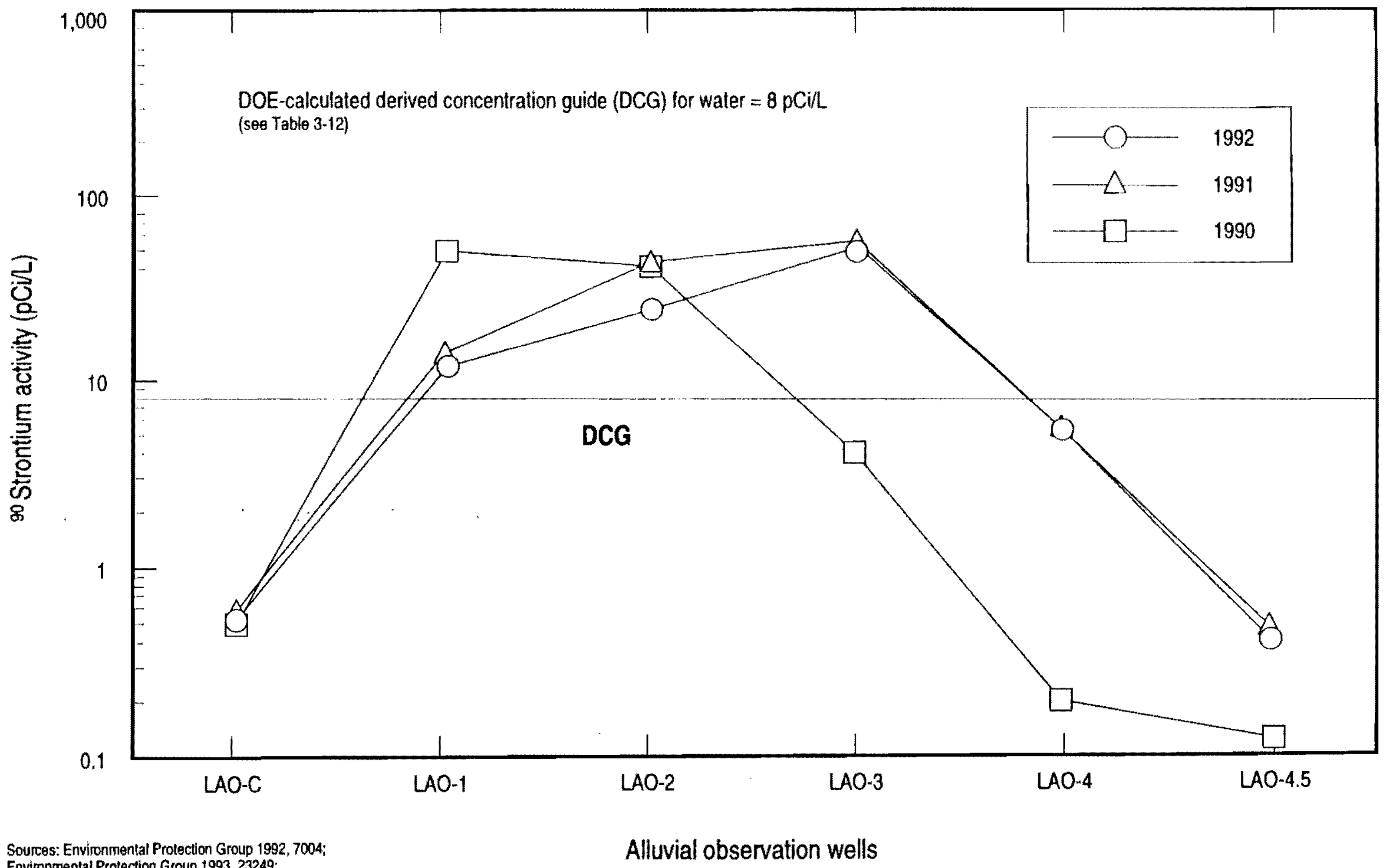
Figure 3-18. Tritium activities in alluvial ground water in upper Los Alamos Canyon.



Sources: ESG 1977, 5703; ESG 1979, 5819;
ESG 1982, 6245; ESG 1983, 6418

F 3-19 / LA&P WP / 111895

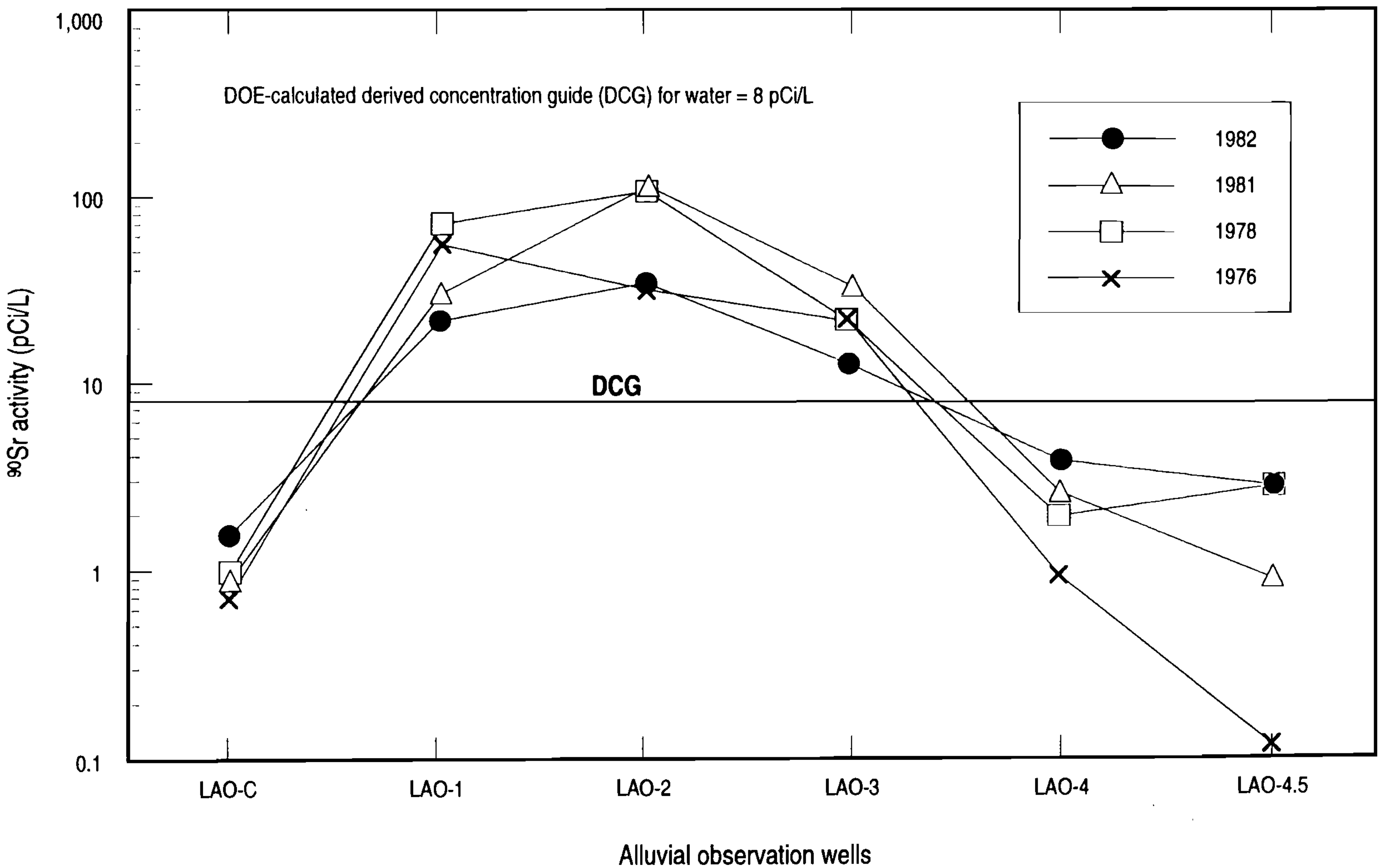
Figure 3-19. Tritium activities in alluvial ground water in upper Los Alamos Canyon.



Sources: Environmental Protection Group 1992, 7004;
Environmental Protection Group 1993, 23249;
Environmental Protection Group 1994, 35363

F 3-20 / LA&P WP / 110295

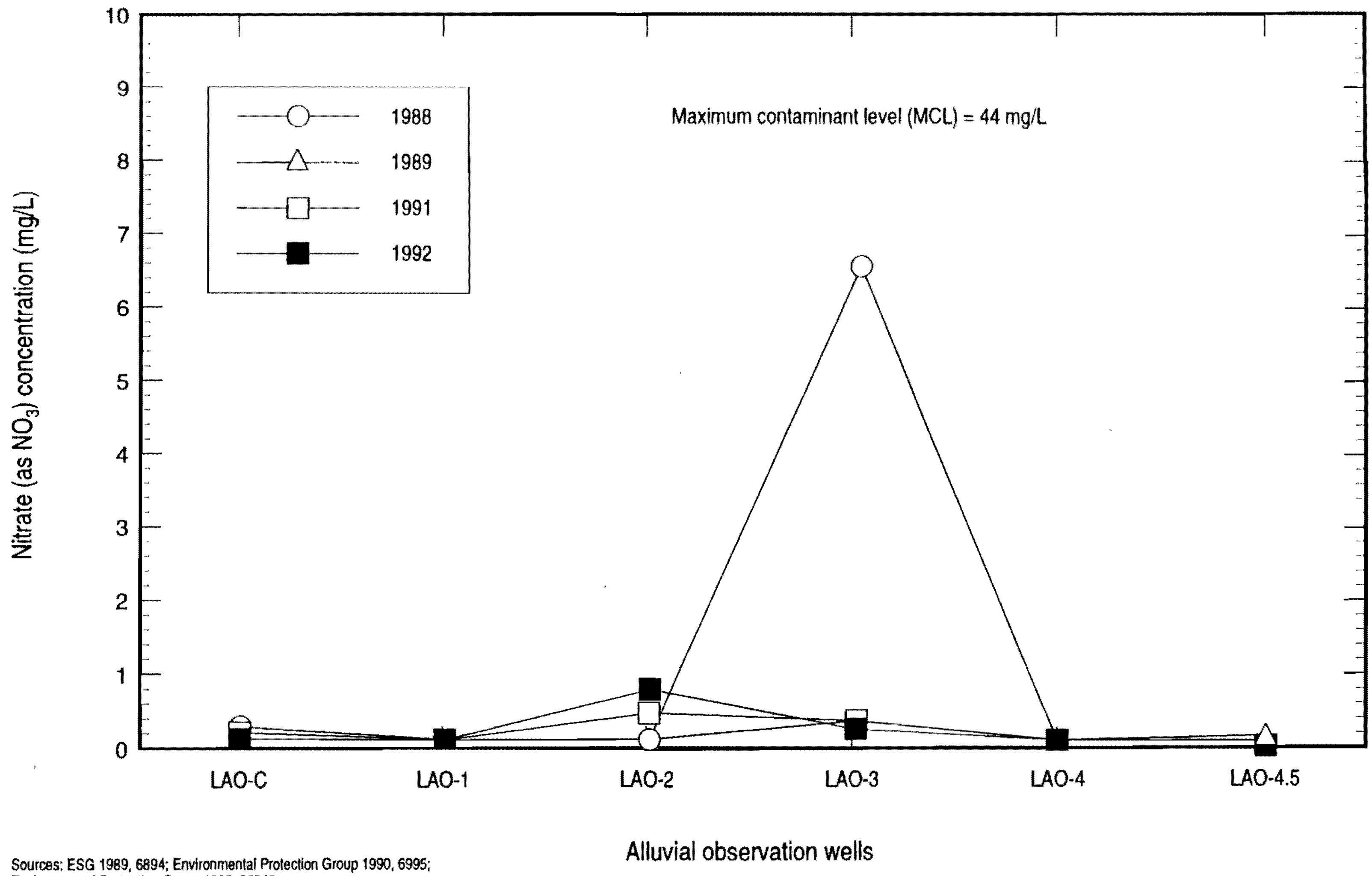
Figure 3-20. Strontium-90 activities in alluvial ground water in upper Los Alamos Canyon.



Sources: ESG 1977, 5703; ESG 1979, 5819;
ESG 1982, 6245; ESG 1983, 6418

F 3-21 / LA&P WP / 112495

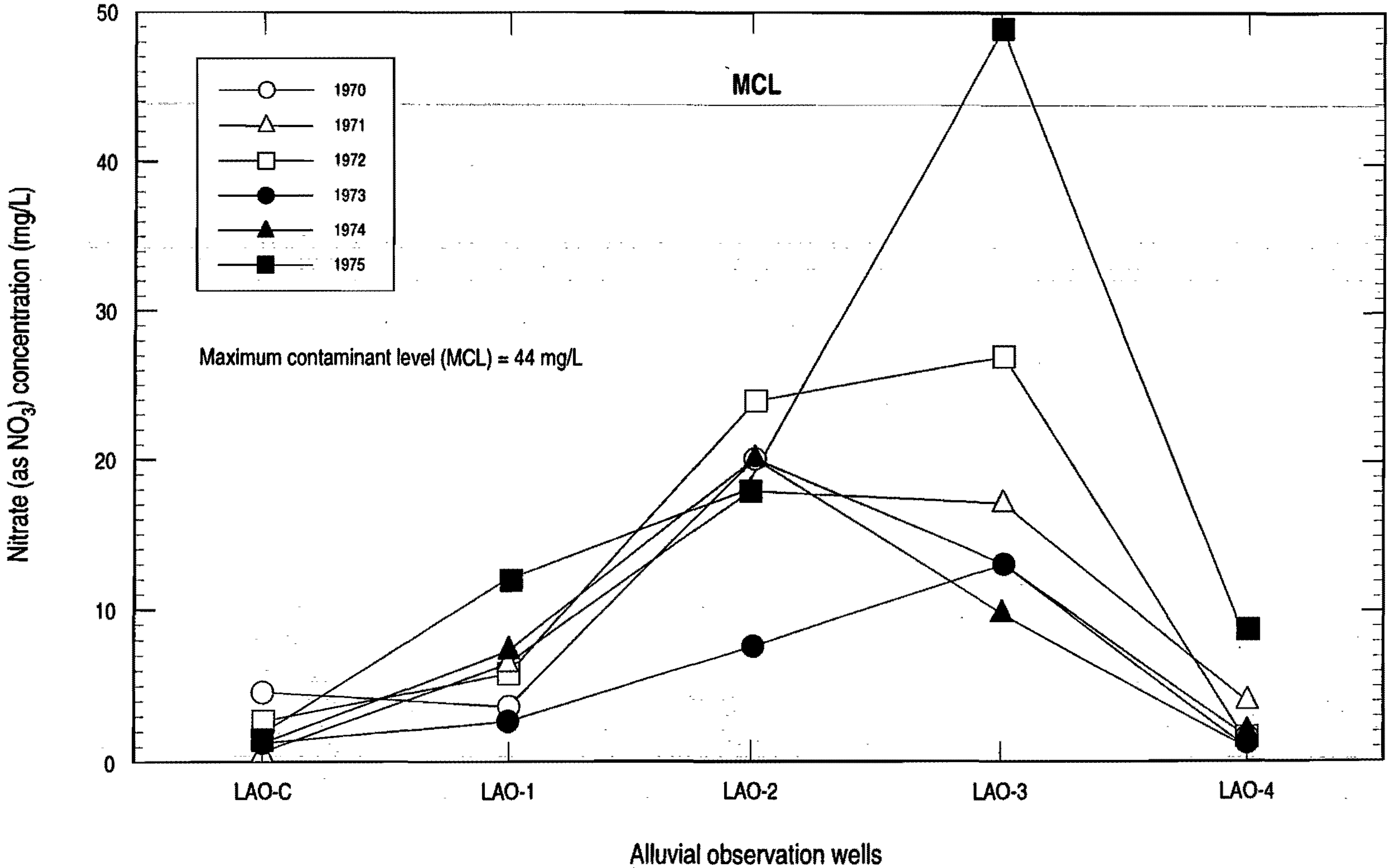
Figure 3-21. Strontium-90 activities in alluvial ground water in upper Los Alamos Canyon.



Sources: ESG 1989, 6894; Environmental Protection Group 1990, 6995;
Environmental Protection Group 1993, 23249;
Environmental Protection Group 1994, 35363

F 3-22 / LA&P WP / 110295

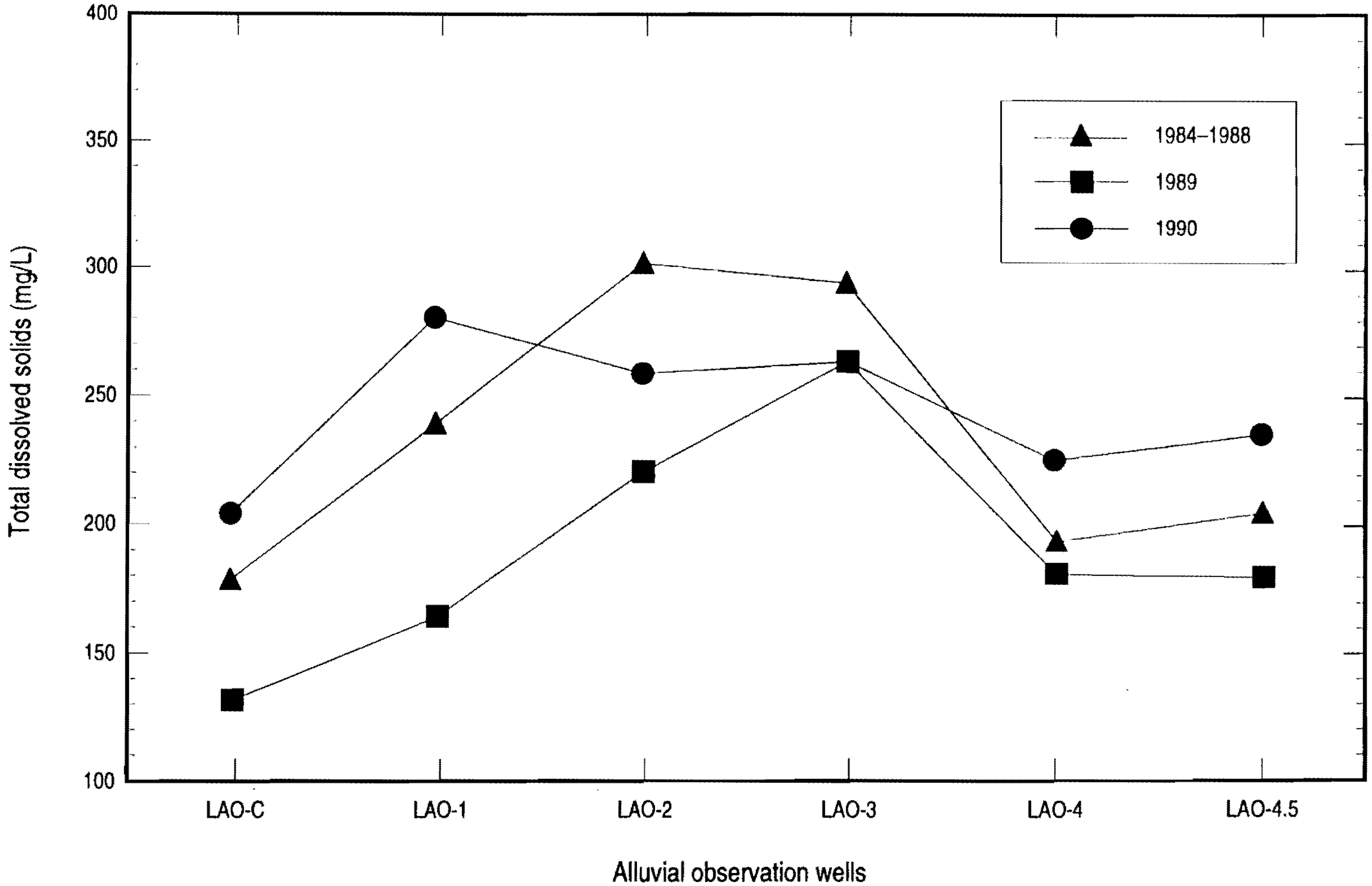
Figure 3-22. Nitrate concentrations in alluvial ground water in upper Los Alamos Canyon.



Sources: Kennedy et al. 1971, 4800; Herceg 1972, 31458; Herceg 1972, 4955; Herceg 1973, 4966; Schlager and Apt 1974, 5467; Apt and Lee 1975, 5488; Apt and Lee 1975, 5488; Apt and Lee 1976, 5559

F 3-23 / LA&P WP / 111895

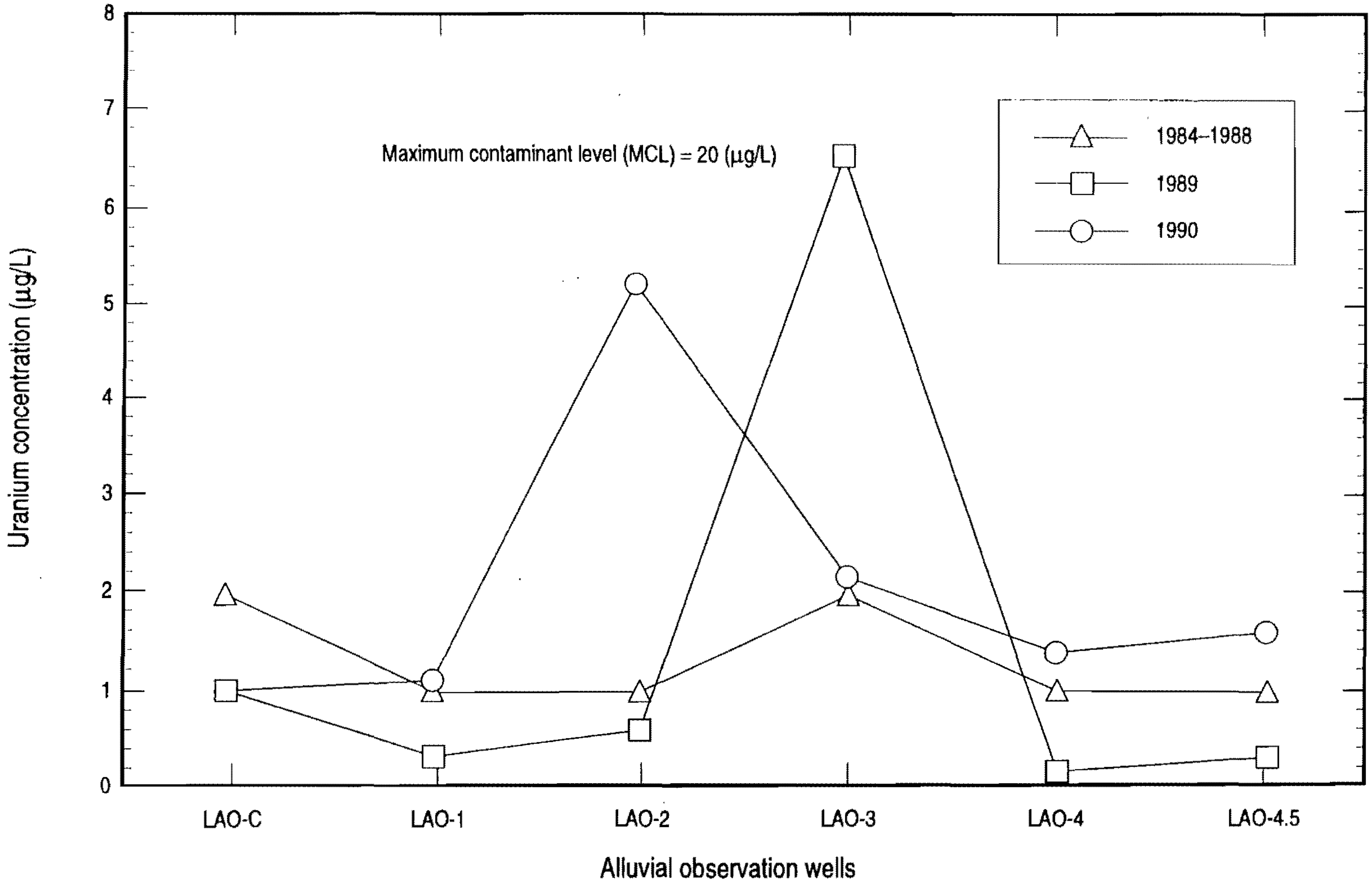
Figure 3-23. Nitrate concentrations in alluvial ground water in upper Los Alamos Canyon.



Sources: ESG 1985, 6610; ESG 1986, 6626; ESG 1987, 6678; ESG 1988, 6877; ESG 1989, 6894; Environmental Protection Group 1990, 6995; Environmental Protection Group 1992, 7004

F 3-24 / LA&P / 111895

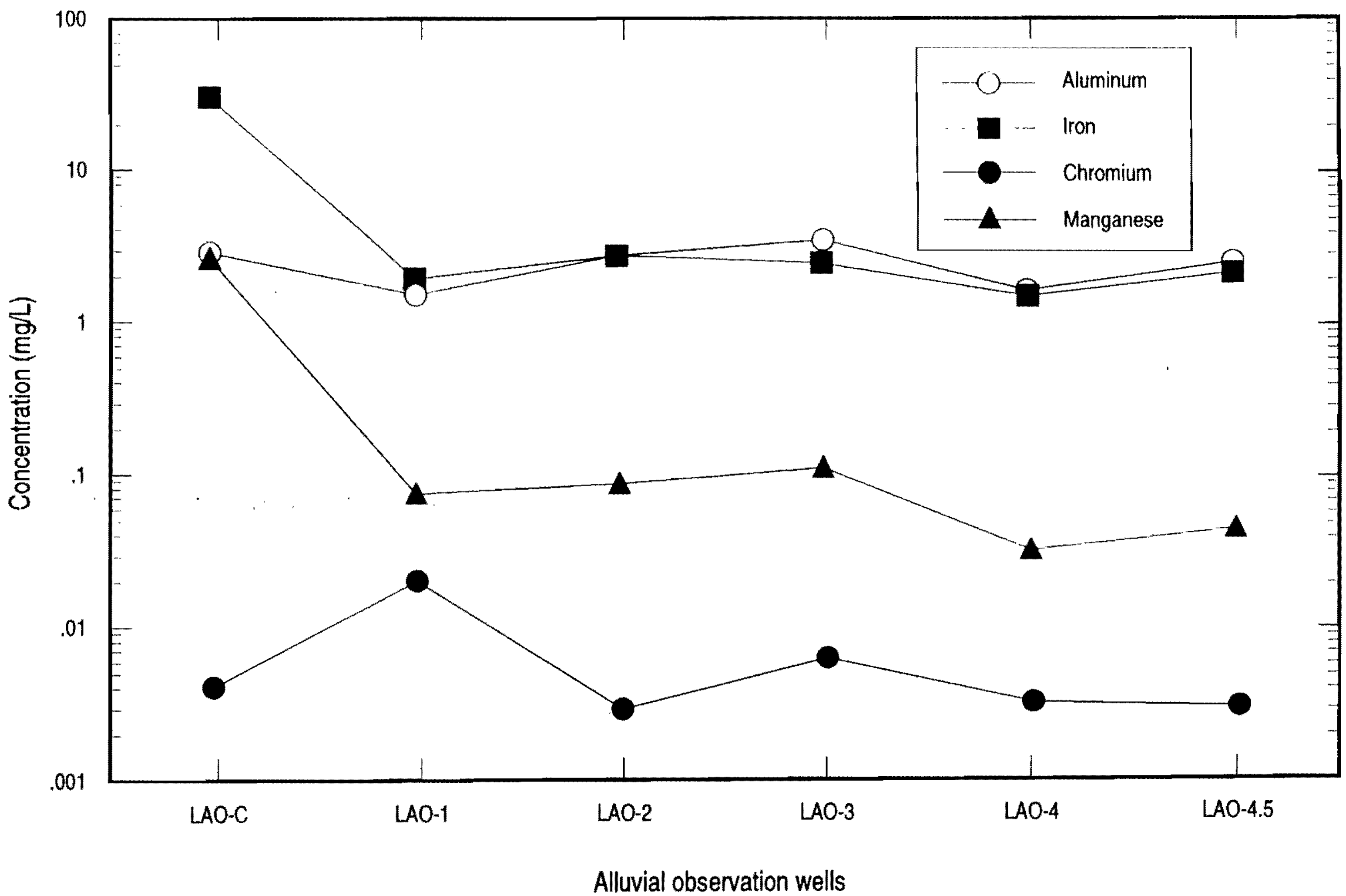
Figure 3-24. Total dissolved solids concentrations in alluvial ground water in upper Los Alamos Canyon.



Sources: ESG 1985, 6610; ESG 1986, 6626; ESG 1987, 6678; ESG 1988, 6877; ESG 1989, 6894; Environmental Protection Group 1990, 6995; Environmental Protection Group 1992, 7004

F 3-25 / LA&P WP / 111895

Figure 3-25. Uranium concentrations in alluvial ground water in upper Los Alamos Canyon.



Source: Environmental Protection Group 1990, 6995

F 3-26 / LA&P WP / 110295

Figure 3-26. Trace metal concentrations in alluvial ground water in upper Los Alamos Canyon.

TABLE 3-11

RADIOCHEMICAL QUALITY OF WATER IN ALLUVIUM FROM LOS ALAMOS CANYON 1967 THROUGH 1975[a]

Location	Year	No. of Anal.	Gross-Alpha	Gross-Beta	^{238}Pu	^{239}Pu	^{137}Cs	^{3}H	Total U (μg/L)
LAO[b]-C	1970	1	<1	4	<0.05	<0.05	—[c]	<1000	0.4
	1971	2	<1	3	<0.05	<0.05	<350	<1000	1.0
	1972	4	<1	5	0.06	0.07	<350	<1000	1.0
	1973	4	<1	3	<0.05	<0.05	<40	1150	<0.4
	1974	4	1	8	<0.05	<0.05	<40	650	0.5
	1975	3	3	5	<0.05	<0.05	<40	1000	0.5
LAO-1	1967	1	<1	50	<0.05	<0.05	—	41000	1.3
	1968	3	3	37	<0.05	0.08	<250	30000	<0.4
	1969	3	<1	36	<0.05	0.06	—	22000	0.4
	1970	4	<1	76	0.05	0.05	—	—	<0.4
	1971	4	1	94	0.05	0.27	<350	20750	0.6
	1972	4	1	127	0.17	0.18	<350	19600	<0.4
	1973	5	2	140	<0.05	0.06	<40	36000	<0.4
	1974	4	2	147	<0.05	<0.05	40	27000	<0.4
	1975	3	1	56	<0.05	<0.05	<20	7000	<0.4
LAO-2	1967	1	<1	91	<0.05	<0.05	—	475000	2.0
	1968	3	3	59	<0.05	0.06	<250	273000	1.5
	1969	2	1	77	0.10	0.60	—	337000	1.6
	1970	3	<1	80	<0.05	0.14	<250	184000	0.6
	1971	2	1	101	0.15	0.33	<350	52000	0.9
	1972	3	2	188	0.09	0.19	<350	153000	2.6
	1973	4	22	294	<0.05	0.11	<40	46000	<0.4
	1974	3	2	247	<0.05	0.10	<40	18000	<0.4
	1975	3	4	157	<0.05	0.05	<20	72000	0.7
LAO-3	1967	1	<1	45	<0.05	0.05	—	214000	<0.4
	1968	3	2	61	0.07	0.08	<250	126000	0.8
	1969	2	2	49	<0.05	0.06	—	350000	1.3
	1970	4	2	56	<0.05	0.08	<250	73000	0.8
	1971	3	3	95	0.07	0.08	<350	38000	1.2
	1972	4	3	92	0.10	0.15	<350	187000	3.0
	1973	5	3	47	0.06	0.05	50	35000	<0.4
	1974	3	2	75	0.35	0.08	50	11000	0.9
	1975	3	6	81	<0.05	<0.05	—	11000	3.1
LAO-4	1967	1	<1	9	<0.05	0.06	—	222000	0.8
	1968	3	5	16	0.05	0.05	250	61000	1.2
	1969	2	<1	9	<0.05	<0.05	—	55500	<0.4
	1970	1	<1	10	<0.05	<0.05	—	66000	<0.4
LAO-4.5	1969	3	<1	5	<0.05	<0.05	—	43000	0.7
	1970	5	1	26	0.06	0.07	—	78000	<0.4
	1971	3	1	5	0.07	0.08	—	24000	0.4
	1972	4	2	10	0.09	0.06	<350	28000	1.1
	1973	4	1	8	<0.05	<0.05	<40	22000	<0.4
	1974	3	1	107	<0.05	<0.05	<20	8000	<0.4
	1975	3	2	47	<0.05	0.06	—	18000	0.8
LAO-5	1967	1	<1	4	<0.05	<0.05	—	126000	<0.4
	1968	2	1	8	<0.05	0.09	<250	70000	1.2
	1969	2	<1	5	<0.05	<0.05	—	56000	0.7
LAO-6	1968	1	2	18	0.17	0.25	<250	75000	0.4
	1969	1	<1	7	<0.05	<0.05	<250	51000	<0.4

a. Average of a number of analyses in pCi/L, except as noted
b. LAO means observation well in Los Alamos Canyon.
c. — means not analyzed.

(LANL 1981, 6059)

of treated sewage from TA-41 (solid waste management unit [SWMU] No. 41-002) and industrial effluents from TA-21 are the predominant sources of nitrate in upper Los Alamos Canyon (LANL 1981, 6059; LANL 1993, 21404). However, concentrations of nitrate in the alluvial ground water have decreased since the 1960s (ESG 1971–1995). Nitrate is mobile under the oxidizing conditions that prevail in the alluvium and serves as a conservative ground water tracer along with chloride and tritium.

The TDS concentration in alluvial ground water generally increases by a factor of two downgradient from observation well LAO-C eastward to observation well LAO-3 (Figure 3-24). Sodium, chloride, bicarbonate, and other major ions increase in concentrations downgradient from observation well LAO-C. A sharp decrease in TDS occurs between observation wells LAO-3 and LAO-4. Geochemical modeling suggests that the change is not due to the precipitation of any saturated mineral phases; therefore, the decrease may be the result of mixing alluvial ground water with ground water from the Bandelier Tuff (the Otowi Member or the Guaje Pumice Bed). Observation well LAO-4 is completed in alluvium and weathered tuff (Purtymun 1995, 45344). The TDS concentration and major cation concentrations of ground water samples collected from the Guaje Pumice bed in observation wells LADP-3 and LAOI(A)-1.1 (see Section 3.7.5) are lower than those from observation well LAO-3, which is completed only in alluvium.

Concentrations of uranium are generally within the microgram per liter (µg/L) range; however, concentrations of uranium that are elevated above a baseline in observation well LAO-C occur in ground water collected from observation wells LAO-2 and LAO-3 (Figure 3-25). Elevated concentrations of uranium have been documented (LANL 1981, 6059) in surface water samples collected in DP Canyon. These concentrations may account for the elevated uranium concentration observed in alluvial ground water.

To further examine the geochemistry of uranium, the computer code MINTEQA2 (Allison et al. 1991, 49930) was used to determine stable dissolved species. Calculations suggest that uranium [U(VI)] is stable as $UO_2(CO_3)_2^{2-}$. This species has been shown experimentally to adsorb only partially onto mineral surfaces (such as kaolinite, smectite, hydrous iron oxides, silica glass, and solid organic matter) at near neutral and higher pH values in the presence of CO_2 gas (Hsi and Langmuir 1985, 48816; Waite et al. 1994, 49929). Since only partial adsorption of this species to mineral surfaces would be expected, elevated concentrations in surface water would be expected to be reflected in elevated concentrations in alluvial ground water.

Concentrations of several trace metals in unfiltered samples (total metals) analyzed in 1990 by the Laboratory are shown in Figure 3-26 (Environmental Protection Group 1992, 7004). Being unfiltered samples, the reported concentrations include both dissolved metals and those released from suspended particulate matter during sample digestion with acid. Concentrations of iron, manganese, and aluminum vary from LAO-C to LAO-2, but downgradient of LAO-2 concentrations vary only slightly.

Aluminum is a major constituent of the silicate minerals comprising the alluvium, and the presence of any suspended particles in ground water samples will result in elevated aluminum concentrations being reported in analyses. Iron and manganese are geochemically similar to each other in aqueous solutions, and these two species show similar concentration distributions in alluvial ground water.

Concentrations of chromium at LAO-1 are about 0.02 mg/L, which is slightly elevated relative to the other monitoring wells. Potassium dichromate was used as a fungicide for the cooling water (SWMU No. 2-005) at TA-2, which is located upgradient from

LAO-1 (LANL 1993, 21404). Under moderately oxidizing conditions that prevail in the alluvium in upper Los Alamos Canyon, chromium is stable as $Cr(OH)_2^+$, $Cr(OH)_3^0$ and $Cr(OH)_4^-$ (Rai and Zachara 1984, 50142) above pH 6.5. These species may not be completely adsorbed onto mineral surfaces, which could account for the elevated concentrations of chromium observed at LAO-1. The maximum contaminant level for total chromium is 0.1 mg/L, and no analytical results of ground water samples collected in upper Los Alamos Canyon exceed this standard.

Solid-solution phase calculations were performed with MINTEQA2 (Allison et al. 1991, 49930) using analytical results obtained from filtered (less than 0.45 μm) alluvial ground water samples collected in 1994. The purpose of the calculations was to assess the importance of precipitation reactions and to determine speciated forms of natural and anthropogenic solutes.

Alluvial ground water is calculated to be in equilibrium with silica glass but oversaturated with respect to silica gel. These amorphous phases are abundant in the alluvium that was derived from the Bandelier Tuff (Broxton et al. 1995, 50121), and they could be important adsorbents for radionuclides (such as ^{90}Sr and ^{137}Cs) found in alluvial ground water. Figure 3-27 shows the values of the saturation index (SI) (saturation index for these phases). The SI is a measure of the degree of under- or over- saturation of a solid phase in water [SI = $\log_{10}$ {activity product/solubility product}]; at equilibrium SI = 0). Calculations also show that ground water is undersaturated with respect to calcite and is oversaturated with respect to feldspars and other silicates observed in the Bandelier Tuff (results not shown in Figure 3-27). These calculations imply that most of the high-temperature silicates found in the Bandelier Tuff formed during magma genesis and are not in equilibrium with alluvial ground water.

Calculations using MINTEQA2 suggests that strontium in alluvial ground water is stable as Sr^{2+}, that is, undersaturated with respect to solid strontium sulfate and carbonate phases (Figure 3-28). Thus Sr^{2+}, rather than precipitating as a solid phase, probably undergoes cation exchange reactions with clay phases, competing for exchange sites with other divalent cations such as Ca^{2+} and Mg^{2+} (Rai and Zachara 1984, 50142). Cation exchange, in addition to radioactive decay ($t_{1/2}$ = 28 yr) and dilution, may account for the decreased concentration of ^{90}Sr along the ground water flow path in upper Los Alamos Canyon.

These calculations suggest that ion exchange probably is the predominant process controlling strontium mobility in Los Alamos Canyon. Coprecipitation of strontium with barium, as $Ba_{1-x}Sr_xSO_4$, is thermodynamically possible based on model simulations using MINTEQA2. Barite ($BaSO_4$) and celestite ($SrSO_4$) have the same crystal structure and show complete solid solution, although natural materials commonly have compositions near one of the end-members (Hurlbut and Klein 1977, 47193).

Table 3-12 summarizes DOE's derived concentration guides (DCGs) for public dose for several radionuclides of interest in the alluvial aquifer. Activities of ^{90}Sr in some observation wells exceed the DCGs for drinking waters. The isotope ^{90}Sr is considered likely to be the most important radionuclide for risk assessment in Los Alamos Canyon and Pueblo Canyon because of its widespread distribution in the alluvium in upper Los Alamos Canyon.

Although the ground water flow rate is substantial, it is clear from the previous discussion that a complete flushing of contaminants within the alluvium in upper Los Alamos Canyon has not occurred. The data suggest that contaminants remain in the sediments and alluvial ground water in upper Los Alamos Canyon. Trends in the data also suggest that residual releases may occur from the source inventories at TA-2 and TA-21.

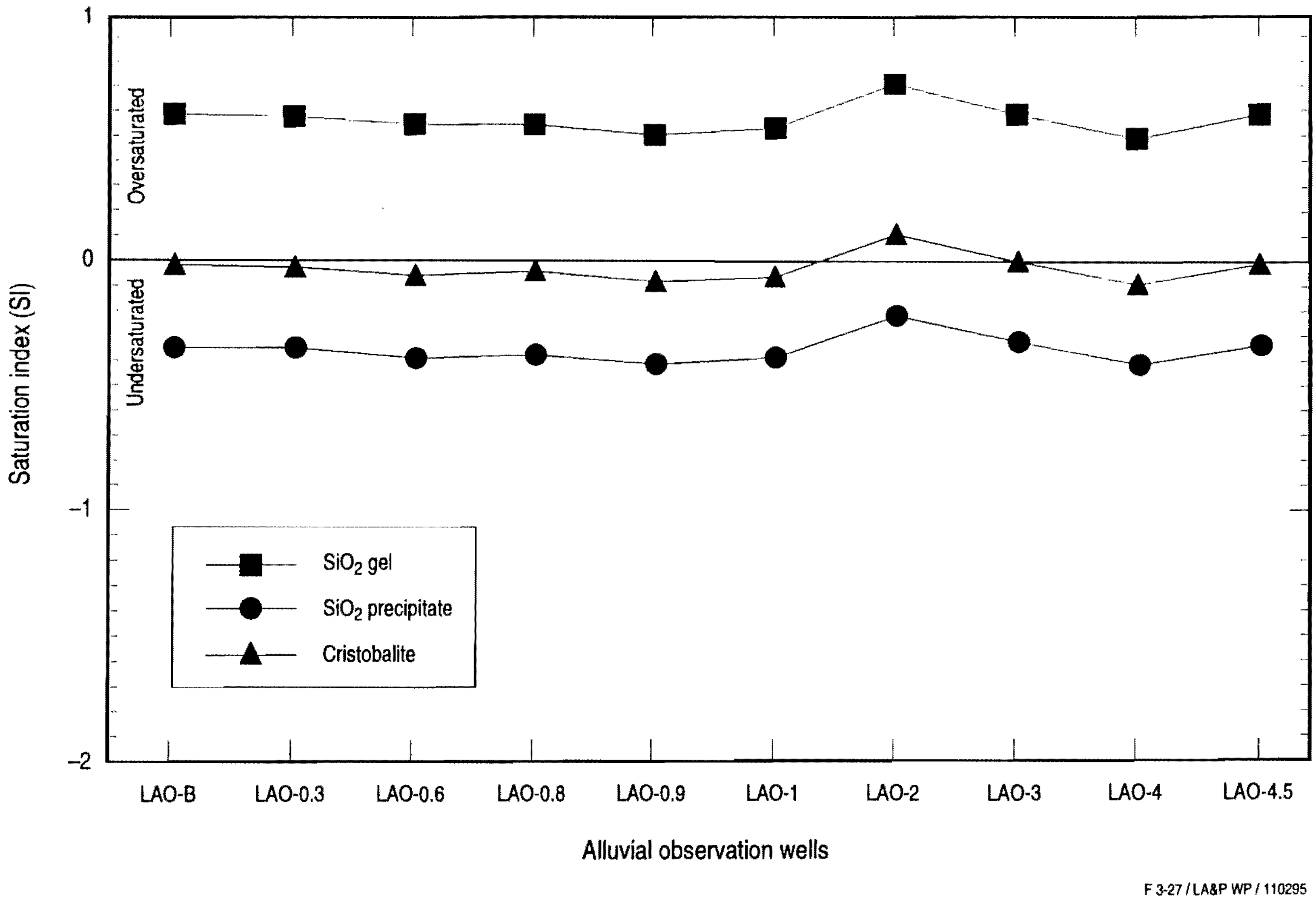
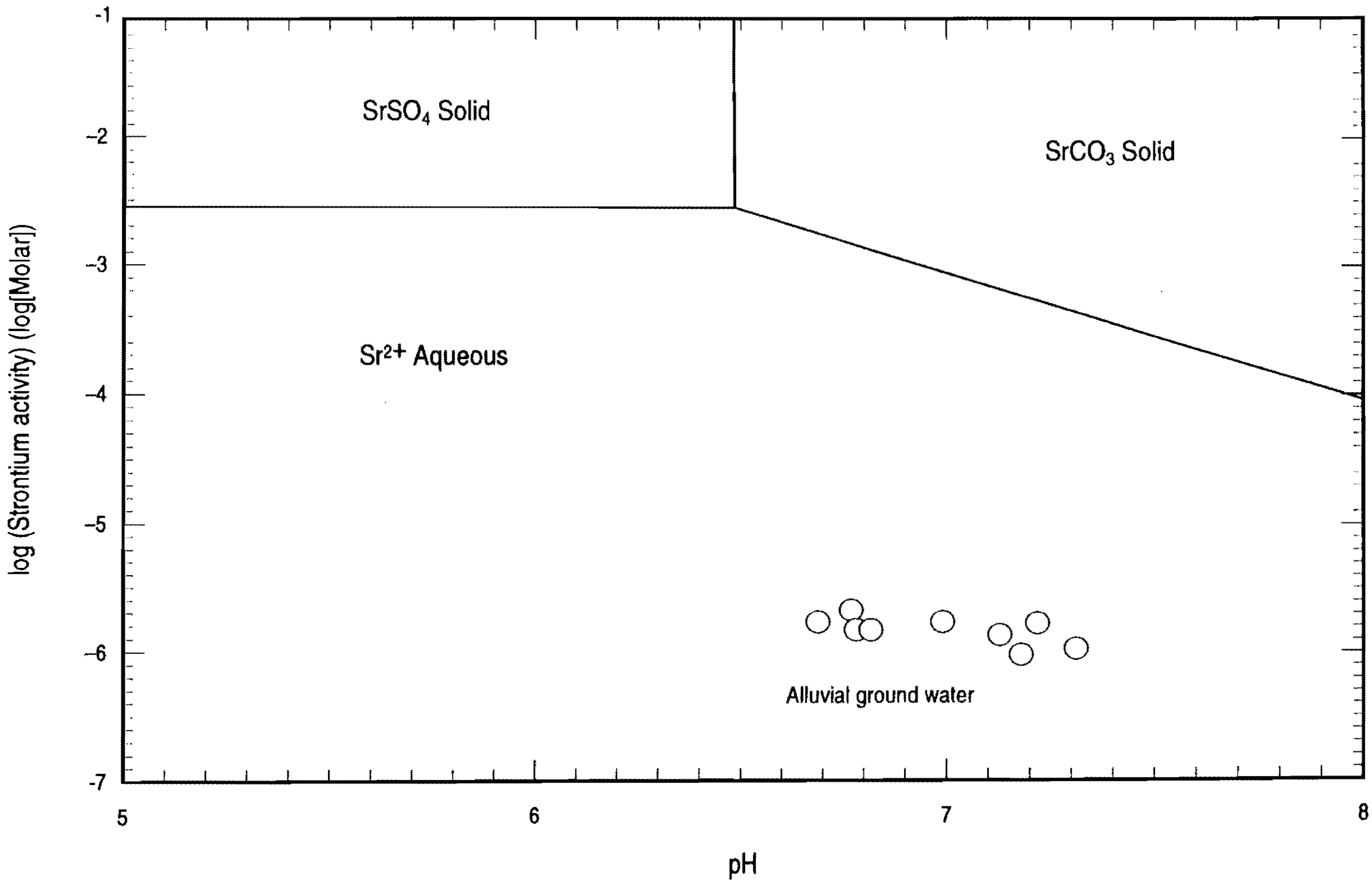


Figure 3-27. Saturation indices for silica minerals in alluvial ground water in upper Los Alamos Canyon.



Sources: Allison et al. 1991, 49930;
Brookins 1988, 49928

F 3-28 / LA&P WP / 110295

Figure 3-28. Activity diagram for the H_2O-Sr-SO_4-HCO_3 system, at 25°C, for alluvial ground water in Los Alamos Canyon.

TABLE 3-12

DOE-CALCULATED DERIVED CONCENTRATION GUIDES FOR PUBLIC DOSE FROM WATER

Nuclide	Calculated Guides for Drinking Water (pCi/L)
^{3}H	20,000
^{90}Sr[a]	8
^{137}Cs	120
^{234}U	20
^{235}U	24
^{238}U	24
^{238}Pu	1.6
^{239}Pu[a]	1.2
^{240}Pu	1.2
^{241}Am	1.2
Natural uranium	0.020 (mg/L)

a. Guides for ^{239}Pu and ^{90}Sr are the most appropriate to use for gross-alpha and gross-beta, respectively.

3.7.4.2 Pueblo Canyon

From 1954 through 1965, the quality of ground water in the Pueblo Canyon alluvium was monitored at 18 shallow observation wells (LANL 1981, 6059). The locations of these wells are shown in Figure A-2 in Appendix A of this work plan. The shallow well APCO-1, installed in 1990, is currently used to monitor ground water quality in the alluvium.

Background water quality is not known in Pueblo Canyon because no upgradient observation wells are installed west of the confluence of Acid Canyon and Pueblo Canyon. The composition of water in Los Alamos Reservoir is used as a point of reference for discussions below.

Results of chemical analyses of unfiltered ground water samples collected from observation wells PC-1, PC-2, and PC-3 show that alluvial ground water contains elevated concentrations (relative to those in Los Alamos Reservoir) of chloride, nitrate, and other major ions (Table 3-13) (LANL 1981, 6059). TDS concentrations and pH values generally decrease along the ground water flow path within Pueblo Canyon. The pH values ranged from 10.4 (in observation well AC-3) to 7.1 (in observation well PO-4A) for ground water samples collected between 1954 and 1964 (LANL 1981, 6059).

Table 3-14 shows data for sodium, chloride, fluoride, nitrate, TDS, and pH for alluvial ground water at Hamilton Bend Spring. Concentrations were elevated above those in Los Alamos Reservoir. The pH values were slightly alkaline, consistent with data collected in the alluvium of Los Alamos Canyon. This spring was evidently supported by recharge from the Pueblo sewage treatment plant, which closed in 1990. The spring has been completely dry since about 1990.

Activities of total plutonium (^{238}Pu plus ^{239}Pu) in alluvial ground water also decrease downgradient from Acid Canyon (Table 3-15). The highest activity of total plutonium

TABLE 3-13

CHEMICAL QUALITY OF WATER IN ACID CANYON AND PUEBLO CANYON 1954 THROUGH 1964[a]

Station	No. of Analyses	Cl	F	NO_3	TDS[b]	pH
AC[c]-3	25	30	3.4	38	481	10.4
AC-4	29	38	4.4	35	765	10.0
AC-5	8	26	3.0	65	553	9.6
PC[d]-1	24	27	1.8	22	300	7.5
PC-2	31	28	2.2	28	542	7.4
PC-3	29	27	2.3	33	430	7.5
PC-4	23	30	1.9	40	432	7.3
PC-5	9	32	1.8	42	315	7.3
PC-6	37	25	1.3	12	373	7.4
PC-7	21	30	1.6	28	338	7.4
PC-8	16	29	1.1	36	275	7.4
PC-9	25	29	1.2	16	430	7.4
PC-10	30	27	1.4	19	379	7.3
PC-11	13	29	1.5	28	361	7.2
PO[e]-1A	9	27	1.2	7	327	7.4
PO-4A	15	25	1.7	23	318	7.1
PO-4B	10	28	0.9	10	330	7.2
Hamilton Bend Spring	31	30	0.8	18	336	7.5
Otowi Seep	4	33	1.6	2	275	7.5

a. Average of a number of analyses in mg/L, except pH (units)
b. TDS = total dissolved solids
c. AC = alluvial observation well in Acid Canyon
d. PC = alluvial observation well in Pueblo Canyon
e. PO = alluvial observation well in Pueblo Canyon

(LANL 1981, 6059)

TABLE 3-14

CHEMICAL QUALITY OF WATER FROM THE ALLUVIUM AT HAMILTON BEND SPRINGS, PUEBLO CANYON 1970 THROUGH 1975[a]

Year	No. of Analyses	Na	Cl	F	NO_3	TDS[b]	pH
1970	2	74	37	3.3	13	476	7.2
1971	—[c]	—	—	—	—	—	—
1972	2	69	40	1.7	18	370	7.6
1973	2	66	52	4.2	18	370	7.5
1974	2	72	51	3.9	16	374	7.4
1975	2	70	37	0.9	22	359	7.7

a. Average of a number of analyses in mg/L, except pH (units)
b. TDS = total dissolved solids
c. — means not analyzed.

(LANL 1981, 6059)

TABLE 3-15

TOTAL PLUTONIUM IN WATER FROM THE ALLUVIUM ACID CANYON AND PUEBLO CANYON 1954 THROUGH 1965[a]

Station	1954	1955	1956	1957	1958	1959
AC[b]-3	828	468	—[c]	—	5.3	2.9
AC-4	342	34	—	—	1.9	42
AC-5	198	554	—	—	4.9	—
PC[d]-1	3.6	1.4	1.8	0.7	<0.5	<0.5
PC-2	21	6.3	5.8	1.8	<0.5	10.9
PC-3	6.3	2.7	1.8	0.9	1.3	<0.5
PC-4	7.7	3.2	5.8	0.9	0.5	<0.5
PC-5	6.8	—	—	—	0.5	0.5
PC-6	8.6	3.6	3.6	1.8	1.8	<0.5
PC-7	14	5.8	3.2	1.8	<0.5	<0.5
PC-8	5.4	—	—	0.9	<0.5	<0.5
PC-9	8.6	—	3.2	2.7	0.7	<0.5
PC-10	—	—	—	<0.5	<0.5	<0.5
PC-11	—	—	—	—	—	<0.5
PO[e]-1A	—	—	—	2.7	1.9	<0.5
PO-4A	—	—	—	1.5	<0.5	<0.5
PO-4B	—	—	—	—	<0.5	<0.5
Hamilton Bend Spring	4.5	11.7	2.7	0.6	<0.5	<0.5
Otowi Seep	9.9	—	2.7	—	<0.5	<0.5

Station	1960	1961	1962	1963	1964	1965
AC-3	<0.5	—	14.6	18.2	—	—
AC-4	4.0	1.3	—	—	—	—
AC-5	<0.5	—	—	—	—	—
PC-1	—	—	—	—	—	—
PC-2	—	—	—	—	—	—
PC-3	<0.5	<0.5	—	—	—	—
PC-4	—	—	<0.5	<0.5	—	—
PC-5	—	—	—	—	—	—
PC-6	<0.5	<0.5	<0.5	0.9	0.8	—
PC-7	—	—	—	—	—	—
PC-8	—	—	—	—	—	—
PC-9	—	—	<0.5	<0.5	<0.5	—
PC-10	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
PC-11	<0.5	2.7	<0.5	<0.5	0.9	<0.5
PO-1A	<0.5	—	—	—	<0.5	—
PO-4A	<0.5	—	—	—	<0.5	<0.5
PO-4B	<0.5	—	—	—	—	<0.5
Hamilton Bend Spring	<0.5	0.5	<0.5	1.0	0.9	—
Otowi Seep	<0.5	—	3.8	<0.5	0.8	<0.5

a. Average of a number of analyses in pCi/L
b. AC = alluvial observation well in Acid Canyon
c. — means not analyzed.
d. PC = alluvial observation well in Pueblo Canyon
e. PO = alluvial observation well in Pueblo Canyon

(LANL 1981, 6059)

(828 pCi/L) was observed in 1954 at observation well AC-3. The pH of that ground water sample in 1954 was 10.4. At this high pH the plutonium was probably complexed with carbonate, possibly forming a soluble anion.

3.7.5 Intermediate Perched Zone

Four observation wells are completed in intermediate perched zones within the Guaje Pumice Bed, Puye Formation, and interbedded basalt flows within Los Alamos Canyon and Pueblo Canyon. Observation wells LADP-3 and LAOI(A)-1.1 (located in upper Los Alamos Canyon) are completed in the Guaje Pumice Bed, and TW-1A and TW-2A (located in Pueblo Canyon) are completed in the Puye Formation and interbedded basalt flows.

3.7.5.1 Guaje Pumice Bed—Los Alamos Canyon

Observation wells LADP-3 and LAOI(A)-1.1 (Figure A-2 in Appendix A of this work plan) are completed in an intermediate-depth saturated zone of variable thickness in the Guaje Pumice Bed in upper Los Alamos Canyon. At observation well LADP-3, a saturated thickness of 5 ft occurs at a depth of 325 ft. At observation well LAOI(A)-1.1, a saturated thickness of 22 ft occurs at a depth of 295 ft. The stratigraphy encountered in the boreholes for these wells was discussed in Section 3.6.3.1.

In May 1995, tritium activity measured in observation well LAOI(A)-1.1 was 2.0 pCi/L, and the concentration of chloride was 1.01 mg/L. These latter analytical results suggest that observation well LAOI(A)-1.1 could serve as a background observation well for the Guaje Pumice Bed in upper Los Alamos Canyon.

In April 1995, a ground water sample collected from observation well LADP-3 had 1472 ± 38 pCi/L of tritium (Table 3-16). Tritium activities and chloride concentrations (21.7 mg/L) in observation well LADP-3 suggest that recent water derived from the alluvium is recharging the Guaje Pumice Bed in upper Los Alamos Canyon (Broxton et al. 1995, 50119) (Figure 3-29). The Omega West Reactor is the most reasonable source of tritium in observation well LADP-3, and the elevated chloride concentrations probably are derived from road salt. Low-level ^{137}Cs and plutonium isotopes were not detected in observation well LADP-3, and ^{137}Cs was not detected in observation well LAOI(A)-1.1 (data not shown in Table 3-16). Recharge from the alluvium to the Guaje Pumice Bed probably is occurring between observation wells LAOI(A)-1.1 and LADP-3 (Figure 3-29).

3.7.5.2 Cerros del Rio Basalts—Pueblo Canyon

Water infiltrating from the alluvium recharges the intermediate perched zone within the Cerros del Rio basalts and the Puye Formation under the middle reach of Pueblo Canyon (LANL 1981, 6059). In Pueblo Canyon ground water probably moves eastward in the fractured, interbedded Cerros del Rio basalts and the Puye Formation. Some of the ground water discharges from Basalt Spring in lower Los Alamos Canyon approximately 0.6 mi below its confluence with Pueblo Canyon. Samples of ground water from TW-2A have chemical compositions reflecting the characteristics of the alluvial ground water in the middle reach of Pueblo Canyon. Tritium has been detected in TW-2A. Other radionuclides have not been detected, except one anomalous value for plutonium in 1992, which exceeded the DOE derived concentration guide for

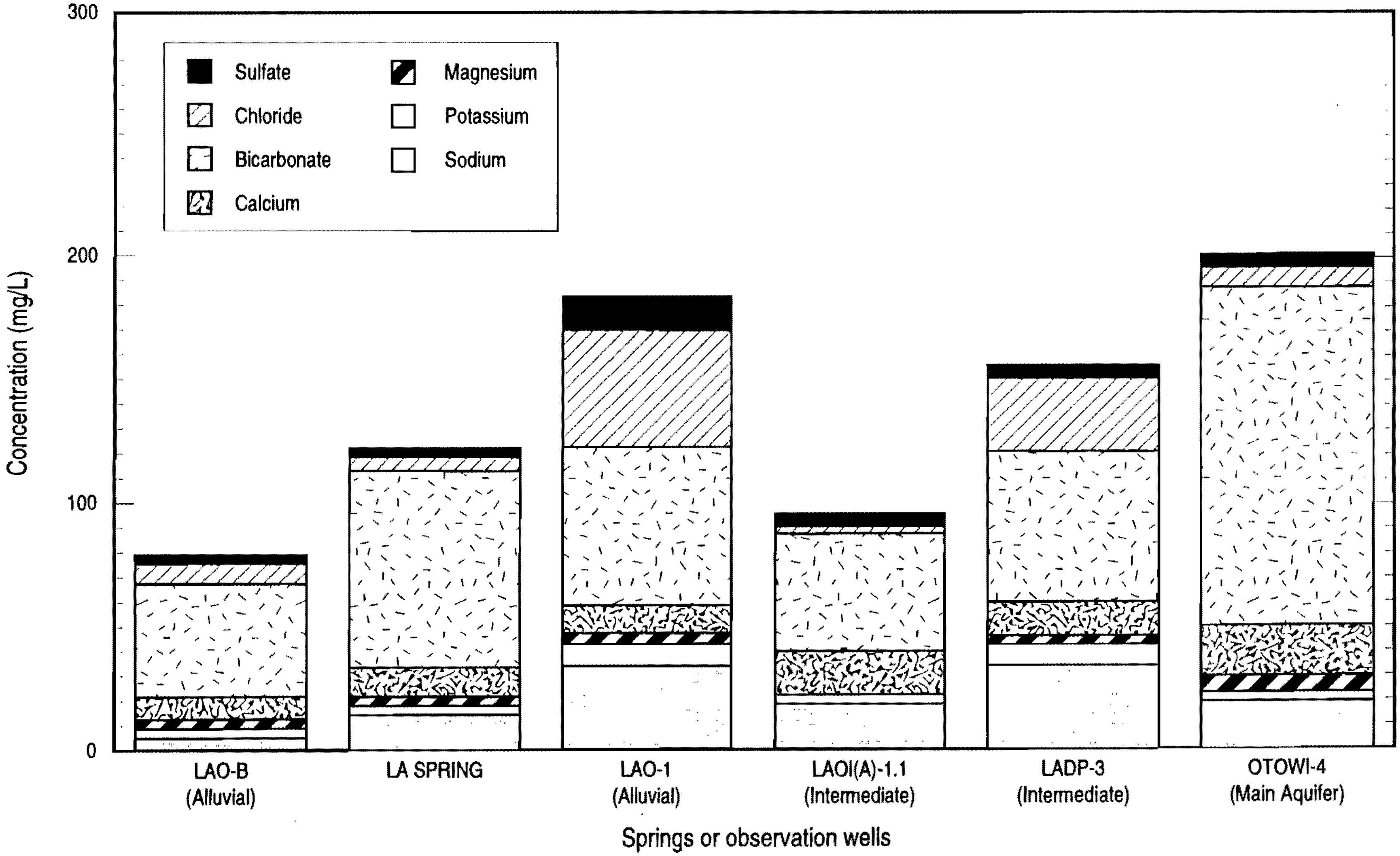
TABLE 3-16

SUMMARY OF ANALYSIS ON FILTERED GROUND WATER SAMPLES, GUAJE PUMICE BED, INTERMEDIATE PERCHED ZONE, UPPER LOS ALAMOS CANYON

Sample No.	LAC95-20	PP94-120	PP93-36	LAC95-36	LAC95-13	PP94-119
Well	LADP-3	LADP-3	LADP-3	LAOI(A)-1.1	LAOI(A)-1.1	LAOI(A)-1.1
Date	04/26/95	12/16/94	12/01/93	05/17/95	02/16/95	11/17/94
Analysis[a,b]						
Al	0.05	0.03	0.21	0.51	6.40	0.31
As	<0.002	0.0004	<0.001	<0.002	0.0005	0.0003
B	0.03	0.025	0.04	<0.01	0.010	0.014
Ba	0.03	0.02	0.02	0.02	0.02	<0.01
Br	<0.05	0.03	0.07	<0.05	<0.02	<0.02
Ca	10.2	7.76	11.7	6.37	4.03	1.63
Cd	<0.0002	0.0025	<0.001	<0.0002	<0.0002	<0.0005
Cl	35.1	21.7	46.8	1.01	1.04	1.49
Co	<0.0002	<0.0002	0.004	<0.0002	<0.0002	<0.0002
Cr	0.007	0.005	0.003	<0.002	0.002	<0.002
Cs	<0.002	<0.002	0.002	<0.002	<0.002	<0.002
Cu	0.002	0.002	0.008	0.002	<0.002	0.005
F	0.18	0.12	0.38	0.14	0.13	0.18
Fe	<0.01	<0.01	0.13	0.19	0.76	0.11
HCO_3	56.8	60.1	65.0	60.4	56.3	51.0
K	7.56	6.33	8.7	5.46	6.04	3.62
Li	<0.01	<0.01	0.02	<0.01	<0.01	<0.01
Mg	3.06	2.44	4.08	1.19	1.01	0.37
Mn	0.03	0.03	0.44	0.03	0.07	0.06
Mo	<0.002	0.002	0.022	0.003	0.006	0.006
Na	25.2	22.9	33.8	13.4	14.5	18.6
NH_4	0.22	0.09	0.32	0.05	0.05	0.39
Ni	0.011	0.010	0.026	<0.002	<0.002	0.002
NO_2	<0.02	<0.02	0.37	<0.02	<0.02	<0.02
NO_3	1.10	0.73	1.21	1.32	<0.02	0.96
Pb	<0.002	<0.002	<0.002	<0.002	0.004	<0.002
pH (field)	—[c]	6.87	—	7.01	—	—
pH (lab)	7.44	6.87	6.62	7.32	7.29	7.05
PO_4	<0.1	0.19	<0.02	<0.1	<0.05	<0.05
Rb	0.041	0.035	0.046	0.023	0.027	0.010
Sb	<0.002	<0.0002	<0.001	<0.002	<0.0002	<0.0002
SiO_2	59.7	54.1	42.8	67.8	95.9	64.4
SO_4	5.93	4.78	12.8	1.88	2.23	4.18
Sr	0.08	0.06	0.13	0.05	0.04	0.02
V	0.002	0.013	—	<0.002	<0.01	0.003
Zn	0.04	0.67	0.16	0.05	0.06	0.13
TDS[d]	205	182	229	160	189	148
^3H (pCi/L)	1472	1849	5974	2.01	2.30	0.77

a. All analysis are in mg/L, except where noted.
b. The following chemical constituents are not shown because they are below the detection limits as indicated: Ag<0.0005 mg/L, Be <0.002 mg/L. Hg <0.0002 mg/L, I <0.0002 mg/L, S_2O_3<0.01 mg/L, Ti <0.002 mg/L, Se <0.0002 mg/L.
c. — means not analyzed.
d. TDS = total dissolved solids

(LANL 1993, 21404; Broxton et al. 1995, 50119)



Sources: Environmental Protection Group 1995, 50285; Broxton et al. 1995, 50119

F 3-29 / LA&P WP / 111895

Figure 3-29. Water quality data for alluvial, intermediate perched zone and main aquifer ground water in upper Los Alamos Canyon.

drinking water (Environmental Protection Group 1994, 35363). This value has not been confirmed or rejected as a valid indication of contamination. The results of prior analyses were very much lower.

Ground water quality in the intermediate perched zone is monitored by samples collected from TW-1A, TW-2A (Table 3-17), and the discharge at Basalt Spring (Tables 3-10 A, B, and C). Ground water samples collected from TW-2A have chemical compositions reflecting a contribution from alluvial ground water in middle to lower Pueblo Canyon. The Los Alamos County sewage treatment plant is the most likely source of the constituents observed in TW-1A and Basalt Spring.

Tritium and total plutonium (^{238}Pu and ^{239,240}Pu) have been detected in TW-2A (Environmental Protection Group 1994, 35363). More recently, low-detection-limit measurements of tritium and ^{14}C (see Table 3-19 in Section 3.7.6.2) have indicated the possible presence of Laboratory contaminants in samples collected from TW-1A and TW-2A. Measurements of ^{14}C in ground water samples collected from TW-1A show the presence of recent surface contamination because the ^{14}C activity is much higher than that found in atmospheric precipitation.

In summary, analytical results of ground water samples collected from the three intermediate perched zone observation wells (TW-1A, TW-2A, and LADP-3) and Basalt Spring that contain tritium, chloride, and other solutes demonstrate recent recharge from the alluvium to the intermediate perched zone in Pueblo Canyon and Los Alamos Canyon. The analytical results for TW-1A, TW-2A, and Basalt Spring are consistent with previous analytical data collected by the USGS in the 1960s. Results of chemical analyses from observation well LAOI(A)-1.1 did not confirm elevated concentrations of chloride and activities of tritium; the ground water chemistry of this well probably represents background conditions within the Guaje Pumice Bed.

3.7.6 Main Aquifer

Several test wells (TW-1, TW-2, TW-3, TW-4, and LA-1A) and supply wells (Otowi 4, LA-1B, LA-2, LA-3, LA-4, LA-5, and LA-6) are completed within the Santa Fe Group (main aquifer) in Los Alamos Canyon and Pueblo Canyon. Most of the discussion of the hydrochemistry of the test wells is referenced to water-quality data collected from TW-3 (Table 3-18) because this test well probably represents uncontaminated conditions within the main aquifer of the Laboratory. Analyses of ground water samples collected from TW-1 and TW-2 show the presence of contaminants (chloride, nitrate, and tritium), which may be the result of contaminant migration through bedrock from the intermediate perched zones to the Santa Fe Group or contaminant migration along improperly sealed boreholes of wells completed in the 1940s.

3.7.6.1 General Chemistry

Beneath Los Alamos Canyon, the ground water of the main aquifer is characterized by more alkaline pH values (8.1 to 8.2) than those measured on ground water samples collected from the alluvium (7.0 to 7.3) and from the intermediate perched zones (7.3 to 7.7) (Environmental Protection Group 1994, 35363). The TDS concentrations of ground water samples collected from the main aquifer (Table 3-18) are generally less than the TDS of those collected from the alluvium (Tables 3-10 A, B, and C) and intermediate perched zone (Table 3-16) in Los Alamos Canyon and Pueblo Canyon. From 1984 to 1988, the average TDS concentration in ground water samples collected from TW-3, located below the confluence of Los Alamos Canyon and DP Canyon, was

TABLE 3-17

WATER-QUALITY DATA FROM INTERMEDIATE PERCHED ZONE WELLS CERROS DEL RIO BASALTS, PUEBLO CANYON

Element/Parameter	TW[a]-1A	TW-2A
pH (field)	7.7	7.3
Total dissolved solids (mg/L)	266	196
Radiochemical (pCi/L)		
^{90}Sr	0.6 (0.9)[b]	0.0 (0.9)[b]
^{137}Cs	1.2 (1.2)	3.0 (13)
^{238}Pu	0.00 (0.03)	0.019 (0.03)
$^{239,240}Pu$	0.043 (0.023)	1.28 (0.091)
^{241}Am	N/A[c]	0.011 (0.03)
Gross-alpha	2 (1)	2 (1)
Gross-beta	6 (1)	7 (1)
Gross-gamma	110 (100)	110 (100)
Major Constituents (mg/L)		
SiO_2	35	62
Ca	33	38
Mg	8.6	7.3
K	7	4
Na	59	24
Cl	49	41
F	0.9	0.2
CO_3	<1	<1
HCO_3	108	86
PO_4-P	4.1	0.1
SO_4	31	26
NO_3-N	1.82	3.21
CN	<0.01	<0.01
Trace Metals (mg/L)		
Ag	<0.03	<0.03
Al	0.23	<0.02
As	<0.002	<0.002
B	0.23	0.127
Ba	0.03	0.03
Be	<0.002	<0.002
Cd	<0.01	<0.01
Cr	<0.02	<0.02
Co	0.009	<0.004
Cu	<0.03	<0.03
Fe	57.4	0.97
Hg	0.0007	<0.0001
Total uranium (µg/L)	0.3 (0.2)	0.4 (0.2)

a. TW = test well
b. Radioactivity counting uncertainties (±1 standard deviation) are shown in parentheses.
c. N/A means analysis not performed, lost, or not completed.

(Blake et al. 1995, 49931; Environmental Protection Group 1994, 35363; Environmental Protection Group 1993, 23249)

TABLE 3-18

WATER-QUALITY DATA FROM THE MAIN AQUIFER WELLS SANTA FE GROUP, LOS ALAMOS CANYON AND PUEBLO CANYON

Element/Parameter	LA-A[a]	LA-1B[a]	LA-2[a]
pH (field)	7.2	7	8.1
Total dissolved solids (mg/L)	141.7	632.4	194.9
Radiochemical (pCi/L)			
^{90}Sr	N/A[b]	N/A	N/A
^{137}Cs	N/A	229 (120)[c]	40 (92)
^{238}Pu	N/A	0.008 (0.012)	0.000 (0.010)
$^{239,240}Pu$	N/A	0.008 (0.010)	-0.005 (0.009)
^{241}Am	N/A	N/A	N/A
Gross-alpha	N/A	30 (7)	6 (2)
Gross-beta	N/A	3 (1)	2 (0)
Gross-gamma	N/A	-0.0 (70)	0 (70)
Major Constituents (mg/L)			
SiO_2	6.4	38.9	30.8
Ca	3.71	7.1	10.7
Mg	0.03	0.31	0.14
K	1.63	2.51	1.54
Na	37.2	166	33.1
Cl	7.74	18.6	2.58
F	0.29	2.87	0.61
CO_3	7	11.1	6.9
HCO_3	67.7	346	88
PO_4-P	<0.02	<0.02	<0.02
SO_4	8.95	35.5	7.5
NO_3-N	0.04	2.26	2.06
CN	N/A	<0.01	<0.01
Trace Metals (mg/L)			
Ag	<0.001	<0.001	<0.001
Al	<0.1	<0.1	<0.1
As	<0.05	<0.05	<0.05
B	0.13	0.38	0.08
Ba	<0.01	0.04	0.08
Be	N/A	N/A	N/A
Cd	<0.001	<0.001	<0.001
Cr	<0.002	0.027	0.011
Co	<0.002	<0.002	<0.002
Cu	<0.002	<0.002	<0.002
Fe	0.33	0.01	0.01
Hg	N/A	<0.0002	<0.0002
Total uranium (µg/L)	N/A	6.0	6.1

a. Former supply well

b. N/A means analysis not performed, lost, or not completed.

c. Radioactivity counting uncertainties (± standard deviation) are shown in parentheses.

(Blake et al. 1995, 49931; Evironmental Protection Group 1994, 35363; Environmental Protection Group 1993, 23249)

TABLE 3-18 (continued)

WATER-QUALITY DATA FROM THE MAIN AQUIFER WELLS SANTA FE GROUP, LOS ALAMOS CANYON AND PUEBLO CANYON

Element/Parameter	LA-5[a]	Otowi 4[a]	TW-1[b]
pH (field)	8.1	7	8.1
Total dissolved solids (mg/L)	183	308.2	290
Radiochemical (pCi/L)			
^{90}Sr	N/A[c]	N/A	0.2 (1.0)[d]
^{137}Cs	74 (81)	N/A	1.1 (1.3)
^{238}Pu	0.038 (0.014)	-0.006 (0.030)	0.005 (0.030)
$^{239,240}Pu$	0.010 (0.010)	0.006 (0.020)	0.013 (0.020)
^{241}Am	N/A	N/A	0.000 (0.030)
Gross-alpha	0 (1)	3 (1)	2 (1)
Gross-beta	2 (0)	5 (1)	6 (1)
Gross-gamma	80 (70)	110 (100)	160 (100)
Major Constituents (mg/L)			
SiO_2	38.7	105	56
Ca	19.5	21	49
Mg	0.76	8.06	9.7
K	2.49	3.56	4
Na	15.8	21	16
Cl	3.22	7.03	30
F	0.44	0.28	0.4
CO_3	0	0	3
HCO_3	93.5	137	97
PO_4-P	<0.02	<0.02	0.2
SO_4	5.63	5.05	22
NO_3-N	1.75	<0.02	6.45
CN	<0.01	N/A	<0.01
Trace Metals (mg/L)			
Ag	<0.001	<0.001	<0.03
Al	<0.1	<0.1	<0.02
As	0.05	<0.05	<0.002
B	0.04	<0.05	0.066
Ba	0.06	0.05	0.08
Be	N/A	<0.001	<0.002
Cd	<0.001	<0.001	<0.01
Cr	0.008	0.007	<0.02
Co	<0.002	<0.002	<0.004
Cu	<0.002	0.004	<0.03
Fe	0.03	<0.01	0.77
Hg	<0.0002	<0.0002	0.0007
Total uranium (µg/L)	1.0	<1	2.7 (0.3)

a. Current minor supply well (see text)
b. Test well
c. N/A means analysis not performed, lost, or not completed.
d. Radioactive counting uncertainties (± 1 standard deviation) are shown in parentheses.

(Blake et al. 1995, 49931; Environmental Protection Group 1994, 35363; Environmental Protection Group 1993, 23249)

TABLE 3-18 (continued)

WATER-QUALITY DATA FROM THE MAIN AQUIFER WELLS SANTA FE GROUP, LOS ALAMOS CANYON AND PUEBLO CANYON

Element/Parameter	TW-2[a]	TW-3[a]	TW-4[a]
pH (field)	8.2	N/A[b]	8.7
Total dissolved solids (mg/L)	114	255.6	121.3
Radiochemical (pCi/L)			
^{90}Sr	0.7 (0.8)[c]	0.2 (0.8)	0.2 (0.7)
^{137}Cs	0.7 (1.0)	1.7 (1.2)	N/A
^{238}Pu	0.00 (0.010)	-0.025 (0.030)	0.005 (0.030)
$^{239,240}Pu$	0.043 (0.023)	0.005 (0.020)	0.063 (0.020)
^{241}Am	0.020 (0.030)	0.039 (0.030)	0.025 (0.030)
Gross-alpha	0 (0)	1 (1)	0 (1)
Gross-beta	3 (1)	3 (0)	3 (1)
Gross-gamma	40 (100)	-110 (100)	40 (90)
Major Constituents (mg/L)			
SiO_2	59	79.6	6
Ca	12	17.6	11.6
Mg	3	5.15	3.82
K	1	2.33	3.42
Na	13	12.2	12.8
Cl	3	3.06	3.24
F	0.5	0.41	0.26
CO_3	<1	0	3.2
HCO_3	59	99.2	73.4
PO_4-P	0.4	0.04	<0.02
SO_4	3	3	2.56
NO_3-N	0.17	2.61	0.02
CN	<0.01	N/A	N/A
Trace Metals (mg/L)			
Ag	<0.03	<0.001	<0.001
Al	<0.02	<0.1	<0.1
As	<0.002	<0.05	<0.05
B	0.023	0.03	0.06
Ba	0.02	0.03	0.06
Be	<0.002	<0.001	<0.001
Cd	<0.01	<0.001	<0.001
Cr	<0.02	0.003	<0.002
Co	<0.004	<0.002	<0.002
Cu	<0.03	0.002	0.003
Fe	2.58	0.002	0.03
Hg	<0.0001	0.03	<0.002
Total uranium (µg/L)	<0.2(0.0)	<2.0	<1.0

a. Test well
b. N/A means analysis not performed, lost, or not completed.
c. Radioactivity counting uncertainties (± 1 standard deviation) are shown in parentheses.

(Blake et al. 1995. 49931; Environmental Protection Group 1994, 35363; Environmental Protection Group 1995, 50285)

129 ± 49 mg/L. Calcium tends to be the predominant cation, and bicarbonate is the dominant anion. The increasing bicarbonate concentrations in successively deeper saturated zones is probably due to both the presence of calcite ($CaCO_3$) and possibly through the oxidation of natural organic matter to CO_2 (Drever 1988, 49933). Ground water samples collected from TW-3 are dissolved calcium-sodium-bicarbonate solutions (Environmental Protection Group 1994, 35363). Results of speciation calculations using MINTEQA2 (Allison et al. 1991, 49930) suggest that TW-3 ground water is in equilibrium with calcite and that dissolved concentrations of calcium and bicarbonate are controlled by this equilibrium.

Concentrations of chloride are less than 8 mg/L at TW-3 (Table 3-18) (Environmental Protection Group 1994, 35363). These concentrations suggest that this well does not contain significant amounts of alluvial and Guaje Pumice Bed ground water, which are characterized by elevated concentrations of chloride in upper Los Alamos Canyon.

TW-1 is located west of TW-1A in Pueblo Canyon (see Figure A-2 in Appendix A of this work plan) and is completed in the Santa Fe Group at a total depth of 642 ft (Purtymun 1995, 45344). Unusually high water levels observed in 1991 at TW-1 (main aquifer) and water-quality data collected over several decades from this well suggest a downward communication of ground water from the intermediate perched zone (identified in TW-1A) to the main aquifer.

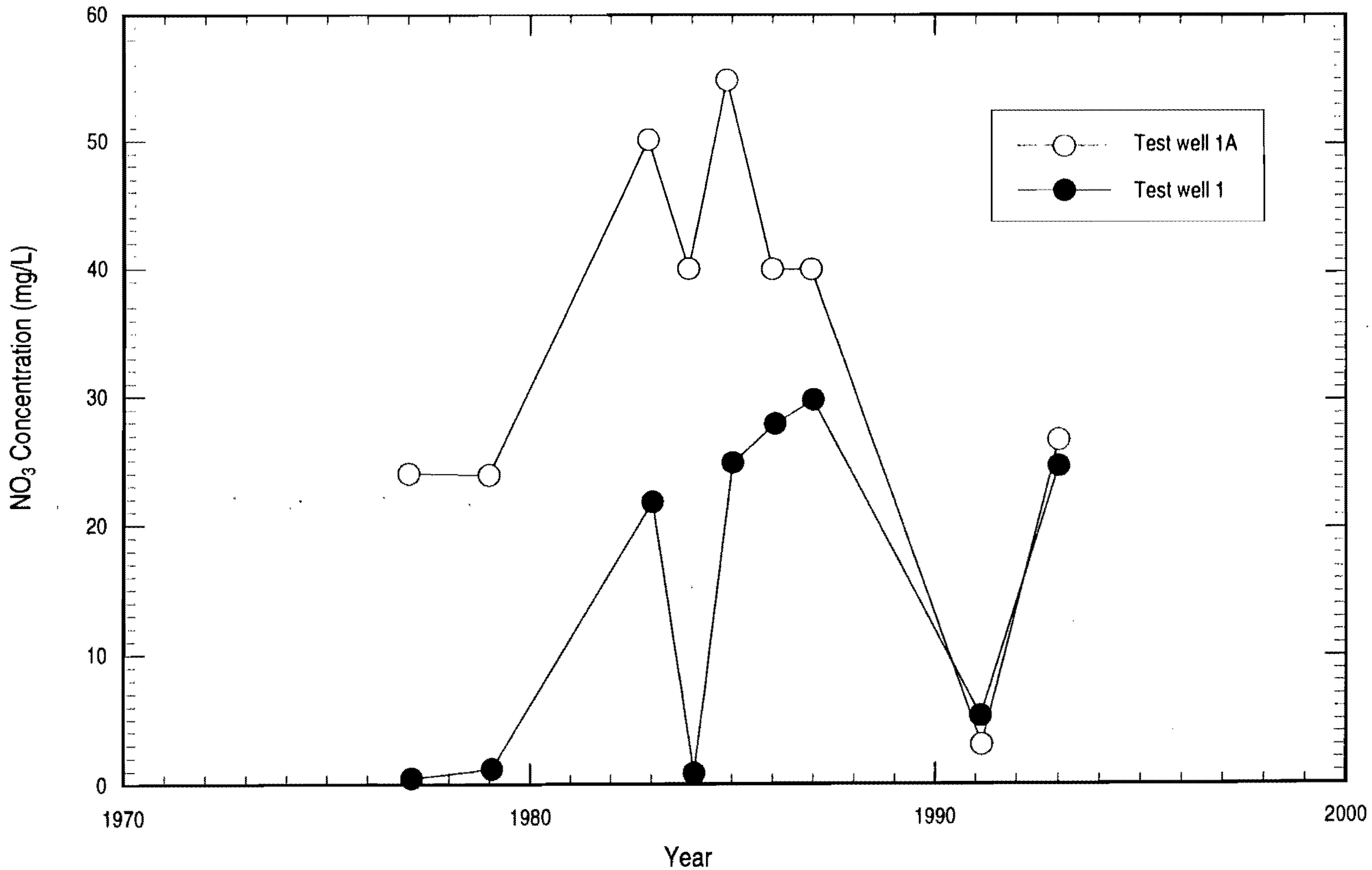
Figures 3-30 and 3-31 show distributions of nitrate and chloride, respectively, over time in TW-1A and TW-1. The similarity in the patterns of nitrate and chloride in both wells suggests hydraulic connection between the wells possibly through fractured rock. Under near neutral pH conditions, both of these anions are mobile. If leakage from TW-1A to the Santa Fe Group is occurring, chemical mixing between the two aquifers would be expected. This mixing would produce similar concentrations of these two anions in both wells continuously over time.

Figure 3-32 shows activities of tritium in TW-1A and TW-1. Tritium activities are higher in TW-1 than in TW-1A, the reverse of the pattern of nitrate and chloride concentrations in the two wells. The reason for the difference is unknown.

At TW-1A and TW-1, barometric pressure data collected by Steven McLin of the Laboratory's Water Quality and Hydrology group (ESH-18) suggest that the two aquifers are hydraulically disconnected (data presented by McLin in an ER Project technical session on May 26, 1993).

These data suggest that the elevated concentrations of nitrate and chloride, and the above-background tritium levels (from recent, low-detection-limit analyses) observed in TW-1 may be the result of ground water migrating through pores and fractures (especially the latter) characteristic of the Cerros del Rio basalt and the Puye Formation. Another hypothesis that may account for the contaminant distributions in TW-1 is that fluid movement along the ungrouted, cable-tool casings at TW-1 provides a conduit for ground water flow. A third hypothesis, related also to the unusually high water levels in TW-1A noted above, is leakage from the drilling of supply well Otowi-4, located about 600 ft west of TW-1A and TW-1.

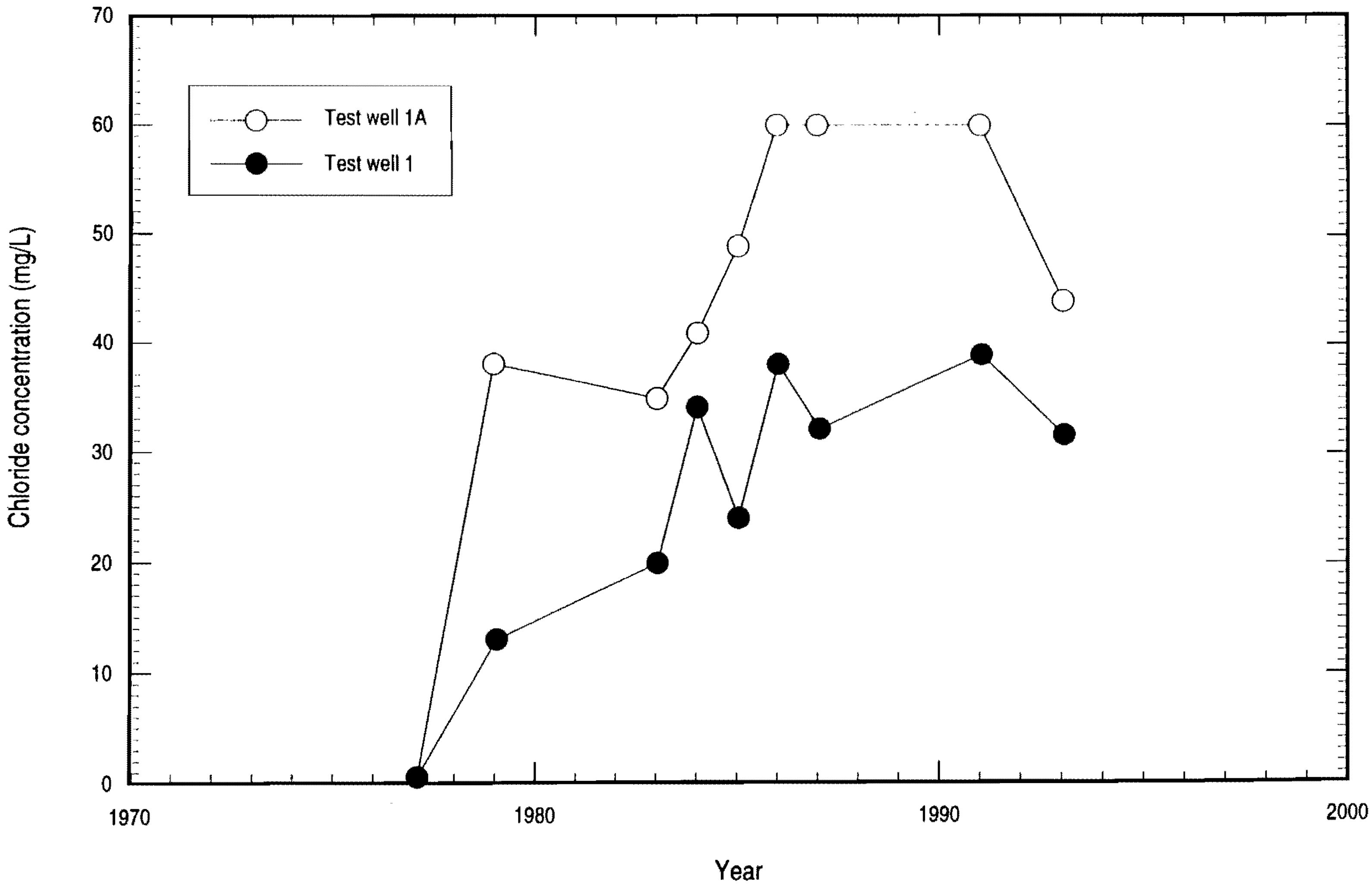
Results of chemical analyses of ground water samples collected from former supply wells LA-1A, LA-1B, LA-2, LA-3, LA-4, LA-5, and LA-6 from 1962 to 1993 show that sodium and bicarbonate are the predominant ions. Concentrations of sodium and bicarbonate typically range from 15 to 300 mg/L and from 70 to 300 mg/L, respectively. Concentrations of calcium generally range from 3 to 30 mg/L. Nitrate concentrations, typically range from 0.2 to 10 mg/L.



Sources: ESG 1978, 5724; ESG 1980, 5961; ESG 1984, 6523;
ESG 1985, 6610; ESG 1986, 6626; ESG 1987, 6678; ESG 1988, 6877; Environmental Protection Group 1993, 23249; Environmental Protection Group 1995, 50285

F 3-30 / LA&P WP / 111895

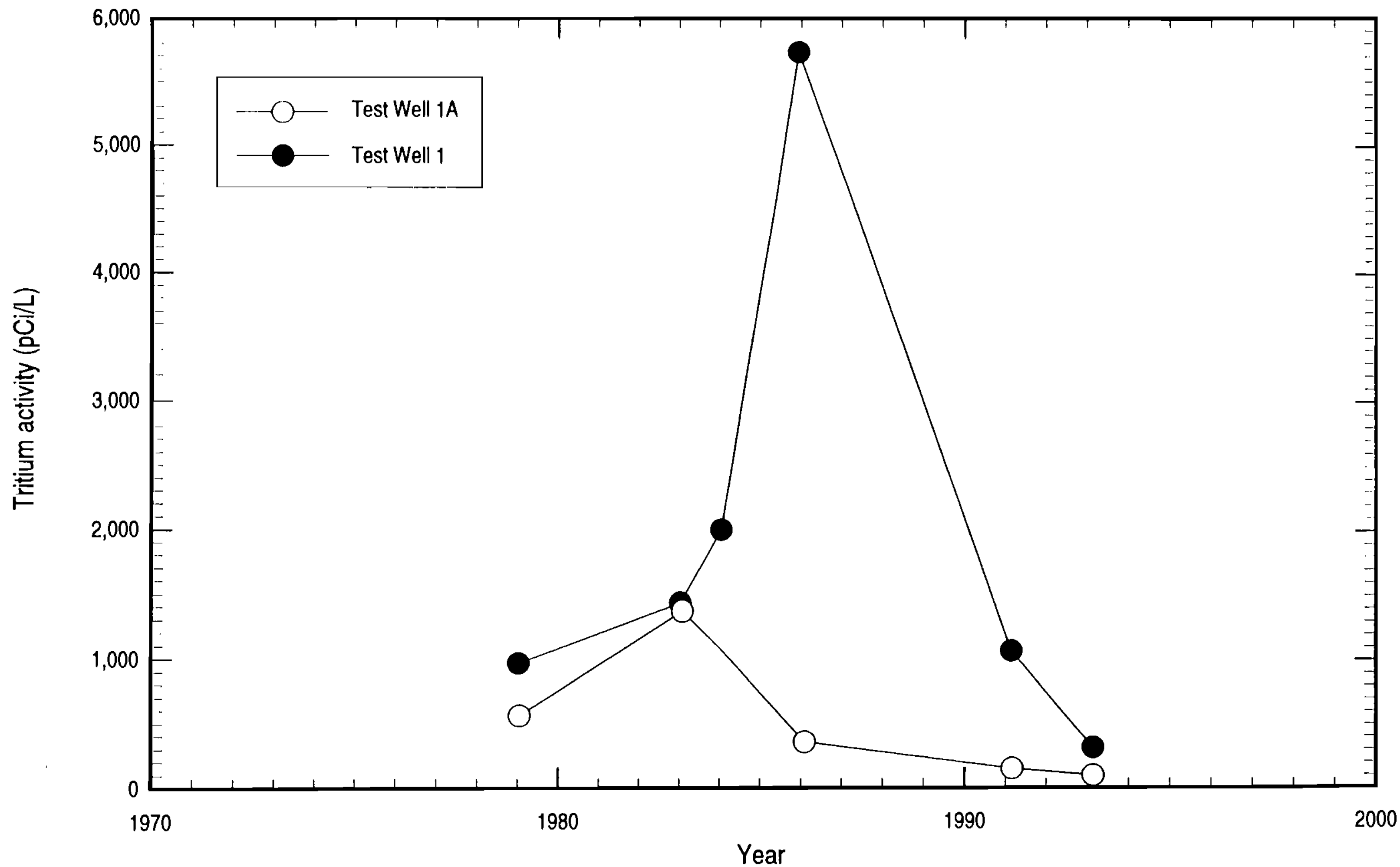
Figure 3-30. Nitrate concentrations in TW-1A and TW-1 in Pueblo Canyon.



Sources: ESG 1978, 5724; ESG 1980, 5961; ESG 1984, 6523; ESG 1985, 6610; ESG 1986, 6626; ESG 1987, 6678; ESG 1988, 6877; Environmental Protection Group 1993, 23249; Environmental Protection Group 1995, 50285

F 3-31 / LA&P WP / 111895

Figure 3-31. Chloride concentrations in TW-1A and TW-1 in Pueblo Canyon.



Sources: ESG 1980, 5961; ESG 1984, 6523; ESG 1985, 6610;
ESG 1987, 6678; Environmental Protection Group 1993, 23249;
Environmental Protection Group 1995, 50285

F 3-32 / LA&P WP / 111895

Figure 3-32. Tritium activities in TW-1A and TW-1 in Pueblo Canyon.

LA-5 provides water to residences at Totavi. The remaining LA-designated wells in lower Los Alamos Canyon were taken out of service by 1991, and several have been plugged and abandoned. Wells LA-1A, LA-1B, LA-2, and LA-5 were turned over to San Ildefonso Pueblo in 1993.

Figures 3-33 and 3-34 show concentrations of selected anions (chloride and nitrate) and cations (calcium and sodium) in ground water samples collected from the former supply wells in lower Los Alamos Canyon in March 1963 and March 1977. Chemical analyses from these two years were selected for presentation because they provide the greatest time interval during which ground water samples were collected from all the former supply wells in lower Los Alamos Canyon. Former supply well LA-4 is located up the canyon, immediately east of the Laboratory boundary, and supply well LA-1B is located down the canyon closest to the Rio Grande (see Figure A-2 in Appendix A of this work plan).

Concentrations of nitrate were fairly constant down-canyon in the former supply wells, whereas concentrations of chloride increased by factors of five and six in former supply wells LA-2 and LA-1B, respectively over the up-canyon wells. The increase in chloride concentration in former supply well LA-2 may be the result of recharge from surface waters carrying dissolved road salt or, in the case of LA-1B, from greater input of older ground water at greater depths. Older ground water characteristically shows higher concentrations of major ions like chloride because it has had greater opportunity to dissolve material from the rock through which it passes. The presence of older ground water in supply well LA-1B is supported by ^{14}C age determinations summarized in Table 3-19.

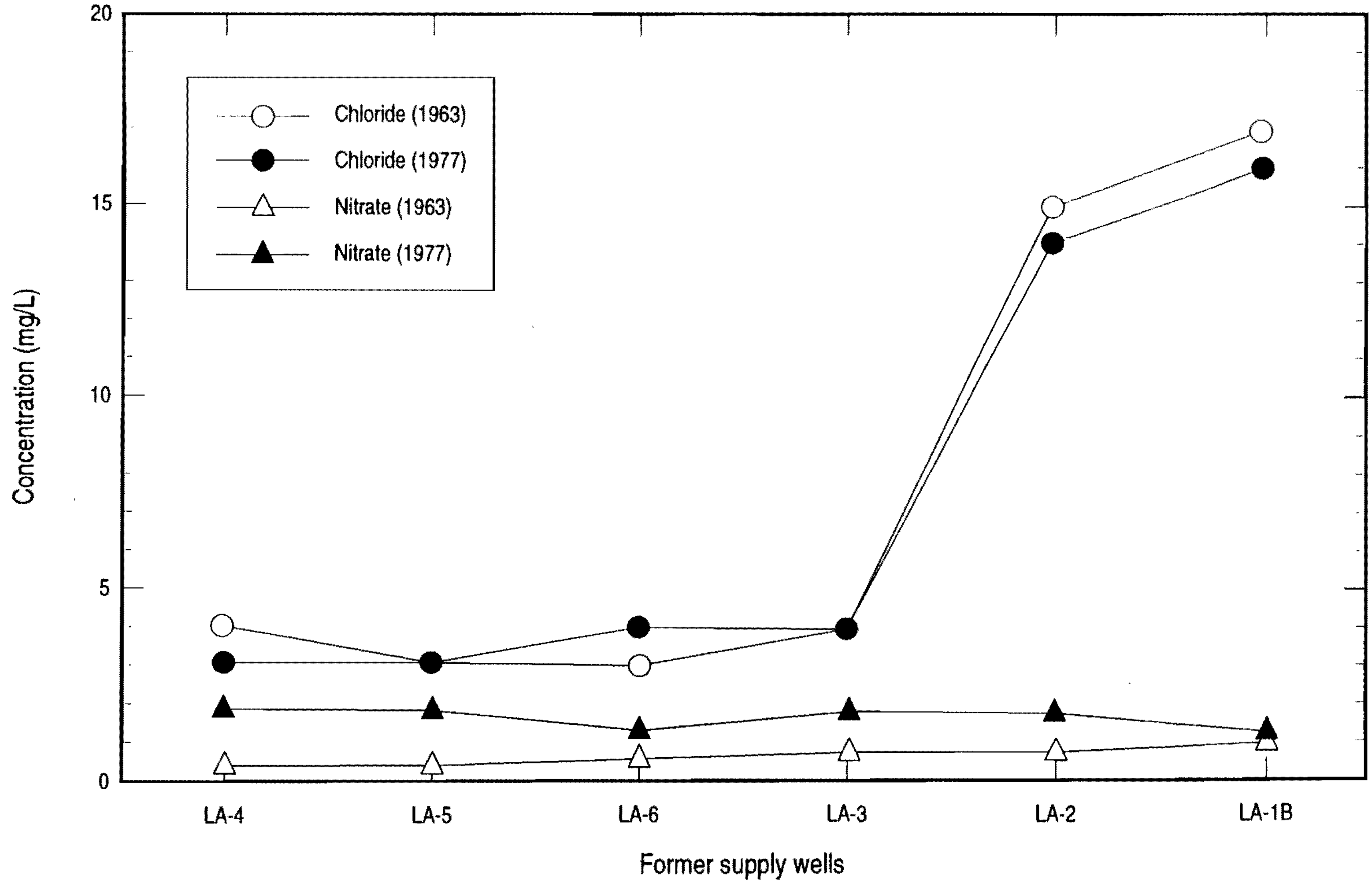
Concentrations of calcium and sodium while showing not noticeable trend with time, fluctuate considerably down-canyon suggesting that cation exchange, in which calcium replaces sodium on mineral surfaces, may be an important geochemical process for controlling concentrations of these two cations.

Several factors contribute to variations in ground water chemistry in the Santa Fe Group observed within lower Los Alamos Canyon. These supply wells have screened intervals over hundreds of feet, and ground water samples probably reflect contributions from different zones. Dilution of chemical constituents may occur from sampling large depth intervals within the supply wells. In addition, unfiltered samples, which contain both dissolved constituents and constituents sorbed on suspended matter, were probably collected from the supply wells. Therefore, inferences about geochemical interactions of water and sediment are more ambiguous than similar inferences would be for more restricted zones of saturation and analyses of only filtered samples.

Radiochemical analyses of ^{90}Sr, ^{137}Cs, ^{238}Pu, and $^{239,240}Pu$ generally indicate no detectable contamination of the main aquifer based on reported quantification limits and precision of the analyses of the samples (Environmental Protection Group 1995, 50285).

3.7.6.2 Low-Level Tritium Analyses and Age Estimates

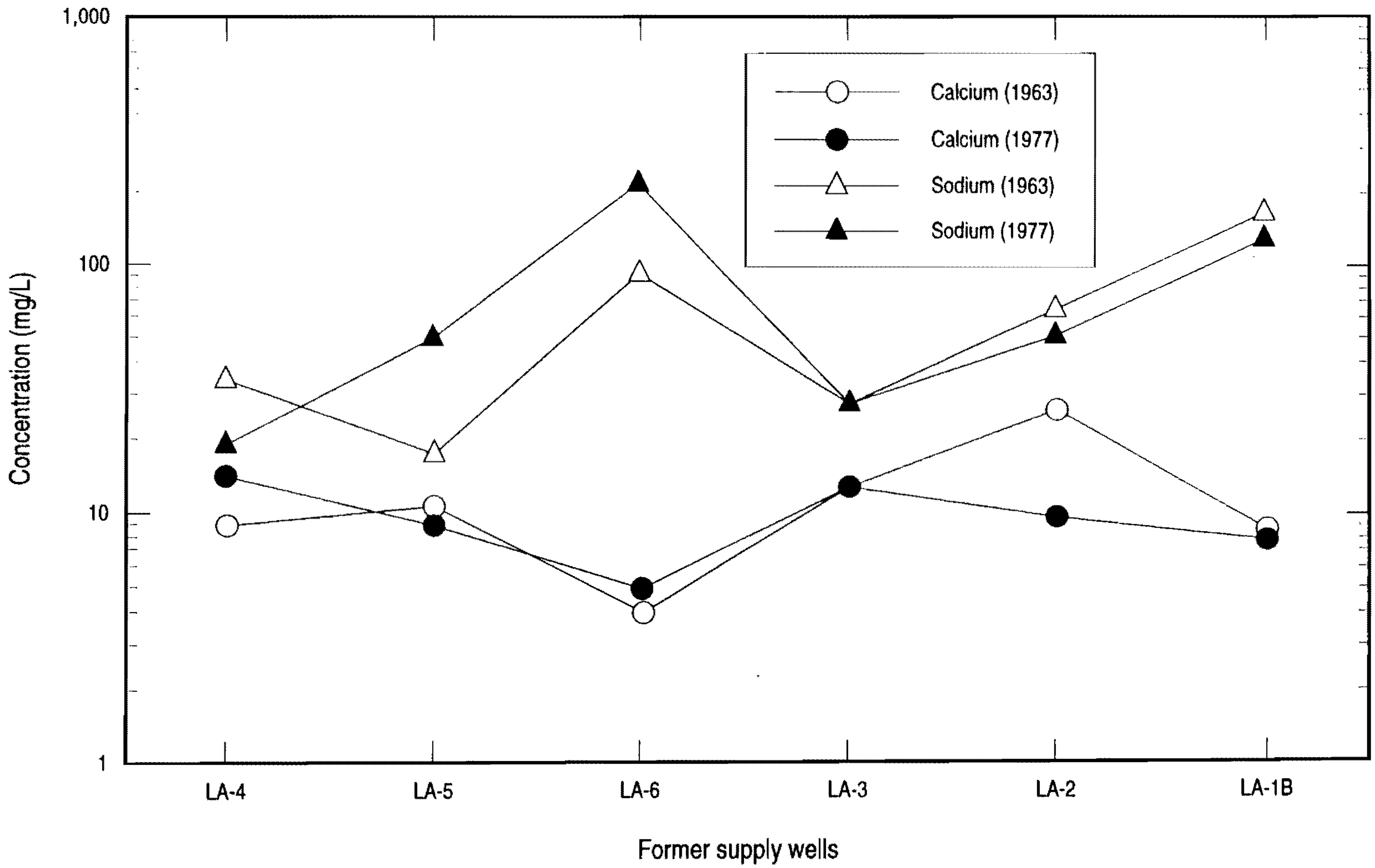
In an effort to better understand the nature and extent of recharge to the Santa Fe Group in the Los Alamos area, a series of isotopic measurements on selected ground water samples has been initiated by Laboratory and other DOE researchers. Tritium is present in contemporary precipitation on the Pajarito Plateau at levels ranging from 21 to 450 pCi/L (Adams et al. 1995, 47192). These levels reflect input from airborne releases, from atmospheric nuclear testing, and from cosmic ray production in the upper atmosphere (ESG 1971–1995, Purtymun et al. 1987, 6687). Tritium in ground



Sources: Purtymun 1966, 11779; ESG 1978, 5724

F 3-33 / LA&P WP / 111895

Figure 3-33. Concentrations of chloride and nitrate in supply wells in lower Los Alamos Canyon.



Sources: Purtymun 1966, 11779; ESG 1978, 5724

F 3-34 / LA&P WP / 111895

Figure 3-34. Concentrations of calcium and sodium in supply wells in lower Los Alamos Canyon.

water may result from recharge of these rainwaters to the alluvium and intermediate perched zones. Flow to deeper aquifers (such as the main aquifer) would have to be very rapid for this tritium (which has a half-life of 12.33 years) to reach the water table.

Table 3-19 summarizes the low-level tritium data for wells completed in the main aquifer (Santa Fe Group) and the intermediate perched zones. The levels of tritium measured range from less than a hundredth of a percent to about one percent of the current drinking water standard for tritium (20,000 pCi/L). Most of the measured tritium levels in these wells are lower than can be detected by the EPA-specified analytical methods normally used to determine compliance with drinking water regulations.

Activities of tritium in the ground water samples collected from selected supply wells in Los Alamos Canyon (Table 3-19) range from 0.58 ± 0.29 pCi/L to about 63.0 ± 2.2 pCi/L. These activities are lower than most of the range for tritium in contemporary precipitation cited above. Higher activities of tritium (700 pCi/L) were present in the atmosphere in northern New Mexico during 1962 and 1963, when tritium from atmospheric testing reached its peak (Environmental Protection Group 1993, 23249). The presence of tritium in the main aquifer might indicate recharge by very young (approximately 30 to 50 years) rainwater. However, samples from most of the main aquifer supply wells show such low values of tritium that they cannot contain any significant component of such young water. Thus, the ground water in the main aquifer is generally older than the period of atmospheric nuclear testing.

TW-4 is located on a mesa east of the area where discharges occurred from untreated waste lines from former TA-1 (from 1944 to 1951) and from the liquid waste treatment plant at former TA-45 (from 1951 to 1964). The well had been capped and out of service for about 20 years until the fall of 1992 when it was refurbished and equipped with a new pump. This operation included the introduction of some water for cleaning and priming the pump. The total depth of TW-4 is about 1200 ft, and it is completed in the upper zone of the Tschicoma Formation (main aquifer). Analytical results of the water sample taken in May 1993 showed a tritium activity of 10.7 ± 0.4 pCi/L. Temperature measurements collected on ground water pumped from TW-4 suggest that the well may not have been pumped long enough to completely purge any introduced water, which may constitute a possible source of tritium.

Well LA-1A was constructed in 1946 as part of water supply investigations for the USGS. The well penetrated about 78 ft of channel alluvium and then continued into the main aquifer to a total depth of about 400 ft. The well flowed under artesian pressure. However, neither the completion method nor the depth of any perforations are documented. Well LA-1A probably is not grouted, and subsequently alluvial ground water containing tritium may have leaked down the well annulus producing anomalous tritium values. The tritium activity in a May 1993 sample was 63.0 ± 2.2 pCi/L (Table 3-19).

By contrast, nearby supply well, LA-1B (completed in 1960), is cased to 1750 ft with the screen starting at 326 ft. The surface casing was cemented through the alluvium at a depth of 64 ft. This well showed much lower tritium (0.58 ± 0.29 pCi/L) in samples collected in May 1993 (Table 3-19).

Additional analytical results were obtained from the former supply well LA-2, drilled in 1946, which penetrated about 60 ft of alluvium overlying the Santa Fe Group. The total depth of former supply well LA-2 was 882 ft, with screens or slotted casing installed in the completed well beginning at a depth of 105 ft. Tritium activity in the water from the well was 12.9 ± 0.4 pCi/L (Table 3-19). Some downward movement of water might be

TABLE 3-19

LOW-LEVEL TRITIUM MEASUREMENTS AND CARBON-14/TRITIUM-BASED AGE ESTIMATES IN GROUND WATER IN LOS ALAMOS CANYON AND PUEBLO CANYON

	Date	^{3}H Concen.	^{14}C	^{14}C Age Estimates		^{3}H Age Estimates	
		(pCi/L)	(%modern)	Min[a]	Max[b]	Piston Flow[c]	Well Mixed[d]
Santa Fe Group Production Wells							
LA-1 A	5/12/93	63.04 ± 2.24	13.9	6250	16300	20–30	10–50
LA-1B	5/12/93	0.58 ± 0.29	<0.9	>27000	>39000	>60	>8000
LA-2	5/12/93	12.9 ± 0.42	27.2	5850	10800	35–40	~400
LA-5	5/12/93	0.8 ± 0.32	—	—	—	—	—
O-4	2/3/93	1.02 ± 0.61	25.0	3890	11500	>50	>5000
Santa Fe Group Test Wells							
TW-1	5/19/93	348.8 ± 12.8	237.2	Contaminated[e]		Contaminated[e]	
TW-2	5/19/93	2.6 ± 0.3	57.3	<0[f]	4610	~40	>1500
TW-3	5/20/93	2.85 ± 0.29	40.45	921	7480	~40	>1500
TW-4	5/19/93	10.69 ± 0.35	57.1	<0[f]	4630	~35	~500
Guaje Pumice Bed, Basalt Flows, Puye Formation							
LAOI-1.1	2/16/95	2.3 ± 0.35	—	—	—		
TW-1a	5/19/93	146.6 ± 4.8	182.2	Contaminated[e]			
TW-2a	5/19/93	2236.8 ± 73.6	—	—		Contaminated[e]	
LADP-3		5760	—	—		Contaminated[e]	
Basalt Spring	12/29/92	160.3 ± 5.4	—	—		20–30	<20
Lower Los Alamos Canyon (at Otowi Bridge)							
Halladay House Well	5/12/93	0.93 ± 0.29	10.7	13400	18500	>50	>5000
Otowi House Well	5/12/93	143.3 ± 4.8	—	—	—		>5000

a. Assumes dilution by "dead" carbon from dissolution of carbonates, estimated by $\delta^{13}C$
b. Assumes radioactive decay only, no dilution by dissolution of carbonates
c. Piston flow model assumes no mixing or dilution with other water.
d. Well-mixed model assumes complete mixing in reservoir, inflow = outflow, no other inputs
e. "Contaminated" indicates that the sample contains tritium or ^{14}C greater than could be attributed to any atmospheric precipitation.
f. Applying dilution factor (a) results in meaningless minimum age

Related tritium (^{3}H) information for context	
Prebomb atmospheric moisture	~20 pCi/L
Peak levels in atmospheric precipitation in northern New Mexico (mid-1960s)	~7000 pCi/L
Those levels decayed to present	~700 pCi/L
Typical levels in contemporary precipitation (North American continent)	30–45 pCi/L
Typical levels in contemporary precipitation (Los Alamos vicinity)	60–350 pCi/L
EPA drinking water standard	20,000 pCi/L
Proposed EPA maximum contaminant level and DOE guide for drinking water	60,000 pCi/L
Low-level detection limit	0.3 pCi/L
Standard detection limit	300–600 pCi/L

expected in this well as a result of the construction methods and the shallow placement of the screen.

Two private residences located at Otowi Bridge have shallow wells; however, the construction of the wells is not documented. The Otowi House, north of Los Alamos Canyon, has one of these shallow wells, which (based on evaluation of the composition of the water) probably draws water from the alluvium and gravels of the Rio Grande and possibly from the alluvium of Los Alamos Canyon. A sample taken from this well in May 1993 had a tritium concentration of 143.3 ± 4.8 pCi/L (Table 3-19). This result is reasonable because alluvial ground water would reflect recent water derived from both precipitation and ground water flow from the portions of Los Alamos Canyon containing Laboratory-derived tritium.

The second deeper well, at the Halladay House located on the south side of Los Alamos Canyon, was sampled in February 1992 and May 1993. Analytical results of the water samples (Table 3-19) are consistent with the chemical content of ground water derived from the main aquifer (Santa Fe Group). The well is located far enough away from the stream channel that it is unlikely to have penetrated any saturated alluvium.

3.7.6.3 Carbon-14 Age Estimates

The isotope ^{14}C decays to ^{14}N by emission of a beta particle; it has a half-life of 5730 years. Therefore, ^{14}C can be used to date materials with ages of a few hundred to tens of thousands of years. Most of the ^{14}C in the air is produced by cosmic rays in the upper atmosphere and mixes rapidly throughout the atmosphere. Measurements of ^{14}C in waters may be used to infer the time since the water last reached equilibrium with the surface air.

The maximum possible age is determined from the measured ratio of ^{14}C to common carbon, which gives an age based on the radioactive decay of ^{14}C. This value is commonly greater than the actual age because the carbon in the infiltrating water is diluted by the dissolution of older (even completely nonradioactive) carbonate minerals or organic material. Estimating this dilution effect requires measurement of other carbon isotopes and assumptions about mixing. Calculating a minimum age based on the estimated dilution can lead to very young or negative ages if the carbon geochemistry is not well characterized. It is also possible that ^{14}C from other sources such as laboratory effluents or atmospheric nuclear testing (the so-called Bomb Pulse carbon) could raise the amount of ^{14}C in a sample and lead to an inferred age that is very young or even negative.

About 25 analyses of ^{14}C activity in ground water samples collected from the main aquifer (Santa Fe Group) in the Los Alamos vicinity have been completed. Selected results applicable to the Los Alamos Canyon and Pueblo Canyon vicinity are listed in Table 3-19. Measurements of ^{14}C indicate that ground water in the Santa Fe Group may have maximum ages ranging from a few thousand years in the central and western part of the Pajarito Plateau up to as much as 40,000 years at the Rio Grande in Los Alamos Canyon. Deep flow paths characterized by long residence times may account for the old ages of ground water, which suggests that ground water flow within the Santa Fe Group is complex and delineation of flow paths is not straightforward.

Several of the ground water samples gave very young or negative ages, which indicates either inappropriate assumptions about the degree of interaction with rock and soil or admixture of young, possibly anthropogenic, carbon. Ground water samples collected from TW-1 possibly have recent ^{14}C contamination. The well also shows significant recent recharge based on tritium measurements. Ground water samples collected from the main aquifer with very young estimated ages came from TW-2 (negative age), TW-3 (921 years), and TW-4 (negative age). The analytical result for TW-4 may be an indication of recent recharge because low-level tritium was also detected (Table 3-19).

3.8 Biological Setting

3.8.1 Regional Vegetation

Northern New Mexico's semiarid environment supports a diversity of plants whose distribution is largely determined by elevation. Generally, arid-climate vegetation dominates at low elevations, and vegetation adapted to more consistent moisture grows at higher elevations. The varied topography and vertical relief of the Jemez Mountains and the Pajarito Plateau support an especially rich and diverse subset of the regional vegetation. Vegetation types are classified into two main formations: wetlands and uplands. Most of the streams in Los Alamos County are ephemeral and do not support wetland vegetation. However, permanent flows from springs, Laboratory facilities, and Los Alamos County facilities create a few permanent or near-permanent streams in some canyons. These streams are discussed in Section 3.8.4. The vegetation is subdivided into several plant communities, all of which are upland communities.

The Plains and Great Basin Riparian-Deciduous Forest community grows at the lowest elevations in Los Alamos County along the Rio Grande floodplain, about 5000 ft above sea level. The trees that characterize this vegetation type, such as cottonwood, willow, non-native salt cedar, and Russian olive, are restricted to areas where water is available at or near the ground surface throughout the year.

Above the Rio Grande floodplain at elevations ranging from about 5600 to 6200 ft, one-seed juniper becomes the most common overstory species, which is often intermixed with lesser amounts of piñon. Both of these tree species, typical of the Great Basin Conifer Woodland community, are tolerant of a relatively dry climate. Together they form an open piñon-juniper woodland at elevations of about 6200 to 6900 ft on the Pajarito Plateau.

As the elevation increases toward the Jemez Mountains, the Great Basin Conifer Woodland community gradually grades into the Rocky Mountain Montane Conifer Forest community where increased precipitation allows ponderosa pine to become a dominant species at about 6900 to 7500 ft. White fir and Douglas fir grow along the north-facing slopes at intermediate elevations. These species are often intermixed with ponderosa pine and form a mixed-conifer community. Species of the Rocky Mountain Subalpine Conifer Forest and Woodland community occur along the extreme western edge of Los Alamos County and are more prevalent at the higher elevations of the Jemez Mountains.

3.8.2 Previous Studies

Before 1994 other investigators completed several site-specific studies within or near Los Alamos Canyon and Pueblo Canyon. During those investigations, researchers obtained information on threatened, endangered, or sensitive (TES) species and baseline ecological data.

3.8.2.1 Plants

Several investigators surveyed vegetation in portions of Los Alamos Canyon. Table B-1 in Appendix B of this work plan contains a checklist of plant species that were identified during those surveys and lists the surveys used to prepare the checklist.

3.8.2.2 Wildlife

3.8.2.2.1 Invertebrates

Terrestrial Invertebrates

Although no invertebrate studies have been completed within Los Alamos Canyon or Pueblo Canyon, at least 164 families of terrestrial arthropods have been identified elsewhere on Laboratory property. Most of these families are very likely to inhabit the Los Alamos Canyon and Pueblo Canyon as well (see Table B-2 in Appendix B of this work plan).

Aquatic Invertebrates

Few studies of aquatic invertebrates have been conducted in Los Alamos County. Currently, the ecological studies team (EST) in the Laboratory's Environmental Assessments and Resource Evaluations group (ESH-20) is collecting and identifying aquatic insects within and adjacent to Laboratory property. Eighty-one aquatic insect families have been collected to date. Five species of aquatic mollusks were found on Laboratory property, and further surveys are expected to yield additional species.

3.8.2.2.2 Vertebrates

Fish

No fish have been found on Laboratory property, although some were observed in and downstream from Guaje Reservoir and Los Alamos Reservoir and below Ancho Springs at the confluence of White Rock Canyon and the Rio Grande. Fish habitat exists in the Rio Grande at the confluence with Los Alamos Canyon.

Reptiles and Amphibians

Investigators identified 17 lizard and snake species in the Laboratory area. In 1978 Bogart (circa 1978, 50038) surveyed for reptiles and amphibians in Los Alamos County. He found 8 reptile species in Los Alamos Canyon (see Table B-3 in Appendix B of this work plan).

Birds

More than 200 bird species have been identified in Los Alamos County (Travis 1992, 12015), which include at least 112 species of birds known to breed in the area. Of the breeding bird species, 39 are permanent residents and 59 are migratory summer residents. ESH-20 personnel set up bird transects in Los Alamos Canyon. Other surveys have also gathered information on local bird activities (Kennedy 1988, 50037;

Kennedy 1989, 04-0318; Sinton and Kennedy 1993, 04-0312). Table B-4 in Appendix B of this work plan contains a checklist of the birds found in Los Alamos Canyon during the above studies.

Mammals

Twenty-nine small mammal species have been found in the Laboratory area. Mule deer and elk are the most visible large mammals in the region. These species generally winter in the lower elevations of the Pajarito Plateau, including many of the mesas and canyons along the central and eastern portions of Los Alamos County. Large mammals generally spend the summer at higher elevations in the Jemez Mountains. However, recent surveys in the Los Alamos County area indicate that growing numbers of large mammals reside throughout the year at lower elevations. Table B-5 in Appendix B of this work plan contains a list of the mammal species found in the Laboratory area.

3.8.2.3 Threatened, Endangered, and Sensitive Species

3.8.2.3.1 Plants

Foxx and Tierney (1980, 5949; 1984, 5950; 1985, 5951) completed several surveys of threatened and endangered plant species and National Environmental Policy Act compliance surveys for proposed projects in Los Alamos Canyon. They found no threatened or endangered plant species.

3.8.2.3.2 Wildlife

Previous surveys in Los Alamos Canyon reported only one endangered species, the Jemez Mountains salamander. Ramotnik found the specimen in an area south of the OU 1078 boundary on the north-facing slope (Ramotnik 1986, 1100). Kennedy (1988, 50037) reported two diurnal raptors nesting in Los Alamos Canyon east of Omega Site, which are classified as sensitive by the state of New Mexico (Cooper's hawk and the red-tailed hawk). Both species have nested in ponderosa pine on the canyon floor since 1983. The Cooper's hawk nesting site is one of the sites within Los Alamos County that has a high reproduction success.

3.8.3 Survey Results

3.8.3.1 Level 1 Surveys

During the Level 1 (reconnaissance) surveys, the EST established sampling locations; located the best access routes for future work; and began observing wildlife, terrain, and the degree of disturbance at the site. In addition, the reconnaissance surveys identified four general plant zones to use as search criteria in the EST TES database.

- Piñon-juniper woodlands
- Wetlands
- Riparian areas
- Conifer forest (ponderosa pine)

The EST established eight vegetation transects in Los Alamos Canyon and Pueblo Canyon to evaluate the understory and overstory components of the vegetative cover.

3.8.3.1.1 Species Identified in the EST Database Search

The initial search of the EST TES database revealed a number of species whose general habitat requirements matched the vegetation types identified in Los Alamos Canyon and Pueblo Canyon. This list includes plants and animals from federal and state listings.

Federal- and State-Listed Species

Table 3-20 lists federal- and state-listed wildlife species that could be found in Los Alamos Canyon and Pueblo Canyon, their habitat, and the occurrence potential. The species are listed in order of potential for occurrence from high to low.

Federal-Listed Species

Four species met the search criteria for federal-listed endangered, threatened, or proposed candidate species: bald eagle, peregrine falcon, spotted bat, and meadow jumping mouse. Suitable habitat for the bald eagle is present in White Rock Canyon and near the Rio Grande. The peregrine falcon, spotted bat, and meadow jumping mouse are discussed in more detail in Section 3.8.3.3.1

State-Listed Species

Three species met the search criteria and were classified by the state of New Mexico as either endangered or threatened: bald eagle, spotted bat, and peregrine falcon.

3.8.3.2 Level 2 Surveys

Level 2 (habitat evaluation) surveys were conducted.

3.8.3.2.1 Overstory of Los Alamos Canyon

Portions of Los Alamos Canyon and Pueblo Canyon are located primarily within a ponderosa pine community with some mixed-conifer. Other overstory species found in these canyons were one-seed juniper, Gambel oak, Douglas fir, white fir, and Rio Grande cottonwood. The common midstory species are Gambel oak and Fendler's rose. Willow was recorded as a major midstory species in drainage channel transects. East of state road 4, the Los Alamos Canyon floor is a riparian woodland dominated by Rio Grande cottonwood. Shrub layer dominance depends on topography and elevation.

In upper Los Alamos Canyon, the EST recorded a total of 40 species (13 overstory and 27 understory). The forest is an aspen- and Douglas-fir-dominated conifer community with a secondary canopy of Engelmann spruce and white fir. Cliffbush dominates the shrub layer. Chokecherry and Rocky Mountain maple bound the riparian zone within this forest community. Below Los Alamos Reservoir, Engelmann spruce and Douglas fir are the dominant tree species. Rocky Mountain maple, thinleaf alder,

TABLE 3-20

THREATENED AND ENDANGERED SPECIES POTENTIALLY OCCURRING IN LOS ALAMOS CANYON AND PUEBLO CANYON

Common Name	Scientific Name	Legal Status	Habitat	Potential for Occurrence
Mexican spotted owl	*Strix occidentalis lucida*	Federally threatened	Mixed-conifer	High
Peregrine falcon	*Falco peregrinus*	Federally endangered State endangered	Ponderosa-piñon	High
Jemez Mountains salamander	*Plethodon neomexicanus*	Candidate for federal listing State endangered	Spruce-fir to mixed-conifer	Moderate to high
Spotted bat	*Euderma maculatum*	Candidate for federal listing State endangered	Riparian zones Ponderosa Spruce-fir Piñon-juniper	Moderate to high
Meadow jumping mouse	*Zapus hudsonius luteus*	Candidate for federal listing State endangered	Wetland	Moderate to high
Northern goshawk	*Accipiter gentilis*	Candidate for federal listing	Ponderosa	Moderate
Pine marten	*Martes americana*	State endangered	Spruce-fir	Moderate
Occult little brown bat	*Myotis lucfugus occultus*	Candidate for federal listing State endangered	Rivers-streams	Moderate
Helleborine orchid	*Epipactis gigantea*	State endangered	Riparian zones	Moderate
Wood lily	*Lilium philadelphicum*	Candidate for federal listing State endangered	Mixed-conifer in moist areas	Moderate
Broad-billed hummingbird	*Cynanthus latirostris*	State endangered	Riparian zones	Low to moderate

TABLE 3-20 (continued)

THREATENED AND ENDANGERED SPECIES POTENTIALLY OCCURRING IN LOS ALAMOS CANYON AND PUEBLO CANYON

Common Name	Scientific Name	Legal Status	Habitat	Potential for Occurrence
Lilljeborg's pea-clam	*Pisidium lilljeborgi*	State endangered	Lakes-ponds	Low to moderate
Western toad	*Bufo boreas*	State endangered	Lakes-ponds	Low
Common black hawk	*Buteogallus anthracinus*	State endangered	Riparian zones	Low
Bald eagle	*Haliaeetus leucocephalus*	Federally endangered State endangered	Riparian zones	Low
Mississippi kite	*Ictinia mississippiensis*	State endangered	Riparian zones	Low
Whooping crane	Grus *americana*	Federally endangered	Rivers-streams	Low
Least tern	*Sterna antillarum*	Federally endangered State endangered	Rivers-streams	Low
White-faced ibis	*Plegadis chihi*	Candidate for federal listing	Wetland	Low
Willow flycatcher	*Empidonax traillii*	Federally proposed State endangered	Riparian zones	Low
Rio Grande silvery minnow	*Hybognathus amarus*	Federally proposed State endangered	Rivers-streams	Low
Bluntnose shiner	*Notropis simus*	State endangered	Rivers-streams	Low
Say's pond snail	*Lymnaea caperata*	State endangered	Wetland	Low

(Foxx 1995, 50039)

water birch, and chokecherry are the dominant riparian species. Cliffbush and Gambel oak occupy the slopes adjacent to the riparian area. Between the Omega West Reactor site and state road 4, water birch and willow species border a mostly dry stream channel. Ponderosa pine dominates one-seed juniper and Gambel oak on the surrounding forested canyon floor.

3.8.3.2.2 Overstory of Pueblo Canyon

On the middle and upper canyon floors in Pueblo Canyon, ponderosa pine dominates a secondary tree canopy of one-seed juniper. Piñon is also present in the secondary tree layer in the middle canyon. The shrub layer is skunkbush sumac, big sagebrush, and rubber rabbitbrush. Rocky Mountain maple dominates the riparian zone in the upper canyon, and New Mexico olive dominates the riparian zone in the lower canyon. Willow dominates chokecherry and Gambel oak in the shrub layer on the canyon floor. Skunkbush sumac is also prominent along the stream channel.

3.8.3.2.3 Understory of Los Alamos Canyon

The understory of Los Alamos Canyon is predominantly blue grama grass, brome grass, and cheat grass. In the upper canyon, cutleaf coneflower, wild strawberry, and James geranium are the dominant understory species in the riparian zone. Below Los Alamos Reservoir, redtop (a grass) and raspberry are the dominant understory species along the stream channel. Between the Omega West Reactor site and state road 4, the grasses (redtop and smooth brome) are the dominant understory species. The canyon tributaries are dominated by mountain muhly, redtop, bluegrass, and sedge. Moss is commonly a major component of the understory. The dominant species on the lower canyon floor are rushes, bluegrass, and Fendleris rose. Open meadows are dominated by bluegrass, tarragon, and trailing fleabane.

3.8.3.2.4 Understory of Pueblo Canyon

Blue grama grass constitutes 50% or more of the understory cover on the lower and middle canyon floors and the riparian zone. Western wheatgrass, dropseed, and needlegrass are all present, constituting less than 10% of the cover. Forbs such as golden aster, tarragon, and horseweed reside on the canyon floors. Along the stream channel, stinging nettle dominates a plant assemblage composed of sweetclover, horseweed, and raspberry.

3.8.3.3 Level 3 Surveys

3.8.3.3.1 Species Selected for Level 3 (Species-Specific) Surveys

The Level 2 (habitat evaluation) surveys identified habitat in Los Alamos Canyon and Pueblo Canyon suitable for the wildlife species listed below. Where possible, the EST completed Level 3 (species-specific) surveys to confirm the presence or to infer the absence of these species in Los Alamos Canyon and Pueblo Canyon.

For each species of concern identified in the Level 2 survey, the EST compared the habitat information gathered during field surveys with the habitat requirements. If habitat requirements were not met for any species of concern, then the EST conducted no further surveys. The EST expected no impact to state- or federal-listed species for sites that did not meet habitat requirements. The EST conducted site-specific surveys for the species of concern if habitat requirements were met. Pre-established survey protocols, which often require certain meteorological or seasonal conditions, dictate the conduct and timing of these species-specific surveys. In each location to be sampled, the EST noted all wetlands and floodplains within the survey area employing the national wetland inventory maps and field checks.

Characteristics of wetlands, floodplains, and riparian areas are noted using criteria outlined in the *Federal Manual For Identifying and Delineating Jurisdictional Wetlands* (Federal Interagency Committee for Wetland Delineation 1989, 45910). However, wetland boundaries were not delineated during these surveys. Boundary delineation of wetlands, if present, will be conducted just before site sampling (based on hydrophytic plants, hydric soils, and hydrology). Delineations are valid for only two years; therefore, they are most appropriately conducted at the time of sampling.

Databases containing historical information and biological reports of any previous surveys within or near the area to be sampled, were reviewed and summarized to provide background information concerning the site. These summaries provide inventory information that can be used in future ecological risk assessments and pathways analysis. Database searches indicated that potential species of concern for Los Alamos Canyon and Pueblo Canyon (based on habitat and/or known occurrences) are the northern goshawk, Mexican spotted owl, peregrine falcon, common black hawk, bald eagle, willow flycatcher, broad-billed hummingbird, Mississippi kite, spotted bat, Say's pond snail, meadow jumping mouse, Jemez Mountains salamander, wood lily, checker lily, helleborine orchid, Sandia alumroot, and Pagosa phlox (see Table 3-20).

As a result of a habitat evaluation of Los Alamos Canyon and Pueblo Canyon, eight of these species appear to have a moderate to high potential for occurrence in the area: Mexican spotted owl, peregrine falcon, Jemez Mountains salamander, spotted bat, meadow jumping mouse, northern goshawk, helleborine orchid, and wood lily. The results of the field habitat evaluation indicate that the habitat elements needed for these species are present.

Mexican Spotted Owl

The Mexican spotted owl inhabits mixed-conifer and ponderosa-Gambel oak forests in mountains and canyons. Although this species has not been observed in Los Alamos Canyon and Pueblo Canyon, a potential habitat is located near this area, and spotted owl territories may extend into Los Alamos Canyon and Pueblo Canyon.

Peregrine Falcon

Peregrine falcons nest where they can establish breeding territories with areas suitable for both nesting and foraging. Optimal habitat includes both the following:

- breeding territories near cliffs that are within areas of ponderosa pine and piñon and
- large nearby gulfs of air, which permit peregrine falcons to attack their prey from above.

Topography is the primary determining factor in characterizing peregrine falcon breeding habitat (Johnson 1985, 04-0315). Peregrine falcon foraging areas may extend to 20 mi from the nest site, but an estimated 90% of the foraging occurs within a radius of 10 mi.

Surveys were conducted because some components of suitable habitat occur within Los Alamos Canyon and Pueblo Canyon. The northern portion of the Laboratory, including Los Alamos Canyon and Pueblo Canyon, are within the breeding and foraging territories for the peregrine falcon.

Jemez Mountains Salamander

The Jemez Mountains salamander inhabits cool, moist, north-facing slopes and shaded riparian areas in mixed-conifer forests between 7185 and 10,795 ft in elevation. This species has been found on north-facing slopes in Los Alamos Canyon and has the potential to inhabit moist riparian areas in Los Alamos Canyon and Pueblo Canyon.

Spotted Bat

The spotted bat is a federal-listed candidate and is listed by the New Mexico Department of Game and Fish State Game Commission as endangered. Under this category, a species's survival is likely to be at risk in the foreseeable future. Spotted bats are distributed throughout much of the western United States and northwestern Mexico (Watkins 1977, 04-0321), but these bats are rarely captured. The first recorded capture of spotted bats in New Mexico occurred in 1961 when two spotted bats were captured at Ghost Ranch in Rio Arriba County (Constantine 1961, 04-0316). Since then, the Museum of Southwestern Biology has captured a few specimens (Findley 1972, 04-0317). Spotted bats have been found at Lake Roberts, Mount Taylor, and the Jemez Mountains. This species has not previously been found in Los Alamos County but has recently been found in Bandelier National Monument.

The spotted bat's habitat varies. It has been observed in grassland, desert shrub, piñon-juniper, ponderosa, mixed-conifer, spruce-fir, and riparian habitats (New Mexico Department of Game and Fish 1988, 50120). It has most often been seen in areas with sage brush, rabbitbrush, short grasses, and open ponderosa pine (Tyrell and Brack 1990, 04-0313). Key habitat for this species includes the following:

- a source of water with standing pools for foraging,
- rock crevices on high cliff faces, and
- loose rocks or boulders under which to shelter during the day.

The bat's diet seems to consist mainly of nocturnal moths (Leonard and Fenton 1983, 04-0319). Bats will return to the same roost sites night after night.

The spotted bat is found in caves and rock crevices in piñon-juniper, ponderosa, mixed-conifer, and riparian areas. Suitable roosting for the spotted bat exists in Los Alamos Canyon and Pueblo Canyon. Any spotted bats present are expected to roost in these areas.

During 1991, limited bat mist netting on Laboratory property did not capture any spotted bats. Attempts to mist net in the vicinity of Los Alamos Canyon and Pueblo Canyon were not successful, perhaps because of heavy rains. Also, a team of independent contractors supported by EST personnel surveyed Los Alamos Canyon for bats again in the summer of 1992. Two nights of mist netting captured no spotted bats (Tyrell and Brack 1992, 04-0314).

Meadow Jumping Mouse

The meadow jumping mouse prefers wetlands and other mesic habitats, such as permanent streams and wet meadows. Joan Morrison, state expert on the meadow jumping mouse, evaluated habitat in Los Alamos Canyon where the water flows are intermittent but dependable in late spring to early summer because of releases from Los Alamos Reservoir. She reported an area near the reservoir that may have a suitable habitat (Morrison 1990, 1099; Morrison 1992, 04-0320).

The meadow jumping mouse habitat includes the following:

- permanent free-flowing water, riparian zones along streams and ditches, or wet meadows near cattail marshes associated with major rivers (Morrison 1992, 04-0320);
- dry higher ground near waterways to provide locations for nesting and hibernation;
- damp or moist soil with no standing water; and
- dense, tall vegetation (0.5 m or greater) dominated by grasses and forbs that provides thick cover and food sources.

In the Jemez Mountains and the Española area, the meadow jumping mouse is most active from June through September; breeding occurs between May and September (New Mexico Department of Game and Fish 1988, 50120). During the summer of 1992, the EST set up a trapping grid in Los Alamos Canyon, west of the Diamond Drive bridge and approximately 2.5 mi downstream from Los Alamos Reservoir. Traps were set for four nights without results. Traps were not set farther downstream where the flow was intermittent and less dependable during the summer.

Northern Goshawk

The northern goshawk inhabits mature ponderosa pine forests. This species has been recorded as nesting near the boundaries of Los Alamos Canyon and Pueblo Canyon and hunting within the northwest portions of the Laboratory. The northern goshawk could be present within Los Alamos Canyon and Pueblo Canyon.

Helleborine Orchid

The helleborine orchid is found in damp woods, seepage slopes, springs, streams, and riparian areas within the elevation range of 6000 to 8500 ft. (upper Los Alamos Canyon). Los Alamos Canyon has a perennial stream that may support this species.

Wood Lily

The wood lily grows in moist shaded areas in ponderosa pine to mixed-conifer forests. The wood lily was not found during vegetation surveys in Los Alamos Canyon and Pueblo Canyon, but it has previously been recorded in the upper canyons on Laboratory property. The habitat in Los Alamos Canyon and Pueblo Canyon is dominated by ponderosa pine, which fits the requirements for this species.

3.8.4 Floodplains and Wetlands

Hydrologists from ESH-18 have delineated floodplains in Los Alamos Canyon, Pueblo Canyon, and Bayo Canyon. Using the national wetlands inventory maps drawn up by the United States Fish and Wildlife Service on wetlands at the Laboratory, the EST determined that the streambed in Los Alamos Canyon and Pueblo Canyon is an intermittent riverine wetland. The national wetlands inventory maps also indicate that six wetlands are located in the floodplain. One of them was classified as a broad-leaved deciduous, shrub-scrub palustrine, temporarily-flooded wetland, and the other five were classified as broad-leaved deciduous, forested palustrine, temporarily-flooded wetlands. The EST did not delineate exactly where wetlands occur because the exact sampling locations for site characterization are uncertain. However, when the ER Project determines the sampling plan, the EST will delineate the applicable wetland boundaries.

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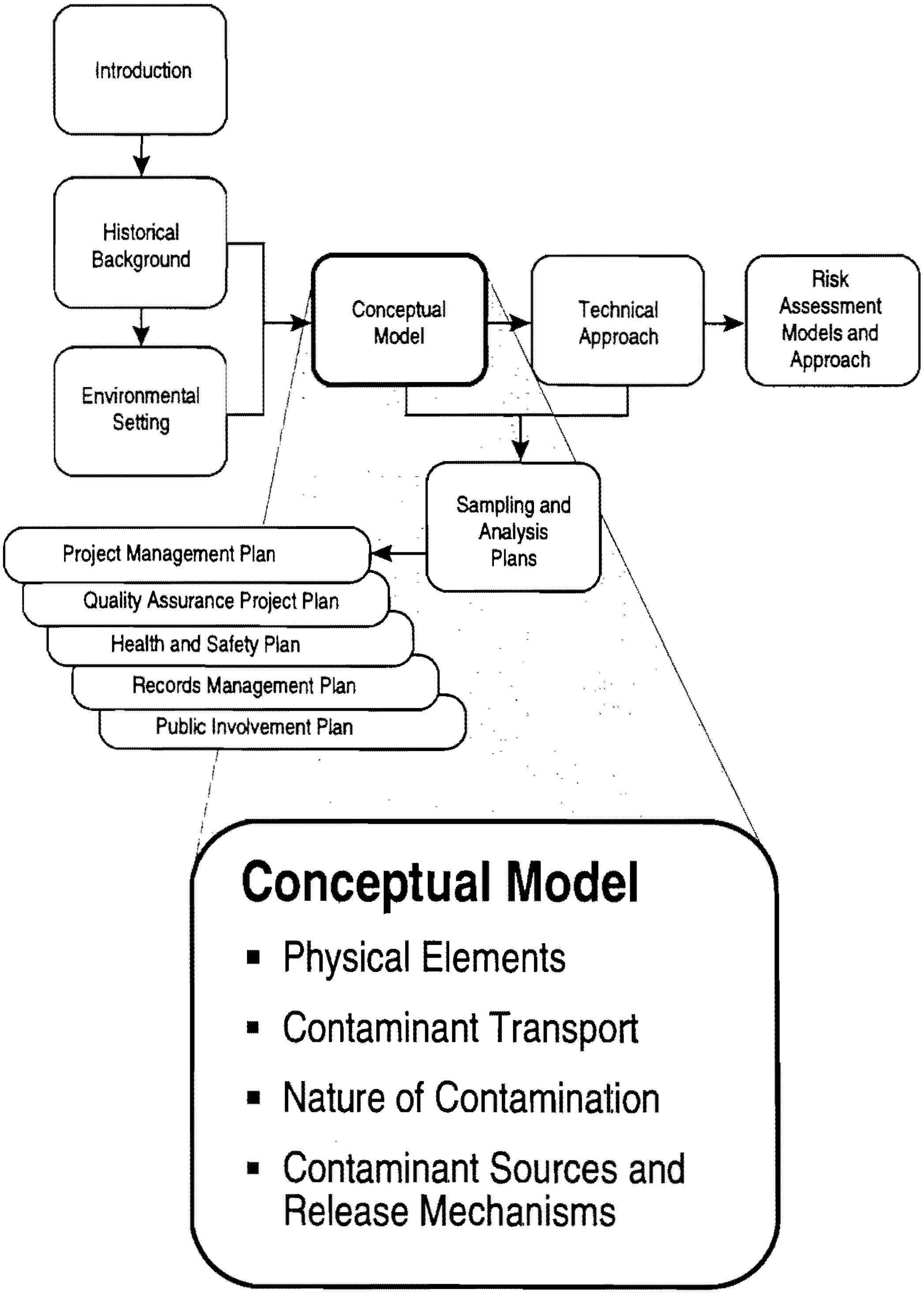
Chapter 4



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4.0 CONCEPTUAL MODEL

4.1 Introduction

This chapter summarizes the significant geologic, hydrologic, and biological features, events, and processes operating in Los Alamos Canyon and Pueblo Canyon that could reasonably affect estimates of impact (including human health risk) to humans and the environment from Laboratory-derived contaminants. This chapter places these features, events, and processes (which are described in greater detail in the preceding chapters of this work plan) within a conceptual framework that is intended to support a credible human health risk assessment for current contamination conditions and to project trends of reasonable future impacts. The human health risks will be evaluated for personnel working in the canyons and for the public occupying the canyons for a variety of purposes. In addition, impacts to the ecological system will be assessed.

The conduct of this investigation and other canyon investigations will involve working with the neighboring Pueblos (Cochiti, Jemez, San Ildefonso, and Santa Clara) to define and evaluate impacts to cultural resources valued by the American Indian population. This commitment fulfills part of the Laboratory's responsibility for stakeholder involvement. The approach to evaluating present-day risks (the term "present-day risks," discussed further in Section 5.1.2 in Chapter 5 of this work plan, means human health risk assessment using present-day contamination levels for exposure scenarios now and in the near future) is being defined, and this conceptual model may not yet fully reflect American Indian concerns. Section 4.3 discusses how the conceptual model will be revised to reflect investigation data as well as changing impact assessment objectives.

4.1.1 Purpose

The purpose of the conceptual model is to incorporate known significant features, events, and processes into a comprehensive view that is then used to guide the development of the technical rationale for investigations in Los Alamos Canyon and Pueblo Canyon. The conceptual model articulates the major assumptions (some of which need to be tested), the features that need to be described more accurately, and the models of processes that might need to be refined to adequately evaluate impacts. The conceptual model description helps identify the investigations needed to refine impact assessments. These investigations are described in the sampling and analysis plans in Chapter 7 of this work plan.

4.1.2 Relationship of the Conceptual Model to Impact Assessment

The conceptual model describes the potential pathways by which contaminants could be transported from Laboratory sources to potential receptors. It identifies connections among these transport pathways and connections between transport pathways and exposure pathways to humans, plants, and animals.

The distinction between pathways for long-distance transport and pathways for exposure is important because some media can serve as both, and confusion can arise from the overlap. For example, wind can transport contaminated dust long distances from source areas, but wind transport is not considered to be a major route for dispersal of contamination in Los Alamos Canyon and Pueblo Canyon. On the other hand, the inhalation of wind-suspended sediment that has been transported by streams is considered to be a dominant pathway of exposure to humans. Thus, surface water is considered to be an important transport pathway, whereas wind is considered to be primarily an exposure pathway.

The exposure pathways are part of the human health risk assessment model and ecological impact assessment model described in Chapter 6 of this work plan. The selection of potential receptors and exposure pathways depends on the structure and assumptions of the assessment models. The conceptual model for contaminant occurrence and transport, discussed in this chapter, addresses the exposure pathways selected for consideration in the assessment models described in Chapter 6.

The potential human exposure scenarios for Los Alamos Canyon and Pueblo Canyon include the following:

- use by Laboratory workers;
- recreational use by the public;
- use by the American Indian population for residential, cultural, and religious purposes, farming, ranching, and hunting;
- habitation by the local biological community, taking into consideration the effects of human occupation.

Chapter 6 of this work plan describes these exposure scenarios in detail.

4.1.3 Development of the Conceptual Model

The conceptual model for contaminant occurrence and transport was developed from the data and information presented in Chapters 2 and 3 of this work plan. The conceptual model is illustrated in Figure 4-1, which shows Pueblo Canyon and upper Los Alamos Canyon.

The conceptual model identifies potential sources of contamination, relevant pathways for transport, and likely pathways for exposure based on current knowledge of the distribution of contaminants in and adjacent to the canyons system. The transport pathway descriptions include the predominant release mechanisms, transport processes, and the contaminated media for each transport pathway. The conceptual model includes those elements that are likely to influence decisions about remediation in the canyon environment.

The remainder of this chapter discusses the elements of this conceptual model in detail and the process by which revisions to it will be made as new data are acquired and the knowledge and concerns of stakeholders are addressed.

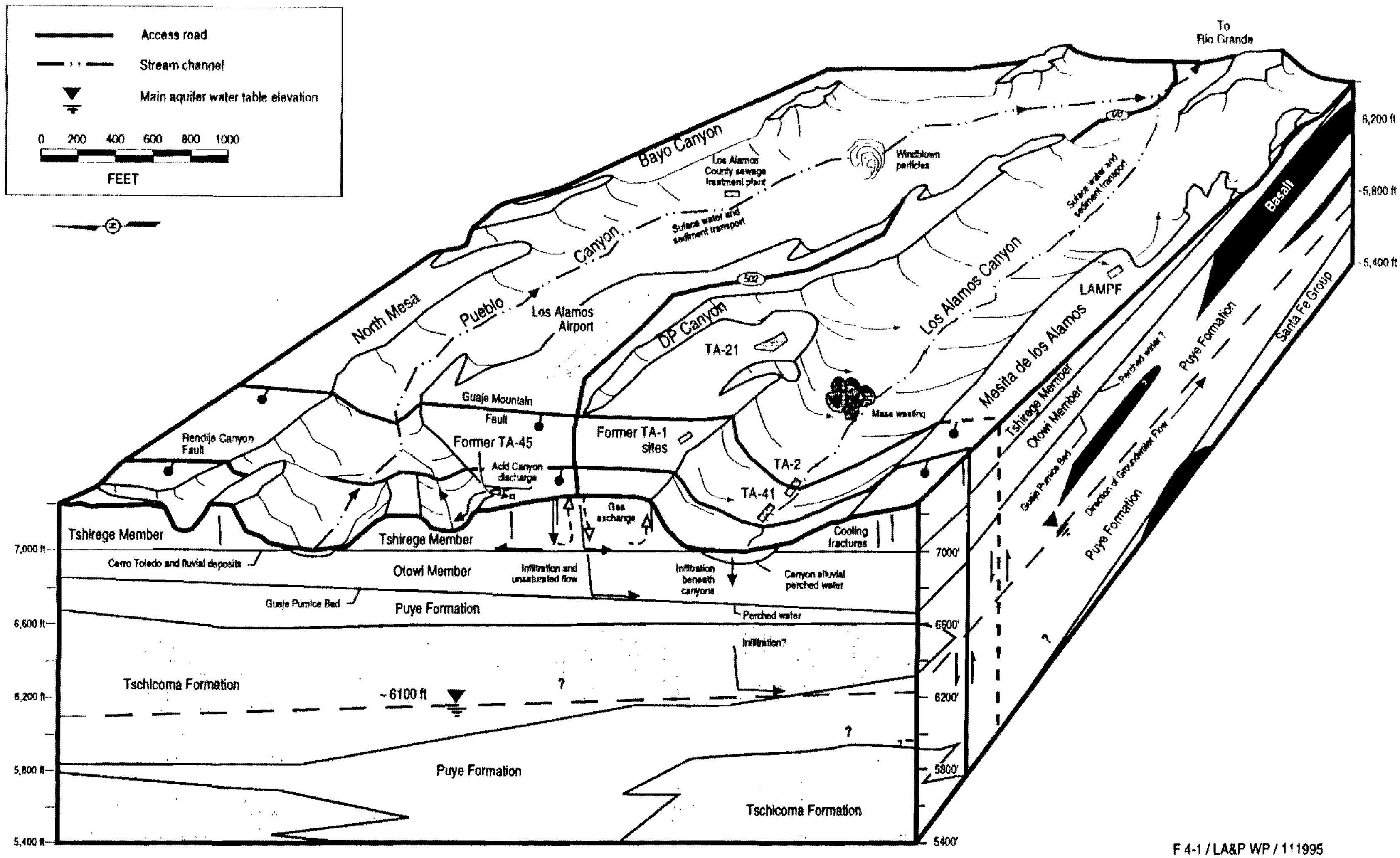


Figure 4-1. Schematic illustration of the conceptual model for contaminant transport in upper Los Alamos Canyon and Pueblo Canyon.

4.2 Contaminant Transport Conceptual Model

The major elements of the conceptual model are discussed in the order of their ability to disperse and transport contaminants.

- Surface water and sediment transport
- Ground water transport
- Biological transport
- Atmospheric transport

The elements of the conceptual model are summarized in Table 4-1. The assumptions, features, events, and processes related to transport are described in greater detail in Chapters 2 and 3 of this work plan; the references for the data and conclusions are contained in those detailed discussions.

4.2.1 Surface Water and Sediment Transport

Sediment transport by surface water is believed to be one of the predominant contaminant transport pathways in Los Alamos Canyon and Pueblo Canyon. Surface waters redistribute sediments and associated contaminants within the Laboratory boundaries and also transport these contaminants off-site. Although contaminants have been discharged over the years primarily as dissolved components in liquid effluent, most of the actinides and fission products are rapidly adsorbed from the liquid phase discharge onto sediment particles. The sediments with the adsorbed contaminants are redistributed by sediment transport processes occurring subsequent to the original release. Therefore, understanding sediment transport processes is necessary to understanding contaminant transport.

Sediment transport occurs during both floods and sustained releases from outfalls, such as the Los Alamos County sewage treatment plant. Sediment transported by these flows is either redeposited downstream at various locations along Los Alamos Canyon and Pueblo Canyon or transported to the Rio Grande. One effect of continued sediment transport over time is to decrease the total inventory of contaminants in some upstream areas and increase the inventory in some downstream areas. Currently the largest portion of the plutonium originally discharged from former Technical Area (TA) -45 into Acid Canyon is believed to reside within inactive channel deposits in lower Pueblo Canyon 5 to 10 km downstream from the original source (see Figure 3-9 in Chapter 3 of this work plan).

Sediments and associated contaminants deposited in different geomorphic locations, such as active channels, inactive channels, and floodplains or low terraces, will remain in place for varying lengths of time. Transport of sediments in active channels can occur during relatively frequent, moderate-sized storm or snowmelt flows, whereas transport of sediments currently residing in floodplains and low terraces require infrequent large floods when the stream channel can erode laterally. Contaminants in floodplains and low terraces may remain in storage for decades to centuries.

TABLE 4-1

ELEMENTS OF THE CONCEPTUAL MODEL FOR LOS ALAMOS CANYON AND PUEBLO CANYON

Pathway/Mechanism	Concepts/Hypotheses
Surface water and sediment transport	
Surface water runoff	• Precipitation will partition among evaporation, transpiration, infiltration, and runoff. • Surface runoff is concentrated by natural topographic features and man-made diversions. • Surface runoff can transport contaminants in solution, but contaminant movement associated with suspended particles or local bed sediments will dominate the transport of radionuclides. • Contaminant movement as dissolved species will be partly retarded by adsorption onto natural organic, clay, metal hydrous oxides, and other highly sorptive phases in solid porous media. • Surface runoff has redistributed contaminants on suspended sediments substantial distances downstream from their original sources within active channels, inactive channels, and floodplains and low terraces, and has carried contaminants to the Rio Grande.
Erosion and transport of soils and sediments	• Surface soil erosion and sediment transport are a function of runoff intensity and frequency, vegetative cover, topography, and soil properties. • Contaminants tend to adsorb onto soil and sediment particles, which can be transported by runoff and concentrated in depositional areas of the canyons. • Concentrations of contaminants in sediments tend to decrease downstream because of dilution with clean sediments. • Concentrations of contaminants in sediments can be highly variable in any part of a canyon because of variations in sediment age, sediment particle size, mineralogy, and source areas for the sediment that can vary between runoff events. • Residence times for contaminated sediments at different canyon sites can vary from several years in active channels to hundreds or thousands of years for some floodplain sediments. • Channel incision, lateral bank erosion, and sediment redistribution will be most active during large floods. • Contaminant transport in streams occurs predominantly by bedload and suspended sediment transport. • Sediment transport can segregate sediments by size, which might reconcentrate contaminants in low-energy depositional areas. • Floods can extend the area of contaminant dispersal in a canyon floor away from the stream channel.
Ground water transport	
Alluvial ground water	• Perennial alluvial ground water is present in portions of Los Alamos Canyon and Pueblo Canyon that receive discharges from sources within or adjacent to the canyons. • The thickness and longitudinal extent of the alluvial saturated zones vary seasonally, with maximums occurring during spring snowmelt and summer storms. • Water in the alluvium will flow down the canyon; flow processes can be represented by a homogeneous porous medium model. • Retardation of contaminants will be primarily by sorption in the alluvium onto mineral, organic, or organic-coated mineral particles. • Water in the alluvium enters the underlying rock units; the migration process depends on the properties of the interface between the two units. • Recharge to intermediate zones of perched ground water occurs from the alluvium.

TABLE 4-1 (continued)

ELEMENTS OF THE CONCEPTUAL MODEL FOR LOS ALAMOS CANYON AND PUEBLO CANYON

Pathway/Mechanism	Concepts/Hypotheses
Infiltration and vadose zone flow and transport	• Infiltration into the surface soils depends on the rate of rainfall or snowmelt, existing soil moisture content, depth of soil, rate of evaporation and transpiration, and soil and bedrock properties. • Contaminated surface runoff infiltrates the alluvium. Dissolved contaminants infiltrate more readily than contaminants adsorbed onto sediment particles. • Transport of normally insoluble or strongly sorbed contaminants in the unsaturated zone can occur by movement of suspended solids (colloids). Nonsorbing species (for example, tritium or anionic species) migrate in solution. • Infiltration into and percolation through tuff and underlying bedrock units depends primarily on the unsaturated hydraulic properties of the rock units. • Steady-state liquid flow at depth can be very slow in unsaturated tuff and other bedrock units. • Joints and fractures in bedrock can provide additional pathways for infiltration, transient flow, and lateral transport in the subsurface. • Fractures contribute to liquid flow and transport at moisture contents above some critical value. Below this value, flow in the rock matrix will predominate. • Retardation of contaminant migration will be caused by mineral precipitation and sorption onto mineral grains in the bedrock units, especially the Bandelier Tuff.
Lateral flow and perching at unit contacts	• Contrast in hydraulic properties between layers can divert flow laterally and cause zones of perched ground water to develop near the contact of the Guaje Pumice Bed and the underlying Puye Formation or Cerros del Rio basalts. • Laterally diverted ground water flow can return to the surface in springs or seeps. • Several intermediate-depth perched ground water zones are present. Their lateral extent and hydraulic continuity are uncertain. • Steady-state conditions can adequately describe the hydraulic character of the intermediate perched zones, although some non-steady-state rapid responses have been seen where these zones approach the alluvium or the surface.
Vapor transport	• Vapor-phase transport is important only for tritium and some volatile organic compounds. • Vapor-phase transport is controlled by the vapor pressure of the contaminant and the porosity, permeability, moisture content, and moisture characteristic properties of the unsaturated medium (soil, sediment, or rock). • Exchange of pore gas with the atmosphere (a significant mechanism for tritium release) is controlled by temperature gradients and atmospheric pressure variations. • Fractured bedrock can facilitate gas exchange between rock and the atmosphere. In certain environments this process can strongly influence water flux.
Saturated zone flow and transport	• Water in the main aquifer moves generally eastward from the Jemez Mountains toward the Rio Grande under natural gradients. • The main aquifer is recharged in part from the west, probably from the Jemez Mountains, with possibly significant contributions from fault and fracture zones on the Pajarito Plateau and, at some locations, from alluvial ground water. • Contamination of the main aquifer has occurred near the Rio Grande and elsewhere through infiltration below low-elevation canyon floors, recharge on the Pajarito Plateau, or poorly constructed wells. • Numerous permeable units in the Puye Formation, the Tshicoma Formation, and the Santa Fe Group comprise the main aquifer.

TABLE 4-1 (continued)

ELEMENTS OF THE CONCEPTUAL MODEL FOR LOS ALAMOS CANYON AND PUEBLO CANYON

Pathway/Mechanism	Concepts/Hypotheses
Biological transport	
Plant uptake	• The ability of plants to absorb contaminants depends on soil and water chemistry, soil microflora activities, and contaminant characteristics. • Contaminants in the rooting zone can be assimilated into the roots and redistributed throughout plant tissues. • Contaminants in plant tissues can be redistributed by herbivore feeding and by erosional transport of dying leaves, branches, stems, and roots. • Certain contaminants, such as tritium, can be transpired to the atmosphere. • Plant surfaces can be contaminated by resuspension of contaminated soil and deposition on stems and leaves or by deposition of atmospheric contaminants.
Animal uptake	• Animals can ingest contaminants by consuming water from streams or wells (for example, stock tanks). • Animals consume leaves, stems, roots, and plant products (such as nectar) and any contaminants they contain. • Animals also consume contaminants that adhere to the surfaces of plant tissues. Predatory animals ingest contaminants that are in or on their prey. • Animals can ingest soil intentionally or incidentally while grooming. • Animal behavior patterns and the elimination of feces and urine can disperse contaminants away from source areas. • Humans can consume the flesh from contaminated animals that have moved away from contaminated areas. • Behavior can decrease the degree of exposure to environmental contaminants because food or water might not be obtained from a single site, or behavior might cause animals to be exposed to multiple, antagonistic contaminants.
Bioturbation	• Burrowing invertebrates (such as earthworms) and vertebrates (such as pocket gophers) redistribute contaminants vertically and horizontally. • Large, hoofed animals can alter the characteristics of the plant cover and the soil surface.
Biotic/abiotic interaction	• Vegetative cover affects erosion by both water and wind. Animal feeding behaviors affect vegetative cover. • Disturbance of the soil surface by vertebrates also affects the rates of erosion processes.
Atmospheric transport	
Wind-borne dust	• Entrainment is limited to contaminants in surface sediments. • Entrainment, dispersal, and deposition are controlled by sediment properties, surface roughness, vegetative cover, and terrain. • Entrainment, dispersal, and deposition are affected by wind speed, stability of the wind direction, and precipitation.
Gas/vapor dispersion	• Gas exchange between the subsurface and the atmosphere provides the release mechanism for volatile contaminants. • Gas exchange between the rock or soil and the atmosphere is a function of temperature and pressure gradients. • Fractures can be facilitators of gas exchange between rock and the atmosphere. • Atmospheric conditions affecting dispersal include wind speed, stability of the wind direction, and precipitation.

Contaminants that are associated with sediments and transported by surface water can be available for uptake by humans through the following pathways:

- ingestion of unfiltered water from streams,
- ingestion of sediments,
- inhalation of airborne particulates derived from the sediments,
- dermal contact,
- consumption of plants and animals that have been contaminant receptors, and
- direct exposure to sediments containing gamma-emitting radioactive contaminants.

4.2.2 Ground Water Transport

The transport of contaminants in sediment or bedrock under saturated and unsaturated flow conditions, is considered a significant transport pathway in Los Alamos Canyon and Pueblo Canyon. Ground water occurs in three types of saturated zones: the alluvium, intermediate perched zones, and the main aquifer. Each of these saturated zones provides transport pathways within the environment and to human receptors in the Los Alamos area.

In Los Alamos Canyon, ground water in the alluvium and the intermediate perched zones supplies water for plants, wildlife, and livestock through return flow into streams or springs. Ground water in the main aquifer provides municipal and industrial water to Los Alamos County. The main aquifer, through wells and springs, is also a source of water to residents, livestock, wildlife, and plants at San Ildefonso Pueblo. Therefore, ground water is considered an important exposure pathway. However, ground water in unsaturated zones is considered to be only a transport pathway between saturated zones, not an exposure pathway.

Contaminants could migrate among the three saturated zones. Contaminants will migrate down the canyon through the alluvium in interaction with the surface water. Ground water from the alluvium is a source of recharge for the intermediate perched zone in the Guaje Pumice Bed in Los Alamos Canyon. Vertical flow velocities of at least 15 ft per year have been determined (based on observed low-level contamination in upper Los Alamos Canyon). In middle and lower Pueblo Canyon and at Basalt Spring in lower Los Alamos Canyon, alluvial ground water recharges the intermediate perched zones in the Puye Formation and the Cerros del Rio basalts. See Sections 3.6 and 3.7 in Chapter 3 of this work plan for a more detailed discussion of ground water flow rates.

Potential recharge zones for deeper ground water (the intermediate perched zones and main aquifer) include fault and fracture zones such as the Pajarito fault, the Rendija Canyon fault, and the Guaje Mountain fault. Flow can also occur through the porous matrix of the nonwelded Otowi Member of the Bandelier Tuff under saturated flow conditions (perhaps at the contacts of bedrock units beneath the alluvium). Unsaturated flow through the porous matrix is considered unlikely to provide substantial recharge to deeper zones because estimates of unsaturated hydraulic conductivities from moisture characteristic data are substantially lower than those necessary to account for the observed rates of ground water flow from the alluvium to the intermediate perched zones (see Sections 3.6 and 3.7 in Chapter 3 of this work plan). However, the hydraulic connection between the alluvium and the intermediate perched zones has been fully described. Without such a description, the possibility of multiple connections, including pathways to the main aquifer, must be considered a working hypothesis to be evaluated.

Currently the extent and thickness of and the direction and rate of ground water flow within the several intermediate perched zones are poorly understood. Likewise, hydraulic connections among the three fully saturated zones and the ground water flow rates along those connections are not well understood. Contaminants are present in the alluvium. Hydraulic interconnections between the alluvium and the intermediate perched zones are known to exist. A better understanding of the intermediate perched zones and the interconnections with the alluvium is important to evaluating potential exposures to humans and the environment by these pathways.

Ground water in the main aquifer beneath the regional water table generally has long residence times, with little or no evidence of a hydraulic connection between the alluvium and the main aquifer. However, rapid recharge of the alluvial ground water to the main aquifer does occur in Los Alamos Canyon and Pueblo Canyon, especially where the distance between the two hydrogeologic units is minimal (≤ 100 ft) and where older wells believed to have poorly sealed annuli are present (see Section 3.7 in Chapter 3 of this work plan).

Ground water in the alluvium has historically had the highest concentrations of contaminants of any ground waters in the area. Contaminant occurrence is due to discharges into Los Alamos Canyon and Pueblo Canyon (see Chapter 2 of this work plan). Ground water within the intermediate perched zones generally contains lower concentrations of the known contaminants. Ground water in the main aquifer appears to be uncontaminated. Laboratory-derived tritium is the contaminant of main concern because of its mobility. In specific locations the main aquifer shows very low levels of tritium (≤ 500 pCi/L), which are well below the MCL and may be due to atmospheric inputs rather than Laboratory releases (see Section 3.7 in Chapter 3 of this work plan).

4.2.3 Biological Transport

Biological transport is considered to be less important than surface water and sediment transport or ground water transport as a means of dispersing contaminants. However, uptake and transport of contaminants by plants and animals can be important transport and exposure pathways. Plants and animals can be exposed directly to contaminants and can assimilate contaminants from water, sediments, and soils into tissues. Animals can ingest the contaminants and transport them to other organisms, including humans.

The availability of soil- or sediment-borne contaminants to plant tissues depends on soil chemistry, which is influenced by soil microflora, mineralogy, and the chemical and physical characteristics of the contaminants. Contaminants in the root zone of plants can be assimilated by roots and redistributed to different parts (such as leaves, stems, seeds, or fruits) or products (such as nectar or pollen) and be made available for ingestion by biological receptors. After certain contaminants, such as tritium (in the form of tritiated water), have been assimilated by the roots, the contaminants can be transpired to the atmosphere.

Plant surfaces can become contaminated by deposition of airborne contaminants or by rain splash. These contaminants can then be assimilated by the plant and gradually released to soils by subsequent rainwash or by wind-aided, dry removal. The dropping of leaves and other dead or dying plant tissues also returns contaminants to the ground where they are subject to erosion or dissolution.

Animals can ingest contaminants that are in plants (or on plant surfaces), other animals, or the soil. Incidental ingestion of soil by animals occurs during grooming and feeding. The amount of incidental soil that is ingested while feeding is affected by where and how the animals forage. Animals can also ingest soil intentionally. The extent to which animals redistribute contaminants depends on their behavior, physiology, and the characteristics of individual contaminants.

In the process of obtaining food and shelter, certain burrowing vertebrates and invertebrates cause soils to be redistributed laterally and vertically. This process, called bioturbation, can cause surface contaminants to become buried and underground contaminants to be brought to the surface. Currently its potential significance in Los Alamos Canyon and Pueblo Canyon is unknown.

Erosion is affected by plants and animals. Dynamic and heterogeneous plant communities produce vegetative cover that affects erosion rates. The characteristics of these plant communities are affected by interactions with animals, including humans. Large, hoofed animals can also affect erosional processes by disturbing the soil surface.

4.2.4 Atmospheric Transport

Transport of fine-grained contaminated particles by wind can be a means of dispersal in Los Alamos Canyon and Pueblo Canyon. Resuspension of sediment by winds is considered to be one of the predominant pathways for radiological exposure to humans because dust can easily be lifted high enough to be inhaled by humans (see Chapter 6 of this work plan for a discussion of exposure pathways and scenarios). Current understanding of wind patterns in the canyons and the interaction between mesa-top and canyon winds is preliminary; however, wind resuspension and transport of sediments out of the canyons is not expected to be a significant contaminant transport pathway.

The predominant wind direction on the Pajarito Plateau is from the south/southwest. Diurnal variations are important, with local east winds during the day and local west winds (drainage winds) at night. Wind directions on the mesa tops are considered to be at least partially independent of those in the canyons. For example, during the warmer months south or southwest winds on the mesa tops can induce north or northwest canyon winds. This coupling of wind directions, called a wind rotor, has been observed in Los Alamos Canyon; portions of Pueblo Canyon may also be susceptible to such interactive processes.

Wind speed on the mesa tops is sufficient to transport contaminated dust from the mesa tops to the canyons, especially during the spring when the winds are strongest. However, the Environmental Restoration Project will remediate such contamination sources.

Sediment suspension by wind is affected by the distribution of grain sizes in the sediment, moisture content, snow cover, and vegetative cover. All these factors suggest that wind suspension of sediments will be less effective in the canyons (which are typically well-vegetated and moist) than is wind suspension of dust on the mesa tops (which are typically thinly vegetated and dry). The broader and shallower reaches of the canyons are more favorable sites for wind suspension of sediments. Wind-borne transport of contaminants out of the canyons is probably relatively insignificant except, possibly, in broader and shallower reaches that also contain high contaminant inventories.

4.3 Refinement of the Conceptual Model

The conceptual model will be refined by new data from the sampling and analyses proposed in Chapter 7 of this work plan, work at other operable units, the site-wide studies of the Earth Science Council, and investigations coincident with new monitoring well installations proposed under the Laboratory's *Groundwater Protection Management Program Plan* (LANL 1995, 50124).

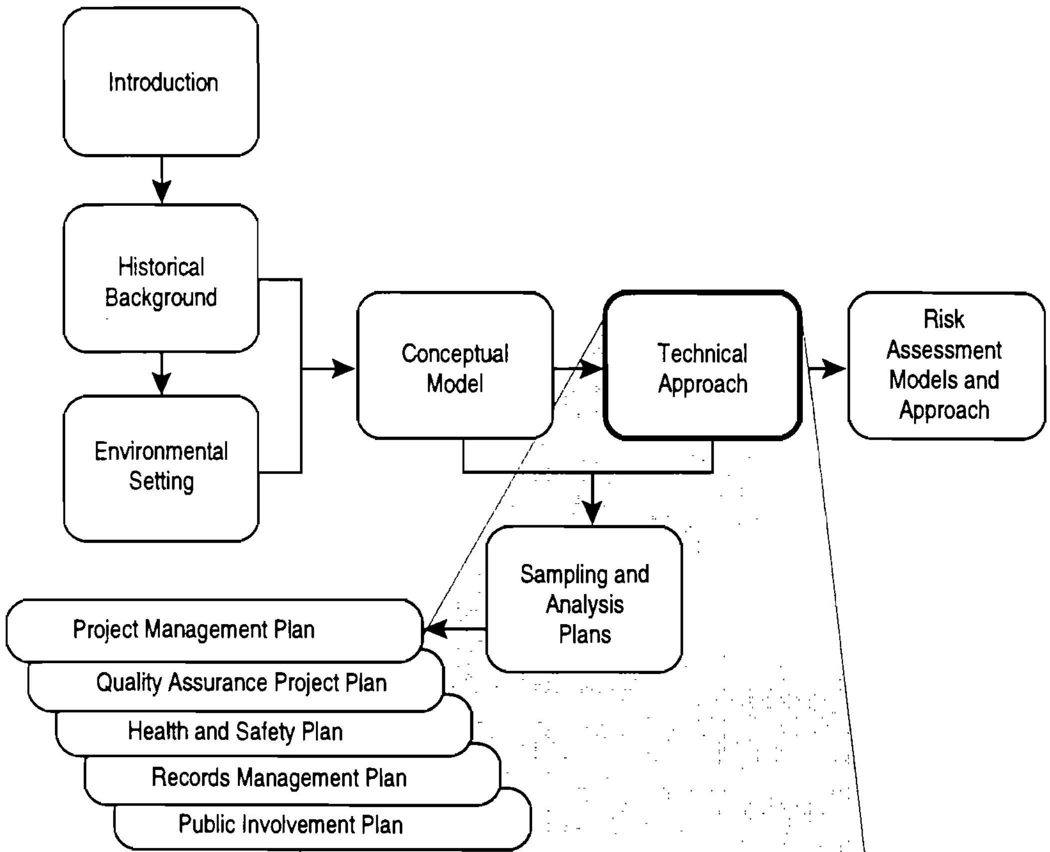
An example of the modification of conceptual models for contaminant transport pathways is the recent completion of intermediate-depth wells (LADP-3 and LAOI(A)-1.1) in Los Alamos Canyon (see Figure A-2 in Appendix A of this work plan). The first well (LADP-3) was installed as part of the Resource Conservation and Recovery Act facility investigation for TA-21 to investigate hydrologic and geologic properties. A previously unrecognized zone of saturation was discovered in the Guaje Pumice Bed at a depth of 300 ft. Water sample analyses indicated low-level contamination with tritium. (See Chapter 3 of this work plan.) This discovery caused a major revision of hydrologic models for the Pajarito Plateau. Previously, hydrologic models had presumed that recharge from the alluvium was very limited. Zones of perched water were presumed to occur mainly where alluvium lay stratigraphically close to strata capable of perching infiltrating water. It was also considered likely that recharge through intervening unsaturated rock would be too slow to transport detectable contamination to any great depth.

The second well (LAOI(A)-1.1) was placed downstream from TA-2 in an area where contamination of the alluvium was expected but where the presence or absence, thickness, and degree of contamination of intermediate perched zones were unknown. New chemical analysis data from the well have indicated an additional, geochemically distinct zone of saturation within the Puye Formation. The on-site data for well samples indicate little contamination (relative to that found in LADP-3) with tritium activities less than 4 pCi/L and chloride concentrations less than 8 mg/L, both of which are within the range of background concentration (see Section 3.7 in Chapter 3 of this work plan). The absence of substantial contamination at depth is driving further re-evaluation of the model, as the presence of a fracture zone between TA-2 and the well had been expected to provide a conduit for contamination like that in LADP-3.

Reference for Chapter 4

(LANL) Los Alamos National Laboratory, October 25, 1995. "Groundwater Protection Management Program Plan" (draft), Revision 2.0, Los Alamos, New Mexico. **(LANL 1995, ER ID Number 50124)**

Chapter 5



Technical Approach

- Regulatory Framework and Requirements
- Expedited Site Characterization
- Decision Process
- Impact Assessment

5.0 TECHNICAL APPROACH

This chapter describes the technical approach for conducting investigations in Los Alamos Canyon and Pueblo Canyon. The only solid waste management units (SWMUs) located within the area covered by this investigation are the SWMUs in Technical Area (TA) -2 and TA-41 (which are being studied in the Resource Conservation and Recovery Act [RCRA] facility investigation [RFI] for Operable Unit 1098). Because those SWMUs are contained in another operable unit, their investigations are addressed in another work plan. Consequently, the technical approach for this work plan is focused on general characterization of the canyon floors and refinement of the conceptual models of contaminant transport pathways (discussed in Chapter 4 of this work plan) to evaluate present-day risk and potential future impacts from Laboratory-derived contaminants.

5.1 Summary of Canyons Investigations Technical Approach

5.1.1 Regulatory Framework for Canyons Investigations

The Installation Work Plan (LANL 1995, 49822) specifies that the Environmental Restoration (ER) Project's technical approach in the canyons investigations will comply with the Hazardous and Solid Waste Amendments (HSWA) Module VIII of the RCRA Part B Operating Permit (EPA 1990, 1585 with modifications dated April 19, 1994) and other regulatory obligations. The requirements for the canyons investigations are defined in Section I.5 of the HSWA Module, which states the following.

> The Permittee shall submit one or more Task/Site Workplans for studies to evaluate the 15 major drainage areas or Canyon systems at the facility. These studies must address each system as an integrated unit and evaluate them for potential impacts of contaminants from SWMUs. The plans must address the existence of contamination and the potential for movement or transport to or within Canyon watersheds, and interactions with the alluvial aquifers and the main aquifer. The studies shall evaluate the potential for offsite exposure through these pathways including the ground water and possible impacts on the Rio Grande.

The requirement to submit one or more task/site work plans for investigations to evaluate the 15 (currently the Laboratory considers 19 canyons) major drainage areas or canyon systems at the facility is addressed in part by this work plan, which is the first of a series. Chapter 1 of this work plan discusses the canyons to be studied and the subsequent documents that will address investigations of other canyons systems or groups of systems, including all those required in the operating permit. The remainder of the text of Section I.5 of the HSWA Module contains both requirements and criteria for the design of investigations. These requirements are discussed in detail in Section 5.2.1.

Section Q of the HSWA Module, which describes the scope of work for RFIs, calls for comprehensive characterization of hydrogeological and geochemical properties relevant to contaminant migration in soils and sediments. The canyons are not facilities in the sense of Section Q. They are natural environments containing contaminated media transported from nearby Laboratory facilities, mostly located on adjacent mesa tops. This task/site work plan is not an RFI work plan in the typical sense; rather it is a work plan that describes investigations of the role of canyons as collection points and transport pathways for contaminants derived from nearby SWMUs. Nevertheless, this work plan follows the guidelines for conducting RFIs as outlined in Section Q. These guidelines include obtaining the following hydrogeological and geochemical information (adapted from Section Q, Table III.A [Environmental Setting]):

- geological and hydrogeological characteristics that affect ground water flow and quality beneath the facilities;
- topographic features that might influence the ground water flow system;
- representative, accurate classification and description of near-surface hydrogeological units that may be part of the migration pathways at the facility (that is, the aquifers and any intervening saturated and unsaturated units);
- zones of near-surface fracturing or channeling in consolidated or unconsolidated deposits and zones of high or low permeability that might direct and restrict the flow of contaminants;
- representative description of water level or fluid pressure monitoring; and
- man-made influences that might affect the hydrogeology of the site.

Moreover, the canyon-specific requirements in Section I.5 of the HSWA Module for investigations to evaluate the potential for off-site exposure necessitates that much of the same information called for in facility-specific RFIs be obtained in the canyons investigation as well.

5.1.2 Purpose of the Investigation

The purposes of this investigation are

1. to determine to what extent portions of Los Alamos Canyon and Pueblo Canyon have been or are likely to be affected by the combined releases, in the past and in the immediate future, from all sites that could contribute residual contamination to them and
2. to re-examine contaminant transport mechanisms, refine the conceptual model, and project future impacts of the contaminants in the affected media that may result from future transport of the contaminants to other locations and other media.

The investigation supports an integrated assessment of the present-day risk to human health from Laboratory-derived contaminants, and an evaluation of the potential for transport, through all accessible pathways, to cause unacceptable off-site impacts in the future.

As described in Section 5.1.4, risk assessment calculations will be performed using present-day contamination levels and exposure scenarios that are applicable today and in the foreseeable future. These calculations are referred to as a present-day risk assessment to distinguish them from the more qualitative evaluations of the potential for future off-site exposure and impacts.

Although assessments of present-day and potential future impacts to the canyon ecosystems are required by the HSWA Module and discussed in this work plan, much of the work to define potential future impacts will be integrated into a broader program of studies, which is currently being defined by the ER Project in consultation with the Department of Energy (DOE), the Environmental Protection Agency, the New Mexico Environment Department, and tribal representatives from neighboring Indian Pueblos.

5.1.3 Expedited Site Characterization

The characterization approach in this work plan is a *focused* sampling strategy designed to minimize the additional information needed to meet the objectives by collecting data specifically to test a conceptual model and to enable performance of human health risk assessments. The strategy is discussed in more detail in Section 5.3.4.

The sampling and analyses plans (SAPs) for the focused sampling strategy will be implemented using an expedited site characterization approach where possible. Expedited site characterization is a cost-effective method for characterizing large, complex sites and has been implemented at several sites within the DOE complex (such as Pantex, Savannah River Site, and Fernald). It is a focused and flexible characterization approach intended to expedite the evaluation of risks and potential remedial options. It requires the participation of a team of scientists with wide-ranging field experience and expertise under the direction of a technical manager with broad familiarity with the appropriate disciplines in field sampling, analysis, and decision-making. The expedited site characterization approach requires active and continual participation by the technical team and frequent dialogue with regulators so that the strategy can be modified as new field data are received. Consequently, measurement and analysis options and the number and locations of sampling sites will be partly determined on the basis of field information. The success of this approach depends on rapid analysis and integration of data to ensure that modification to the sampling plans can be implemented during the field investigations, if necessary.The conceptual model, as discussed in Chapter 4 of this work plan, will be continually evaluated and revised as needed, and the SAP will be revised accordingly on the basis of information gathered during field investigations.

5.1.4 Risk Assessment

Human health risks associated with present-day chemical and radiological contamination in Los Alamos Canyon and Pueblo Canyon will be evaluated using various land use scenarios that are relevant to specific portions of the canyons system. For example, residential use is considered only for those reaches of the canyons where the canyon floor is wide enough for residential construction. In general, human health risks are evaluated for likely future use in a canyon reach using current conditions of contaminant distribution and concentration.The conceptual model plus the results of fate and transport modeling will be used to project future impacts. If increased contaminant concentrations are predicted to occur in exposure media in the future, an assessment of the scope and significance of the anticipated impacts will be performed.

Data collected from sampled media (sediment, air, surface water, and ground water) will be used to develop representative contaminant concentrations in each medium for use in present-day risk assessment. For sediments, this concentration will generally be calculated for each geomorphic unit within a sampled canyon reach. Representative contaminant concentrations in air and water will be determined for an appropriate volume of the medium (for example, a water-bearing zone or portion thereof) that is the exposure pathway.

Ecological impacts from contaminants will be evaluated for selected receptors indicative of the overall health of the canyons ecosystem. For both human health risk and ecological impact assessments, the relative impacts of potential remedial actions (if target risk values are exceeded) will be considered.

5.1.5 Impacts Through Contaminant Transport

In addition to concerns regarding human health risk from the affected media, it is also necessary to address concerns regarding possible future impacts from the contaminants when and if they are redistributed in or transported out of the canyons to other locations and other media. The intention of this investigation is to develop a sound understanding not only of how much contamination is present and where the contaminants are located today but also of how (transport processes) and how fast (rates) contaminants move in the canyons system.

A conceptual model of the present-day locations of contaminants and the transport processes and pathways by which the contaminants are expected to move was presented in Chapter 4 of this work plan. The conceptual transport model, specifically Table 4-1, is viewed as a set of hypotheses to be tested by data obtained in this investigation. The field sampling and analyses approach is designed to enable testing of key hypotheses of the conceptual model and revision of the conceptual model as appropriate.

The end product of this approach will be an improved and verified conceptual model and estimates (using numerical models discussed in Section 5.3.1) of quantities, concentrations, and rates of transport of contaminants in various media. This improved conceptual model of contaminant transport mechanisms and rates will be used both to evaluate future impacts and to guide future decisions regarding environmental management of the canyons.

5.1.6 General Technical Approach

The examination of existing information and the development of a conceptual model (Chapters 2, 3, and 4 of this work plan) enable focused sampling to address uncertainties in both the conceptual model and the concentrations of potential contaminants. This focus on active re-examination of the conceptual model and of the rationale for characterization is intended to keep sampling focused on critical data needs throughout the investigation.

The approach is summarized in the flow chart in Figure 5-1. The process is divided into three stages: preliminary evaluation, planning and investigation, and assessment. These stages and the tasks and decisions to be completed during them are discussed in the remainder of this chapter.

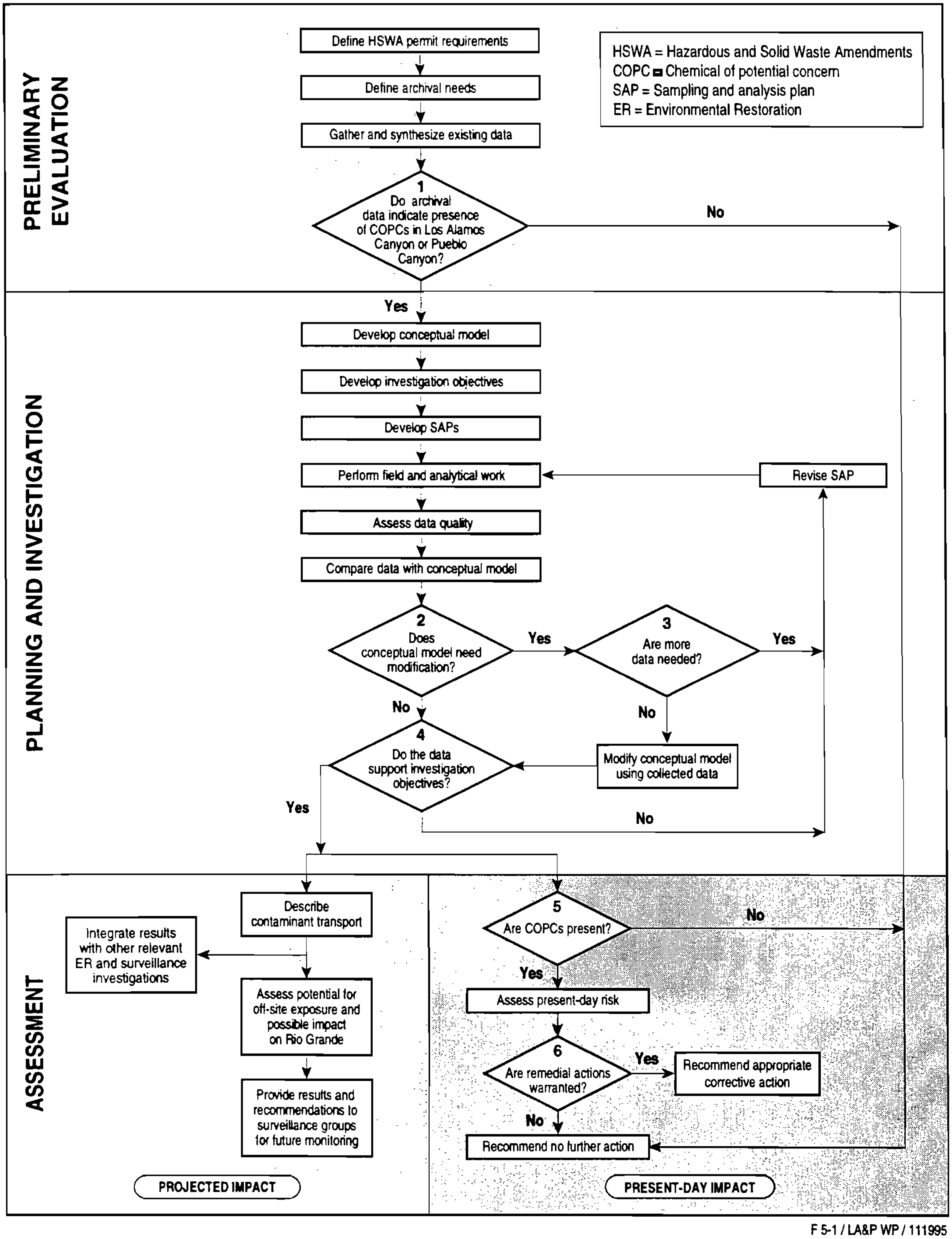


Figure 5-1. General technical approach for the canyons.

5.2 Preliminary Evaluation

The steps in the preliminary evaluation have already been completed for Los Alamos Canyon and Pueblo Canyon. The results of this work are presented in the preceding chapters of this work plan.

In the case of Los Alamos Canyon and Pueblo Canyon, potential contaminants were identified from the history of Laboratory operations within and adjacent to the canyons (see Chapter 2 of this work plan). The actual presence of many potential contaminants in the canyons has already been established as discussed in Chapter 3 of this work plan and, along with others to be analyzed for, are considered chemicals of potential concern (COPCs).

5.2.1 Define HSWA Permit Requirements

The language of the HSWA Module that is cited in Section 5.1.1 outlines three requirements for each of the work plans for the canyons. An approach to meeting each requirement has been identified as discussed below. In addition, spatial and temporal boundaries for the investigation have been established.

Requirement

These investigations must address each system as an integrated unit and evaluate them for potential impacts of contaminants from SWMUs.

Implementation

Characterization of contaminants in sediments will span the length of the canyons but with emphasis on those areas closest to potential release sites, those areas that presently have residences (such as Totavi), and those areas critical to estimating the present-day risk and testing the conceptual model concerning contaminant transport processes. Sediment sampling will be focused on (but not limited to) those sediments deposited after 1943, both in channels and on floodplains. Sampling and analysis of pre-1943 alluvium will be conducted as part of the investigation of alluvial ground water. Ground water in the alluvium and the intermediate perched zones will be sampled and analyzed at strategic points along the length of the canyons. Data will be used to test hypotheses regarding hydraulic connections.

Requirement

The plans must address the existence of contamination and the potential for movement or transport to or within canyon watersheds and interactions with the alluvial aquifers and the main aquifer.

Implementation

The investigation will focus on areas most likely to contain contaminants (see above), determine settings where the greatest contaminant inventories occur (such as in canyon sediments deposited after 1943), and assess the susceptibility of the contaminants to redistribution by fluvial processes, solute transport, and wind resuspension.

The investigation will also focus on hydrologic zones most likely to contain contaminants (the near-surface alluvial and intermediate perched zones). Investigations in shallow and intermediate-depth boreholes will provide information on the nature of ground water contamination and assess the potential for these ground water bodies to serve as contaminant transport pathways. Results of these investigations also will be used to locate and design ground water monitoring systems. Hydrologic investigations will be coordinated with studies and monitoring well installation currently proposed for the *Groundwater Protection Management Program Plan* (LANL 1995, 50124) and with ER Project site-wide hydrology studies so that data collected by these three program elements are complementary and mutually supporting.

Studies of the deep unsaturated zone (below the intermediate perched zones) and the main aquifer may be necessary within the investigations described in this work plan where the intermediate perched zones contain contaminants above the maximum contaminant levels (MCLs) for drinking water or where the main aquifer already shows evidence of being affected by Laboratory-derived contaminants. Additional criteria that will be considered in deciding whether to study deeper zones include emergence of evidence for connections between the main aquifer and the intermediate perched zones, or development of other evidence requiring major revision to the conceptual model of the main aquifer. Any decision to investigate the main aquifer will be made by the technical team in consultation with the regulatory agencies (see Chapter 7 of this work plan).

Requirement

The investigations shall evaluate the potential for off-site exposure through these pathways including the ground water and possible impacts on the Rio Grande.

Implementation

Characterization activities will lead to a human health risk assessment under present-day contamination conditions for Laboratory employees, recreational users of the canyons, traditional users of the land (American Indians), and residents of Totavi and the Halliday and Otowi houses. In addition, the data collected will be used to assess levels of contaminants in sediments, surface waters, and ground waters entering the Rio Grande. Information about transport pathways and processes will be summarized and used to refine the conceptual model by which the potential for off-site exposures will be evaluated. Recommendations will be made concerning the need for remedial actions and future monitoring activities based on the refined conceptual model.

The implementation approach for this requirement has important consequences for the investigations proposed in this work plan. The approach differentiates two major aspects of the assessment of impacts of Laboratory operations: present-day impact, for which human health risk and ecological impact assessments will be performed; and projected impacts for which transport processes at the surface and at depth will be evaluated to assess the potential for exposure outside the Laboratory boundaries and impacts on the Rio Grande.

The boundaries of the Los Alamos Canyon and Pueblo Canyon investigation were also defined as part of this effort. The Los Alamos Canyon and Pueblo Canyon system is interpreted to extend from the western Laboratory boundary to the Rio Grande. The system includes the canyon floors and extends laterally from the stream channel to the modern floodplain deposits. The system includes the stream channel vertically to the deepest ground water bodies affected by significant contamination (greater than MCLs).

The temporal boundaries were also determined. The current investigation will collect data for evaluating present-day risk. It will evaluate the potential impact of transport in the watersheds of Los Alamos Canyon and Pueblo Canyon as well as the portion of the ground water system affected by the two canyons. The characterization results and monitoring wells will be transferred to the Environmental Protection Group for continued long-term surveillance and regional studies after the investigation described here is complete.

5.2.2 Define Archival Needs

5.2.2.1 Nature and Extent of Contamination

Archival data and information needs include descriptions of the types and potential sources of contamination in and adjacent to the canyon(s) including sources that might contribute to future contaminant inventories through transport. Previous investigations of technical areas on the mesas that border the canyons and tributaries to the canyons have been reviewed (see Chapter 3 of this work plan) as well as historical information about the past and present uses and operations in these areas (see Chapter 2 of this work plan).

5.2.2.2 Contaminant Transport Mechanisms

Information available on contaminant transport processes includes extensive general theoretical and observational literature and numerical models on sediment, surface water, and ground water movement and on geochemical interaction between sediment and water. In addition, researchers at the Laboratory and under contract to the Laboratory have studied transport processes on the surface and subsurface for decades. Many of the publications from that research are cited in Chapter 3 of this work plan.

The team assembled for the investigation in Los Alamos Canyon and Pueblo Canyon is multidisciplinary and is familiar with both the general literature and the results of relevant prior research at the Laboratory.

5.2.3 Gather and Synthesize Archival Data

5.2.3.1 Gather Existing Data and Information

Archival data, especially that prepared by the ER Project and the Environmental Surveillance Group (ESG), was assembled and reviewed for activities conducted in the main and tributary canyons and on adjacent mesa tops. This review identified known and potential sources of existing contamination and sources that might contribute to future contaminant inventories through transport. New data from other ER Project investigations are being examined as they become available.

The data and information resources available for investigations in Los Alamos Canyon and Pueblo Canyon include all the publications of the United States Geological Survey covering research and monitoring from 1945 through 1970; annual surveillance reports of the ESG (and its successor, the Environmental Protection Group) since 1970; reports of research conducted by Laboratory scientists and subcontractors; and results of RFIs at other operable units. Locations of sampling sites and wells are stored at the Facility for Information Management, Analysis, and Display at the Laboratory. Archival data are currently being entered into a database for rapid access and processing.

5.2.3.2 Synthesize Existing Data and Information

The assembly and synthesis of the existing data proceeds through meetings of the technical team, which is a group of experts in various disciplines including geology, geochemistry, tectonics, hydrology, biology, statistics, and risk assessment. The technical team is drawn from the Laboratory and from contractors whose personnel have special expertise and experience in environmental work at the Laboratory. Staff of the New Mexico Agreement-in-Principle Team also participate in evaluating the available data.

For the investigations in Los Alamos Canyon and Pueblo Canyon, results of this step are discussed in Chapters 2 and 3 of this work plan. Chapter 2 provides background information on the facilities that comprise sources of potential contamination and the prehistoric cultures of the Pajarito Plateau that have left ruins and artifacts in the canyons. Chapter 3 discusses the environmental setting and known or suspected contaminant transport and geochemical processes operating in the canyons. Chapter 6 of this work plan lists potential contaminants (Table 6-1) and COPCs (Table 6-2) for Los Alamos Canyon and Pueblo Canyon.

5.2.4 Decision Point Number 1

Do archival data indicate the presence of COPCs in Los Alamos Canyon or Pueblo Canyon?

5.2.4.1 "No" Decision Outcome

Such a conclusion was not reached for Los Alamos Canyon and Pueblo Canyon.

If such a conclusion had been reached, it would have been appropriate to prepare a report summarizing the available data and the interpretations that support a conclusion that no further studies are needed. Such a recommendation would be appropriate only if sufficient archival information existed to support a conclusion that no contamination above background levels had been identified and that contaminants in areas adjacent to the canyons were highly unlikely to reach the canyons system. The report would need to discuss the quality of the data used to support the decision and the likelihood that the continuing monitoring program might later encounter evidence for significant impact on the canyons system. A recommendation for no further action must be submitted for review and approval as a modification to the HSWA operating permit.

5.2.4.2 "Yes" Decision Outcome

For Los Alamos Canyon and Pueblo Canyon the response to this decision question is "yes" because previous investigations have identified Laboratory-derived potential contamination from past and present discharges and SWMUs on the mesas (Chapter 2 of this work plan) and COPCs in the canyons (Chapter 3 of this work plan). Therefore, a study of these canyons must be conducted, and the process has moved on to the next stage, planning and investigation.

5.3 Planning and Investigation

5.3.1 Develop Conceptual Model

Conceptual models for processes active in Los Alamos Canyon and Pueblo Canyon are presented in Chapter 4 of this work plan, which summarizes the characteristics of major transport pathways discussed in Chapter 3 of this work plan. The dominant transport pathways for contaminants are the surface water and sediment system and the ground water system. Secondary transport pathways are atmospheric and biologic transport. Exposure scenarios and the conceptual exposure model incorporating transport pathways are described in Chapter 6 of this work plan. The predominant exposure pathways are inhalation of resuspended dust; ingestion of water, soil, or sediment; and direct exposure (especially to gamma radiation). A secondary exposure pathway is ingestion of plant or animal material. Both conceptual models (transport and exposure) are based on available information and were used to develop the field investigation activities described in Chapter 7 of this work plan. The conceptual models will be revised as additional information is acquired during the investigation.

Computational models will be used to evaluate human health risks, environmental impacts, and occupational risk during field investigations. Modeling of geochemical processes and contaminant transport, particularly over long periods, will be performed as part of the pathway analysis for impact assessment. This assessment includes evaluation of the potential for off-site exposure and evaluation of possible impacts on the Rio Grande. Table 5-1 lists representative numerical modeling codes that may be used in planning and analysis for this investigation.

5.3.2 Develop Investigation Objectives

The development of investigation objectives follows the data quality objectives (DQO) process outlined by the EPA (EPA 1987, 21524). The DQO process focuses the objectives of the study and ensures that proposed data collection activities are developed from decision criteria and strategies. The results of the DQO process are intended to be a clear definition of the key issues regarding characterization and remediation options and a sampling plan tailored to quantitative goals for data quality.

It has been difficult to tie aspects of characterization in Los Alamos Canyon and Pueblo Canyon to a set of statistically determined objectives for the sampling and analysis program. EPA recognizes the difficulty explicitly in the following guidance for the DQO process:

> Every step of this guidance may not be applicable to data collection activities where specific decisions cannot be identified, such as studies that are *exploratory in nature* **[emphasis added]**. The reason for this distinction is that part of the DQO Process includes formulating statistical hypotheses. If a statistical hypothesis is not linked to a clear decision in which the decision maker can identify potential consequences of making a decision error, then some of the activities recommended in this guidance may not apply. In these cases, it may be possible to frame a *research type study question* **[emphasis added]** in the form of a decision or modify the activities described in this guidance to address the needs of the study (EPA 1987, 21524).

This passage allows for the judgment of technical experts to be relied upon to decide whether investigation objectives have been adequately met. Expert judgement is needed because the canyons investigations address multiple objectives, several of which are *exploratory in nature* and address *research type study questions*. The investigations

TABLE 5-1

COMPUTATIONAL MODELING CODES

Function	Name	Source
Dose assessment	RESRAD	DOE[a]
	CAP88	EPA[b]
	GEOEAS	EPA
	MILDOS	DOE
Geochemical equilibrium	PHREEQE	USGS[c]
	WATEQFC	USGS, CU[d]
	MINTEQA2	EPA
Hydrologic transport	TRACER3D	DOE
	SESIL	EPA
	FEHMN	DOE
	MODFLOW	USGS
Surface and air transport	CREAMS	USDA[e]
	GLEAMS	USDA
	AIRDOS	EPA
Geostatistical data analysis	GEOPAC	EPA
	GEOEAS	EPA

a. DOE = Department of Energy
b. EPA = Environmental Protection Agency
c. USGS = United States Geological Survey
d. CU = University of Colorado
e. USDA = United States Department of Agriculture

also address remediation-related decision-making objectives. Together, these studies will be effective in evaluating present-day and potential future impacts despite difficulty in basing all decisions on tests of statistical hypotheses.

The DQO process coordinates well with the focused sampling strategy and the expedited site characterization approach (see Section 5.1.3) that will be used in characterizing the canyons. It provides the mechanism for determining the value of characterization data in refining estimates of the risk of potential remedial actions (including no further action).

The objectives for investigations of Los Alamos Canyon and Pueblo Canyon are described in the individual sections of Chapter 7 of this work plan. These sections define the SAPs for sediment; surface water; alluvial, intermediate perched zone and main aquifer ground water; and ecosystem characterization. General DQOs are developed for each medium studied in the relevant sections of Chapter 7. Those sections present the logic diagrams, decision points, and decision criteria necessary to develop DQOs. The logic diagrams are derived from the general technical approach shown in Figure 5-1.

5.3.3 Develop Sampling and Analysis Plans

SAPs are developed from investigation objectives.The SAPs for the Los Alamos Canyon and Pueblo Canyon investigations (in Chapter 7 of this work plan) serve as models for media-specific SAPs for future investigations of other canyons.

Sections of Chapter 7 address surficial deposits, alluvial ground water, and intermediate perched zone and main aquifer ground water. Each section presents a series of issues considered significant to defining the present-day risk and projected future impact from Laboratory-derived contaminants.The importance of each issue is described identifying the technical focus and an approach to address the issue.

For surface sediments, a single approach is identified for all the representative reaches of the canyons. For the hydrologic studies, different approaches are identified for each issue. The SAPs for the remaining portions of the canyons system investigation, the atmospheric and ecological subsystems, are described more simply because of their more limited scope.

The SAPs were developed according to the following principles.

- Sampling and analysis will focus on resolving key uncertainties regarding processes and impacts, as defined in Chapter 4 (Conceptual Model) and Chapter 6 (Risk Assessment Models and Approach) of this work plan.
- Major uncertainties in the conceptual model will be addressed by sampling and analysis of critical media for key parameters (see Chapter 7 of this work plan).
- Sediment sampling will focus on providing the data for both a present-day risk assessment and an evaluation of the hypotheses regarding transport and redistribution processes governing the pattern of contamination in the canyons.
- Hydrologic investigations will initially focus on the alluvial and intermediate-depth zones of saturation. These investigations will better define the distribution of key contaminants in ground water and verify transport processes between zones.

5.3.4 Perform Field and Analytical Work

Characterization of contamination in the canyons poses unique challenges. For example, low levels of contaminants in sediments are irregularly distributed over large areas of the canyon floor. These contaminants are periodically redistributed by runoff and storm events resulting in contaminant distributions that vary significantly in both space and time. One approach to characterization of such a large and dynamic system would be to collect samples at fixed intervals over the entire area. This approach is discounted because large portions of the canyons are likely to be uncontaminated, and indiscriminate systematic sampling of all areas is inefficient.

An alternative approach will be used in the Los Alamos Canyon and Pueblo Canyon investigation. Pending evaluation, this approach may be adopted for future investigation of all other canyons as well. The approach is a *focused* sampling strategy designed to maximize the information needed to meet objectives by

1. developing a conceptual model based on previously collected information and knowledge of relevant processes,

2. concentrating sediment sampling in representative reaches of canyons where prior data suggest that human health risk assessments may be warranted,

3. using previous data to determine statistically (where possible) the number of analyses required to obtain representative data with acceptable uncertainties,

4. limiting the analytical suite for most samples to contaminants known to be present, and

5. collecting data to test the components and hypotheses of the conceptual model.

The sampling strategy will be flexible to reflect new field data as they are received. Because this plan is dynamic, choices such as the measurement and analysis options and the number and location of sampling sites are modified on the basis of field information. The success of such a strategy depends on rapid analysis and integration of data to ensure that each input is evaluated sufficiently and in time to allow for resampling if necessary. The conceptual model is thereby adjusted continually on the basis of discovery in the field.

The thorough examination of existing information and the conceptual model enables focused sampling to address uncertainties in both the conceptual model and the contaminant distribution. This approach avoids the collection of large quantities of data that may be irrelevant to the objective. Re-examination of the conceptual model and of the rationale for characterization will keep sampling focused on critical data needs throughout the investigation.

5.3.5 Assess Data Quality

The assessment of the data quality consists of a comparison of the data collected with the objectives outlined under the DQO process. The process is relatively automatic where well-specified quantitative objectives are defined. For those investigations in which conceptual uncertainty is so large that quantitative decision criteria and limits on decision errors cannot be developed, the assessment will rely on expert judgment. These judgments will be documented, and subsequent decisions will be quantified where possible.

Data collected in the canyon investigations are intended to serve the following two objectives:

- conduct a present-day risk assessment as warranted by the contaminant concentrations and

- test and refine the conceptual model of contaminant occurrence and transport.

To meet the former objective, data must be sufficient in number and quality to establish a statistical model for the data set and confidence intervals on measure(s) of central tendency in the data set. Data used to address the latter objective also lend themselves to statistical evaluation but do not need to achieve the same standards as data used for present-day risk assessment.

5.3.6 Compare Data with Conceptual Model

The objective of this comparison is to test the validity of the conceptual model and associated assessments of impacts using interpretation, judgment, and numerical models. If the projections made using the conceptual model adequately match the actual data, then the conceptual model may be considered adequately validated. If the projections of the conceptual model do not match the data, then the model is considered invalid as described. If the adequacy of the model projections is uncertain, then additional data may be needed to reduce the uncertainty. Adequacy of the match between projections and data is a judgmental issue, especially for models of environmental systems.

5.3.7 Decision Point Number 2

Does the conceptual model need modification?

This decision involves judging, based on the comparison discussed above, as to whether the match between the data and the conceptual model is adequate to guide the investigation further.

The judgment of adequacy of the match depends on the spatial density and statistical properties of the data used to address components of the conceptual model. For example, the new data may point up an inadequacy in the model description for a parameter that was not examined in the initial investigations. If the match is considered inadequate, modification of the conceptual model is required (the "yes" path at decision point number 2 shown in Figure 5-1). The decision sequence proceeds to decision point number 3 at which a judgment is made whether the conceptual model can be modified using the available data.

It the match is considered adequate, modification of the conceptual model is not required (the "no" path at decision point number 2 in Figure 5-1). The decision sequence proceeds to decision point number 4 at which a judgment is made whether the data support the investigation objective.

The focus of this decision is on whether the modification necessary to bring the conceptual model into line with the data is clear or whether more data are needed to resolve uncertainties about how the model should be changed.

5.3.7.1 Modification of the Conceptual Model Required

This section refers to the "yes" path at decision point number 2 in Figure 5-1.

If the data do not match the conceptual model adequately, then decision point number 3 calls for a judgment as to whether the data are adequate, nevertheless, to modify or refine the conceptual model. This judgment is based on numbers, locations, parameter coverage, and accuracy of the data.

If more data are required to modify or refine the conceptual model for use in assessing potential future impact (the "yes" path at decision point number 3), then the SAP will be revised, and additional field work will be performed.

If the data are adequate to modify or refine the conceptual model (the "no" path at decision point number 3), then a new description of the conceptual model will be developed and tested against the available data (see Figure 5-1). The modified model will be tested further by the technical team for consistency with other known data and processes. Because the modified model will be validated to all available data, it may need to be tested further unless alternatives to the modified model are shown to have impacts that are not very different from the model itself. This test is part of the test of data adequacy at decision point number 4.

The decision sequence continues from this point to a judgment whether the data support the investigation objectives, decision point number 4 in Section 5.3.8.

5.3.7.2 Modification of the Conceptual Model Not Required

This section refers to the "no" path at decision point number 2 in Figure 5-1.

If the patterns of contaminant occurrence shown by the data are consistent with the patterns predicted or explainable by the conceptual model (specifically for Los Alamos Canyon and Pueblo Canyon the conceptual model as detailed in Table 4-1 in Chapter 4 of this work plan) the model will be considered to have been verified.

The decision sequence continues from this point to a judgment whether the data support the investigation objectives, decision point number 4 in Section 5.3.8.

5.3.8 Decision Point Number 4

Do the data support the investigation objectives?

After the conceptual model is verified, a judgment is made whether the data collected in the investigation are adequate to perform the two types of assessments required in the third and final stage of the investigation.

If the data are not considered adequate, then the wrong types of data or data of inadequate numbers or quality were collected. The action will be to revisit the DQOs, revise the SAPs, and perform additional field and analytical work.

If the data are considered adequate, the investigation proceeds to the assessment stage discussed below.

5.4 Assessment

The assessment stage includes assessment of present-day impacts and assessment of projected impacts including potential for off-site exposure and possible impact on the Rio Grande.

5.4.1 Present-Day Impact

The assessment of present-day impacts begins with a decision as to whether COPCs are present. If they are, human health risk assessment(s) is (are) conducted, and further steps are taken. If COPCs are not present, no further action will be taken.

5.4.1.1 Decision Point Number 5

Are COPCs present?

A determination is made as to whether any of the data collected in the field investigation indicate that contaminants, which archival information indicated might be present, are present (COPCs). The focused sampling approach proposed here is intended to refine the necessary investigations as it proceeds. One of the ways that this refinement occurs is by eliminating from further consideration potential contaminants that are not found to be present, which enables the investigation to search for a progressively more limited suite of contaminants.

If COPCs are not present in any reach or media of Los Alamos Canyon or Pueblo Canyon, no further action will be recommended as described in Section 5.2.4.1.

If COPCs are present, a present-day risk assessment will be performed in those reaches and/or media containing the COPCs as discussed in Section 5.4.1.2 and in Chapter 6 of this work plan.

5.4.1.2 Assess Present-Day Risk

If COPCs are present, then a present-day risk assessment and other evaluations (ecological impact assessment) will be performed and documented for these contaminants. Because many contaminants (especially RCRA metals and some radionuclides) are present in naturally occurring materials, it is necessary to compare contaminant levels with background levels for soils, sediments, and waters. This investigation is designed to provide data for both radiological and nonradiological risk assessment. Because the canyon areas are too large to be assessed throughout their length, risk assessments will evaluate various exposure scenarios using representative values of contaminant concentrations in sediments for a given geomorphic unit in each reach. The scenarios and models for present-day risk and ecological impact assessments are described in Chapter 6 of this work plan.

In general, characterization will lead to present-day risk assessment which, together with decision analysis, will be used to determine the need for remedial action. Health-risk-based analyses or other criteria discussed in Chapter 6 will be used to set cleanup levels in any contaminated areas identified in Los Alamos Canyon and Pueblo Canyon.

5.4.1.3 Decision Point Number 6

Are remedial actions warranted?

Based on the assessment results, a decision will be made to recommend either no further action or some corrective action. If the assessment indicates sufficiently low impact, no further action will be recommended as discussed in Section 5.2.4.1.

If the assessment indicates significant human health risk or ecological impact, corrective actions will be recommended. Potential corrective actions are described in Section 6.7.2 in Chapter 6 of this work plan. They may include further study, long-term monitoring, or some remedial action to reduce the present-day risk or ecological impacts.

5.4.2 Projected Impact

The assessment of projected impacts constitutes the second of the two main objectives of the canyons investigations. Assessment will be performed if COPCs are present in the canyons regardless of whether the COPCs are determined by the present-day risk or ecological impact assessments to be COCs.

5.4.2.1 Describe Contaminant Transport

The assessment of projected impacts requires a description of transport mechanisms within the canyons system. The nature of the description will be (at least) at the level of refined conceptual model that is quantified to the extent possible and may involve the use of refined numerical models (see Section 5.3.2). The results of the field investigations will be used to enhance the conceptual and/or numerical models of contaminant transport.

5.4.2.2 Assess Potential Impact

Some of the radionuclides of potential concern in the canyons system have very long half-lives, and other contaminants (such as metals) do not break down into harmless byproducts. Therefore, potential future impacts need to be addressed in these investigations.

The potential impacts of contaminant transport will be assessed addressing (at a minimum) the issues of potential for human and ecosystem exposure in areas both inside and outside the Laboratory boundaries and potential impacts on the Rio Grande. For all contaminant transport pathways, issues of concern to American Indians and the public are being identified through on-going discussions with representatives of the neighboring Indian Pueblos and the public and will be addressed accordingly.

5.5 Integration with Other Laboratory Activities

The activities proposed in this work plan have been and will continue to be integrated with the ER Project Earth Science Council and other Laboratory-wide environmental efforts, such as the Laboratory's Environmental Surveillance Program. In addition, the canyon investigations will be integrated with work at TAs -2, -21, -41, -43, -53, and -63, former TA-45, and the Los Alamos townsite (former TA-1). The data obtained will improve the understanding of the possible sources of contaminants in the canyons and the mechanisms by which the contaminants are moved to the canyons.

Other integrated activities include the proposed placement of about 80 characterization boreholes and wells in three water-bearing zones and other subsurface characterization efforts as part of studies for the Laboratory's *Groundwater Protection Management Program Plan* (LANL 1995, 50124). The design of these programs is being coordinated among the ER Project, the Environmental Surveillance Program, and the Waste Management Program. This effort will maximize the utility of data obtained for multiple purposes including improved understanding of the regional hydrogeology, contaminant transport pathways, interconnection between water-bearing zones, permeability of the vadose zone, and contaminant occurrence, as well as to enhance the long-term surveillance and monitoring program.

References for Chapter 5

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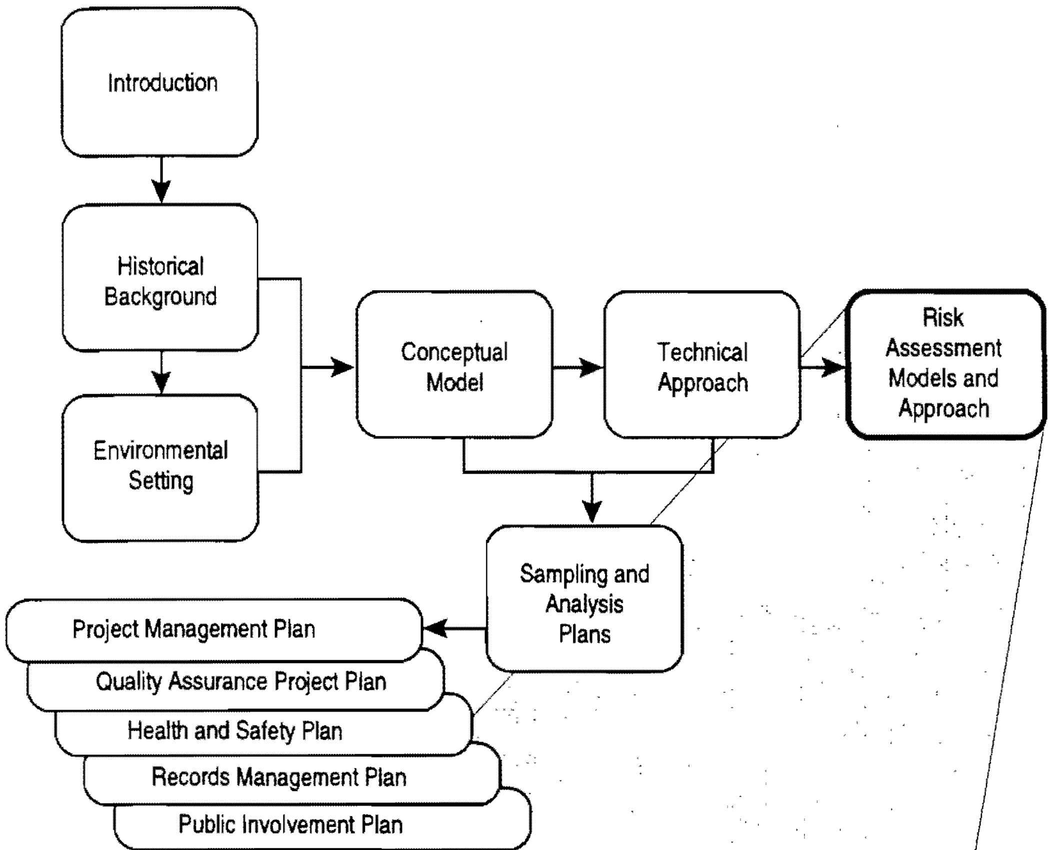
Chapter 6



Risk Assessment Models and Approach

- Chemicals of Potential Concern
- Human Exposure Model
- Ecological Risk Model
- Potential Remedial Activities

6.0 RISK ASSESSMENT MODELS AND APPROACH

6.1 Introduction

This chapter presents the objectives, models, and approaches to the assessment of human health and ecological risk used in the investigations to be conducted in Los Alamos Canyon and Pueblo Canyon.

Section 5.1.3 in Chapter 5 of this work plan describes the focused sampling strategy and the expedited site characterization approach to be used in these investigations. The approach attempts to take full advantage of data that are both extant and now being collected in nearby potential release sites (PRSs). The expedited site characterization begins with a first sampling task (detailed in Chapter 7 of this work plan), which consists of a limited sampling of sites for a wide range of potential contaminants (chemicals that may be present based on archival information). A list of potential contaminants based on the data presented in Chapter 2 of this work plan, which describes the various potential sources of contaminants generated by Laboratory operations, is included in this chapter. Nonintrusive measurements and laboratory analyses of selected samples taken during the expedited site characterization are intended to answer the question: Are any of the potential contaminants present at the selected critical localities?

Those contaminants that are found are considered to be chemicals of potential concern (COPCs) pending screening of the concentrations against known background concentrations or screening action levels (SALs).

The second sampling task, described in Chapter 7 of this work plan, is directed at assessing risk to human populations and to the ecosystems of Los Alamos Canyon and Pueblo Canyon. The second sampling task will involve a limited suite of analyses for contaminants that are considered to pose a potential human health or environmental risk. The suite of contaminants to be analyzed for may be delimited by knowledge of the processes generating and transporting the contaminants and by results of the first task sampling in which a full suite of analyses will be run on a limited set of samples.

The second task sampling will involve collecting and analyzing sediment and air samples in selected reaches of each canyon and collecting and analyzing surface and ground water samples at selected locations to characterize potential contamination. The analysis of samples is intended to address the following question for each reach and for the surface and ground water of each canyon: Do the concentrations of contaminants present an unacceptable human health or ecological risk at representative concentrations present in that reach or location? Risk assessments to determine appropriate risk-based actions will then be conducted. The scope (level of detail) of work for implementing further risk assessments will be developed with input from the Department of Energy (DOE), regulators, and stakeholders.

Target human health risk values are commonly defined as an individual lifetime cancer risk greater than one in ten thousand to one in one million (10^{-4} to 10^{-6}) and a hazard index of unity (40 CFR 300.430[e] [2] [*i*] [A] [2]). The final definition of acceptable risk will be agreed upon after negotiations among the implementors (the Laboratory and DOE), the regulators (the Environmental Protection Agency [EPA] and the New Mexico Environment Department [NMED]), Indian Pueblos, and other stakeholders. The development of risk scenarios will define potential receptors and the pathways of exposure for the contaminants that may be present. An objective of this chapter is to develop those scenarios so that acceptable risk can be evaluated.

6.2 Identification of Chemicals of Potential Concern

6.2.1 Initial Sampling and Decision Criteria

The initial sampling will identify and eliminate from further investigation those chemicals that are not detected at concentrations above background in any sample. The initial analyses will be used to focus additional sampling on a more limited analytical suite. The sampling will be stratified (in the statistical sense) according to recognized hydrogeological and geomorphologic units and considering geochemical characteristics of the contaminants (particularly mobility) that are described in Chapter 3 of this work plan. A diverse analytical suite is proposed initially because the list of potential contaminants in the source areas is large, and large uncertainties remain as to whether these contaminants could reasonably be transported into the canyons.

Maximum values from the analytical data within a reach will be compared with upper tolerance limits (UTLs) of the background distribution for the canyons system, and with other statistical measures, as appropriate, before further sampling is proposed (Environmental Restoration Project Assessments Council 1995, 45753).

6.2.2 Other Values Needed for Regulatory Compliance

For water sources, the questions posed above regarding significant quantities of contaminants and unacceptable risks may be simplified to: Are the water sources present in Los Alamos Canyon and Pueblo Canyon contaminated above acceptable levels? To answer this question, results of analyses of water samples will be compared with federal maximum contaminant levels (MCLs) promulgated under the Safe Drinking Water Act (EPA 1994, 50118), the state of New Mexico drinking water criteria (Water Quality Control Commission regulations) or Pueblo standards, whichever are lower. Where federal or state limits have not been developed, the Laboratory SALs will be used. The locations, rationale, and proposed analytes for each surface and ground water sample are presented in Chapter 7 of this work plan. Every analyte detected in every water sample will be individually compared with the appropriate federal, state, or Pueblo MCL or Laboratory SAL.

6.2.3 Potential Contaminants for the Canyons

Table 6-1 lists the current potential chemicals of concern for Los Alamos Canyon and Pueblo Canyon summarized from the sources discussed in Chapter 2 of this work plan. Existing data from neighboring PRS sampling efforts have been used to create this list. However, note that the analytical results are incomplete and the table contains some generic descriptions of classes of constituents. As results of sample analyses from other field units are evaluated, specific constituents will be identified.

Table 6-2 lists the COPCs with federal and state MCLs and Laboratory SALs for water. Table 6-2 is derived from Table 6-1 considering the likely chemical constituents in contaminant sources and the existence of a recognized concentration standard. The chemical constituents listed in Table 6-2 guide, but do not limit, the selection of analytical protocols for first sampling task and analysis discussed in Chapter 7 of this work plan.

TABLE 6-1

POTENTIAL CONTAMINANTS FOR LOS ALAMOS CANYON AND PUEBLO CANYON

Constituent	TA(s)	Affected Canyon(s)
Acetone	2, 21, 41, 53	Los Alamos
Actinium	21	Los Alamos
Alcohol	21, 41	Los Alamos
^{241}Am	21	Los Alamos
Ammonium citrate (concentrated)	21	Los Alamos
Barium	21	Los Alamos
Benzene	21	Los Alamos
Beryllium	2, 21, 41	Los Alamos
Cadmium	21, 41, 53	Los Alamos
^{137}Cs	1, 2, 21, 41, 45, 53	Acid, Bailey, Los Alamos, Pueblo
Chemical cleaners	53	Los Alamos
Chemical and solvents associated with radionuclides	1, 41, 45	Acid, Bailey, Los Alamos, Pueblo
Chlorine (chloride)	21	Los Alamos
Chlorine and nitrogen compounds	1, 2, 21	Los Alamos
Chromium (hexavalent)	1, 2, 21	Acid, Bailey, Los Alamos
^{60}Co	2, 53	Los Alamos
Copper	21	Los Alamos
Diesel oil	2, 21	Los Alamos
Epoxy resins	53	Los Alamos
Ethanol	21	Los Alamos
Ethylene glycol	21	Los Alamos
Freon	21, 53	Los Alamos
Fuel oil (No. 2)	21	Los Alamos
Gasoline	2, 21, 53	Los Alamos
Iodine	2, 21	Los Alamos
Kerosene	2, 21, 41	Los Alamos
Lead	21, 41, 53	Los Alamos
Mercury	21	Los Alamos
Polychlorinated biphenyls (in oil)	21, 53	Los Alamos
^{238}Pu	1, 2, 21, 41, 43, 45, 53	Acid, Bailey, Los Alamos, Pueblo
$^{239,240}Pu$	1, 2, 21, 41, 43, 45, 53	Acid, Bailey, Los Alamos, Pueblo
Scintillation liquid	53	Los Alamos
Silver	43	Los Alamos
Sodium	21	Los Alamos
^{90}Sr	21, 45	Acid, Los Alamos, Pueblo
Toluene	2, 21, 53	Los Alamos
Trichloroethane	1, 21, 53	Los Alamos
Trichloroethylene	1, 21, 53	Los Alamos
Tritium	1, 2, 21, 41, 53	Los Alamos
Uranium (total)	1, 2, 21, 41, 45, 53	Acid, Bailey, Los Alamos, Pueblo
^{235}U	1, 2, 21, 41, 45, 53	Acid, Bailey, Los Alamos, Pueblo
^{238}U	1, 2, 21, 41, 45, 53	Acid, Bailey, Los Alamos, Pueblo
Waste oils (stored)	21, 53	Los Alamos
Xylene isomers (released)	21, 53	Los Alamos

TABLE 6-2

FEDERAL AND STATE MCLs AND LABORATORY SCREENING ACTION LEVELS FOR GROUND WATER

Chemicals of Potential Concern	New Mexico MCL[a] (mg/L)	Federal MCL (mg/L)	Laboratory Screening Action Level (mg/L)
Acetone	Not listed	Not listed	3.5
Actinium	Not listed	(b,c)	
Alcohol	Not listed	Not listed	11 (as benzyl alcohol)
^{241}Am	Not listed	1.2 pCi/L[b,d]	15 pCi/L[b]
Barium	1	2	2
Benzene	0.01	0.005	0.005
Beryllium	Not listed	0.004	0.004
Cadmium	0.01	0.005	0.005
^{137}Cs	Not listed	(c)	110 pCi/L[c]
Chloride	250	Not listed	
Chromium (total)	0.05	0.1	0.1
^{60}Co	Not listed	(c)	0.2 pCi/L[c]
Copper	1.0	1.3[e]	1.3
Diesel oil	(f)	(f)	
Ethylene glycol	Not listed	Not listed	70
Fission products	Not listed	(b,c)	(b,c)
Fluorene	(g)	Not listed	1.4
Fluoride	1.6	4.0 [and 2.0[h]]	
Freon 11	(g)	Not listed	11
Fuel oil No. 2	(f)	(f)	
Gasoline	(f)	(f)	

a. MCL = maximum contaminant level for drinking water specified at 40 CFR 141 (EPA 1994, 50118)

b. The total of all alpha-emitters (except ^{226}Ra, ^{222}Rn, and U) will not exceed 15 pCi/L in accordance with EPA's proposed rule (EPA 1994, 50118; EPA 1994, 50117).

c. Calculate concentration based on the proposed EPA rule that the concentration of any beta-particle and photon-emitter shall not exceed the dose equivalent of 4 mrem/yr, with calculations made using Federal Guidance Report No. 11 (EPA 1988, 50123). In addition, the sum of the annual dose equivalent of all beta-particle and photon-emitters present (except ^{228}Ra) shall not exceed 4 mrem/yr (EPA 1994, 50118; EPA 1994, 50117).

d. DOE derived concentration guides for water pursuant to DOE Order 5480.11

e. Action level that requires treatment if exceeded

f. Federal MCLs are based on individual chemical constituents, which may be found in various petroleum products. No federal standard exists for petroleum products. However, New Mexico has a "Not be Present" standard for petroleum products in water that pertains to the aesthetic condition of having an undesirable odor or occurring as a floating product on surface water or as a nonaqueous phase liquid (NAPL) (the NAPL standard is currently being proposed).

g. A numeric standard has not been established; however, the contaminant is listed in a narrative standard of "toxic pollutant" (Section 1-101 of the New Mexico Water Quality Control Commission Regulations).

h. For the state of New Mexico, this refers to a health-based aesthetic value; for the EPA, the aesthetic values are merely recommendations.

TABLE 6-2 (continued)

FEDERAL AND STATE MCLs AND LABORATORY SCREENING ACTION LEVELS FOR GROUND WATER

Chemicals of Potential Concern	New Mexico MCL[a] (mg/L)	Federal MCL (mg/L)	Laboratory Screening Action Level (mg/L)
Kerosene	(b)	(b)	
Lead	0.05	0.015[c]	0.05
Mercury	0.002	0.002	0.002
Aroclors (PCBs)	0.001	0.0005	0.0005
^{238}Pu	Not listed	1.6 pCi/L[d,e]	15 pCi/L[d]
$^{239,240}Pu$	Not listed	1.2 pCi/L[d,e]	15 pCi/L[d]
Silver	0.05	0.05 [0.1[f]]	0.17
Sodium	Not listed	Not listed	
Strontium	Not listed	Not listed	21
^{90}Sr	Not listed	8 pCi/L[g]	8 pCi/L[g]
Toluene	0.75	1.0 [0.04 [f,h]]	1
1,1,1-trichloroethane	0.06	0.2	0.2
1,1,2-trichloroethane	0.01	0.005	0.005
Trichloroethylene	0.005	0.005	0.005
Tritium	Not listed	20,000 pCi/L[g]	20,000 pCi/L[g]
Uranium (total)	5	0.020[i]	0.0[i]
^{235}U	Not listed	24 pCi/L[d,e,i,j]	(d,i,j)
^{238}U	Not listed	24 pCi/L[d,e,i,j]	(d,i,j)
Xylenes (total)	0.62	10 [0.02[f,h]]	10
Gross-alpha	Not listed	15 pCi/L[d]	15 pCi/L[d]
Gross-beta and photon-emitters	Not listed	4 mrem/yr[j]	

a. MCL = maximum contaminant level for drinking water specified at 40 CFR 141 (EPA 1994, 50118)
b. Federal MCLs are based on individual chemical constituents, which may be found in various petroleum products. No federal standard exists for petroleum products. However, New Mexico has a "Not be Present" standard for petroleum products in water that pertains to the aesthetic condition of having an undesirable odor or occurring as a floating product on surface water or as a nonaqueous phase liquid (NAPL) (the NAPL standard is currently being proposed).
c. Action level that requires treatment if exceeded.
d. The total of all alpha-emitters (except ^{226}Ra, ^{222}Rn, and U) will not exceed 15 pCi/L in accordance with EPA's proposed rule (EPA 1994, 50118; EPA 1994, 50117).
e. DOE derived concentration guides for water pursuant to DOE Order 5480.11
f. For the state of New Mexico, this refers to a health-based aesthetic value; for the EPA, the aesthetic values are merely recommendations.
g. MCL from Table A, "Average Annual Concentrations Assumed to Produce a Total Body or Organ Dose of 4 mrem/yr," in 40 CFR 141.16 (EPA 1994, 50118)
h. Proposed standard
i. The MCL for total uranium concentration is 0.020 mg/L or 30 pCi/L in accordance with the proposed EPA rule (EPA 1994, 50118; EPA 1994, 50117).
j. Calculate concentration based on the proposed EPA rule that the concentration of any beta-particle and photon-emitter shall not exceed the dose equivalent of 4 mrem/yr, with calculations made using Federal Guidance Report No. 11 (EPA 1988, 50123). In addition, the sum of the annual dose equivalent of all beta-particle and photon-emitters present (except ^{228}Ra) shall not exceed 4 mrem/yr (EPA 1994, 50118; EPA 1994, 50117).

6.3 Conceptual Model for Human Exposure

6.3.1 Relation to Conceptual Model for Contaminant Transport

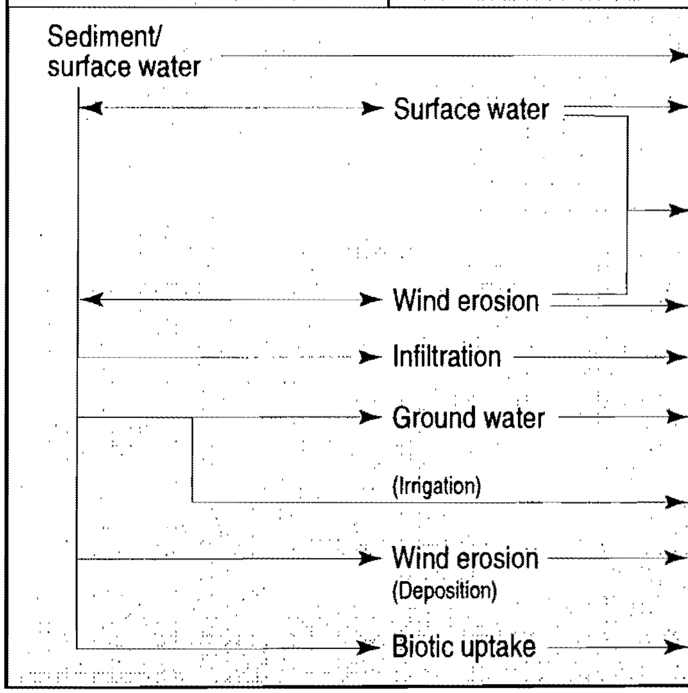
The conceptual model for human exposure, presented in Figure 6-1, identifies potentially contaminated media, release and transport mechanisms, and exposure media for COPCs. Conceptual exposure models are used to illustrate how constituents can move in the environment from contaminated media to receptors (the exposed population). The conceptual model for contaminant transport is presented in Figure 4-1 in Chapter 4 of this work plan. The transport model for the canyons is formulated using available information about potential contaminants and the geochemical, geologic, geomorphologic, hydrologic, and biological environment. Both the exposure and transport models are used to identify appropriate media and locations for sampling and to determine if a risk to human health or the environment exists.

6.3.2 Potential Transport and Exposure Pathways

The primary sources of contaminant release into the canyons are the mesa-top activities of the Laboratory. Technical Area (TA)-2 and TA-41 have released contaminants directly into the canyons (see Chapter 2 of this work plan). After constituents have been released into the canyon environment, they can potentially migrate via

- liquid infiltration into near-surface or subsurface soils;
- sediment transport in surface water;
- volatilization into ambient air;
- wind entrainment and deposition of contaminated dust onto surface soils and plants;
- surface water overflow and subsequent runoff resulting in the contamination of sediments in drainage channels and, possibly, infiltration to ground water;
- uptake by animals from ingestion and inhalation of contaminated media;
- root uptake by plants from contaminated soils; and
- flow in alluvial or intermediate perched zone ground water or the main aquifer.

These major transport pathways (the mechanisms and media by which contaminants are moved from their point of origin) and the related exposure pathways must be present for human exposure to contaminants to occur. The predominant pathways by which humans can be exposed to these transported contaminants are summarized in Figure 6-1. The most significant exposure pathways are expected to be ingestion of contaminated water from either surface flow, springs, or the alluvial ground water, inhalation or ingestion of contaminants in sediment, ingestion of contaminated plant or animal material, and external exposure to radiation from gamma-emitting radionuclides in sediments. Inhalation of volatile chemicals from sediments will not be evaluated because of the short residence time of these constituents in surface deposits. The exposure pathways for various land use scenarios are explained in greater detail in Sections 6.4.2, 6.4.3, and 6.4.4.



Exposure: Medium	Exposure: Route	Human receptors: Native American	Human receptors: Industrial worker	Human receptors: Recreational
Sediment	Ingestion	◆	◆	◆
	Dermal	◆	◆	◆
	External	◆	◆	◆
Surface water	Ingestion	◆	–	◆
	Dermal	□	–	□
Air	Inhalation	◆	◆	◆
Ground water	Ingestion	◆	–	◆
	Inhalation	□	–	–
	Dermal	□	–	□
Plants and Animals	Beef cattle	◆	–	–
	Game	◆	–	–
	Garden/poultry	◆	–	–
	Wood/fuel	◆	–	–
	Wild plants	◆	–	◆

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◆ Primary exposure pathway

□ Secondary exposure pathway (quantitatively evaluated only if sample data or modeling indicate that significant exposure may occur)

– Pathway not evaluated

Figure 6-1. Conceptual model for human exposure pathways.

Perched ground waters are present in Los Alamos Canyon and Pueblo Canyon. Risk calculations for this investigation will incorporate contaminant levels found in the perched zones unless field investigations demonstrate that the perched zones are not usable for water supplies. The potential exists for migration of contaminants from the perched zones to the main aquifer. The sampling and analysis plan (Chapter 7 of this work plan) includes investigations that will provide data needed to evaluate the level of risk from exposure to potentially contaminated ground water from each of these sources.

6.4 Land Use Scenarios and Human Receptors for the Canyons

6.4.1 Development of Land Use Scenarios

Calculations of present-day risk posed by a site are affected by the assumptions made about how the site will be used. The selection of land use scenarios defines the population exposed (receptors), the mechanisms and media by which they are exposed (exposure pathways), and the parameters describing how and to what extent they are exposed (exposure routes and uptake parameters) to be used in risk assessment scenarios. EPA Region VI staff have recommended in discussions regarding risk assessment that risk decisions be based on risk calculations consistent with "reasonable and likely" land use scenarios. The Laboratory has taken the position that many of its sites will continue to be used by the Laboratory for industrial purposes, although some sites may be used for residential or recreational purposes.

An alternative land use scenario, American Indian use, will also be developed and applied, where appropriate, to consider exposures by pathways specific to land uses by the neighboring Indian Pueblos. It is recognized that indigenous people may use the land in a manner that exposes them by pathways not commonly considered in risk assessments. Residential land use (and exposure) is considered within the framework of the American Indian use scenario.

The technical approach defined in Chapter 5 of this work plan specifies that present levels of contamination will be examined by sampled reach. Reaches are lengthwise segments of each canyon defined for purposes of investigation by the geomorphological and hydrologic criteria discussed in Chapter 7 of this work plan. The reaches are named according to the canyon and the reach sequence downstream. The reaches used in this investigation are shown in Figure A-1 in Appendix A and defined in Section 7.2 in Chapter 7 of this work plan. Human health risks will be calculated based on several land use scenarios within each reach, which may be applicable today or may be reasonably projected to occur in the near future. The discussion below refers to Table 6-3.

Continued Laboratory use is considered appropriate in Los Alamos Canyon in the regions of TA-2 and TA-41, where the Laboratory is currently operating (sampled reaches LA-1 and LA-2 are within the boundaries of projected continued Laboratory use).

Recreational use is considered possible in all reaches. American Indian use is appropriate in all areas other than the most developed (LA-2) and the narrowest (P-1). The residential land use scenario (contained within American Indian use) will likely be most conservative; it has the highest potential for contaminant exposure among the land use scenarios. Residential land use is considered possible in all sampled reaches where American Indian use is feasible, with the exception of LA-1, which is targeted for continued Laboratory use.

TABLE 6-3

POTENTIAL LAND USE SCENARIOS

	Scenario[a]			
Sampled Reach	**Continued Laboratory Use**	**Recreational Use**	**Native American Use**	**Residential (Part of Native American use)**
Pueblo 1 (P-1)		X		
Pueblo 2 (P-2)		X	X	X
Pueblo 3 (P-3)		X	X	X
Pueblo 4 (P-4)		X	X	X
Los Alamos 1 (LA-1)	X	X	X	
Los Alamos 2 (LA-2)	X	X		
Los Alamos 3 (LA-3)		X	X	X
Los Alamos 4 (LA-4)		X	X	X
Los Alamos 5 (LA-5)		X	X	X

a. Reaches to be investigated in the canyons are described in Chapter 7.

The following sections present the assumptions for three land use scenarios: the continued-Laboratory-use scenario (with two potential receptors: construction workers and on-site workers); the recreational scenario (with two potential receptors: campers and trail users); and American Indian use (with five potential scenarios: residential, ranchers, hunters, traditional users, and users of the Rio Grande and Cochiti Lake). The exposure pathways discussed below under each land use scenario are proposed and are subject to continuing negotiation with stakeholders. Both primary and secondary exposure pathways, as illustrated in Figure 6-1, are described.

The American Indian use scenarios will be developed with advice and input from the Accord Pueblos. Presented here is a first approximation of appropriate exposure pathways and land uses within the canyons. Rather than grouping exposure pathways to define a scenario for the maximally exposed individual, the exposure pathways are presented separately to specify the appropriate data needed to support information about routes of exposure. Total exposure can then be calculated by addition of dose contributions from all pertinent exposure pathways. This approach is intended to give extensive risk assessment information to the Pueblos to enable them to understand and manage risks and impacts appropriately.

6.4.2 Continued Laboratory Use

Exposure pathways for workers are described below and summarized in Table 6-4.

6.4.2.1 Excavation and Construction Activities

Manual or mechanical movement of contaminated sediment during construction makes contaminated sediment available for the following exposure pathways to on-site workers.

- Inhalation of fugitive dust lofted by wind and construction activities (such as bulldozing) while operating in and adjacent to the construction site

TABLE 6-4

EXPOSURE PATHWAYS FOR CONTINUED LABORATORY USE

Exposure Medium	Exposure Scenario: Construction Worker: Excavation and Building Activities	Exposure Scenario: On-site Worker: Office and Maintenance Activities
Dust in air	INH[d]	INH
Sediment	D[a], E[b], ING[c]	D, E, ING

a. D = dermal contact
b. E = external radiation
c. ING = ingestion
d. INH = inhalation

- Ingestion of sediment or dust
- Dermal contact with sediment
- External radiation by gamma-emitting radionuclides in sediment

6.4.2.2 Office and Maintenance Activities

Office and maintenance workers at a site may be exposed to contaminants through the following exposure pathways.

- Inhalation of fugitive dust suspended by wind in ambient air
- External radiation from gamma-emitting radionuclides in sediment
- Ingestion of sediment or dust suspended by wind
- Dermal contact with sediment

6.4.3 Future Recreational Uses

Exposure pathways for recreational users are described below and summarized in Table 6-5.

6.4.3.1 Short-Term Camping

This land use scenario assumes that individuals camping in the canyons may be exposed to contaminants over periods of several weeks two times a year. Exposure pathways are

- dermal contact with surface or ground water (such as wash water),
- dermal contact with sediment (from bedroll or campfire area),

TABLE 6-5

EXPOSURE PATHWAYS FOR FUTURE RECREATIONAL USE

	Exposure Scenario	
Exposure Medium	**Camper (Short-term)**	**Trail User**
Ground water and surface water	D[a], ING[c]	D, ING
Dust in air	INH[d]	INH
Sediment	D, E[b], ING	D, E, ING
Plants and animals	ING	ING

a. D = dermal contact
b. E = external radiation
c. ING = ingestion
d. INH = inhalation

- external radiation from gamma-emitting radionuclides in sediment in a camping area,
- inhalation of contaminants in fugitive dust suspended by wind in a camping area,
- ingestion of surface water or ground water (water from seeps and springs used as drinking and/or cooking water),
- incidental ingestion of sediment (such as deposition on hands and transfer to mouth while eating or drinking), and
- ingestion of internally or externally contaminated edible plants (such as piñon nuts and berries) that are growing in a camping area.

6.4.3.2 Trail User

This land use scenario assumes that individuals hiking in the canyons (but not camping overnight), bikers riding in the canyons, or horseback riders in the canyons may be exposed to contaminants for periods less than a day for varying frequencies. Exposure pathways are

- dermal contact with sediment while hiking or riding;
- external radiation by gamma-emitting radionuclides in sediment while hiking or riding;
- incidental ingestion of sediment (such as deposition on hands and transfer to mouth while eating or drinking);
- ingestion of surface water or ground water by drinking from a stream, seep, or spring;
- inhalation of contaminants in fugitive dust suspended by wind while hiking or riding;

- dermal contact with surface water (or ground water as seeps or springs) while wading, swimming, or resting in wet areas; and
- ingestion of internally or externally contaminated edible plants (such as piñon nuts and berries) growing along the trail.

6.4.4 American Indian Uses

Representatives of neighboring Indian Pueblos emphasize that the residents want more detailed and specific information regarding risks so that they may become better informed and may manage risks and impacts appropriately for their communities. The following discussion of exposure pathways for a potential American Indian user of Los Alamos Canyon or Pueblo Canyon is intended to provide more detailed information than is usually requested by interested members of the public (a typical risk assessment focuses on the maximally exposed individual to simplify the risk calculations as much as possible).

The difference between the typical scenario and calculations and the American Indian use scenario employed herein is illustrated by the following example. Typically, risk calculations may indicate an insignificant contribution to overall dose from the hunting scenario (which primarily relates to elk, deer, and small game hunting) and discount the scenario from the detailed calculation as an insignificant source of exposure. Because hunting is a traditional activity rather than a sport, and game meat supplies a larger than typical proportion of the diet of American Indians, San Ildefonso Pueblo representatives have asked the Environmental Assessments and Resource Evaluations group (ESH-20) to monitor contamination levels in local elk. Existing data from ESH-20 will be used where possible to calculate the contribution, or potential contribution, by contaminants in the canyons to elk exposure in the area. Contaminant levels in elk, deer, and small game will be estimated as part of the ecological risk assessment. In addition, Pueblo representatives will assist in identifying parameters used for risk calculations, including frequency and duration of activities.

The scenarios detailed below have been submitted to the four neighboring Indian Pueblos for their review, input, and concurrence on the appropriateness of each scenario. The scenarios and exposure pathways are summarized in Table 6-6.

6.4.4.1 Residential

Members of established Indian Pueblo communities (such as Totavi) or potential new communities might be exposed to contaminants via pathways not commonly evaluated in traditional risk assessments. The American Indian residents may be exposed through the following exposure pathways.

- Ingestion of ground water for drinking
- Dermal contact with surface water that may be used to irrigate plants
- Inhalation of contaminated smoke particles from the burning of contaminated wood for heating or cooking
- Inhalation of contaminants in dust while working in the field

TABLE 6-6

EXPOSURE PATHWAYS FOR AMERICAN INDIAN LAND USE

	Exposure Scenario				
Exposure Medium	Residential	Ranching	Hunting	Traditional	Rio Grande and Cochiti Lake
Ground water and surface water	D[a], ING[c], INH[d]	ING		D, ING	D, ING
Dust in air	INH	INH		INH	
Sediments	D, E[b], ING	D, E, ING		D, E, ING	
Plants and animals	ING, INH	ING	ING	D, ING, INH	ING

a. D = dermal contact
b. E = external radiation
c. ING = ingestion
d. INH = inhalation

- Incidental ingestion of, or dermal contact with, sediments during gardening or farming activities
- External radiation from gamma-emitting radionuclides in sediments
- Incidental ingestion of, or dermal contact with, surface water or ground water (in springs or seeps) by children while swimming or wading
- Ingestion of surficially or internally contaminated corn and other fruits and vegetables grown on-site that may be irrigated with contaminated surface or ground water
- Ingestion of wild foods (for example, piñon nuts, wild spinach, and tea) that are harvested on-site
- Ingestion of contaminated eggs or poultry
- Inhalation of volatile organic compounds and tritium (in tritiated water vapor) with domestic use of ground water

6.4.4.2 Ranching

Ranchers who might run cattle in the canyon floor (especially lower Los Alamos Canyon and Pueblo Canyon) might be exposed to contaminants through the following exposure pathways:

- ingestion of meat from cattle that drink contaminated ground water or surface water (such as in a stock pond or tank) or eat plants from contaminated areas;
- ingestion of surface water or ground water by drinking from a stream, seep, or spring;
- inhalation of contaminants in dust during ranching activities;

- incidental ingestion of, or dermal contact with, sediments during ranching activities; and
- external radiation from gamma-emitting radionuclides in sediments during ranching activities.

6.4.4.3 Hunting

Hunters taking elk, deer, or other game (such as squirrels and rabbits) that have grazed in potentially contaminated areas may be exposed through the following exposure pathways:

- ingestion of meat distributed throughout the Indian Pueblo from game whose range includes contaminated regions and
- ingestion of blood, bone, or raw meat from game at the site of the hunt or later.

Exposure pathways appropriate for the trail user are also relevant for hunting (see Table 6-5).

6.4.4.4 Traditional Uses

Traditional activities of Indian Pueblo communities may expose individuals to contaminants by the following exposure pathways:

- inhalation of particulates from the burning of contaminated wood in the kiva and from contaminated dust during ceremonial activities;
- incidental ingestion of sediments or dust, dermal contact with sediments during ceremonial and/or medicinal activities;
- external radiation from sediments during ceremonial and/or medicinal activities;
- incidental ingestion of clay or dermal contact with clay during ceremonial body painting;
- infants' dermal contact with ground water from springs used in naming ceremonies; and
- ingestion, inhalation, or dermal contact of medicinal and ritual plants (roots or leaves) gathered from contaminated regions (plants may be brewed, burned, or used as a poultice on the skin surface).

Hunters and gatherers of ceremonial or medicinal plants may also be exposed through all the exposure pathways described for trail users (see Section 6.4.3.2).

6.4.4.5 Rio Grande and Cochiti Lake

American Indians use the Rio Grande and Cochiti Lake for several specific purposes that may expose them to contaminants through the following exposure pathways:

- dermal contact with surface water while swimming, fishing, ceremonial washing, and conducting other water-related activities;
- ingestion of homegrown fruits and vegetables irrigated with surface water from the subject sources;
- ingestion of water during recreational or ceremonial use; and
- ingestion of fish and other aquatic foods.

The sampling and analysis plans developed for the canyons investigation (Chapter 7 of this work plan) do not support a full risk assessment of the Rio Grande and Cochiti Lake scenario. Data on contaminant concentrations in sediment and water collected in Los Alamos Canyon and Pueblo Canyon can be used to estimate potential contributions from the canyons to current known contaminant levels in the Rio Grande.

6.5 Canyon Ecosystems

The assessment of risk to ecosystems will be based on the EPA framework for ecological risk assessment (EPA 1992, 48847; EPA 1994, 48846). The specific receptors, exposure units, exposure models, and risk assessment models will be determined by negotiations underway among the Laboratory, DOE, EPA, NMED, and the Accord Pueblos. This section describes the initial list of assessment endpoints and preliminary risk assessment models.

Although assessments of present-day and future potential impacts to the canyon ecosystems are required by the HSWA Module and discussed in this work plan, much of the work to define potential future impacts will be integrated into a broader program of studies, which is currently being defined by the Environmental Restoration (ER) Project in consultation with DOE, EPA, NMED, and tribal representatives from neighboring Indian Pueblos.

6.5.1 Overview

An ecological risk assessment is a process that evaluates the likelihood that undesirable ecological effects may occur or are occurring as a result of exposure to one or more stressors (EPA 1992, 48847). It may be a qualitative and/or a quantitative evaluation of the actual or potential impacts of contaminants on the environment, and it shares several features with human health risk assessment. However, it differs from human health risk assessment in a number of ways.

- Because the term "stressor" has been defined for ecological risk assessment as any chemical, physical, or biological entity capable of producing an adverse effect (EPA 1992, 48847), any human activity may be evaluated for its potential to produce adverse effects in the environment.

- Ecological risk assessment should consider effects to receptors that may be individual organisms, populations, communities, or ecosystems (EPA 1992, 48847; EPA 1994, 48846).
- A great deal of flexibility is allowed in what receptors are used in an ecological risk assessment and what is considered an unacceptable risk to the environment.
- The ecological risk assessment should consider the tradeoffs among risks due to contaminants, risks due to remediation activities, and risks due to potential future land uses.

6.5.2 Canyons Ecosystems

The ecological risk assessments for Los Alamos Canyon and Pueblo Canyon rely on a triad of assessment activities shown schematically in Figure 6-2 to evaluate the potential effects of chemical stressors. These assessment activities are chemical characterization of abiotic source media, modeling of ecological exposure and effects, and model testing through measurement of the contaminant concentrations in plants and animals and monitoring of the effects on plants and animals. Similar approaches have been used in large, complex ecological risk assessments (Canfield et al. 1994, 50139). These activities are not necessarily sequential, but they all serve to reduce the uncertainty in the risk assessment.

The ecological component of the canyons investigations will be centered on defining the effects of contaminants that apply stress to and may strain the ecosystem (chemical stressors). The investigation will support the evaluation of potential effects of remediation and of various land use options on the ecosystems of Los Alamos Canyon and Pueblo Canyon (Table 6-7). Evaluation of the different risks is needed to weigh the costs and benefits of different land use and remediation options.

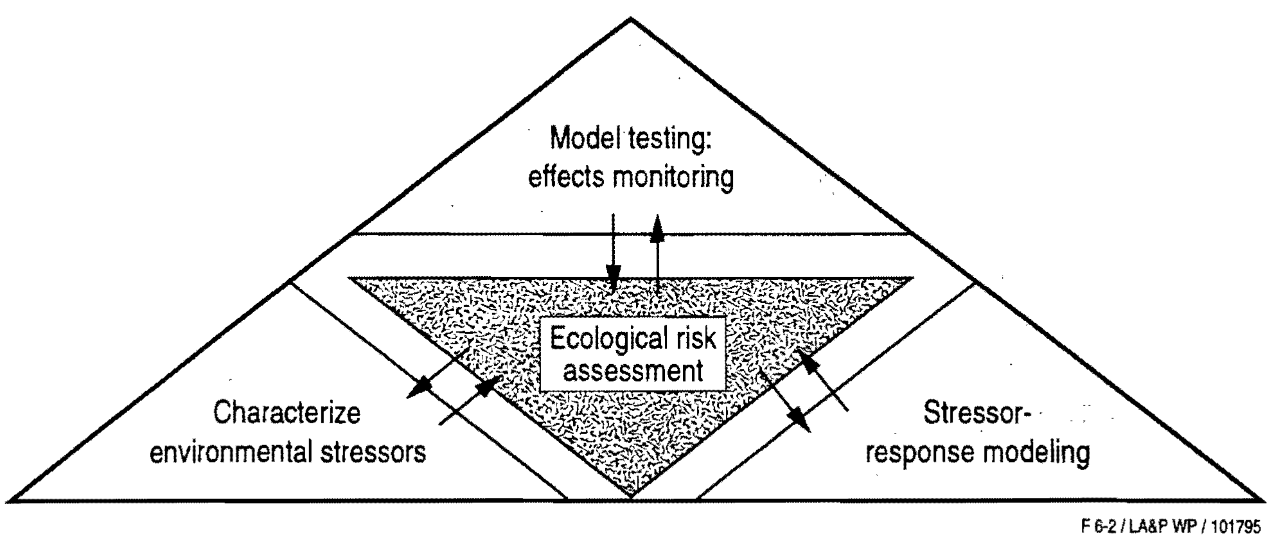

Figure 6-2. Major activities of the proposed triad approach for producing defensible ecological risk assessments.

TABLE 6-7

STRESSORS CONSIDERED IN ECOLOGICAL RISK ASSESSMENTS
FOR LOS ALAMOS CANYON AND PUEBLO CANYON

Stressor	Continued Laboratory Operations		Recreational		Native American Use	
	No Action	Remediation	No Action	Remediation	No Action	Remediation
Chemical	X		X		X	
Physical (Habitat fragmentation)		X	X	X	X	X
Biological (Community alteration)		X	X	X	X	X

6.5.3 Assessment Endpoints

Assessment endpoints are defined by a receptor (an individual organism, population, community, or ecosystem) and by a criterion for unacceptable risk to that receptor (EPA 1992, 48847; EPA 1994, 48846). For example, it may be unacceptable for contaminants to impose any significant added risk of mortality to peregrine falcons, but it may be acceptable for contaminants to cause average population sizes of piñon mice to be reduced by 15%.

A number of schemes are available for selecting assessment endpoints. Table 6-8 presents a matrix of different plant and animal types that help to define the different routes of exposure and potential sources of variation in susceptibility.

For example, land plants can assimilate contaminants directly from air and from dust through their leaves (designated by "U" in Table 6-8). Similarly, land plants can be splashed by dust resuspended by raindrops (designated by "R&R" in Table 6-8). Animals are exposed by a variety of routes including ingestion (designated by "ING" in Table 6-8) for example, by insectivores (which eat insects that are classified as animals) and by omnivores that eat plants and animals. All classes of animals are exposed by inhalation of air (designated by "INH" in Table 6-8) and by dermal contact (designated by "D" in Table 6-8) with water, sediment, or dust.

When selecting assessment endpoints, cultural values also will be considered. Environmental regulations reflect the social values of the dominant culture but may not fully reflect local subcultures (Kellert 1991, 50140). Several species that may be exposed to contaminants in Los Alamos Canyon and Pueblo Canyon are state or federally protected species. (Table 3-20 [Section 3.8.2.3 in Chapter 3] of this work plan lists threatened and endangered species potentially occurring in the canyons). As part of this investigation, species or habitats that are very likely to be present in Los Alamos Canyon and Pueblo Canyon and that are valued by both regional and local cultures are identified as assessment endpoints (Table 6-9).

The measurable ecological characteristic that defines unacceptable impact to the assessment endpoint species, community, or population is defined as the measurement endpoint (EPA 1992, 48847; EPA 1994, 48846). Measurement endpoints are chosen based on their ability to establish causal links between environmental contaminants and an effect on the assessment endpoint. Some typical measurement endpoints

TABLE 6-8

CLASSES OF ECOLOGICAL RECEPTOR POPULATIONS AND THEIR LIKELY EXPOSURE PATHWAYS

A. Plants (Classes)

Exposure Medium	Ecological Receptors[a]			
	Aquatic Plants	Grasses/ Forbs	Shrubs	Trees
Ground water and surface water	U[g]	U	U	U
Air		DEP[c], U	DEP, U	DEP, U
Sediment and dust	U	R&R[f], U	R&R, U	R&R, U
Plants				
Animals				

B. Animals (Classes)

Exposure Medium	Ecological Receptors			
	Herbivores	Insectivores	Carnivores	Omnivores
Ground water and surface water	D[b], ING[d]	D, ING	D, ING	D, ING
Air	INH[e]	INH	INH	INH
Sediment and dust	D, ING	D, ING	D, ING	D, ING
Plants	ING			ING
Animals		ING	ING	ING

a. Exposure to contaminants of concern from various media is dependent on the properties of the contaminant and the exposure pathway defined as plant uptake by roots (also assimilation from leaf surfaces or across cell walls for aquatic algae and diatoms), dermal contact, ingestion, inhalation, atmospheric deposition to plant surfaces, and resuspension and rain splash processes that result in deposition to plant surfaces.
b. D = dermal contact
c. DEP = atmospheric deposition on plant surfaces
d. ING = ingestion
e. INH = inhalation
f. R&R = resuspension and rain splash processes
g. U = plant uptake by roots, assimilation from leaf surfaces, and assimilation across cell walls

include biochemical, physiological, and histological markers of chemical-induced stress (Hugget et al. 1992, 50273; Peakall 1992, 50274; Fossi and Leonzio 1994, 50272); reproduction and survival rates; plant or animal abundance; numbers of species in an ecological community; or fluxes of nutrients in an ecosystem (Bartell et al. 1992, 50268). Proposed measurement endpoints will be discussed further in Chapter 7 of this work plan.

For protected species it is proposed that any increase in the likelihood for reduced survival or reproduction is unacceptable. For the species they depend on, as either prey or forage, it is assumed that reductions of greater than 20% in reproductive rates, survival rates, or average abundance are unacceptable. The same criterion is assumed for receptors having other recreational or ecological value.

6.6 Models for Assessing Human Health and Ecological Risk

Exposure pathways are detailed in tables provided in Section 6.4. Preliminary dose calculations in Pueblo Canyon were performed for this work plan using historical

TABLE 6-9

PROPOSED ASSESSMENT ENDPOINTS FOR ECOLOGICAL RISK

	Potential Exposure Pathways				
	Surface water and soil water	Air	Sediment and dust	Plants	Animals
Jemez Mountains salamander	X	X	X		X
Peregrine falcon	X	X	X		X
Mexican spotted owl	X	X	X	X	X
Meadow jumping mouse	X	X	X		
Spotted bat	X	X	X		X
Aquatic communities (wetlands)	X		X	X	X
Soil community	X		X	X	X
Plant community	X		X		
Animal community	X	X	X	X	X
Elk and deer population	X	X	X	X	
Small game population	X	X	X	X	

Formerly Utilized Sites Remedial Action Program (FUSRAP) data (for all radionuclides) (LANL 1981, 6059) and the RESRAD computer model. These calculations indicated the importance of both the inhalation and plant uptake pathways (Dorries 1995, 49932). To reduce uncertainty in calculating doses from radionuclides via these exposure pathways, both limited air sampling and biological sampling are proposed in Chapter 7 of this work plan. Particular parameters that require field measurement include particulate loading for inhalation exposure pathways and plant uptake factors for the ingestion of contaminated foodstuffs pathway.

Samples of airborne particulates will include separation of a size fraction less than 10 μm in diameter. Selected sediment samples will be processed to separate this size fraction as well to obtain data on the extent of the potential sources of contaminated fine dust (see Chapter 7 of this work plan). Analyses of the fine (less than 10 μm) size fraction will allow more detailed evaluation of the inhalation exposure pathway because only particles smaller than 10 μm are respirable; the remainder are trapped in the nasopharyngeal area and subsequently ingested. Air sampling results will be compared with modeled air concentrations of suspended dust directly above contaminated sediments. Both direct sampling and model estimates of airborne dust concentrations may be used in risk assessment calculations.

The complexity of the exposure scenarios and transport mechanisms for risk assessment in the canyons may result in a high level of uncertainty for numerous exposure parameters used in transport and risk assessment models. It is anticipated that stochastic methods may be employed to quantify the uncertainty associated with risk calculations. The use of stochastic techniques will provide stakeholders with a valuable tool for risk management by describing the probability associated with discrete risk estimates.

Sampling plans developed in Chapter 7 of this work plan support the collection of data needed to generate representative statistics for human health and ecological risk assessments. Each reach sampled will contribute data for multiple land use scenarios.

Data from the radiological survey (Section 7.2.3.3 in Chapter 7 of this work plan) will be used to confirm the transport conceptual model assumptions, find locations of high contamination and, if possible, determine which radionuclides can be eliminated from further analyses. After radiological survey data have been analyzed, risk assessors will work with the technical and field teams to identify full and limited suite analyses for use in risk assessment. Spatial and distributional analyses of laboratory data will be used to derive the appropriate statistic to describe the contaminant source term(s) within each reach. Trend analyses (using screening data where appropriate) may indicate the need to report the risk for several exposure units within one reach (that is, if bimodal distributions are apparent).

6.6.1 Human Health Risk

The human health risk from exposure to COPCs in Los Alamos Canyon and Pueblo Canyon for current or future receptors is expected to be due mainly to radiological contaminants. Radiological risk will be reported as the annual dose to potential receptors. Radiological dose will be reported separately from nonradiological risk.

The computer code RESRAD will be used to calculate human dose from soil (including airborne dust) concentrations of residual radionuclides.

The human health risk from potential exposure to nonradiological COPCs in Los Alamos Canyon and Pueblo Canyon will be calculated following standard EPA methods outlined in the *Risk Assessment Guidance for Superfund* (EPA 1989, 8021).

Because several water sources (surface water, alluvium, intermediate perched zones, and the main aquifer) may be usable in each canyon, each will be treated as an independent water source for risk and dose calculations. Current water pathways that contribute to risk and dose will be calculated separately for each water source and added to each sediment risk and dose (when the ground water pathway is part of the appropriate scenario). Total risk is then presented in a matrix of potential total radiological dose and nonradiological risk from a site. The presentation of total site risk will include risk associated with background concentrations of certain metals and radionuclides in the canyons.

6.6.2 Ecological Risk

The ecological risk from exposure to a COPC is proportional to the intake of the contaminant and inversely proportional to a toxicological reference dose (see Appendix C of this work plan for a discussion of the mathematical relationships for dose and risk). The intake of contaminants via several exposure pathways is estimated by various means, which are described as an exposure assessment. Estimates of the parameters used in exposure assessment will be obtained by consulting the scientific literature. However, to make these assessments more realistic, less conservative, and more defensible, site-specific data on animal feeding behavior, seasonal movements, and other life history parameters are strongly preferred. A number of ecological foraging models and contaminant uptake models may be adapted for use in the canyons (Roese et al. 1991, 50275; DeAngelis 1992, 50270; DeAngelis and Gross 1992, 50271; Gallegos and Wenzel 1990, 6993).

The significance of predicted effects on reproduction and survival of populations can be evaluated using demographic models (Appendix C of this work plan). Although these models do not present a detailed accounting of all relevant processes, they are useful for making risk management decisions based on projections of the viability of populations (Soulé 1987, 50115; Burgman et al. 1993, 50269). Several models (Getz and Haight 1989, 50114) are available for evaluating the population consequences of exposure to environmental contaminants and other sources of disturbance, such as remediation activities.

6.7 Description of Potential Remedial Activities

6.7.1 Cleanup Levels

At canyon locations where present-day risk assessment calculations show that risk to human health or the ecosystem may exceed threshold values, risk-based cleanup levels will be calculated for COPCs identified in the risk assessment. Target human health risk values are defined according to guidance discussed in Section 6.1. Final definitions of unacceptable risk to human health and the environment will be agreed on after negotiations with EPA, NMED, and the Accord Pueblos. Cleanup levels will be calculated using EPA equations and site-specific input parameters. RESRAD or a demonstrably equivalent code will be used to calculate cleanup levels for radionuclides. The range of uncertainty in cleanup levels will be presented by basing the calculation on a reasonable maximally exposed individual and a best estimate of exposure identified in the appropriate land use scenarios. As discussed in Section 6.4.4, such a maximally exposed individual will not be defined for the American Indian use scenario.

6.7.2 Potential Remedial Actions

The Installation Work Plan (LANL 1995, 49822) describes the Laboratory's approach to the Resource Conservation and Recovery Act (RCRA) facility investigation (RFI), which focuses field investigations on determining whether a corrective measures study (CMS) is necessary and on supporting the performance of a CMS, the design and implementation of an accelerated cleanup, or a recommendation for no further action. The staged approach being employed for the Los Alamos Canyon and Pueblo Canyon investigation encourages the identification of key data needs as early in the process as possible to ensure that data collection is always directed toward providing information relevant to refining the conceptual model for contaminant transport and to selection of a remedial action.

The following sections provide a preliminary development and screening of remedial technologies and alternatives for this work plan, but detailed screening and analysis are deferred until additional data are collected. Many of these remedial alternatives can be applied on a small scale to limited areas of contamination as voluntary corrective actions (VCAs). The ER Project has established criteria for distinguishing whether a contaminated site can be classified as a VCA (Glatzmaier and Fesmire 1995, 46071).

An example of a potential series of VCAs in Los Alamos Canyon and Pueblo Canyon would be to excavate localized radionuclide "hot spots" (each less than one cubic yard) that are identified during radiometric surveys in the stream bottoms and overbank deposits. Any "hot spots" located during the surveys could be containerized for sampling by a field team. Such an operation would be efficient, would remove concentrated gamma-emitting radionuclides from the canyon system, and would avoid the potential for these sources to be dispersed by floods.

Even though the nature and extent of potential contaminants present in Los Alamos Canyon and Pueblo Canyon are uncertain, the following general response actions are believed to be technically feasible and appropriate:

- no action;
- institutional control (such as monitoring, fences, and deed control);
- containment;
- treatment;
- removal (excavation to a RCRA mixed-waste or radioactive-waste landfill); and
- combinations of the above (for example, sediment traps whose contents are removed periodically).

This section does not give an all-inclusive list of potential remedial alternatives. It focuses on the most likely types of response actions for Los Alamos Canyon and Pueblo Canyon based on existing data. As additional data are collected during the investigation, applicable remedial action methods will be re-evaluated. Technical options will be compared with respect to implementation, effectiveness, and cost, allowing informed decisions to be made in selecting remedial alternatives.

6.7.2.1 No Action

The no-action category means complete inaction at a given site. This category allows conditions and processes currently occurring at the site to continue.

The no-action alternative may be applicable if field investigation results indicate the following conditions for a site in the canyons:

- no contaminants are present,
- contaminants are present but at concentrations below regulatory action levels, or
- present-day risk assessment demonstrates that the extent of contamination results in no risk or an acceptable risk under an appropriate exposure scenario.

The no-action alternative also serves as a basis for comparison with other alternatives.

To undertake no action is to refrain from intervening in the fate and transport of contaminants. No action does not necessarily perpetuate the status quo because natural processes are transforming a site. In this context, the no-action alternative is considered passive remediation, which recognizes the effects of natural processes such as dilution, biodegradation, volatilization, photolysis, leaching, radioactive decay, precipitation, and adsorption that reduce contaminant concentrations present at a specific site.

The no-action alternative is likely to apply to most surface locations of Los Alamos Canyon and Pueblo Canyon because contaminant concentrations are expected to be below action levels (based on values measured during the FUSRAP [LANL 1981, 6059]) or to pose no significant risk to human health or the environment. Based on results of hydrological, geochemical, and geological investigations to date, as discussed in Chapter 3 of this work plan, major portions of subsurface units also may pose either no risk or an acceptable risk and may require no action.

6.7.2.2 Institutional Control

If field investigation results indicate that contaminants are present in concentrations above regulatory action levels at a given site, other response actions or combinations of response actions (such as monitoring, fencing, or deed control) may be required. For example, the site could be fenced and monitored to evaluate the migration of contaminants over time.

6.7.2.2.1 Monitoring

Monitoring involves no substantial action on contaminated media, but it does provide information about the status of contaminants. In situations in which no other action is taken, monitoring can serve not only to document passive remediation but also to provide early warning if passive remediation fails to adequately protect human health and the environment. Also, monitoring may be needed in situations in which containment, collection and removal, or treatment are undertaken. In these situations, the purpose of monitoring would be to document the effectiveness of the remedial actions and to provide early warning if the remedial action fails.

The monitoring technology applies to the alluvial ground water, intermediate perched ground-water zones and surface drainage within the canyons. These systems have already been monitored to varying degrees.

6.7.2.2.2 Restricted Use

No technology is required to implement restricted access (such as fencing or deed restrictions). Fences already exist in parts of Los Alamos Canyon. Also, most community developments near the Laboratory are confined to the mesa tops. The surrounding land is largely undeveloped; large tracts north, west, and south of the Laboratory boundaries are held by the Santa Fe National Forest, Bureau of Land Management, Bandelier National Monument, General Services Administration, and Los Alamos County. San Ildefonso Pueblo borders the Laboratory to the east. Because most of the surrounding land is controlled by federal government entities, land use restrictions have been applied and can be enforced.

6.7.2.3 Containment

A likely remedial alternative for contaminated sediments in the canyons is believed to be containment followed by long-term monitoring.

Several remediation technologies can be considered for sediments, surface water, and ground water in certain portions of Los Alamos Canyon and Pueblo Canyon. Sediment traps have been used in Mortandad Canyon to contain plutonium- and americium-contaminated sediments. Periodic removal of contaminated sediments is required for this containment technology. Permeable geochemical barriers can be designed to remove cations ($^{90}Sr^{2+}$ and $^{137}Cs^{+}$) and anions ($^{235}[UO_2][CO_3]_2^{2-}$and $^{241}Am[CO_3]_2^{-}$) from surface water and ground water. Ground water pumping technologies can be applied to the alluvium to contain ground water flow and remove ^{90}Sr and other contaminants. Application of pumping technology requires a thorough knowledge of the hydrodynamic properties of the alluvium where sufficient saturated thicknesses warrant use of this technology.

Additional containment alternatives (such as permeable berms, sediment traps, gabions, retaining walls, or levees) may be applicable to Los Alamos Canyon and Pueblo Canyon. These containment alternatives would be used to control or impede the erosion and transport of contaminated canyon sediments. However, additional site characterization data and better definition of potential migration pathways are required to determine whether these alternatives are appropriate and would merit further consideration. If applicable, the alternatives will be addressed during a CMS.

6.7.2.4 Treatment Technologies

Numerous technologies are associated with general response actions involving treatment of sediments or water, either *in situ* or combined with removal. Examples of *in situ* treatment technologies for contaminated sediments that may be applicable are contaminant coprecipitation, immobilization, soil flushing, vapor extraction, vitrification, and biological treatment. Possible ground water treatments include anion and cation exchange techniques.

Insufficient data are available to determine which of these technologies may be applicable. As appropriate, treatment technologies will be evaluated during a CMS. Bench-scale and pilot studies will be used as needed to confirm the feasibility of various treatment technologies.

6.7.2.5 Removal

Removal would be followed by disposal, possibly after some treatment. Surface sediment contamination in the canyons could be remediated by removal. However, removal is not considered advantageous for areas of widespread low-level contamination because the ecological impact of disturbing large areas on the canyon floors would be substantial, and the potential is very high for mobilizing contaminants that are presently stable in sediment deposits. In addition, large volumes of material would likely be involved, which would overwhelm available facilities and require the development of new disposal sites.

6.7.2.6 Combined Technologies

Numerous possible combinations of temporary and/or permanent solutions can be envisioned. One combination with obvious potential application to Los Alamos Canyon and Pueblo Canyon is the construction of sediment traps to capture contaminated sediment, which can then be removed, treated by soil washing techniques to reduce volume, and disposed of. Such sediment traps are already in operation in Mortandad Canyon; sediments are removed from these traps periodically.

Remediation efforts, if needed, will be coordinated with the Environmental Management Program and the Technology Development Program to ensure that applicable, cost-effective technologies will be used.

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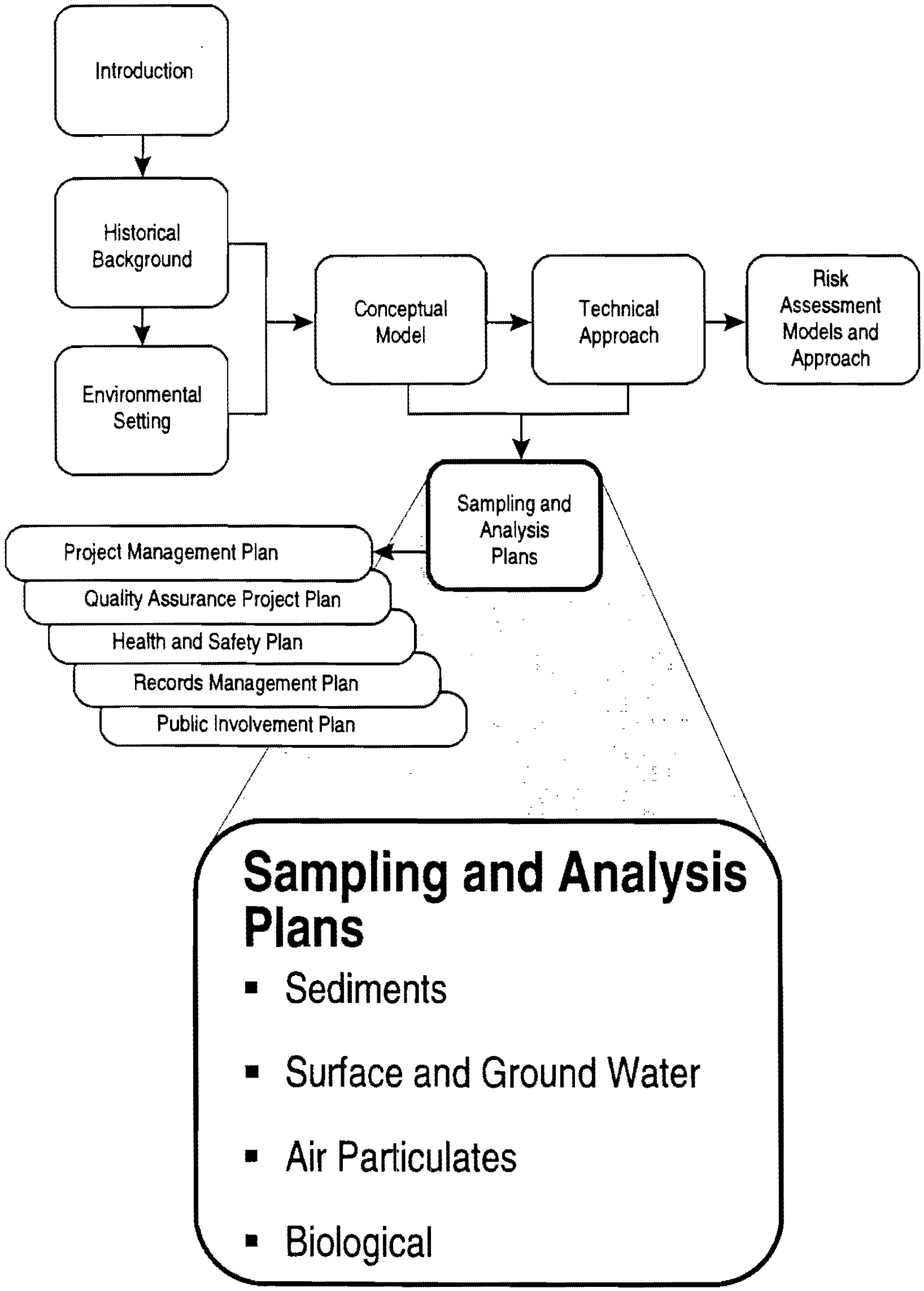
Chapter 7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7.1 Introduction

This chapter describes the rationale and plans behind collecting and analyzing samples and field survey data to characterize Los Alamos Canyon and Pueblo Canyon. The data will be used to support evaluation of present-day risks to human health and the environment from Laboratory-derived contaminants moving through the canyons and evaluation of the potential for future off-site exposure and impact on the Rio Grande. Evaluation of these risks and impacts requires testing and refining of the conceptual model of distribution and transport of contaminants in the canyons (see Chapter 4 of this work plan). In accordance with the expedited site-characterization approach described in Chapter 5 of this work plan, results of field surveys and sampling analyses conducted in initial tasks will be used to revise the conduct of subsequent sampling tasks. Sampling and analysis plans presented in this chapter outline general approaches and principles to be followed and general areas to be sampled. Specific sampling locations will be defined based on data from the initial tasks.

Sections of this chapter present the plans for sampling and analyses of each of the transport pathways described in Chapters 3 and 4 of this work plan. Each section (1) will discuss elements of the transport pathways and their importance, (2) will identify issues to be addressed to assess risk and impacts and identify appropriate remedial measures, and (3) will describe the approaches used to resolve the issues.

Section 7.2 describes sediment characterization in Los Alamos Canyon and Pueblo Canyon. Section 7.3 describes characterization of the hydrologic system including (1) surface water and alluvial ground water, and the alluvium which contains it, (2) the intermediate perched zone ground waters, and (3) the main aquifer. Contaminant transport by sediments and by surface and ground water are considered to be the predominant pathways for transporting Laboratory-derived contaminants to locations where humans could be exposed. Section 7.4 describes the plans for characterizing the air exposure pathway. Section 7.5 describes the biological sampling program, which includes an evaluation of the impact of Laboratory-derived contaminants on the canyon ecosystems and an evaluation of the human health risks from contaminants in plants and animals.

Table 7-1 summarizes the known chemicals of potential concern (COPCs) in the canyons grouped in part according to protocols that will be used in this investigation for a sample analysis. This table is based on the list of chemicals of potential concern, (given in Chapter 6 of this work plan, Table 6-2), and on data from previous studies showing actual occurrence of contaminants in the canyons.

Table 7-2 shows the initial estimates of the numbers and types of samples (for example, sediment, borehole core, or water) to be collected in each canyon. The numbers will be revised throughout the actual characterization in accordance with the expedited site characterization approach. Changes to these numbers of samples will be recorded and described in reports of this investigation, but these sampling and analysis plans will not be revised unless a fundamental mismatch between the data and the conceptual model becomes apparent, as described in Chapter 5 of this work plan, Section 5.3.7.1.

7.2 Sediment Sampling and Analysis Plan

This section presents the sampling and analysis plan for investigating potentially contaminated sediment in selected areas of Los Alamos Canyon and Pueblo Canyon. Nine reaches downstream of known Laboratory sources of contamination have been

TABLE 7-1

CHEMICALS OF POTENTIAL CONCERN IN THE CANYONS AND IN SOURCE AREAS[a]

Known COPCs[b]	Source Areas for Los Alamos Canyon	Source Areas for Pueblo Canyon
Radionuclides		
^{241}Am	TA[c]-21	TA-45
^{137}Cs	TA-2, TA-21	TA-45
^{3}H	TA-2, TA-21, TA-41	TA-45
^{238}Pu	TA-2, TA-21, TA-41	TA-45
^{239}Pu	TA-1, TA-2, TA-21, TA-41	TA-45
^{90}Sr	TA-2, TA-10[d], TA-21	TA-45
Uranium	TA-1, TA-2, TA-10, TA-21, TA-41	TA-45
Organics		
Pesticides	General	General
PCBs[e]	General	General
SVOCs[f]	TA-21	
Trichloroethylene	TA-2, TA-41	
Inorganics		
Antimony	TA-1	
Arsenic	TA-21	
Cadmium	TA-2, TA-41	
Chromium	TA-2, TA-21, TA-41, TA-53	
Lead	TA-1, TA-2, TA-21, TA-41	
Mercury	TA-1	
Zinc	TA-21	

a. This table contains preliminary information from Resource Conservation and Recovery Act facility investigation (RFI) work plans, draft RFI reports, and other available reports.
b. COPC = chemical of potential concern
c TA = Technical Area
d. Source area for Bayo Canyon, which drains into lower Los Alamos Canyon.
e. PCB = polychlorinated biphenyl
f. SVOC = semivolatile organic compound

chosen for investigation. These nine reaches will be characterized by radiological and geomorphic surveys, and by chemical analysis of sediment samples collected from potentially contaminated deposition zones or geomorphic units.

7.2.1 Objectives

The objectives of the sediment investigation are summarized as follows:

- determine the nature and extent of Laboratory-derived contamination associated with sedimentary deposition zones,
- evaluate the present-day risk to human health and ecosystems from contaminated sediments,

TABLE 7-2

INITIAL ESTIMATES OF SAMPLE COLLECTION AND ANALYSIS

Sample Type	Number of Samples		
	Los Alamos Canyon	Pueblo Canyon	Total
Sediment[a] and Core			
"Background" sediment	8	8	16
"Full-suite" sediment	12	8	20
"Limited-suite" sediment	60	48	108
"Key contaminants" sediment[b]	TBD[c]	TBD	TBD
Alluvial borehole core[d]	18	18	36
Intermediate borehole core	14	4	18
Ground[e] and Surface[f] Water			
Surface water	20	16	36
Alluvial (background wells)	—	8	8
Alluvial (observation wells)	18	14	32
Intermediate perched zones (observation wells)	14	4	18
Air Particulate[g]			
Total suspended particulate (annual)	3	1	4
PM10[h] fraction (annual)	3	1	4
Biological			
Garden produce[i]	16	16	32
Garden soil (composite)[j]	2	2	4
Wild plant species[k]	8	8	16
Livestock forage plants[l]	4	4	8

a. Sediment samples will be collected to determine background constituent concentrations ("background") and chemicals of potential concern ("full-suite" and "limited-suite" analyses).

b. Sediment samples will be collected and analyzed for "key contaminants" (for example, ^{137}Cs, Pu, ^{90}Sr) to obtain information about sediment transport mechanisms. Actual number collected will be decided by the technical team on the basis of initial survey and sampling results. (The collection of approximately 50 samples per canyon is anticipated.)

c. TBD = to be determined

d. At a minimum, one core sample will collected above and below each major hydrogeological contact. Additional samples may be collected at the judgment of the field geologists.

e. Alluvial background wells will be sampled quarterly. All observation wells will be sampled at completion and at six months.

f. If surface water is present, samples will be collected quarterly.

g. Air particulate samples will be collected approximately monthly, depending on filter loading, and will be composited to garner an annual sample for each sampling site.

h. PM10 fraction is the respirable particulate fraction (10 µm diameter or less).

i. Four samples each of four different garden produce varieties will be collected from one garden plot in each canyon.

j. Two composite soil samples will be collected from the garden plot in each canyon.

k. Two samples each of four different wild plant species will be collected from each canyon.

l. Two samples of livestock forage plants will be collected from two locations in each canyon.

- collect data to evaluate and refine the conceptual model for contaminant transport, and
- assess the projected impact of contaminated sediments on off-site receptors and on the Rio Grande by identifying the nature and amount of contamination migrating beyond Laboratory boundaries.

The technical approach adopted to achieve these objectives is described in the following section.

7.2.2 Technical Approach for Sediment Investigation

The technical approach for the sediment investigation is outlined in Figure 7-1. The decision logic diagrammed in Figure 7-1 follows that of the general technical approach described in Chapter 5 of this work plan. As discussed in Chapter 4 of this work plan, the key hypotheses of the current conceptual model, which will be tested during the sediment investigation, are summarized as follows.

- The maximum concentrations of contaminants in sediments varies with distance from the source; maximum concentrations generally decrease downstream.
- The deposition and storage of contaminated sediment(s) generally increases downstream. This results in contaminants being dispersed over wider areas of the valley floor and results in relatively high contaminant inventories in some downstream areas.
- Contaminant concentrations vary with depositional setting and depend on the age and type of the sediment deposit (for example, active channel versus floodplain deposit). Sediment deposits of similar age and setting will have similar contaminant concentrations.
- Contaminant concentrations vary with sediment particle size, with the highest concentrations being found in finer-grained sediments.

The sediment sampling and analysis plan will focus on selected areas of Los Alamos Canyon and Pueblo Canyon directly downstream of known contaminant sources. Field surveys and mapping, as well as sampling tasks, will concentrate on nine canyon reaches, each approximately 0.5 to 1 km long. A "reach" refers to a specific area of a canyon that will be treated as a single unit for sampling, analysis, and impact (including present-day and ecosystem risk) assessment. The reaches of canyon proposed for detailed sampling and investigation are shown in Figure A-1 (Appendix A of this work plan). Physical descriptions of each reach are given in Table 7-3. The precise length and area of each canyon reach will be defined by the geomorphic survey to encompass the local variability in geomorphic units and to constitute a reasonable area for use in the impact assessment. Between 5 and 9 km of a total canyon length of 27 km (downstream of the contaminant sources) will be studied in detail. Focusing on relatively short reaches of each canyon will allow the collection of high-quality data in an efficient manner and will increase confidence in the conceptual model of contaminant distribution and the impact assessment.

One or more of the following criteria were used to select the nine reaches.

- Areas where contaminant concentrations are expected to be highest as judged from previous sampling activities and from the proximity of the canyon reach to the source areas
- Areas of current or reasonably possible future land use (recreational, residential, or ranching)
- Areas of different geomorphology to allow better estimates of the total contaminant inventory in the canyon and of variations in contaminant distribution between reaches.

Each selected canyon reach was chosen to address particular issues regarding potential contamination of the individual canyons. The set of reaches is intended to represent key aspects of the entire system within Los Alamos Canyon and Pueblo Canyon. Issues to be addressed by sampling in the individual reaches are discussed in Section 7.2.2.1.

In addition to the field survey and mapping tasks (which are described in Section 7.2.3), the sediment sampling and analysis plan consists of four sampling tasks.

1. Background sample collection.

   Purpose: prepare the data set of background constituent concentrations in sediments.

2. Sample collection for "full-suite" analysis.

   Purpose: analyze for the full suite of COPCs (organic, inorganic, and radionuclide constituents) to define the limited suite of COPCs for the sediment investigation.

3. Sample collection for "limited-suite" analysis.

   Purpose: analyze for the limited suite of COPCs to perform the present-day risk assessment.

4. Sample collection for "key contaminant" analysis (see Section 7.2.4.1.4 for a discussion of "key contaminants").

   Purpose: validate hypotheses concerning sediment transport mechanisms and assess projected impacts.

Section 7.2.4.1 presents the strategy and rationale for sample collection for the sampling tasks. The sampling strategy for any subsequent sampling tasks will be decided based on the data collected in the initial field surveys and sampling. Requirements for additional data will be developed based on the recommendations of the technical team and through frequent dialogue with the regulators. Subsequent sampling may also address particular stakeholder concerns which may arise based on data collected early in the investigation.

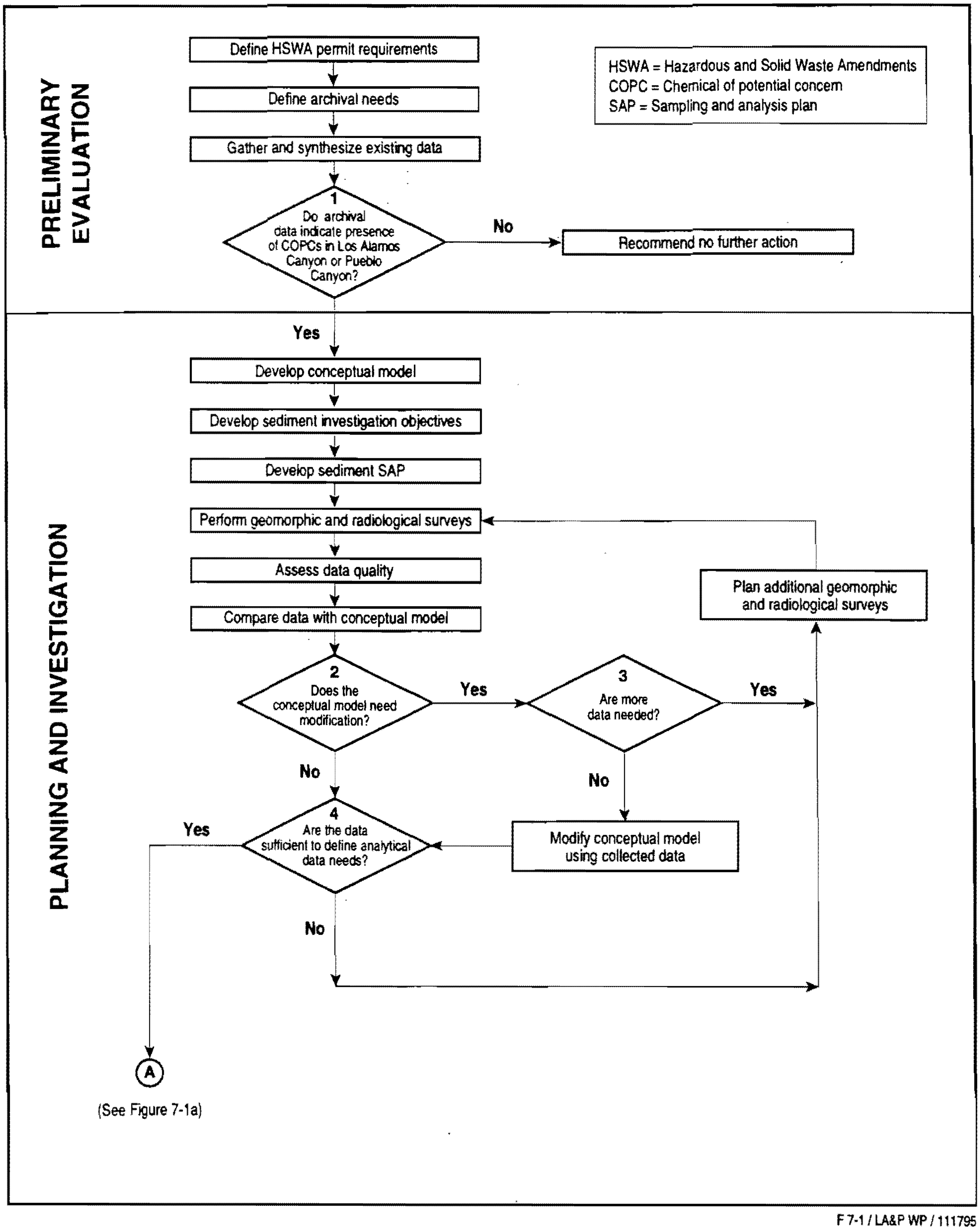

Figure 7-1. Technical approach for sediment investigation.

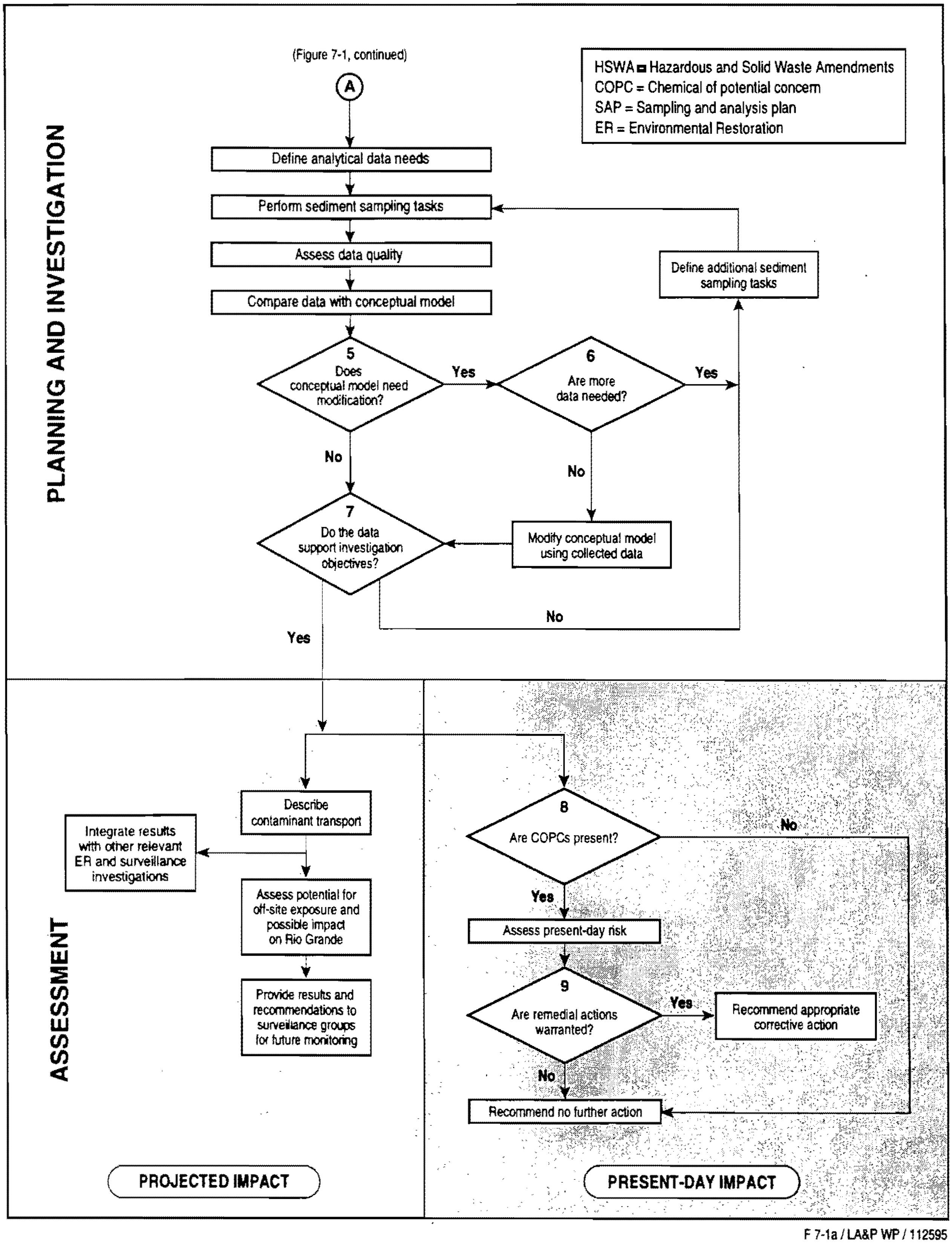

Figure 7-1a. Technical approach for sediment investigation.

TABLE 7-3

DESCRIPTION OF THE NINE CANYON REACHES PROPOSED FOR INVESTIGATION[a]

Reach	Length (m)	Area (× 1000 m^2)	Min. Width (m)	Max. Width (m)	Fall (m) / Gradient (m/km)	Description
Pueblo Canyon						
P-1	960	36	15	82	35/37	Downstream of Acid Canyon. Very narrow canyon floor with narrow channel. Land ownership: LA[b] County.
P-2	1,020	142	48	238	20/20	Possible residential use. Broadening canyon floor with narrow to wide channel. Land ownership: LA County.
P-3	1,050	283	140	420	18/17	Downstream of LA County sewage treatment plant outfall. Broad, flat canyon floor with wide channel. Land ownership: DOE[c]
P-4	1,035	270	140	400	21/20	Above confluence with LA Canyon. Broad to narrowing canyon floor with wide channel. Land ownership: DOE.
Upper Los Alamos Canyon[d]						
LA-1	730	60	60	108	21/24	Downstream of Technical Areas -2 and -41. Narrow, flat canyon floor with narrow, straight channel. Land ownership: DOE.
LA-2	850	76	40	198	20/24	Confluence with DP Canyon. Narrow canyon floor, broader at DP Canyon confluence, narrow channel. Land ownership: DOE.
LA-3	970	136	90	235	22/23	At eastern Laboratory boundary. Broad canyon floor with narrow to wide channel. Land ownership: DOE.
Lower Los Alamos Canyon[d]						
LA-4	1,045	184	115	310	27/26	Totavi reach. Broad, flat canyon floor with narrow to wide channel. Land ownership: San Ildefonso Pueblo.
LA-5	1,000	295	225	380	23/23	Confluence with Rio Grande. Broad, flat canyon floor with very wide channel. Land ownership: San Ildefonso Pueblo.

a. The dimensions of the reaches are approximate. The actual area investigated within each reach will be determined on the basis of the geomorphic characterization.
b. LA = Los Alamos
c. DOE = Department of Energy
d. The division between upper and lower Los Alamos Canyon is the confluence of Pueblo Canyon with Los Alamos Canyon.

The technical approach for the sediment investigation is shown in Figure 7-1. The major stages and decision logic are similar to those discussed in Chapter 5 of this work plan and shown in Figure 5-1. As shown in Figure 7-1, the products of the sediment investigation will be

- data to support an assessment of the present-day risk to on-site (within Laboratory boundaries) receptors and the potential for off-site exposure due to deposits of contaminated sediments in the canyons system,
- a description of contaminant transport down the canyons, and
- an assessment of the potential impact of contaminated sediments moving downstream to the Rio Grande.

7.2.2.1 Canyon Reaches Proposed for Investigation

The following sections describe each of the nine canyon reaches proposed for investigation and the significance of each reach for evaluating present-day risk and potential future impact of Laboratory-derived contaminants. The reaches chosen for the sediment investigation were four reaches in Pueblo Canyon (P-1 through P-4), three reaches in upper Los Alamos Canyon (LA-1 through LA-3), and two reaches in lower Los Alamos Canyon (LA-4 and LA-5). (The division between upper and lower Los Alamos Canyon is the confluence of Los Alamos Canyon and Pueblo Canyon.) Detailed maps of each reach are included with the individual descriptions (Figures 7-2 to 7-10). The boundaries shown on the maps of each reach indicate the general area that will be investigated; more precise definitions of the investigation boundaries will be based on the significant geomorphic units found within the reach. Characterization activities will be focused on those geomorphic units most likely to contain Laboratory-derived contaminants.

7.2.2.1.1 Pueblo Canyon Reaches

Reach P-1: Reach immediately downstream of Acid Canyon

Importance

Reach P-1, which is immediately downstream of Acid Canyon (Figure 7-2), is expected to have the highest concentrations of contaminants derived from Technical Area (TA) -45 (see discussion in Chapters 2 and 3 of this work plan). Therefore, Reach P-1 may present a higher risk to human health and the ecosystem than downstream reaches. A recreational land-use scenario is considered most likely for this area for the present-day risk assessment.

Reach P-2: The first downstream reach with a valley floor wide enough for a residential area outside the 100-year floodplain.

Importance

Downstream of Acid Canyon, Pueblo Canyon widens into a valley floor that could allow residential use outside the 100-year floodplain (Figure 7-3). Reach P-2 is

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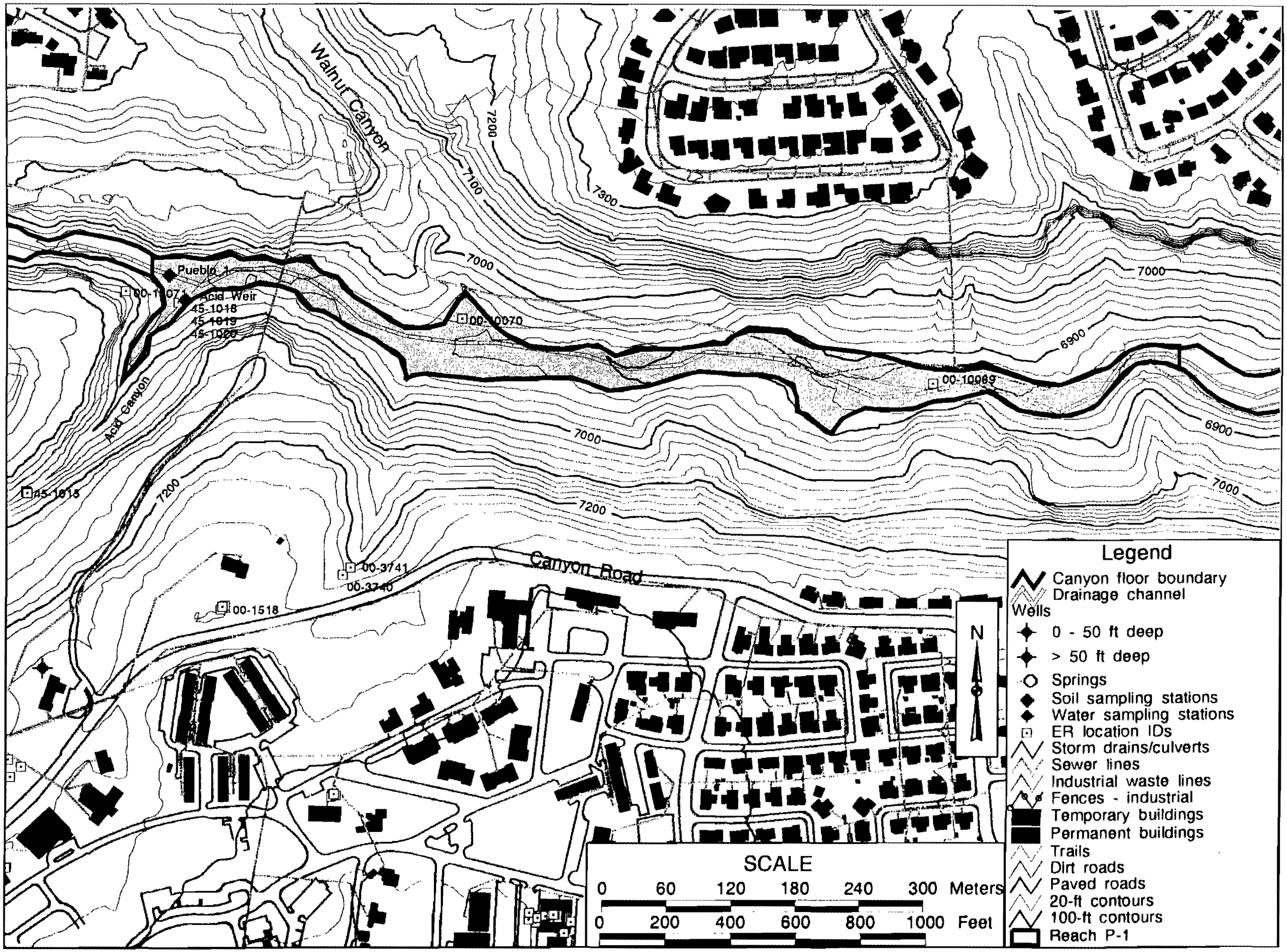


Figure 7-2. Detailed map of Reach P-1 in Pueblo Canyon.

p1 topo detail.ps 11/21/96

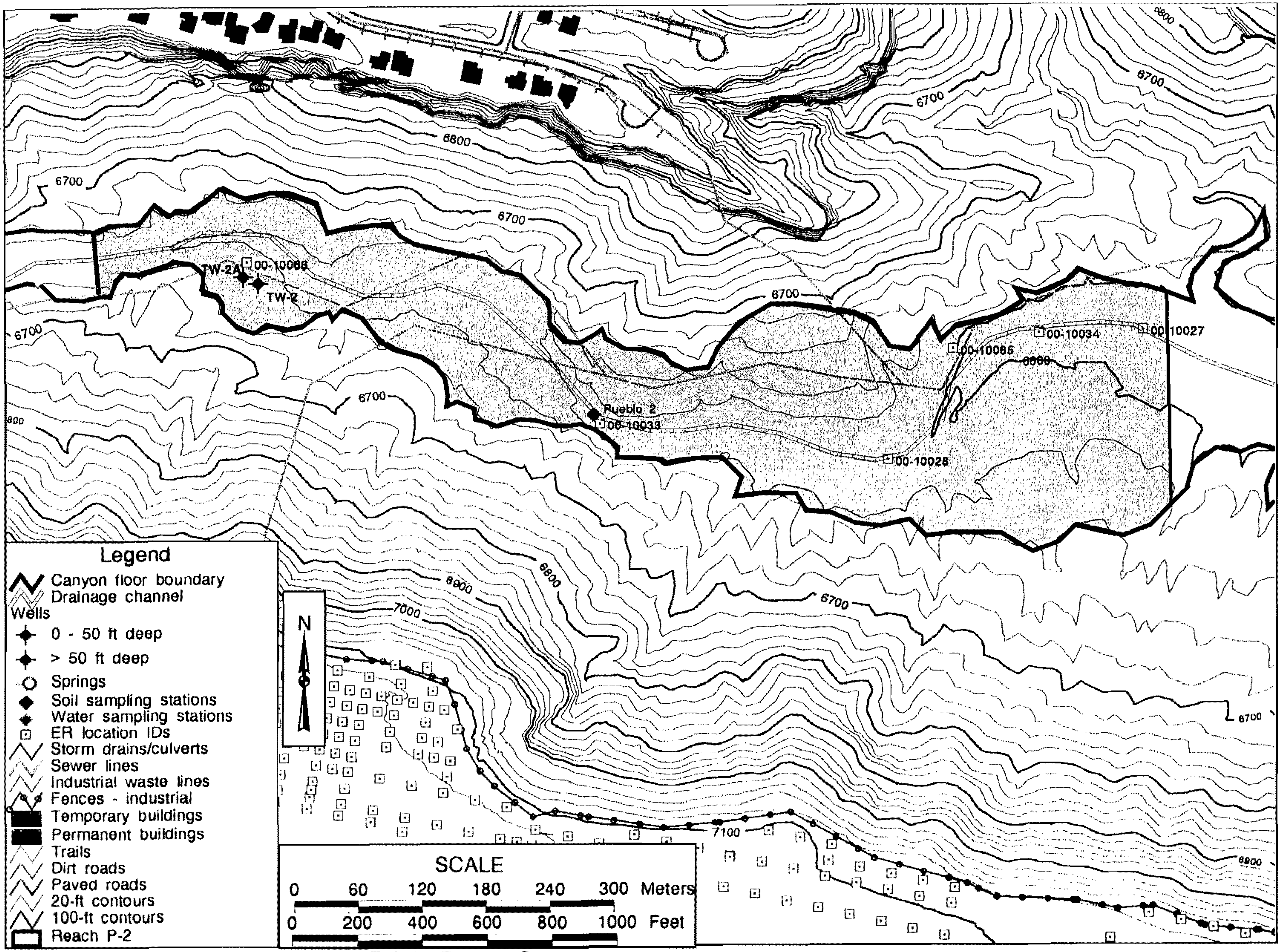


Figure 7-3. Detailed map of Reach P-2 in Pueblo Canyon.

p2 topo detail.ps 11/21/95

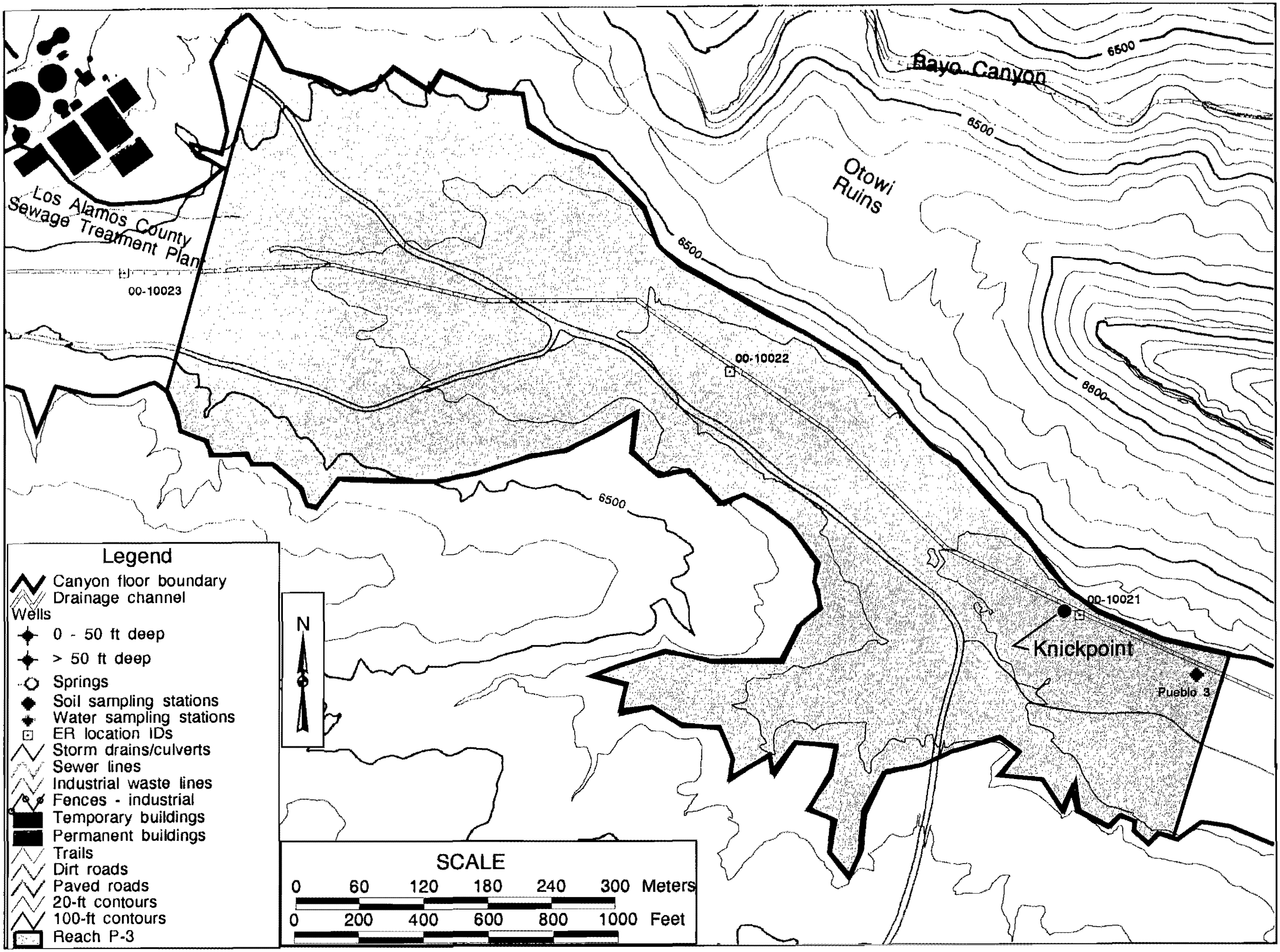


Figure 7-4. Detailed map of Reach P-3 in Pueblo Canyon.

p3_topo_detail.ps 11/21/95

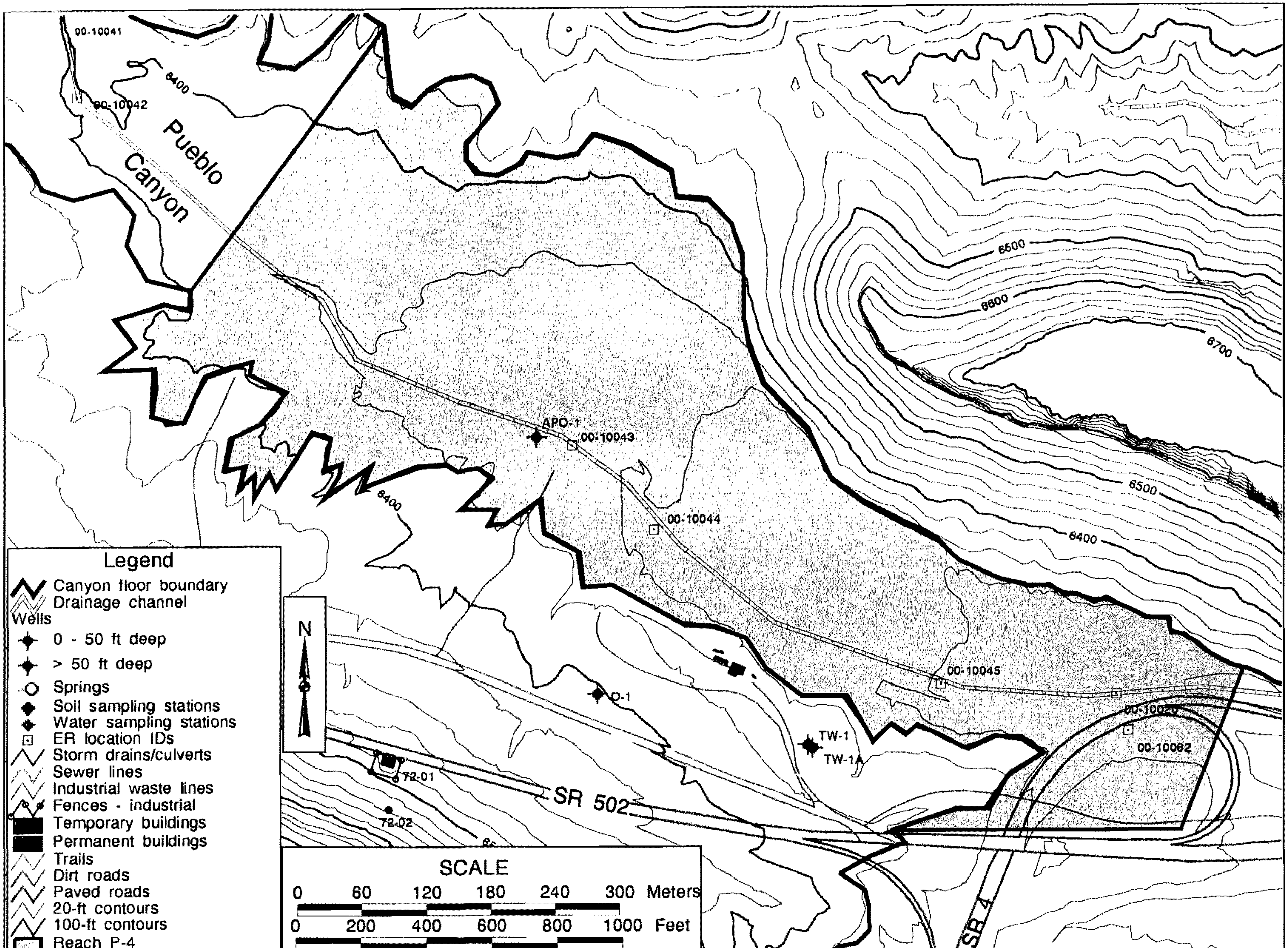


Figure 7-5. Detailed map of Reach P-4 in Pueblo Canyon.

p4_topo_detail.ps 11/21/95

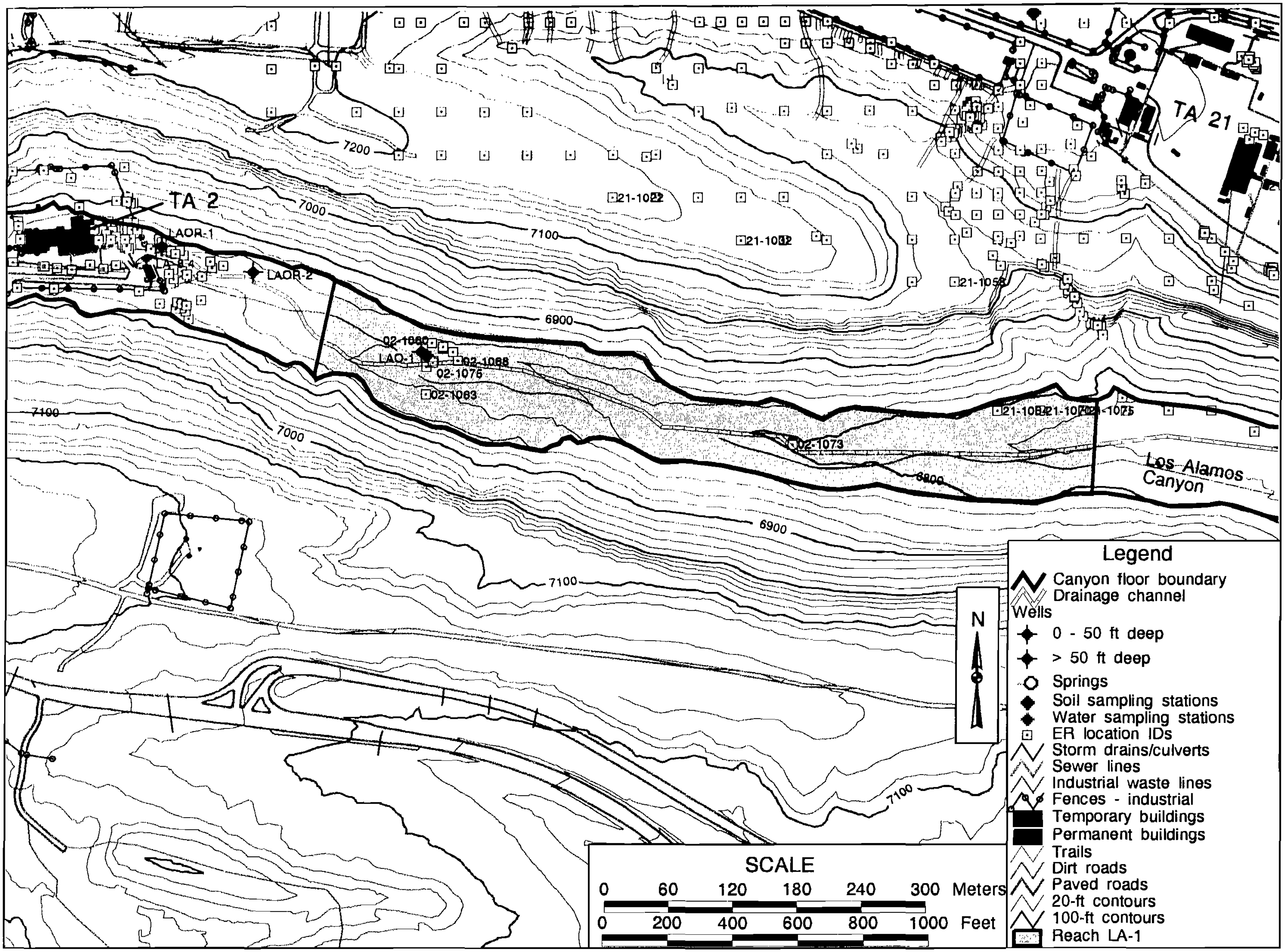


Figure 7-6. Detailed map of Reach LA-1 in upper Los Alamos Canyon.

la1_topo_detail.ps 11/21/95

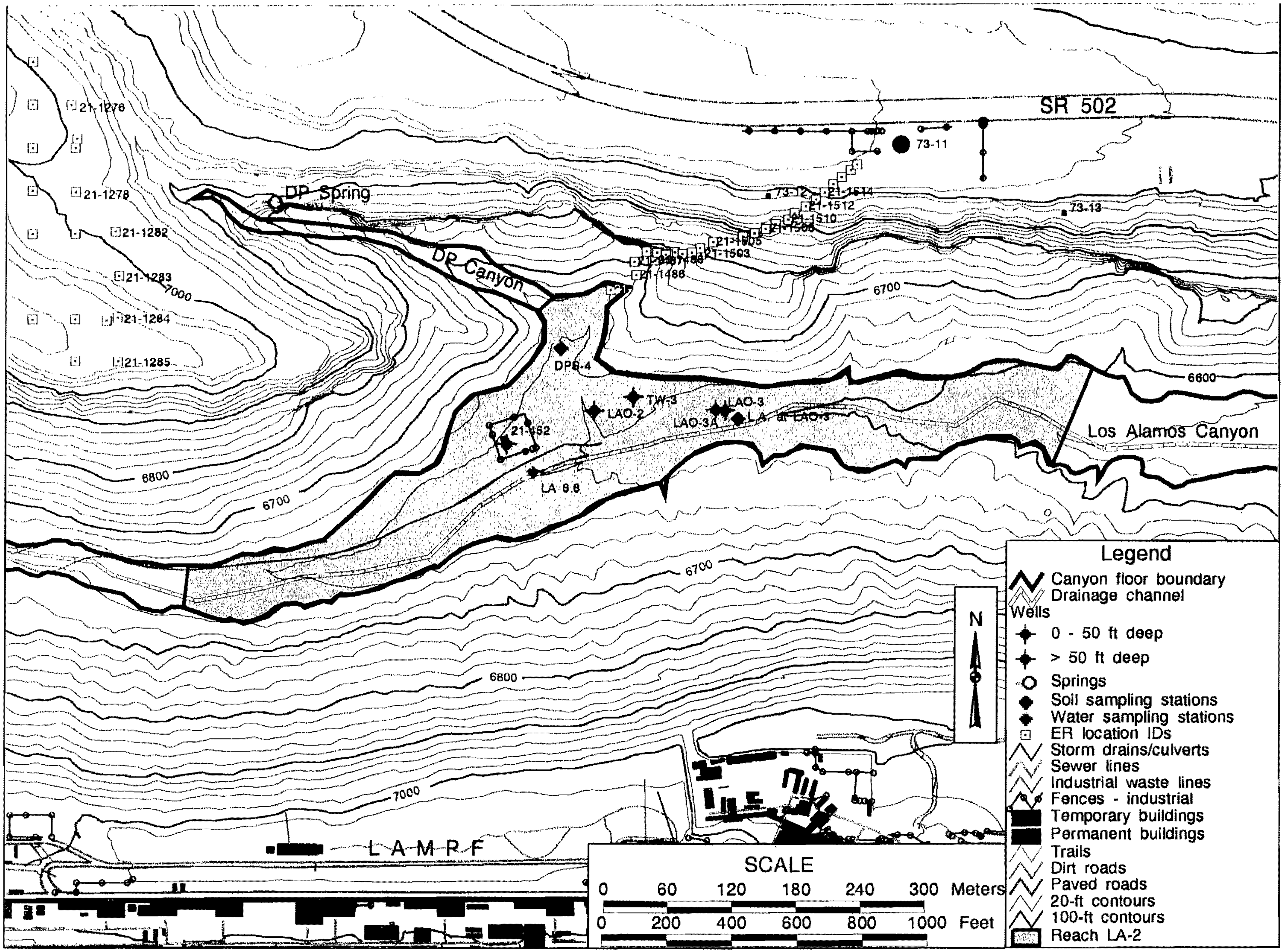


Figure 7-7. Detailed map of Reach LA-2 in upper Los Alamos Canyon.

la2_topo_detail.ps 11/21/95

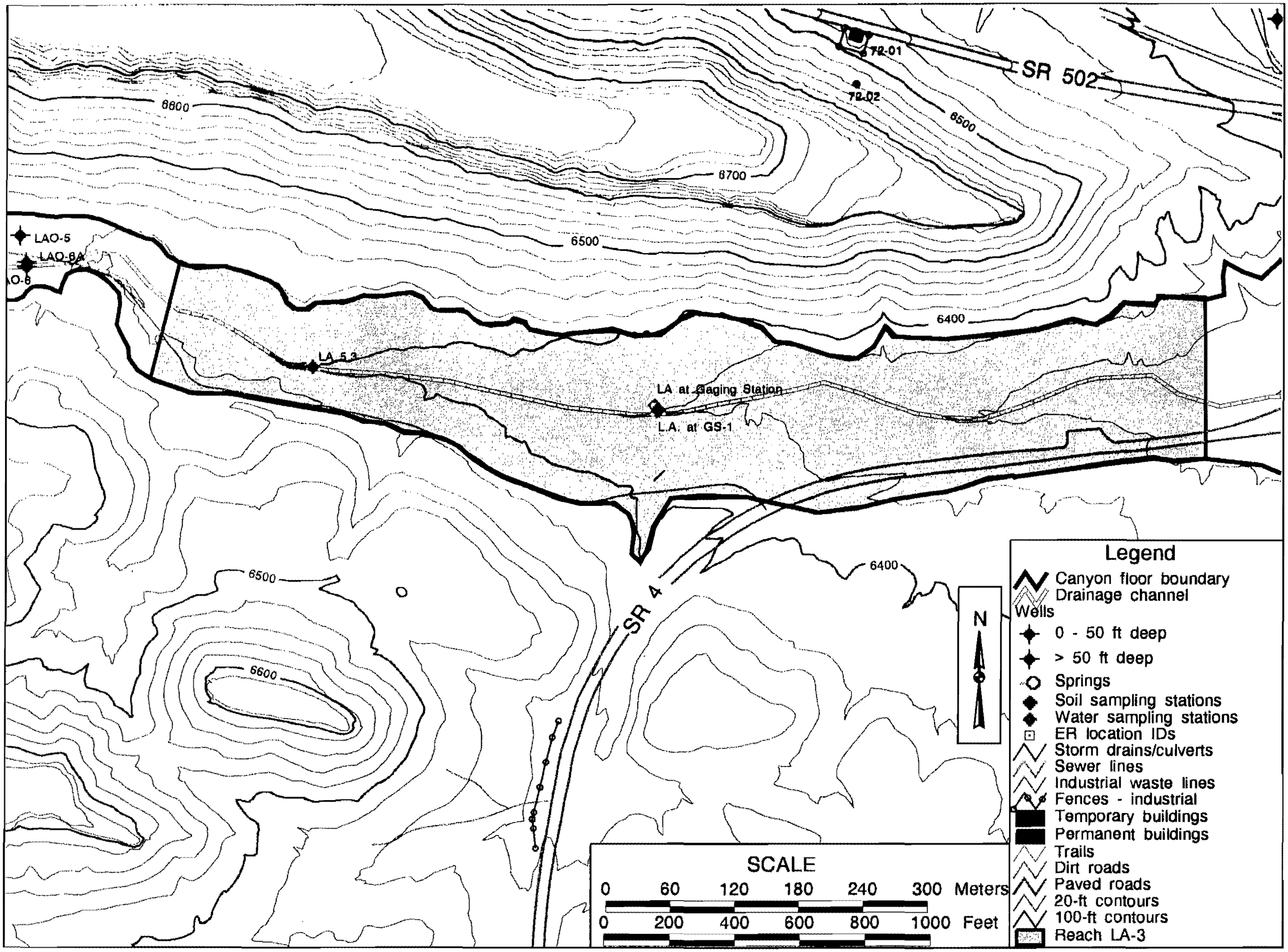


Figure 7-8. Detailed map of Reach LA-3 in lower Los Alamos Canyon.

la3_topo_detail.ps 11/22/95

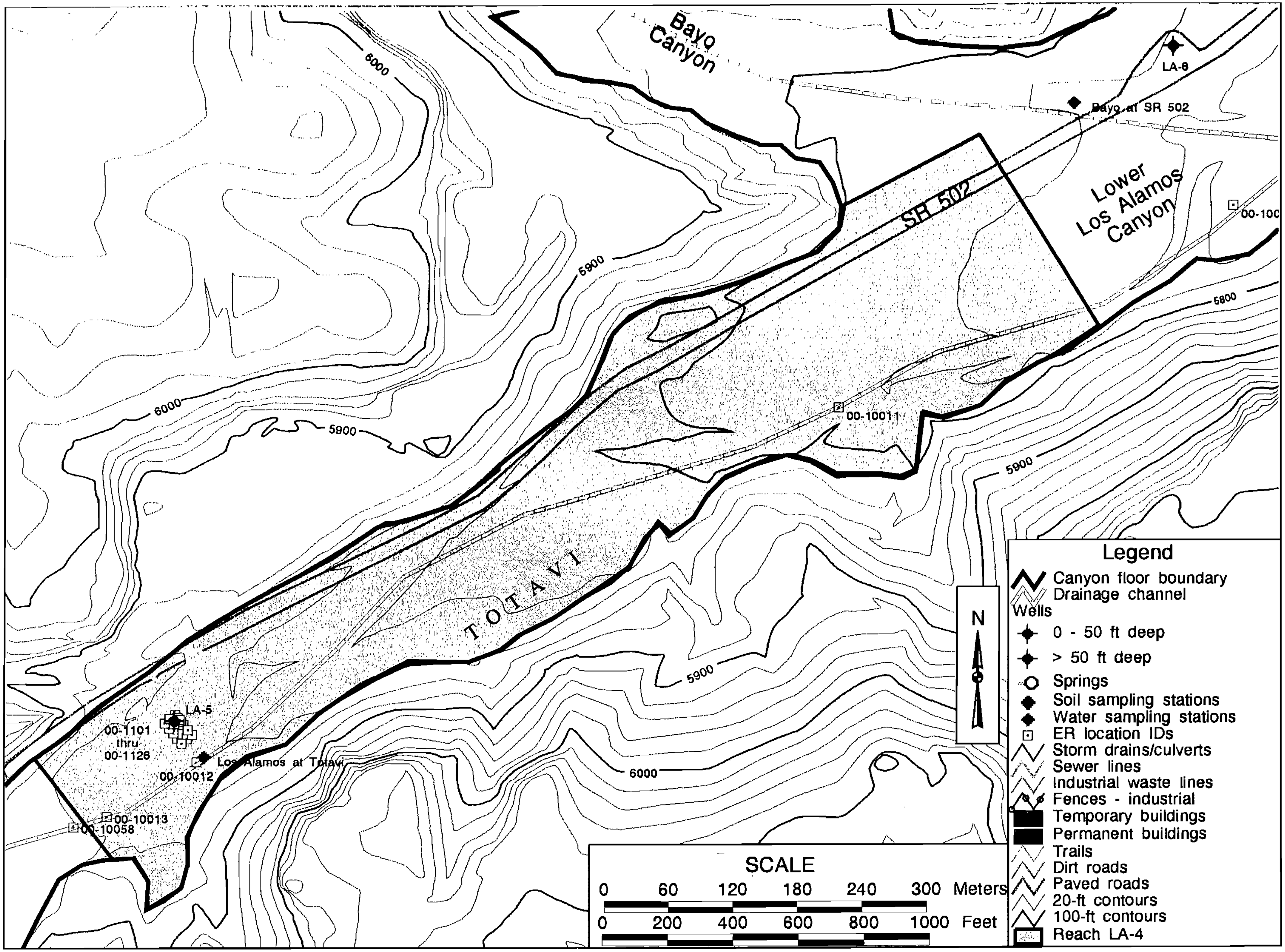


Figure 7-9. Detailed map of Reach LA-4 in lower Los Alamos Canyon.

la4_topo_detail.ps 11/22/95

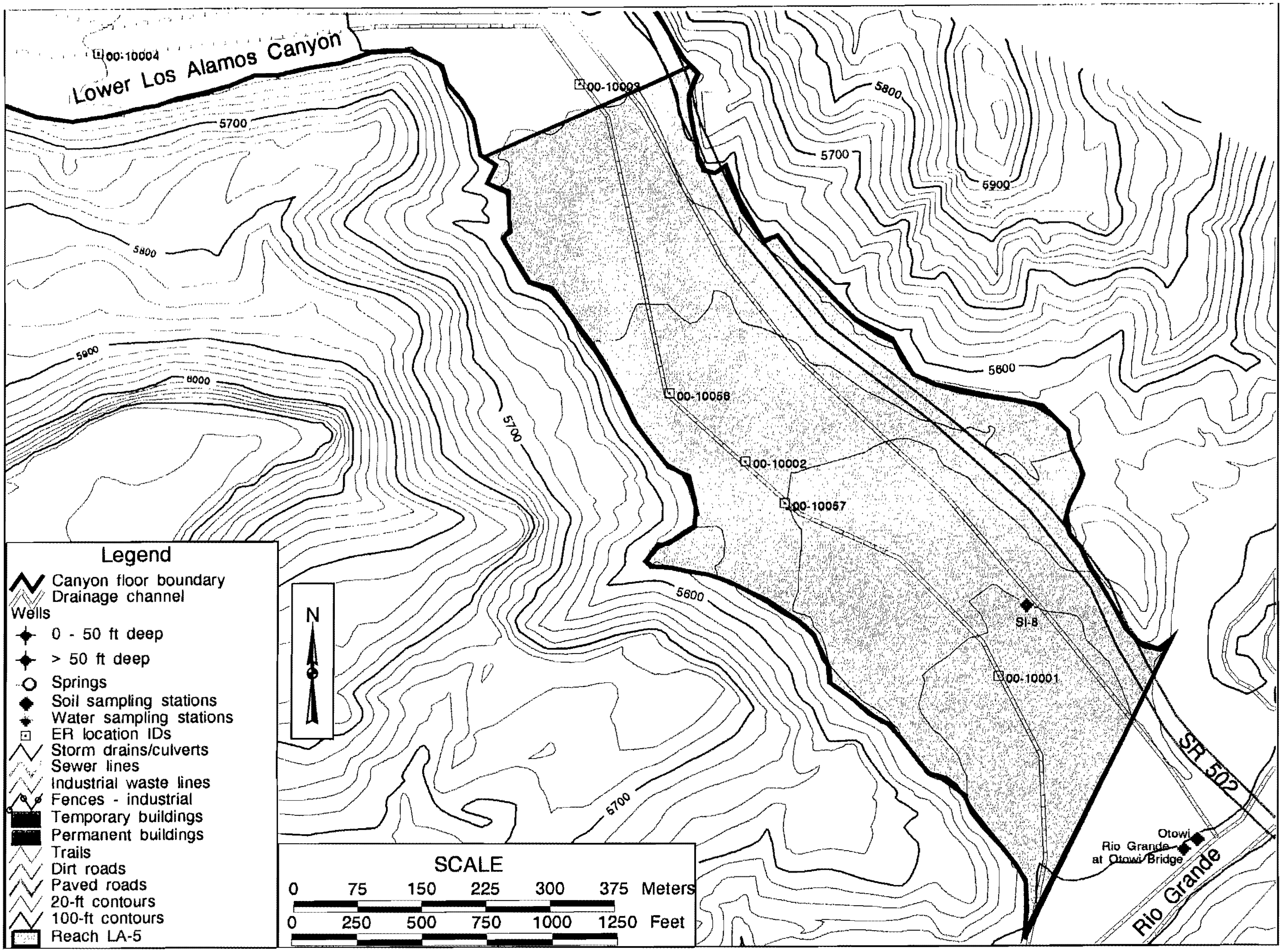


Figure 7-10. Detailed map of Reach LA-5 in lower Los Alamos Canyon.

la5_topo_detail.ps 11/22/95

expected to have the next highest concentration of contaminants derived from TA-45. In addition, this reach is likely to have larger volumes of stored contaminated sediment than the upstream reach (P-1) and is, for that reason, important to calculating an inventory and to establishing the relative importance of this geomorphic setting. Reach P-2 may provide an estimate of the maximum risk to human health for possible future residents in Pueblo Canyon.

Reach P-3: Reach immediately downstream from the Los Alamos County sewage treatment plant outfall

Importance

This reach of Pueblo Canyon, which is immediately downstream of the Los Alamos County sewage treatment plant and near surveillance sediment-sampling station Pueblo-3 (see Figure 7-4), includes a wide area of young sediment deposits. Reach P-3 also contains the highest estimated inventory of total plutonium and ^{241}Am of any reach in the Los Alamos Canyon and Pueblo Canyon systems (LANL 1981, 6059; Graf 1995, 48851). The extent of contamination may be greatest in this reach, resulting in greater impact than reaches with narrower, young sediment deposition zones. Reach P-3 also contains an actively eroding knickpoint where the channel gradient increases abruptly; thus, contaminated sediments stored in Reach P-3 are likely to be remobilized and moved downstream. Characterization of this reach is important to understanding the potential impact of the future transport of contaminants.

Reach P-4: Reach extending upstream from Indian Pueblo land

Importance

This reach (Figure 7-5) lies immediately upstream of San Ildefonso Pueblo land. Contaminants within this reach are the most likely of any in Pueblo Canyon to be transported off-site in the near future. Sampling Reach P-4 will determine the nature and extent of contamination present upstream from San Ildefonso Pueblo and Bandelier National Monument, as well as the nature of contaminants entering these properties from Pueblo Canyon. Previous studies in this area (LANL 1981, 6059; Graf 1995, 48851) indicate significant inventories of plutonium and ^{241}Am. The investigation proposed for Reach P-4 will verify previous studies and estimate contaminant movement over the past 15 years. A recreational land-use scenario is considered most likely for the present-day risk assessment.

7.2.2.1.2 Upper Los Alamos Canyon Reaches

Reach LA-1: Reach immediately downstream of TA-2 and TA-41

Importance

Previous studies in upper Los Alamos Canyon (LANL 1981, 6059; Graf 1995, 48851) indicate significant contamination with ^{137}Cs and ^{90}Sr (from TA-2 and TA-41) and uranium (from the former TA-1 on the mesa top). The reach immediately downstream of TA-2 (see Figure 7-6) is expected to have the highest concentration of contaminants derived from these areas. Therefore, Reach LA-1 may present the greatest present-day risk and future impact from contaminated sediments in Los Alamos Canyon. A recreational land-use scenario is considered most likely for Reach LA-1. Because the geomorphology of this reach has been mapped and sediments have been sampled during field investigations for TA-2 and TA-41, a fewer number of sediment samples may be required for characterization. Evaluation of the data from these Environmental Restoration (ER) Project investigations in Operable Unit 1098 is underway and the results will be included during the investigation of Reach LA-1.

Reach LA-2: Reach at the confluence of Los Alamos Canyon and DP Canyon, near source area TA-21

Importance

A variety of contaminants, including ^{241}Am, ^{137}Cs, ^{238}Pu, ^{239,240}Pu, and uranium, have been released directly through outfalls from TA-21 into Los Alamos Canyon and DP Canyon (LANL 1981, 6059; ESG 1971–1995). Diesel fuel may have been released from sites upstream of TA-21 in DP Canyon. The reach of Los Alamos Canyon extending upstream and downstream from the confluence with DP Canyon (see Figure 7-7) is expected to have the highest concentrations of contaminants derived from TA-21. Characterization of Reach LA-2 will differentiate the contributions of contaminants derived from TA-1, TA-2, and TA-41. Characterization will also allow defining of the present-day risk near these contaminant sources. A recreational scenario is considered most likely for Reach LA-2 for the present-day risk assessment.

Reach LA-3: Reach immediately upstream of the Laboratory boundary and Indian Pueblo land

Importance

This reach (Figure 7-8) lies immediately upstream of San Ildefonso Pueblo lands. Contaminants within this reach, since they are closest to the Laboratory boundaries, are the most likely of any in Los Alamos Canyon to be transported off-site in the near future. Investigating the reach upstream from state route 4 will provide information about the nature and extent of contamination at the Laboratory boundary, as well as the nature of contaminants potentially transported beyond the boundary into San Ildefonso Pueblo and Bandelier National Monument. Several factors—including the relatively low channel gradient, the broad valley floor, and the large channel transmission losses (rapid loss of water from the channel to surrounding sediments)—make it likely that Reach LA-3 will have an accumulation of young, contaminated sediments. Reach LA-3 may also contain a relatively high inventory of contaminants analogous to the contaminant accumulation documented for lower Pueblo Canyon (LANL 1981, 6059). A recreational land-use scenario is considered most likely for this reach for the present-day risk assessment.

7.2.2.1.3 Lower Los Alamos Canyon Reaches

Reach LA-4: Totavi reach, San Ildefonso Pueblo land

Importance

Reach LA-4 (Figure 7-9) contains the first significant deposits of sediment along lower Los Alamos Canyon on San Ildefonso Pueblo land. This reach also lies upstream from the confluence of Los Alamos Canyon with Bayo Canyon and Guaje Canyon, whose sediment loads will dilute contaminant concentrations in Los Alamos Canyon sediments. Reach LA-4 may contain the highest concentrations of Laboratory-derived contaminants along lower Los Alamos Canyon. Three residences are currently situated in Reach LA-4. Investigating of this reach will contribute to the estimates of contamination on Pueblo land and assess the present-day risk to the residential occupants.

Reach LA-5: Mouth of Los Alamos Canyon at the Rio Grande

Importance

Because Reach LA-5 (Figure 7-10) currently has residences and above-background concentrations of plutonium (ESG 1971–1995) are present in sediment in this area. Investigation of Reach LA-5 will contribute to the estimates of contamination on San Ildefonso Pueblo land and assess the impact of contaminants leaving the Los Alamos Canyon system and entering the Rio Grande. A residential land-use scenario (American Indian use) will be applied in the present-day risk assessment in this reach.

7.2.3 Field Surveys and Mapping of the Canyon Reaches

Each of the nine canyon reaches described in Section 7.2.2.1 will be surveyed and mapped, relying primarily on nonintrusive techniques. The survey and mapping tasks include land, radiological, and geomorphic surveys. The object of the survey is to produce detailed, accurate maps of each reach that will indicate the location, extent, and nature of geomorphic and radiological features. In particular, the correlation between geomorphic and radiological features, suggested by the conceptual model (see Chapter 4 of this work plan), will be critically examined by overlaying the results of the geomorphic and radiological surveys. If necessary, geomorphic mapping may be refined on the basis of the field radiological measurements.

Geomorphic and radiological surveys will be carried out concurrently within each canyon reach, and will involve field geologists and radiation-measurement specialists. The field surveys are designed to provide a high density of data. In addition to measuring gross radiation, field x- and gamma-radiation spectroscopy will be used to allow specialists to gather more detailed information about contaminant distribution. These field instruments provide data of high quality faster than the radiochemical analysis of discrete sediment samples. It is anticipated that increasing the amount and quality of data collected in the field will reduce the number of sediment samples required for chemical analysis. With detailed, accurate maps of each canyon reach, sediment samples can be collected at optimum locations to determine the nature and extent of contamination.

The land, geomorphic, and radiological survey tasks are discussed in the following sections. All field survey measurements are critical to the characterization of the canyon reaches.

7.2.3.1 Land Survey

Each canyon reach will be surveyed according to the ER Project standard operating procedure (SOP) LANL-ER-SOP-03.01,R1, "Land Surveying Procedures," to establish the boundaries of the reach and to allow accurate mapping of the field radiological data and the sample locations. Where access to sites outside the Laboratory boundary is required, access agreements will be obtained according to LANL-ER-AP-03.4, "Obtaining Access Agreements for Non-DOE Property." Survey measurements will use the New Mexico state plane coordinate system. All survey data will be submitted to the Facility for Information Management, Analysis, and Display (FIMAD).

7.2.3.2 Geomorphic Survey

Each canyon reach will be investigated according to LANL-ER-SOP-03.08, "Geomorphic Characterization." Field activities will be documented according to LANL-ER-SOP-03.12, "Field and Laboratory Notebook Documentation for ER Earth Sciences Studies." Geomorphic characterization activities focus on identifying, describing, and mapping surface deposits and land forms that provide evidence for processes that can result in storage and/or transport of contaminants. In particular, the survey will focus on identifying young, potentially contaminated sediment deposits. The identifying and mapping of the geomorphic units will be carried out by a professional geomorphologist, as designated by the technical team.

The geomorphic survey of each canyon reach will be guided by the conceptual model of the significant geomorphic features illustrated in Figure 7-11. At least four geomorphic units will be identified for each reach: the active channel, the inactive channel, the active (post-1943 deposition) floodplains, and the inactive (pre-1943) floodplains. Laboratory-derived contaminants are expected to occur in the active and inactive channels, and in the active floodplains but not in the inactive floodplain, which is defined for purposes of this investigation as that portion of the floodplain that was last inundated before 1943.

A further level of geomorphic identification may be required for the more complex canyon reaches. For example, various stages of evolution from channel to floodplain may occur within a reach and the boundary between units may not be distinct. Subunits such as midchannel bars and point bars may also be identified as significant features.

The following is a description of the three major geomorphic units that are expected to contain contaminants.

7.2.3.2.1 Active Channel

Active channel sediment is dominated by coarse sand and gravel. Because heavy metals and radionuclides discharged from the Laboratory in liquid effluent preferentially adsorb to finer-sized sediment particles, it is expected that the active channel may contain the lowest concentrations of contaminants. The sediments in the active channels are the most likely to be transported downstream, both by the relatively frequent low-magnitude floods and by occasional large floods in the canyons.

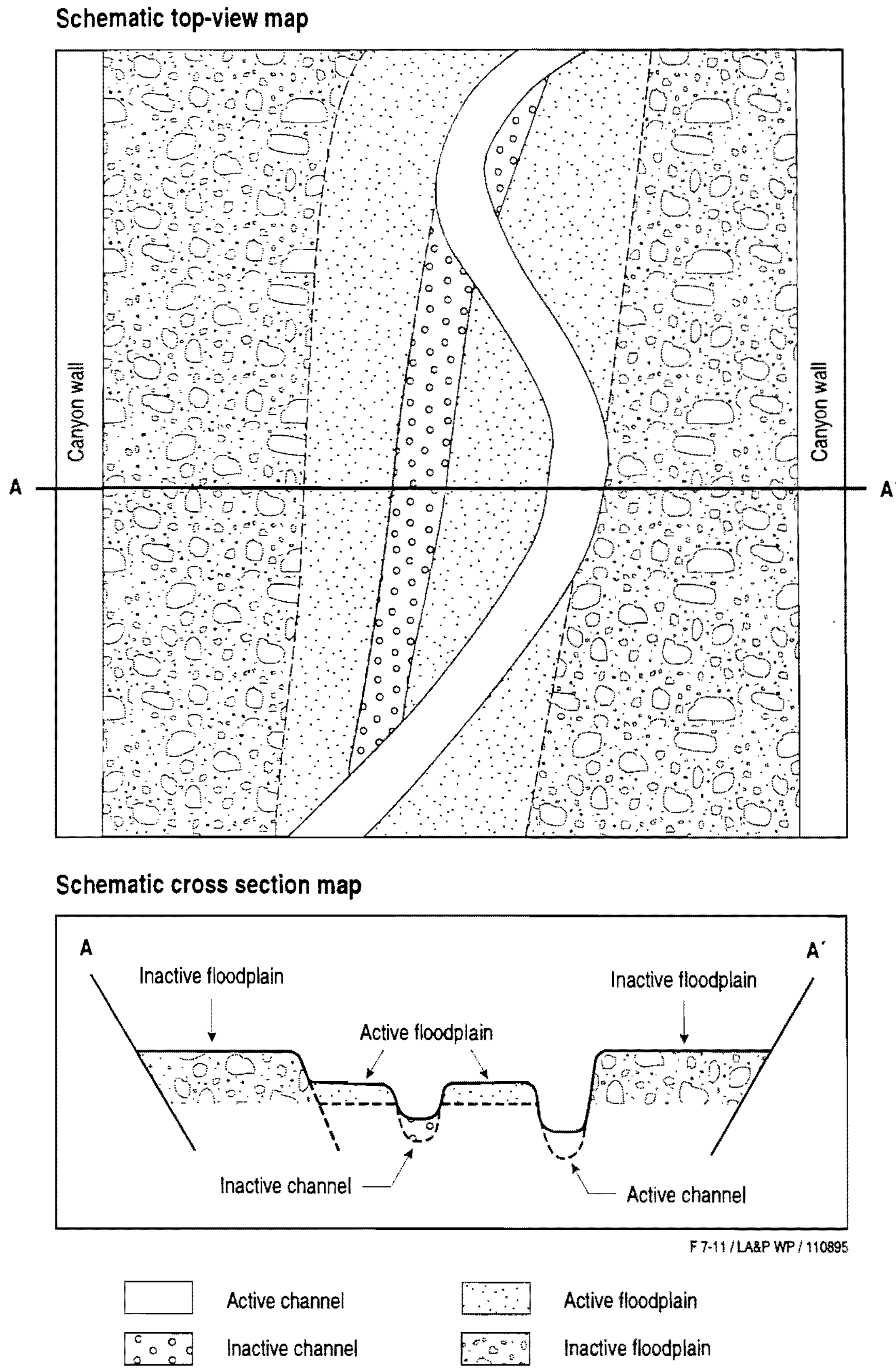


Figure 7-11. Schematic map and cross section of canyon floor showing general geomorphic units.

7.2.3.2.2 Inactive Channel

The inactive channels contain a combination of coarse channel sediment (deposited when the channels were active), and fine sediment (deposited by flooding after the channel became inactive). Contaminant concentrations are expected to vary, depending both on the grain size and the age of the deposit, as contaminant input will have varied over time. Available data suggest that the inactive channel deposits may contain large amounts of contaminants that are available for movement farther downstream either by large floods or by lateral erosion of the active channel.

7.2.3.2.3 Active Floodplains

The active floodplains are the sites of post-1943 sediment deposition. The sediment deposits consist of fine-grained particles deposited from the suspended load of overbank floodwaters in addition to buried coarse-grained sediment . Because heavy metals and radionuclides discharged in liquid effluent preferentially adsorb onto the fine-grained sediment, the contaminant concentrations may be highest in sediments within the active floodplains. The contaminant concentrations are expected to vary with the age of the deposit. Flood deposits in Pueblo Canyon from the late 1940s and the 1950s possibly contain the highest contaminant concentrations. The post-1943 overbank deposits may be relatively thin but widely distributed away from active channels. The sediment in the floodplains may have the longest residence times in the canyons because it probably moves little until mobilized by lateral erosion of the stream bank during large flood events.

Identifying the pre- and post-1943 floodplains is necessary to focus the geomorphic and radiological surveys within the general boundaries of each reach. Boundaries of geomorphic units are commonly marked by distinct topographic breaks, although in places such boundaries may be gradational and more difficult to delineate. Direct visual observation of partially buried objects and debris, especially those that can be linked to Laboratory activities, provide conclusive evidence of post-1943 deposition events and, therefore, the age of some geomorphic units. Further evidence for the age of geomorphic units can be obtained by observing the nature and age of vegetation in different areas of the reach, such as whether the bases of trees are buried by sediment. Flood debris, such as driftwood, may provide additional evidence of the extent of historic flooding and the distribution of historic overbank sediment deposition. One goal of the radiological survey will be to verify the boundaries of pre- and post-1943 sediment deposition. The geomorphic survey will provide the information necessary to guide the radiological survey, discussed in the following section, and the radiological survey will be used to refine the geomorphic mapping, if needed.

7.2.3.3 Radiological Survey

The objectives of the radiological survey are to

- provide information about the surface distribution of radiological contaminants across geomorphic units (for example, the active channels, the inactive channels, and the floodplains),
- provide information about the heterogeneity of contaminant distribution within geomorphic units,
- identify areas or spots where the radioactivity exceeds background levels by a statistically significant amount and which

may be candidates for detailed investigation, and

- provide information about subsurface (depths greater than 1 to 2 cm) deposits of contaminated sediments.

The first iterations of the radiological survey will use nonintrusive surface measurements of gross-alpha, -beta, -gamma, and x-radiation without isotope-specific determination. The gross radiation survey techniques will provide information about radioactivity originating from the surface of the sediment layer. Subsequent iterations may use intrusive subsurface measurements of gross-beta and -gamma radiation. The results of the gross radiation measurements will guide the selection of locations to be surveyed using spectroscopic instruments that will identify specific isotopes. The proposed instrumental techniques and their applications are summarized in Table 7-4.

Because of the shielding of particle emissions by fine particulate surface layers, vegetation cover, and ambient air, it may not be possible to obtain meaningful gross-alpha measurements at the surface using a standard zinc sulfide scintillator. Instead, surface x-radiation measurements can be performed using a Phoswich detector, which will detect the x-radiation emissions that accompany the alpha decay of the transuranic radionuclides (particularly ^{241}Am, ^{235}U, and ^{239}Pu). Meaningful gross-alpha measurements may be obtained by first removing the top 2- to 5-cm surface layer and then by detecting alpha particles using a zinc sulfide scintillator probe. Gross-beta or gross -beta/gamma measurements can be made using a Geiger-Müller pancake probe or gas proportional counter detectors. Detection of gross-gamma radiation can be achieved using a sodium iodide scintillator detector.

TABLE 7-4

DESCRIPTION OF RADIOLOGICAL SURVEY INSTRUMENTATION

Instrument/Detector	Emission Detected	Applications
Zinc sulfide (ZnS) scintillator	α	Gross-alpha radiation screening
Gas proportional counter	α/β	Gross-alpha/-beta radiation screening, field surveys, and point source detection
GM[a] pancake	β/γ	Gross-beta/-gamma radiation screening, field surveys, and point source detection
Plastic scintillator	β	Gross-beta radiation screening
Sodium iodide (NaI[Tl])[b] scintillator	γ	Gamma radiation screening, field surveys, and point source detection
Phoswich (NaI[Tl]/CsI[Tl])[c]	Low-energy x-radiation	Transuranics (U, Pu, Am) field screening, field surveys, and point source detection
FIDLER[d]	Low-energy x-radiation	Transuranics (U, Pu, Am) field screening and subsurface (1–2 cm) detection
LEHPGe[e]	γ/Low-energy x-radiation	Spectroscopic identification and quantification of transuranics (U, Pu, Am) and ^{137}Cs

a. GM = Geiger-Müller
b. NaI[Tl] = thallium-doped sodium iodide crystal
c. CsI[Tl] = thallium-doped cesium iodide crystal
d. FIDLER = field instrument for detecting low-energy radiation
e. LEHPGe = low-energy, high-purity germanium

The radiological survey measurement strategy is sketched in map view in Figure 7-12. The initial walk-over survey will take many short count-time (1 to 10 seconds) measurements. The short count time measurements will provide low-resolution, qualitative data over a large area and allow rapid identification of specific point sources of radioactivity ("hot spots"). Longer count-time (60 seconds or longer) measurements will be made at locations where radiological anomalies are detected and at selected locations within each geomorphic unit to achieve higher resolution data.

The minimum detectable activity of the detectors proposed to be used in a 60 second count of a 100 gram sampling is about 0.2 pCi/g for the gross radiation counters, and between 0.9 pCi/g (NAI[Tl]) and 0.08 pCi/g (low-energy, high-purity germanium [LEHPGe]) for the spectroscopic instruments.

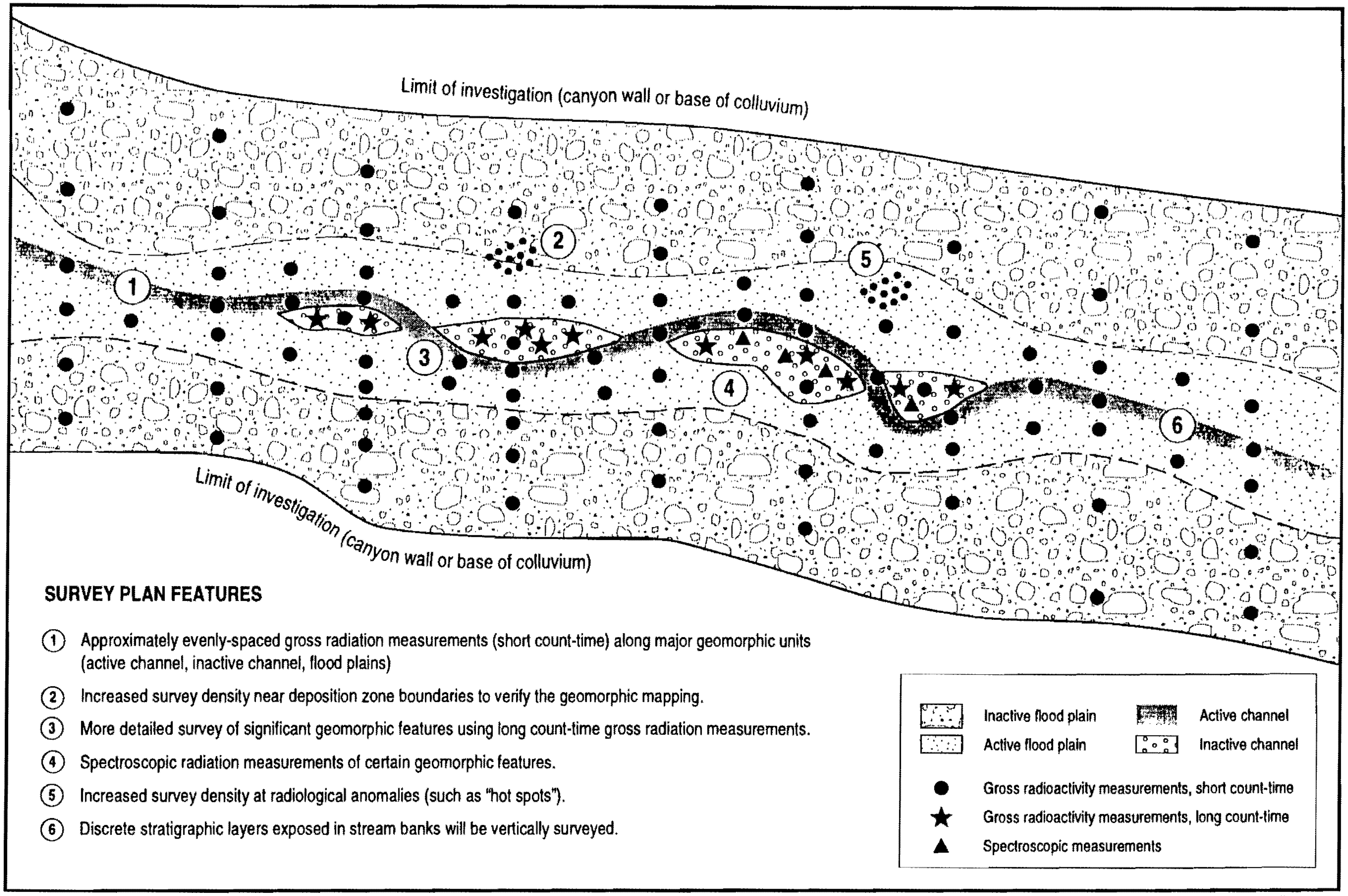
The feasibility of using radiotelemetry techniques, such as the Ultrasonic Ranging and Data System (USRADS) environmental surveying instrument (Chemrad Tennessee Corporation, Oak Ridge, TN) for high-resolution spatial data logging, will be examined. A chief advantage of the radiotelemetry technique is the ability to visualize the radiological survey data in real time. Geodetic measurements will also be made to provide locations for mapping of the radiological survey data.

The radiological survey is designed to provide a statistically significant amount of data for each of the geomorphic units identified by the geomorphic survey. The spacing between stationary measurement points will be varied based on the size and relative location of the geomorphic units investigated. The measurement point spacing may decrease as the boundaries between geomorphic features or deposition zones are encountered and at observed radiological anomalies. Discrete geomorphic features identified as potential deposition zones for contaminated sediments will be surveyed in more detail to provide information about contaminant distributions. The number of measurement points will depend on the size of the deposition zone, but at least three independent measurements will be obtained for a discrete feature.

Measurement points at which radiological anomalies are observed will be candidates for further investigation using spectroscopic detectors. The number of spectroscopic measurements will be decided with the assistance of the team statistician so that a representative number of measurements are made within each canyon reach. Spectroscopic measurements will also be performed in geomorphic features identified as pre-1943 deposition zones for the purposes of comparing and establishing a local radiological background. Two types of detectors have been identified for possible use in collecting spectroscopic data: the LEHPGe detector and the FIDLER (field instrument for detecting low-energy radiation).

To determine whether contaminants are present at subsurface depths and to evaluate possible variations in contaminant concentrations between sediment layers, the vertical faces of bank cuts along active and inactive channels will be surveyed for gamma radioactivity. To provide spatial definition of approximately 1 cm, either a thallium-doped sodium iodide scintillator or a high-purity germanium detector collimated with lead shielding is proposed for the vertical surface survey. Either detector is sensitive to gamma radiation, particularly to the 0.66 MeV emission of the ^{137m}Ba daughter of ^{137}Cs.

An important consideration in designing the field radiological measurements is an appropriate definition of the "background" radioactivity to be used as a decision level for comparison to field measurements. The decision level is usually defined as the



7-12 / LA&P WP / 112095

Figure 7-12. Proposed radiological survey strategy.

mean background value plus twice the standard deviation of the mean. Major contributions to the background count rate are emissions from naturally occurring radioactive material, cosmic rays, and electronic noise. The background level of radioactivity is expected to be different for each canyon reach, depending on proximity to Laboratory emission sources and the geology of the reach. The background count rate for a detector is usually determined by counting an area known to be uncontaminated and located as close to the sampling area as possible. If a known uncontaminated area close to the actual environmental measurement site is not available, the site can be surveyed and a background count rate determined by developing a statistical trend among the lowest measurements.

7.2.4 Sediment Sample Collection and Analysis

This section describes the process design for sediment sample collection in the nine canyon reaches. Particular emphasis is given to the criteria for selecting sample locations within each reach, and the rationale for choice of analytical suites. The methods requirements for sample collection and for the chemical, radiochemical, and geotechnical analyses are also provided in this section.

7.2.4.1 Sampling Design

Samples of sedimentary deposits within significant geomorphic units will be collected in each of the nine reaches proposed for investigation (Section 7.2.2.1). Surface samples will be collected to variable depths ranging from 0 to 1 ft, depending on the sediment stratum thickness. A surface sample interval of 0 to 1 ft is preferred to the 0 to 0.5 ft interval for some sites, (particularly along active and inactive channels), because with the larger sampling interval there is a greater probability of encountering contaminants released in the early years of Laboratory operation (which are now buried beneath younger, cleaner sediment).

To characterize historic deposition zones, subsurface sampling will be conducted in stream cuts and other locations where excavation will not be necessary.

Each sample location will be marked or permanently monumented (where possible), photographed, and assigned a unique ER Project sample location identification number. All samples will be field-screened using hand-held instruments at the point of collection for gross radioactivity and organic vapors. Upon submittal to the Sample Management Office, gross-alpha, -beta, and -gamma radiation measurements will be taken on each sample before transporting to the analytical laboratory.

As explained in Section 7.2.2, four sampling tasks have been defined for the sediment investigation. The four tasks consist of sample collection for background constituents, full-suite COPC, limited-suite COPC, and key contaminant analysis. Table 7-5 summarizes the sediment sample collection design for each of the sampling tasks, which are described in the following sections. Field quality assessment and quality control samples, such as field blanks and collocated samples, will be collected according to the most recent ER Project guidance (LANL 1995, 49822). Quality control samples are not included in the number of samples in Table 7-5.

TABLE 7-5

SUMMARY OF SEDIMENT SAMPLE COLLECTION DESIGN

Location	No. of Samples[a]	Analysis
Pueblo Canyon		
Upper canyon	8	Full-suite analyses for organic, inorganic, and radionuclide constituents; determination of background concentrations
Reaches P-1 and P-4	8[b] (4/reach)	Full-suite analyses for organic, inorganic, and radionuclide constituents; determination of COPCs[c]
Reaches P-1 through P-4	48[b] (12/reach, 4/geomorphic unit[d])	Limited-suite analyses for identified COPCs; representative statistic used for risk assessment
Reaches P-1 through P-4	To be determined[e]	Limited-suite analyses for key contaminants; description of transport mechanisms and assessment of projected impact
Los Alamos Canyon		
Upper canyon	8	Full-suite analyses for organic, inorganic, and radionuclide constituents; determination of background concentrations
Reaches LA-2, LA-3, and LA-5	12[b] (4/reach)	Full-suite analyses for organic, inorganic and radionuclide constituents; determination of COPCs
Reaches LA-1 through LA-5	60[b] (12 / reach, 4/geomorphic unit[d])	Limited-suite analyses for identified COPCs; representative statistic used for risk assessment
Reaches LA-1 through LA-5	To be determined[e]	Limited-suite analyses for key contaminants; description of transport mechanisms and assessment of projected impact

a. Surface sediment samples will be collected at depths of 0 to 1 ft.

b. The stated number represents the minimum number of samples that will be collected. Sufficient samples will be collected and analyzed to arrive at a reliable representative statistic for the contaminant concentrations.

c. COPC = chemical of potential concern

d. Additional samples may be collected if geomorphic units are subdivided to a more detailed level of identification, based on field surveys and judgment of field geologist.

e. The number of samples collected in this sampling task will be decided based on results of earlier sampling events.

7.2.4.1.1 Background Sample Collection

To prepare a data set of background constituent concentrations, background samples will be collected from areas upstream of the known Laboratory contaminant source areas. The background samples will be analyzed for the full suites of analytes defined in Section 7.2.4.3. Full-suite analyses are needed to establish background levels for all possible contaminants and to identify Laboratory-derived contaminants from Los Alamos townsite-derived contaminants.

At least two areas, one each in Los Alamos Canyon and Pueblo Canyon, will be selected in canyon reaches judged to be unaffected by Laboratory discharges. A minimum of eight sediment samples will be collected from each area, with three samples collected from the active channel and five samples collected from the floodplain. Samples collected from the active channel are expected to be dominated by coarse sediments and will not be size-sorted before analysis. Samples collected from the floodplain will exhibit a wide range of sediment particle sizes, and before analysis will be size-sorted into two aliquots: less than 125-µm and greater than 125-µm diameter. The two aliquots will undergo separate chemical analysis to evaluate the dependence of constituent concentrations on particle size. After the preliminary data set is evaluated, the technical team will decide the need for additional samples to develop a representative statistic for the background constituent distribution.

It is expected that the sediments in those reaches of Los Alamos Canyon and Pueblo Canyon that lie upstream of the Laboratory boundary will have a higher proportion of Tschicoma dacite and a smaller proportion of Bandelier Tuff than the sediments in downstream reaches. Therefore, the chemical composition of background samples collected upstream may not be entirely comparable to the background chemical composition in downstream reaches, as they represent a dacite-rich end member of the sediment geochemistry. Where possible, sediment samples will be collected from inactive (pre-1943) floodplains in the downstream reaches and analyzed to evaluate the comparability to the background chemical composition data set. In some reaches proposed for investigation, it may not be possible to obtain samples representative of a tuff-rich end member because of widespread contaminated sediments. Instead, the background chemical composition data sets available for other canyons on the Pajarito Plateau dominated by Bandelier Tuff (for example, Indio and Ancho Canyons) may be suitable.

7.2.4.1.2 Sample Collection for Full-Suite Analysis

Sediment samples will be collected and analyzed for a full suite of COPCs to define the limited suite of COPCs for subsequent sampling and analysis tasks. Constituent concentrations will be compared to the background data set to identify the COPCs that may pose potential human health or ecological risks. The results of the full-suite analyses will also be used to evaluate the comparability and representativeness of data collected in previous investigations. Full analytical suites for organic, inorganic, and radionuclide constituents are defined in Section 7.2.4.3.

Sediment samples for full-suite analysis will be collected from the canyon reaches closest to known source areas, from reaches immediately upstream of the eastern Laboratory boundary and from the reach at the confluence of Los Alamos Canyon system with the Rio Grande: specifically, reaches P-1 and P-4 in Pueblo Canyon and reaches LA-2, LA-3, and LA-5 in Los Alamos Canyon.

A minimum of four samples will be collected in each of the five reaches at locations where the highest radioactivity (alpha, beta, or gamma) is measured in the radiological survey. If numerous locations with elevated radioactivity are found in a reach, the technical team may decide to increase the number of samples collected for full-suite analysis to adequately characterize the nature of contamination. All full-suite analytical measurements planned are critical to the sediment investigation.

7.2.4.1.3 Sample Collection for Limited-Suite Analysis

Sediment samples for limited-suite analysis will be collected from each of the nine canyon reaches proposed for investigation. The sampling strategy will focus on representing the heterogeneity of each potentially contaminated geomorphic unit present in a reach. The specific sample locations will be identified on the basis of the geomorphic characterization and the radiological survey measurements, according to the following criteria.

- A minimum of four samples will be collected from each of three potentially contaminated geomorphic units in a reach: the active channel, the inactive channel, and the active floodplain.

- Within each potentially contaminated geomorphic unit, a minimum of two samples will be collected from locations at which the highest radioactivity (alpha, beta, or gamma) is measured in the radiological survey (which may include some locations from which the samples for full-suite analysis were collected).

- Within each potentially contaminated geomorphic unit, a minimum of two samples will be collected from randomly selected locations at which the radioactivity is at or near the decision level established by the radiological survey.

- If the geomorphic complexity of the reach warrants subdivision of a geomorphic unit to a more detailed level of identification, a minimum of four samples will be collected from each additional geomorphic level.

The results of the limited-suite and full-suite analyses comprise the data set that will be used for the human health and ecological risk assessments. The total number of samples collected for limited-suite analysis will depend upon the observed distribution of the COPC concentrations and will be sufficient to develop a defensible, representative statistic for present-day risk assessment purposes.

7.2.4.1.4 Sample Collection for Key Contaminant Analysis

Additional sediment samples will be collected to provide information about the distribution of contaminants to address hypotheses related to sediment transport mechanisms as discussed in Section 7.2.2, and to refine the conceptual transport model (Chapter 4 of this work plan). Because of the prohibitive cost of full-suite analysis, it is proposed to focus the analyses on certain "key" contaminants to obtain data for a large number of samples at a reasonable cost.

The key contaminants will be selected according to the following criteria:

- any contaminant which is present at levels such that it may contribute significantly to the present-day human health or ecological risk, and/or

- any contaminant for which a correlation with the concentration or behavior of other contaminants can be established and which can be quickly and inexpensively analyzed.

Plutonium is a candidate under the first criterion. A large volume of data collected to determine the present-day distribution of plutonium in the Los Alamos and Pueblo Canyon systems will increase confidence in both the present-day risk and the projected impact assessments. Under the second criterion, radionuclides such as ^{137}Cs or ^{90}Sr may be likely candidates. Cesium behaves similarly to other COPCs, such as plutonium and heavy metals. A strong correlation between the concentrations of ^{137}Cs and plutonium has been noted previously in Mortandad and DP Canyons (Nyhan et al. 1982). Strontium, which usually exists as Sr^{2+} in aqueous solution, may be an analog for uranium (as the uranyl ion, UO_2^{2+}), because the two species have similar geochemical traits and are more mobile in aqueous environments than ^{137}Cs. Key contaminant concentrations will be measured in samples from particular geomorphic units, different sediment strata, and sedimentary deposits of different ages. The data will be used to

- verify the boundaries between pre- and post-1943 sedimentary deposits,
- evaluate and refine the conceptual model for contaminant release and transport,
- verify previous estimates of the contaminant inventory, and
- assess projected impacts of Laboratory-derived contaminants on off-site areas and the Rio Grande.

The number and location of additional sediment samples will be determined on the basis of the radiological and geomorphic surveys within each reach. It is anticipated that a large number of samples (50 or more from each canyon) may be required to provide data of sufficient quantity and quality.

The data from key contaminant analyses will be used to support risk assessment only if the quality of the data meets standards normally accepted for such uses and/or if an acceptable correlation between the concentration of the key contaminants and the COPCs used in human health risk assessment can be established.

7.2.4.2 Sampling Methods

Surface sediment samples will be collected using the methods and ER Project SOPs listed in Table 7-6. Most samples collected in the initial sampling tasks will be grab (0 to 0.5 ft depth) or vertical composite (0 to 1 ft depth intervals) samples. Grab or vertical composite samples may be collected at depths exceeding 1 ft based on the judgment of field geologists. The tools used to collect the sediment samples will depend on the cohesion of the sediment material, the collection depth, and the presence of flowing or standing surface water. A scoop or ring sampler will be used to collect surface sediment samples at depths of 0 to 0.5 ft. A spade or hand auger may be used to collect sediment samples at depths up to 1 ft. A hand auger will be used to collect samples at depths exceeding 1 ft. If undisturbed lithologic samples are required to examine sedimentary strata, an open tube (Trier) or thin-wall tube sampler will be employed. If surface water is present at the sampling location, a scoop, trowel, or hand corer will be used to collect grab sediment samples.

TABLE 7-6

SUMMARY OF SEDIMENT SAMPLING METHODS REQUIREMENTS

Sampling Tools	Sample Types	Sampling Depth	LANL-ER-SOP No.
Spade and scoop	Surface grab	0–1 ft	06.09
Ring sampler	Surface grab	0–0.5 ft	06.11
Thin-wall tube	Surface grab; lithologic (undisturbed)	0–5 ft	06.10
Hand auger	Surface or subsurface grab; vertical composite	0–5 ft	06.10
Open tube (Trier)	Lithologic (undisturbed)	0–5 ft	06.17
Scoop and trowel	Grab (under surface water)	0–0.5 ft	06.14
Hand corer	Grab (under surface water)	0–0.5 ft	06.14

All samples will be collected using the applicable ER Project SOPs for the collection, preservation, identification, storage, transport, and documentation of environmental samples, as described in Section 4.4 in Chapter 4 of the Installation Work Plan (IWP) (LANL 1995, 49822). Decontamination of sampling equipment will be performed in accordance with LANL-ER-SOP-01.08, "Field Decontamination of Drilling and Sampling Equipment." Wash water and other wastes generated during the sampling operation will be managed and disposed of in accordance with LANL-ER-AP-05.3, "Management of ER Program Wastes."

7.2.4.3 Analytical Methods

Sediment samples collected according to criteria outlined in Section 7.2.4.1.2 will undergo full-suite analyses for organic, inorganic, and radionuclide constituents. All analyses will be performed at an ER Project-approved fixed-site laboratory. The analytical suites and methods for analysis of organic constituents are listed in Table 7-7. The analytical suites include semivolatile organic compounds (SVOCs), organochlorine

TABLE 7-7

ANALYTE SUITES AND ANALYTICAL METHODS FOR ANALYSIS OF ORGANIC CONSTITUENTS IN SEDIMENT SAMPLES[a]

Analyte Suite	Analytical Method	Analytical Protocol[b]
Organochlorine pesticides	GC/ECD[c]	SW-8081A
Polychlorinated biphenyl compounds	GC/ECD	SW-8081A or SW-8082
Semivolatile organic compounds	GC/MS[d]	SW-8270
Volatile organic compounds[e]	GC/MS	SW-8260

a. Detailed analyte lists and estimated quantitation limits can be found in the Environmental Restoration Project analytical services statement of work (LANL 1995, 49738).
b. EPA SW-846 Methods (EPA 1986, 31733)
c. GC/ECD = gas chromatography/electron capture detector
d. GC/MS = gas chromatography/mass spectrometry
e. Sediment samples will be analyzed for volatile organic compounds only if field screening indicates their presence.

pesticides, and polychlorinated biphenyl compounds (PCBs), which will be analyzed in each sample. Analysis for volatile organic compounds (VOCs) will be performed on any sample for which a significant organic vapor measurement is obtained by field screening using hand-held instruments. All analyses for organic constituents will be performed according to EPA SW-846 protocols (EPA 1986, 31733). The detailed analyte lists, estimated quantitation limits (EQLs), required quality control (QC) procedures, and the acceptance criteria are found in the ER Project analytical services statement of work (LANL 1995, 49738).

The target analytes, estimated detection limits (EDLs), and analytical methods for inorganic constituents are listed in Table 7-8. All analyses for inorganic constituents will be performed according to EPA SW-846 protocols, using mineral acid sample extraction procedures for the inductively coupled plasma emission spectroscopy, graphite furnace atomic absorption, and inductively coupled plasma mass spectrometry techniques.

The target analytes and their half-lives, detected emission, EQLs, and analytical methods for radionuclide constituents are listed in Table 7-9. Before chemical separation and counting for alpha or beta emissions, samples will undergo a complete digestion or fusion procedure. All samples submitted for tritium analysis will also be analyzed for moisture content. The analyte list for the gamma spectroscopy analysis, Table 7-10, includes long-lived activation and fission products, as well as shorter-lived daughter products. The shorter-lived daughter products are included in the analyte list in order to verify the presence of the longer-lived parents. The shorter-lived radionuclides (half-life less than 180 days) are not considered to be COPCs. Sediment samples will be prepared for gamma spectroscopy measurements by homogenization and drying; no sample extraction will be performed. The required QC procedures and acceptance criteria for both the inorganic and radiochemical analyses are found in the ER Project analytical services statement of work (LANL 1995, 49738).

Sediment samples will be collected to represent specific geomorphic strata, and it is important that the laboratory sample be representative of the sediment stratum that is collected in the field. To identify patterns in the distribution of heavy metals and radionuclides in the geomorphic strata, it is important that the sample preparation method be consistent. To meet the objectives for representativeness and comparability, the sediment samples will be well-mixed in the field using a stainless steel bowl and spoon before containerizing. Large stones and organic and other debris will be removed from the sample by hand. Sediment samples submitted for inorganic and radiochemical analyses will be homogenized by the laboratory but will not be sieved or otherwise size-sorted (with the exception of the background samples). The laboratory will be instructed to take representative aliquots from the homogenized sample for each analysis.

All analyses for the limited suite of COPCs will use the methods and procedures described for the full-suite analyses.

Analyses for key contaminants will use either the fixed-site laboratory procedures or mobile laboratory facility measurements (if reliable methods are available) or a combination of fixed-site and mobile laboratory analyses. The technical team chemist will choose the appropriate methods based on the data quality objectives developed for the key contaminant sampling task.

In addition to the chemical and radiochemical analyses, selected sediment samples will undergo geotechnical analysis for particle size distribution, using the American

TABLE 7-8

ANALYTE LIST, ESTIMATED DETECTION LIMITS, AND ANALYTICAL METHODS FOR INORGANIC CONSTITUENTS IN SEDIMENT SAMPLES

Analyte	EDL[a] (mg/kg)	Analytical Method	Analytical Protocol[b]
Metals			
Aluminum	40	ICPES[c]	SW-6010B
Antimony	12	ICPES or ICPMS[d]	SW-6010B or SW-6020
Arsenic	2	GFAA[e] or ICPMS	SW-7060 or SW-6020
Barium	40	ICPES	SW-6010B
Beryllium	1	ICPES	SW-6010B
Boron	10	ICPES	SW-6010B
Cadmium	1	ICPES	SW-6010B
Calcium	500	ICPES	SW-6010B
Chromium	2	ICPES	SW-6010B
Cobalt	10	ICPES	SW-6010B
Copper	5	ICPES	SW-6010B
Iron	20	ICPES	SW-6010B
Lead	0.6	GFAA or ICPMS	SW-7421 or SW-6020
Magnesium	1000	ICPES	SW-6010B
Manganese	3	ICPES	SW-6010B
Mercury	0.1	CVAA[f]	SW-7471A
Nickel	8	ICPES	SW-6010B
Potassium	500	ICPES	SW-6010B
Selenium	1	GFAA or ICPMS	SW-7741 or SW-6020
Silver	2	ICPES	SW-6010B
Sodium	500	ICPES	SW-6010B
Thallium	2	GFAA or ICPMS	SW-7841 or SW-6020
Titanium	1	ICPES	SW-6010B
Uranium (total)	0.5	ICPMS	SW-6020
Vanadium	10	ICPES	SW-6010B
Zinc	4	ICPES	SW-6010B
Other inorganics			
Total cyanide	0.05	Colorimetry	SW-9012A

a. EDL = estimated detection limit
b. EPA SW-846 Method (EPA 1986, 31732).
c. ICPES = inductively coupled plasma emission spectroscopy
d. ICPMS = inductively coupled plasma mass spectrometry
e. GFAA = graphite furnace atomic absorption
f. CVAA = cold vapor atomic absorption

TABLE 7-9

ANALYTE LIST, ESTIMATED QUANTITATION LIMITS, AND ANALYTICAL METHODS FOR RADIONUCLIDE CONSTITUENTS IN SEDIMENT SAMPLES

Analyte	Half-Life (yr)	Detected Emission	EQL[a] (pCi/g)	Analytical Method
^{3}H	12.3	β	300 pCi/L	LSC[b]
^{238}Pu	87.7	α	0.1	α-Spectrometry
$^{239,240}Pu$[c]	2.410×10^{4}	α	0.1	α-Spectrometry
^{90}Sr	29.1	β	2.0	GPC[d]
^{230}Th	7.54×10^{4}	α	0.1	α-Spectrometry[e]
^{232}Th	1.40×10^{10}	α	0.1	α-Spectrometry
^{234}U	2.46×10^{5}	α	0.1	α-Spectrometry
^{235}U	7.04×10^{8}	α	0.1	α-Spectrometry
^{238}U	4.47×10^{9}	α	0.1	α-Spectrometry
Gamma spectroscopy[f]	–	γ	1[g]	γ-Spectroscopy
Gross-alpha	–	α	10.0	GPC or LSC
Gross-beta	–	β	10.0	GPC or LSC
Gross-gamma	–	γ	2.0	NaI(Tl)[h] or HPGe[i] detection

a. EQL = estimated quantitation limit
b. LSC = liquid scintillation counting
c. The ^{239}Pu and ^{240}Pu isotopes cannot be distinguished by alpha spectrometry. The half-life of ^{239}Pu is given.
d. GPC = gas proportional counter
e. Radionuclide may also be analyzed by inductively coupled plasma mass spectrometry.
f. The gamma spectroscopy analyte list is given in Table 7-10.
g. The minimum detectable activity for ^{241}Am and ^{137}Cs is 1 pCi/g; the value for other analytes will vary.
h. NaI(Tl) = thallium-doped sodium iodide
i. H PGe = high-purity germanium

Society for Testing and Materials (ASTM) methods described in LANL-ER-SOP-11.02, "Particle Size Distribution of Soil/Rock Samples." Specifically, ASTM Method D 422-63 will be used to determine the 10 µm size fraction (respirable particulate) in sediment samples. Other geotechnical analyses, such as mineralogy, may be performed at the discretion of the technical team geologists.

7.2.5 Reconciliation with Data Quality Objectives

This section briefly describes the data quality objectives process (EPA 1994, 50288) as completed for the geomorphic and radiological surveys and the sediment sampling portion of this chapter.

TABLE 7-10

ANALYTE LIST AND HALF-LIVES OF RADIONUCLIDES MEASURED USING GAMMA SPECTROSCOPY

Analyte	Half-Life (yr)
COPCs[a]	
^{241}Am[b]	432.2
^{60}Co	5.271
^{137}Cs[b]	30.0
Other[c]	
Actinium series isotopes (daughters of ^{235}U)	
Decay products of activation products	
Thorium series isotopes (daughters of ^{232}Th)	
Uranium series isotopes (daughters of ^{238}U)	

a. COPC = chemical of potential concern
b. Required estimated quantitation limit for these radionuclides is 1 pCi/g or 1 pCi/L.
c Certain short-lived daughter products are measured to verify the presence of the longer-lived parent isotopes. Daughter product isotopes with half-lives less than 180 days are not considered to be COPCs.

7.2.5.1 Geomorphic and Radiological Survey Data Quality Objectives

1. State the problem

What areas in the selected reaches are representative of the distribution of contaminants in the various sedimentary facies defined for the canyons?

2. Identify the decision(s)

- Are geomorphic units sufficiently homogeneous to require no subdivision?
- Where should reach samples be taken for full-suite analytical chemistry?
- Where should reach samples be taken for limited-suite chemical analysis?

3. Identify inputs to decision(s)

From geomorphic mapping:

- Identified mapping units
- Characteristics of post-1943 sedimentary deposits

- Areal extent of units

From radiation survey:

- Gross-alpha, -beta, and -gamma readings at selected locations
- Field gamma spectroscopy at selected locations

4. Define the study boundaries

- Temporal - The sampling should generally be restricted to sediments deposited after 1943, when potential contamination of the canyons began. Limited sampling of older sediments may be conducted in order to test the validity of criteria for distinguishing post-1943 sediment and to gauge the importance of other potential contaminant transport pathways.
- Spatial - The sampling will be restricted to the stream channel and its floodplain in Los Alamos Canyon and Pueblo Canyon, in areas downstream of the first identified location of Laboratory-derived contamination. Background samples may be taken outside or inside this area.

5. Develop a decision rule

- Geomorphic - Post-1943 sediments will be categorized by geomorphic unit and a separate sample strategy will be developed for each unit. The sampling and analyses will be as described in Section 7.2.4.1 for full-suite and limited-suite sampling.
- Radiation - Any locations with radiation levels above the decision level, as established from the distribution of the radiation survey data, will be candidates for full-suite analysis. The selected sites will be sampled according to the plan described in Section 7.2.4.1. Radiation screening results will be examined to determine whether the original geomorphic units are adequately homogeneous and easily characterized to define the risks using average values for these units. The need to subdivide units into a more detailed level of identification may be established by the site geomorphologist's judgment.

Decision #1

If the radiation screening data indicate wide scatter (coefficient of variation of >100%) or an apparently bimodal distribution of data for any geomorphic unit, then the site geomorphologist will identify an appropriate subdivision of the unit.

Decision #2

If "hot spots" (radioactivity exceeding background levels by a statistically significant amount) are identified in the radiation survey, the four with the highest value in the channel (active or inactive) and the floodplain will be identified for full-suite sampling, according to the approach described in Section 7.2.4.1. If fewer than four "hot spots" are identified, locations with the highest measured levels will be sampled to complete the four samples planned.

Decision #3

If "hot spots" are identified in the radiation survey, the two with the highest value in each geomorphic unit will be sampled. Two other samples will be selected at random from among the other locations sampled by the radiation survey. If either of these hot-spot locations has already been identified for full-suite analysis, then another randomly sampled location will be substituted.

6. Specify limits or uncertainty

The choice of sample locations for full-suite and limited-suite sampling relies extensively on the geomorphologist's judgment, and decision errors will not be quantified.

7.2.5.2 Sediment Sampling Data Quality Objective

1. State the problem

> What is the nature and extent of contamination in the Los Alamos Canyon and Pueblo Canyon systems?

2. Identify the decision(s)

Decision #1

What contaminants are present in Los Alamos Canyon and Pueblo Canyon?

Decision #2

What are the average contaminant concentrations in sediments determined using the limited suite of COPCs in each of the geomorphic units within each of the key reaches?

3. Identify inputs to decision

- Sample location
- Sample unit
- Concentrations of contaminants in each sample

4. Study boundaries

    - Only the reaches identified in Section 7.2.2.1. will be sampled.

5. Develop a decision rule

Decision #1

For each geomorphic unit within a reach, at least one sample will be collected for each "hot spot" identified through field screening. If the number of "hot spots" in each unit exceeds two, then those two with the highest radiation readings will be sampled. Other locations within the reaches will be sampled on a random basis.

Decision #2

Any contaminant identified at concentrations greater than two standard deviation units above the mean for background in the full-suite analyses will be added to the limited analytical suite for all samples from that reach.

Decision #3

Any contaminant whose mean concentration exceeds two standard deviation units above the mean for background will be evaluated in the risk assessment for that reach.

6. Specify limits or uncertainty

From the Formerly Utilized Sites Remedial Action Program (FUSRAP) (LANL 1981, 6059) data, it is estimated that the average concentration can be determined within a relative error of 100% by sampling four samples per unit per reach. These relative errors are considered to adequately limit decision errors.

7.3 Surface and Ground Water Sampling and Analysis Plan

This section presents the sampling and analysis plan for investigating surface water and ground water in Los Alamos Canyon and Pueblo Canyon. Surface water sampling is included with the ground water investigation because water in the canyon channels is in hydraulic contact with the alluvial ground water. The strategy for sampling surface water, alluvial intermediate perched zone, and main aquifer (Santa Fe Group) ground water is described. Borehole cores will also be sampled and analyzed to determine the baseline geochemistry of the water-bearing zones and for analysis of hydrologic properties. To meet the objectives of the ground water investigation, installation of 16 alluvial observation wells and 9 intermediate perched zone observation wells is proposed. Sampling and analysis of surface and ground water will focus on characterizing the hydrology of Los Alamos Canyon and Pueblo Canyon, as well as characterizing the nature of Laboratory-derived contaminants present in ground water.

7.3.1 Objectives

The objective of the surface and ground water sampling and analysis plan is to address Hazardous and Solid Waste Amendments (HSWA) requirements for characterizing the hydrology of the canyons to determine the Laboratory's impact on surface and ground water. The ground water investigations address the presence of Laboratory-derived contaminants and will evaluate potential off-site exposures and impacts on the Rio Grande resulting from interactions between surface water and ground water in different water-bearing zones.

The investigation has three components:

- surface water sampling,
- alluvial ground water sampling, and
- intermediate perched zone and main aquifer ground water sampling.

These three components of the ground water sampling and analysis plan are presented separately for clarity; however, all investigations are viewed as contributing to the understanding of a large, integrated hydrologic system.

The sampling and analysis plan is designed to be flexible, and the objectives and approaches will be refined and modified as new data are obtained. Revisions to the conceptual model for contaminant transport (see Chapter 4 of this work plan) will be based on integrating results from all three components of the investigation as well as an evaluation of data from other previous and ongoing Laboratory studies as discussed in Chapter 5 of this work plan. Information gathered from implementing this work plan will also be used to focus hydrologic characterization efforts in future canyon work plans.

7.3.2 Technical Approach

The technical approach to the surface and ground water investigation is shown in Figure 7-13. The major stages and decision logic are similar to those discussed in Chapter 5 of this work plan and shown in Figure 5-1.

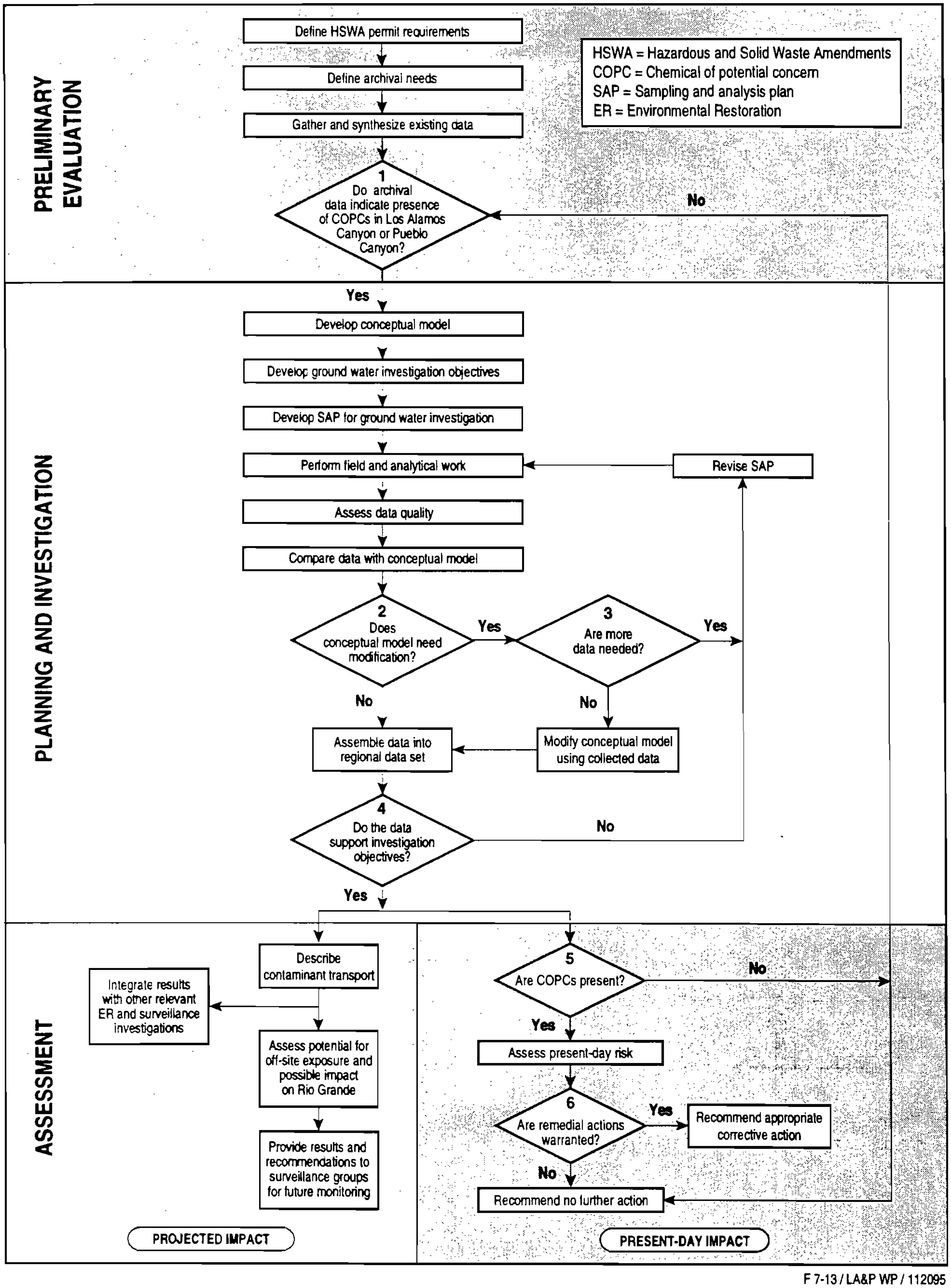


Figure 7-13. Technical approach for ground water investigation.

The key hypotheses of the current conceptual model for contaminant transport that will be tested during the ground water investigation are summarized as follows.

- Maximum concentrations of contaminants may be associated with alluvial ground water close to potential source areas.
- Dilution and attenuation by geochemical processes will decrease downgradient contaminant concentrations downgradient within a water-bearing zone.
- Alluvial water-bearing zones are sources of recharge to intermediate perched zones.
- For many chemical species, attenuation will decrease contaminant concentrations in ground water as it migrates through the unsaturated zone toward intermediate perched zones.
- Intermediate perched zones may receive some recharge from uncontaminated watersheds west of the Laboratory. Contaminant concentrations in water entering these perched zones are diluted.
- Intermediate perched zones occur within with major canyon systems, particularly those that head in the Jemez Mountains. These zones are believed to be narrow and ribbon-like rather than laterally extensive. However, some lateral spreading may occur downgradient, if the canyon course and the dip of the perched zone do not coincide.
- In addition to proximity to major canyons, the location of intermediate perched zones is controlled by hydrogeologic characteristics of subsurface units (for example, in permeable beds above clay-rich layers).
- Intermediate perched zone and alluvial ground water may be minor sources of recharge to the main aquifer.
- If present, Laboratory-derived contaminants in the main aquifer are likely to vary in concentration. The contaminant concentrations are probably below maximum contaminant levels (MCLs) for drinking water because (1) the large volume of water in the main aquifer dilutes contaminant concentrations in recharge, and (2) contaminant concentrations in alluvial and intermediate perched zone ground water are expected to decrease with increasing depth due to dilution and geochemical attenuation along vertical migration pathways.

The general approach used for the ground water investigation is as follows.

- Investigations will focus initially on alluvial and intermediate perched zone ground water.
- Investigations in alluvium will focus on determining the continuity of alluvial water-bearing zones, the potential for recharge

from the alluvium to deeper zones, and the nature of contamination.

- Investigating the intermediate perched zones will focus on determining the occurrence of ground water, interconnection with alluvial ground water, the nature and extent of contamination and hydrogeologic features controlling contaminant distribution.

- Main aquifer studies will be pursued if contaminant concentrations exceeding MCLs are found in intermediate perched zones or evidence shows that the main aquifer already contains Laboratory-derived contaminants.

- Additional criteria that will be considered in deciding whether to pursue studies in the main aquifer include emergence of evidence for connections between the main aquifer and intermediate perched zones or development of other evidence requiring major revision to the conceptual model of the main aquifer.

- Selected wells completed in the main aquifer will be sampled for low-level tritium and other chemical species to determine whether the main aquifer is affected by Laboratory-derived contaminants. These samples will also test the hypothesis of mixing of young water (derived from shallow sources) with old water (main aquifer) in lower Los Alamos Canyon.

- Recommendations will be made about corrective measures to ground water bodies and monitoring strategies for use by the Laboratory's Water Quality and Hydrology group (ESH-18).

- Data collected in this ground water investigation will be used with data from other previous and ongoing Laboratory studies to improve the conceptual model of the hydrogeology of the Pajarito Plateau.

Proposed alluvial wells and proposed intermediate perched zone wells are described in Table 7-11 and Table 7-12 respectively. Locations are shown in Figures 7-14, 7-15, and 7-16. The surface and ground water sample collection is summarized in Table 7-13 in Section 7.3.3.1.

7.3.3 Ground Water Sample Collection and Analysis

This section describes the sampling design for collecting surface water and ground water (alluvial, intermediate perched zone, and main aquifer) samples and borehole core samples. Particular emphasis is given to the criteria for selecting the locations of the proposed new wells. The methods for sample collection and for chemical, radiochemical, and geotechnical analyses are also provided in this section.

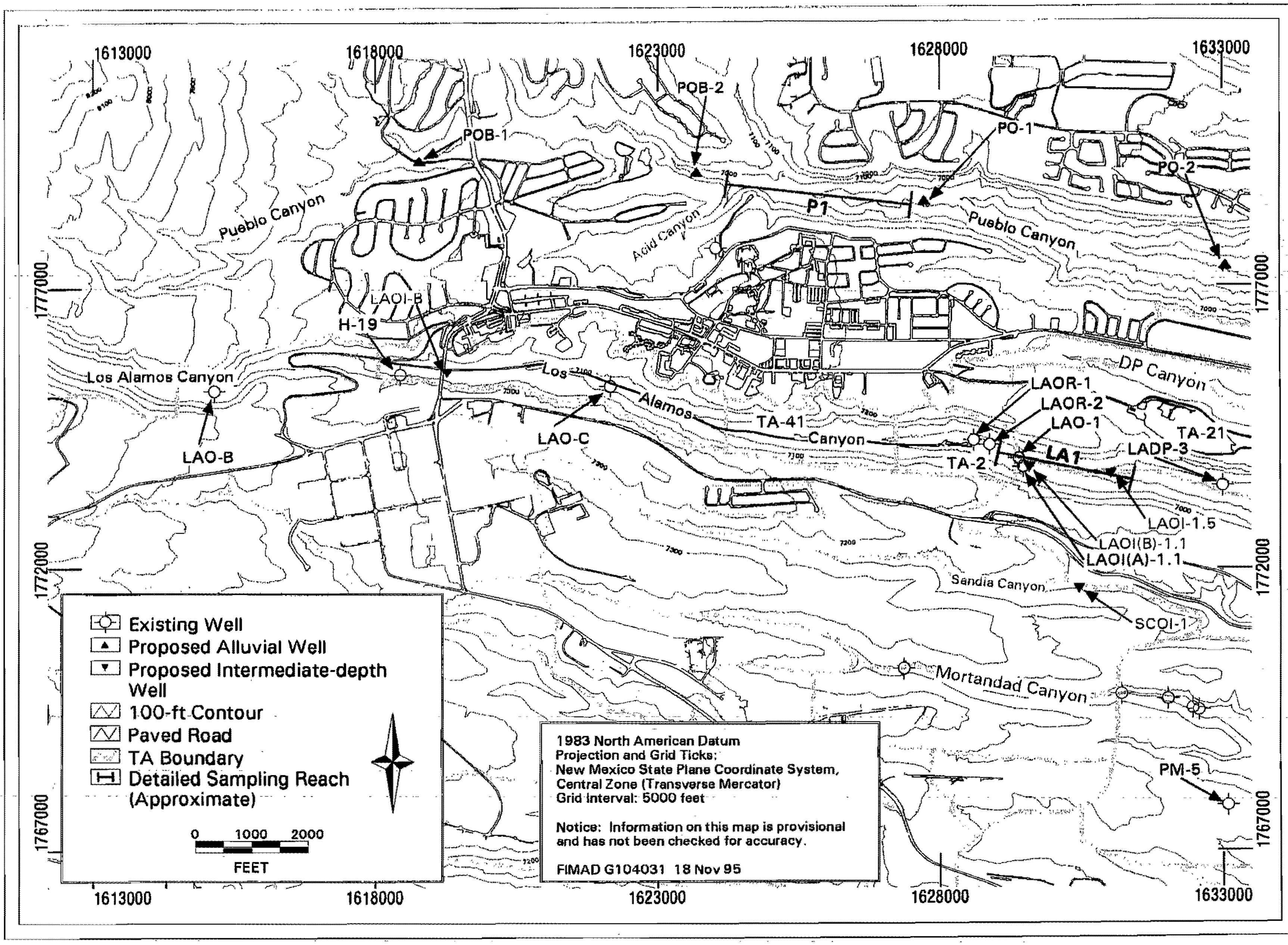


Figure 7-14. Proposed well locations: western Los Alamos and Pueblo Canyons

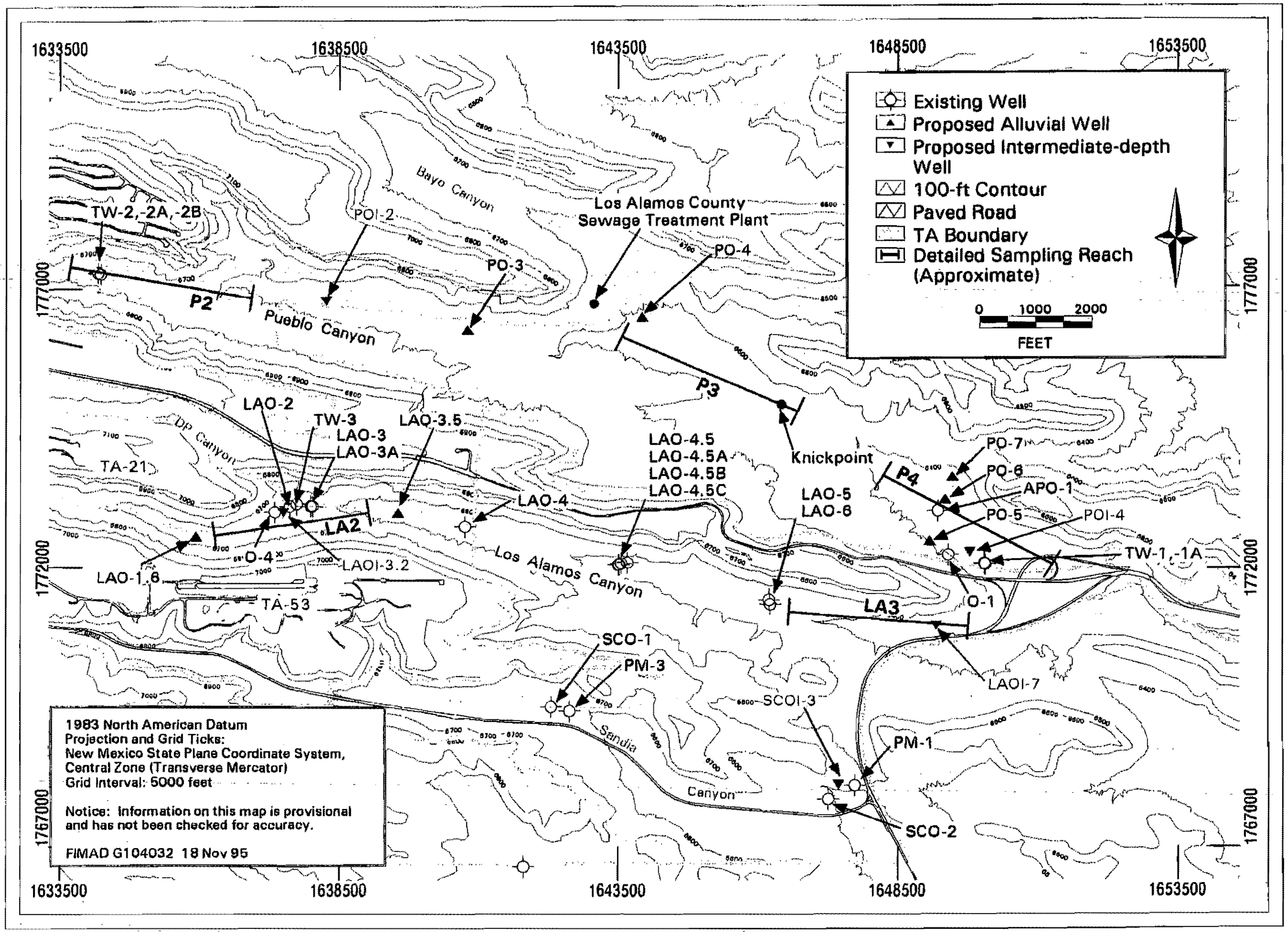


Figure 7-15. Proposed well locations: central Los Alamos and Pueblo Canyons

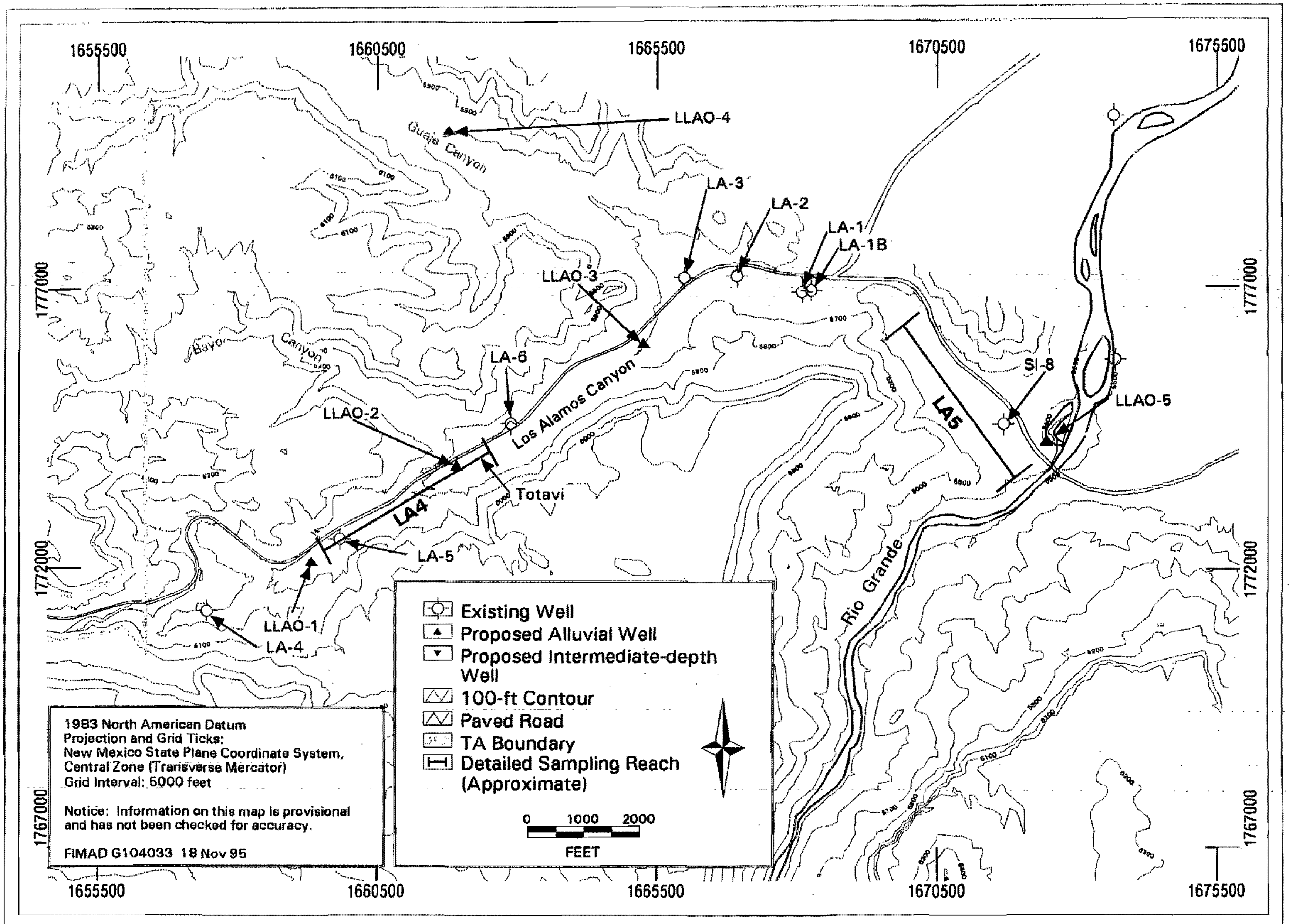


Figure 7-16. Proposed well locations: eastern Los Alamos and Pueblo Canyons

TABLE 7-11

DESCRIPTION OF PROPOSED ALLUVIAL WELLS

Well Designation[a]	Purpose	Location[b]
Pueblo Canyon		
POB-1	Background	West of Diamond Drive
POB-2	Background	West of confluence of Pueblo Canyon and Acid Canyon
PO-1	Observation	Reach extending from Acid Canyon to LA County STP[c]
PO-2	Observation	Reach extending from Acid Canyon to LA County STP
PO-3	Observation	Reach extending from Acid Canyon to LA County STP
PO-4	Observation	Immediately downstream of LA County STP
PO-5	Observation	Transect near existing well APO-1, near confluence with Los Alamos Canyon
PO-6	Observation	Transect near existing well APO-1, near confluence with Los Alamos Canyon
PO-7	Observation	Transect near existing well APO-1, near confluence with Los Alamos Canyon
PP-3 (A,B,C)	Piezometer	Pueblo Canyon piezometer well nests
Los Alamos Canyon		
LAO-1.6	Observation	West of confluence of Los Alamos Canyon and DP Canyon
LAP-4.5 (A,B,C)	Piezometer	Los Alamos Canyon piezometer
LAO-3.5	Observation	Between existing wells LAO-3 and LAO-4
LLAO-1	Observation	Reach extending from Basalt Springs to Rio Grande
LLAO-2	Observation	Reach extending from Basalt Springs to Rio Grande
LLAO-3	Observation	Reach extending from Basalt Springs to Rio Grande
LLAO-4	Observation	Within Guaje Canyon
LLAO-5	Observation	Adjacent to Rio Grande
LLAP-2.5 (A, B, C)	Piezometer	Los Alamos Canyon piezometer well nests

a. LA = Los Alamos Canyon; LLA = lower Los Alamos Canyon; P = Pueblo Canyon
b. See Figures 7-14 through 7-16 for proposed locations.
c. STP = sewage treatment plant

7.3.3.1 Sampling Design

The strategy for sampling surface water in the canyon channels and the ground water underlying Los Alamos Canyon and Pueblo Canyon is presented in this section. The ground water sampling strategy requires the construction of 16 alluvial observation wells and 9 intermediate perched zone observation wells. The alluvial ground water investigation requires construction of 9 observation wells (including 2 background wells) and 1 piezometer well nest in the alluvium in Pueblo Canyon. Construction of 7 observation wells and 2 piezometer well nests in the alluvium in Los Alamos Canyon is also proposed. The intermediate perched zone investigation requires construction of 5 observation wells in Los Alamos Canyon, 2 observation wells in Pueblo Canyon, and 2 observation wells in Sandia Canyon. Core samples will be collected with

TABLE 7-12

DESCRIPTION OF PROPOSED INTERMEDIATE PERCHED ZONE WELLS[a]

Well Designation[b]	Location[c]
LAOI-7	East of existing wells LAO-5 and LAO-6
POI-4	West of existing wells TW-1A and TW-1
SCOI-3	Vicinity of existing well PM-1
LAOI-3.2	Vicinity of existing well LAO-3
LAOI-1.5	Between existing wells LAOI(A)-1.1 and LADP-3
LAOI(B)-1.1	Near existing well LAOI(A)-1.1, but extending deeper
SCOI-1	In Sandia Canyon, southeast of existing well LAOI(A)-1.1
POI-2	East of existing wells TW-2A and TW-2
LAOI-B	East of existing well H-19

a. Intermediate perched zone wells are listed in order of priority.
b. LA = Los Alamos Canyon; P = Pueblo Canyon; SC = Sandia Canyon; O = observation; I = intermediate
c. See Figures 7-14 through 7-16 for proposed locations.

borehole advancement. Initial sampling of the main aquifer (in the Santa Fe Group) will rely on existing main aquifer wells, the locations of which are shown in Figure A-2 (Appendix A of this work plan).

The proposed intermediate perched zone wells are described in Table 7-12 — listed in order of priority. The priority of the proposed alluvial wells, which are listed geographically in Table 7-11, is as follows.

1. Pueblo Canyon background wells (POB-1 and POB-2)

2. Upper Pueblo Canyon observation wells in the reach extending from Acid Canyon to the Los Alamos County sewage treatment plant (PO-1, PO-2, and PO-3)

3. Lower Pueblo Canyon observation wells in the reach extending downstream from the Los Alamos County sewage treatment plant to the confluence with Los Alamos Canyon (PO-4 through PO-7)

4. Lower Los Alamos Canyon observation well at the mouth of the Rio Grande (LLAO-5)

5. Upper Los Alamos Canyon observation well upstream of DP Canyon (LAO-1.6)

6. Lower Los Alamos Canyon observation wells in the reach extending from Basalt Springs to the Rio Grande and within Guaje Canyon (LLAO-1 through LLAO-4)

7. Upper Los Alamos Canyon observation well sited between existing wells LAO-3 and LAO-4 (LAO-3.5)

8. Piezometer well nests in Pueblo Canyon and Los Alamos Canyon (PP-3, LLAP-2.5, and LAP-4.5)

TABLE 7-13

SUMMARY OF SURFACE WATER AND GROUND WATER SAMPLE COLLECTION DESIGN

Hydrological Zone	No. of Wells	Sampling Frequency	Annual No. of Samples
Pueblo Canyon			
Surface water		Once per quarter per reach[a]	16
Alluvial, background wells[b]	2	Once per quarter	8
Alluvial, observation wells[b]	7	At completion and six months	14
Intermediate-perched, observation wells[b]	2	At completion and six months	4
Los Alamos Canyon			
Surface water		Once per quarter per reach	20
Alluvial, observation wells[b]	7	At completion and at six months	14
Intermediate-perched, observation wells[b]	7[c]	At completion and at six months	14

a. If surface water is present, samples will be collected in each of the nine canyon reaches (four in Pueblo Canyon, five in Los Alamos Canyon) described in Section 7.2.2.1. Numbers of samples are the most that will be collected if water is available.

b. At a minimum, one core sample will be collected above and below each major hydrogeological contact. Additional samples may be collected at the judgement of the field geologist.

c. Includes two intermediate perched zone observation wells in Sandia Canyon

Table 7-13 summarizes the surface water and ground water sample collection design. The sampling strategy for each of the hydrologic zones is described in detail in the following sections, as is the strategy for the collection of borehole core samples. Where new wells are proposed, the rationale for the well location is discussed in terms of a specific issue to be addressed, as well as the approach taken to address the issue.

7.3.3.1.1 Surface Water Sampling

Surface water in stream channels of the canyons consists—most of the time—of water that recharged the alluvium previously and re-emerges from it, normally at a location downgradient of the point of recharge. In this respect, surface water is in hydraulic connection with ground water in the alluvium. The few times when the two are not in hydraulic connection occur during periods of low precipitation when the alluvium is largely dewatered and the depth to ground water increases. Because the surface water is so closely linked to the alluvial water system (both chemically and hydraulically over short periods), information about contamination in the surface waters is important to gaining a complete understanding of the operation of the connected systems.

Surface water samples will be collected on a quarterly basis for one year, from each of the nine canyon reaches in Los Alamos and Pueblo Canyons as described in Section 7.2.2.1. Surface water samples will also be collected on a quarterly basis at Basalt Spring (see Figure A-2 in Appendix A of this work plan) and any other springs or seeps identified in the canyons. The number and location of the surface water samples will be determined in the field based on the availability of water at the time of sample collection. Surface water samples will be collected in the middle of the stream to provide representative surface water chemical data for each reach or spring. All surface water samples will be filtered to remove particulates larger than 0.45 μm. Surface water samples will undergo the same chemical analyses as alluvial ground water samples, as described in Section 7.3.4.3. The analytical data will be supplemented by the unfiltered surface water samples collected of environmental monitoring by the Laboratory's Water Quality and Hydrology group (ESH-18).

7.3.3.1.2 Alluvial Ground Water Sampling

The HSWA Module requires that this work plan investigate the potential for movement or transport of contaminants within canyon watersheds and interactions with alluvial ground water and other ground water. Three characteristics of ground water in the alluvium are relevant to these requirements for investigation.

- Continuity

  The alluvium is generally continuously saturated in two or more zones of variable thickness extending most of the length of Los Alamos Canyon from Sierra de Los Valles to the Rio Grande. The alluvium in Pueblo Canyon contains zones of saturation of variable thickness and extent.

- Potential Recharge to Deeper Ground Water

  The alluvial ground water in Los Alamos Canyon may provide a source of recharge to saturated zones in the Guaje Pumice Bed, the Puye Formation, the Cerros del Rio basalt, and the Santa Fe Group. A similar situation exists in at least some reaches of Pueblo Canyon.

- Levels of Contamination

  The highest measured levels of contaminants (including tritium, plutonium isotopes, ^{90}Sr, ^{137}Cs, and nitrate) and most likely the highest inventories of these contaminants in ground water occur in the alluvium in Los Alamos Canyon and Pueblo Canyon, based on Laboratory monitoring data (LANL 1981, 6059; ESG 1967–1994).

The sampling and analysis plan for alluvial ground water in Los Alamos Canyon and Pueblo Canyon addresses a set of specific issues relevant to understanding aspects of each of these three characteristics of the alluvium. These issues are discussed in the succeeding sections for each of the major canyon reaches.

Ground water sampling will be conducted in existing and new wells. Ground water will be sampled from most wells two times, once during relatively high surface water flow and again at relatively low (or no) surface water flow. The movement of ground water in the alluvium is rapid enough to respond to seasonal variations in stream flow, resulting in detectable changes in the ground water quality (ESG 1970–1994). The purpose of the two samples is to define the effect on contaminant concentrations of seasonal variation in surface water flow. Background observation wells will be sampled quarterly for one year to refine understanding of the seasonal variation.

Existing wells, which are already sampled for environmental monitoring, may be resampled one time for chemical analysis described in Section 7.3.3.3. These wells include LA-1A, LA-1B, LA-2, LA-5, TW-1, TW-1A, TW-2, TW-2A, TW-3, TW-4, Otowi-1, and Otowi House.

All samples will be filtered to remove particulates larger than 0.45 μm. Analyses of these samples will be supplemented by analyses of unfiltered samples collected for environmental monitoring by the Laboratory's Water Quality and Hydrology group (ESH-18).

Proposed Alluvial Wells in Pueblo Canyon

Issue Number 1

What is the background/baseline chemical composition of alluvial ground water?

Importance

To define the levels of contamination in ground water resulting from Laboratory activities, it is necessary to define the chemical characteristics of ground water entering Laboratory property. This water may be uncontaminated by local anthropogenic activity or it may reflect the composition of water entering Laboratory property after passing through parts of the Los Alamos townsite. The important chemical parameters (see Section 7.3.3.3) include major ions, neutral species, trace elements, organic compounds, and radionuclides (^{241}Am, ^{137}Cs, ^{90}Sr, ^{238}Pu, ^{239,240}Pu, ^{234}U, ^{235}U, and ^{238}U). Existing well LAO-B, discussed in Chapter 3, Section 3.7, will provide background data for Los Alamos Canyon. Presently there are no wells in upper Pueblo Canyon to evaluate background chemical compositions. Because the geologic and hydrologic environment of upper Pueblo Canyon is distinct from that of Los Alamos Canyon, it is unlikely that the background well LAO-B can adequately represent the chemical properties of unaltered ground water in Pueblo Canyon.

Approach

One or two background observation wells will be installed in the alluvium in upper Pueblo Canyon (POB-1 and POB-2 in Table 7-11 and Figure 7-14). These wells will be sited (1) west of Diamond Drive and (2) west of the confluence of Acid Canyon and Pueblo Canyon. Some concern exists about whether a site can be found west of Diamond Drive (POB-1) because of steep, rocky sites and thin alluvium. The wells will be installed according to the approach described in Section 7.3.3.2.1. These wells are expected to be less than 30 ft deep and have a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. Water samples will be analyzed for major and minor ions, neutral species, trace elements, field-measured parameters, organic compounds, and for the following radionuclides: low-detection-level tritium, ^{241}Am, ^{137}Cs, ^{90}Sr, ^{238}Pu, ^{239,240}Pu, ^{234}U, ^{235}U, and ^{238}U. Analyses and methods are discussed in Section 7.3.3.3.

Issue Number 2

Is alluvial ground water continuous in middle Pueblo Canyon, and is there present or likely future contamination?

Importance

The reach of Pueblo Canyon from the mouth of Acid Canyon to the point where effluent from the active Los Alamos County sewage treatment plant enters the stream channel has the highest concentrations of plutonium in the alluvium (LANL 1981, 6059). It also has known contamination (tritium, chloride, phosphate, and nitrate) from previous discharges from TA-45 and from the former Pueblo and Central sewage treatment plants in both the intermediate perched zone (in well TW-2A) and the main aquifer in the Santa Fe Group (in well TW-2). These contaminants probably migrated through the alluvium. In 1992, the annual sampling of TW-2A showed plutonium at levels exceeding the DOE-derived concentration guide for drinking water (Environmental Protection Group 1994, 35363). This anomalous value has not been duplicated but cannot be shown to be invalid. There is also potential for transport of contaminants down-canyon in ground water and for deep percolation of contaminated ground water.

Approach

Three shallow observation wells (PO-1, PO-2, and PO-3 in Table 7-11 and Figures 7-14 and 7-15) will be installed in the alluvium to determine the depth and thickness of saturation and to evaluate the chemical composition of the ground water. The wells will be installed as described in Section 7.3.3.2.1. They are expected to be less than 50 ft deep and will have a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. The weathered bedrock immediately beneath the contact with the alluvium will be sampled by taking a 5-ft core in well PO-1. Samples from each of the cored intervals will be analyzed as described in Section 7.3.3.3. Water samples will be analyzed for the major and minor ions, neutral species, trace elements, field-measured parameters, and organic compounds, and for the following radionuclides: low-detection-level tritium, ^{241}Am, ^{137}Cs, ^{90}Sr, ^{238}Pu, ^{239,240}Pu, ^{234}U, ^{235}U, and ^{238}U. Analyses and methods are described in Section 7.3.3.3. A limited number of drive points may be used to guide well placement and to collect water quality samples.

Issue Number 3

What is the lateral and vertical extent of the alluvial ground water and the degree of contamination in lower Pueblo Canyon?

Importance

The reach of Pueblo Canyon from the Los Alamos County sewage treatment plant to state route 4 is important for characterization because contaminants are present in the alluvial sediments and ground water, and contaminants in ground water might move from the alluvium into bedrock units below.

This reach is estimated to contain the largest inventory of plutonium in sediments (LANL 1981, 6059) in the canyon. In this case, the alluvial ground water may have been contaminated with plutonium and associated radionuclides. Water samples collected from well APCO-1 show levels of ^{241}Am and ^{239,240}Pu above background (Environmental Protection Group 1994, 35363). In addition, the ground water may have been an important part of the pathway for known (tritium, chloride, phosphate, and nitrate) and potential anthropogenic contamination to occur in both the intermediate perched zone (in well TW-1A) and in the main aquifer (in well TW-1) in this reach.

The Puye Formation underlies alluvium in most of this reach and is locally exposed at the surface. It may provide a faster pathway for downward percolation of surface and ground water than does the Bandelier Tuff exposed further up the canyon. There is also little information on the sorption capacity of the Puye Formation. Therefore, the potential for migration of geochemically reactive species (such as ^{241}Am, ^{137}Cs, ^{90}Sr, and plutonium) is uncertain. Nevertheless, they are likely to migrate more slowly than conservative species (such as tritium, chloride, and nitrate), because most of the Puye sediment contains at least some clay fraction, and these species commonly adsorb onto clay minerals. The potential exists for further movement of contaminants from the surface through the alluvium to intermediate perched zone ground water that will reach Basalt Spring and could reach main aquifer drinking water wells in lower Los Alamos Canyon on San Ildefonso Pueblo land.

Approach

One alluvial observation well (PO-4) will be installed to define the extent of saturation and to evaluate the chemistry of the ground water immediately downstream of the outfall from the Los Alamos County sewage treatment plant. One three-well transect (PO-5, PO-6, and PO-7) will be installed to define the width of the saturated zone. The exact location of the three-well transect may be changed from that shown in Figure 7-15 based on evaluation of stratigraphy found in other boreholes nearby. The wells will be installed as described in Section 7.3.3.2.1. They are expected to be less than 50 ft deep and will have 10-ft screens placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. They are listed in Table 7-11 as PO-4 through PO-7 and shown in Figure 7-15. The weathered bedrock immediately beneath the contact with the alluvium in PO-6 will be sampled by taking a 5-ft core. Samples from the cored interval will be analyzed as described in Section 7.3.3.3. Water samples will be taken from PO-4, one of the transect wells, and existing well APO-1. Water samples will be analyzed for the major and minor ions, neutral species, trace elements, field-measured parameters, organic compounds, and for the following radionuclides: low-detection-level tritium, ^{241}Am, ^{137}Cs, ^{90}Sr, ^{238}Pu, ^{239,240}Pu, ^{234}U, ^{235}U, and ^{238}U. Analyses and methods are described in 7.3.3.3.

Issue Number 4

How significant is percolation from the alluvium through bedrock to deeper horizons?

Importance

Alluvial ground water in Pueblo Canyon provides a potential source of recharge to the Guaje Pumice Bed, the Puye Formation, and Cerros del Rio basalts. Zones of active recharge may be located by identifying significant declines in hydraulic head over short distances. Vertical percolation of ground water may occur where the alluvium lies on top of bedrock fault zones and stratigraphic boundaries that cross Pueblo Canyon. The HSWA Permit requires a characterization of such hydrogeological and geochemical properties relevant to contaminant migration in soils and sediments above the regional aquifer. This issue combines concerns about percolation from the alluvium into the underlying bedrock for the full extent of Pueblo Canyon below Acid Canyon. In addition, it will be necessary to examine hydraulic head data and determine the water balance in the alluvium to quantify the amount of water available for percolating into the bedrock.

Approach

Three groups of nested small-diameter piezometers will be driven or drilled into the alluvium at locations to be determined from field inspections after the completion of other alluvial wells in Pueblo Canyon (PP-3A, PP-3B, and PP-3C in Table 7-11). Piezometer groups will be placed within known fault zones and at stratigraphic boundaries to identify locations most likely to have significant vertical percolation of ground water and to quantify the vertical percolation rates. Water-level measurements will be made to estimate the hydraulic heads at each piezometer location and to identify possible changes in vertical gradients. These measurements will be made quarterly for one year to examine seasonal changes in gradients.

Measurement of surface water discharge will also be used to quantify water percolation in the lower reach. If data on discharge from the Los Alamos County sewage treatment plant and the existing stream gaging station in lower Pueblo Canyon are insufficient to determine percolation rates, it may be necessary to install and operate additional gaging stations.

Proposed Alluvial Wells in Upper Los Alamos Canyon

Issue Number 5

How is the composition of alluvial ground water affected by direct discharges from TA-21 west of the DP Canyon and Los Alamos Canyon confluence?

Importance

Previous data from alluvial observation wells (LAO-1, LAO-2, LAO-3) show activities of ^{90}Sr above the DOE-derived concentration guide for drinking water value of 8 pCi/L (see Section 3.7), due either to direct releases from Los Alamos Canyon sources or to DP Canyon releases (LANL 1981, 6059; ESG 1966–1994). Well LAO-1 identifies the component contributed from upstream of TA-21. Distinguishing the component from TA-21 discharges to Los Alamos Canyon from that migrating in through DP Canyon may be significant to establishing rates of migration for some contaminants. The purpose of characterizing alluvial ground water at the location proposed below is to establish water chemistry for a reach in upper Los Alamos Canyon that may receive discharges from TA-21.

Approach

One baseline alluvial observation well will be installed west of the confluence of DP Canyon and upper Los Alamos Canyon (LAO-1.6 in Table 7-11 and Figure 7-15). The well will be east of discharge points from TA-21. The well will be installed as described in Section 7.3.3.2.1. It is expected to be less than 30 ft deep and will have a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. The weathered bedrock immediately beneath the contact with the alluvium will be sampled by taking a five-foot core. Samples from the cored interval will be analyzed as described in Section 7.3.3.3. Water samples will be analyzed for the major and minor ions, neutral species, stable isotopes, trace elements, field-measured parameters, organic compounds, and for the following radionuclides: low-detection-level tritium, ^{241}Am, ^{137}Cs, ^{90}Sr, ^{238}Pu, ^{239,240}Pu, ^{234}U, ^{235}U, and ^{238}U. Analyses and methods are discussed in Section 7.3.3.3.

Issue Number 6

To what extent does alluvial ground water mix with ground water in underlying rock units between wells LAO-3 and LAO-5?

Importance

Significant decreases in concentrations of chloride, sodium, tritium, and ^{90}Sr occur between LAO-3 and LAO-4 (Chapter 3 of this work plan, Section 3.7). These changes may be the result of mixing alluvial ground water (which has relatively high total dissolved solids [TDS]) with Guaje Pumice Bed ground water. Existing data suggest that alluvial ground water is mixing with water in a shallow intermediate perched zone resulting in the dilution of solutes.

Significant infiltration from the stream may occur between LAO-3 and LAO-4.5. During the 1960s and 1970s, high activities of tritium (as much as 200,000 pCi/L) and other contaminants were observed in LAO-3, LAO-4, and LAO-4.5. The fate of this contaminated water has not been resolved. This contaminated alluvial ground water may be recharging the Guaje Pumice Bed and Puye Formation in upper Los Alamos Canyon west and southeast of state route 4 at the Laboratory boundary.

Approach

One alluvial observation well will be installed between existing wells LAO-3 and LAO-4 (LAO-3.5 in Table 7-11 and Figure 7-15). This alluvial observation well will be used to determine the extent of ground water exchange between the alluvium and the possible intermediate perched zone in the Guaje Pumice Bed (the bedrock unit which appears to directly underlie the alluvium between LAO-3 and LAO-4). This well will be used to determine where the ground water is diluted or whether the tuff immediately below the alluvium contains the diluted ground water.

The well will be installed as described in Section 7.3.3.2.1 and is expected to be less than 50 ft deep and will contain a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. The weathered bedrock immediately beneath the contact with the alluvium in the well will be sampled. Samples from the cored interval will be analyzed as described in Section 7.3.3.3. Water samples will be analyzed for the major and minor ions, neutral species, stable isotopes, trace elements, field-measured parameters, organic compounds, and for the following radionuclides: low-detection level tritium, ^{241}Am, ^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{234}U, ^{235}U, and ^{238}U.

Issue Number 7

How much percolation occurs beneath the upper Los Alamos Canyon alluvium?

Importance

The alluvial ground water in upper Los Alamos Canyon provides a source of potential recharge to the Guaje Pumice Bed, the Puye Formation, and the Cerros del Rio basalt. Zones of recharge may be located by identifying significant declines in hydraulic head over short distances. Vertical percolation of ground water may occur where the alluvium lies on top of bedrock fault zones and stratigraphic boundaries that cross Los Alamos Canyon. The HSWA Module requires a characterization of such hydrogeological and geochemical properties relevant to contaminant migration in soils and sediments above the regional aquifer.

Approach

Three groups of nested, small-diameter piezometers will be driven or drilled into the alluvium at locations to be determined from field inspections after completion of other alluvial wells in Los Alamos Canyon (LAP-4.5A, LAP-4.5B, and LAP-4.5C in Table 7-11). Piezometer groups will be placed within both known fault zones and at stratigraphic boundaries to identify locations most likely to have significant vertical percolation of ground water and to quantify the vertical percolation rates. Water-level measurements will be made to estimate the hydraulic heads at each piezometer location and to identify possible changes in vertical gradients. These measurements will be made quarterly for one year to examine seasonal changes in gradients. This approach is parallel to that approach proposed in Issue Number 4.

Measurement of surface water discharge will also be used to quantify water percolation in the lower reach. If data on discharge from the Los Alamos County sewage treatment plant and the existing stream gaging station in lower Pueblo Canyon are insufficient to determine percolation rates, it may be necessary to install and operate additional gaging stations.

Proposed Alluvial Wells in Lower Los Alamos Canyon

Issue Number 8

What is the lateral and vertical extent and the degree of contamination of alluvial ground water in lower Los Alamos Canyon?

Importance

The reach of Los Alamos Canyon below Basalt Spring is important for characterization because contaminants are present in the alluvial sediments and ground water, where they might move into bedrock units below. This lower reach is estimated to contain a substantial inventory of plutonium in sediments (LANL 1981, 6059). The alluvial ground water may have been contaminated with plutonium and associated radionuclides.

Surface water is hydraulically connected to the alluvial aquifer. Return flow water from the alluvium is used by wildlife and livestock in lower Los Alamos Canyon. Bayo Canyon and Guaje Canyon are major secondary drainages providing surface water and ground water flow to lower Los Alamos Canyon; they may contribute Laboratory-derived contaminants as well. Residents in and adjacent to lower Los Alamos Canyon are concerned about the potential for contamination in surface water and ground water. The chemistry and hydraulic properties of the alluvium are not defined in lower Los Alamos Canyon.

Approach

Five alluvial observation wells will be installed in lower Los Alamos Canyon (LLAO-1 through LLAO-5 in Table 7-11 and Figure 7-16) to determine the extent of saturation and the chemistry of the water. A background/baseline observation well (LLAO-4) will be installed in Guaje Canyon above the confluence with lower Los Alamos Canyon.

The wells will be installed as described in Section 7.3.3.2.1. They are expected to be less than 100 ft deep and will have 10-ft screens placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. The weathered bedrock immediately beneath the contact with the alluvium in each well will be sampled. Observation well LLAO-4 will be located in Guaje Canyon upstream of the disturbed borrow pits used for road construction to monitor water quality in this canyon. Samples from the cored interval will be analyzed as described in Section 7.3.3.3. Water samples will be analyzed for the major and minor ions, neutral species, trace elements, field-measured parameters, organic compounds, and for the following radionuclides: low-detection-limit tritium, ^{241}Am, ^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{234}U, ^{235}U, and ^{238}U.

Issue Number 9

How much percolation occurs beneath the alluvium in lower Los Alamos Canyon?

Importance

The alluvial ground water in lower Los Alamos Canyon provides a potential source of recharge to the Puye Formation and Santa Fe Group. Zones of active recharge may be located by identifying significant declines in hydraulic head over short distances. Vertical percolation of ground water may occur where the alluvium lies on top of stratigraphic boundaries that cross lower Los Alamos Canyon. In addition, the separation between the saturated alluvium and the main aquifer narrows and disappears in the lower end of the reach. The nature of interactions between these two aquifers in this area is unknown; contaminant transfer from the alluvium to the main aquifer, if it occurs at all, is most likely to occur here. The HSWA Module requires characterization of hydrogeological and geochemical properties relevant to contaminant migration in soils and sediments above the regional aquifer. In addition, it may be necessary to examine the water balance in the alluvium to quantify the amount of water available to percolate into the bedrock. This approach is parallel to those proposed for Issues Number 4 and 7.

Approach

One set of three nested piezometers will be driven or drilled to different depths within the alluvium at locations to be determined from field inspections after completion of other alluvium wells in lower Los Alamos Canyon (LLAP-2.5 [A,B, and C] in Table 7-11). The piezometer nest will be placed at stratigraphic boundaries or in the zone where the main aquifer approaches the base of the alluvium to identify the location most likely to have significant vertical percolation of ground water and to quantify that percolation. Water-level measurements will be made to estimate hydraulic heads in each piezometer to identify changes in vertical hydraulic gradients, quarterly for one year to reflect seasonal variations.

Issue Number 10

What is the impact of the hydrocarbon plume on contaminant transport in the alluvial ground water near Totavi in lower Los Alamos Canyon?

Importance

A hydrocarbon plume (Environmental Protection Group 1995, 50285) has affected the quality of the water in the alluvium at Totavi. Biochemical reactions controlling the degradation (oxidation) of benzene, toluene, ethylbenzene, xylene isomers, and other aliphatic hydrocarbon contaminants have lowered the oxidation-reduction potential in the alluvial ground water. These chemical reactions, involving organic compounds and trace elements, are commonly observed within organic-rich ground water plumes. Dissolution of metal hydroxides under reducing conditions—based on Eh-pH arguments (Brookins 1988, 49928)—can, and may have, decreased the sorptive capacity of the alluvium. The alluvium contains naturally occurring trace elements (iron, manganese, arsenic) in addition to possible Laboratory contaminants (radionuclides) that could be mobilized as a consequence.

In order to evaluate the extent of any impacts from the Laboratory, it is necessary to determine what portion of any contaminants at Totavi are derived from an underground storage tank located there and what portion are from the Laboratory. Evaluating the fate and transport of Laboratory-derived contaminants within the mixed leachate plume is of primary importance at Totavi. Better understanding of the hydrology and water chemistry in this portion of lower Los Alamos Canyon will enable evaluating potential vertical movement of Laboratory-derived contaminants through the alluvium to the Santa Fe Group, which contains the main aquifer. Evaluating the fate and transport of the hydrocarbon plume is beyond the scope of this work plan.

Approach

Laboratory staff and contractors will work with the Accord Pueblos, the Bureau of Indian Affairs, and the New Mexico Environment Department (NMED) to evaluate water chemistry and hydrology. Chemical data from the Laboratory's Water Quality and Hydrology group (ESH-18) are currently being evaluated. A background well (LLAO-1) located west of Totavi will be installed to monitor ground water quality upgradient of the hydrocarbon plume (see Table 7-11 and Figure 7-16). The results of this study will be used to determine locations of two other observation wells (LLAO-2 and LLAO-3 [Figure 7-16]) at Totavi to evaluate the effect of the hydrocarbon plume on Laboratory-derived contaminants within the alluvium and possibly within the uppermost saturated zone of the Santa Fe Group. Water samples will be analyzed for the major and minor ions, neutral species, trace elements, field-measured parameters, organic compounds, and for the following radionuclides: low-detection-limit tritium, ^{90}Sr, ^{99}Tc, ^{137}Cs, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, ^{239,240}Pu, and ^{241}Am. Analyses and methods are discussed in Section 7.3.3.3.

Issue Number 11

How much infiltration of potentially contaminated surface water occurs to the alluvium and the main aquifer adjacent to the Rio Grande?

Importance

Existing tritium contamination of the well water at Otowi House (143.3 ± 4.8 pCi/L, Table 3-19), though well below the MCL for tritium (20,000 pCi/L), is relatively high compared to natural background and is of concern to stakeholders. Low levels of tritium have also been measured in main aquifer wells LA-1A and LA-2 (see Table 3-19 in Chapter 3 of this work plan). Better understanding of the hydrologic and chemical system is needed to estimate the present-day human health risk and the potential future impact from infiltration of potentially contaminated surface water. It is unclear whether the tritium is derived from surface water or from the alluvium in lower Los Alamos Canyon. This issue is closely related to main aquifer Issue Number 3 discussed in Section 7.3.3.1.5.

Approach

One alluvial observation well will be installed (LLAO-5 in Table 7-11 and Figure 7-16) to determine the direction of ground water flow at Otowi House (adjacent to the Rio Grande) and to further evaluate ground water chemistry. The well will be installed as described in Section 7.3.3.2.1. It is expected to be less than 100 ft deep and will have a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. Chemical data and hydrologic information collected from this observation well will be used to evaluate the degree of mixing of surface water with alluvial ground water. Careful logging of core and possible installation of nested piezometers nearby (see Issue 9) will help determine vertical gradient changes with depth. Water samples will be analyzed for the major and minor ions, neutral species, trace elements, field-measured parameters, organic compounds, and for the following radionuclides: low-detection-limit tritium, ^{90}Sr, ^{99}Tc, ^{137}Cs, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, ^{239,240}Pu, and ^{241}Am. Analyses and methods are discussed in Section 7.3.3.3.

7.3.3.1.3 Intermediate Perched Zone Ground Water Sampling

The intermediate perched zones lie between the likely sources and locations of presently known contamination in Los Alamos Canyon and Pueblo Canyon and the deeper main aquifer. These intermediate perched zones may serve either as pathways or as barriers to the transport of contaminants to the main aquifer, depending on the hydraulic conductivity of the perching layer found at the base of the zone. Individual zones could serve as a barrier in one location and as a pathway in another.

Sampling in the intermediate perched zones will focus on the large uncertainties about their nature and extent, their potential to affect transport, and their potential to be a source of contaminants to potential receptors. Investigations will be conducted to clarify the following major uncertainties about the behavior of ground water in these zones:

- the extent of occurrence and the degree of interconnection of such ground water in Los Alamos Canyon and Pueblo Canyon,
- the degree of contamination occurring within the perched zones,
- the mechanisms by which intermediate perched zones are recharged,
- the properties of hydrostratigraphic units and/or the nature of mechanisms that cause the perching, and
- the potential for lateral migration to off-site locations where contaminated water could be used.

Initial investigations will involve drilling, coring, and well installation at new locations to characterize the intermediate perched zones. Results of these initial studies will determine the extent to which it will be necessary to investigate the hydrologic properties of strata underlying the intermediate perched zones, including those that contain the main aquifer.

The intermediate-depth borehole and well installation program addresses a number of specific issues. Each well has unique features because of the specific issues to be addressed and the importance of understanding the nature and extent of intermediate perched zones. Because the intermediate perched zones have not been studied extensively, each new well adds substantially to the available information base on the geohydrology of the Pajarito Plateau and, therefore, benefits not only the ER Project but ongoing ground water monitoring programs at the Laboratory (for example, the proposed Ground Water Protection and Monitoring Plan [GWPMP]).

Most boreholes advanced to intermediate depths will be cored continuously to enable detailed geologic logging. The objectives of continuous coring are to add to the stratigraphic data base of the region and to enable evaluating the mechanism of perching, sources of recharge, stratigraphic correlation, and hydraulic properties of the zone should an intermediate perched zone be encountered. As discussed in Section 7.3.3.1.4, not all cores will necessarily be preserved or analyzed (except as needed to prepare a geologic log of the borehole). Boreholes will be advanced to a depth sufficient to penetrate a likely perching zone and some distance (100 ft) through any perched zone encountered to determine the potential for downward movement of water. Boreholes will be completed as observation wells if a perched zone is encountered.

The investigation includes installing nine intermediate-depth wells in Los Alamos Canyon and Pueblo Canyon, listed in Table 7-12 (in Section 7.3.2) in order of priority according to the value of the information expected from each. The approximate well locations are shown in Figures 7-14 through 7-16. Well locations are based on review of existing hydrologic and geologic data and are intended to add detail to the current description of intermediate perched zones in Los Alamos Canyon, Pueblo Canyon, and Sandia Canyon.

Ground water will be sampled upon completing the well and again after approximately six months to account for unusual variations. Ground water samples will be analyzed for major and minor ions, neutral species, organic compounds, low-detection-limit tritium, ^{14}C, ^{90}Sr, ^{99}Tc, ^{137}Cs, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, and ^{241}Am, stable isotopes, trace elements, and field-measured parameters. The analytical suite may be altered if further characterization objectives are identified on the basis of the first analysis.

Discussion of the issues, importance, and approach to intermediate perched zone characterization follow.

Issue Number 1

Is intermediate perched zone ground water beneath Los Alamos Canyon connected to the discharge at Basalt Spring?

Importance

The chemical composition of water from Basalt Spring indicates input of contaminants (nitrate, chloride, phosphate) derived from the Pueblo Canyon alluvial ground water

(Section 3.7 in Chapter 3 of this work plan). Tritium has also been detected in this water. Tritium and other radionuclides have been detected in the alluvial ground water in upper Los Alamos Canyon. The Los Alamos Canyon alluvium is in contact with the Puye Formation at well LAO-4.5; this contact may be a pathway for downward migration of alluvial ground water to the intermediate perched zone encountered in deeper wells in Los Alamos Canyon. This water may in turn be connected to the discharge at Basalt Spring, which is fed by an intermediate perched zone in the Cerros del Rio basalt in Pueblo Canyon. Investigating the degree of interconnection between intermediate perched zones in two canyons at the Laboratory boundary addresses a requirement of the HSWA Module to (1) address interactions between alluvial ground water and the main aquifer and (2) the regional extent and direction of flow.

Approach

One borehole will be advanced through the Cerros del Rio basalt between Los Alamos Canyon and Basalt Spring and a well installed (LAOI-7 in Table 7-12 and Figure 7-15). The well will be used to test the continuity of the Cerros del Rio basalt ground water between Los Alamos Canyon and Basalt Spring. It is expected to be no more than 150 ft deep (Figure 7-17) and will have a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. The well will be installed, completed, and characterized as described in Section 7.3.3.2.2. Seven cores will be preserved in all. Ground water samples will be analyzed for major and minor ions, neutral species, organic compounds, low-detection-limit tritium, ^{14}C, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, stable isotopes, trace elements, and field-measured parameters, as discussed in Section 7.3.3.3.

Issue Number 2

How, and to what extent are contaminants transported from surface water and alluvial ground water to the intermediate perched zone in lower Pueblo Canyon and to Basalt Spring in lower Los Alamos Canyon?

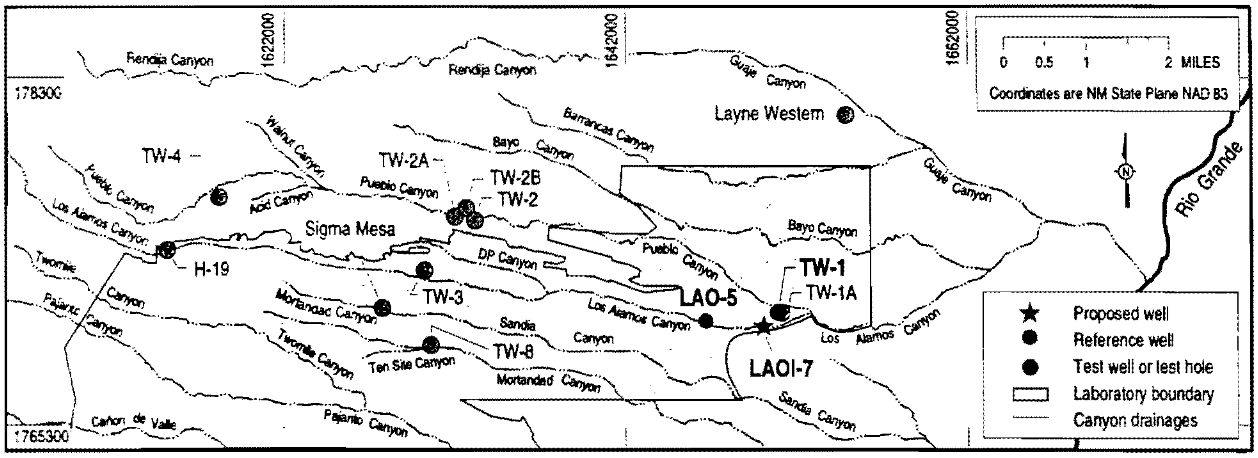
Importance

As discussed in Section 3.7 in Chapter 3 of this work plan, TW-1A and Basalt Spring have tritium activities above background and TW-1A may have detectable ^{239}Pu. In addition, there is clear indication of a pathway to the discharge point (Basalt Spring) on San Ildefonso Pueblo land. There is a need to better define the mechanism and to quantify the potential transport of these contaminants.

Approach

One intermediate-depth well will be installed (POI-4 in Table 7-12 and Figure 7-15) in lower Pueblo Canyon close to but northwest (upgradient) of wells TW-1A and TW-1 to examine existing and potential movement of contaminants, especially to Basalt Spring. It is expected to be no more than 150 ft deep (Figure 7-18) and will have a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. The well will be installed, completed and characterized as described in Section 7.3.3.2.2. Eight cores will be preserved in all. The water samples will be analyzed for major and minor ions, neutral species, organic compounds, low-detection-limit tritium, ^{14}C, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, stable isotopes, trace elements, and field-measured parameters, as discussed in Section 7.3.3.3.

Well LAOI-7 (LA Canyon approximately 1 mile east of LAO-5)



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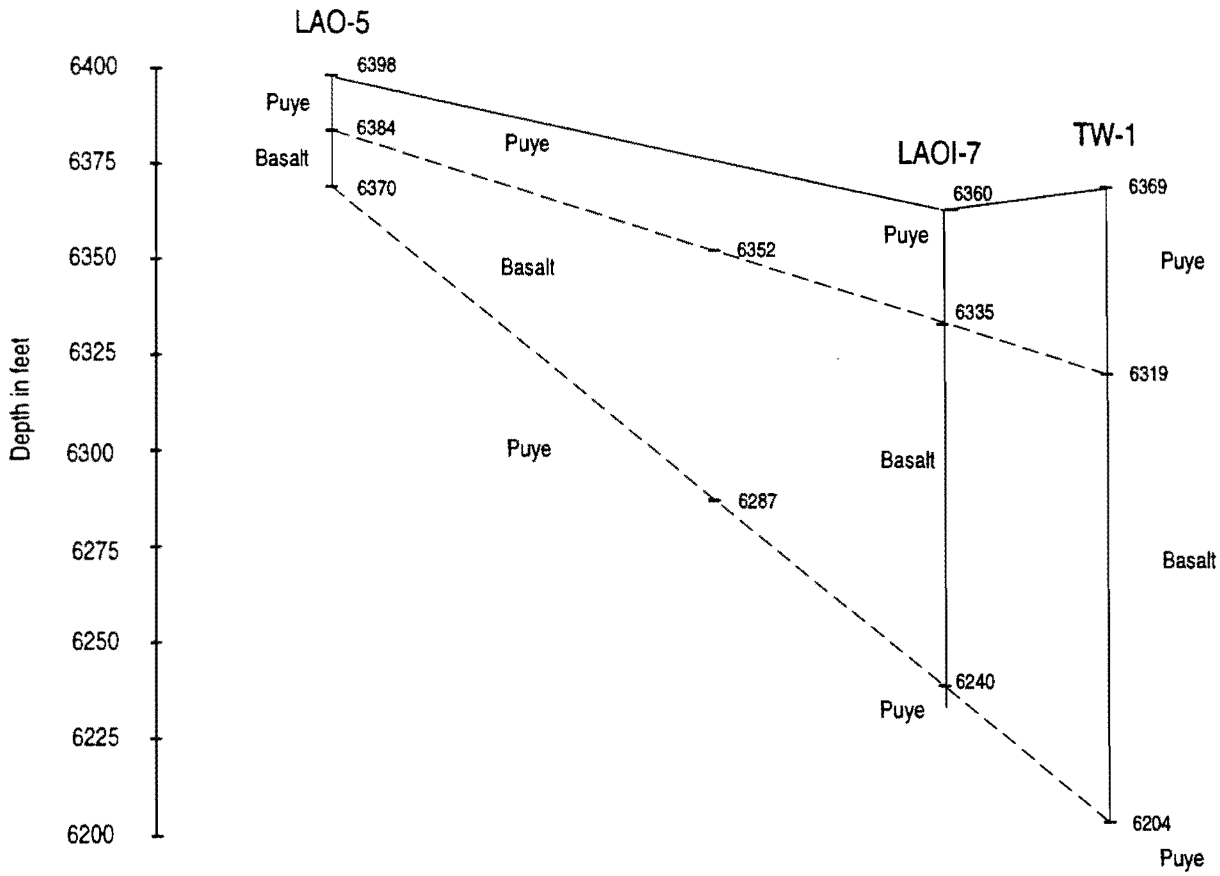


Figure 7-17. Expected stratigraphic section for proposed intermediate perched zone well LAOI-7.

Well POI-2 (Pueblo Canyon, 1 mile east of TW-2)
Well POI-4 (Pueblo Canyon west of TW-1, 2.2 miles east of TW-2)

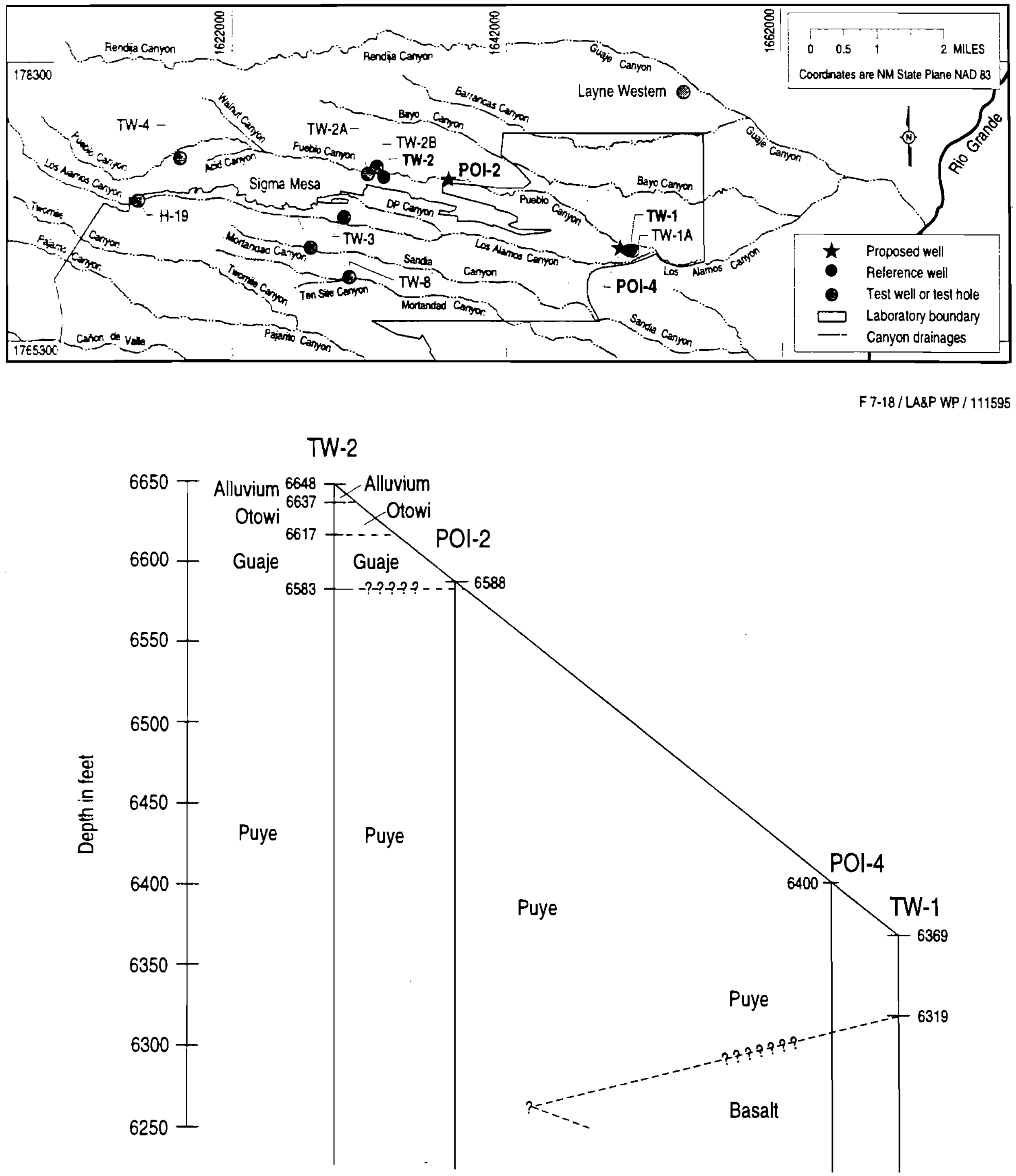


Figure 7-18. Expected stratigraphic section for proposed intermediate perched zone wells POI-2 and POI-4.

Pumping tests will be conducted to determine bulk aquifer hydraulic properties, in the new well, and in TW-1A and possibly TW-1.

Issue Number 3

Is intermediate perched zone ground water flowing from Los Alamos Canyon southeastward toward Sandia Canyon?

Importance

Ground water is present in the Cerros del Rio basalt in supply well PM-1 in Sandia Canyon (see Figure 7-15). Contamination has been observed in intermediate perched zone ground water in the Guaje Pumice Bed in well LADP-3 in Los Alamos Canyon. A structure contour map of the base of the Guaje Pumice Bed, the perching horizon in wells LADP-3 and LAOI(A)-1.1, suggests a southeasterly gradient for the pre-Bandelier Tuff land surface. Water levels in TW-1A and at Basalt Spring, and perched water observed during advancement of the borehole for supply well PM-1, also suggest a southeasterly gradient. If contaminated ground water is flowing in this direction, wells installed southeast of Los Alamos Canyon might encounter contaminated ground water at intermediate depths.

Approach

An observation well will be installed (SCOI-3 in Table 7-12 and Figure 7-14) to the depth of the perched water found in the Cerros del Rio basalt in the vicinity of well PM-1 in Sandia Canyon. It is expected to be about 450 ft deep (Figure 7-19). A second observation well will be installed southeast of LAOI(A)-1.1 in Sandia Canyon (SCOI-1 in Table 7-11 and Figure 7-14). It is expected to be about 400 ft deep (Figure 7-20). Both wells will have a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. The wells will be drilled, completed, and characterized as described in Section 7.3.3.2.2. Nine cores will be preserved from each of the wells. The water samples will be analyzed for major and minor ions, neutral species, organic compounds, low-detection-limit tritium, ^{14}C, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, stable isotopes, trace elements, and field-measured parameters, as discussed in Section 7.3.3.3.

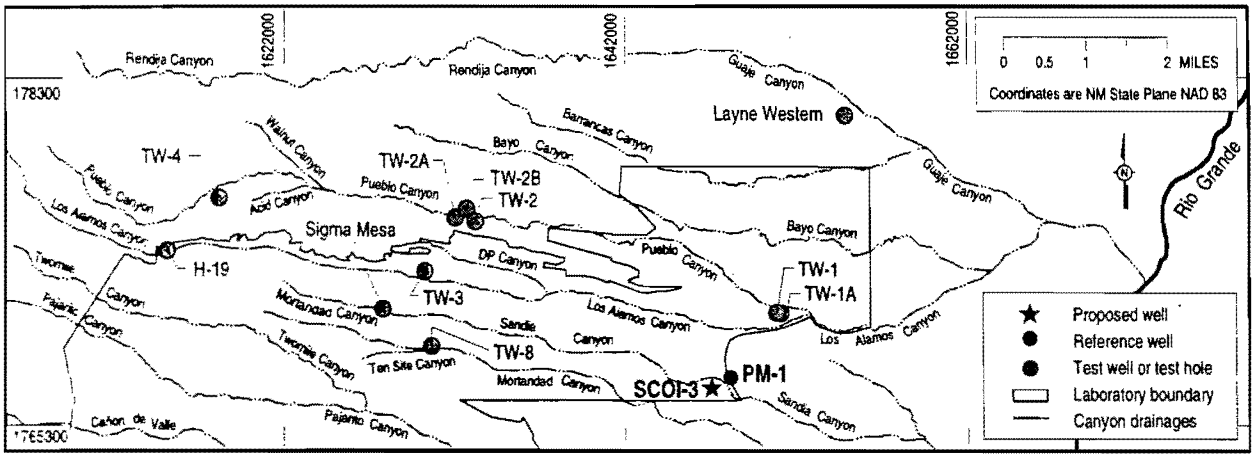
Issue Number 4

Does an intermediate perched zone exist in Los Alamos Canyon between DP Canyon and state road 4, and is it contaminated?

Importance

In 1990 an intermediate perched zone was observed in a borehole televiewer log in supply well Otowi-4. In addition, the composition of alluvial ground water changes between wells LAO-3 and LAO-4, suggesting possible mixing with intermediate perched zone ground water, as discussed in Issue Number 6 in the section on alluvial ground water. The extent and continuity of the intermediate perched zones are unknown. Along much of this reach, alluvium is in contact with the Guaje Pumice Bed, the Puye Formation, or the Cerros del Rio basalt, each of which may provide perching horizons. The alluvial ground water in this section of Los Alamos Canyon between DP Canyon

Well SCOI-3 (Sandia Canyon, vicinity of PM-1)



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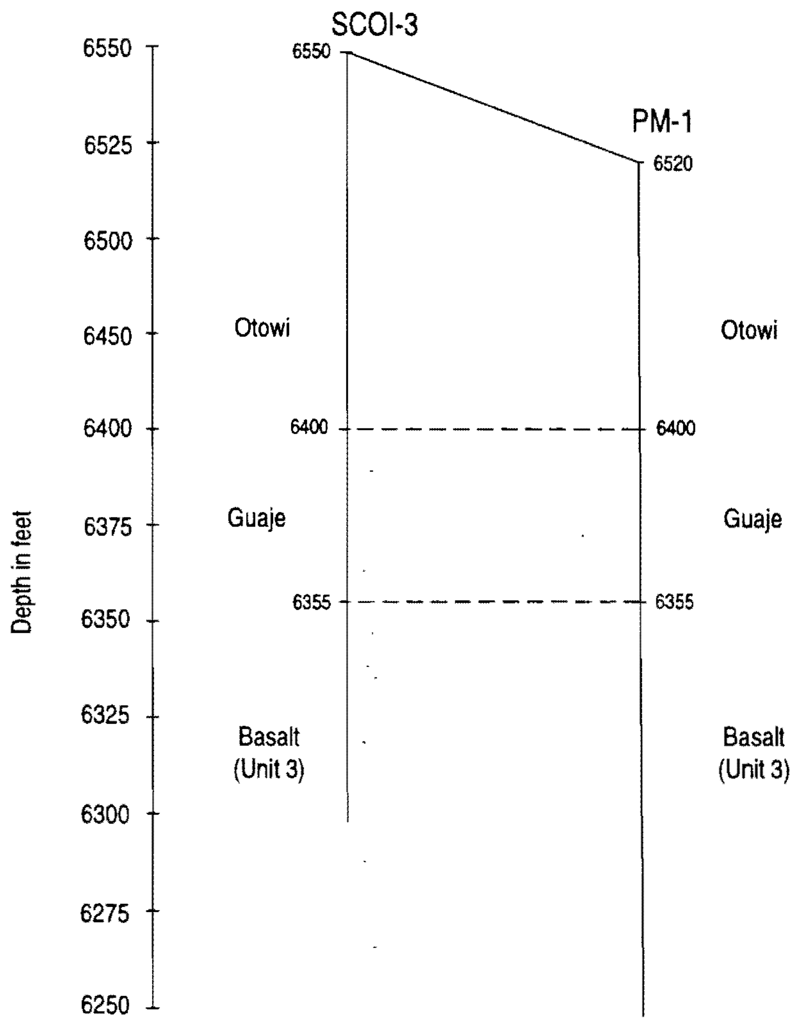


Figure 7-19. Expected stratigraphic section for proposed intermediate perched zone well SCOI-3.

Well SCOI-1 (Sandia Canyon, Southeast of LAOI(A)-1.1)

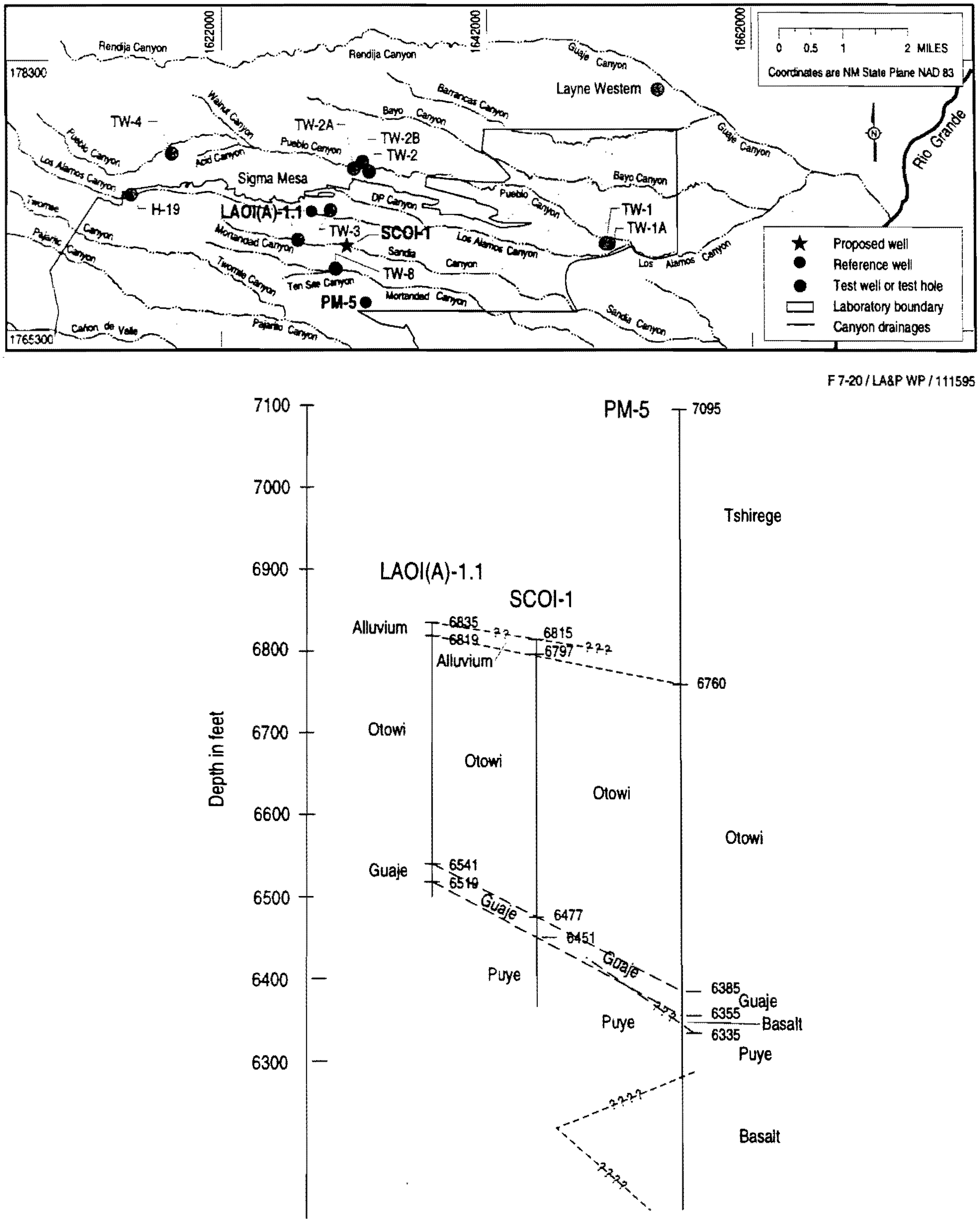


Figure 7-20. Expected stratigraphic section for proposed intermediate perched zone well SCOI-1.

and state road 4 is known, from measurements made in the 1960s and 1970s, to have been contaminated with tritium.

Approach

An observation well will be installed into the Cerros del Rio basalt where a perched zone might be expected (LAOI-3.2 in Table 7-12 and Figure 7-15). It is expected to be approximately 300 ft deep (Figure 7-21) and will have a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. The well will be installed, completed, and characterized as described in Section 7.3.3.2.2. Ten cores will be preserved in all. The water samples will be analyzed for major and minor ions, neutral species, organic compounds, low-detection-limit tritium, ^{14}C, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, ^{239,240}Pu, ^{241}Am, stable isotopes, trace elements, and field-measured parameters, as described in Section 7.3.3.3.

Issue Number 5

How and where is contamination transferred from the alluvium to the intermediate perched zone in the Guaje Pumice Bed east of TA-2 in Los Alamos Canyon?

Importance

Tritium occurs in intermediate perched zone ground water from well LADP-3 but not in well LAOI(A)-1.1. Perched water occurs in the Guaje Pumice Bed in both wells but in the Puye Formation only in LAOI(A)-1.1. Understanding the continuity of these intermediate perched zones (and the possible transfer mechanisms for water to and between them) is necessary to evaluate the likelihood of contaminant transport to and beneath intermediate perched zones. Understanding unsaturated and saturated flow in this reach may be very important to establishing the significance of fault and fracture zones as conduits for downward water movement.

Approach

An observation well (LAOI-1.5 in Table 7-12 and Figure 7-14) will be installed between LAOI(A)-1.1 and LADP-3. This new well may be used in conjunction with LAOI(A)-1.1 for a tracer test. It is expected to be approximately 375 ft deep (Figure 7-22) and will have a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. The well will be installed, completed, and characterized as described in Section 7.3.3.2.2. Nine cores will be preserved in all. The water samples will be analyzed for major and minor ions, neutral species, organic compounds, low-detection-limit tritium, ^{14}C, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, ^{239,240}Pu, ^{241}Am, stable isotopes, trace elements, and field-measured parameters, as discussed in Section 7.3.3.3.

Issue Number 6

By what mechanism(s) does ground water perching occur in the Puye Formation near LAOI(A)-1.1 in Los Alamos Canyon?

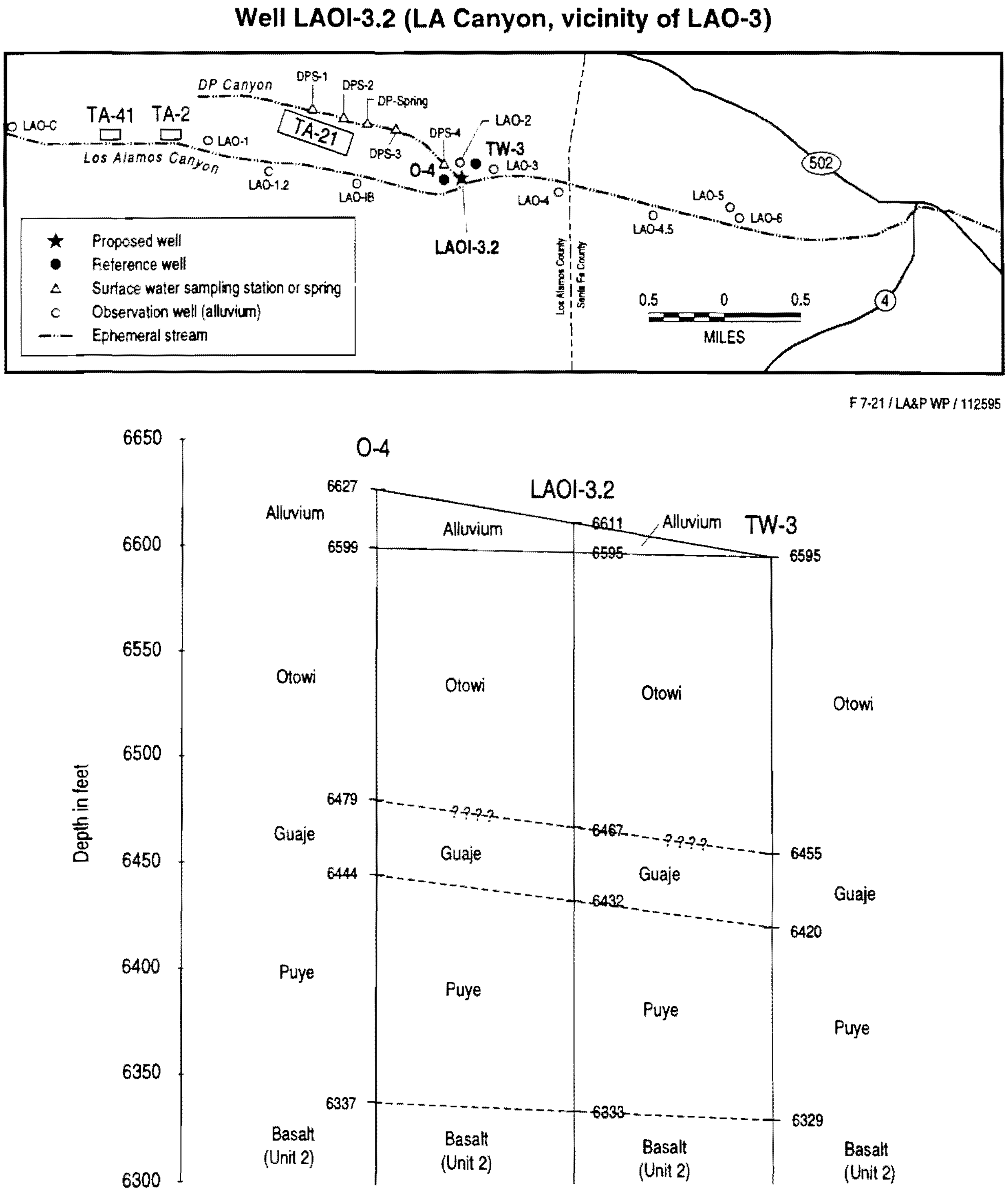
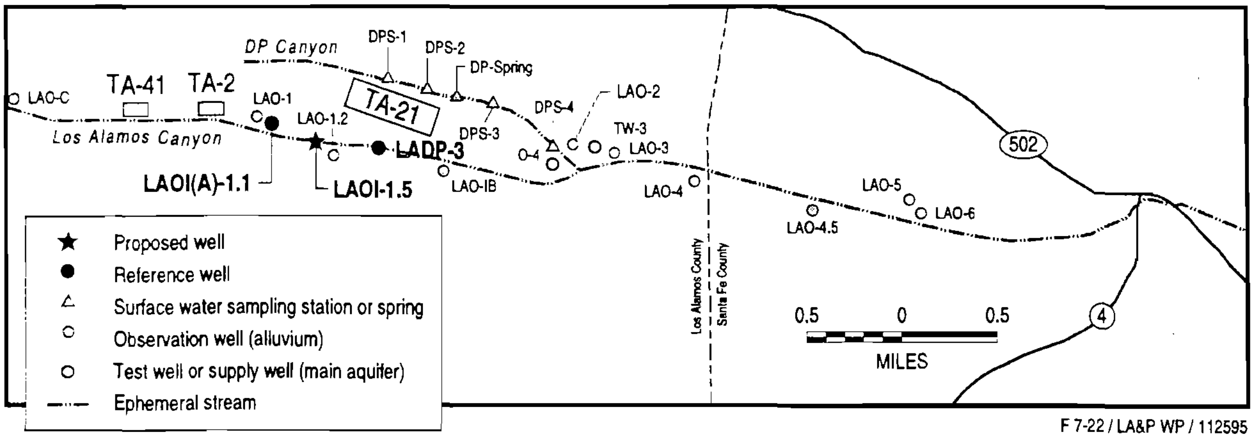


Figure 7-21. Expected stratigraphic section for proposed intermediate perched zone well LAOI-3.2.

Well LAOI-1.5 [LA Canyon between LAOI(A)-1.1 and LADP-3]



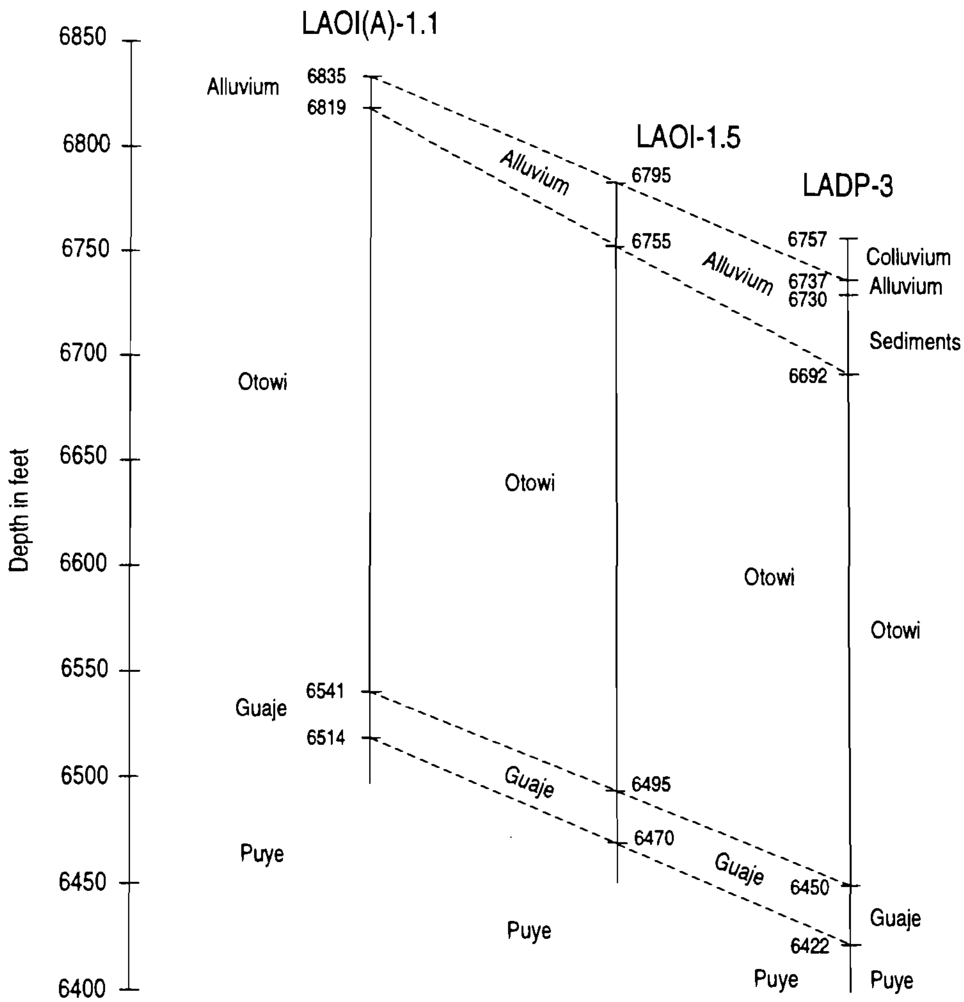


Figure 7-22. Expected stratigraphic section for proposed intermediate perched zone well LAOI-1.5.

Importance

Gaining a better understanding of hydrologic relationships in this area is important to establishing the significance of fault/fracture zones as a mechanism for downward water movement.

Approach

One observation well (LAOI(B)-1.1 in Table 7-12 and Figure 7-14) will be installed to a greater depth than LAOI(A)-1.1 (323 ft) in order to examine the possible mechanisms for perched ground water accumulation in the Puye Formation. It is expected to be about 350 ft deep (Figure 7-23) and will have a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. The well will be drilled, completed, and characterized as described in 7.3.3.2.2. Nine cores will be preserved in all. The water samples will be analyzed for major and minor ions, neutral species, organic compounds, low-detection-limit tritium, ^{14}C, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, stable isotopes, trace elements, and field-measured parameters, as discussed in Section 7.3.3.3.

Issue Number 7

Does an intermediate perched zone exist east of well TW-2A in Pueblo Canyon and, if so, how is it recharged?

Importance

Ground water in TW-2A contained plutonium activities of 1.280 ± 0.091 pCi/L (above the DOE derived concentration guides for drinking water of 1.2 pCi/L) in one sample, which may be an analytical outlier, and tritium activities of 2,900 ± 500 pCi/L—well above a natural background of 64 pCi/L (LAO-B). The extent of the intermediate perched zone is not known, nor are possible mechanisms for its recharge. It is possible that the abandoned well TW-2B provides a pathway for contaminants to this zone and that the well should be plugged.

Approach

A new well will be installed east of TW-2A (POI-2 in Table 7-12 and Figure 7-15) and completed in the same intermediate perched zone. It is expected to be about 150 ft deep (Figure 7-18) and will have a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thicknesses. The well will be installed, completed and characterized as described in Section 7.3.3.2.2. Eight cores will be sampled and preserved in all. The water samples will be analyzed for major and minor ions, neutral species, organic compounds, low-detection-limit tritium, ^{14}C, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, stable isotopes, trace elements, and field-measured parameters, as discussed in section 7.3.3.3. To define the hydrologic and geochemical properties of the perching layer, resampling of TW-2A for the same analyte list will be conducted if contaminants are detected in POI-2.

Issue Number 8

What is the source of recharge for the intermediate perched zone in upper Los Alamos Canyon east of the Pajarito Fault Zone?

Well LAOI(B)-1.1 [LA Canyon Near LAOI(A)-1.1]

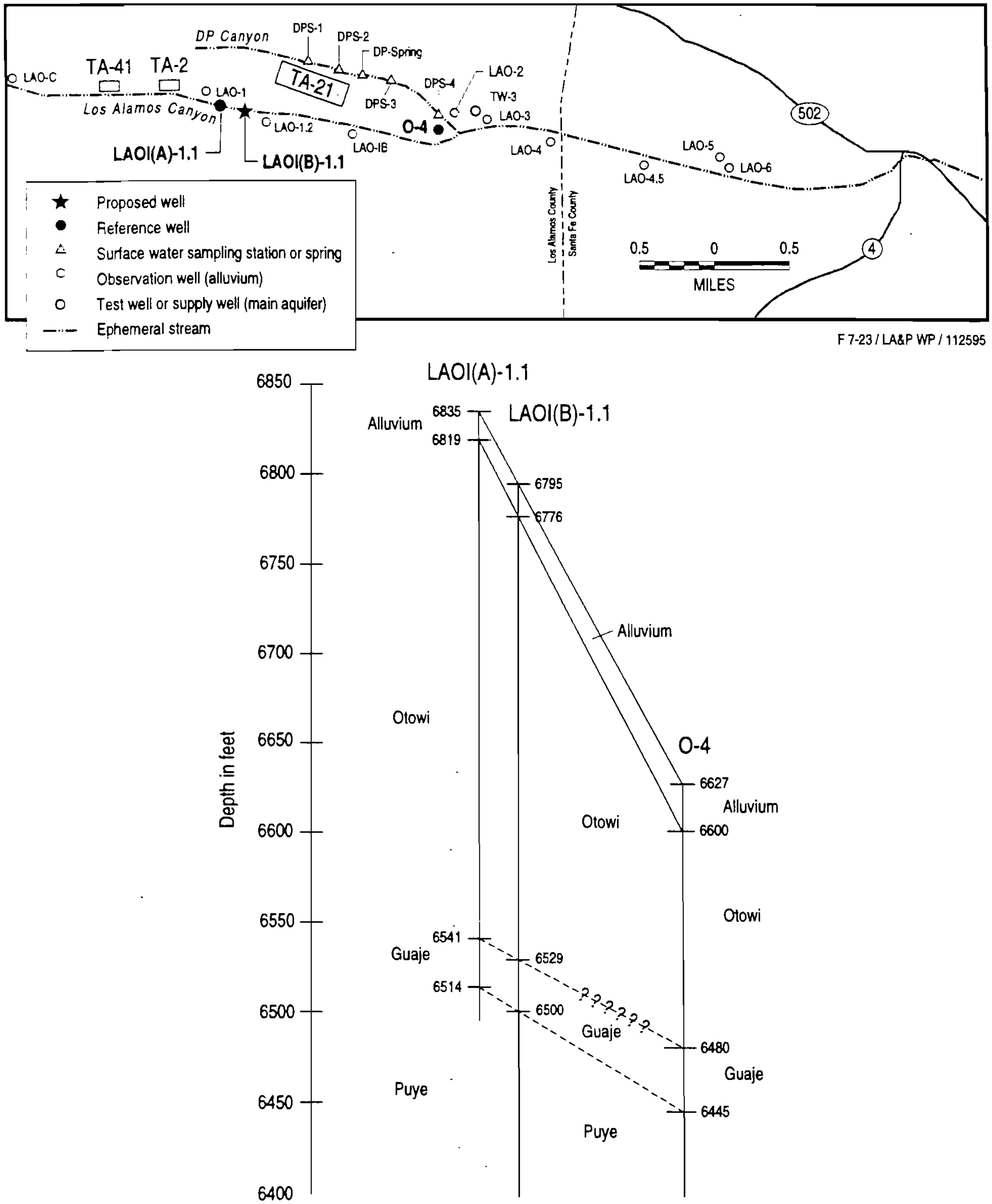


Figure 7-23. Expected stratigraphic section for proposed intermediate perched zone well LAOI(B)-1.1.

Importance

Logs from the borehole for abandoned well H-19, located immediately west of the Los Alamos Canyon bridge, suggest that an intermediate perched zone exists in the Guaje Pumice Bed at this location. Confirming the presence of this intermediate perched zone at the location may define its lateral extent. The hydrologic characteristics of the zone and the chemical composition of the ground water would enable further examination of recharge in this portion of upper Los Alamos Canyon, possibly along the Pajarito Fault Zone. The chemical composition of ground water in this zone will be used as a basis of comparison to determine ground water sources and to determine ground water quality trends in the Guaje Pumice Bed further downgradient in Los Alamos Canyon.

Approach

One new observation well will be installed (LAOI-B in Table 7-12 and Figure 7-14) east of well H-19 to confirm the presence of an intermediate perched zone. It is expected to be about 450 ft deep (Figure 7-24) and will have a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness. The well will be installed, completed, and characterized as described in Section 7.3.3.2.2. Fourteen cores will be sampled and preserved. Water samples will be analyzed for major and minor ions, neutral species, organic compounds, low-detection-limit tritium, ^{14}C, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, stable isotopes, trace elements, and field-measured parameters, as discussed in Section 7.3.3.3.

Issue Number 9

Does the intermediate perched zone that discharges from Basalt Spring extend further east in lower Los Alamos Canyon?

Importance

Basalt Spring, which contains contaminants (tritium, phosphate, chloride, and nitrate)—apparently originating from the surface flow and alluvial ground water in Pueblo Canyon—supports perennial flow in part of lower Los Alamos Canyon and provides water for plants, livestock, and wildlife. It is unclear whether the levels of contamination are likely to be greater or less in the future because of the episodic nature of contaminant releases from the Laboratory.

It is also unclear whether other discharges from the intermediate perched water zone occur elsewhere in Los Alamos Canyon to the east of Basalt Spring.

Approach

Surface discharges, such as Los Alamos Spring, will be characterized and an attempt will be made to determine if any other discharges take place further east in Los Alamos Canyon or to the southeast in Sandia Canyon. Using aerial photographs or other remote sensing information, a detailed surface reconnaissance will be conducted to look for evidence of seeps and springs. Water samples will be analyzed for major and minor ions, neutral species, trace elements, organic compounds, low-detection-level tritium, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and field-measured parameters, as described in Section 7.3.3.3.

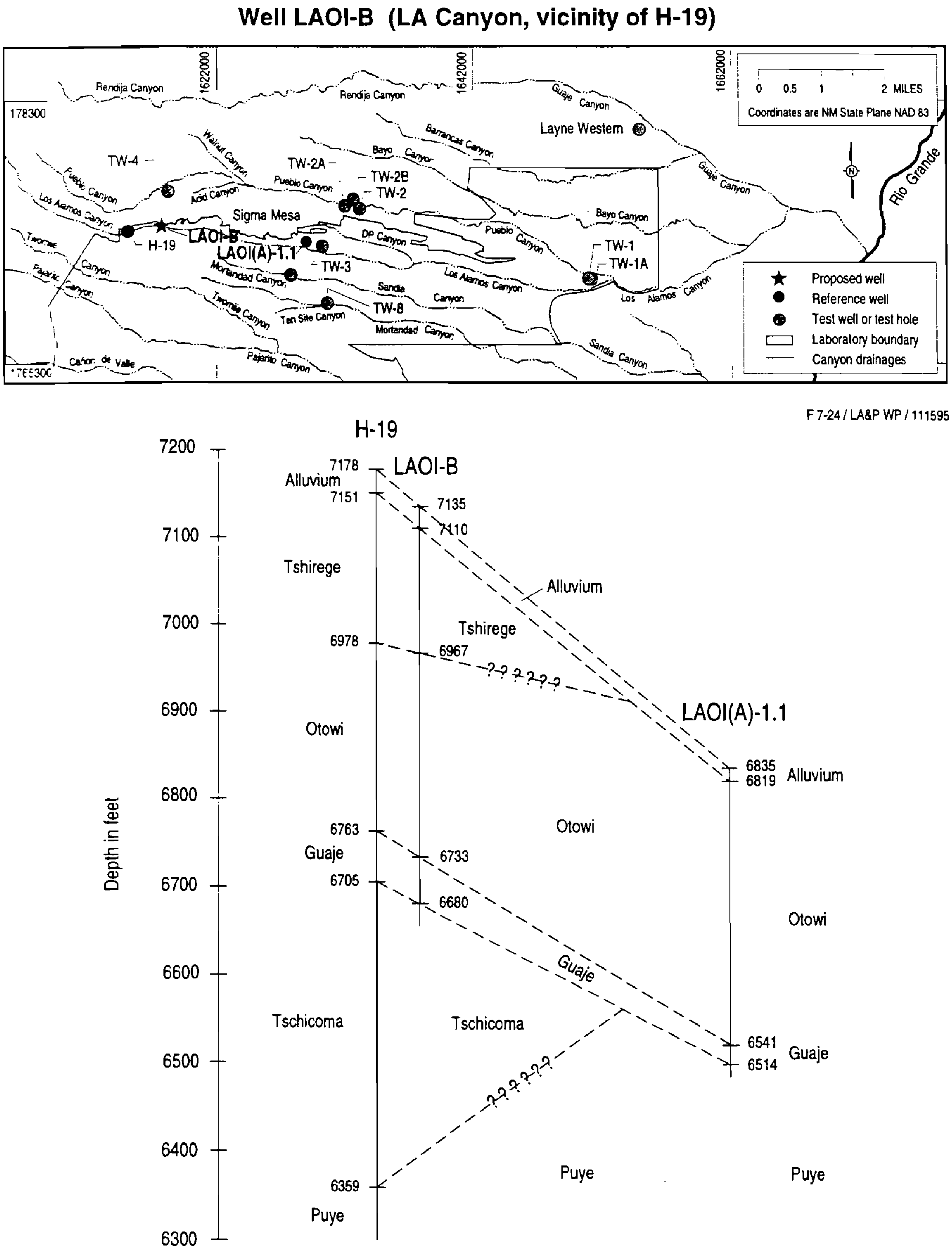


Figure 7-24. Expected stratigraphic section for proposed intermediate perched zone well LAOI-B.

7.3.3.1.4 Intermediate-Depth Borehole Characterization

For each of the intermediate-depth boreholes, the characterization approach includes a systematic set of steps to be completed. These steps are described in this section.

1. Construct a detailed lithologic log during drilling.

A lithologic log will be prepared from cores (when taken), cuttings, and drilling-performance data. The technical team will save, with appropriate packaging and storage, some cuttings and/or cores for possible future mineralogical, chemical, or hydrologic analyses.

2. Run a geophysical logging suite.

Geophysical logs will be run generally only in the intermediate perched zone boreholes, although compact neutron moisture log tools can be run in shallower holes if a small, truck-mounted rig is available. For the intermediate-depth boreholes, natural gamma, neutron moisture, and density logs may be collected, if the drilling method and the hole stability permit. Other geophysical logs may be considered if (in the opinion of the technical team) they satisfy a particular need in a given location.

3. Collect cores at selected intervals.

At least one interval of core will be collected (depending on the number and types of analyses to be performed) in each hydrogeologic unit and immediately above and below each major hydrogeologic contact.

7.3.3.1.5 Santa Fe Group (Main Aquifer) Sampling

The Santa Fe Group (main aquifer) will be included in the initial characterization efforts by sampling from and taking other measurements in existing wells completed in the main aquifer. These efforts will attempt to

- add greater confidence to the present understanding of the conceptual model and
- confirm or clarify existing questionable or uncertain data.

The focus of the main aquifer testing is to identify possible locations for downward movement of potentially contaminated ground water and to pick appropriate locations for investigating main aquifer conditions with new wells. The characterization effort for the main aquifer will initially center on reevaluating information from existing wells completed in the main aquifer and on selective resampling and analysis of those wells.

The following are the major components of the main aquifer testing.

- Resampling of LA-1B, LA-2, and LA-5 for low-detection-limit tritium, organic compounds, major and minor ions, trace elements, stable isotopes, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and field-measured parameters.

- Reevaluate existing ^{14}C measurements made on main aquifer ground water considering carbonate geochemistry to help interpret the existing ^{14}C data. This evaluation is critical in estimating the proportion of contemporary recharge to different parts of the main aquifer.
- Perform mixing studies using existing geochemical data including major ion chemistry, stable isotopes, radiogenic isotopes, and trace elements for main aquifer wells LA-1A, LA-1B, and LA-2. The objective is to test the hypothesis of mixing young water (based on ^{3}H data) with old water (based on ^{14}C data and major ion chemistry).
- Resampling of Sacred Spring and Indian Spring. Previous low-detection-limit tritium sampling may have been affected by mixing with surface or atmospheric moisture and may not reflect the actual source of water in the spring.

The proposed sampling and analysis, and the evaluation of existing geochemical and hydrologic data, includes efforts to address the following four major issues and questions regarding the main aquifer ground water.

Issue Number 1

Are the ^{14}C minimum-age estimates for TW-2, TW-3, and TW-4 true indications of young water?

Importance

The ^{14}C minimum-age estimates for these wells, if valid, would indicate a significant component of very young water in the main aquifer. These age estimates depend on estimates of the nature and degree of interactions of the ground water with the surrounding rock matrix. Reevaluation of existing data and possible resampling of the wells will improve understanding of the degree of interaction and establish the validity of previous age estimates.

Approach

Existing data on carbon isotopes and carbonate chemistry will be reexamined to ensure the validity of previous age estimates. If determined necessary, wells TW-2, TW-3, and TW-4, and Sacred Spring and Indian Spring will be resampled. Samples will be processed using careful filtration techniques, and analyzed for major and minor ions, neutral species, trace elements, organic compounds, low-detection-limit tritium, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and field-measured parameters as discussed in Section 7.3.3.3. In addition, samples will be analyzed for selected chemical and isotopic tracers to refine understanding of the water chemistry.

Issue Number 2

What is the mechanism by which tritium has reached the main aquifer in lower Pueblo Canyon at TW-1?

Importance

Geologic data suggest a plausible pathway from the alluvium to the main aquifer through the Puye Formation. Confirmation of such a pathway could explain the measured levels of tritium and ^{14}C, as well as the chloride and nitrate concentrations in TW-1. Results of this investigation will be used to evaluate the potential for these and other contaminants to reach the main aquifer and water supply wells in the future. The objective is to understand whether changes in the water level in TW-1 are caused by well-bore leakage, recharge from the alluvium, or recharge from intermediate perched zone ground water beneath lower Pueblo Canyon (or some combination).

Approach

New well POI-4 (Table 7-12 and Figure 7-15), installed primarily for the characterization of the intermediate perched zone, will be used also to determine whether flow is occurring beneath the Cerros del Rio basalts in the Puye Formation. A tracer test involving TW-1, TW-1A, and POI-4 may help to evaluate whether well-bore leakage in the vicinity of TW-1A and TW-1 is responsible for the observed contaminants.

Issue Number 3

What is the mechanism for tritium-contaminated recharge to the main aquifer in the vicinity of wells LA-2 and LA-1A?

Importance

Well LA-2 may be used by San Ildefonso Pueblo as a future water supply. In the vicinity of LA-2 and LA-1A, the recharge mechanism responsible for the appearance of tritium in the main aquifer needs to be better defined, so that the potential for increased contamination can be evaluated.

Approach

Existing data collected at LA-1A, LA-1B, and LA-2 will be evaluated before collecting new water samples. If ground water samples are collected, they will be analyzed for major and minor ions, neutral species, trace elements, organic compounds, low-detection-limit tritium, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, and field-measured parameters as discussed in Section 7.3.3.3. Interpretation of this data will be closely integrated with work on alluvial ground water Issue Number 11 discussed in Section 7.3.3.1.2.

Issue Number 4

Are there variations in age and chemistry of ground water with increasing depth in the main aquifer?

Importance

Well Otowi-1 is expected to become operational sometime in 1996. This supply well provides an opportunity to selectively sample different zones of the main aquifer in the Santa Fe Group.

Approach

The opportunity to sample the new supply well Otowi-1, near the confluence of Pueblo Canyon and Los Alamos Canyon, may take place in 1996. This well will be sampled at the earliest possible time when construction is underway to equip and connect the well to the Los Alamos County water supply. A small submersible pump will be temporarily installed with swab plates to restrict the zone of pumping and to collect samples from different levels in the screened section of the well. This well will be sampled for major and minor ions, neutral species, trace elements, organic compounds, low-detection-level tritium, ^{14}C, ^{90}Sr, ^{137}Cs, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, $^{239,240}Pu$, ^{241}Am, stable isotopes, and field-measured parameters as described in Section 7.3.3.3. Results of the analyses will provide direct input into risk assessment data and should help clarify the possible recharge sources and vertical structure of the main aquifer to a depth of more than 2500 ft.

7.3.3.2 Sampling Methods

Well construction activities will be completed, to the extent possible, in accordance with procedures outlined in LAN-ER-SOP-05.01, "Monitor Well Construction," NMED Well Construction and Abandonment Guidelines, and well construction requirements specified in Section C(1) of the HSWA Module. A well design and completion matrix addressing these procedural requirements can be found in Appendix J of the proposed GWPMP document. Well development will follow the procedures outlined in LANL-ER-SOP-05.02, "Well Development." Water level readings in the new wells will be performed in accordance with LANL-ER-SOP-07.02, "Fluid Level Measurements." Drilling methods (hollow-stem augering and rotary drilling) are described in LANL-ER-SOP-04.01, "Drilling Methods and Drill Site Management." Specific methods for the alluvial and intermediate-depth borehole drilling are described in the following sections. Surface water, ground water, and borehole core samples will be collected according to the ER Project SOPs listed in Table 7-14.

All samples will be collected using the applicable ER Project SOPs for the collection, preservation, identification, storage, transport, and documentation of environmental samples, as described in Section 4.4. in Chapter 4 of the IWP (LANL 1995, 49822). Decontamination of sampling equipment will be performed in accordance with

TABLE 7-14

GROUND WATER AND BOREHOLE CORE SAMPLING METHODS REQUIREMENTS

Activity	LANL-ER-SOP No.
Surface water sampling	06.13
Monitor well construction	05.01
Well development	05.02
Purging of wells for representative sampling	06.01
Pressure transducer measurements	07.01
Fluid level measurements	07.02
Drilling methods and drill-site management	04.01
General borehole logging	04.04
Core-barrel sampling for subsurface earth materials	06.26
Field logging, handling, and documentation of borehole samples	12.01

LANL-ER-SOP-01.08, "Field Decontamination of Drilling and Sampling Equipment." Wash water and other wastes generated during the sampling operation will be managed and disposed of in accordance with LANL-ER-AP-05.3, "Management of ER Program Wastes."

7.3.3.2.1 Alluvial Borehole Drilling

The drilling objective will be to penetrate the base of the alluvium and the saturated zone of bedrock. Boreholes will be cored approximately 5 ft into the unsaturated zone of underlying bedrock. The purpose of the core is to sample and characterize the possible zones of perching for the alluvial ground water. At a minimum, one core sample will be collected above and below each major hydrological contact. Shallow boreholes will be completed as alluvial observation wells with 2-in.-diameter polyvinyl chloride (PVC), or suitable equivalent casing and screen. These wells will contain a 10-ft screen placed at the water table (top of the screen at the water table) to account for variations in saturated thickness.

Subsurface investigations will use drilling techniques that are dependent upon the type and quantity of sample material required, the planned borehole total depth (TD), the constituents of interest, type of contamination controls, and rigor associated with maintenance of the sample integrity. Hollow-stem augers and rotary systems are the two primary forms of drilling routinely used at the Laboratory. Alluvial boreholes will be advanced using hollow-stem augers wherever possible to ensure that the water table interval and the base of the alluvium can be identified precisely.

Hollow-stem augers with 5-ft-long, split-barrel samplers are used routinely for drilling and sampling (coring) to depths of up to 250 ft below ground surface in volcanic tuff. They can be used to obtain HX- or CP-size (variable-diameter) core material for radiochemical and chemical analysis. Fluid circulation is not required to drill and sample with a hollow-stem auger—a significant advantage over most conventional rotary applications. In some cases, deionized water may be introduced directly to the borehole with a decontaminated, stainless steel dart bailer system. The disadvantages to the system are its depth limitation (may be less than 250 ft if basalts are encountered), rate of penetration, disturbance to core material associated with the sampling process, and generation of relatively large volumes of "cutting" materials that may include contaminants at some sites.

7.3.3.2.2 Intermediate-Depth Borehole Drilling

It may be possible to use hollow-stem augers in drilling some intermediate-depth wells. Experience shows that penetration of the Otowi Member of the Bandelier Tuff can be achieved to depths up to approximately 250 ft. However, the Puye Formation, and especially the Cerros del Rio basalts, will require rotary drilling methods. Also, drilling and sampling operations to depths greater than 250 ft (in volcanic tuff) will generally utilize a rotary drilling strategy. Before drilling each well, the depth and target formation will be reviewed, in consultation with the drilling organization, to determine which method is appropriate for different segments of the borehole.

Rotary systems can drill larger-diameter deeper boreholes than hollow-stem auger equipment. In general, rotary applications have a greater rate of penetration than hollow-stem auger tools and can be used to collect core from hard-rock systems. The disadvantage of rotary systems is the need to circulate a fluid in the borehole. The fluid can impact sample quality.

Rotary drilling with wire-line coring systems—capable of providing HX- or CP-size cores—will probably be employed for intermediate-depth coring to as great a depth as possible. In general, the core barrel will be lined to facilitate sample handling and containment at the surface. Several forms of rotary wire-line systems may be used including a punch core, a modified pitcher barrel, and a conventional rotary wire-line system. Fluids to be circulated in the rotary systems may include air, water, and inert gases (for example, argon) but generally, air will be used as the circulating fluid. Sidewall cross-contamination will be minimized by using conventional circulation (through the bit). In general, circulation fluids will be air filtered through a high-efficiency particulate air system or an air mist using deionized water. An inert gas may be introduced to those environments where the redox potential is a significant concern. The appropriate circulation fluid will be selected based on the target analytes, target sample depth, and site-specific borehole conditions. Steps to avoid introducing muds, special polymers, and other proprietary constituents will be taken and such drilling materials will be used only after field personnel have determined that the hole cannot be advanced without the special additives. Borehole particulate and gaseous tracers will be used, as appropriate, to help determine sample integrity and overall adequacy of the sampling program.

Intermediate perched zone wells will be installed with a minimum 4-in.-diameter casing. A surface casing extending below the alluvium will be grouted in place before advancing the borehole into bedrock. Special precautions will be taken to provide proper annular seal for boreholes and wells approaching or greater than 300 ft depth in conformance with the HSWA Module requirements to prevent potential downward migration of contaminated water.

Well completion will depend upon the hydrogeologic conditions encountered at the target horizon. If perched ground water is found, the well will be completed with a 10-ft stainless steel screen and stainless steel casing to the boundary of the perched zone. From the perched zone boundary to the surface, an alternate casing such as standard steel or PVC may be used with a dielectric to minimize cost. A permanent ground water pump suitable for sample collection may be installed.

7.3.3.3 Analytical Methods

This section describes the methods for analyzing ground water samples for organic, inorganic, and radionuclide constituents, and describes the methods for analyzing borehole core samples for inorganic and radionuclide constituents and geotechnical parameters. Analysis of ground water and borehole samples has two purposes: (1) to detect and measure Laboratory-derived COPCs, and (2) to obtain information about the baseline geochemistry of the water-bearing zones.

7.3.3.3.1 Analysis of Ground Water Samples

Ground water samples collected according to the strategy outlined in Section 7.3.3.1 will initially undergo full-suite analyses for organic, inorganic, and radionuclide constituents at an ER Project-approved fixed-site laboratory. The analytical suites and methods for analysis of organic constituents are listed in Table 7-7 (Section 7.2.4.3). The analytical suites include SVOCs, organochlorine pesticides, PCBs, and VOCs. All analyses for organic constituents will be performed according to EPA SW-846 protocols (EPA 1986, 31733). The detailed analyte lists, EQLs, required QC procedures, and the acceptance criteria are found in the ER Project analytical services statement of work (LANL 1995, 49738). The first sample collected from each alluvial and intermediate perched zone well and at each surface water sampling location will undergo analysis for the full suite of organic constituents. If organic constituents are identified as COPCs for a particular sampling location, all subsequent samples from that location will be analyzed for organic COPCs. Any organic compound reported to be below the method detection limit will be excluded from subsequent limited-suite analyses.

All water samples collected over a one-year sampling period will be analyzed for inorganic constituents in order to identify COPCs and to obtain a better understanding of the baseline geochemistry of surface water and ground water. The target analytes, EDLs, and analytical methods for inorganic constituents are listed in Table 7-15. All water samples collected for inorganic analyses will be filtered to remove particles larger than 0.45 μm at the time of collection. Analyses of these samples will be supplemented by analyses of unfiltered samples collected for environmental monitoring by the Laboratory's Water Quality and Hydrology group (ESH-18). Measurements for inorganic constituents include analyses for 26 dissolved metals, major anions (bromide, chloride, fluoride, nitrate, and sulfate), minor anions (chlorate, nitrite, and phosphate), dissolved silica, and total cyanide. All analyses for inorganic constituents will be performed according to EPA SW-846 protocols (EPA 1986, 31732) or EPA standard methods for chemical analysis of water. The required QC procedures and acceptance criteria for the metals and total cyanide analyses are found in the ER Project analytical services statement of work (LANL 1995, 49738).

The target analytes and their half-lives, detected emission, EQLs, and analytical methods for radionuclide constituents are listed in Table 7-16. In addition to measurements of gross-alpha, -beta, and -gamma radioactivity, the radionuclide analytes include ^{241}Am, tritium, ^{90}Sr, ^{99}Tc, and isotopes of plutonium, thorium, and uranium. The analyses for low-detection-limit tritium and ^{236}U will help identify whether recent recharge to an aquifer has occurred. The analyte list for the gamma spectroscopy analysis given in Table 7-10 (Section 7.2.4.3) includes long-lived activation and fission products, as well as their shorter-lived daughter products. The shorter-lived daughter products are included in the analyte list to verify the presence of the longer-lived parents. The shorter-lived radionuclides (half-life less than 180 days) are not considered to be COPCs. The required QC procedures and acceptance criteria for the radiochemical analyses are found in the ER Project analytical services statement of work (LANL 1995, 49738).

Water samples will also be analyzed for the additional parameters listed in Table 7-17. To better understand the nature of recharge to an aquifer, analysis for ^{14}C and stable isotope ratios deuterium/hydrogen and $^{18}O/^{16}O$ will be performed to estimate the age of water and to help identify specific sources of recharge. Analyses for ^{13}C and dissolved organic carbon (humic acids) will be performed to provide better understanding of the baseline organic geochemistry of the ground water. The field measurements listed in Table 7-18, which include alkalinity, dissolved oxygen, pH, specific conductance, temperature, and turbidity, will be made at the time of sample collection.

7.3.3.3.2 Analysis of Borehole Core Samples

Borehole core samples collected according to the criteria outlined in Section 7.3.3.1.4 will undergo analysis for inorganic constituents and the radionuclide constituents listed in Tables 7-9 and 7-10 (Section 7.2.4.3) at an ER Project-approved fixed-site laboratory. The purpose of the analyses is to identify COPCs and to obtain a better understanding of the baseline geochemistry of the water-bearing zones. The target analytes, EDLs, and analytical methods for inorganic constituents are listed in Table 7-19.

TABLE 7-15

ANALYTE LIST, ESTIMATED DETECTION LIMITS, AND ANALYTICAL METHODS FOR INORGANIC CONSTITUENTS IN GROUND WATER SAMPLES[a]

Analyte	EDL[b] (µg/L)	Analytical Method	Analytical Protocol
Metals (dissolved)			
Aluminum	200	ICPES[c]	SW-6010B
Antimony	60	ICPES or ICPMS[d]	SW-6010B or SW-6020
Arsenic	10	GFAA[e] or ICPMS	SW-7060 or SW-6020
Barium	200	ICPES	SW-6010B
Beryllium	5	ICPES	SW-6010B
Boron	10	ICPES	SW-6010B
Cadmium	5	ICPES	SW-6010B
Calcium	50	ICPES	SW-6010B
Chromium	10	ICPES	SW-6010B
Cobalt	50	ICPES	SW-6010B
Copper	25	ICPES	SW-6010B
Iron	20	ICPES	SW-6010B
Lead	3	GFAA or ICPMS	SW-7421 or SW-6020
Magnesium	50	ICPES	SW-6010B
Manganese	15	ICPES	SW-6010B
Mercury	0.2	CVAA[f]	SW-7470A
Nickel	40	ICPES	SW-6010B
Potassium	500	ICPES	SW-6010B
Selenium	5	GFAA or ICPMS	SW-7741 or SW-6020
Silver	10	ICPES	SW-6010B
Sodium	50	ICPES	SW-6010B
Thallium	10	GFAA or ICPMS	SW-7841 or SW-6020
Titanium	10	ICPES	SW-6010B
Uranium (total)	1	ICPMS	SW-6020
Vanadium	50	ICPES	SW-6010B
Zinc	20	ICPES	SW-6010B
Anions (dissolved)			
Bromide	100	IC[g]	SW-9056
Chlorate	100	IC	SW-9056
Chloride	100	IC	SW-9056
Fluoride	20	IC	SW-9056
Nitrate	40	IC	SW-9056
Nitrite	40	IC	SW-9056
Phosphate	20	IC	SW-9056
Sulfate	100	IC	SW-9056
Other Inorganics (dissolved)			
Silica	1000	Colorimetry	EPA Method 370.1
Total cyanide	50	Colorimetry	SW-9012A

a. All water samples will be filtered to remove particles larger than 0.45 µm at the time of collection.
b. EDL = estimated detection limit
c. ICPES = inductively coupled plasma emission spectroscopy
d. ICPMS = inductively coupled plasma mass spectrometry
e. GFAA = graphite furnace atomic absorption
f. CVAA = cold vapor atomic absorption
g. IC = ion chromatography

TABLE 7-16

ANALYTE LIST, ESTIMATED QUANTITATION LIMITS, AND ANALYTICAL METHODS FOR RADIONUCLIDE CONSTITUENTS IN GROUND WATER SAMPLES[a]

Analyte	Half-Life (yr)	Detected Emission	EQL[b] (pCi/L)	Analytical Method
^{241}Am	432.2	α	0.1	α-Spectrometry
^{3}H	12.3	β	300	LSC[c]
^{3}H (low level)	12.3	β	1	Electrolytic enrichment
^{238}Pu	87.7	α	0.1	α-Spectrometry
$^{239,240}Pu$[d]	2.410×10^{4}	α	0.1	α-Spectrometry
^{90}Sr	29.1	β	5.0	GPC[e]
^{99}Tc	2.13×10^{5}	β	0.1	GPC or ICPMS[f]
^{230}Th	7.54×10^{4}	α	0.1	α-Spectrometry[g]
^{232}Th	1.40×10^{10}	α	0.1	α-Spectrometry[g]
^{234}U	2.46×10^{5}	α	0.1	α-Spectrometry[g]
^{235}U	7.04×10^{8}	α	0.1	α-Spectrometry[g]
^{236}U	2.342×10^{7}	–	0.1	TI/MS[h]
^{238}U	4.47×10^{9}	α	0.1	α-Spectrometry[g]
Gamma spectroscopy[i]	–	γ	20[j]	γ-Spectroscopy
Gross-alpha	–	α	3.0	GPC or LSC
Gross-beta	–	β	3.0	GPC or LSC
Gross-gamma	–	γ	100	NaI(Tl)[k] HPGe[l] detection

a. All water samples will be filtered to remove particles larger than 0.45 μm at the time of collection.
b. EQL = estimated quantitation limit
c. LSC = liquid scintillation counting
d. The ^{239}Pu and ^{240}Pu isotopes cannot be distinguished by alpha spectrometry. The half-life of ^{239}Pu is given.
e. GPC = gas proportional counter
f. ICPMS = inductively coupled plasma mass spectrometry
g. Radionuclide may also be analyzed by ICPMS.
h. TI/MS = thermal ionization/mass spectrometry
i. The gamma spectroscopy analyte list is given in Table 7-10.
j. The EQL for ^{241}Am and ^{137}Cs is 20 pCi/L; the EQL for other analytes will vary.
k NaI(Tl) = thallium-doped sodium iodide
l. HPGe = high-purity germanium

TABLE 7-17

ANALYTE LIST AND ANALYTICAL METHODS FOR ADDITIONAL PARAMETERS IN GROUND WATER SAMPLES[a]

Analyte	Analytical Method
Stable Isotopes[b]	
Carbon-14, Carbon-13	Accelerator MS[c]
Deuterium/hydrogen	Accelerator MS
Oxygen-18/Oxygen-16	MS
Other Analytes	
DOC[d] (humic acids)	Modified EPA Method 415
Hardness (as $CaCO_3$)	EPA Method 130

a. All water samples will be filtered to remove particles larger than 0.45 µm at the time of collection.
b. Stable isotopes will be measured in intermediate-depth ground water samples.
c. MS = mass spectrometry
d. DOC = dissolved organic carbon

Measurements for inorganic constituents include analyses for twenty-six dissolved metals, major anions (bromide, chloride, fluoride, and sulfate), dissolved silica, and total cyanide. All analyses for inorganic constituents will be performed according to EPA SW-846 protocols (EPA 1986, 31732) or EPA Standard Methods for chemical analysis of wastes. Core samples will be processed using mineral acid extraction procedures for analysis of trace metals. The anions and dissolved silica analyses will be performed on the leachate formed from a deionized water slurry of the homogenized core samples. The required QC procedures and acceptance criteria for the metals and total cyanide analyses are found in the ER Project analytical services statement of work.

Core material from characterization boreholes will also be analyzed for the properties identified in Table 7-20. The geotechnical, geochemical, hydrologic, and geophysical analyses will be performed on selected core samples based on the judgement of the field geologist.

TABLE 7-18

FIELD MEASUREMENTS FOR GROUND WATER SAMPLES

Measurement	Precision[a]	Method
Alkalinity	±1 mg/L $CaCO_3$	EPA Method 310.1
Dissolved oxygen	±0.1 mg/L	LANL-ER-SOP-06.02
pH	±0.02	LANL-ER-SOP-06.02
Specific conductance	±1 µmho/cm (25° C)	LANL-ER-SOP-06.02
Temperature	±1 °C	LANL-ER-SOP-06.02
Turbidity (nephelometric)	±1 NTU[b]	EPA Method 180.1

a. Precision with which measurement will be recorded.
b. NTU = nephelometric turbidity units

TABLE 7-19

ANALYTE LIST, ESTIMATED DETECTION LIMITS, AND ANALYTICAL METHODS FOR INORGANIC CONSTITUENTS IN BOREHOLE CORE SAMPLES

Analyte	EDL[a] (mg/kg)	Analytical Method	Analytical Protocal
Metals			
Aluminum	40	ICPES[b]	SW-6010B
Antimony	12	ICPES or ICPMS[c]	SW-6010B or SW-6020
Arsenic	2	GFAA[d] or ICPMS	SW-7060 or SW-6020
Barium	40	ICPES	SW-6010B
Beryllium	1	ICPES	SW-6010B
Boron	10	ICPES	SW-6010B
Cadmium	1	ICPES	SW-6010B
Calcium	500	ICPES	SW-6010B
Chromium	2	ICPES	SW-6010B
Cobalt	10	ICPES	SW-6010B
Copper	5	ICPES	SW-6010B
Iron	20	ICPES	SW-6010B
Lead	0.6	GFAA or ICPMS	SW-7421 or SW-6020
Magnesium	1000	ICPES	SW-6010B
Manganese	3	ICPES	SW-6010B
Mercury	0.1	CVAA[e]	SW-7471A
Nickel	8	ICPES	SW-6010B
Potassium	500	ICPES	SW-6010B
Selenium	1	GFAA or ICPMS	SW-7741 or SW-6020
Silver	2	ICPES	SW-6010B
Sodium	500	ICPES	SW-6010B
Thallium	2	GFAA or ICPMS	SW-7841 or SW-6020
Titanium	1	ICPES	SW-6010B
Uranium (total)	0.5	ICPMS	SW-6020
Vanadium	10	ICPES	SW-6010B
Zinc	4	ICPES	SW-6010B
Anions[f]			
Bromide	0.1	IC[g]	SW-9056
Chloride	0.1	IC	SW-9056
Fluoride	0.02	IC	SW-9056
Sulfate	0.1	IC	SW-9056
Other Inorganics			
Silica (dissolved)[f]	1000	Colorimetry	EPA Method 370.1
Total cyanide	0.05	Colorimetry	SW-9012A

a. EDL = estimated detection limit
b. ICPES = inductively coupled plasma emission spectroscopy
c. ICPMS = inductively coupled plasma mass spectrometry
d. GFAA = graphite furnace atomic absorption
e. CVAA = cold vapor atomic absorption
f. Anions and dissolved silica analyses will be performed on the leachate formed from a deionized water slurry of the homogenized core sample.
g. IC = ion chromatography

TABLE 7-20

GEOTECHNICAL, GEOCHEMICAL, HYDROLOGIC, AND GEOPHYSICAL ANALYSES OF BOREHOLE CORE SAMPLES

Analysis	Analytical Method
Geotechnical analyses	
Bulk density, dry density	ASTM[a] D-4531-86
Distribution coefficient (K_d)	Batch Method
Porosity (total and effective)	API[b] Method 40, Section 3.58
Soil classification	ASTM D-2488
Geochemical analyses	
Mineralogical composition	X-ray diffraction, electron microprobe[c]
Hydrologic analyses	
Moisture content (gravimetric and volumetric)	ASTM D-4531-86
Moisture potential	Pressure plate extractor (or other techniques)
Saturated hydraulic conductivity	ASTM D-2434-68
Geophysical analyses	
Lithological logging	TBD[d]
Natural gamma logging	TBD
Neutron moisture logging	TBD

a. ASTM = American Society for Testing and Materials
b. API = American Petroleum Institute
c. Geochemical analyses are described in the LANL-ER-SOPs-09 series.
d. TBD = to be determined

7.3.4 Reconciliation with Data Quality Objectives

This section describes the data quality objectives process (EPA 1994, 35363) as completed for the surface and ground water sampling and analysis portion of this chapter.

7.3.4.1 Alluvial Ground Water Data Quality Objectives

1. State the problem

> What is the present-day risk posed by contaminants migrating in the alluvial ground water in Los Alamos Canyon and Pueblo Canyon? Will that risk change with time?

2. Identify the decision(s)

- What is the areal extent of the alluvial ground water?

- Are there or could there be contaminant levels above the SALs?

  (Note: where MCLs exist for ground water contaminants, these values are used by the ER Project. Where no MCL exists, the SAL is based on a risk assessment.)

- Is there a process or pathway for exposure?

3. Identify inputs to decision(s)

- Moisture content/saturation, water levels, saturated thickness, temporal variations

- Analyses of core and/or water samples for geochemical parameters and species, including contamination indicators, temporal water quality variations, and a validated conceptual model of ground water chemistry

- Hydrologic properties, geologic structure, hydraulic gradients and predicted flow directions, land-use scenarios, spring-discharge information, current/planned well-withdrawal points, and a validated conceptual model of the hydrologic system

4. Define the study boundaries

- Spatial

  For initial planning use, the study will be limited by the boundaries for the Los Alamos Canyon and Pueblo Canyon investigation.

- Temporal

  Two sampling events approximately six months apart

  Quarterly spring flow measurements

  Chemical indicators sufficient to determine seasonal effects

  Quarterly sampling of background wells

- Interpretive Study

  The data needed to evaluate potential future impacts from contaminant transport within or outside of the Laboratory boundary must provide adequate validation of models of saturated zone and geochemical-transport properties to indicate that potential future impacts of contaminants are not substantially larger than present-day risks.

- Risk Assessment Study

  The data needed to evaluate the present-day risk should be collected as part of a single field program. Any major delay (more than three years from start to finish) could make it difficult to evaluate potential interannual variations in separate elements of the risk assessment.

  Because the field data will be collected in the first three years of the field investigation program, it is anticipated that the present-day risk assessment investigations will be completed in the fourth year (see Chapter 6 of this work plan, Section 6.1).

5. Develop a decision rule

Present-day risk assessment investigations will consider alluvial ground water if the following conditions are found:

- sufficient saturated thickness exists and persists over time for the water-bearing zone to qualify as an aquifer;
- contaminant concentrations are above SALs or MCLs, or trends in concentration of contaminants suggest that they may exceed SALs or MCLs in the future; and
- existing, or reasonably likely future land uses could lead to significant exposure.

6. Specify limits or uncertainty

Decisions depend on the professional judgment of the geochemist, hydrogeologist, geologist, risk assessor, and statistician. At this point, the conceptual model is not certain enough to allow formulation of statistical decision criteria. A broad range of issues have been defined that, depending upon the outcome of the field investigation, would contribute confidence to future decisions about the presence of any significant risk from alluvial ground water transport pathways.

Table 7-21 shows the relationship between the data quality objectives laid out above and the issues listed in Section 7.3.3.1.2.

7.3.4.2 Data Quality Objectives for Intermediate Perched Zone and Main Aquifer (Santa Fe Group) Ground Waters

1. State the problem

   Does the potential exist for contaminants to move to intermediate perched zones and the main aquifer and pose a potential risk?

2. Identify the decision(s)

   - Are intermediate perched zone and main aquifer ground waters present?

TABLE 7-21

RELATIONSHIP OF ALLUVIAL GROUND WATER ISSUES TO DATA QUALITY OBJECTIVE DECISIONS

Alluvial Ground Water Sampling and Analysis Issues[a]	Related DQO[b] Decision(s)
Issue No. 1: What is the background/baseline chemical composition of the alluvial ground water?	Decision No. 3: Is there a process or pathway for exposure?
Issue No. 2: Is alluvial ground water continuous in middle Pueblo Canyon, and is there present or likely future contamination?	Decisions No. 1, No. 2, and No. 3: What is the areal extent of alluvial ground water? Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 3: What is the lateral and vertical extent of the alluvial ground water and the degree of contamination in lower Pueblo Canyon?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 4: . How significant is percolation from the alluvium through bedrock to deeper horizons?	Decisions No. 1, No. 2, and No. 3: What is the areal extent of alluvial ground water? Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 5: How is the composition of alluvial ground water affected by discharges from TA-21 and TA-53, and by anthropogenic disturbance?	Decision No. 2: Are there or could there be contaminant levels above the SALs?
Issue No. 6: To what extent does alluvial ground water mix with ground water in underlying rock units between wells LAO-3 and LAO-5?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 7: How much deep percolation occurs beneath the upper Los Alamos Canyon alluvium?	Decisions No. 1, No. 2, and No. 3: Does intermediate ground water exist? Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure.
Issue No. 8: What is the lateral and vertical extend, and the degree of contamination of alluvial ground water in lower Los Alamos Canyon?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 9: How much deep percolation occurs beneath the alluvium in lower Los Alamos Canyon?	Decisions No. 1, No. 2, and No. 3: Does intermediate ground water exist? Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 10: What is the extent and impact of the hydrocarbon plume near Totavi on the alluvial ground water in lower Los Alamos Canyon?	Decisions No. 2 and No. 3: Are there or could there be contamination levels above the SALs? Is there a process or pathway for exposure?
Issue No. 11: How much infiltration of potentially contaminated surface water occurs to the alluvium and the main aquifer adjacent to the Rio Grande?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?

a. See Section 7.3.3.1.2

b. DQO = data quality objective

- Are there or could there be contaminant levels at or above the SALs or MCLs?

- Is there a process or pathway for exposure?

3. Identify inputs to decision(s)

- Moisture content/saturation, water levels, saturated thickness, temporal variations

- Analyses of core and/or water samples for geochemical parameters and species including contamination indicators, temporal water quality variations, and a validated conceptual model of aquifer chemistry

- Hydrologic properties, geologic structure, hydraulic gradients and predicted flow directions, land-use scenarios, spring-discharge information, current/planned well-withdrawal points, validated conceptual model of hydrologic system.

4. Define the study boundaries

- Spatial

For initial planning use, the study will be limited by the boundaries for the Los Alamos Canyon and Pueblo Canyon investigation. Portions of Sandia Canyon are also included in this investigation. Decisions 1 and 3 may require extension of the study area east and south of the limits of the canyons and possibly deeper toward the main aquifer, depending upon the actual observations.

- Temporal

–Field Study

Monthly ground water levels for one year

Monthly spring-flow measurements

Chemical indicators sufficient to determine seasonal effects

–Interpretive Study

The data needed to evaluate potential impacts from contaminant transport within or outside of the Laboratory boundary must provide adequate validation of models of aquifer distribution and transport properties to indicate that future impacts of transported contaminants are not substantially larger than present risks.

–Risk Assessment Study

These data needed to evaluate the present-day risk should be collected as part of a single field program. Any major delay (more than three years from start to finish) could make it difficult to evaluate potential interannual variations in separate elements of the risk assessment. Otherwise, the present-day risk can be evaluated at any time, once the data are collected.

Because the field data will be collected in the first three years of the program, it is anticipated that present-day risk assessment investigations will be completed in the fourth year.

5. Develop a decision rule

Present-day risk assessment investigations will consider intermediate perched zone and main aquifer ground water if the following conditions are found:

- sufficient saturated thickness exists and persists over time to qualify as an aquifer;
- contaminant concentrations are above SALs or MCLs, or trends in concentration of contaminants suggest that they may exceed SALs or MCLs in the future; and
- existing or reasonably likely future land uses could lead to significant exposure.

6. Specify limits or uncertainty

Professional judgments of a hydrogeologist, geologist, geochemist, risk assessor, and statistician are needed. At this point, the conceptual model is not certain enough to allow formulation of statistical decision criteria. We have defined a broad range of issues that, depending upon the outcome of the field investigation, would contribute confidence to future decisions about the presence of any significant risk from deep ground water transport pathways.

Table 7-22 shows the relationship between the data quality objectives laid out above and the issues listed in Sections 7.3.3.1.3 and 7.3.3.1.5.

TABLE 7- 22

RELATIONSHIP OF INTERMEDIATE AND MAIN AQUIFER ISSUES TO DATA QUALITY OBJECTIVE DECISIONS

Intermediate Perched Zone Sampling and Analysis Issues[a]	Related DQO[b] Decision(s)
Issue No. 1: Is an intermediate perched zone beneath Los Alamos Canyon connected to the discharge at Basalt Spring?	Decision No. 3: Is there a process or pathway for exposure?
Issue No. 2: How, and to what extent, are contaminants transported from surface water and alluvial ground water to the intermediate perched zone in lower Pueblo Canyon and to Basalt Spring?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 3: Is intermediate perched water flowing southeastward toward Sandia Canyon?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 4: Does an intermediate perched zone exist in Los Alamos Canyon between DP Canyon and state route 4, and is it contaminated?	Decisions No. 1 and No. 2: Does intermediate ground water exist? Are there or could there be contaminant levels above the SALs?
Issue No. 5: How and where is contamination transferred from the alluvium to the intermediate perched zone in the Guaje Pumice Bed east of TA-2?	Decision No. 2: Are there or could there be contaminant levels above the SALs?
Issue No. 6: How is ground water perched in the Puye Formation in the vicinity of well LAOI(A)-1.1?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 7: Does an intermediate perched zone exist east of well TW-2A, and how is it recharged?	Decisions No. 1, No. 2, and No. 3: Does intermediate ground water exist? Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure.
Issue No. 8: What is the source of recharge for the intermediate perched zone in upper Los Alamos Canyon?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 9: Does the intermediate perched zone that discharges from Basalt Spring extend further east?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 1: Are the ^{14}C minimum age estimates for TW-2, TW-3. and TW-4 true indications of young water?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure
Issue No. 2: Do low-detection limit measurements of tritium in wells TW-2, TW-3, TW-4, and LA-5 indicate contamination of either the well bore or the main aquifer?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 3: Is tritium present in the main aquifer in lower Pueblo Canyon?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 4: What is the source of tritium-contaminated recharge to the main aquifer in the vicinity of wells LA-2 and LA-1A?	Decision No. 2: Are there or could there be contaminant levels above the SALs?

a. See Section 7.3.3.1.3
b. DQO = data quality objective

TABLE 7- 22 (continued)

RELATIONSHIP OF INTERMEDIATE AND MAIN AQUIFER ISSUES TO DATA QUALITY OBJECTIVE DECISIONS

Intermediate Perched Zone Sampling and Analysis Issues[a]	Related DQO[b] Decision(s)
Issue No. 1: Are the ^{14}C minimum age estimates for TW-2, TW-3, and TW-4 true indications of young water?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure
Issue No. 2: Do low-detection limit measurements of tritium in wells TW-2, TW-3, TW-4, and LA-5 indicate contamination of either the well bore or the main aquifer?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 3: Is tritium present in the main aquifer in lower Pueblo Canyon?	Decisions No. 2 and No. 3: Are there or could there be contaminant levels above the SALs? Is there a process or pathway for exposure?
Issue No. 4: What is the source of tritium-contaminated recharge to the main aquifer in the vicinity of wells LA-2 and LA-1A?	Decision No. 2: Are there or could there be contaminant levels above the SALs?

a. See Section 7.3.3.1.3
b. DQO = data quality objective

7.4 Air Particulate Sampling and Analysis Plan

7.4.1 Objectives

The objective of air particulate sampling in Los Alamos Canyon and Pueblo Canyon is to provide information on the annual total suspended particulate matter load, the respirable particulate matter fraction (10 µm diameter or less, also known as PM10), and the types and concentrations of radionuclides adhering to respirable dust particles. This information will be used in the present-day human health risk assessment (see Chapter 6 of this work plan).

7.4.2 Air Particulate Sample Collection and Analysis

This section describes the strategy for collecting suspended air particulates by siting air-sampling stations in reaches of Los Alamos Canyon and Pueblo Canyon. This section will also discuss the type of air-sampling equipment required to collect monthly samples in remote locations and the subsequent analysis of the annual composited samples.

7.4.2.1 Sampling Design

The air-sampling stations will be set up in four separate locations in the Los Alamos Canyon and Pueblo Canyon systems, as shown in Figure 7-25. The stations will be located at the following sites:

- in the vicinity of observation well TW-2 in Pueblo Canyon,
- near the confluence of DP Canyon and Los Alamos Canyon,
- near the confluence of Pueblo Canyon and Los Alamos Canyon, and
- in the vicinity of the Otowi house, at the mouth of Los Alamos Canyon.

These air-sampling locations were chosen to fill recognized gaps in the Laboratory's existing air monitoring system. The present AIRNET air monitoring system on the mesa tops of the Pajarito Plateau does not address the sampling needs of the canyon systems, especially in lower Los Alamos Canyon near the Rio Grande.

7.4.2.2 Sampling Methods Requirements

The four air-sampling stations are sited in remote locations. High-volume samplers will not be suitable because of their power needs. Small-volume (up to 4 L/min, less for the PM10 fraction) air pumps that can be powered by marine batteries will be used in these stations. The batteries will be exchanged and recharged on a monthly basis. Small-volume systems, operated continuously, are expected to sample up to 2000 m^3 of air per year. The air pumps will be adapted so that two separate air particulate fractions are collected: total suspended particulate matter, and the PM10 components of the airborne particulate matter. The pumps will be equipped with glass-fiber filters that will be changed approximately monthly to avoid overloading. The monthly samples will be composited to obtain an annual particulate sample.

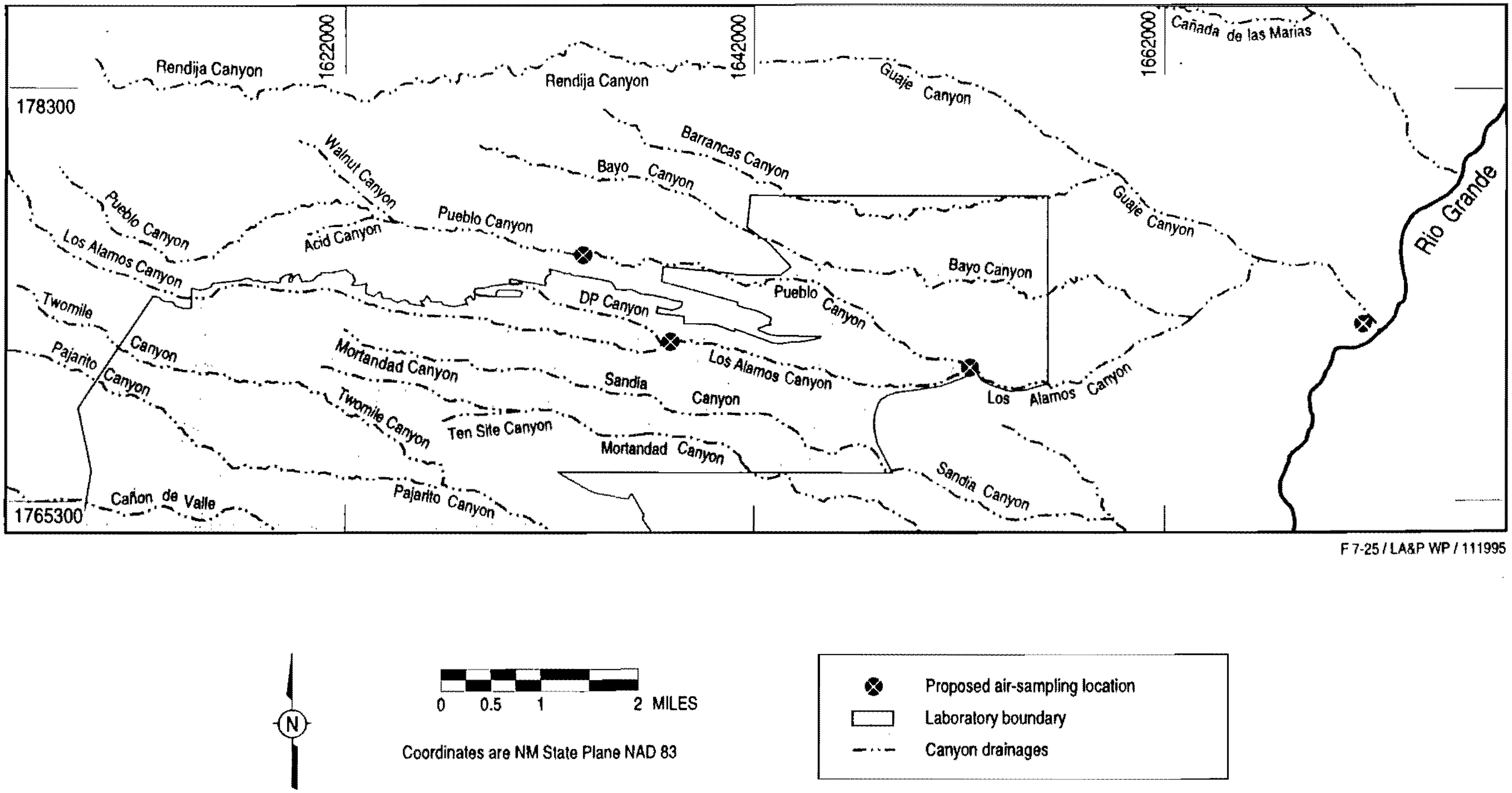


Figure 7-25. Proposed air-sampling locations in Los Alamos Canyon and Pueblo Canyon.

7.4.2.3 Analytical Methods Requirements

The annual air particulate sample will be measured for total suspended particulate matter and the PM10 component. Other particle-size fractions may also be identified. Measurement of particle-size fractions may be accomplished by either sieving, using a scanning-electron microscope, or using laser light-scattering analysis.

The total and size-sorted composite air particulate samples from all four sampling stations will be analyzed for radionuclide constituents, including ^{137}Cs, ^{90}Sr, and isotopes of plutonium and uranium. The analytical methods are listed in Table 7-9 (Section 7.2.4.3). Particulate samples will undergo complete digestion before being analyzed for alpha and beta emitters. Alpha emitters will be analyzed by radiochemical separation and alpha spectrometry. Beta emitters will be analyzed by gas proportional counter, and gamma emitters will be analyzed by gamma spectroscopy. Because analysis of gamma-radiation emitters is by a nondestructive technique, gamma spectroscopy will be performed first.

7.4.3 Reconciliation with Data Quality Objectives

The results of the radiochemical analyses will be used in present-day risk assessment for inhalation of dust resuspended from the canyon bottoms. Total suspended particulate loads and adhering radionuclides will be apportioned into the respirable particle-size fraction and the larger-size fraction that may be ingested following deposition in the nasopharyngeal region. Total suspended particulate matter may also be used to evaluate dust loading on vegetables as part of a gardening/farming land-use scenario in risk assessment.

7.5 Biological Sampling and Analysis Plan

This section presents the sampling and analysis plan for investigating the Los Alamos Canyon and Pueblo Canyon ecosystem. The biological investigation includes assessment of the impact of Laboratory-derived contaminants on ecosystem receptors, which may be directly exposed, and human receptors, who may be exposed by consuming garden produce, native plants, or native wildlife living in the canyons (see Chapter 6 of this work plan).

7.5.1 Objectives

The objective of the biological investigation in the Los Alamos Canyon and Pueblo Canyon system is to assess the impact of Laboratory-derived contaminants on environmental and human receptors. The objective will be achieved by examining the three components of the Los Alamos Canyon and Pueblo Canyon ecosystem summarized below.

- Ecosystem receptors (including selected species and biological communities) which are likely to be affected by Laboratory-derived contaminants will be studied. The selected species include threatened or endangered species, or surrogates for these species if examination risks further threat. The biological communities to be studied represent broad units of the ecosystem and include the aquatic, soil, plant, and animal communities.

- Wetlands, which are a critical regulated environment, will be included in the biological investigation. Wetlands are a sensitive habitat for many species, and their evaluation is integral with the aquatic community evaluation.

- The potential impact on human receptors of Laboratory-derived contaminants in plants and animals that are either part of the diet of or used in American Indian tribal ceremonies will be assessed.

An integrated ecological risk investigation approach for the ER Project is presently under development, and it will be implemented after DOE, regulator, and stakeholder approval. The first two objectives described above will be addressed by the Laboratory-wide ecological risk investigations. The third objective will be addressed as part of this investigation, and the data will support human health risk for American Indian use scenarios. These data will also be used as a source for future site-wide ecological risk investigations. The appropriate level of detail for ecological risk assessments has not yet been determined.

7.5.2 Technical Approach

As defined in Chapter 6 of this work plan, Section 6.5.2, an assessment endpoint consists of two parts: the potential receptor of the contaminant and a criterion for unacceptable risk to the receptor. The measurement endpoint is the parameter which will be used to determine the impact of the contamination. The proposed assessment endpoints, including the potential receptors and corresponding measurement endpoints, are listed in Table 7-23 for each of the three components described in Section 7.5.1. The following sections describe the approach to evaluating each component of the ecosystem assessment.

7.5.2.1 Assessment of Ecosystem Receptors

Environmental sampling to evaluate exposure to ecological risk receptors will not be proposed until the assessment endpoints and their exposure units have been agreed upon with the regulators, with appropriate input from stakeholders. Negotiations are underway between the Laboratory, DOE, EPA, NMED, and the Accord Pueblos to define the assessment endpoints, exposure units, exposure models, and risk models. In addition, Laboratory personnel have worked with the Accord Pueblos to help define appropriate risk scenarios for the American Indian population in the vicinity of Los Alamos Canyon and Pueblo Canyon. When an agreement has been reached, a preliminary assessment using available data will be conducted to assess uncertainties and identify sensitive parameters in the models. The sampling and analysis plan will focus on collecting data for the most sensitive and uncertain parameters identified for the ecological risk assessment.

Biological sampling to support ecological risk assessment is not appropriate at this time. Although the exposure units for ecological receptors may closely resemble the Los Alamos Canyon and Pueblo Canyon boundaries described in Chapter 3 of this work plan, additional areas need to be considered when designing sampling and analysis plans. For example, it is unlikely that Pueblo Canyon and Bayo Canyon contain discrete wildlife populations, so they may become part of a single exposure unit. Therefore, the appropriate criteria for impact assessment on biological communities may require examining areas that extend beyond Los Alamos Canyon and Pueblo Canyon. In some cases, evaluating the entire collection of the Pajarito Plateau canyon systems may be necessary to support appropriate ecosystem risk assessments.

TABLE 7-23

PROPOSED BIOLOGICAL ASSESSMENT ENDPOINTS

Receptor(s)	Measurement Endpoints	Rationale for Selection
Ecosystem Receptors: Threatened Endangered Species		
Jemez Mountains Salamander	Chemical uptake or measured adverse effects on related salamander species	Indicator of impacts to moist, mixed-conifer habitats; sensitive to remediation-caused disturbances; effects of contaminants on amphibians are poorly understood
Peregrine Falcon	Biomarker response in Cooper's hawks and/or juvenile falcons; measured reproductive success rates; chemical concentrations in prey species	Species with a history of contaminant-induced population impacts; sensitive to remediation-caused disturbances; substantial population data are available for Cooper's hawks
Mexican Spotted Owl	Concentration in cast pellets and/or prey; biomarker response in juvenile owls	Species potentially affected by COPCs[a] in small mammals; sensitive to remediation-caused disturbances
Meadow Jumping Mouse	Biomarker response in this or a surrogate species, measurement of population characteristics	Species is an indicator of COPC effects in small mammals; sensitive to remediation-caused disturbance effects
Spotted Bat	Biomarker response in this or a surrogate species of bats	Species is sensitive to remediation-caused disturbance effects; effects of contaminants on bats are poorly understood
Ecosystem Receptors: Communities		
Aquatic Community	Benthic invertebrate community structure, chemical water qual-ity criteria, frog embryo teratogenesis assay	A sensitive community which integrates and may expose many species to many sources of contaminants; community measures may detect changes in species interactions that are not detectable with single-species approaches; makes use of available data.
Soil Community	Biomarker response in soil organ-isms (microbes and/or earth-worms in field or laboratory bio-assays), decomposition rates	Effects on these organisms are indicative of ecosystem-level effects on soil productivity. Soil communities are key processors of energy and nutrients in ecosystems; soil organisms are part of ecological exposure pathways.
Plant Community	Community diversity indices, concentrations in plant tissues	Community indices may detect ecosystem effects not detectable from single-species approaches and also make use of available data; contaminant concentrations in plants are needed for exposure assessments (ecotoxicological and human).
Animal Community	Bird community diver-sity indices, concentrations in animal tissues, biomarker re-sponses of small mammals (pocket gophers) and western bluebirds	Bird community measures are relatively inexpensive and may detect changes in species interactions that are not detected with a single-species approach; pocket gophers and bluebirds have relatively high sediment ingestion rates, represent pathways to other ecological receptors, and they are easily sampled; their population dynamics are easily studied; makes use of available data.

a. COPC = chemical of potential concern

TABLE 7-23

PROPOSED BIOLOGICAL ASSESSMENT ENDPOINTS

Receptor(s)	Measurement Endpoints	Rationale for Selection
Regulated Environments		
Wetlands	Benthic invertebrate community structure, chemical water quality criteria, frog embryo teratogenisis assay	A sensitive habitat (many species use wetlands for part of their life cycle) which integrates many sources of contaminants, and may expose many species to them; evaluation is integral with aquatic community evaluation.
Biological System Contributors to Human-Health Risk		
Garden produce	Concentrations of COPCs[a] in washed and unwashed produce	Part of human exposure pathway; required for human-health risk assessment
Elk/deer population	Concentrations in tissues	Part of human exposure pathway, and part of animal community ecological risk assessment.
Small game populations	Concentrations in tissues, biomarker responses, population characteristics	Part of human exposure pathway, and part of animal community ecological risk assessment.

a. COPC = chemical of potential concern

The investigations for sediment, ground water, and air particulate proposed in the preceding sections of Chapter 7 will provide important data for the ecological risk assessment. For example, hydrogeologic and geomorphic units are natural sources of environmental heterogeneity within exposure units and they may form natural boundaries between some exposure units. Therefore, mapping and characterizing heterogeneous units will provide essential data to ecological exposure assessments.

7.5.2.2 Wetlands Investigation

Because stream flow occurs seasonally for extended periods of time, or even continuously in some canyon reaches, identifiable wetlands are present in Los Alamos Canyon and Pueblo Canyon. An inventory of wetlands is in preparation by the Environmental Assessments and Resource Evaluations group (ESH-20) as part of an ongoing survey of the canyons of the Pajarito Plateau. Until the wetlands inventory is completed, discrete sampling in the initial stages of the investigation will be limited.

The biological evaluation of wetlands will be performed in collaboration with a US Fish and Wildlife Service investigation of water quality in the canyon systems of the Pajarito Plateau. Sediment and water sampling will be deferred to the Fish and Wildlife Service investigation, although sediment and surface water samples collected in the concurrent investigations described in this chapter will be used to plan future sampling efforts. Further requirements for sediment and water sampling will be evaluated in the core document for all Pajarito Plateau canyon systems (described in Chapter 1 of this work plan), which will address wetlands definition and evaluation in a comprehensive manner.

7.5.2.3 Biological System Contributors to Human-Health Risk

Exposure pathways for assessing human-health risk include the ingestion of fish, wildlife, native plants, and domesticated plants (see Section 6.3 in Chapter 6 of this work plan). Sampling in Los Alamos Canyon and Pueblo Canyon is proposed to determine whether native plants, garden produce, and domestic livestock are significant pathways for human exposure. The first component of this evaluation will be the garden produce study, which is specific to each canyon. Because American Indian ceremonial plants and game animals are gathered or hunted in wider areas, evaluation of these exposure pathways will be deferred to studies defined in the core document for the Pajarito Plateau canyon systems.

One garden plot each will be established in Los Alamos Canyon and Pueblo Canyon after on-site review with a Pueblo representative. The produce species grown in the plots will include four varieties of vegetables. Four samples will be harvested from each species when edible portions are mature. Two samples will be analyzed after washing and two unwashed samples will be analyzed. A composite surface sediment sample from the garden plot will be used to characterize levels of COPCs, soil organic matter, and elemental nutrients (calcium, magnesium, nitrogen, phosphorus, and potassium). A split of the composited surface sediment sample will be analyzed for sediment particle size distribution. The analytical suite for COPCs will be the limited suite defined by the sediment investigation, as described in Section 7.2.4.1.3.

The vegetables grown in the plots will be selected from those most important to the American Indian diet, as defined by Indian Pueblo representatives. The locations will also be agreed upon with the Indian Pueblos and restricted to arable areas outside the active channel in reaches of Los Alamos Canyon and Pueblo Canyon previously chosen for sediment characterization. The garden plots will be located in areas of apparently elevated COPC levels to provide a conservative assessment of potential risk. For these reasons, further definition of the produce sampling program must wait until the sediment investigation is well advanced.

American Indian populations also gather wild edible plants and other plants used for ceremonial purposes. The Indian Pueblo representatives will be consulted to define significant species routinely gathered in each canyon. From these, four species will be selected for each canyon. Because of the ceremonial significance of some of these species, sampling will be conducted by Accord Pueblo representatives. Exact sampling locations may not be disclosed. Two samples from each species will be taken, for a total of eight samples from each canyon. The plants will be analyzed for the limited suite of COPCs.

Two samples of livestock forage will be taken from each reach that has been sampled in the sediment investigation and considered suitable for grazing. The suitability of a reach for livestock grazing will be determined in consultation with stakeholders. Sampling will occur during periods identified by American Indian stakeholders as likely grazing periods. The livestock forage samples will be analyzed for the limited suite of COPCs.

7.5.3 Reconciliation with Data Quality Objectives

This section briefly describes the data quality objectives process (EPA 1994, 50288) as completed for the investigation of biological system contributors to human health risk.

1. State the problem

> Contaminants transported from Laboratory operations into Los Alamos Canyon and Pueblo Canyon may result in exposure to humans that consume garden produce, native plants, or native wildlife living in the canyons.

2. Identify the decision(s)

The data for this investigation is being collected to provide site-specific values for a variety of parameters used in standard risk models so risk scenarios of particular concern to the American Indian population are modeled. The risk-related decisions will be identified and made by the neighboring Pueblos on the basis of risk assessments conducted for this investigation.

3. Identify inputs to decision(s)

From geomorphic mapping

- Identified and mapped geomorphic units
- Characteristics of post-1943 sedimentary deposits
- Areal extent of geomorphic units

From radiation survey

- Gross-alpha, -beta, and -gamma readings at selected locations
- Field gamma spectroscopy at selected locations

From previous Laboratory studies

- Range of vegetation-soil ratios (ratio of contaminant concentrations in the vegetation to concentration in the soil) for Laboratory samples are expected to be from 0.0004 to 0.116 for plutonium isotopes and from 0.05 to 0.026 for ^{137}Cs (White et al. 1981, 11994). Values for other contaminants will be tabulated where available.
- Coefficients of variation (standard deviation divided by mean value) for contaminant concentration are expected to be approximately 1.35 for soils and 0.70 for vegetation (White and Hakonson 1979, 11995). The coefficient of variation is characteristically less variable for parameters than the mean value or standard deviation.
- Radionuclide concentrations of vegetables are expected to be affected by soil organic matter, height from soil surface, soil texture, soil chemistry, rain-splash, variety of produce, and preparation practices (White et al. 1981, 11994; Dreicer et al. 1984, 8592; Foster et al. 1985, 8035).

From American Indian stakeholders

- Preferred locations for garden plots
- Vegetables to be grown in garden plots
- Samples of edible wild plants or ceremonial plants

From this study

- Concentrations of COPCs in produce

4. Define the study boundaries

- Spatial

  The sampling should generally be restricted to sediments de posited after 1943, when potential contamination of the canyons by Laboratory operations began. The produce study will be restricted to arable areas outside the active channel in Los Alamos Canyon and Pueblo Canyon. The garden plots should be located in areas of apparent elevated COPC levels, if any are identified.

- Temporal

  The study will emphasize current human-health risk. Assessing the present-day risk in the canyons will provide a baseline that can be used by ongoing environmental surveillance activities to document expected mitigation of human-health risks as a result of the ER Project.

- Field Study

  Field studies are expected to span approximately one field season. These studies will require results of nonintrusive field surveys and full-suite analyses of canyon sediments, as described in Section 7.2. Biological samples will have to be collected after the sediment investigations are complete. It is still reasonably likely that a single field season will suffice to complete the study.

- Interpretive Study

  Interpretation and assessment is expected to require approximately one year from the completion of data collection.

5. Develop a decision rule

The data will be acceptable unless errors in the sampling process or analytical procedures are identified during data validation. If the values are not within the range of standard values, the site-specific values will generally be used for risk assessments.

6. Specify limits or uncertainty

Based on reported uptake of plutonium by vegetation in Los Alamos Canyon, Pueblo Canyon, and Mortandad Canyon (White and Hakonson 1979, 11995; White et al. 1981, 11994) a relative error of 100 to 200% is to be expected in the garden produce data and in the native plant data. As many of these measurements will be the first site-specific values available and risk levels are expected to be reasonably low (as indicated by existing data), this relative error is considered adequate for these investigations.

References for Chapter 7

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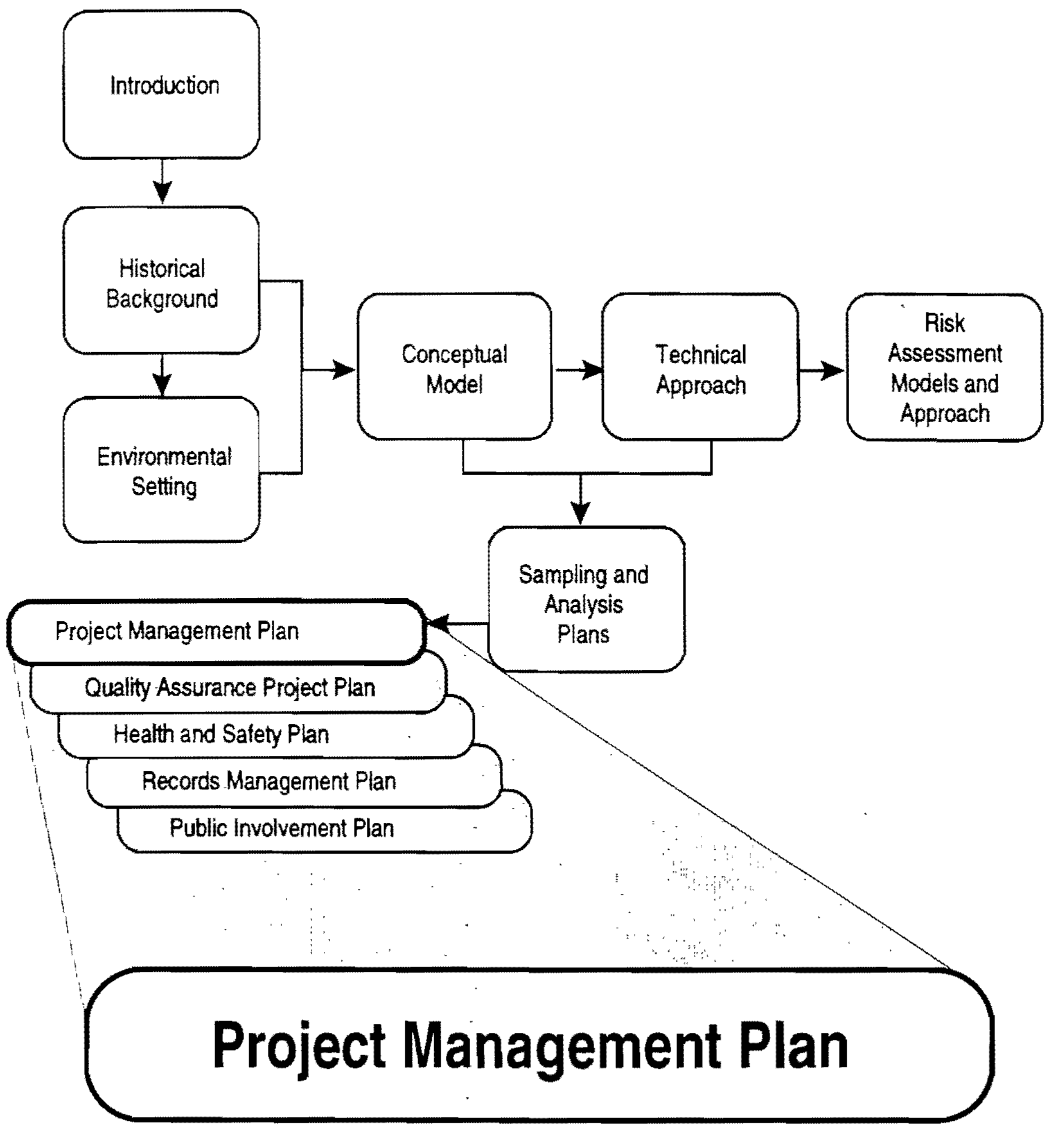
Annex I


Introduction
Historical Background
Environmental Setting
Conceptual Model
Technical Approach
Risk Assessment Models and Approach
Sampling and Analysis Plans
Project Management Plan
Quality Assurance Project Plan
Health and Safety Plan
Records Management Plan
Public Involvement Plan
Project Management Plan

1.0 INTRODUCTION

This annex addresses the project management plan requirements of the Hazardous and Solid Waste Amendments (HSWA) Module (Task II, p.39) of the Laboratory's Resource Conservation and Recovery Act (RCRA) Part B Permit (EPA 1990, 1585) and presents the technical approach, management structure, schedule, budget, and reporting milestones for implementing the Los Alamos Canyon and Pueblo Canyon investigation as set forth in this task/site work plan. The project management plan for the Los Alamos Canyon and Pueblo Canyon investigation is an extension of the Environmental Restoration (ER) Project Program Management Plan given in Annex I of the Installation Work Plan (IWP) (LANL 1993, 26077) and contains no significant departures from the IWP guidelines.

2.0 TECHNICAL APPROACH

The approach used for the Los Alamos Canyon and Pueblo Canyon investigation is based on the ER Project's overall technical approach as described in Chapter 3 of the IWP (LANL 1995, 49822). The technical approach for the Los Alamos Canyon and Pueblo Canyon investigation is described in Chapter 5 of this work plan and is illustrated in Figure 5-1. The general philosophy is to develop and iteratively refine the conceptual model through carefully planned stages of investigation and data interpretation. The data gathered and the subsequent interpretation will be used to define the nature and extent of contamination and the likelihood for contaminant migration in Los Alamos Canyon and Pueblo Canyon.

The technical objectives of the Los Alamos Canyon and Pueblo Canyon investigation, as presented in Chapter 5 of this work plan, are as follows:

- to determine to what extent portions of Los Alamos Canyon and Pueblo Canyon have been or are likely to be affected by the combined releases (in the past and in the immediate future) from all sites that could contribute residual contamination to them and
- to re-examine contaminant transport mechanisms, refine the conceptual model, and project future impacts of the contaminants in the affected media that may result from future transport of the contaminants to other locations and other media. The investigation is intended to support an integrated assessment of the present-day impact (including human health risk) from Laboratory-derived contaminants and an evaluation of the potential for transport (through all accessible pathways) to cause unacceptable off-site impacts in the future. Aquifer investigations are integral to this approach.

2.1 Technical Implementation Rationale

The scheduling of the investigations is based on the following rationale and priorities, as illustrated in Figure I-1

Two relatively independent investigation paths are part of the schedule logic and the investigation rationale. These include (1) sampling and analysis of surface sediments and (2) sampling and analysis of surface water and ground water.

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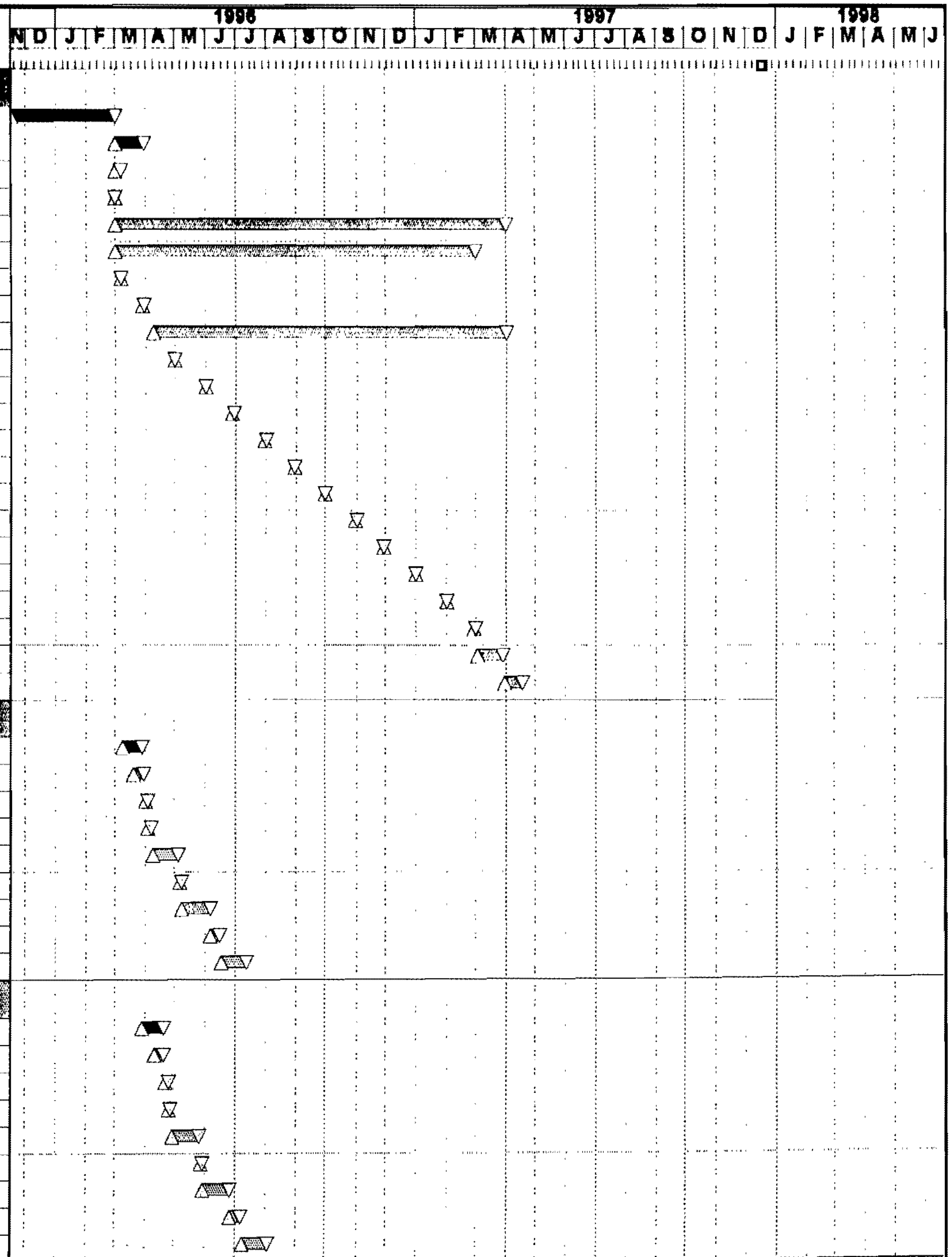
Activity Description	Orig Dur	Early Start	Early Finish
[illegible]			
PILOT STUDY: WRITE CONTRACTS & PREP FOR FIELD WK	75	17NOV95	29FEB96
PILOT STUDY: CONDUCT LAND SURVEY	21	01MAR96	29MAR96
PILOT STUDY: BACKGROUND SED. SAMPLING	3	01MAR96	05MAR96
PILOT STUDY: INSTALL DUST SAMPLING STATIONS	1	01MAR96	01MAR96
PILOT STUDY: WASTE MANAGEMENT	282	01MAR96	31MAR97
PILOT STUDY: GEOMORPHIC MAPPING	261	01MAR96	28FEB97
PILOT STUDY: ANLS. B/GROUND SED. SAMPLES	1	06MAR96	06MAR96
PILOT STUDY: SAMPLE 4 STATIONS-MAR96	1	29MAR96*	29MAR96
PILOT STUDY: POST SAMPLE MONUMENTING	256	08APR96	31MAR97
PILOT STUDY: SAMPLE 4 STATIONS-APR96	1	30APR96*	30APR96
PILOT STUDY: SAMPLE 4 STATIONS-MAY96	1	31MAY96*	31MAY96
PILOT STUDY: SAMPLE 4 STATIONS-JUN96	1	28JUN96*	28JUN96
PILOT STUDY: SAMPLE 4 STATIONS-JUL96	1	31JUL96*	31JUL96
PILOT STUDY: SAMPLE 4 DUST MON. STATIONS-AUG96	1	30AUG96*	30AUG96
PILOT STUDY: SAMPLE 4 STATIONS-SEP96	1	30SEP96*	30SEP96
SAMPLE 4 STATIONS-OCT96	1	31OCT96*	31OCT96
SAMPLE 4 STATIONS NOV96	1	29NOV96*	29NOV96
SAMPLE 4 STATIONS DEC96	1	31DEC96*	31DEC96
SAMPLE 4 STATIONS JAN97	1	31JAN97*	31JAN97
SAMPLE 4 STATIONS FEB97	1	28FEB97*	28FEB97
ANALYSIS OF DUST SAMPLES	20	03MAR97	28MAR97
ASSESSMENT-DUST SAMPLES	15	31MAR97	18APR97
REACH P-4, PUEBLO CANYON			
PILOT STUDY: P-4 RADIATION SURVEY	15	08MAR96*	28MAR96
PILOT STUDY: P-4 SPECTROSCOPIC SURVEY	8	20MAR96	29MAR96
PILOT STUDY: P-4 DATA ANLS & SITE SELECTION	3	01APR96	03APR96
PILOT STUDY: P-4 COLL.SED. FOR FULL SUITE ANLS	2	04APR96	05APR96
PILOT STUDY: P-4 ANLS FULL SUITE SAMPLES	20	08APR96	03MAY96
PILOT STUDY: P-4 COLL. SMPLS LIMITED SUITE ANLS	2	06MAY96	07MAY96
PILOT STUDY: P-4 ANALYZE LIMITED SUITE SAMPLES	20	08MAY96	04JUN96
PILOT STUDY: P-4 EVAL. DATA ADEQ. FOR RISK ASSMT	8	05JUN96	14JUN96
PILOT STUDY: P-4 COLL & ANLS ADDL. SAMPLES	20	17JUN96	12JUL96
REACH P-1, PUEBLO CANYON			
PILOT STUDY: P-1 RADIATION SURVEY	15	29MAR96*	18APR96
PILOT STUDY: P-1 SPECTROSCOPIC SURVEY	8	10APR96	19APR96
PILOT STUDY: P-1 DATA ANLS & SITE SELECTION	3	22APR96	24APR96
PILOT STUDY: P-1 COLL.SED. FOR FULL SUITE ANLS	2	25APR96	26APR96
PILOT STUDY: P-1 ANLS FULL SUITE SAMPLES	20	29APR96	24MAY96
PILOT STUDY: P-1 COLL. SMPLS LIMITED SUITE ANLS	2	27MAY96	28MAY96
PILOT STUDY: P-1 ANALYZE LIMITED SUITE SAMPLES	20	29MAY96	25JUN96
PILOT STUDY: P-1 EVAL. DATA ADEQ. FOR RISK ASSMT	8	26JUN96	05JUL96
PILOT STUDY: P-1 COLL & ANLS ADDL. SAMPLES	20	08JUL96	02AUG96



Project Start 17NOV95
Project Finish 28JAN98
Data Date 17NOV95
Plot Date 24NOV95

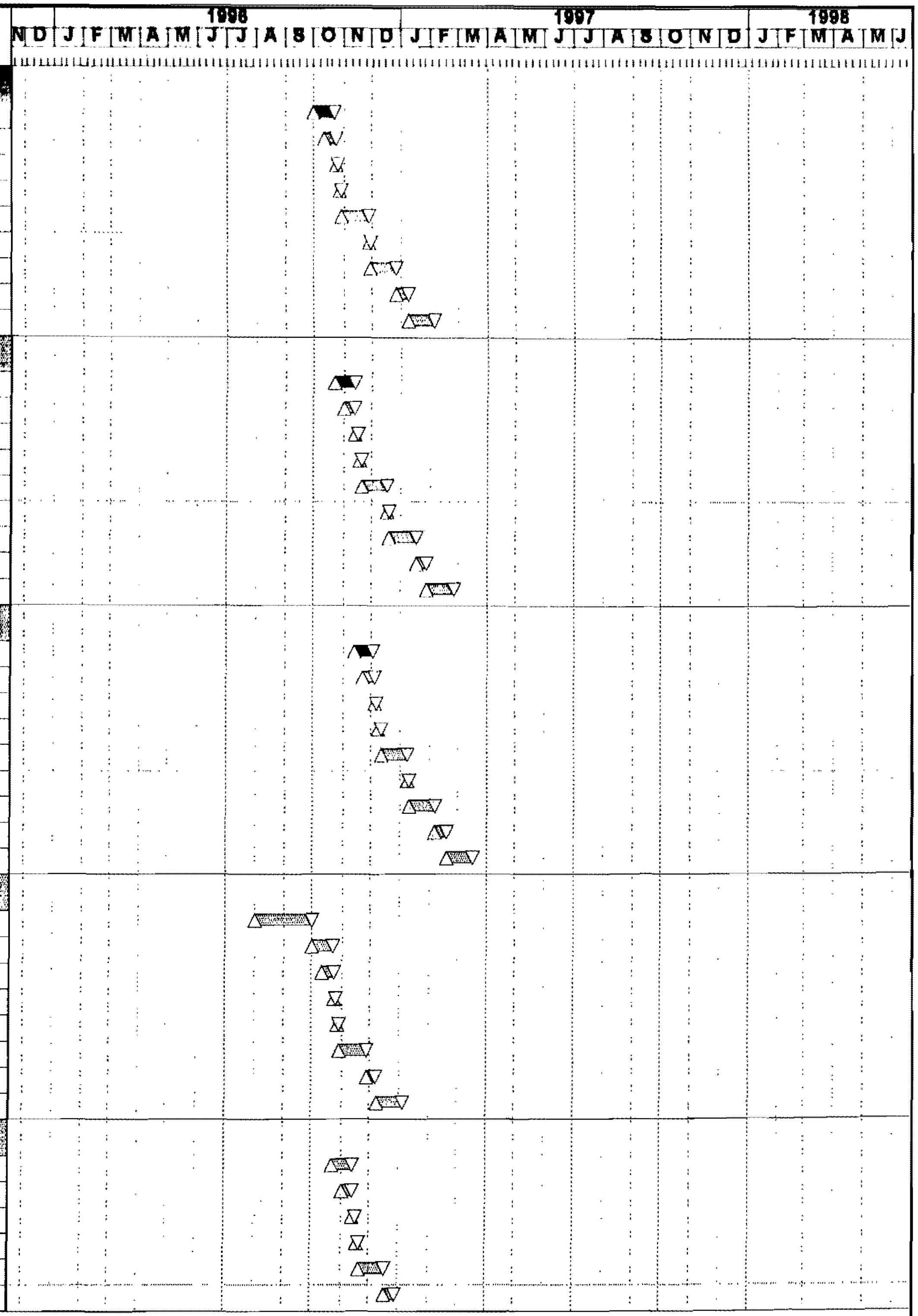
Early Bar
Progress Bar
Critical Activity

Sheet 1 of 5

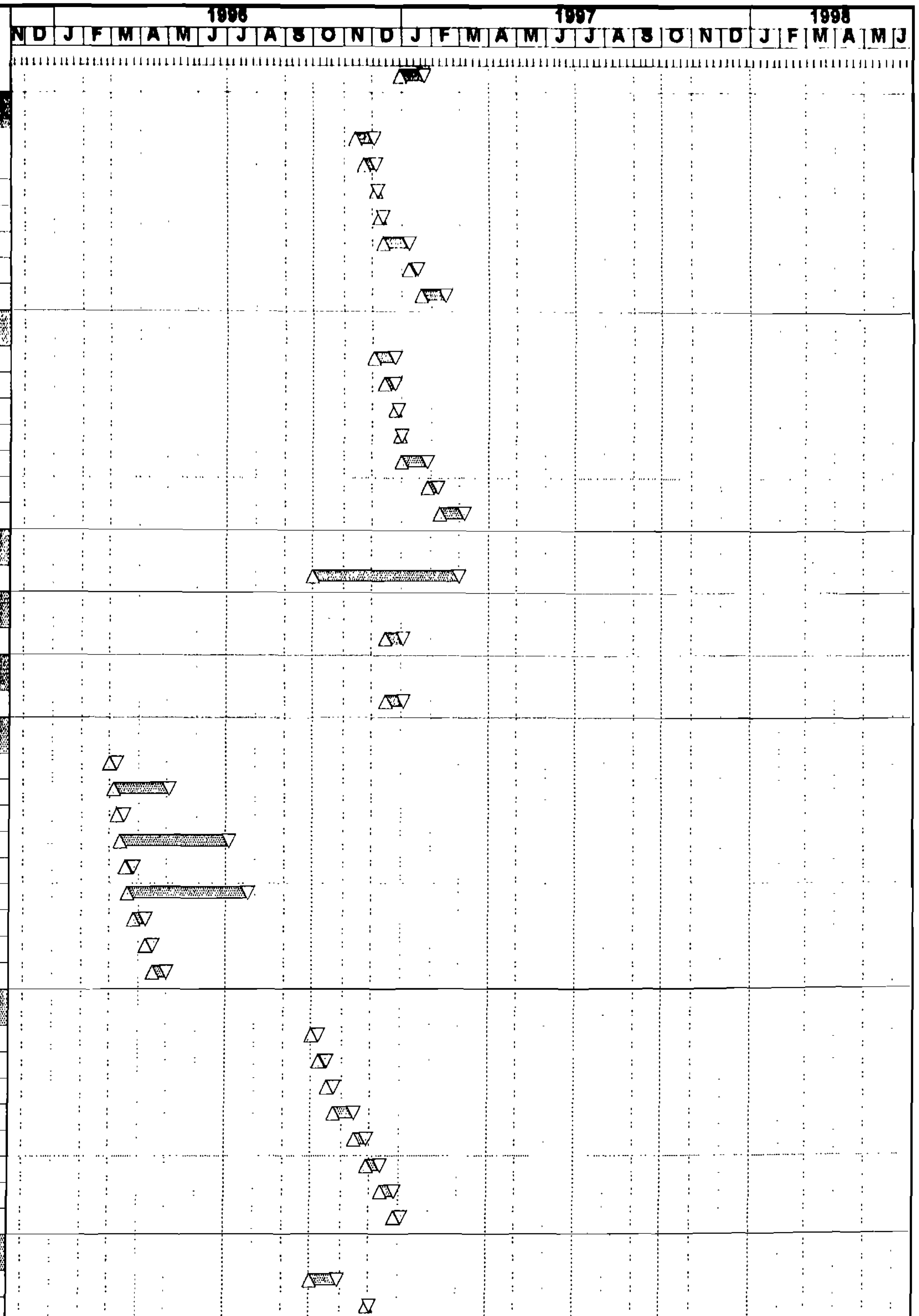
Figure I-1
Schedule for Los Alamos and Pueblo Canyon Field Work

Los Alamos NATIONAL LABORATORY

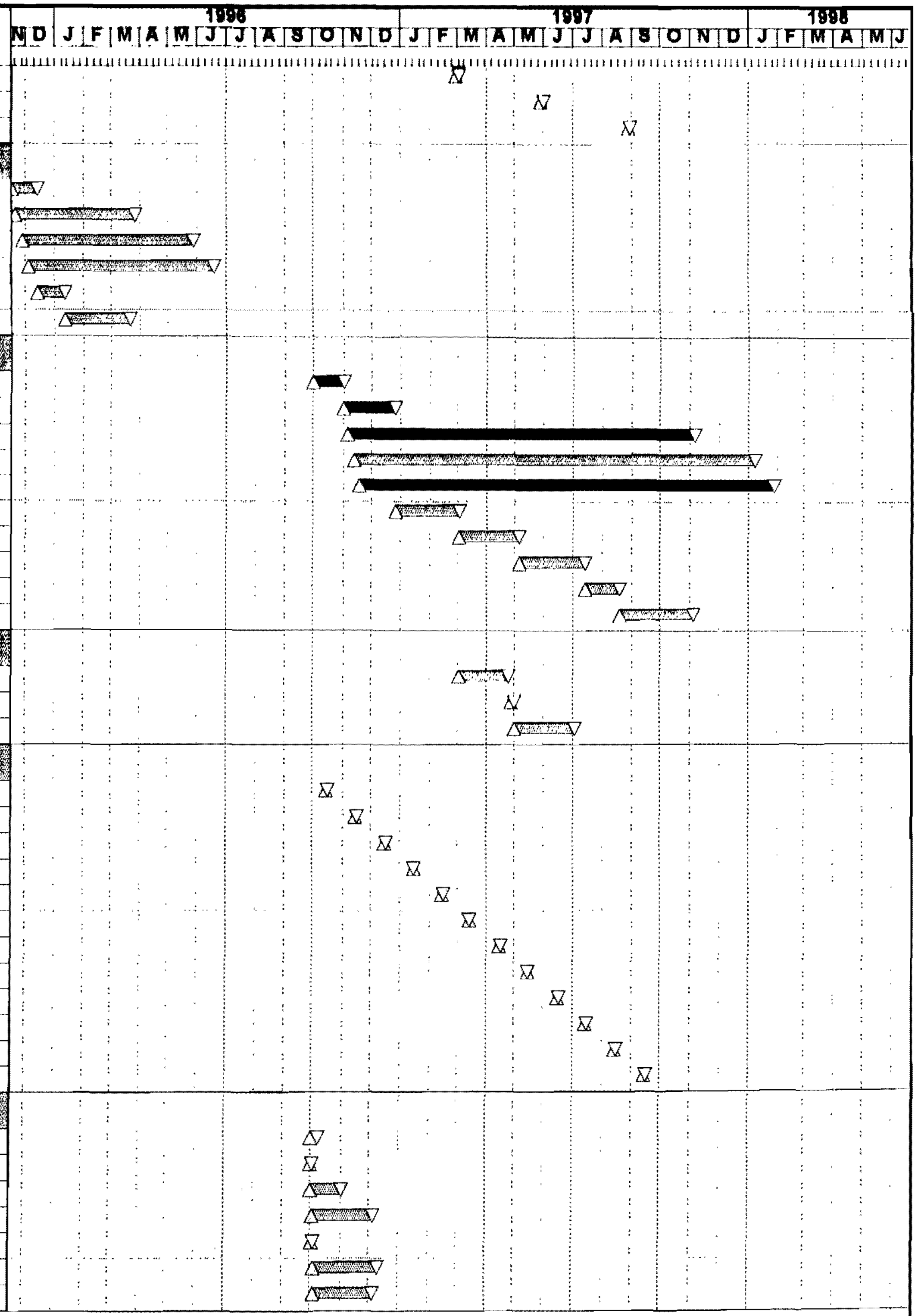
Activity Description	Orig Dur	Early Start	Early Finish
REACH [illegible]			
LA3 RADIATION SURVEY	15	01OCT96*	21OCT96
LA3 SPECTROSCOPIC SURVEY	8	11OCT96	22OCT96
LA3 DATA ANLS & SITE SELECTION	3	23OCT96	25OCT96
LA3 COLL.SED. FOR FULL SUITE ANLS	2	28OCT96	29OCT96
LA3 ANLS FULL SUITE SAMPLES	20	30OCT96	26NOV96
LA3 COLL. SMPLS LIMITED SUITE ANLS	2	27NOV96	28NOV96
LA3 ANALYZE LIMITED SUITE SAMPLES	20	29NOV96	26DEC96
LA3 EVAL. DATA ADEQ. FOR RISK ASSMT	8	27DEC96	07JAN97
LA3 COLL & ANLS ADDL. SAMPLES	20	08JAN97	04FEB97
REACH LA-2, LOS ALAMOS CANYON			
LA2 RADIATION SURVEY	15	22OCT96*	11NOV96
LA2 SPECTROSCOPIC SURVEY	8	01NOV96	12NOV96
LA2 DATA ANLS & SITE SELECTION	3	13NOV96	15NOV96
LA2 COLL.SED. FOR FULL SUITE ANLS	2	18NOV96	19NOV96
LA2 ANLS FULL SUITE SAMPLES	20	20NOV96	17DEC96
LA2 COLL. SMPLS LIMITED SUITE ANLS	2	18DEC96	19DEC96
LA2 ANALYZE LIMITED SUITE SAMPLES	20	20DEC96	16JAN97
LA2 EVAL. DATA ADEQ. FOR RISK ASSMT	8	17JAN97	28JAN97
LA2 COLL & ANLS ADDL. SAMPLES	20	29JAN97	25FEB97
REACH LA-5, LOS ALAMOS CANYON			
LA5 RADIATION SURVEY	15	12NOV96*	02DEC96
LA5 SPECTROSCOPIC SURVEY	8	22NOV96	03DEC96
LA5 DATA ANLS & SITE SELECTION	3	04DEC96	06DEC96
LA5 COLL.SED. FOR FULL SUITE ANLS	2	09DEC96	10DEC96
LA5 ANLS FULL SUITE SAMPLES	20	11DEC96	07JAN97
LA5 COLL. SMPLS LIMITED SUITE ANLS	2	08JAN97	09JAN97
LA5 ANALYZE LIMITED SUITE SAMPLES	20	10JAN97	06FEB97
LA5 EVAL. DATA ADEQ. FOR RISK ASSMT	8	07FEB97	18FEB97
LA5 COLL & ANLS ADDL. SAMPLES	20	19FEB97	18MAR97
REACH P-2, PUEBLO CANYON			
WRITE CONTRACTS & FIELD PREP. FY97	43	01AUG96*	30SEP96
P-2 RADIATION SURVEY	15	01OCT96*	21OCT96
P-2 SPECTROSCOPIC SURVEY	8	11OCT96	22OCT96
P-2 DATA ANLS & SITE SELECTION	3	23OCT96	25OCT96
P-2 COLL. SMPLS LIMITED SUITE ANLS	2	28OCT96	29OCT96
P-2 ANALYZE LIMITED SUITE SAMPLES	20	30OCT96	26NOV96
P-2 EVAL. DATA ADEQ. FOR RISK ASSMT	8	27NOV96	06DEC96
P-2 COLL & ANLS ADDL. SAMPLES	20	09DEC96	03JAN97
REACH P-3, PUEBLO CANYON			
P-3 RADIATION SURVEY	15	22OCT96	11NOV96
P-3 SPECTROSCOPIC SURVEY	8	01NOV96	12NOV96
P-3 DATA ANLS & SITE SELECTION	3	13NOV96	15NOV96
P-3 COLL. SMPLS LIMITED SUITE ANLS	2	18NOV96	19NOV96
P-3 ANALYZE LIMITED SUITE SAMPLES	20	20NOV96	17DEC96
P-3 EVAL. DATA ADEQ. FOR RISK ASSMT	8	18DEC96	27DEC96



Activity Description	Orig Dur	Early Start	Early Finish
P-3 COLL & ANLS ADDL. SAMPLES	20	30DEC96	24JAN97
REACH LA-4, LOS A[illegible]			
LA4 RADIATION SURVEY	15	12NOV96	02DEC96
LA4 SPECTROSCOPIC SURVEY	8	22NOV96	03DEC96
LA4 DATA ANLS & SITE SELECTION	3	04DEC96	06DEC96
LA4 COLL. SMPLS LIMITED SUITE ANLS	2	09DEC96	10DEC96
LA4 ANALYZE LIMITED SUITE SAMPLES	20	11DEC96	07JAN97
LA4 EVAL. DATA ADEQ. FOR RISK ASSMT	8	08JAN97	17JAN97
LA4 COLL & ANLS ADDL. SAMPLES	20	20JAN97	14FEB97
LA-1, LOS ALAMOS CANYON			
LA1 RADIATION SURVEY	15	03DEC96	23DEC96
LA1 SPECTROSCOPIC SURVEY	8	13DEC96	24DEC96
LA1 DATA ANLS & SITE SELECTION	3	25DEC96	27DEC96
LA1 COLL. SMPLS LIMITED SUITE ANLS	2	30DEC96	31DEC96
LA1 ANALYZE LIMITED SUITE SAMPLES	20	01JAN97	28JAN97
LA1 EVAL. DATA ADEQ. FOR RISK ASSMT	8	29JAN97	07FEB97
LA1 COLL & ANLS ADDL. SAMPLES	20	10FEB97	07MAR97
GARDEN PRODUCE STUDY			
PILOT STUDY: GARDEN PRODUCE STUDY	109	01OCT96*	28FEB97
WILD EDIBLE/CEREMONIAL PLANT STUDY			
PILOT STUDY: WILD EDIBLE/CEREM.PLANT STUDY	13	16DEC96*	01JAN97
LIVESTOCK FORAGE STUDY			
PILOT STUDY: LIVESTOCK FORAGE STUDY	13	16DEC96*	01JAN97
ALLUVIAL WELLS-FY96			
PILOT STUDY: POB2 -30FT WELL,DRILL/CORE/LOG	5	01MAR96	07MAR96
PILOT STUDY: FY96 ALLUVIAL WELLS SAMPLING	42	05MAR96	01MAY96
PILOT STUDY: PO-2 50FT WELL,DRILL/CORE/LOG	6	08MAR96	15MAR96
PILOT STUDY: ALLUVIAL WELLS.ANLS WATER SAMPLES	82	12MAR96	03JUL96
PILOT STUDY: PO-4 50FT WELL,DRILL/CORE/LOG	6	18MAR96	25MAR96
PILOT STUDY: ALLUVIAL WELLS.ANLS CORES SAMPLES	92	19MAR96	24JUL96
PILOT STUDY: LLAO5 100FT WELL DRILL/CORE/LOG	10	26MAR96	08APR96
PILOT STUDY: LAO-1.6 30FT WELL,DRILL/CORE/LOG	5	09APR96	15APR96
PILOT STUDY: LLAO-1 100FT WELL,DRILL/CORE/LOG	10	16APR96	29APR96
ALLUVIAL WELLS-FY97			
POB-1 30FT WELL,DRILL/CORE/LOG	5	01OCT96*	07OCT96
PO-1 50FT WELL,DRILL/CORE/LOG	6	08OCT96	15OCT96
PO-3 50FT WELL,DRILL/CORE/LOG	6	16OCT96	23OCT96
PO-5/6/7(3@50FT)DRILL/CORE/LOG	15	24OCT96	13NOV96
LLAO-2 100FT WELL,DRILL/CORE/LOG	10	14NOV96	27NOV96
LLAO-3 100FT WELL,DRILL/CORE/LOG	10	28NOV96	11DEC96
LLAO-4 100FT WELL,DRILL/CORE/LOG	10	12DEC96	25DEC96
LAO-3.5 50FT WELL,DRILL/CORE/LOG	6	26DEC96	02JAN97
ALLUVIAL WELLS; PIEZOMETER NESTS			
INSTALL PIEZOMETER NESTS(12)	20	01OCT96*	28OCT96
QUARTERLY WATER LEVEL MEASUREMENTS	2	29NOV96*	02DEC96

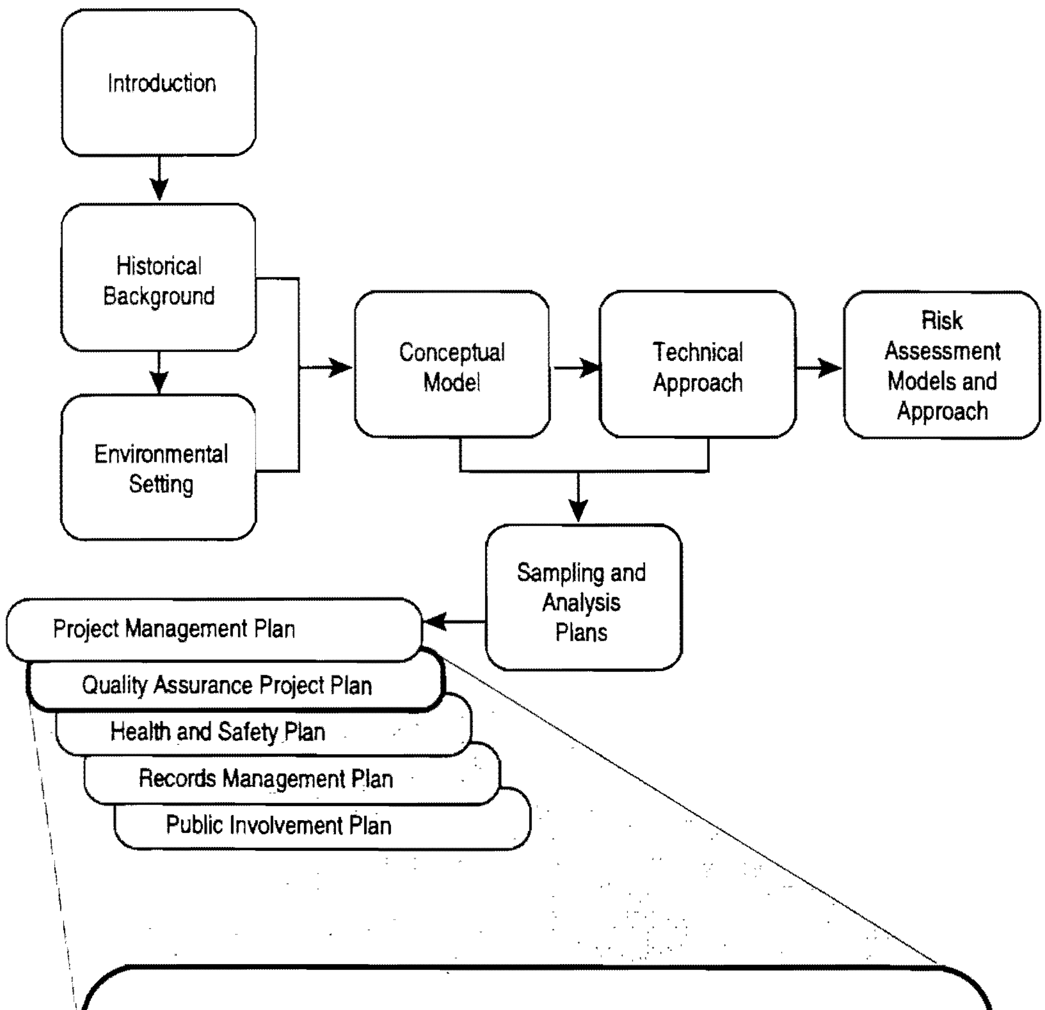


Activity Description	Orig Dur	Early Start	Early Finish
QUARTERLY WATER LEVEL MEASUREMENTS	2	28FEB97*	03MAR97
QUARTERLY WATER LEVEL MEASUREMENTS	2	29MAY97*	30MAY97
QUARTERLY WATER LEVEL MEASUREMENTS	2	28AUG97*	29AUG97
INTERMEDIATE WELLS-FY96			
PILOT STUDY: LAOI-7 250/150FTWELL,DRILL/CORE/LOG	20	17NOV95	14DEC95
PILOT STUDY: INTERMEDIATE WELLS SAMPLING	90	21NOV95	25MAR96
PILOT STUDY: INTERMED.WELLS ANLS.WATER SAMPLES	130	28NOV95	27MAY96
PILOT STUDY:INTERMED.WELLS ANLS CORE SAMPLES	140	05DEC95	17JUN96
PILOT STUDY: POI-4 250/150FT WELL,DRILL/CORE/LOG	20	15DEC95	11JAN96
PILOT STUDY: SCOI-3 550/450FTWELL,DRILL/CORE/LOG	50	12JAN96	21MAR96
INTERMEDIATE WELLS-FY97			
WRITE CONTRACTS / MOBILIZE-SURF.WTR	23	01OCT96*	31OCT96
LAOI-3.2 400/300FTWELL,DRL/CORE/LOG	40	01NOV96	26DEC96
SAMPLE INTERMEDIATE WELLS FY97	262	05NOV96	05NOV97
ANALYZE WATER SAMPLES- FY97	302	12NOV96	07JAN98
ANALYZE CORE SAMPLES-FY97	312	19NOV96	28JAN98
LAOI-1.5 475/375FTWELL,DRL/CORE/LOG	47	27DEC96	03MAR97
LAOI(B)1.1 450/375FTWELL,DRL/CRE/LG	45	04MAR97	05MAY97
SCOI-1 500/400FTWELL,DRL/CORE/LOG	50	06MAY97	14JUL97
POI-2 300/200FTWELL,DRILL/CORE/LOG	25	15JUL97	18AUG97
LAOI-B 550/450FTWELL,DRL/CORE/LOG	55	19AUG97	03NOV97
SPRING RECONNAISSANCE-FY97			
SPRING RECONAISSANCE	40	03MAR97*	25APR97
SPRING SAMPLING	3	28APR97	30APR97
ANALYZE SPRING SAMPLES	45	01MAY97	02JUL97
WATER LEVEL MEASUREMENTS			
WATER LEVEL MEASUREMENTS-OCT96	1	15OCT96*	15OCT96
WATER LEVEL MEASUREMENTS-NOV96	1	15NOV96*	15NOV96
WATER LEVEL MEASUREMENTS-DEC96	1	16DEC96*	16DEC96
WATER LEVEL MEASUREMENTS-JAN97	1	15JAN97*	15JAN97
WATER LEVEL MEASUREMENTS-FEB97	1	14FEB97*	14FEB97
WATER LEVEL MEASUREMENTS-MAR97	1	14MAR97*	14MAR97
WATER LEVEL MEASUREMENTS-APR97	1	15APR97*	15APR97
WATER LEVEL MEASUREMENTS-MAY97	1	15MAY97*	15MAY97
WATER LEVEL MEASUREMENTS-JUN97	1	16JUN97*	16JUN97
WATER LEVEL MEASUREMENTS-JUL97	1	15JUL97*	15JUL97
WATER LEVEL MEASUREMENTS-AUG97	1	15AUG97*	15AUG97
WATER LEVEL MEASUREMENTS-SEP97	1	15SEP97*	15SEP97
SURFACE WATER-FY97			
ALL SURFACE WATER SAMPLES-QUARTERLY	5	01OCT96*	07OCT96
BASALT SPRING SAMPLING	1	01OCT96*	01OCT96
CONDUCT STREAM GAGING	23	01OCT96*	31OCT96
BASALT SPRING SAMPLE ANALYSIS	45	02OCT96	03DEC96
BASALT SPRING SAMPLING	1	02OCT96*	02OCT96
ANALYZE WATER SAMPLES	48	03OCT96*	09DEC96
BASALT SPRING SAMPLE ANALYSIS	45	03OCT96	04DEC96



Activity Description	Orig Dur	Early Start	Early Finish
ALL SURFACE WATER SAMPLES-QUARTERLY	5	28OCT96*	01NOV96
STREAM GAGING-COLLECT DATA & ANLS	60	01NOV96	23JAN97
ANALYZE WATER SAMPLES	5	04NOV96	08NOV96
ALL SURFACE WATER SAMPLES-QUARTERLY	5	25NOV96*	29NOV96
ANALYZE WATER SAMPLES	48	27NOV96	31JAN97
BASALT SPRING SAMPLING	1	29NOV96*	29NOV96
BASALT SPRING SAMPLE ANALYSIS	45	02DEC96	31JAN97
ALL SURFACE WATER SAMPLES-QUARTERLY	5	24FEB97*	28FEB97
ANALYZE WATER SAMPLES	48	26FEB97	02MAY97
BASALT SPRING SAMPLING	1	28FEB97*	28FEB97
BASALT SPRING SAMPLE ANALYSIS	45	03MAR97	02MAY97
MAIN AQUIFER FY96			
PILOT STUDY: OTOWI-1 WELL ZONAL SAMPLING	10	01MAR96*	14MAR96
PILOT STUDY: OTOWI-1 WELL ZONAL SAMPLE ANALYSIS	48	05MAR96	09MAY96
PILOT STUDY: CONTAMINATION STUDY-TW-1 &TW-1A	86	03JUN96*	30SEP96
MAIN AQUIFER FY97			
COMPILE/EVAL.AQUIF.AGE/LA CYN RE-CHG	21	03MAR97*	31MAR97
COLLECT ADDL.SAMPLES AND ANALYZE	60	01APR97	23JUN97
CHARACTERIZATION REPORTS			
CHARACTERIZATION REPORTS	262	21JUN96*	23JUN97

Annex II



Quality Assurance Project Plan

1.0 INTRODUCTION

This quality assurance project plan (QAPP) provides specific instructions to the Laboratory and its subcontractors to ensure that the work performed during the investigation of Los Alamos Canyon and Pueblo Canyon will be of the quality required to satisfy investigation objectives. This plan addresses the 16 essential elements presented in the Environmental Protection Agency (EPA) document "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans" (EPA 1980, 0552). This annex is based on the Laboratory's generic QAPP (LANL 1991, 0412).

1.1 Facility Description

A description of Laboratory facilities and descriptions of individual areas are presented in Chapter 2 of the Installation Work Plan (IWP) (LANL 1995, 49822).

1.2 Environmental Restoration Project

A description of the Environmental Restoration (ER) Project is presented in Chapter 1 of the IWP (LANL 1995, 49822).

1.3 Investigation Description

The purpose of expedited characterization for Los Alamos Canyon and Pueblo Canyon is to study and/or define potential movement of contaminants from pre-existing and existing technical areas into the canyon floors. The general philosophy is to develop and iteratively refine the Los Alamos Canyon and Pueblo Canyon work plan conceptual model through careful investigation and data interpretation. The data gathered and subsequent interpretation will be used to define the nature and extent of contamination and the likelihood for waste migration in Los Alamos Canyon and Pueblo Canyon. An objective is to support interim corrective measures or a corrective measures study using the minimum amount of data.

Technical Area (TA) -2 and TA-41 are located within Los Alamos Canyon and are sources of contamination. TA-2 has housed a series of research nuclear reactors; TA-41 is used for weapons development and long-term studies of weapons subsystems. The most probable contaminants from these activities are radiological and chemical constituents, which include uranium, plutonium, tritium, fission products, chromium, mercury, acids, and solvents. No technical areas presently exist in Pueblo Canyon.

Former TA-1 (presently the Los Alamos townsite), TA-21, and TA-53 are potential external sources of contamination for Los Alamos Canyon. TA-1 and TA-45 were potential external sources of contamination for Pueblo Canyon via Acid Canyon. The suspected contaminants for both canyons include radionuclides (uranium, plutonium, cesium, strontium, tritium, and americium) and metals.

1.3.1 Investigation Objectives

The comprehensive investigation objectives are described in Chapter 5 of this work plan. Specific objectives to be investigated are presented in Chapter 7 of this work plan.

1.3.2 Investigation Schedule

The anticipated investigation schedule is provided in Chapter 1 and Annex I of this work plan.

1.3.3 Investigation Scope

The scope of the investigation is presented in Chapter 5 of this work plan.

1.3.4 Background Information

Background information for Los Alamos Canyon and Pueblo Canyon is presented in Chapter 2 of this work plan, and the environmental setting is presented in Chapter 3.

1.3.5 Intended Data Uses

The intended data uses are described in Chapter 6 of this work plan.

2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

The overall organizational structure of the of the ER Project is presented in Chapter 1 of the IWP (LANL 1995, 49822). A complete description of the responsibilities under this organizational structure can be found in Annex I of this work plan.

Primary ER Project assignments and telephone numbers are as follows.

- Field project leader: Allyn Pratt 505-667-9768 or 505-667-4308
- Quality program project leader: Larry Souza 505-665-0470
- Health and safety project leader: Oliver Wilton 505-665-2950
- Technical team leader: David Broxton 505-667-2492
- Field operations manager: Deba Daymon 505-662-1327
- Field team leader(s): to be determined
- Field team members: to be determined

The quality assurance (QA) responsibilities of the team members for the investigation of Los Alamos Canyon and Pueblo Canyon are described in the following sections. Brief descriptions of the education and relevant experience of the personnel are provided in Appendix E of this work plan. The responsibilities described for each team member can be delegated to other qualified individuals as required to meet investigation demands.

2.1 Field Project Leader

The field project leader (FPL)

- oversees day-to-day operations, including planning, scheduling, and reporting technical and related administrative activities;
- ensures preparation of planning documents and procedures for conducting scientific investigations;
- ensures that the Los Alamos Canyon and Pueblo Canyon investigation complies with applicable environmental regulations, Department of Energy (DOE) orders, University of California and Laboratory policy, and applicable New Mexico laws and regulations;
- prepares monthly and quarterly reports for the ER Project manager;
- oversees subcontractors, as appropriate;
- coordinates with the technical team leader;
- conducts technical reviews of milestones and final reports;
- interfaces with the quality program project leader (QPPL) to resolve quality concerns and to coordinate audits with the QA staff;
- complies with the ER Project's health and safety, field sampling, and records management procedures;
- oversees the field work, manages the field team leader(s) and other field team members, and issues programmatic guidance to team members; and
- complies with the technical and QA requirements for the ER Project.

The FPL will assign work for the Los Alamos Canyon and Pueblo Canyon investigation through the use of specific written scopes of work for both subcontractors and internal Laboratory personnel and groups. The assignment of work to subcontractors will be controlled through Laboratory procurement procedures. The assignment of work within the Laboratory will be controlled through the use of the internal statement of work (SOW).

As required by the internal SOW procedure, internal work will be assigned only after a completed SOW is provided to the FPL in response to the detailed scope of work. Section II of the SOW provides documentation of responsibilities for the Los Alamos Canyon and Pueblo Canyon investigation. Copies of the completed SOW will be provided to the FPL, and Section II of the SOW will be provided to the people to whom the work has been assigned. If any additional personnel are assigned after the SOW has been completed, Section II of the SOW must be completed for each additional person.

2.2 Quality Program Project Leader

The QPPL

- ensures that the quality program is properly implemented;
- ensures that independent organizations adequately and effectively evaluate the quality program;
- verifies that ER Project personnel and subcontractors properly implement the quality program;
- oversees the Los Alamos Canyon and Pueblo Canyon QA staff;
- resolves disputes and issues stop-work orders regarding quality;
- reviews and approves quality-related plans and implementing procedures;
- conducts QA audits, reviews, and surveillance;
- coordinates QA audits with the FPL; and
- prepares monthly QA reports for the ER Project manager.

The QPPL functions in parallel with the Los Alamos Canyon and Pueblo Canyon investigation. The QPPL reports directly to the ER Project manager on day-to-day activities and to the Environmental Management (EM) division director, when necessary, to resolve QA issues.

2.3 Health and Safety Representative

The health and safety representative

- ensures that the Los Alamos Canyon and Pueblo Canyon Health and Safety (H&S) Plan is properly implemented;
- reviews and approves site-specific H&S plans;
- informs the FPL and the field team leader(s) of health and safety issues;
- ensures that the Los Alamos Canyon and Pueblo Canyon investigation complies with applicable health and safety aspects of environmental regulations, DOE orders, University of California and Laboratory policy, and applicable New Mexico laws and regulations; and
- oversees the Los Alamos Canyon and Pueblo Canyon health and safety staff.

2.4 Technical Team Leader

The primary disciplines currently represented on the Los Alamos Canyon and Pueblo Canyon technical team are geology, geochemistry, chemistry, hydrology, statistics, biology, archeology, geomorphology, risk assessment, and health physics. The composition of the technical team may change with time as the technical expertise needed to implement the canyons investigation changes. Responsibilities are as follows:

- provide technical input and advice for appropriate disciplines throughout the investigation and
- participate in field work, data analysis, report preparation, work plan modifications, and planning of subsequent investigations, as necessary.

2.5 Field Operations Manager

The field operations manager

- oversees daily field operations, including planning, scheduling, and implementing field activities;
- manages day-to-day field team activities;
- coordinates field team activities with the FPL; and
- ensures the quality and completeness of field team deliverables.

2.5.1 Field Team Leader(s)

The field team leader(s)

- receive assignments from the field team manager for implementation in the field and
- direct the execution of field sampling activities using crews of field team members as appropriate for the activity.

2.5.2 Field Team Members

Depending on the activity being conducted, the field team members will include a site safety officer, appropriate subcontractors, sampling personnel, and staff members with technical knowledge of geology, hydrology, statistics, chemistry, and other applicable disciplines. The field team members will comply with the ER Project's technical, administrative, and QA procedures as described in this annex and with the directions given by the technical team leader, the field team leader(s), and the FPL.

3.0 QUALITY ASSURANCE OBJECTIVES FOR MEASUREMENT DATA

The QA objectives for measurement data are expressed in terms of the precision, accuracy, representativeness, completeness, and comparability of the data. The precision, accuracy, and completeness objectives for the Los Alamos Canyon and Pueblo

Canyon investigation are based on the criteria specified in Section 5.0 of the generic QAPP (LANL 1991, 0412). The analytical methods that will be used for the ER Project's analyses are based on EPA methods, when available, or other methods generally recognized by the Laboratory and accepted institutions such as the American Society for Testing and Materials.

The overall QA objective is to develop and implement procedures that will ensure quality in field sampling, field testing, chain of custody, laboratory analysis, data validation, data analysis, and data reporting. Specific procedures for sampling, chain of custody, audits, preventive maintenance, and corrective action are described in other sections of this annex or in specific procedures referenced by this annex. This section defines the goals for accuracy, precision, completeness, representativeness, and comparability. QA goals for field measurements are also discussed.

3.1 Levels of Quality Control

The levels of quality control (QC) described in Section 5.1 and Tables V.1 and V.2 of the generic QAPP (LANL 1991, 0412) will be used for the Los Alamos Canyon and Pueblo Canyon investigation with one exception: reagent blanks will not be collected as field QC samples because the use of reagents in the field will be limited to preservation reagents that will also be added to the rinsate blanks. The data quality objectives (DQOs) for the canyons investigation can be met without the use of reagent blanks.

3.2 Precision, Accuracy, and Sensitivity of Analyses

The precision, accuracy, and sensitivity of the laboratory analytical data will be equivalent to or appropriate to site-specific conditions. The analytical results of samples collected within Los Alamos Canyon and Pueblo Canyon will be based on the limits provided in Tables V.3 through V.12 of the generic QAPP (LANL 1991, 0412). The sensitivity requirements provided in the generic QAPP have been changed for selected analytes to address the screening action levels (SALs) and/or maximum contaminant levels specified in Appendix J of the IWP (LANL 1993, 26078). These SALs and the required sensitivity for each analyte included in the investigation are listed in Tables II-1, II-2, II-3, II-4, II-5, and II-6. Information about the latest SAL values is available on-line and from the Facility for Information Management, Analysis, and Display. These tables also list suggested analytical methods capable of meeting the present SALs. Several alternate methods are listed in Table II-7 that may be required to meet the SALs. The precision and accuracy for these methods are discussed in the following sections.

3.3 Quality Assurance Objectives for Precision

The QA objectives for precision for the Los Alamos Canyon and Pueblo Canyon investigation will be taken from SW-846 (EPA 1986, 31732; EPA 1986, 31733) as described in Sections 5.3, 5.3.1, and 5.3.2 and Table V.11 of the generic QAPP (LANL 1991, 0412). All the precision requirements described in the generic QAPP will apply to the canyons investigation with the following additions:

- for the additional metal analytical methods specified in Table II-7, the relative percent difference limits specified for metals in Section 5.3.1 of the generic QAPP will be applied and

TABLE II-1

ANALYTE LIST, ESTIMATED QUANTITATION LIMITS, AND SCREENING ACTION LEVELS FOR RADIONUCLIDE ANALYTES

Analyte	Estimated Quantitation Limit		Screening Action Level	
	Water[a] (pCi/L)	Soil (pCi/g)	Water (pCi/L)	Soil (pCi/g)
^{241}Am	0.1	0.1	15	22
^{3}H	300	300 pCi/L	20,000	260
^{3}H (low level)	1	–	–	–
^{238}Pu	0.1	0.1	15	27
$^{239,240}Pu$	0.1	0.1	15	24
^{90}Sr	5.0	2.0	8	4.4
^{99}Tc	0.1	0.1	3,900	28
^{230}Th	0.1	0.1	15	0.08
^{232}Th	0.1	0.1	15	0.77
^{234}U	0.1	0.1	–	13
^{235}U	0.1	0.1	–	10
^{236}U	0.1	0.1	–	–
^{238}U	0.1	0.1	–	67
Gamma spectroscopy[b]	20[c]	1	–	–
Gross-alpha	3.0	10.0	15	–
Gross-beta	3.0	10.0	–	–
Gross-gamma	100	2.0	–	–

a. All water samples will be filtered to remove particles larger than 0.45 μm.
b. The gamma spectroscopy analyte list is given in Table II-2.
c. The estimated quantitation limit for ^{241}Am and ^{137}Cs is 1 pCi/g or 20 pCi/L; the value for other analytes will vary.

- for the additional organic analytical methods specified in Table II-7, the required QC procedures and acceptance criteria are found in the ER Project analytical services statement of work (LANL 1995, 49738).

3.4 Quality Assurance Objectives for Accuracy

The QA objectives for accuracy for the Los Alamos Canyon and Pueblo Canyon investigation, excluding radiological contaminants, will be from SW-846 (EPA 1986, 31732; EPA 1986, 31733) as described in Sections 5.4, 5.4.1, and 5.4.2 and Tables V.11 and V.12 of the generic QAPP (LANL 1991, 0412). All the accuracy requirements described in the generic QAPP will apply to the canyons investigation with the following additions:

- for the additional metal analytical methods specified in Table II-7, the percent recovery limits specified for metals in Section 5.4.1 of the generic QAPP will be applied and

TABLE II-2

ANALYTE LIST AND HALF-LIVES OF RADIONUCLIDES MEASURED USING GAMMA SPECTROSCOPY[a]

Analyte	Half-Life[b]	Analyte	Half-Life
Actinium Series (daughters of ^{235}U)		**Thorium Series (daughters of ^{232}Th)**	
^{211}Bi	2.14 m	^{228}Ac	6.13 h
^{211}Pb	36.1 m	^{212}Bi	60.55 m
^{231}Pa	3.276×10^4 y	^{212}Pb	10.64 h
^{223}Ra	11.434 d	^{224}Ra	3.66 d
^{219}Rn	3.96 s	^{208}Tl	3.07 m
^{227}Th	18.718 d		
^{235}U	7.038×10^8 y		
Activation Products (and their decay products)		**Uranium Series (daughters of ^{238}U)**	
^{241}Am[c]	432.2y	^{214}Bi	19.9 m
^{57}Co	270.9 d	^{210}Pb	22.3 y
^{60}Co	5.271 y	^{214}Pb	26.8 m
^{54}Mn	312.5 d	^{234m}Pa[d]	1.17 m
^{22}Na	2.602 y	^{226}Ra	1600 y
^{237}Np	2.14×10^6 y	^{234}Th	24.10 d
^{233}Pa	27.0 d		
^{75}Se	119.78 d		
^{88}Y	106.6 d		
^{65}Zn	243.9 d		
Fission Products		**Miscellaneous Annihilation Radiation**	
^{140}Ba	12.74 d	^{40}K	1.277×10^8 y
^{144}Ce	284.3 d	^{109}Cd[e]	462.0 d
^{134}Cs	2.062 y	^{139}Ce[e]	137.6 d
^{137}Cs[c]	30.0 y	^{203}Hg[e]	46.60 d
^{152}Eu	13.33 y	^{113}Sn[e]	115.1 d
^{129}I	1.57×10^7 y	^{85}Sr[e]	64.84 d
^{140}La	40.272 h		
^{106}Ru	368.2 d		

a. Radionuclides with half-lives less than 180 days are not considered to be chemicals of potential concerns (COPCs). They are included in the analyte list to verify the presence of longer-lived parent isotopes.
b. s = seconds; m = minutes; h = hours; d = days; y = years
c. Required estimated quantitation limit for these radionuclides is 1 pCi/g or 1 pCi/L.
d. Metastable isotope
e. Radionuclides used for laboratory control standard; not considered to be COPCs

TABLE II-3

ANALYTE LIST, ESTIMATED QUANTITATION LIMITS, AND SCREENING ACTION LEVELS FOR VOLATILE ORGANIC COMPOUNDS

	Estimated Quantitation Limit		Screening Action Level[b]	
Analyte[a]	Water (μg/L)	Soil (μg/kg)	Water (μg/L)	Soil (μg/mg)
Chloromethane	10	10	1.5E+00	2.0E+00
Vinyl chloride	10	10	2.0E+00	5.2E-03
Bromomethane	10	10	8.7E+00	1.5E+01
Chloroethane	10	10	–[c]	–
Acetone	20	20	6.1E+02	2.0E+03
Dichlorodifluoromethane	10	10	3.9E+02	1.1E+02
Iodomethane	5	5	–	–
Trichlorotrifluoroethane	5	5	5.9E+04	4.1E+03
Trichlorofluoromethane	5	5	1.3E+03	7.1E+02
Methylene chloride	5	5	5.0E+00	1.1E+01
1,1-Dichloroethene	5	5	7.0E+00	3.8E-02
Carbon disulfide	5	5	2.1E+01	1.6E+01
1,1-Dichloroethane	5	5	8.1E+02	8.4E+02
1,2-Dichloroethene (total)	10	10	7.0E+01	5.9E+01
Bromochloromethane	5	5	1.8E-01	1.4E+00
Chloroform	5	5	1.6E-01	5.3E-01
1,2-Dichloroethane	5	5	5.0E+00	4.4E-01
1,1-Dichloropropene	5	5	–	–
2-Butanone	20	20	–	–
2,2-Dichloropropane	5	5	–	–
1,1,1-Trichloroethane	5	5	2.0E+01	3.0E+03
Carbon tetrachloride	5	5	5.0E+00	4.7E-01
Benzene	5	5	5.0E+00	1.4E+00
1,2-Dichloropropane	5	5	5.0E+00	6.8E-01
Trichloroethene	5	5	5.0E+00	7.1E+00
Dibromomethane	5	5	–	–
Bromodichloromethane	5	5	1.8E-01	1.4E+00
t-1,3-Dichloropropene	5	5	8.1E-02	5.1E-01
c-1,3-Dichloropropene	5	5	–	–
1,1,2-Trichloroethane	5	5	5.0E+00	1.4E+00
1,3-Dichloropropane	5	5	–	–

a. Tentatively identified compounds (TICs) may be requested. If requested, they should be identified and quantitated per the Contract Laboratory Program method for volatiles, OLM02.0 (or more recent).

b. Screening action level values are available from the Facility for Information Management, Analysis, and Display.

c. Value is not available.

TABLE II-3 (continued)

ANALYTE LIST, ESTIMATED QUANTITATION LIMITS, AND SCREENING ACTION LEVELS FOR VOLATILE ORGANIC COMPOUNDS

	Estimated Quantitation Limit		Screening Action Level[b]	
Analyte[a]	Water (μg/L)	Soil (μg/kg)	Water (μg/L)	Soil (μg/mg)
Chlorodibromomethane	5	5	–[c]	–
4-Methyl-2-Pentanone	20	20	–	–
Toluene	5	5	1.0E+03	1.9E+03
2-Hexanone	20	20		
1,2-Dibromoethane	5	5	5.0E-02	5.1E-03
Tetrachloroethene	5	5	5.0E+00	7.0E+00
Chlorobenzene	5	5	1.0E+02	1.6E+02
1,1,1,2-Tetrachloroethane	5	5	4.3E-01	4.8E+00
Ethylbenzene	5	5	7.0E+02	6.9E+02
o,m,p-Xylene (mixed)	5	5	1.0E+04	9.9E+02
Styrene	5	5	1.0E+02	2.2E+03
Bromoform	5	5	8.5E+00	5.6E+01
1,1,2,2,-Tetrachloroethane	5	5	5.5E-02	9.0E-01
1,2,3-Trichloropropane	5	5	1.6E-03	6.6E-03
Isopropylbenzene	5	5	–	–
Bromobenzene	5	5	–	–
n-Propylbenzene	5	5	–	–
2-Chlorotoluene	5	5	–	–
4-Chlorotoluene	5	5	–	–
1,3,5-Trimethylbenzene	5	5	2.4E+00	6.4E+00
tert-Butylbenzene	5	5	6.1E+01	1.3E+02
1,2,4-Trimethylbenzene	5	5	3.0E+00	8.0E+00
sec-Butylbenzene	5	5	–	–
1,3-Dichlorobenzene	5	5	6.0E+02	2.8E+03
1,4-Dichlorobenzene	5	5	7.5E+01	7.4E+00
p-Isopropyltoluene	5	5	–	–
1,2-Dichlorobenzene	5	5	6.0E+02	2.3E+03
n-Butylbenzene	5	5	–	–
1,2-Dibromo-3-Chloropropane	10	10	2.0E-01	3.2E-01

a. Tentatively identified compounds (TICs) may be requested. If requested, they should be identified and quantitated per the Contract Laboratory Program method for volatiles, OLM02.0 (or more recent).

b. Screening action level values are available from the Facility for Information Management, Analysis, and Display.

c. Value is not available.

TABLE II-4

ANALYTE LIST, ESTIMATED QUANTITATION LIMITS, AND SCREENING ACTION LEVELS FOR SEMIVOLATILE ORGANIC COMPOUNDS

Analyte[a]	Estimated Quantitation Limit		Screening Action Level[b]	
	Water (µg/L)	Soil (µg/kg)	Water (µg/L)	Soil (µg/mg)
Acenaphthene	10	330	–[c]	–
Acenaphthylene	10	330	–	–
Aniline	20	660	1.1E+01	1.9E+01
Anthracene	10	330	–	–
Azobenzene	20	660	6.1E-01	4.0E+00
Benzo(a)anthracene	10	330	9.2E-02	6.1E-01
Benzoic acid	50	3300	1.5E+05	1.0E+05
Benzo(b)flouranthene	10	330	9.2E-02	6.1E-01
Benzo(K)flouranthene	10	330	9.2E-02	6.1E+00
Benzo(g,h,i)perylene	10	330	–	–
Benzo(a)pyrene	10	330	2.0E-01	6.1E-02
Benzyl alcohol	20	1300	1.1E+04	2.0E+04
Bis(2-chloroethoxy)methane	10	330	–	–
Bis(2-chloroethyl)ether	10	330	9.8E-03	7.4E-02
4-Bromophenyl phenylether	10	330	–	–
Butylbenzylphthalate	10	330	7.3E+03	1.3E+04
4-Chloroaniline	20	1300	1.5E+02	2.6E+02
4-Chloro-3-methylphenol	20	660	–	–
2-Chloronaphthalene	10	330	–	–
2-Chlorophenol	10	330	1.8E+02	3.3E+02
4-Chlorophenyl phenylether	10	330	–	–
Chrysene	10	330	–	–
Dibenz(a,h)anthracene	10	330	9.2E-03	6.1E-02
Dibenzofuran	10	330	1.5E+02	2.6E+02
1,2-Dichlorobenzene	10	330	6.0E+02	2.3E+03
1,3-Dichlorobenzene	10	330	6.0E+02	2.8E+03
1,4-Dichlorobenzene	10	330	7.5E+01	7.4E+00

a. Tentatively identified compounds (TICs) may be requested. If requested, they should be identified and quantitated per the Contract Laboratory Program method for volatiles, OLM02.0 (or more recent).

b. Screening action level values are available from the Facility for Information Management, Analysis, and Display.

c. Value is not available

TABLE II-4 (continued)

ANALYTE LIST, ESTIMATED QUANTITATION LIMITS, AND SCREENING ACTION LEVELS FOR SEMIVOLATILE ORGANIC COMPOUNDS

	Estimated Quantitation Limit		Screening Action Level[b]	
Analyte[a]	Water (µg/L)	Soil (µg/kg)	Water (µg/L)	Soil (µg/mg)
3,3-Dichlorobenzidine	20	660	1.5E-01	9.9E-01
2,4-Dichlorophenol	10	330	1.1E+02	2.0E+02
Diethylphthalate	10	330	2.9E+04	5.2E+04
Dimethyl phthalate	10	330	3.7E+05	1.0E+05
2,4-Dimethylphenol	10	330	7.3E+02	1.3E+03
2,4-Dinitrophenol	50	1600	7.3E+01	1.3E+02
Di-n-butylphthalate	10	330	–[c]	–
4,6-Dinitro-2-methylphenol	50	1600	–	–
2,4-Dinitrotoluene	10	330	7.3E+01	1.3E+02
2,6-Dinitrotoluene	10	330	3.7E+01	6.5E+01
Di-n-octyl phthalate	10	330	7.3E+02	1.3E+03
Bis(2-ethylhexyl)phthalate	10	330	6.0E+00	3.2E+01
Fluoranthene	10	330	1.5E+03	2.6E+03
Fluorene	10	330	2.4E+02	3.0E+02
Hexachlorobenzene	10	330	1.0E+00	2.8E-01
Hexachlorobutadiene	10	330	8.6E-01	5.7E+00
Hexachlorocyclopentadiene	10	330	5.0E+01	4.5E+02
Hexachloroethane	10	330	4.8E+00	3.2E+01
Indeno(1,2,3-cd)pyrene	10	330	9.2E-02	6.1E-01
Isophorone	10	330	7.1E+01	4.7E+02
2-Methylnaphthalene	10	330	–	–
2-Methylphenol	10	330	1.8E+03	3.3E+03
4-Methylphenol	10	330	1.8E+02	3.3E+02
Naphthalene	10	330	2.4E+02	8.0E+02
2-Nitroaniline	50	1600	2.2E+00	3.9E+00
3-Nitroaniline	50	1600	–	–
4-Nitroaniline	20	660	–	–
Nitrobenzene	10	330	1.8E+01	3.3E+01

a. Tentatively identified compounds (TICs) may be requested. If requested, they should be identified and quantitated per the Contract Laboratory Program method for volatiles, OLM02.0 (or more recent).

b. Screening action level values are available from the Facility for Information Management, Analysis, and Display.

c. Value is not available.

TABLE II-4 (continued)

ANALYTE LIST, ESTIMATED QUANTITATION LIMITS, AND SCREENING ACTION LEVELS FOR SEMIVOLATILE ORGANIC COMPOUNDS

Analyte[a]	Estimated Quantitation Limit		Screening Action Level[b]	
	Water (µg/L)	Soil (µg/kg)	Water (µg/L)	Soil (µg/mg)
2-Nitrophenol	10	330	–[c]	–
4-Nitrophenol	50	1600	–	–
N-Nitrosodimethylamine	10	330	1.3E-03	8.7E-03
N-Nitrosodiphenylamine	10	330	1.4E+01	9.1E+01
N-Nitroso-di-n-propylamine	10	330	9.6E-03	6.3E-02
2,2'-oxybis(1-Chloropropane)	10	330	–	–
Pentachlorophenol	50	1600	1.0E+00	2.5E+00
Phenanthrene	10	330	–	–
Phenol	10	330	2.2E+04	3.9E+04
Pyrene	10	330	1.1E+03	2.0E+03
1,2,4-Trichlorobenzene	10	330	7.0E+01	6.2E+02
2,4,5-Trichlorophenol	50	1600	3.7E+03	6.5E+03
2,4,6-Trichlorophenol	10	330	6.1E+00	4.0E+01

a. Tentatively identified compounds (TICs) may be requested. If requested, they should be identified and quantitated per the Contract Laboratory Program method for volatiles, OLM02.0 (or more recent).

b. Screening action level values are available from the Facility for Information Management, Analysis, and Display.

c. Value is not available.

TABLE II-5

ANALYTE LIST, ESTIMATED QUANTITATION LIMITS, AND SCREENING ACTION LEVELS FOR ORGANOCHLORINE PESTICIDES AND POLYCHLORINATED BIPHENYL COMPOUNDS

Analyte	Estimated Quantitation Limit[a]	Screening Action Level[b] Water (µg/L)	Screening Action Level[b] Soil (µg/mg)
Aldrin	0.05	4.0E-03	2.6E-02
a-BHC	0.05	–[c]	–
b-BHC	0.05	–	–
d-BHC	0.05	–	–
U-BHC (Lindane)	0.05	–	–
a-Chlordane	0.05	2.0E+00	3.4E-01
g-Chlordane	0.05	–	–
4,4'-DDD	0.10	2.8E-01	1.9E+00
4,4'-DDE	0.10	2.0E-01	1.3E+00
4,4'-DDT	0.10	2.0E-01	1.3E+00
Dieldrin	0.10	4.2E-03	2.8E-02
Endosulfan I	0.05	1.8E+00	3.3E+00
Endosulfan II	0.10	–	–
Endosulfan sulfate	0.10	–	–
Endrin	0.10	2.0E+00	2.0E+01
Endrin ketone	0.10	–	–
Endrin aldehyde	0.01	–	–
Heptachlor	0.05	4.0E-01	9.9E-02
Heptachlor epoxide	0.05	2.0E-01	4.9E-02
Methoxychlor	0.50	4.0E+01	3.3E+02
Toxaphene	5.00	3.0E+00	4.0E-01
Aroclor-1016	1.00	5.0E-01	1.0E+00
Aroclor-1221	2.00	–	–
Aroclor-1232	1.00	–	–
Aroclor-1242	1.00	–	–
Aroclor-1248	1.00	–	–
Aroclor-1254	1.00	5.0E-01	1.0E+00
Aroclor-1260	1.00	–	–

a. Determination of estimated quantitation limits for various matrices:

Matrix	Factor
Ground water	1
Low-concentration soil by sonication	33
High-concentration soil and sludges by sonication	1,000
Non-water-miscible waste	10,000

b. Screening action level values are available from the Facility for Information Management, Analysis, and Display.

c. Value is not available.

TABLE II-6

ANALYTE LIST, ESTIMATED DETECTION LIMITS, AND ANALYTICAL METHODS FOR INORGANIC CONSTITUENTS

Analyte	Analytical Method	Estimated Detection Limit Water[b] (µg/L)	Estimated Detection Limit Soil (µg/kg)	Screening Action Level[a] Water (µg/L)	Screening Action Level[a] Soil (µg/mg)
Metals					
Aluminum	ICPES[c]	200	40	3.7E+04	7.7E+04
Antimony	ICPES or ICPMS[d]	60	12	6.0E+00	3.1E+01
Arsenic	GFAA[e] or ICPMS	10	2	5.0E+01	
Barium	ICPES	200	40	1.0E+03	5.3E+03
Beryllium	ICPES	5	1	4.0E+00	
Boron	ICPES	10	10	3.3E+03	5.9E+03
Cadmium	ICPES	5	1	5.0E+00	3.8E+01
Calcium	ICPES	50	500	–[f]	–
Chromium	ICPES	10	2	1.8E+02	3.0E+01
Cobalt	ICPES	50	10	2.2E+03	4.6E+03
Copper	ICPES	25	5	1.3E+03	2.8E+03
Iron	ICPES	20	20	–	–
Lead	GFAA or ICPMS	3	0.6	5.0E+01	4.0E+02
Magnesium	ICPES	50	1000	–	–
Manganese	ICPES	15	3	1.8E+02	–
Mercury	CVAA[g]	0.2	0.1	2.0E+00	2.3E+01
Nickel	ICPES	40	8	1.0E+02	1.5E+03
Potassium	ICPES	500	500	–	–
Selenium	GFAA or ICPMS	5	1	5.0E+01	3.8E+02
Silver	ICPES	10	2	5.0E+01	3.8E+02
Sodium	ICPES	50	500	–	–
Thallium	GFAA or ICPMS	10	2	–	–
Titanium	ICPES	10	1	–	–
Uranium (total)	ICPMS	1	0.5	2.0E+01	2.3E+02
Vanadium	ICPES	50	10	2.6E+02	5.4E+02
Zinc	ICPES	20	4	1.1E+04	2.3E+04

a. Screening action level values are available from the Facility for Information Management, Analysis, and Display.
b. All water samples will be filtered to remove particles larger than 0.45 µm.
c. ICPES = inductively coupled plasma emission spectroscopy
d. ICPMS = inductively coupled plasma mass spectrometry
e. GFAA = graphite furnace atomic absorption
f. Screening action level value is not available. Site-specific background value will be used if available.
g. CVAA = cold vapor atomic absorption

TABLE II-6 (continued)

ANALYTE LIST, ESTIMATED DETECTION LIMITS, AND ANALYTICAL METHODS FOR INORGANIC CONSTITUENTS

Analyte	Analytical Method	Estimated Detection Limit Water[b] (µg/L)	Estimated Detection Limit Soil (µg/kg)	Screening Action Level[a] Water (µg/L)	Screening Action Level[a] Soil (µg/mg)
Anions					
Bromide	IC[c]	100	0.1	–[d]	–
Chlorate	IC	100		–	–
Chloride	IC	100	0.1	–	–
Fluoride	IC	20	0.02	4.0E+03	3.9E+03
Nitrate	IC	40		1.0E+04	1.0E+05
Nitrite	IC	40		1.0E+03	6.5E+03
Phosphate	IC	20		–	–
Sulfate	IC	100	0.1	–	–
Other Inorganics					
Silica (dissolved)	Colorimetry	100	100	–	–
Total cyanide	Colorimetry	50	0.05	–	–

a. Screening action level values are available from the Facility for Information Management, Analysis, and Display.
b. All water samples will be filtered to remove particles larger than 0.45 µm.
c. IC = ion chromatography
d. Screening action level value is not available. Site-specific background value will be used if available.

TABLE II-7

ADDITIONAL ANALYTICAL METHODS FOR LOS ALAMOS CANYON AND PUEBLO CANYON

Analytical Protocol[a]	Description
Organic Analytes	
SW-846 Method 8021	Volatile holgenated and aromatic compounds
SW-846 Method 8061	Phthalate esters
SW-846 Method 8141	Organophosphate pesticides
SW-846 Method 8310	Polynuclear aromatic compounds
TBD[b]	Bromoform
TBD	1,1-Dichloroethene
TBD	cis-1,3-Dichloropropene
TBD	trans-1,3-Dichloropropene
TBD	Vinyl chloride
TBD	Benzo(a)pyrene
TBD	bis(2-Chloroethyl)ether
TBD	bis(2-Ethylhexyl)phthalate
TBD	p-Chloroaniline
TBD	3,3-Dchlorobenzidene
TBD	2,4-Dinitrotoluene
TBD	2,6-Dinitrotoluene
TBD	Hexachlorobenzene
TBD	o-Nitroaniline
TBD	n-Nitrosodiphenylamine
TBD	n-Nitrosodipropylamine
TBD	pentachlorophenol
TBD	2,4,6-Trichlorophenol
Inorganic Methods	
SW-846 Method 7471A	Mercury
SW-846 Method 6010B	Antimony
SW-846 Method 7421 or 6020	Lead
SW-846 Method 7741 or 6020	Selenium
SW-846 Method 7841 or 6020	Thallium

a. The method numbers given are from SW-846 Test Methods for Evaluating Solid Waste (EPA 1986, 31732; EPA 1986, 31733).
b. To be determined

TABLE II-7 (continued)

ADDITIONAL ANALYTICAL METHODS FOR LOS ALAMOS CANYON AND PUEBLO CANYON

Analytical Protocol[a]	Description
Inorganic Methods (continued)	
SW-846 Method 7870	Tin
SW-846 Method 7060 or 6020	Arsenic
SW-846 Method 6010B	Beryllium
SW-846 Method 6010B	Cadmium
SW-846 Method 6010B	Barium
SW-846 Method 6010B	Chromium
SW-846 Method 6010B	Silver
SW-846 Method 9012A	Cyanide
Anions	
SW-9056	Bromide
SW-9056	Chlorate
SW-9056	Chloride
SW-9056	Fluoride
SW-9056	Nitrate
SW-9056	Nitrite
SW-9056	Phosphate
SW-9056	Sulfate
Other Parameters	
EPA Method 370.1	Silica
EPA Method 310.1	Alkalinity
LANL-ER-SOP-06.02,R0	Dissolved oxygen
LANL-ER-SOP-06.02,R0	pH
LANL-ER-SOP-06.02,R0	Specific conductance
LANL-ER-SOP-06.02,R0	Temperature
EPA Method 180.1	Turbidity
Modified EPA Method 415	Dissolved organic carbon
EPA Method 130	Hardness
Accelerator MS	Carbon-14

a. The method numbers given are from SW-846 Test Methods for Evaluating Solid Waste (EPA 1986, 31732; EPA 1986, 31733).

TABLE II-7 (continued)

ADDITIONAL ANALYTICAL METHODS FOR LOS ALAMOS CANYON AND PUEBLO CANYON

Analytical Protocol[a]	Description
Other Parameters (continued)	
Accelerator MS	Deuterium/Hydrogen
MS	Oxygen-16/Oxygen-18
ASTM D-4531-86	Bulk density, Dry density
Batch method	Distribution coefficient
API Method 40, Section 3.58	Porosity
ASTM D-2488	Soil classification
X-ray diffraction, electron microprobe	Mineralogical composition
ASTM D-4531-86	Moisture content (gravimetric and volumetric)
Pressure plate extractor	Moisture potential
ASTM D-2434-68	Saturated hydraulic conductivity

a. The method numbers given are from SW-846 Test Methods for Evaluating Solid Waste (EPA 1986, 31732; EPA 1986, 31733).

- for the additional organic analytical methods specified in Table II-7, the required QA/QC procedures and acceptance criteria are found in the ER Project analytical services statement of work (LANL 1995, 49738).

3.5 Representativeness, Completeness, and Comparability

The representativeness of the analytical data will be attained through the technical approach described in Chapter 5 and the specific sampling and analysis plans described in Chapter 7 of this work plan. Additional information to be used to attain representativeness is included in the discussions of site-specific data needs and DQOs in Chapters 6 and 7, respectively, of this work plan and in the list of site-specific standard operating procedures (SOPs) given in Tables 7.6, 7.14 and 7.18 in Chapter 7.

The completeness goal of 90% set for the ER Project will apply to the Los Alamos Canyon and Pueblo Canyon investigation as described in Section 5.5 of the generic QAPP (LANL 1991, 0412). Additional actions will be required when the completeness goals are not achieved for critical samples.

Comparability will be achieved through the use of the standard methods listed in Tables II-1, II-2, II-3, II-4, II-5, and II-6 as well as through the use of ER Project SOPs. The comparability requirements specified in Section 5 the generic QAPP will apply to the Los Alamos Canyon and Pueblo Canyon investigation.

3.6 Field Measurements

The primary QA objectives for field measurements described in Section 5.6 of the generic QAPP (LANL 1991, 0412) apply to the Los Alamos Canyon and Pueblo Canyon investigation. These QA objectives will be achieved through the use of appropriate methodology described in the ER Project SOPs for each site activity. These SOPs are listed in Table II-8.

3.7 Data Quality Objectives

The qualitative and quantitative statements that specify the quality of the data required to support the Los Alamos Canyon and Pueblo Canyon investigation decision process are described in this work plan. The analyte-specific sensitivity, precision, and accuracy requirements presented in Tables II-1, II-2, II-3, II-4, II-5, II-6, and II-8 describe the QA objectives for measurement data that could be considered to provide for the collection of analytical data with acceptable levels of uncertainty. The decision process and acceptable levels of uncertainty are presented in Chapter 5; site-specific decisions and investigation objectives are described in Chapter 6 of this work plan. The sampling and analysis strategies and approaches as well as the required sampling and analyses for each site are described in Chapter 7.

TABLE II-8

STANDARD OPERATING PROCEDURES FOR LOS ALAMOS CANYON AND PUEBLO CANYON WORK PLAN

Number	Description
General Instructions	
LANL-ER-SOP-01.01	General Instructions for Field Investigations
LANL-ER-SOP-01.02	Sample Containers and Preservation
LANL-ER-SOP-01.03, R1	Handling, Packaging, and Shipping of Samples
LANL-ER-SOP-01.04, R2	Sample Control and Field Documentation
LANL-ER-SOP-01.05	Field Quality Control Samples
LANL-ER-SOP-01.06	Management of RFI-Generated Waste
TBD[a]	Data Validation Procedures
Health and Safety in the Field	
ER Project Health and Safety Plan	Personal Protective Equipment
ER Project Health and Safety Plan	Respirators
ER Project Health and Safety Plan	Pre-Entry Briefings for Site Personnel
ER Project Health and Safety Plan	Pre-Entry Briefings for Visitors
ER Project Health and Safety Plan	Safety Meetings and Inspections
ER Project Health and Safety Plan	Heat and Cold Stress and Natural Hazards
ER Project Health and Safety Plan	General Equipment Decontamination
ER Project Health and Safety Plan	Personnel Decontamination
ER Project Health and Safety Plan	Accident/Incident Reporting
ER Project Health and Safety Plan	Radiation Protection
ER Project Health and Safety Plan	Training and Medical Surveillance
Field Surveys	
TBD	Hand-held Instruments for Field Screening of VOCs
TBD	Hand-held Instruments for Field Screening of Radioactive Substances
LANL-ER-SOP-03.02, R1	General Surface Geophysics
Drilling, Excavating, and Soil Sampling Techniques	
LANL-ER-SOP-04.01	Drilling Methods and Drill Site Management
LANL-ER-SOP-04.04	General Borehole Logging
TBD	Spill Control During Drilling
Sampling Techniques	
LANL-ER-SOP-06.02	Field Analytical Measurements of Groundwater
LANL-ER-SOP-06.03	Sampling for Volatile Organics
LANL-ER-SOP-06.05	Soil Water Samples
LANL-ER-SOP-06.09	Spade and Scoop Method for Collection of Soil Samples

a. This procedure is in preparation.

TABLE II-8 (continued)

STANDARD OPERATING PROCEDURES FOR LOS ALAMOS CANYON AND PUEBLO CANYON WORK PLAN

Number	Description
Sampling Techniques (continued)	
LANL-ER-SOP-06.10	Hand Auger and Thin-Wall Tube Sampler
LANL-ER-SOP-06.11	Stainless Steel Surface Soil Sampler
LANL-ER-SOP-06.13	Surface Water Sampling
LANL-ER-SOP-06.14	Sediment Material Collection
LANL-ER-SOP-06.17	Trier Sampler for Sludges and Moist Powders or Granules
LANL-ER-SOP-06.19	Weighted Bottle Sampler for Liquids and Slurries in Tanks
TBD[a]	Field Surveying of Sample Locations
Curatorial Sample Management	
LANL-ER-SOP-12.01, R1	Field Logging, Handling, and Documentation of Borehole Samples
LANL-ER-SOP-12.02, R1	Transportation, Receipt, and Admittance of Borehole Samples for the Sample Management Facility
LANL-ER-SOP-12.03	Acceptance of Non-borehole Samples by the Sample Management Facility
LANL-ER-SOP-12.04, R1	Physical Processing and Storage of Borehole Samples at the Sample Management Facility
LANL-ER-SOP-12.05, R1	Examination of Samples at the Sample Management Facility
Quality Procedures	
LANL-ER-QP-01.1Q	Audits
LANL-ER-QP-01.2Q	Surveys
LANL-ER-QP-01.3Q	Deficiency Reporting
Administrative Procedures	
LANL-ER-AP-01.3	Review and Approval of Environmental Restoration Program Plans and Reports
LANL-ER-AP-01.5	Revision or Interim Change of Environmental Program Controlled Documents
ICN NO. 002	Interim Change Notice for LANL-ER-AP-01.5, R0
LANL-ER-AP-02.1, R1	Procedure for LANL ER Records Management
LANL-ER-AP-03.2	Handling Media and Public Requests for Information During Field Work
LANL-ER-AP-04.1, R1	Identification, Documentation, and Reporting of Newly Discovered Potential Release Sites for the Environmental Restoration Program
LANL-ER-AP-04.2	Reporting of Newly Identified Releases from Solid Waste Management Units

a. This procedure is in preparation.

3.8 Quality Improvement

The Los Alamos Canyon and Pueblo Canyon investigation will be conducted following the quality improvement guidelines described in Section 20.0 of the Quality Program Plan (LANL 1991, 7651). The quality improvement activities to be conducted as part of the investigation include the following:

- a kickoff meeting where all participants meet to discuss the responsibilities of each participant, schedules and how they impact the overall investigation, nonconformance reporting, health and safety requirements, and feedback on the project plans;
- readiness reviews before beginning each major field activity to cover the same topics discussed at the kickoff meeting and how these topics relate to the field activity to be conducted;
- daily tailgate meetings to review the daily sampling objectives and health and safety aspects of the work to be conducted by the field crew that day; and
- a closeout meeting at the end of each major sampling activity to review the performance and to suggest improvements for subsequent activities.

4.0 SAMPLING PROCEDURES

The activities to be conducted during the Los Alamos Canyon and Pueblo Canyon investigation will follow the procedures described in this section and in Section 6 of the generic QAPP (LANL 1991, 0412). The SOPs to be used during the investigation are listed in Table II-8. These procedures cover the sample collection, handling, and shipping procedures, as well as the QA procedures that will be followed during the investigation. These procedures were selected from the ER Project procedures listed in Appendix M of the IWP (1993, 26078).

4.1 Quality Control Samples

QC samples will be collected as described in Section 6.1 of the generic QAPP (LANL 1991, 0412) with the exceptions given in Section 3.1 of this annex.

4.2 Sample Preservation During Shipment

All samples will be handled following the guidance in Section 6 of the generic QAPP (LANL 1991, 0412) and the appropriate ER Project SOPs listed in Table II-8. The following specific SOPs will be used for sample preservation during shipment. Samples will be controlled and documented in the field following LANL-ER-SOP-01.04, R2, "Sample Control and Field Documentation." Samples will be contained and preserved following LANL-ER-SOP-01.02, "Sample Containers and Preservation." The essential sample container and preservation information for LANL-ER-SOP-01.02 that pertains to the investigation of Los Alamos Canyon and Pueblo Canyon is summarized in Table II-9. The handling, packaging, and shipping of samples will follow LANL-ER-SOP-01.03, R1, "Handling, Packaging, and Shipping of Samples."

TABLE II-9

SAMPLE CONTAINER TYPES, VOLUMES, PREPARATION, SPECIAL HANDLING, PRESERVATION, HOLDING TIMES, AND MINIMUM SAMPLE QUANTITIES

Analysis	Containers	Handling and Preservation	Holding Time[a]
Soil Samples			
Gross-alpha, -beta, and -gamma spectroscopy	1, 250-ml plastic	Store 4°C	6 m
Isotopic plutonium, tritium, and ^{90}Sr	1, 250-ml plastic	Store 4°C	6 m
Volatiles by Method 8240	3, 60-ml amber glass with Teflon-lined cap	Store 4°C, handle upwind from equipment fumes, no contact with plastic or gloves	14 d
Metals, cyanide, total uranium, and ^{99}Tc	1, 250-ml plastic	Store 4°C	6 m all metals except mercury, which is 28 d and cyanide 14 d
Volatiles including Methods 8240 and 8021	3, 60-ml amber glass with Teflon-lined caps	Store 4°C, handle upwind from equipment fumes, no contact with plastic or gloves	14 d
Semivolatiles, and organochlorine pesticides and PCBs[b] including Methods 8270, 8310, 8061, and 8080	2, 120-ml amber glass with Teflon-lined cap	Store 4°C, handle upwind from equipment fumes, no contact with plastic or gloves	7 d until extraction, 30 d thereafter
Metals and cyanide	1, 250-ml plastic	Store 4°C	6 m all metals except mercury, which is 28 d and cyanide which is 14 d
Total petroleum hydrocarbons	1, 250-ml plastic	Store 4°C	7 d until extraction, 30 d thereafter
Water Samples			
Gross-alpha, -beta, and -gamma spectroscopy	1, 1-L plastic	Store 4°C	6 m
Isotopic plutonium, tritium, and ^{90}Sr	1, 1-L plastic	Store 4°C	6 m
Metals and total uranium	1, 500-ml plastic	Preserve with HNO_3 to pH < 2 and store 4°C	6 m uranium and all metals except mercury, which is 28 d
Volatiles including Methods 8240 and 8021	3, 40-ml amber glass with Teflon-lined caps per method	Store 4°C, handle upwind from equipment fumes, no contact with plastic or gloves	14 d
Semivolatiles, and organochlorine pesticides and PCBs, including Methods 8270, 8310, 8061, and 8080	2, 1-L amber glass with Teflon-lined cap per method	Store 4°C, handle upwind from equipment fumes, no contact with plastic or gloves	7 d until extraction, 30 d thereafter
Metals	1, 500-ml plastic	Preserve with HNO_3 to pH < 2 and store 4°C	6 m all metals except mercury, which is 28 d
Cyanide	1, 250-ml plastic	Preserve with NaOH to pH > 12 and store 4°C	14 d

a. d = days; m = months
b. PCB = polychlorinated biphenyl

4.3 Equipment Decontamination

Equipment will be decontaminated following the procedure described in Section 6.3 of the generic QAPP (LANL 1991, 0412). Any equipment-specific decontamination procedures specified in the sampling equipment SOPs will also be followed.

4.4 Sample Designation

As described in Section 6.4 of the generic QAPP (LANL 1991, 0412), LANL-ER-SOP-01.04, R2, "Sample Control and Field Documentation," will be followed for designating sample numbers. The sample numbers will be designated with the assistance of ER Project personnel familiar with this SOP.

5.0 SAMPLE CUSTODY

5.1 Overview

The strict chain-of-custody procedures contained in LANL-ER-SOP-01.04, R2 "Sample Control and Field Documentation," and described in Section 7.1 of the generic QAPP (LANL 1991, 0412) will be followed during the Los Alamos Canyon and Pueblo Canyon investigation. These procedures will be followed to ensure the proper handling of samples from collection to analysis, including the final disposition of the analytical samples.

5.2 Field Documentation

5.2.1 Sample Identification

A numbering system has been developed to identify each borehole location, monitoring well, and sample collected during surface water, ground water, sediment, waste stream, soil, and air sampling activities. This numbering system provides a tracking procedure for all data retrieval. Sampling identification numbers will be assigned in accordance with LANL-ER SOP-01.04, R2, "Sample Control and Field Documentation." Familiarity with the sample numbering system among the key Laboratory staff will ensure that the numbering system is universally applied to samples collected during the investigation.

5.2.2 Field Logs

All data collection activities performed at a site will be documented using indelible blue or black ink, either in a field notebook or on ER Project forms. Field notebooks will be bound books and will be assigned to individual field personnel for the duration of their assignment. Entries will be as detailed and descriptive as possible so that a particular situation can be recalled without relying on an individual's memory.

5.2.3 Data Collection Forms

As the primary means of ensuring the collection of accurate field and sampling information, standardized data collection forms will be used. ER Project forms have been developed and will be used to record data in a consistent format that limits individual interpretations or preferences. By explicitly outlining reporting methods, identifying appropriate units of measure, and specifying alternative test procedures, these forms provide a measure of QC and QA in the data collection process.

The standard data collection forms prepared for the ER Project SOPs group data and information according to problem-solving needs. There are a means of preventing the collection of invalid or redundant data and eliminating critical data gaps. Each data collection form precisely defines what data are necessary to accurately characterize a particular property or relationship. This process reduces the likelihood of initiating field sampling for laboratory analyses and then discovering that key pieces of information have not been collected and that further sampling is required.

Each SOP for a data collection activity provides an example of all forms required for the accurate recording of the procedure. A blank form will be used for each new location or sample, as specified by the SOP. During an ER Project field investigation, each form will be completed as accurately and completely as possible, as directed by the example and instructions contained in the SOP. Before submittal to the ER Project Records-Processing Facility, all data collection forms will be reviewed by the appropriate ER Project field team leader or other applicable technical reviewer. The review will ensure completeness and accuracy in both form completion and data integrity. The reviewer will then sign the form and record the date and time.

5.2.4 Corrections to Documentation

Incorrect entries will be crossed out with a single line and signed and dated by the person originating the entry and by the appropriate ER Project field team leader as described in Section 7.2.4 of the generic QAPP (LANL 1991, 0412). The correct information will be entered, and the correction will be signed and dated by the person making the correction. There will be no erasures or deletions from any data document record.

5.3 Sample Management Office

All samples will initially be transported by the field operations manager or designated field team member to the Sample Management Office. As described in Section 7.3 of the generic QAPP (LANL 1991, 0412), the Sample Management Office will coordinate the sample collection activities with the required chemical analysis. The procedures for sample handling will follow those described in Section 4.0 of this annex.

5.4 Laboratory Documentation

The laboratory documentation procedures described in Section 7.4 and the related subsections in the generic QAPP (LANL 1991, 0412) will be followed for all samples collected and analyzed during the Los Alamos Canyon and Pueblo Canyon investigation.

5.5 Sample Handling, Packaging, and Shipping

All samples shipped off-site will be shipped by courier, such as Federal Express, to the appropriate participating fixed-site laboratory. Only samples that contain a material listed in the Hazardous Material Table (49 CFR 172.101) (EPA 1989, 0092) should be handled, package, and shipped as hazardous material. The US Department of

Transportation and the International Air Transport Association have established specific regulations governing the package of hazardous samples for shipment. LANL-ER-SOP-01.03, R1, "Handling, Packaging, and Shipping of Samples," provides information and references that must be reviewed before selecting appropriate packaging materials, shipping containers, and shipping labels.

5.6 Final Evidence File Documentation

All Los Alamos Canyon and Pueblo Canyon investigation participants will maintain records to document the QA/QC activities and to provide support for possible evidential proceedings. All records generated during the investigation are the property of the ER Project Office. The Records Management Plan (Annex IV of this work plan) and the ER Project Records Management Program (LANL 1995, 49822) describe the procedures that will be followed to provide final evidence documentation.

6.0 CALIBRATION PROCEDURES AND FREQUENCIES

The calibration procedures and their frequencies for the Los Alamos Canyon and Pueblo Canyon investigation are described in Section 8 of the generic QAPP (LANL 1991, 0412).

7.0 ANALYTICAL PROCEDURES

ER Project routine analytical services are summarized in Table II-10, which lists the analytical suites, methods, and protocols provided through the Sample Management Office. Routine services include the analysis of trace inorganic constituents, volatile organic compounds, semivolatile organic compounds, organochlorine pesticides, polychlorinated biphenyl compounds, and high explosives. Routine radiochemical analyses include gamma spectrometry, measurements of gross radioactivity and the analysis of a range of radionuclides including the alpha-emitting isotopes of plutonium, thorium, and uranium. Routine analyses are performed only at ER Project-approved fixed-site laboratories. The required analyte lists, estimated quantitation limits (EQLs), analytical protocols (including sample preparation), and QC acceptance criteria are described in the ER Project analytical services statement of work (LANL 1995, 49738). The analyte lists and EQLs for the analytical measurements proposed for the Los Alamos Canyon and Pueblo Canyon investigation are given in Tables II-1 through II-5.

The required QC procedures and QC samples for the routine analytical services are based on the requirements for EPA's SW-846 (EPA 1986, 31732; EPA 1986, 31732) or Contract Laboratory Program methods. Required QC activities include initial and continuing calibrations, analysis of system monitoring compounds, and analysis of method blank, matrix spike, duplicate, and laboratory control samples. The QC acceptance criteria are based on criteria given in the national functional guidelines for organic data review (EPA 1994, 04-0325) and inorganic data review (EPA 1994, 04-0324). Where EPA-promulgated QC criteria are not available, notably for the radiochemical analyses, the ER Project has established the acceptance criteria.

Some analyses and measurements may be performed in mobile laboratory facilities. The performance of mobile laboratory methods will be evaluated before field samples

TABLE II-10
ANALYTICAL METHODS AND PROTOCOLS FOR ENVIRONMENTAL RESTORATION PROJECT ROUTINE ANALYTICAL SERVICES

Analytical Suite	Analytical Method	Analytical Protocol[a]
Inorganic analytes		
Trace metals	ICPES[b], ICPMS[c], or GFAA[d]	SW-6010, SW-6020, or SW-7000 series
Cyanide (total)	Colorimetry	SW-9012A
Mercury	CVAA[e]	SW-7470, SW-7471
Organic analytes		
Volatile organic compounds	GC/MS[f]	SW-8260
Semivolatile organic compounds	GC/MS	SW-8270
Organochlorine pesticides	GC/ECD[g]	SW-8081
Polychlorinated biphenyl compounds	GC/ECD	SW-8081 or SW-8082
High explosives	HPLC[h]	SW-8330
Radiochemical analytes		
^{241}Am	Alpha spectrometry	–[i]
Gamma spectroscopy analytes	NaI(Tl) or HPGe detection	–
Gross-alpha radiation	Gas proportional counter or iquid scintillation	–
Gross-beta radiation	Gas proportional counter or liquid scintillation	–
Gross-gamma radiation	NaI(Tl) or HPGe detection	–
^{238}Pu, $^{239,240}Pu$	Alpha spectrometry	–
^{226}Ra	Alpha spectrometry or gamma spectroscopy	–
^{228}Ra		–
^{90}Sr	Gas proportional counting	–
^{228}Th	Alpha spectrometry	–
^{230}Th, ^{232}Th	Alpha spectrometry or ICPMS	–
Tritium	Liquid scintillation	–
^{234}U, ^{235}U, ^{238}U	Alpha spectrometry or ICPMS	–
Uranium (total)	ICPMS or kinetic phosphorescence analysis	ASTM D-5174-91

a. EPA SW-846 methods (EPA 1986, 31732; EPA 1986, 31733) or the Contract Laboratory Program equivalent methods are required.
b. ICPES = inductively coupled plasma emission spectroscopy
c. ICPMS = inductively coupled plasma mass spectrometry
d. GFAA = graphite furnace atomic absorption
e. CVAA = cold vapor atomic absorption
f. GC/MS = gas chromatography/mass spectrometer
g. GC/ECD = gas chromatography/electron capture detector
h. HPLC = high-performance liquid chromatography
i. The methods used for the radiochemical analyses must be submitted to the laboratory for approval.

are submitted for analysis. Mobile laboratory methods will be used only when the method performance has been demonstrated to provide data of the required quality for the investigation.

For the additional parameters specified in Table II-7, the approved analytical laboratories will provide analytical method SOPs for the analyses to be conducted. The methods that require development will be documented to demonstrate that the appropriate level of data quality can be achieved before the methods are approved for use in the Los Alamos Canyon and Pueblo Canyon investigation. All analyses will be performed by an analytical laboratory with demonstrated proficiency for each parameter required.

8.0 DATA REDUCTION, VALIDATION, AND REPORTING

The analytical data package is a hard copy document submitted by the analytical laboratory that reports the results of the requested analyses for the samples that were submitted. Any associated QC data that may have been requested is also included. The analytical data package submitted to the ER Project by the subcontractor laboratories must include the hard copy raw data (such as preparation bench sheets, instrument printouts, and chromatograms), which are used to arrive at the reported results. The supporting raw data are required for validation of the analytical data package. The analytical data package also contains the signed Chain of Custody form, which is required to provide full traceability and legal defensibility of the analytical data.

Analytical results may also be reported in the form of an electronic data deliverable. The electronic transmission of analytical data streamlines the data handling process. Data integrity is ensured by minimizing manual entry into user electronic databases. However, the raw data and signed Chain of Custody form must be retained, either in hard copy form or as an electronic facsimile.

Analytical data verification and validation, as defined in the IWP (LANL 1995, 49822), are procedures used to determine if analytical data packages generated in support of Laboratory decision-making meet the quality requirements that are defined in the site-specific sampling and analysis plan. Verification is a check of the data deliverables (both hard copy and electronic) against the stated acceptance criteria to ensure that what has been ordered has been delivered, so that payment may be made.

For routine analyses carried out by subcontractor laboratories, the acceptance criteria for the analytical data packages have been defined in the statement of work (LANL 1995, 49738). The acceptance criteria provide an objective set of criteria against which the analytical data packages can be checked. The requirements for analytical services include control criteria for specific QC samples and procedures that must be adhered to by the analytical laboratory. The acceptance criteria check the four Cs: completeness, compliance, consistency, and correctness. The data verification process does not require scrutiny of the raw data, other than a check that they are present. Therefore, most aspects of the data verification process can be automated and performed electronically.

Analytical data validation procedures are concerned with determining whether individual results should be qualified because of the potential impact of flaws in the data quality on the decision-making process. There are two tiers of validation, "routine" and "focused," with differing degrees of scrutiny of the analytical data package. Routine validation can be considered an extension of the verification process, in which QC indicators, such as surrogates or spikes, are compared with clearly defined limits to ascertain whether the data are technically valid. The IWP states that the EPA guidelines for inorganic (EPA 1994, 04-0324) and organic (EPA 1994, 04-0325) data review will be used for the validation of ER Project analytical data packages, where applicable. It should be noted that the acceptance criteria for routine analysis are largely based on the national functional guidelines. Therefore, there is a large amount of overlap of the verification and validation criteria for ER Project analytical data packages.

The result of the routine data validation is usually the attachment of data qualifiers, such as the designation "J" (estimated) or "R" (unusable), to data points for which deficiencies have been identified. The responsibility for deciding whether the qualified analytical data should be used in the decision-making process rests with the data user. As with data verification, most aspects of the routine data validation process can be automated and performed electronically. The combination of data verification and routine data validation provides an assessment of the technical and legal defensibility of the analytical data package.

Focused data validation is a process that focuses on those characteristics of the analytical data that impact directly the decisions to be made with the analytical data. An examination of the raw data is usually required in a focused validation. There are various ways to focus data validation depending on the ultimate use of the data. Different data uses emphasize different characteristics, such as the possibly of false positives or negatives, or inadequate limits of detection. Three situations in which the quality of the analytical data is critical, and thus focused validation may be required, are discussed in the IWP: (1) a risk-based decision for no further action; (2) an expedited cleanup of a site; and (3) a corrective measures study.

Since the focused data validation is tailored to individual requirements, it should be carried out by the individual data user. Unlike baseline validation, the focused procedure cannot be standardized for a large number of customers. Therefore, the focused validation procedure does not lend itself to automation and cannot by performed electronically. It cannot be ascertained in advance which analytical data packages may require a focused validation and which ones would include scrutiny of the raw data. The ER Project currently requires that the raw data be included with every analytical data package as the most cost-effective way to ensure that the raw data are available when needed by the data user.

The raw analytical data are also closely examined in an analytical data package assessment, which is an in-depth manual audit of the analytical data package. Analytical data package audits are a component of the QA oversight program for analytical services currently being developed by the ER Project and should be conducted on at least 10% of all analytical data packages received from each analytical laboratory.

The ER Project, as the user or client of the analytical services, is responsible for ensuring that data verification and validation are performed. These procedures are carried out by a qualified representative of the ER Project manager who is independent of the analytical laboratory. Although the analytical laboratory usually performs a data review before delivering the product (which may include the attachment of data qualifiers), the laboratory does not perform data verification or validation. Verification and validation must be independent of the laboratory data review.

9.0 INTERNAL QUALITY CONTROL CHECKS

Internal QC checks will allow evaluation of consistency and validity of generated data. Confidence in generated data in the form of internal QC checks will allow personnel to work efficiently. Internal QC checks will be conducted as described in Section 11 of the generic QAPP (LANL 1991, 0412), with the exception of the field reagent blanks described in Section 3.1 of this annex.

10.0 PERFORMANCE AND SYSTEM AUDITS

Performance and system audits will be conducted during the Los Alamos Canyon and Pueblo Canyon investigation as identified in Section 12 of the generic QAPP (LANL 1991, 0412). Audits will be conducted at least once per year or once per task, whichever is more frequent. In addition, all procedures used during the investigation will be audited at least once.

11.0 PREVENTIVE MAINTENANCE

Proper preventive maintenance of field and laboratory equipment is a necessary element for achieving equipment reliability. All field and laboratory instruments and equipment will be maintained to the manufacturer's recommendations and specifications. System checks and service will be performed on a schedule specified by the manufacturer. Maintenance will be performed when the instrument will not adequately tune or calibrate. The preventive maintenance procedures for both field and laboratory equipment specified in Section 13 of the generic QAPP (LANL 1991, 0412) will be followed during the Los Alamos Canyon and Pueblo Canyon investigation.

12.0 SPECIFIC ROUTINE PROCEDURES USED TO ASSESS DATA PRECISION, ACCURACY, REPRESENTATIVENESS, AND COMPLETENESS

Precision, accuracy, and completeness are a means of evaluating the consistency of generated data and providing data that is comparable to the data produced for other field unit investigations. The Los Alamos Canyon and Pueblo Canyon investigation will use the procedures described in Section 14 of the generic QAPP (LANL 1991, 0412) to assess data precision, accuracy, representativeness, and completeness.

13.0 CORRECTIVE ACTION

Corrective action will occur if one of following three situations arises: (1) specific requirements of the analysis method or SOPs are not met; (2) data quality objectives for precision, accuracy and completeness are not achieved; or (3) laboratory or field data review indicates that data are incomplete or that improper calculation, methodology, or technique was employed, or that an instrument malfunction has occurred. The procedures, reporting requirements, and authority for initiating corrective action during the Los Alamos Canyon and Pueblo Canyon investigation will follow those defined in Section 15 of the generic QAPP (LANL 1991, 0412).

14.0 QUALITY ASSURANCE REPORTS

QA reports to management will be prepared following the guidelines provided in Section 16 of the generic QAPP (LANL 1991, 0412).

References for Annex II

EPA (US Environmental Protection Agency), December 29, 1980. "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans," QAMS-005/80, Office of Monitoring Systems and Quality Assurance, Office of Research and Development, Washington, DC. **(EPA 1980, 0552)**

EPA (US Environmental Protection Agency), November 1986. "Test Methods for Evaluating Solid Waste, Volume IA: Laboratory Manual, Physical/Chemical Methods," SW-846, Revision 0, Third Edition, Washington, DC. **(EPA 1986, ER ID Number 31732)**

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EPA (US Environmental Protection Agency), July 1989. "Identification and Listing of Hazardous Waste," *Code of Federal Regulations*, Protection of Environment, Title 40, Part 261, Washington, DC. **(EPA 1989, 0092)**

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EPA (US Environmental Protection Agency), December 1994. "US EPA Contract Laboratory Program National Functional Guidelines for Organic Data Review," EPA-540/R-94/090, Washington, DC. **(EPA 1994, 04-0325)**

LANL (Los Alamos National Laboratory), May 1991. "Generic Quality Assurance Project Plan for RCRA Facility Investigations for the Los Alamos National Laboratory Environmental Restoration Program," Rev. 0, Los Alamos National Laboratory Report, Los Alamos, New Mexico. **(LANL 1991, 0412)**

LANL (Los Alamos National Laboratory), June 1991. "Los Alamos National Laboratory Quality Program Plan for Environmental Restoration Activities," Los Alamos National Laboratory Report LA-UR-91-1844, Los Alamos, New Mexico. **(LANL 1991, ER ID Number 7651)**

LANL (Los Alamos National Laboratory), November 1993. "Installation Work Plan for Environmental Restoration," Revision 3, Vol. II, Los Alamos National Laboratory Report LA-UR-93-3987, Los Alamos, New Mexico. **(LANL 1993, ER ID Number 26078)**

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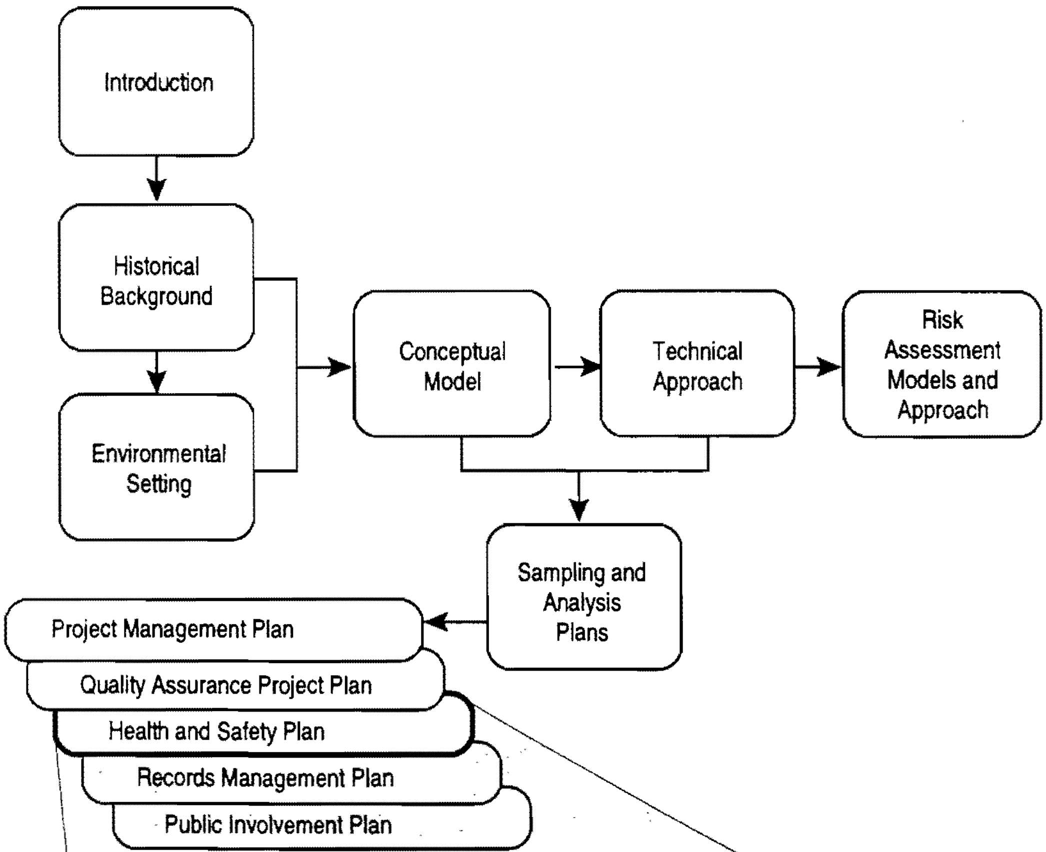
LANL (Los Alamos National Laboratory), July 1995. "Statement of Work – Analytical Support," Revision 2, RFP No. 9-XS1-Q4257, Los Alamos, New Mexico. **(LANL 1995, ER ID Number 49738)**

Annex III



Health and Safety Plan

1.0 INTRODUCTION

This annex contains the Health and Safety (H&S) Plan (hereafter referred to as this H&S plan), which has been developed for the Resource Conservation and Recovery Act (RCRA) task/site investigation for Los Alamos Canyon and Pueblo Canyon. This H&S plan provides the framework within which personal protection will be provided during the implementation of the Los Alamos Canyon and Pueblo Canyon investigation. Site-specific H&S plans will be prepared before beginning any field task. Site-specific H&S plans also will describe the specific measures to be taken for personal protection during implementation of the task and will define individual responsibilities, which are outlined in this H&S plan. Overall health and safety policy for the Environmental Restoration (ER) Project is provided in Chapter 6 of the Installation Work Plan (IWP) (LANL 1995, 49822).

As field investigation progresses, measures for personal protection may be identified that are more effective than those identified in this annex. Deviations from this H&S plan will be documented in the pertinent site-specific H&S plan along with the reasons for that deviation. As changes are required, this H&S plan will be updated.

This H&S plan includes an assessment of potential hazards, justification for personal protection requirements, and site-specific emergency response procedures. A copy of this H&S plan will be kept on-site at all times.

The specific purpose of this annex is to establish guidelines for field workers involved in the Los Alamos Canyon and Pueblo Canyon investigation. A new H&S plan must be initiated for any corrective actions. In addition to general guidance in the IWP, the following regulations and standards were used to develop the procedures set forth in this plan: Laboratory policies, *ES&H Program Documents*, DOE orders, Occupational Safety and Health Administration (OSHA) regulations, National Institute for Occupational Health (NIOSH) standards, American Conference of Governmental Industrial Hygienists (ACGIH) recommendations, Nuclear Regulatory Commission regulations, and Environmental Protection Agency (EPA) guidance. Applicable state and local regulations also will be followed.

The responsibilities of workers with regard to health and safety as described herein do not distinguish whether Laboratory employees or subcontractors are implementing this H&S plan. If it is necessary to modify this H&S plan for implementation, EPA will be notified of any modifications.

Detailed background information, including descriptions of specific site hazards, for the Los Alamos Canyon and Pueblo Canyon investigation is contained in Chapter 2 of this work plan. Detailed maps showing the locations of access roads, topography, and other health and safety related features are contained in Figures A-3 and A-4 in Appendix A of this work plan.

2.0 FIELD UNIT WORK ORGANIZATION

The following information describes policies and standards set forth in this H&S plan, including specific lines of responsibility, standards and regulations, and requirements for audits and variances of health and safety policies.

2.1 General Responsibilities

General task/site investigation responsibilities are outlined in Chapter 6 of the IWP (LANL 1995, 49822). Listed below are specific responsibilities for workers involved in the investigation for the Los Alamos Canyon and Pueblo Canyon.

2.2 Individual Responsibilities

Within line management of the ER Project, certain Laboratory employees and subcontractors have specific health and safety responsibilities. Figure III-1 shows a field work organization chart with line organization responsibilities. Other organizational charts pertinent to the Los Alamos Canyon and Pueblo Canyon investigation are presented in Annex I of this work plan.

2.2.1 Deputy Directors

The deputy directors of the Environmental Management (EM) Program and the Environment, Safety, and Health (ESH) Division are responsible for ensuring that programmatic health and safety concerns are addressed. They also are responsible for promoting a comprehensive health and safety program that covers special areas such as

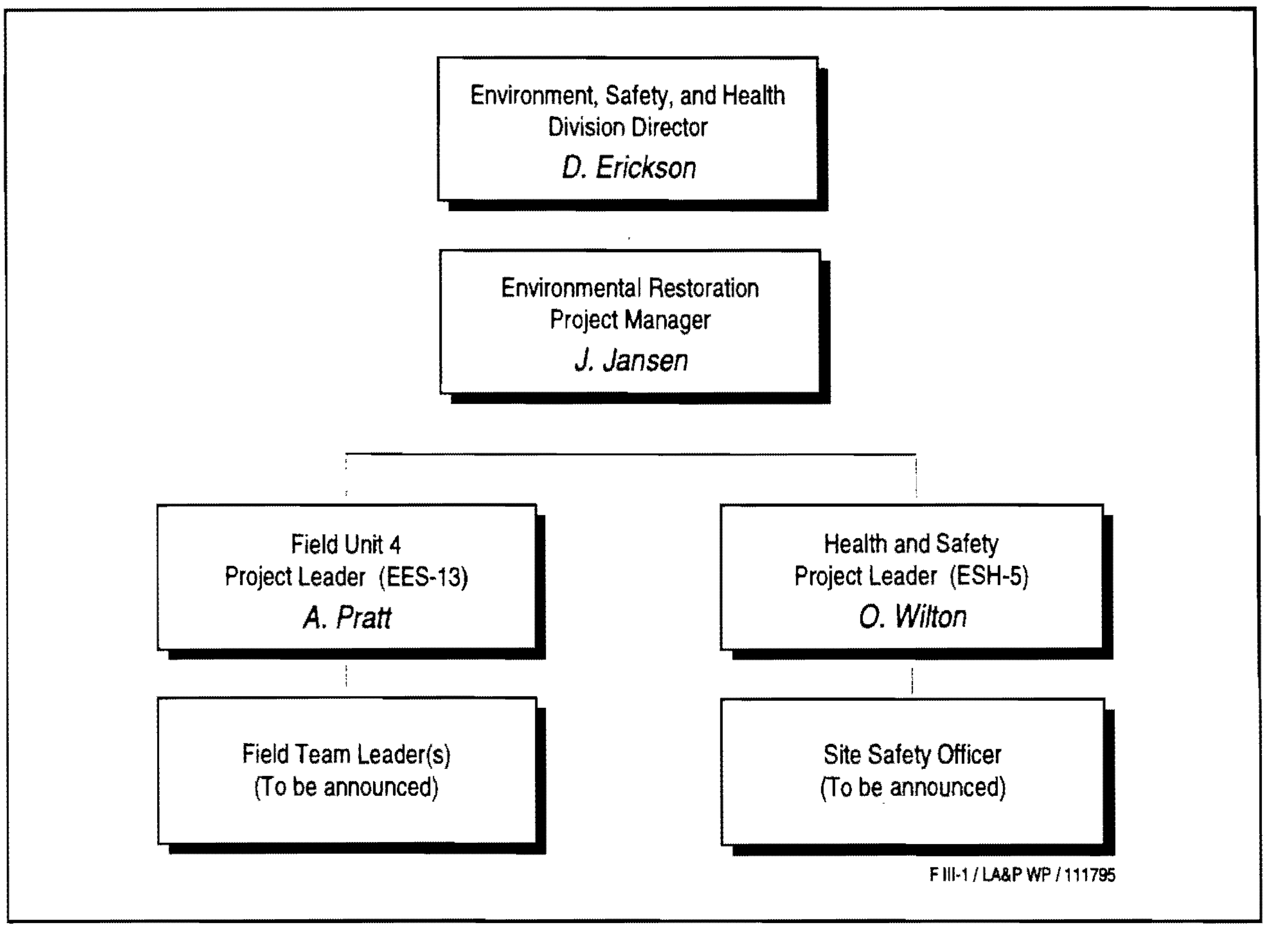


Figure III-1. Field work organization chart.

radiation protection, occupational medicine, industrial safety, industrial hygiene, criticality safety, waste management, and environmental protection and preservation.

2.2.2 Environmental Restoration Project Manager

The ER Project manager is responsible for the overall health and safety program for ER Project activities. The project manager ensures that the health and safety programs are established, implemented, and supported.

2.2.3 Field Unit Health and Safety Representative

The field unit health and safety representative is responsible for updating and implementing the ER Project Health and Safety Plan (Section 6.3.2 of Chapter 6 of the IWP) (LANL 1995, 49822) and for reviewing operable unit H&S plans. The field unit health and safety representative also is responsible for interfacing and coordinating with Laboratory personnel to use resources appropriate for the ER Project health and safety program, and to ensure ER Project compliance with all applicable health and safety policies and regulations. In conjunction with the field team manager, the field unit health and safety representative oversees day-to-day health and safety activities in the field.

2.2.4 Field Project Leader

The field project leader (FPL) is responsible for the RCRA investigations in Los Alamos Canyon and Pueblo Canyon. Specific health and safety responsibilities include

- prepare, review, implement, and revise task/site investigation health and safety documents and
- interface with the field unit health and safety representative to resolve health and safety concerns.

2.2.5 Field Team Leader

The field team leader is responsible for implementing the sampling and analysis plan, this H&S plan, and the quality assurance project plan for the Los Alamos Canyon and Pueblo Canyon investigation. Other health and safety responsibilities include

- ensuring the health and safety of the field team members;
- assigning a site safety officer to ensure compliance with this H&S plan;
- knowing emergency response procedures and notification requirements and their implementation;
- acting as a backup to the site safety officer in the event of an emergency;
- coordinating field activities with Laboratory personnel and subcontractors, as needed;

- reading and complying with this H&S plan; and
- ensuring day-to-day compliance with the health and safety procedures set forth in this H&S plan.

2.2.6 Site Safety Officer

In addition to the responsibilities outlined in Section 6.3.2.3.1 in Chapter 6 of the IWP (LANL 1995, 49822), the following responsibilities specific to the Los Alamos Canyon and Pueblo Canyon investigation also will apply to the site safety officer:

- reading and enforcing this H&S plan;
- evaluating the potential hazards that may exist in either Los Alamos Canyon or Pueblo Canyon;
- being informed about the results of sample analysis pertaining to health and safety as the investigation and remediation work progresses;
- concurring with the field team leader about the location of exclusion area boundaries;
- presenting safety briefings to workers;
- determining protective clothing requirements for workers;
- determining personal dosimetry requirements for workers;
- maintaining a current list of telephone numbers for emergency situations;
- having an operating radio transmitter and receiver in case telephone service is not available;
- maintaining an up-to-date copy of this H&S plan;
- maintaining an up-to-date copy of the emergency plan and procedures for the investigation;
- establishing the safety requirements to be followed by visitors;
- providing visitors with a safety briefing;
- maintaining a logbook of workers and visitors within the exclusion area at a site;
- determining whether workers can perform their jobs safely under prevailing weather conditions;
- taking control of an emergency situation;
- ensuring that all workers have been trained in the appropriate safety procedures and have read and understood this H&S

plan, and that all requirements are followed during investigation activities;

- conducting daily health and safety briefings for the field team leader and field team members;
- conducting daily health and safety audits of the work activities; and
- having authority and requiring that field work be terminated if unsafe conditions develop or an imminent hazard is perceived.

2.2.7 Field Team Members

Field team members are responsible for conducting the assigned work in a manner that ensures that data collected are technically valid and legally defensible. In doing so, they are also responsible for observing applicable health, safety, and environmental procedures; for using prescribed personal protective equipment; for promptly reporting accidents, injuries, and unsafe conditions; and for participating in required medical and biological monitoring programs.

2.3 Health and Safety Audits

Health and safety audits (including daily safety checks) will be performed during activities associated with this H&S plan to ensure compliance with the ER Project health and safety plan (HASP). These audits will be conducted at least quarterly with a minimum of one audit during the Los Alamos Canyon and Pueblo Canyon investigation.

Audits will be conducted by the site safety officer or a competent designee. Results will be documented in the standard operating procedure (SOP) training documentation checklist. The use of the checklist is outlined in ER Project SOP LANL-ER-SOP-01.01, "General Instructions for Field Investigations." The ESH Division and EM Program deputy directors, the ER Project manager, the field unit health and safety representative, and the FPL will receive copies of this report, which also will be retained at the work site. The site safety officer will coordinate with the field team leader to correct any deficiencies. Readiness checklists must be completed before starting work.

The ESH Division and the EM Program also may conduct health and safety audits separately or concurrently with the internal ER Project audits to ensure compliance with the *ES&H Program Documents*, which are available on-line.

2.4 Variances from Health and Safety Requirements

When special conditions exist, a written request for a variance from a specific health and safety requirement may be submitted by the site safety officer to the field team leader and the field unit health and safety representative. If the field team leader and the field unit health and safety representative agree with the request, the request will be reviewed by the FPL or a designee. As appropriate, higher levels of management may be consulted. The condition of the request will be evaluated and, if appropriate, a variance specifying the conditions under which the requirement may be modified will be granted in writing. The variance will become part of this H&S plan.

3.0 HAZARD ASSESSMENT AND PERSONAL PROTECTION REQUIREMENTS

The following section identifies potential hazards associated with the field activities within Los Alamos Canyon and Pueblo Canyon. Tables III-3 and III-4 (discussed later in this section) summarize the anticipated initial levels of personal protection and exposure limits at potential sites within Los Alamos Canyon and Pueblo Canyon. Tables III-2 and III-5 summarize suspected contaminants and properties of radionuclides within Los Alamos Canyon and Pueblo Canyon. Specific hazard information of this type will be reviewed again before work is performed at that particular location. Training in the use of all required personal protective equipment will be provided, and only trained and/or certified workers will be allowed to use such equipment.

3.1 Identification of Hazards and Risk Analysis

The site safety officer will monitor field conditions and worker exposure to physical, chemical, biological, and radiological hazards. If a previously unidentified hazard is discovered, the site safety officer will contact the field team manager and the field unit health and safety representative and will address the hazard. A safety analysis will be performed on the hazard to identify the potential harm, the likelihood of occurrence, and measures to reduce the risk. The analysis will then be written and added to this H&S plan as an amendment. The amendment must be reviewed and approved by the field unit health and safety representative and the FPL and signed by appropriate field team leaders and field team members, showing that they have knowledge of the newly identified hazard.

3.1.1 Physical Hazards

Injuries occur most often from exposure to physical hazards. These injuries range from minor cuts and bruises to fatalities caused by serious unexpected events. The severity of these events may be controlled by using sound inspection and monitoring practices. Therefore, this section is dedicated to outlining the potential physical hazards, as well as some preventive measures, for this investigation.

3.1.1.1 Noise

Constant exposure to noise may have an adverse affect on the ability of workers to hear and understand normal speech. Before 1979, the medical profession had defined hearing impairment as an average hearing threshold level in excess of 25 decibels (dB) at 500, 1000, 2000, and 3000 hertz. Therefore, limits have been established to prevent hearing loss in excess of this level. Some activities during the Los Alamos Canyon and Pueblo Canyon investigation have the potential to exceed these levels (for example, operation of drill rigs and other heavy machinery). Table III-1 shows The standards that have been established by ACGIH for noise exposure.

Because decibels are logarithmic units, they cannot be added or subtracted. In fact, if the intensity of a noise is doubled, there will be a corresponding increase of only three decibels. The following are examples of some common noises and the associated levels: an average residence is approximately 50 dB, conversational speech is 60 dB, a very noisy restaurant is 80 dB, a subway is 90 dB, and a jet plane is 120 dB.

If a sound level meter is not available for monitoring noise, a simple test will identify levels above 85 dB. If at arm's length (3 ft) normal conversation is not possible, engineering controls, administrative controls, or personal protective equipment should be used.

TABLE III-1

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS NOISE EXPOSURE STANDARDS

Duration/Day (hours)	Sound Level (dB[a])
16	80
8	85
4	90
2	95
1	100
0.5	105
0.25	110
0.125	115

a. dB = decibels

3.1.1.2 Pinch Points

Pinch points are generally associated with activities using tools or equipment with turning or moving parts such as a drill rig, a backhoe, or even small hand tools. The moving parts may be equipped with guards. If this is the case, periodic inspections must be performed to ensure that the guards have not been removed. The guards are generally removed by field workers if the guards slow the progress of the operator or make the tool difficult to use. When inspections show that guards have been removed, the tools or equipment should be tagged and not used until the guard has been replaced.

With larger equipment, hydraulic mechanisms and tools are encountered more often. Guarding of these hazardous areas is more difficult. Also, the severity of injury is much greater with hydraulic equipment because of the amount of force created by hydraulically driven machinery. Initial inspections become more important in identifying areas of concern and informing field team members of the potential hazards. The most efficient and comprehensive procedure for inspections is to require that they be performed by a competent person who has experience with that particular piece of machinery. Most equipment can be inspected in less than 30 minutes using a checklist. The site safety officer will obtain a checklist before the start of field activities.

OSHA requires that most equipment be inspected yearly. This inspection is generally conducted by the manufacturer, representative, or dealer. These inspections are to be documented and kept with the piece of equipment. This procedure ensures that the equipment is properly maintained and free of any parts that could potentially become hazardous to the operator or bystanders.

3.1.1.3 Slipping, Tripping, and Falling Hazards

Injuries from slipping, tripping, and falling hazards are the most common around drill rigs, backhoe operations, and uneven terrain. These hazards are caused by either poor housekeeping, bad weather conditions, or the uneven terrain caused by soil excavation. Procedures may be developed to reduce the likelihood of injuries caused by slipping, tripping, and falling. The site safety officer will ensure that good housekeeping practices are followed. These practices include the following: keeping tools stored in an accessible but out-of-the-way place; keeping the work area free of soil piles as much as possible; reminding workers to be aware of uneven terrain; and marking trench and borehole boundaries.

3.1.1.4 Explosion, Fire, and Oxygen Deficiency

Significant potential for flammable (or combustible) and oxygen-deficient atmospheres is not anticipated while drilling, trenching, and sampling during the Los Alamos Canyon and Pueblo Canyon investigation.

Any work with flammable materials will be done according to Laboratory Administrative Requirement 6-5, "Flammable and Combustible Liquids," and Technical Bulletins 602, "Flammable Gases," 603, "Solvents," and 604, "Epoxies," which are available online. The ER Project HASP also will be followed.

As necessary, measurements of explosion potential will be made in enclosed spaces or in boreholes using a combustible gas indicator (CGI)/oxygen meter. If the CGI indicator shows concentrations greater than 20% of the lower explosive limit (LEL), activities in that area will cease. The work area will be evacuated, and the appropriate safety measures will be implemented. Continued CGI readings will be made by the site safety officer to determine the appropriate time for workers to return to the area.

Oxygen levels will be measured in enclosed or confined spaces and in areas that are not ventilated frequently (for example, low-lying areas). Air-purifying respirators will be worn when oxygen concentrations are between 19 and 21%. If oxygen levels fall below 19%, the area must be evacuated, or supplied-air respirators must be furnished to workers in these areas.

Oxygen-rich atmospheres create an increased potential for fires. Therefore, if oxygen levels exceed 25%, the area will also be evacuated. If an evacuation becomes necessary, the area will be ventilated, and the site safety officer will continue monitoring oxygen levels. The site safety officer will determine when it is safe for workers to return and resume work.

3.1.1.5 Heat Stress

Heat stress occurs when the body's physiological processes fail to maintain a normal body temperature because of excess heat. This failure is enhanced when impervious clothing is worn during hot summer months. The best cure for heat stress is prevention. Acclimation to heat is the most effective method, but drinking plenty of water, avoiding alcohol consumption, and taking frequent cooling breaks are also effective. When the body's cooling system starts to fail, a number of symptoms begin to occur. Heat stress monitoring will be performed according to the ER Project HASP. Listed below are the physical reactions that can occur, ranging from mild to fatal.

3.1.1.5.1 Heat-Related Illness

- Heat rash is caused by exposure to heat and humid air aggravated by changing clothes. It decreases the ability to tolerate heat and becomes a nuisance. If heat rashes occur, the victim should keep the area cool and dry.

- Heat cramps are caused by profuse sweating with inadequate fluid intake and chemical replacement (especially of salts and potassium). The signs include muscle spasms and pain in the extremities and abdomen. If heat cramps occur, the victim should drink plenty of fluids, (water is best), add slightly more salt to food, and replace potassium by eating bananas.

- Heat exhaustion is caused by an increased heat stress to the body and an inability of various organs to meet the increased demand to cool the body. The signs include shallow breathing; pallor; cool, moist skin; profuse sweating; dizziness; and lassitude. If heat exhaustion occurs, it is best to get the victim to a cool shady area (not in air conditioning), allow the body to cool slowly, and give the victim plenty of fluids. Depending on the severity, the victim should wait a certain period of time before returning to the hot area.

- Heat stroke is the most severe of the heat-related injuries; it occurs when the body's cooling system shuts down completely. The signs include red, hot, dry skin; lack of perspiration; nausea; dizziness and confusion; strong rapid pulse; and coma. The body must be cooled immediately, and the victim should be sent to the nearest hospital for immediate medical attention to prevent severe injury and/or death.

3.1.1.5.2 Work and Rest Schedule

When working in protective clothing, the following guidelines for calculating work and rest schedules should be used.

Calculate the adjusted temperature as follows:

T(adjusted) = T(actual) x (13 x sunshine fraction)

Sunshine Fraction

100% sunshine	=	no cloud cover	=	1.00
75% sunshine	=	25% cloud cover	=	0.75
50% sunshine	=	50% cloud cover	=	0.50
25% sunshine	=	75% cloud cover	=	0.25
0% sunshine	=	100% cloud cover	=	0.00

Work Schedule

Adjusted Temperature	Active Work Time (min/hr)
75° or less	50
80°	45
85°	40
90°	35
95°	30
100°	20
105°	10
110°	0

3.1.1.6 Cold Exposure

Persons working outdoors in temperatures at or below freezing can suffer from cold-related injuries. Exposure to extreme cold for short periods of time can cause severe injury to the body surface or can result in profound generalized cooling (hypothermia), which can cause death in extreme cases. Body areas that have high surface area to volume ratios (such as fingers, toes, and ears) are the most susceptible.

Cold stress monitoring will be performed according to ER Project HASP. Listed below are the physical reactions that can occur, ranging from mild to fatal.

3.1.1.6.1 Cold-Related Illness

- Frost nip or incipient frostbite is characterized by a sudden whitening of the skin. If this occurs, the victim should warm hands slowly and change into warm, dry clothing.
- Superficial frostbite causes skin to become very waxy or white and superficially firm but flexible underneath. If frostbite occurs, the victim should go indoors and place the hands in warm (100° to 105°F) water. The affected tissue should not be rubbed. The victim should receive medical attention as soon as possible after the affected body part has been warmed.
- Deep frostbite is characterized by cold, pale, solid skin tissue that also may be blistered. Blisters should not be popped. The victim should be warmed in the same manner as above.
- Systemic hypothermia is caused by exposure to freezing or rapidly dropping temperatures. Symptoms are usually exhibited in four stages: 1) shivering; 2) apathy, listlessness, sleepiness, and (sometimes) rapid cooling of the body to less than 95°F; 3) unconsciousness, glassy stare, slow pulse, and slow respiration; and 4) freezing of the extremities. In severe cases systemic hypothermia can result in death. The victim should be moved to a warm area as soon as possible, changed into warm, dry clothing, and receive medical attention as soon as possible.

The best cure for cold-related injuries is prevention, which includes dressing in warm, insulated clothing. If the potential exists for getting wet, workers should wear wool clothing and take frequent warming breaks.

3.1.1.7 Electric Shock

Individuals working on the Los Alamos Canyon and Pueblo Canyon investigation have the potential for exposure to electrical shock during drilling, trenching, and sampling activities. The source of this hazard may be from encountering overhead power lines, using portable equipment, and digging and/or hand auguring into underground utilities. Compliance with the following requirements will significantly reduce the chance of worker exposure to electrical shock.

- Only qualified and licensed workers will be allowed to operate drilling, trenching, or sampling equipment.

- Heavy equipment and energized tools will be inspected by a competent person before use and will meet all applicable local, state, and federal standards.
- While in use, drill rigs will maintain a 35-ft minimum distance from overhead power lines.
- In transit, with the boom lowered, the closest approach to a power line will be 16 ft.
- All areas to be drilled will be cleared through the Laboratory utilities manager before drilling activities begin.
- Any cord with the grounding stem removed will be taken out of service and repaired or thrown away.
- Ground fault interrupters will be used on all portable electrical equipment.

3.1.2 Chemical Hazards

Table III-2 lists the suspected chemical and radiological substances likely to be encountered during the Los Alamos Canyon and Pueblo Canyon investigation. Table III-3 lists the initial levels of required personal protection. Possible chemical exposure hazards during the Los Alamos Canyon and Pueblo Canyon investigation may include inhalation and ingestion of nonradioactive substances. Dermal hazard is not significant for metals in general, if the metals are not present as organic complexes.

Table III-4 summarizes the available exposure standards and guidelines for the chemical hazards anticipated to occur at the site. If unexpected chemical contaminants are identified during the investigation, they will be added to the list of chemicals of potential concern. The site safety officer will be responsible for adding chemicals to this table and for notifying field workers, as necessary.

3.1.3 Radiological Hazards

Radionuclides that may be present during the investigation include ^{238}Pu, ^{239,240}Pu, ^{235}U, and ^{238}U. Tritium, ^{137}Cs, ^{90}Sr, and other fission products are present in much smaller

TABLE III-2

SUSPECTED CHEMICAL AND RADIOLOGICAL SUBSTANCES WITHIN LOS ALAMOS CANYON AND PUEBLO CANYON

Chemical and Radiological Substance	
^{137}Cs	^{90}Sr
^{99}Tc	Uranium (total)
Plutonium (total)	^{60}Co
Tritium	Chromium III
Chromium IV	^{241}Am
Mercury	

TABLE III-3

INITIAL LEVELS OF PROTECTION ANTICIPATED FOR LOS ALAMOS CANYON AND PUEBLO CANYON

	Field Surveys	Surface Sampling	Subsurface Sampling
Los Alamos Canyon	D[a]	C[b] D	CD
Pueblo Canyon	D	CD	CD

a. D = Level D personal protective equipment
b. C = Level C personal protective equipment

amounts. Table III-5 summarizes health and safety information for these radionuclides.

Individuals working on-site may be exposed to radioactivity during field investigations by the following three principal pathways:

- inhalation or ingestion of radionuclide particulates,
- dermal absorption of radionuclide particulates through wounds, and
- exposure to direct radiation from contaminated materials.

Soils will be screened in accordance with the ER Project HASP. If additional radionuclides are discovered during the investigation, they will be added to the list of potential hazards. The site safety officer will be responsible for adding radionuclides to the list and for notifying field workers, as necessary.

TABLE III-4

EXPOSURE LIMITS FOR SIGNIFICANT CONTAMINANTS

Chemical Substance	OSHA[a] PEL[b] (mg/m^3)	OSHA Ceiling (mg/m^3)	OSHA STEL[c] (mg/m^3)	ACGIH[d] TWA[e] (mg/m^3)	ACGIH STEL (mg/m^3)
Chromium III	0.5[f]			0.5	
Chromium IV	0.1[g]			0.05	
Mercury		0.1			
Beryllium	0.002	0.005	0.025	0.002	
^{137}Cs					
Uranium	0.25		0.6	0.2	0.6

a. OSHA = Occupational Safety and Health Administration
b. PEL = permissible exposure limit
c. STEL = short-term exposure limit
d. ACGIH = American Conference of Governmental Industrial Hygienists
e. TWA = time-weighted average
f. As a chromous salt
g. For chromium as chromic acid

TABLE III-5

RADIOLOGICAL PROPERTIES OF ENVIRONMENTALLY SIGNIFICANT RADIONUCLIDES IN LOS ALAMOS CANYON AND PUEBLO CANYON

Radionuclide	Mode of Decay (energy, MEV)	DAC[a] (μCi/mL)	Critical Organ[b]	Radioactive Half-Life[c] (yrs)	Monitoring Instrument
^{60}Co	γ (1.17, 1.33)	1×10^{-8}	GI[d] tract total body	5.27	GM[e], NaI[f]
^{238}Pu	α (5.50, 5.46)	3×10^{-12}	Bone	87.7	Alpha scintillometer, FIDLER
^{239}Pu	α (5.16, 5.11)	2×10^{-12}	Bone	2.41×10^{4}	Alpha scintillometer, FIDLER
^{240}Pu	α (5.17, 5.12)	2×10^{-12}	Bone	6560	Alpha scintillometer, FIDLER
^{242}Pu	α (4.90, 4.86)	2×10^{-12}	Bone	3.75×10^{5}	Alpha scintillometer
^{241}Am	α (5.49, 5.44)	2×10^{-12}	Bone	432.7	Alpha scintillometer, FIDLER
^{234}U	α (4.77, 4.72)	2×10^{-11}	Kidney	2.46×10^{5}	Alpha scintillometer
^{235}U	α (4.40, 4.37)	2×10^{-11}	Kidney	7.04×10^{8}	Alpha scintillometer
^{238}U	α (4.15, 4.20)	2×10^{-11}	Kidney	4.47×10^{9}	Alpha scintillometer
^{3}H	β (0.018)	2×10^{-5}	Total body	12.3	Liquid scintillometer
^{137}Cs	β (0.512)	7×10^{-8}	Total body	30.17	GM, NaI
^{90}Sr	β (0.546)	2×10^{-9}	Bone	29.1	GM, NaI

a. DAC = derived air concentration (DOE draft Order 5480.11)
b. Critical organ is that part of the body most susceptable to radiation damage under the specific conditions being considered.
c. Half-lives from the Knolls Atomic Power Lab "Chart of the Radionuclides" (1988)
d. GI = gastrointestinal
e. GM = Geiger-Müller detector
f. NaI = sodium iodide gamma scintillometer

3.1.4 Biological Hazards

Biological hazards are likely to occur in some areas of Los Alamos Canyon and Pueblo Canyon. Mosquitoes, ticks, spiders, and rodents (including mice and rats) are likely to be encountered. In addition, rattlesnakes may be encountered, especially near brushy or rocky areas and near structures and debris. Workers who regularly walk through such areas should wear high-top boots or snake leggings. The grass should be mowed (where appropriate) to control rodents and snakes.

If snake bite occurs, the Occupational Medicine Group (ESH-2) should be notified immediately. The only first aid treatment that should be administered is an ice pack or a cold pack placed just above the affected area to slow blood flow. The victim's heart rate should be kept as low as possible by keeping the victim as still and calm as possible. If workers are bitten by insects, first aid creams may be applied by the site safety officer to ease the symptoms caused by the bite. If a worker is bitten by a rodent, attempts should be made to obtain the animal, and medical assistance should be sought as soon as possible.

3.1.5 Traffic

Traffic control will be maintained in and around the job site at all times to avoid worker injuries and prevent equipment damage. Work areas regularly occupied by pedestrians will be delineated so that vehicle equipment operators will not enter them. Delineation will be accomplished using barricades, warning signs, warning lights, and traffic cones.

If work takes place in or near heavy traffic areas, these areas will be appropriately marked with the aforementioned devices as necessary to protect workers. Workers will wear fluorescent orange and/or reflective clothing and vests when working in and around traffic areas.

Sufficient parking will be provided. Vehicles not being actively used will be parked so that they do not interfere with traffic. When a vehicle is being maneuvered in a confined area with limited visibility, workers positioned outside the vehicle will give assistance to the operator.

Pedestrian and civilian traffic have the right-of-way on-site. Pedestrians should be careful when they are around heavy equipment and when they are walking near roads. Pedestrians should always make eye contact and wait for a signal to proceed before passing close to or in front of operating equipment or moving vehicles.

All drivers and operators will adhere to speed limits, signs, and road markings. Equipment operators and ground workers should be especially careful when air-line respirators are in use because of the potential for injury if an air line were to become tangled in the track or wheel of a vehicle or equipment. Under no circumstances will breathing-air systems that supply air to respirators be attached to vehicles or equipment.

3.1.6 Topography

To reduce hazards associated with changes in topography, the site safety officer will inspect each site for potential hazards. Some of these hazards can be alleviated by removing any obstacles in immediate work areas, clearing icy surfaces, and placing tools in an accessible but protected area. Boundaries surrounding excavations, trenches, and boreholes will be marked. All field team members will be informed of the potentially hazardous locations and the controls for the duration of the work in each area.

3.1.7 Lightning

Lightning usually strikes the tallest object in an area and takes the most conductive route to the ground. Buildings or vehicles can provide adequate protection if a storm occurs. A large building with a metal structure is the safest because electric current will run along the outside metal frame and into the ground. An automobile with a metal roof serves the same purpose; however, convertibles or other fabric-topped vehicles are not safe because lightning can burn through the fabric.

Wood or brick buildings that are not protected by lightning rods have high potential for a strike, which travels down natural conductors such as wiring or pipes. Any contact with an underground conductor can be dangerous. Telephones, faucets, electrical equipment, and metal fences are examples of ungrounded conductors.

A person situated in the open during a lightning storm should crouch to avoid being the tallest object. A tingling sensation or hair standing on end signal that lightning is about to strike and that a crouching position must be assumed immediately. The safest crouching position is to place the hands on the knees and keep the knees and feet together while remaining as low as possible. Stretching out flat on damp soil could cause the body to attract current running into the ground from a nearby tree. Keeping feet and knees spread or placing the hands on the ground could complete a circuit and cause high-voltage current to run through the body.

A grove of trees affords more protection than a single tree. Lower ground is also safer; however, sizable ditches and ravines present the danger of a person being carried away by flood waters.

Side strikes injure more people than direct strikes. Side strikes are caused when electric current jumps from its present conductor to a more effective conductor. Because the human body is a better conductor than a tree trunk, a person should stay 6 ft away from a tree to avoid a side strike. A group of people taking shelter under a grove of trees should stand 6 ft apart to avoid side strikes from one person to another.

The force of electrical current temporarily disrupts the nervous system. Therefore, even if breathing and heartbeat have stopped, a lightning victim may not be dead. Many victims can be revived by artificial respiration and cardiopulmonary resuscitation. After the lightning flash is over, current is no longer running through the body, and it is safe to touch a lightning victim. Even a victim who seems only slightly stunned should receive immediate medical attention because internal organs may be damaged.

3.2 Task-by-Task Risk Analysis

According to 29 CFR Part 1910.120, a task-by-task risk analysis is required. These tasks are related to specific operations or activities in the field investigation. The preceding section identified the physical, chemical, radiological, and biological hazards known or suspected to be present during the Los Alamos Canyon and Pueblo Canyon investigation. This section is designed to discuss many of the proposed tasks, identify which of the hazards apply, and estimate the likelihood of exposure. Sections 3.3, 3.4, and 3.5 identify methods for eliminating or reducing the potential exposure to the hazards associated with these tasks.

3.2.1 Drilling

The potential for exposure is high.

Associated hazards include a possibility for serious physical injury. Injuries may range from bruised and cut fingers to death. Working around a drill rig allows for entanglement and pinch points in many parts of the rig. These injuries are generally minor but have the potential for amputating fingers. Other severe injuries may occur from failure of wire rope under extreme stress. If the rope breaks under high tension, it will act as a whip, which could decapitate workers in the area.

Chemical and radiological hazards also are created when drilling disturbs or penetrates contaminated soil.

3.2.2 Hand Augering

The potential for exposure is moderate.

Associated hazards are similar to those of drilling. The potential for contact with contaminated soil is enhanced, and this operation will have a tendency to stir up dust. Powered hand augers present hazards of operator entanglement and pinch points but to a lesser degree than drill rigs. With a nonpowered hand auger, the probability of physical injury is greatly reduced.

3.2.3 Trenching

The potential for exposure is high.

The main physical hazard associated with trenching operations results from the use of heavy equipment and the potential for cave-ins. Operators of heavy equipment are trained to be aware of workers around the area. However, operators can be distracted or lose concentration. Therefore, workers must be alert while backhoes are operating. Cave-ins can occur in trenches of all depths, but this hazard can be reduced substantially by limiting trench depths to 5 ft or less. Physical injuries as a result of cave-ins range in severity and can result in death.

Chemical and radiological hazards may be encountered while trenching is in progress. The most concentrated worker exposure may occur from the resuspension of contaminated dust. Air monitoring at this time is critical. In contrast, the accumulation of organic vapors inside the trench will most likely occur after the trench has been completed. However, this is not expected to be significant during the Los Alamos Canyon and Pueblo Canyon investigation because of the lack of significant organic contamination.

3.3 Engineering Controls

OSHA regulations state that when possible, engineering controls should be used as the first line of defense for protecting workers from hazards. Engineering controls are mechanical means for reducing hazards to workers, such as the guarding of moving parts on machinery and tools or using a ventilation hood in a laboratory to remove contaminant vapors. Unfortunately, engineering controls are not as easily accomplished in an uncontrollable environment, such as the outdoors. However, the following controls are some possibilities that can be used while working in the field.

3.3.1 Engineering Controls for Airborne Dust

Hazardous airborne dust can evolve in two forms. Nuisance dust can be created as a result of earth work in dry conditions. A standard level has been established at 15 mg/m^3 for airborne dust particles. Also, radionuclides and/or hazardous substances can attach to soil particles that become entrained and can pose a hazard. Engineering controls can help prevent and/or control airborne dust.

During drilling or any other activity where localized dust is being generated, a small garden sprayer of water may be used to wet the soil enough to suppress the dust. Although this technique can be effective in some cases, sprayers do not discharge a large amount of water, and spraying must be repeated often to maintain effectiveness.

Where there are high winds in a large, dusty area with little or no vegetation, small quantities of water are not effective. In this instance, a water truck may be used to wet the area enough to suppress the dust. Frequently repeated applications are required to be effective.

3.3.2 Engineering Controls for Airborne Volatiles

Drilling and trenching activities may produce gases, fumes, or mists. These volatiles may be easily inhaled or ingested by workers with no protection. Engineering controls may be implemented to reduce the exposure to these hazards. Wind can remove toxic vapors from the work area with careful positioning of equipment, such as a drill rig. For example, a rig might be positioned so that the prevailing wind blows toward the side of the rig. This position allows the vapors to be blown away from workers behind the rig, prevents the vapors from collecting under the rig, and allows for an upwind approach of workers not performing duties related to the drilling.

Alternative ventilation methods are accomplished by mechanical means, which may not be as effective as wind in open areas but are more practical in closed or confined spaces. Fans may be used to push, or more effectively pull, contamination from a confined space. Pulling air into the confined space is more effective at removing vapors; whereas, forcing air into a confined area provides for better ensurance of acceptable oxygen levels from ambient air. This procedure has been used effectively by fire departments, which may be consulted for information on the most effective method for each situation.

3.3.3 Engineering Controls for Noise

Engineering controls for noise are difficult to implement in uncontrolled environments. Drilling and trenching are likely to produce the highest range of noise levels. On drill rigs, the highest level of noise produced is generated by the engine, which is located on the side of a drill rig. Fortunately, most of the work is performed away from the engine at the back of the drill rig. Often the rear and front of the engine are covered to further lessen noise levels. If noise levels reach 90 dB, additional barriers should be used, if possible, to reduce excessive noise exposure.

3.3.4 Engineering Controls for Trenching

Trenching often presents field workers with hazards associated with slipping, tripping, falling, and crushing-type hazards. In most cases, entry into an excavation deeper than 5 ft should be avoided whenever possible. However, it is sometimes necessary to enter these trenches to obtain the needed information. OSHA has developed regulations for trenches and excavations. Included in the regulations are engineering controls for the prevention of cave-ins. These controls include the addition of benching, sloping, and shoring to the excavation. Benching is a systematic series of steps dug around the excavation at a specified angle of repose. The angle of repose depends on the type of soil present. Sloping is a similar system of stabilizing soil that is created without the steps. Again, the angle of repose is determined by the type of soil. This method is generally used for medium-sized excavations, such as tank removal. In general, neither of these soil-stabilization methods is a convenient technique for exploratory trenches. The third method that OSHA suggests is shoring. Many different varieties of shoring are available, but the objective is the same. The sides of the excavation are supported by some type of wall that is braced to prevent cave-ins. This method is used most often in deep, narrow trenches for installing water pipes or drainage systems and in exploratory trenches. One drawback to using shoring is that it is expensive and time-consuming, especially for a trench that is scheduled to be open for only one or two days.

3.3.5 Engineering Controls for Drilling

Working with and around drill rigs presents workers with many hazards caused by the number of moving parts and the power associated with the equipment. Engineering controls for drilling operations include the installation of guarding, where possible, to prevent crushing injuries and, more importantly, an inspection program to ensure replacement of worn or broken parts. As stated, in Section 3.1.1, the inspections should be performed at the beginning of the job and regularly during the investigation.

3.4 Administrative Controls

Administrative controls are necessary when hazards are present and engineering controls are not feasible. Administrative controls are a method for controlling the degree to which workers are exposed to a hazard. Examples include the amount of time a worker spends in a hazardous area or the distance to a hazardous area. Such controls can be instituted easily in most cases and are effective measures for decreasing worker exposure.

3.4.1 Administrative Controls for Airborne Chemical and Radiological Hazards

Chemical and radiological hazards are to be monitored during the performance of duties in a contaminated zone. If the concentration of radionuclides or toxic materials exceed the limits established in this work plan, workers may be removed from the area until natural or mechanical ventilation brings the levels to background. This method would prevent the need to use personal protective equipment. In addition, workers should enter the contaminated zone only when required to do so. This method complies with DOE's policy of maintaining exposures as low as reasonably achievable.

Because the exposure limits consider the average amount of exposure during an 8-hr day, workers exposed at a higher concentration for a portion of the day may conduct tasks in an uncontaminated area to lower the average for the day. For chemical contaminants, the higher concentrations must be lower than those considered to be immediately dangerous to life and health and the threshold limit value ceiling limits.

3.4.2 Administrative Controls for Noise

Administrative controls for noise include both time and distance. The principle is very much like the controls used for both airborne chemical and radiological hazards. Noise is discussed in Section 3.1.1.1, and guidelines on administrative controls established by ACGIH are listed in Table III-1. The intent is to increase the distance between the noise and the worker or decrease the time spent at the source. Sound pressure or intensity follows the inverse square law: as the distance from the source increases, the sound level decreases proportionally to the square of the distance.

If reduction of exposure time or distance is not possible, personal protective equipment must be worn to protect workers.

3.4.3 Administrative Controls for Trenching

Administrative controls are the most effective methods for reducing the hazards of trench excavations that may be proposed for the canyons investigation. These administrative controls were established by OSHA during the development of the regulations. The objective of administrative controls for trenching is to avoid creating a hazardous condition. All trenches should be excavated to a depth less than 5 ft, where possible. However, monitoring inside the trench and means of egress (every 25 ft) must be implemented at a depth of 4 ft. Soil piles, tools, and other debris must be stored at least 2 ft from the edge of the trench. To restrict access, all trenches must be marked when the area is not occupied.

Even though standard procedures are followed, accidents may occur because of human error or other circumstances. A backhoe operator may not see or know if workers are present in a trench. Therefore, whenever workers are in a trench, the operator must shut down the equipment until the trench has been evacuated. Inspections should be made by a competent person before any field team member is allowed to enter a trench. Additionally, workers are required to be aware of conditions inside a trench and activities going on outside the trench.

3.4.4 Administrative Controls for Working Near the Mesa Edge

Slipping, tripping, and falling hazards exist near steep slopes. These hazards may be avoided by good housekeeping in work areas near the mesa edge. Additionally, workers should not get closer than 5 ft to the edge unless close approach is really required. If necessary, barrier tape will be used to delineate this restricted area.

3.5 Personal Protective Equipment and Systems

If engineering and administrative controls are not suitable, personal protective equipment should be used as a last line of defense against hazards. This equipment may be used alone or as a supplement to existing safety systems to enhance the degree of safety for workers. Personal protective equipment is clothing or apparatus that are worn by field team members to protect them from a certain type or group of hazards. Some examples of personal protective equipment are Tyvek clothing, hardhats, gloves, safety harnesses, and respirators. The maintenance, inspection, procedures, and training for personal protective equipment usage will follow the ER Project HASP. The following sections discuss the protective equipment or systems to be used in certain situations.

3.5.1 Protection Levels and Protective Clothing

EPA has established four levels of protection for workers entering potentially hazardous sites. Contaminants have been identified at areas within Los Alamos Canyon and Pueblo Canyon, such as Technical Area (TA) -2 and TA-41. Therefore, an assessment of personal protective levels has been made based on each of the contaminants, investigation activities, and the areas to be investigated (see Table III-3). Action levels for upgrades in levels of protection are based on the above factors and are discussed in Section 3.5.2.

Level C protection will include the following:

- full-face, air-purifying respirators (approved by the Mine Safety and Health Administration and NIOSH) with cartridges or canisters capable of filtering contaminants of concern;
- contaminant-resistant clothing suitable for protection against the hazards of concern;
- inner gloves (polyvinyl chloride, latex, or nitrile);
- rubber outer gloves, which provide an effective barrier between the wearer and the contamination;
- steel-toed safety boots made of rubber or leather when disposable boot covers are worn; and
- hardhats, safety glasses, and hearing protection, as needed.

Modified Level D protection will include the following:

- cloth or Tyvek coveralls or work uniforms;
- rubber or leather outer gloves providing the best protection for the activity being performed;
- steel-toed safety boots and optional boot covers, as needed; and
- hardhats, safety glasses, and hearing protection, as needed.

The field team leaders are required to provide this equipment to each of their field team members.

The Los Alamos Canyon and Pueblo Canyon investigation will be conducted according to Laboratory Administrative Requirement 12-1, "Personal Protective Equipment," and Technical Bulletins 1201, "Eye and Face Protection," 1202, "Protective Clothing," and 1203, "Respiratory Protective Equipment," which are available on-line.

3.5.2 Action Levels for Upgrade in Protection

Monitoring instruments are to be used in conjunction with laboratory analysis to establish the exposure levels of field team members. These instruments will monitor for radiation, volatile organics, corrosives, flammable vapors, and particulates. Action levels will be established based on the results obtained during site-specific monitoring. In some instances, laboratory screening and analysis with a quick turnaround will be necessary to determine the actual level of the specific chemical contaminant in air. For instance, there are no direct reading instruments for metals other than mercury, but there is a real time aerosol monitor (RAM) that determines the amount of respirable dust present in the breathing zone. Thus, soil concentrations of metals of concern from laboratory analyses can be used to calculate the total concentration in air, based on a total particulate reading from the RAM.

Results of the calculations will be confirmed with air sampling. Air sampling during the Los Alamos Canyon and Pueblo Canyon investigation will be used predominately to determine alpha contamination in air. The organization selected to implement the monitoring will supply the method of maintenance and calibration for the specific instruments to be used.

3.5.2.1 Monitoring Instruments

The monitoring instruments to be used during this investigation are listed in the following sections.

- Photoionization detectors and flame ionization detectors

  Photoionization and flame ionization detectors are used to monitor total organic vapors. A description of these detectors is located in the ER Project HASP.

- CGIs are used to monitor the concentration of flammable gases and vapors. A description of the CGI is located in the ER Project HASP.

- Oxygen meters

  Portable oxygen meters are used to measure ambient oxygen concentrations in confined spaces or areas. A description of the oxygen meter is located in the ER Project HASP.

- Real time aerosol monitors

  Real time aerosol monitors are designed to monitor respirable particulate matter (<10 μ). These instruments measure reflected light, which is converted to units of mg/m^3. These instruments are useful if there are known concentrations in soil of alpha contaminants, particulates, and metals. Soil samples will be submitted for laboratory analysis, and the results will be used to determine action levels for the contaminants that are present.

- Colorimetric indicator tubes

  Colorimetric indicator tubes may be used to quickly measure the approximate concentrations of specific vapors or gases. A description of the colorimetric indicators is located in the ER Project HASP.

- High- and low-volume air samplers

  High- and low-volume air samplers are used to collect particulates on a filter that is subsequently analyzed to determine the types and concentrations of airborne contaminants (for example, alpha contamination). A description of the air samplers is found in the ER Project HASP.

- Radiation survey meters

A variety of radiation survey meters will be used in the investigation to determine the levels to which workers are exposed to radiation. Alpha scintillometers will be used to screen cores and workers leaving the contamination zone. A mR meter or a Geiger-Müller detector will be used to establish gamma (and beta) exposure to field team members. In addition, thermoluminescent dosimeters (TLDs) will be worn by all workers.

3.5.3 Action Levels

The following guidelines are to be used during the Los Alamos Canyon and Pueblo Canyon investigation. When applicable, ER Project SOPs describe measuring procedures and frequency of monitoring.

3.5.3.1 Organics

Levels of organic contamination in Los Alamos Canyon and Pueblo Canyon have been estimated from the historical information gathered during the preparation of this work plan. In general, organic contaminants are expected to be at or near background levels. If field monitoring or laboratory analysis proves this conclusion to be unfounded, appropriate guidelines will be instituted to ensure the health and safety of the workers.

3.5.3.2 Combustible Vapors

As appropriate, the CGI will be used to monitor for combustible atmospheres during drilling and trenching. One-minute readings will be used for boreholes and trenches to give the instruments time to equilibrate. At 20% of the LEL, workers will be evacuated, and engineering controls will be used to reduce the concentration of combustible vapors. Workers may resume work when levels drop below 10% of the LEL.

3.5.3.3 Particulates, Metals, Polychlorinated Biphenyls, and Alpha Contamination

As appropriate, real time aerosol monitors will be used in conjunction with laboratory data to determine the concentrations in air. Samples will be obtained to determine the amount of contamination in soil, and an action level will be calculated for that particular work area.

3.5.4 Safety Systems and Equipment

A variety of safety equipment will be used to protect workers from physical hazards and to minimize exposure to hazardous chemicals and radionuclides during field activities within Los Alamos Canyon and Pueblo Canyon.

3.5.4.1 Hearing Protection

If noise levels are above 85 dB and neither engineering nor administrative controls are practical, hearing protection will be required. Two basic types of hearing protection are available: disposable and reusable ear plugs and ear muffs. Ear plugs may reduce noise levels 25 to 30 dB; ear muffs may reduce noise levels 35 to 40 dB if worn properly. Product information for specific protective devices will be used to determine the effective noise reduction rating.

3.5.4.2 Trench Protection

Trench boxes and trench shields have been developed for trench operations where benching, sloping, and shoring are not feasible. A trench box or shield is a box constructed from a strong metal or wood that is wide enough for workers to move around inside and perform their duties. OSHA regulations specify criteria for the trench box to be considered safe. The trench box is placed in the trench and attached to a backhoe so that it may be pulled along as the work progresses. This type of system is used often in the installation of water systems. The walls of the trench may not be viewed from the box, and protection is voided when workers leave the box.

3.5.4.3 Fire Protection

A fire extinguisher is classed by the type of fire it is designed to extinguish. However, a fire extinguisher may be effective for more than one class of fire.

- Class A - ordinary combustible materials (wood, paper, and textiles)
- Class B - flammable liquids (oil, grease, and paint)
- Class C - electrical fires
- Class D - metals capable of rapid oxidation (magnesium, sodium, zinc, aluminum, uranium, and zirconium)

3.5.4.4 Other Safety Equipment

In addition to the personal protective devices described above, other safety equipment may be used as needed. Laboratory Administrative Requirement 12-2, "Seat Belts," (available on-line) will be followed. Warming and cooling equipment may be necessary to minimize stress from climatic conditions. Emergency equipment will also be necessary for immediate response and emergency treatment. Additionally, the location of such equipment must be clearly marked, and workers should know the location and be trained in its use.

3.5.5 General Safety Practices and Mitigation Measures

Some hazards can be minimized by implementing specific safety procedures, work practices, special equipment, worker training, and emergency response equipment in case of an accident. Sections 6.9 and 6.10 in Chapter 6 of the IWP (LANL 1995, 49822) discuss some of these practices. The following routine measures will be taken.

- Daily planning and/or preactivity meetings will be held for all workers involved in field activities. These meetings will discuss health and safety concerns and refresh workers on the emergency response plans.
- Control zones will be established for safety as well as contamination and decontamination procedures. The type and size of the control zones will depend on the type of field activity to be conducted. The level of protection will be based on site-specific task/site investigation areas. For informational and medical support, control zones will have maps posted that identify direct routes to administrative and medical facilities.

- If troublesome levels of dust are generated during augering or drilling activities, water may be used to suppress dust for the protection of field workers.
- The buddy system will be employed as a general practice.

3.6 Site Access Control

3.6.1 Restricted Access and Exclusion Zones

Restricted access or exclusion zones will be established before work begins at contaminated sites to protect workers from unnecessary exposure to toxic materials and to prevent the spread of contamination. A general description of exclusion zones is found in Section 6.5 in Chapter 6 of the IWP (LANL 1995, 49822).

3.6.2 Decontamination

Workers, equipment, and vehicles that have been located in contaminated areas may carry residual contamination. Although protective clothing, respirators, and good work practices can help reduce contamination, decontamination may be necessary to prevent exposure of workers and the inadvertent spread of contaminants.

Vehicles and equipment that are suspected of being contaminated will be cleaned with high-pressure steam or equally effective systems. Vehicles and equipment suspected of being contaminated with alpha contamination will be screened with alpha survey instruments before being released from the site.

Worker decontamination can be performed in all levels of protection. Disposable protective equipment does not need to be decontaminated but should be disposed of as a hazardous waste. Reusable protective equipment must be decontaminated using a soap and water wash and two successive rinses. Visual inspections of the equipment will help determine the effectiveness of the decontamination process. As with the equipment, workers will be screened with an alpha scintillometer when working with or near alpha-contaminated material. ER Project SOPs, established to guide the decontamination process, will be maintained on-site and will be followed at all times. Worker decontamination procedures are specified in the ER Project HASP. Laboratory Administrative Requirements for Waste Management are 10-1, "Radioactive Liquid Waste," 10-2, "Low-Level Radioactive Solid Waste," 10-3, "Hazardous and Mixed Waste," and 10-5, "Transuranic (TRU) Solid Waste," which are available on-line.

In addition to the following list, Section 6.8 in Chapter 6 of the IWP (LANL 1995, 49822) contains information on decontamination.

- The level of decontamination required will depend on the nature and magnitude of contamination and the type of protective clothing worn. Disposable clothing (for example, Tyvek) will not be washed because water may transport contamination through the paper garment to the skin.
- Waste water and materials used during decontamination will be contained for appropriate disposal. Arrangements will be made with the Laboratory for acquisition and disposal of drums containing soapy water, rinse water, methanol, and trash.

3.7 Worker Training

Worker training will follow the requirements set forth in Section 6.10 in Chapter 6 of the IWP (LANL 1995, 49822). Field workers will be given copies of all relevant SOPs and will be briefed on their use. Field workers also will read this H&S plan and Chapter 6 of the IWP.

3.8 Medical Surveillance

In addition to the guidance provided in Section 6.11 in Chapter 6 of the IWP (LANL 1995, 49822), the following paragraph describes specific program requirements.

Field team members who are exposed to contaminated materials during ER Project remedial investigation shall participate in a medical examination program provided by the Laboratory according to 29 CFR Part 1910 or DOE Order 5480.1B (Chapter VIII) requirements. Suitability of field team members for conducting field sampling activities, including respirator use, shall be evaluated and documented by a physician. Medical programs must comply with the requirements of DOE Order 5480.1B Chapter VIII or 29 CFR Part 1910, as appropriate. Laboratory Administrative Requirements 2-1, "Occupational Medicine Program," and 6-4, "Biological Monitoring for Hazardous Materials," and Laboratory Standard LS107-11.0, "Radiation Dosimetry Monitoring," shall be followed. (These documents are all available on-line.)

3.9 Records and Reporting Requirements

The field unit health and safety representative, working with the FPL, the site safety officer, and the field team manager, will ensure that health and safety records are maintained within the appropriate Laboratory group as required by DOE orders. The records are as follows.

- DOE-AL Order 5000.3A, Unusual Occurrence Reporting
- DOE Form 5484.3, Attachment 1, Supplementary Record of Occupational Injuries and Illnesses
- DOE Form 5484.4, Attachment 2, Tabulation of Property Damage Experience
- DOE Form 5484.5, Attachment 4, Report of Property Damage of Loss
- DOE Form 5484.6, Attachment 13, Annual Summary of Whole Body Exposures to Ionizing Radiation
- DOE Form 5484.1, Attachment 14, Summary of Exposure Resulting in Internal Body Depositions of Radioactive Materials for CY 19
- DOE Form 5484.8, Attachment 10, Termination Occupational Exposure Report
- DOE Form OSHA-200, Attachment 7, Log of Occupational Injuries and Illnesses

- DOE Form EV-102A, Attachment 8, Summary of Department of Energy and Department of Energy Contractor Occupational Injuries and Illnesses

- DOE Form 5421.1, Attachment 15, Unplanned Releases Form

Copies of these reports will be stored with the appropriate Laboratory group. Specific reporting responsibilities are given in the following sections and in Chapter 1 of the Laboratory's *Environment, Safety, and Health Manual*, which is available on-line.

3.9.1 Exposure and Medical Reports

Confidential records of the medical status of each field team member, obtained through the employee medical surveillance program, will be maintained with the appropriate Laboratory group. The requirements established below must be met in addition to the requirements set forth in Section 6.11 in Chapter 6 of the IWP (LANL 1995, 49822). Field team members will be issued a radiation dosimeter by the Laboratory, according to the *LANL Radiological Control Manual* (LANL 1994, 43737).

DOE Forms 5484.1, "Summary of Exposures Resulting in Internal Body Depositions of Radioactive Materials for CY 19," and 5484.6, "Annual Summary of Whole Body Exposures to Ionizing Radiation," will be submitted annually (by March 31) for monitored employees. Preparation of these reports will be coordinated with the Health Physics Operations Group (ESH-1).

3.9.2 Unusual Occurrences

All unusual occurrences must be reported by the field unit site safety officer to the field unit health and safety representative, the field team manager, and the Field Unit 4 project leader in accordance with Section 6.9.3 in Chapter 6 of the IWP (LANL 1995, 49822).

3.9.3 Accident or Incident Reports

The FPL will submit a complete DOE Form F 5484.X for any of the following accidents or incidents, according to Laboratory Administrative Requirement 1-1, "Accident and Occurrence Reporting," which is available on-line.

- Occupational injury is any injury such as a cut, fracture, sprain, or amputation that results from a work accident or from an exposure involving a single incident in the work environment.

  Note: Conditions resulting from animal bites, such as insect or snake bites, or from one-time exposure to chemicals are considered injuries.

- Occupational illness is any abnormal condition or disorder, other than one resulting from an occupational injury, caused by exposure to environmental factors associated with employment. It includes acute and chronic illnesses or diseases that may be caused by inhalation, absorption, ingestion, or direct contact with a toxic material.

- Property damage losses of $1000 or more must be reported. Accidents that cause damage to DOE property, regardless of fault, or accidents wherein DOE may be liable for damage to a second party, are reportable if damage is $1000 or more. Included are damage to facilities, inventories, equipment, and properly parked motor vehicles. Excluded is damage resulting from a DOE-reported vehicle accident.

- Government motor vehicle accidents resulting in damages of $150 or more, involving an injury (unless the government vehicle is not at fault), or sustaining damage of less than $150 to the government vehicle and injury to occupants of the government vehicle occupants must be reported.

Accidents also are reportable to DOE if

- damage to a government vehicle that is not properly parked is greater than or equal to $250,
- damage to DOE property is greater than or equal to $500 and the driver of a government vehicle is not at fault,
- damage to any private property or vehicle is greater than or equal to $250 and the driver of a government vehicle is at fault, and
- any person is injured and the driver of a government vehicle is at fault.

3.10 Worker Information

The site safety officer shall ensure that the following DOE and Laboratory forms are posted where field team leaders and field team members can easily read them.

- Form F 5480.2, Occupational Safety and Health Protection
- Form F 5480.4, Occupational Safety and Health Complaint Form
- Laboratory Special Work Permit
- OSHA Job Safety and Health Protection Form

The Laboratory health and safety standard concerning workers' right-to-know also shall be posted at the work site.

Other information that shall be made available to site workers include

- the IWP (LANL 1995, 49822), this work plan, and ancillary documents;
- pertinent Laboratory health and safety documents including administrative policies and the ER Project HASP;
- field monitoring data; and
- personal monitoring data (for example, TLD results) and personal medical records for the requesting individual.

4.0 EMERGENCY RESPONSE AND NOTIFICATION

This section provides information on responding to emergency situations. Laboratory Administrative Requirements 1-2, "Emergency Preparedness," and 1-8, "Working Alone," and Technical Bulletin 101, "Emergency Preparedness," were used to develop this section. (These documents are available on-line.)

4.1 Emergency Contacts

The names of persons and services to contact in case of emergencies are given in Attachment III-2 of the ER Project HASP. This emergency contact form will be copied and posted in prominent locations at the work site. Two-way radio communication will be maintained at remote sites when possible.

The emergency contact number for the Laboratory is 911.

4.2 Contingency Plans

This section considers contingency plans for specific types of emergencies. The site safety officer, with assistance from the field team manager and, if needed, the field team leader, shall have responsibility and authority for coordinating all emergency response activities until the proper authorities arrive and assume control. Evacuation plans and routes used by the Chemical Science and Technology Division and the Engineering Sciences and Applications Divisions are discussed in Section 4.2.3.

4.2.1 Fire or Explosion

In the event of a fire, the work area will be evacuated, and the Laboratory fire department will be notified. In the event of an explosion, all workers will be evacuated, and no one will enter the work area until it has been cleared by Laboratory explosion safety personnel from the Engineering Sciences and Applications Division.

If a combustible gas meter indicates gas concentrations at levels of 20% of the LEL, workers will be evacuated from that area. The site safety officer will continue monitoring to determine when equipment should be removed or when workers may re-enter the area and resume work.

4.2.2 Worker Injuries

In case of serious injuries, the victim(s) will be transported to a medical facility as soon as possible. The Laboratory fire department provides emergency transport services. Minor injuries may be treated by trained personnel in the work area. All injuries should be reported to the Occupational Medicine Group (ESH-2). If an injured person has been contaminated with chemicals, decontamination will be performed to prevent further exposure (as outlined in the ER Project HASP) only if it will not aggravate the injury. Treatment of life-threatening or serious injuries will be undertaken first.

4.2.3 Emergency Response Plan

A map will be attached to each field copy of the site-specific H&S plans generated for work in Los Alamos Canyon and Pueblo Canyon. The map will define the routes to the Occupational Medicine Group (ESH-2) and the Los Alamos Medical Center.

For general emergencies that require evacuation (such as fire, medical, security, or releases) an emergency response plan specific to Los Alamos Canyon and Pueblo Canyon is required. The signal for site evacuation will be two long blasts on an air horn. The crew will gather at a muster area at or near the work site designated by the site safety officer. One person should find the nearest phone, and the evacuation route used by field workers should be away from the affected area and toward the site-specific designated muster area. At the muster area, all workers will wait until everyone in the field crew has been accounted for. The site safety officer will determine the next course of action.

A major release or fire involving hazardous or radioactive materials may warrant a different approach. This emergency will be signaled by two short blasts on an air horn. If the signal is heard, workers will meet at a predetermined area, which will be determined based on wind conditions. A portable wind sock or streamer will be positioned at each work location, and workers will be notified of the location. If the horn is sounded, all workers will move in an upwind direction as much as possible without entering a plume. If the source of the fire or release is directly upwind, workers will move away from the plume (if visible). After a safe distance has been reached, all workers are to be accounted for. The field team manager and the site safety officer will be responsible for this task. At that time, the site safety officer will determine the next course of action.

For a less severe accident, such as a minor release or small fire, site evacuation may not be necessary. This scenario will be signaled by one long blast on an air horn. All workers will meet at a designated muster area, and all workers will be accounted for by the field team leader and/or site safety officer.

These procedures will be reviewed at least once per week to remind field workers of the procedures and the signals. The signals are summarized below for easy reference. This information will be posted at prominent locations at each work location with other health and safety information.

- Major fire - two long blasts on the air horn
- Major release - two short blasts on the air horn
- Minor fire or release - one long blast on the air horn

4.2.4 Additional Emergencies

For information on accidental release of hazardous materials into the environment, unusual events, site emergencies, and general emergencies, see Section 6.9 in Chapter 6 of the IWP (LANL 1995, 49822).

4.3 Notification Requirements

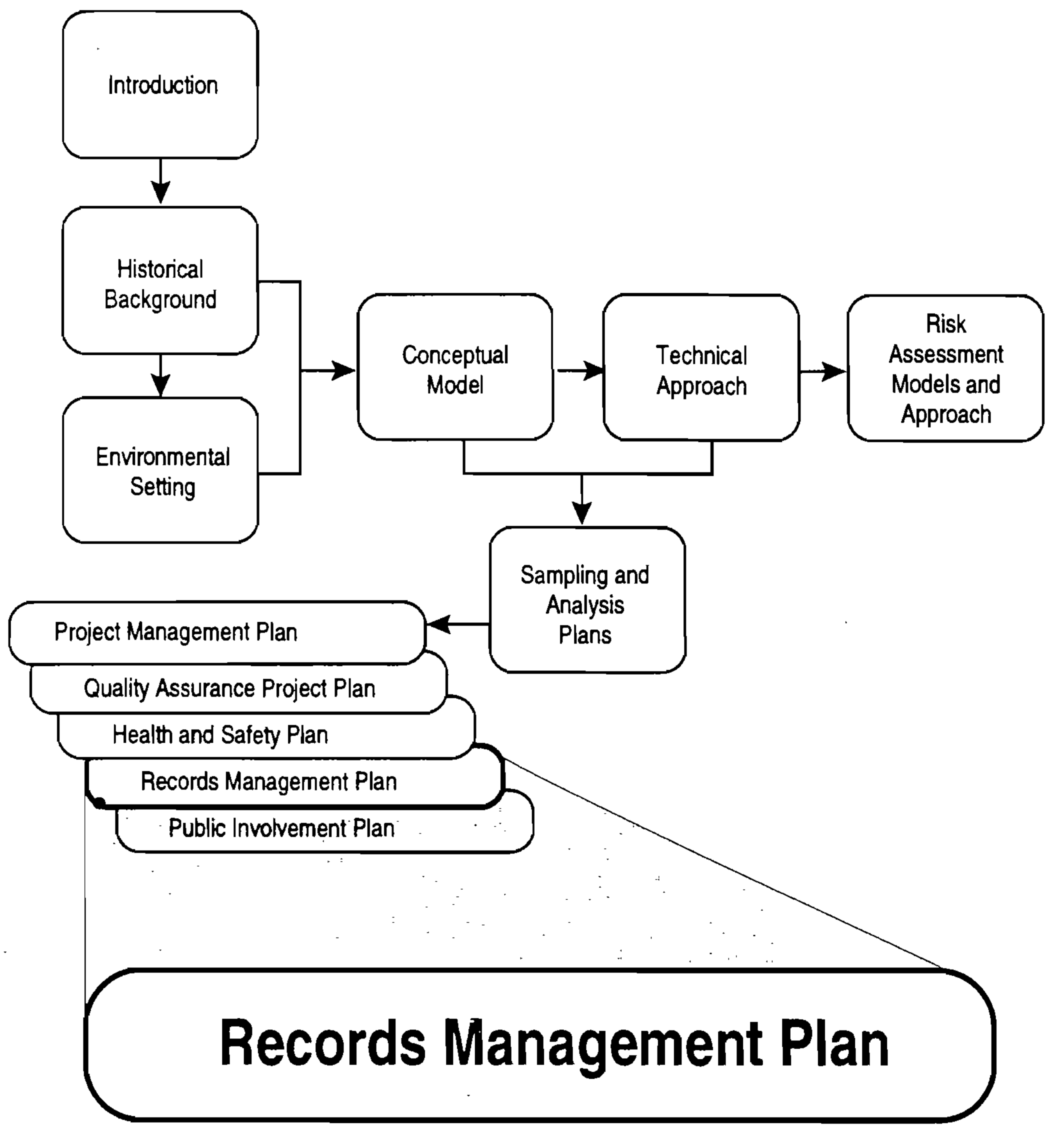
In emergency situations, field team members will notify the site safety officer. The site safety officer's responsibility is to notify the appropriate emergency assistance personnel (such as fire, police, or ambulance), the field team's manager, and the ESH Division Office according to DOE Order 5500.2 and DOE-AL Orders 5500.2B and 5000.3A. The ESH Division Office is responsible for implementing notification and reporting requirements according to DOE Order 5484.1A, DOE Order 5484.2, and DOE-AL Order 5484.2.

References for Annex III

LANL (Los Alamos National Laboratory), 1994. "LANL Radiological Control Manual," Los Alamos, New Mexico. **(LANL 1994, ER ID Number 43737)**

LANL (Los Alamos National Laboratory), February 1995. "Installation Work Plan for Environmental Restoration," Revision 4, Los Alamos National Laboratory Report LA-UR-95-740, Los Alamos, New Mexico. **(LANL 1995, ER ID Number 49822)**

Annex IV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Records Management Plan

1.0 INTRODUCTION

The Records Management Plan for the Environmental Restoration (ER) Project at Los Alamos National Laboratory (the Laboratory) is described in Chapter 5 of the Installation Work Plan (IWP) (LANL 1995, 49822). The purposes of the Records Management Plan are to meet the requirements for protecting and managing records (including technical data), to provide an ongoing tool to support the technical efforts of the ER Project, and to function as a support system for management decisions for the duration of the ER Project.

The ER Project uses the following statutory definition of a record (44 USC 33010). Records are defined as

> . . . books, papers, maps, photographs, machine-readable materials, or other documentary materials, regardless of physical form or characteristics, . . . appropriate for preservation . . . because of the informational value of the data in them.

The Records Management Plan establishes general guidelines for managing records, regardless of their physical form or characteristics, that are generated and/or used by the ER Project. The Records Management Plan will be implemented consistently to meet the requirements of the Quality Assurance Project Plan (Chapter 4 of the IWP) (LANL 1995, 49822) and to provide an auditable and legally defensible system for records. Another important function of the Records Management Plan is to maintain the publicly accessible documentation comprising the administrative record required by the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA).

2.0 IMPLEMENTATION OF THE RECORDS MANAGEMENT PLAN

Section 5.2.2 of the IWP (LANL 1995, 49822) describes the implementation of the Records Management Plan. Records management activities for the Los Alamos Canyon and Pueblo Canyon investigation will follow the guidelines summarized in that section. As the Records Management Plan develops to support canyons investigation needs, additional detail will be provided in annual updates of the IWP.

The Records Management Plan incorporates a threefold approach based on records control and commitment to quality guidelines: a structured work flow for records, the use of approved procedures, and the compilation of a referential information base. ER Project records are those specifically identified in quality procedures, administrative procedures (APs), standard operating procedures, ER Project records management plans, management guidance documents, and records identified by ER Project participants as being essential to the project. Records are processed in a structured work flow. The records management procedure (LANL-ER-AP-02.1, R1, "Procedure for LANL ER Records Management") governs records management activities, which include records identification, submittal, review, indexing, retention, protection, access, retrieval, and correction (if necessary). Other procedures, such as LANL-ER-AP-01.3, "Review and Approval of Environmental Restoration Program Plans and Reports," LANL-ER-AP-01.4, "Distribution of Controlled Documents Prepared for the Environmental Restoration Program," and LANL-ER-AP-01.5, "Revision or Interim Change of Environmental Program Controlled Documents," are also followed.

Records (including data) will be protected in and accessed through the referable information base. The referable information base is composed of the Records-Processing Facility (RPF) and the Facility for Information Management, Analysis, and Display

(FIMAD). RPF personnel receive ER Project records, assign an ER identification number, and process records for delivery to FIMAD. The RPF will complement FIMAD in certain aspects of data capture, such as scanning. The RPF also functions as an ER Project reference library for information that is inappropriate either in form (for example, old records) or in content (for example, the *Federal Register*) for storage at FIMAD. FIMAD provides the hardware and software necessary for data capture, display, and analysis. The information will be readily accessible through a network of work stations. Configuration management accounts for, controls, and documents the planned and actual design components of FIMAD.

3.0 USE OF ER PROJECT RECORDS MANAGEMENT FACILITIES

The RPF and FIMAD will be used to manage records resulting from work conducted in Los Alamos Canyon and Pueblo Canyon. Interaction with these facilities is described in LANL-ER-AP-2.01, Chapter 5 of the IWP (LANL 1995, 49822), and other ER Project procedures and management guidance documents, as appropriate.

4.0 COORDINATION WITH THE QUALITY PROGRAM

Records will be protected throughout the process, as described in Section 5.4 of the IWP (LANL 1995, 49822) and in LANL-ER-AP-02.1. The originator is responsible for protecting records until they are submitted to the RPF. The level of protection afforded by the originator will be commensurate with the value of the information contained in the record. After a record has been received, the RPF will temporarily store the original of the record in 1-hr fire-rated equipment and will provide a copy of the record to FIMAD. The RPF will then send the original record to a dual-storage area for long-term storage in a protected environment.

5.0 COORDINATION WITH THE HEALTH AND SAFETY PROGRAM

Section 5.5 of the IWP (LANL 1995, 49822) notes two exceptions to the records storage process. The Laboratory's Occupational Medicine Group (ESH-2) will maintain medical records because of their confidential nature. Training records will be maintained by the ER Project Office and in some cases by the contractors. ER training records contain information about the completion of training, the dates of required refresher training, and the site(s) each worker visits regularly.

6.0 COORDINATION WITH PROJECT PLANNING AND CONTROL

Specific reporting requirements are ER Project deliverables and, as such, are monitored by the Project Planning and Control Team. Records resulting from work conducted in the canyons contribute to the development of these deliverables.

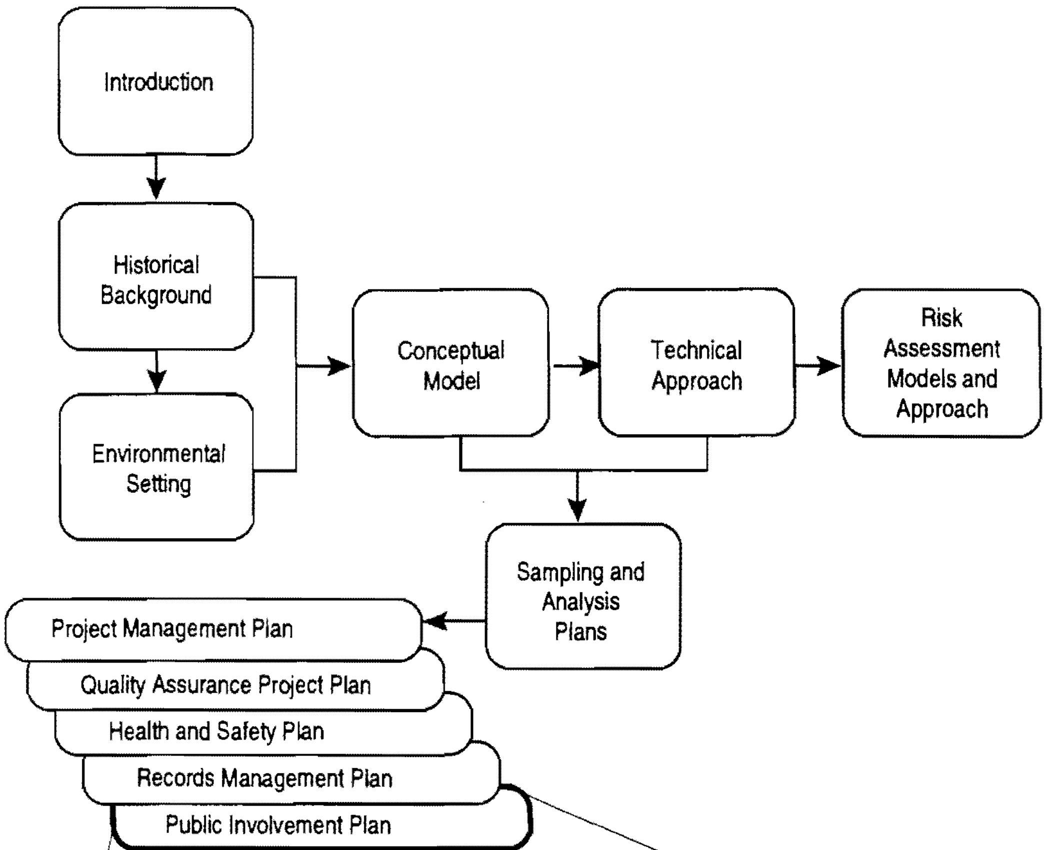
7.0 COORDINATION WITH THE PUBLIC INVOLVEMENT PROGRAM

The Resource Conservation and Recovery Act and CERCLA require that records be made available to the public. Two complementary approaches are being implemented: hard copy and electronic access. A community reading room allows public access to hard copies of key documents. A work station and necessary data links are being prepared to allow public access to the FIMAD database.

Reference for Annex IV

LANL (Los Alamos National Laboratory), February 1995. "Installation Work Plan for Environmental Restoration," Revision 4, Los Alamos National Laboratory Report LA-UR-95-740, Los Alamos, New Mexico. **(LANL 1995, ER ID Number 49822)**

Annex V



Public Involvement Plan

1.0 OVERVIEW OF PUBLIC INVOLVEMENT PLAN

The Public Involvement Plan specific to the Los Alamos Canyon and Pueblo Canyon task/site investigation follows the directives, goals, and regulatory requirements set forth in Chapter 7 of the Installation Work Plan for the Environmental Restoration (ER) Project (LANL 1995, 49822) and the "Plan for Increasing Public Participation in Cleanup Decisions for the Los Alamos National Laboratory" (Working Group and Lefkoff 1995, 44013), which was developed with public input.

This Public Involvement Plan was developed specifically to provide an avenue for meaningful public participation in making recommendations for cleanup decisions at the Laboratory. In addition, recommendations were made to develop effective communications between the neighboring communities (including the Pueblos) and the ER Project staff during the investigation, characterization, and cleanup activities at the Laboratory.

The Laboratory, as a hazardous waste treatment, storage, and disposal facility, operates under a Resource Conservation and Recovery Act permit issued by the New Mexico Environment Department. Module VIII of this permit, the Hazardous and Solid Waste Amendments (HSWA) Module, issued by the Environmental Protection Agency (EPA 1990, 1585), governs all environmental restoration activities. The HSWA Module requires the ER Project to perform certain activities for public involvement, such as

- establishing a mailing list of interested parties;
- creating fact sheets, news releases, work plans, final reports, newsletters, and quarterly technical reports;
- creating a public information repository and reading room for ER Project materials;
- conducting informational meetings for the public;
- conducting tours and briefings; and
- establishing procedures for immediate notification of neighboring Pueblos or other affected parties if a newly discovered off-site release could impact them.

Although the ER Project public involvement effort has implemented these activities since 1991, beginning in 1994 the ER Project has expanded its effort to develop a more broad-based approach for outreach to other northern New Mexico communities. This effort is supported by the following goals:

- broaden the base of involved individuals and groups;
- begin to build trust by focusing on personal contact, dialogue, and mutual education;
- obtain meaningful public input on decisions regarding cleanup issues; and
- learn a better, more cost-effective way of involving the public early in major activities of the ER Project.

To accomplish those goals, the following objectives have been established:

- make information readily available and give to the public the information it needs to understand environmental restoration cleanup issues and provide the ER Project with recommendations;
- respond to requests for information as soon as possible;
- increase contacts with the public in ways that encourage interaction, such as establishing dialogues with members of community organizations;
- use community leaders, as well as Laboratory and ER Project representatives who live in the neighboring communities, as community contacts;
- involve the public in the cleanup process before decisions are made;
- treat the public as equals;
- ask for assistance from community members and use them as experts on their community's concerns and needs;
- develop alternatives for determining cleanup levels and site prioritization; and
- evaluate the effectiveness and efficiency of each of the public participation activities.

2.0 PUBLIC INVOLVEMENT ACTIVITIES

2.1 Information Sheets

The Community Involvement and Outreach Office staff will prepare information sheets for the Los Alamos Canyon and Pueblo Canyon activities and update the sheets whenever new information becomes available. Information sheets will be reviewed by ER Project staff and informally reviewed by members of the public before they are completed.

2.2 Dissemination of Information

Information on Los Alamos Canyon and Pueblo Canyon will be distributed via the existing mailing list of approximately 2000 individuals and organizations. In addition, information materials will be available at the Laboratory Community Reading Room (1350 Central Avenue in Los Alamos) and in the information repositories at the public libraries of Santa Fe, Española, and Los Alamos. The Governor's Office at San Ildefonso Pueblo will also have information available to Pueblo members. Anyone who would like more information about the ER Project can call 1-800-357-8301.

2.3 Community Meetings

Initially, an information meeting will be scheduled at a central location to introduce the public to the forthcoming activities in Los Alamos Canyon and Pueblo Canyon. The field project leader, assisted by Community Involvement and Outreach Office staff, will present information and respond to questions and concerns raised by the public. In addition, meetings will be scheduled with community groups to inform them and to establish a dialogue about their concerns and interests. These meetings may take many forms, such as meetings in homes, brown bag presentations, or more structured meetings during a group's regularly scheduled meeting time. The primary purpose of these meetings will be personal interaction, dialogue, and opportunities for early involvement in environmental restoration issues.

2.4 Pueblo Interaction

The interactions with the Pueblos will be closely coordinated between the field project leader, the Community Involvement and Outreach Office, and the Community Involvement and Outreach Office.

2.5 Tours of Los Alamos Canyon and Pueblo Canyon Sites

It will be helpful to the public to see the actual cleanup sites associated with Los Alamos Canyon and Pueblo Canyon. Tours will be scheduled as potential release sites are scheduled for corrective action, during public meetings, or at the specific request of the public. For these activities, ER Project personnel will take into consideration times convenient for the public such as late afternoons, evenings, and weekends.

2.6 Responses to Inquires

Inquires about the Los Alamos Canyon and Pueblo Canyon activities may be directed to the

- Field Unit 4 field project leader, Allyn Pratt, at 505-667-4308 or
- Community Involvement and Outreach staff at 1-800-357-8301.

A specific briefing may also be held upon request.

2.7 Quarterly Technical Progress Reports

As the Los Alamos Canyon and Pueblo Canyon work plan is implemented, the ER Project will document technical progress in quarterly progress reports. These reports will be available at the Laboratory Community Reading Room.

References for Annex V

EPA (US Environmental Protection Agency), April 10, 1990. Module VIII of RCRA Permit No. NM0890010515, EPA Region VI, issued to Los Alamos National Laboratory, Los Alamos, New Mexico, effective May 23, 1990, EPA Region VI, Hazardous Waste Management Division, Dallas, Texas. **(EPA 1990, ER ID Number 1585)**

LANL (Los Alamos National Laboratory), February 1995. "Installation Work Plan for Environmental Restoration," Revision 4, Los Alamos National Laboratory Report LA-UR-95-740, Los Alamos, New Mexico. **(LANL 1995, ER ID Number 49822)**

Working Group and Lefkoff (Working Group for Public Participation in Cleanup Decisions and Merle Lefkoff and Associates) 1995. "Plan for Increasing Public Participation in Cleanup Decisions for the Los Alamos National Laboratory," Los Alamos National Laboratory Report LA-UR-95-381, Los Alamos, New Mexico. **(Working Group and Lefkoff 1995, ER ID Number 44013)**

Appendix A

Maps

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Figure A-1. Los Alamos Canyon and Pueblo Canyon site map.

FIMAD Plot ID: 104029 18 Nov 95

Figure A-2. Existing wells and surface water sampling locations in Los Alamos Canyon and Pueblo Canyon.

FIMAD Plot ID: 104030 18 Nov 95

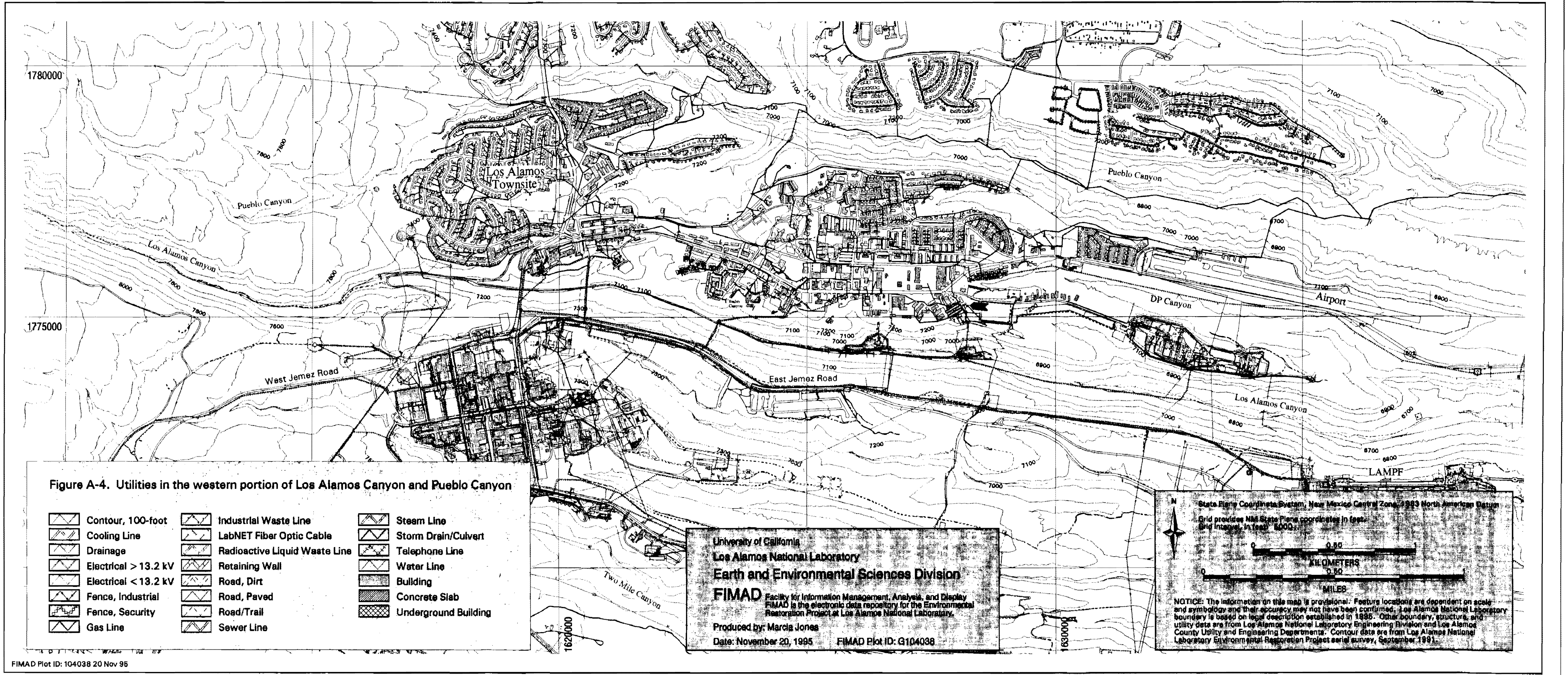

Figure A-4. Utilities in the western portion of Los Alamos Canyon and Pueblo Canyon

FIMAD Plot ID: 104038 20 Nov 95

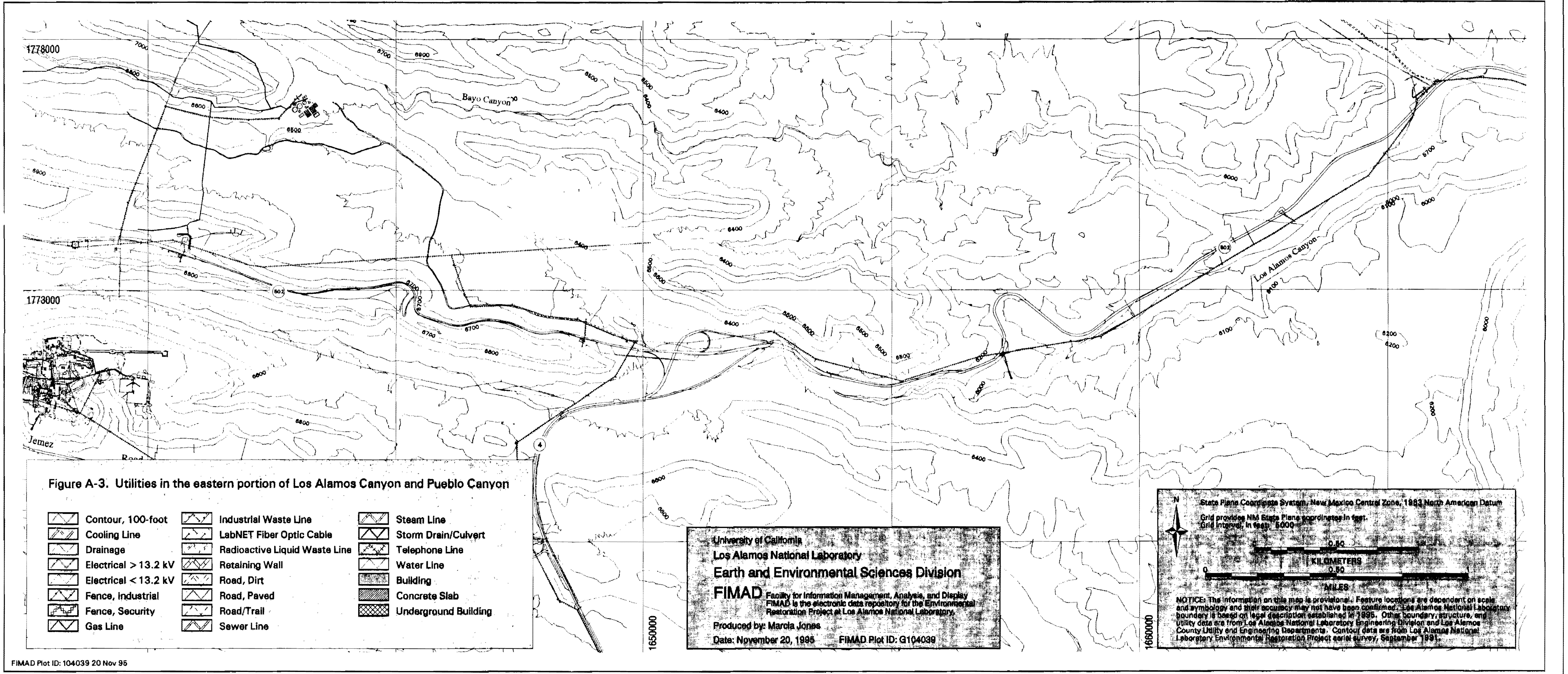

Figure A-3. Utilities in the eastern portion of Los Alamos Canyon and Pueblo Canyon

Appendix B

Plant and Animal Checklists

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TABLE B-1

PLANT CHECKLIST FOR LOS ALAMOS CANYON

Family	Scientific Name	Common Name	Indicator Status[a]
Aceraceae	*Acer glabrum neomexicanum*	New Mexico maple	Facultative[b]
Amaranthaceae	*Amaranthus retroflexus*	Pigweed	
Anacardiaceae	*Rhus radicans*	Poison ivy	
	R. trilobata	Shunkbush sumac	
Berberidaceae	*Berberis fendleri*	Colorado barberry	
Betulaceae	*Betula occidentalis*	Birch	Faculatative wetland[c]
Boraginaceae	*Cryptantha jamesii*	James hiddenflower	
	Lithospermum multiflorum	Puccoon	
Cactaceae	*Coryphantha vivipara*	Pincushion cactus	
	Opuntia spp.	Prickly pear cactus	
Capparidacieae	*Polanisia trachysperma*	Clammyweed	
Caryophyllaceae	*Arenaria fendleri*	Fendler's sandwort	
Celestraceae	*Pachystima myrsinites*	Myrtle boxleaf	Facultative
Ceratophyllaceae	*Clematis pseudoalpina*	Rocky Mountain clematis	
Chenopodiaceae	*Atriplex canescens*	Four-wing saltbush	Facultative
	Chenopodium album	Lamb's quarters	
	C. fremontii	Fremont goosefoot	
	C. graveolens	Chenopodium	
	Kochia scoparia	Summer cypress	
	Salsola iberica	Russian thistle	
Compositae	*Achillea lanulosa*	Yarrow	
	Ambrosia coronopifolia	Ragweed	
	Antennaria parvifolia	Pussytoes	
	Artemisia carruthii	Wormwood	
	A. dracunculus	False tarragon	
	A. franserioides	Ragweed sagebrush	
	A. frigida	Estafiata	
	A. ludoviciana	Wormwood	
	A. tridentata	Big sagebrush	
	Bahia dissecta	Wild chrysanthemum	
	Brickellia spp.	Bricklebush	
	Chrysopsis foliosa	Golden aster	
	Chrysothamnus nauseosus	Rubber rabbitbrush	
	Cirsium sp.	Thistle	
	Conyza canadensis	Horseweed	Facultative upland[d]
	Erigeron flagellaris	Fleabane	
	E. divergens	Fleabane daisy	
	Eupatorium herbaceum	Throughwort	
	Franseria confertifolia	Bursage	

a. Status of whether species occurs wholly or partially in a wetland or nonwetland area is given, if available.
b. Facultative means equally likely to occur in wetlands or nonwetlands (estimated probability 34–66%).
c. Facultative wetland means usually occurs in wetlands (estimated probability 67–99%) but occasionally found in nonwetlands.
d. Facultative upland means usually occurs in nonwetlands (estimated probability 67–99%) but occasionally found in wetlands (estimated probability 1–33%).

TABLE B-1 (continued)

PLANT CHECKLIST FOR LOS ALAMOS CANYON

Family	Scientific Name	Common Name	Indicator Status[a]
Compositae (continued)	*Gaillardia pulchella*	Firewheel	
	Grindelia aphanactis	Gumweed	
	Gutierrezia sarothrae	Snakeweed	
	Haplopappus spinulosus	Spiny goldenweed	
	Helianthus annuus	Sunflower	Facultative[b]
	Hymenopappus filifolius	Yellow cut-leaf	
	H. argentea	Perky sue	
	H. richardsonii	Bitterweed	
	Iva spp.	Marsh-elder	Facultative
	Senecio sp.	Groundsel	
	Solidago spp.	Goldenrod	
	Taraxacum officinale	Dandelion	Facultative upland[c]
	T. trifidum	Greenthread	
	Townsendia exscapa	Easter daisy	
	Tragopogon dubius	Salisfy, Goatsbeard	
	Verbesina encelioides	Crownbeard	Facultative
	Viguiera multiflora	Showy goldeneye	
	Xanthium strumarium	Cocklebur	Facultative
Convolvulaceae	*Ipomoea coccinea*	Star glory	Facultative
Cornaceae	*Cornus stolonifera*	Dogwood	Facultative wetland[d]
Cruciferae	*Descurainia* sp.	Mustard	
	Erysimum capitatum	Western wallflower	
	Lesquerella intermedia	Bladderpod	
Cupressaceae	*Juniperus monosperma*	One-seeded Juniper	
	J. scopulorum	Rocky Mountain juniper	
Cyperaceae	*Carex* spp.	Sedge	
Eleagnaceae	*Eleagnus angustifolia*	Russian olive	Facultative wetland
Ericaceae	*Arctostaphylus uva-ursi*	Bearberry	
Euphorbiaceae	*Croton texensis*	Doveweed	
	Euphorbia dentata	Spurge	
Fagaceae	*Quercus gambelii*	Gambel oak	
Geraniaceae	*Erodium cicutarium*	Filaree	
	Geranium caespitosum	James geranium	
Gramineae	*Agropyron smithii*	Western wheatgrass	Facultative
	Andropogon scoparius	Little bluestem	
	Aristida spp.	Three-awn	
	Blepharoneuron tricholepsis	Pine dropseed	
	Bouteloua eriopoda	Black grama	
	Bouteloua gracilis	Blue grama	

a. Status of whether species occurs wholly or partially in a wetland or nonwetland area is given, if available.

b. Facultative means equally likely to occur in wetlands or nonwetlands (estimated probability 34–66%).

c. Facultative upland means usually occurs in nonwetlands (estimated probability 67–99%) but occasionally found in wetlands (estimated probability 1–33%).

d. Facultative wetland means usually occurs in wetlands (estimated probability 67–99%) but occasionally found in nonwetlands.

TABLE B-1 (continued)

PLANT CHECKLIST FOR LOS ALAMOS CANYON

Family	Scientific Name	Common Name	Indicator Status[a]
Gramineae (continued)	*Bromus anomalus*	Nodding brome	
	B. inermis	Smooth brome	
	B. marginatus	Mountian brome	
	B. tectorum	Downy chess	
	Dactylis glomerata	Orchard grass	
	Elymus canadensis	Wild rye	Facultative[b]
	Festuca octoflora	Six-weeks fescue	
	Hilaria jamesii	Galleta	
	Hordeum sp.	Barley	Facultative
	Muhlenbergia montana	Mountain muhly	
	M. torreyi	Ring muhly	
	Oryzopsis asperifolia		
	Oryzopsis hymenoides	Indian ricegrass	Facultative upland[c]
	Phleum pratense	Common timothy	Facultative upland
	Poa fendleriana	Mutton grass	
	Poa spp.	Bluegrass	
	Sitanion hystrix	Bottlebrush squirreltail	
	Sporobolus cryptandrus	Sand dropseed	Facultative upland
	Stipa spp.	Needle and thread	
Labiateae	*Monarda pectinata*	Ponymint	
Leguminosae	*Lupinus caudatus*	Lupine	
	Melilotus albus	White sweet clover	Facultative upland
	Melilotus officinalis	Yellow sweet clover	Facultative upland
	Petalostemum spp.	Clover	
	Robinia neomexicana	New Mexico locust	
	Thermopsis pinetorum	Big golden-pea	
	Vicia americana	American vetch	
Liliaceae	*Allium cernuum*	Nodding onion	
	Yucca baccata	Banana yucca	
Linaceae	*Linum neomexicana*	New Mexico yellow flax	
Loasaceae	*Mentzelia pumila*	Stickleaf	
Nyctaginaceae	*Mirabalis multiflora*	Wild four o'clock	
	M. oxybaphoides	Vining four o'clock	
Oleaceae	*Forestiera neomexicana*	New Mexico olive	Facultative upland
Onagraceae	*Oenothera* spp.	Evening primrose	
Pinaceae	*Abies concolor*	White fir	
	Picea pungens	Blue spruce	Facultative
	Pinus edulis	Pinon pine	
	P. flexilis	Limber pine	
	P. ponderosa	Ponderosa pine	Facultative upland
	Pseudotsuga menziesii	Douglas fir	

a. Status of whether species occurs wholly or partially in a wetland or nonwetland area is given, if available.

b. Facultative means equally likely to occur in wetlands or nonwetlands (estimated probability 34–66%).

c. Facultative upland means usually occurs in nonwetlands (estimated probability 67–99%) but occasionally found in wetlands (estimated probability 1–33%).

TABLE B-1 (continued)

PLANT CHECKLIST FOR LOS ALAMOS CANYON

Family	Scientific Name	Common Name	Indicator Status[a]
Plantaginaceae	*Plantago* sp.	Plantain	
Polemoniaceae	*Ipomopsis aggregata*	Skyrocket	
	Ipomopsis longiflora	Blue skyrocket	
Polygonaceae	*Eriogonum jamesii*	Antelope sage	
	E. leptophyllum	Wild buckwheat	
	Rumex spp.	Dock	
Polypodiaceae		Fem	
Portulacaceae	*Portulaca* sp.	Purslane	
Ranunculaceae	*Clematis ligusticifolia*	Western's virgin bower	Facultative[b]
	Clematis pseudoalpina	Rocky Mountain clematis	
	Delphinium sp.	Larkspur	
	Thalictrum fendleri	Fendler meadowrue	Facultative upland[c]
Rosaceae	*Cercocarpus montanus*	Mountain mahogany	
	Fallugia paradoxa	Apache plume	
	Fragaria americana	Wild strawberry	
	Potentilla pulcherrima	Cinquefoil	
	Rosa woodsii	Wild rose	Facultative upland
	Rubus strigosus	Wild raspberry	Facultative
Rutaceae	*Ptelea trifoliata*	Narrowleaf hoptree	Facultative upland
Salicaceae	*Populus tremuloides*	Aspen	Facultative upland
	P. angustifolia	Narrowleaf cottonwood	Facultative wetland[d]
	Salix spp.	Willow	
Saxifragaceae	*Jamesia americana*	Cliffbush	Facultative upland
	Philadelphus microphyllus	Mockorange	
	Ribes cereum	Wax current	
Scrophulariaceae	*Castilleja integra*	Foothills paintbrush	
	Penstemon barbatus	Scarlet bugler	
	P. secundiflorus	Beardtongue	
	P. virgatus	Variegated penstemon	Facultative upland
	Verbascum thapsus	Mullein	
Solanaceae	*Solanum nigrum*	Black nightshade	
	Physalis foetens	Groundcherry	
Ulmaceae	*Ulmus* sp.	Elm	
Umbelliferae	*Pseudocymopterus montanus*	Yellow mountain parsley	
Valerianaceae	*Valeriana acutiloba*	Valeriana	
Vitaceae	*Parthenocissus inserta*	Virginian creeper	

a. Status of whether species occurs wholly or partially in a wetland or nonwetland area is given, if available.

b. Facultative means equally likely to occur in wetlands or nonwetlands (estimated probability 34–66%).

c. Facultative upland means usually occurs in nonwetlands (estimated probability 67–99%) but occasionally found in wetlands (estimated probability 1–33%).

d. Facultative wetland means usually occurs in wetlands (estimated probability 67–99%) but occasionally found in nonwetlands.

(Foxx and Hoard 1984, 50041; Martin and Hutchins 1980, 50040)

TABLE B-2

TERRESTRIAL ARTHROPOD CHECKLIST FOR LOS ALAMOS CANYON AND PUEBLO CANYON

Terrestrial Insects Found on Laboratory Property as of December 1994		
Order	**Family**	**Common Name**
Thysanura (bristletails)	Lepismatidae	Silverfish
	Machilidae	Jumping bristletail
Collembola (springtails)	Sminthuridae	Globular springtail
	Entomobryidae	Slender springtail
	Isotomidae	Smooth springtail
	Hypogastruridae	Elongate-bodied springtail
Odonata (dragonflies and damselflies)	Aeshnidae	Darner
	Libellulidae	Common skimmer
	Coenagrionidae	Narrow-winged damselfly
	Gomphidae	Clubtail
Phasmida (walkingsticks)	Heteronemiidae	Common walkingstick
Orthoptera (grasshoppers and crickets)	Acrididae	Short-horned grasshopper
	Gryllacrididae	Camel cricket
	Gryllidae	True cricket
Plecoptera (stoneflies)	Perlidae	Common stonefly
Dermaptera (earwigs)	Forficulidae	Common earwig
Thysanoptera (thrips)	Thripidae	Common thrip
Hemiptera (true bugs)	Belostomatidae	Giant water bug
	Miridae	Plant bug
	Reduviidae	Assassin bug
	Phymatidae	Ambush bug
	Lygaeidae	Seed bug
	Cydnidae	Burrower bug
	Scutelleridae	Shield-backed bug
	Pentatomidae	Stink bug
	Anthocoridae	Minute pirate bug
	Coreidae	Squash bug
	Nabidae	Damsel bug
Homoptera (cicadas and kin)	Cicadidae	Cicada
	Aphididae	Aphids
	Cercopidae	Spittlebugs
	Cicadellidae	Leafhoppers
	Coccidaea	Soft scales
	Delphacidae	Planthoppers
	Eriosomatidae	Gall-making aphids
	Psyllidae	Jumping plantlice
Neuroptera (net-veined insects)	Myrmeleontidae	Antlion
	Hemerobiidae	Brown lacewings
	Raphidiidae	Snakefly

TABLE B-2 (continued)

TERRESTRIAL ARTHROPOD CHECKLIST FOR LOS ALAMOS CANYON AND PUEBLO CANYON

Terrestrial Insects Found on Laboratory Property as of December 1994		
Order	**Family**	**Common Name**
Coleoptera (beetles)	Cicindelidae	Tiger beetle
	Carabidae	Ground beetle
	Silphidae	Carrion beetle
	Lampyridae	Firefly
	Cantharidae	Soldier beetle
	Lycidae	Net-winged beetle
	Buprestidae	Metallic wood-boring beetle
	Staphylinidae	Rove beetle
	Erotylidae	Pleasing fungus beetle
	Nitidulidae	Sap beetle
	Coccinellidae	Ladybird beetle
	Tenebrionidae	Darkling beetle
	Meloidae	Blister beetle
	Cerambycidae	Long-horned beetle
	Lucanidae	Stag beetle
	Scarabaeidae	Scarab beetle
	Chrysomelidae	Leaf beetle
	Curulionidae	Weevil
	Dermestidae	Dermestid beetle
Lepidoptera (butterflies and moths)	Papilionidae	Swallowtail
	Lycaenidae	Copper
	Hesperiidae	Skipper
	Pieridae	White, sulphur, and orange
	Nymphalidae	Brush-footed butterfly
	Satyridae	Satyr, nymph, and artic
	Noctuidae	Noctuid moth
	Sphingidae	Sphinx moth
	Saturniidae	Giant silkworm moth
	Gelechiidae	Gelechiid moth
	Geometridae	Measuring worms
	Pterophoridae	Plume moth
Diptera (flies)	Tabanidae	Horseflies and deer flies
	Therevidae	Stiletto fly
	Asilidae	Robber fly
	Bombyliidae	Bee fly
	Syrphidae	Hover fly
	Tachinidae	Tachinid fly
Siphonaptera (fleas)	Pulicidae	Dog fleas
Hymenoptera (bees, ants, and wasps)	Ichneumonidae	Ichneumonid wasp
	Cynipidae	Gall wasp
	Mutillidae	Velvet ant
	Scoliidae	Scoliid wasp
	Formicidae	Ant
	Pompilidae	Spider wasp
	Eumenidae	Euminid wasp
	Vespidae	Vespid wasp
	Sphecidae	Sphecid wasp
	Halictidae	Metallic wasp
	Megachilidae	Leafcutting bee
	Apidae	Honey bees and bumble bees

TABLE B-2 (continued)

TERRESTRIAL ARTHROPOD CHECKLIST FOR LOS ALAMOS CANYON AND PUEBLO CANYON

Noninsect Terrestrial Arthropods Found on Laboratory Property as of December 1994

Class/Order	Family
Chilopoda (centipedes)	Geophilidae Lithobiidae
Diplopoda (millipedes)	Julidae
Arachnida/Acarina (spiders and mites)	Anystis Bdellidae Ascidae Bryobiidae Calligonellidae Cryptognathidae Cunaxidae Erythraeidae Eupodidae Gymnodamaeidae Laelapidae Nanorchestidae Paratydaeidae Phytoseiidae Rhagidiidae Rhaphignathidae Scutacaridae Stigmaeidae Stigmaeidae Tenuipalpidae Terpnacaridae Trombidiidae Tydeidae Tarsonemidae Zerconidae
Archnida/Araneida	Agelenidae Amaurobiidae Anyphaenidae Araneidae Clubionidae Dictynidae Gnaphosidae Hahniidae Linyphiidae
Archnida/Araneida	Lycosidae Micryphantidae Miryphantidae Oonopidae Pholcidae Tetragnathidae Salticidae Theridiidae Thomisidae
Arachnida/Opiliones	Phalangiidae

TABLE B-3

REPTILES AND AMPHIBIANS IN LOS ALAMOS CANYON

Family	Scientific Name	Common Name
Bufonidae	*Bufo woodhousei*	Woodhouse toad
Colubridae	*Hypsiglena torquata*	Night snake
	Masticophis taeniatus	Stripped whipsnake
	M. flagellum	Coachwhip
	Opheodrys vernalis	Smooth green snake
	Pituophis melanoleucus	Gopher snake
	Thamnophis elegans	Western terestrial garter snake
	Thamnophis sirtalis	Common garter snake
Hylidae	*Hyla arenicolor*	Canyon treefrog
Iguanidae	*Crotaphytus collaris*	Common collared lizard
	Phrynosoma douglassi	Short-horned lizard
	Sceloporus undulatus	Eastern fence lizard
	Urosaurus ornatus	Tree lizard
Pelobatidae	*Scaphiopus multiplicatus*	Southern spadefoot
Scinicidae	*Eumeces multivirartus*	Many-lined skink
Teiidae	*Cnemidophorus velox*	Plateau stripped whiptail
Viperidae	*Crotalus atrox*	Western diamonback rattlesnake
	Crotalus viridis	Western rattlesnake

(Bogart circa 1978, 50038)

TABLE B-4

BIRD CHECKLIST FOR LOS ALAMOS CANYON

Family	Scientific Name	Common Name
Accipitridae	*Accipiter cooperii*	Cooper's hawk
	Accipiter gentilis	Northern goshawk
	Buteo albonatus	Zone-tailed hawk
	B. jamaicensis	Red-tailed hawk
Aegithalidae	*Psaltriparus minimus*	Bushtit
Apodidae	*Aeronautes saxatalis*	White-throated swift
Caprimulgidae	*Chordeiles minor*	Common nighthawk
	Phalaenoptilus nuttallii	Common poorwill
Carthartidae	*Cathartes aura*	Turkey vulture
Columbidae	*Columba fasciata*	Band-tailed pigeon
	Zenaida macroura	Morning dove
Corvidae	*Agelaius phoeniceus*	Red-winged blackbird
	Amphelocoma coerulescens	Scrub jay
	Corvus corax	Common raven
	Cyanocitta stelleri	Steller's jay
	Euphagus cyanocephalus	Brewer's blackbird
	Gymnorhinus cyanocephalus	Pinon jay
	Nucifraga columbiana	Clark's nutcracker
	Pica pica	Black-billed magpie
Emberizidae	*Calamospiza grammacus*	Lark sparrow
	Carduelis pinus	Pine siskin
	Coccothraustes vespertinus	Evening grosbeak
	Dendroica coronata	Yellow-rumped warbler
	D. digrescens	Black-throated gray warbler
	D. gracial	Grace's warbler
	D. petechia	Yellow warbler
	Icterus galbula	Northern oriole
	Icterus spurius	Orchard oriole
	Junco hyemalis	Dark-eyed junco
	Loxia curvirostra	Red crossbill
	Melospiza melodia	Song sparrow
	Molothrus aster	Brown-headed cowbird
	Oporornis tolmiei	MacGillivray's warbler
	Passer domesticus	House sparrow
	Passerina cyanea	Indigo bunting
	P. amoena	Lazuli bunting
	Pheucticus melanocephalus	Black-headed grosbeak
	Pipilo chlorurus	Green-tailed towhee
	P. fuscus	Canyon towhee
	P. erythrophthalmus	Rufous-sided towhee
	Piranga flava	Hepatic tanager
	P. ludoviciana	Western tanager
	Pooecetes gramineus	Vesper sparrow
	Spizella passerina	Chipping sparrow
	Sturnella neglecta	Western meadowlark
	Vermivora celata	Orange-crowned warbler
	Vermivora virginiae	Virginia's warbler
Falconidae	*Falco sparverius*	American kestrel

TABLE B-4 (continued)

BIRD CHECKLIST FOR LOS ALAMOS CANYON

Family	Scientific Name	Common Name
Fringillidae	*C. psaltria*	Lesser goldfinch
	Carpodacus cassinii	Cassin's finch
	C. mexicanus	House finch
	Guiraco caeulea	Blue grosbeak
	Hesperiphona vespertina	Evening grosbeak
	Loxia curvirostra	Red crossbill
Hirundinidae	*Hirundo pyrrhonota*	Cliff swallow
	Tachycineta thalassina	Violet-green swallow
Muscicapidae	*Catharus guttatus*	Hermit thrush
	Myadestes townsendii	Townsend's solitaire
	Polioptila caerulea	Blue-gray gnatcatcher
	Sialis currucoides	Mountain bluebird
	S. mexicana	Western bluebird
	Turdus migratorius	American robin
Paridae	*Parus gambeli*	Mountain chickadee
	P. inornatus	Plain titmouse
Picidae	*Colaptes auratus*	Northern flicker
	Melanerpes formicivorus	Acorn woodpecker
	M. lewis	Lewis' woodpecker
	Picoides villosus	Hairy woodpecker
	P. pubescens	Downy woodpecker
	P. tridactylus	Northern three-toed woodpecker
	Sphyrapicus thyroideus	Williamson's sapsucker
Rallidae	*Rallus limicola*	Virginia rail
Sittidae	*Certhia americana*	Brown creeper
	Sitta carolinensis	White-breasted nuthatch
	S. pygmaea	Pygmy nuthatch
Sturnidae Trochilidae	*Stumus vulgaris*	European starling
	Archilocus alexandri	Black-chinned hummingbird
	Selasphorus platycercus	Broad-tailed hummingbird
	S. rufus	Rufous hummingbird
Troglodytidae	*Catherkes mexicanus*	Canyon wren
	Salpinctes obsoleuts	Rock wren
	Thromanes bewickii	Bewick's wren
	Troglodytes aedon	House wren
Tyrannidae	*Contopus borealis*	Olive-sided flycatcher
	Contopus sordidulus	Western wood-pewee
	Western wood-pewee	Hammond's flycatcher
	E. oberholseri	Dusky flycatcher
	E. occidentalis	Cordilleran flycatcher
	Empidonax wrightii	Gray flycatcher
	Myiarchus cinerascens	Ash-throated flycatcher
	Sayornis saya	Say's Phoebe
	Tyrannus vociferans	Cassin's kingbird
Tytonidae	*Buto virginianus*	Great horned owl
	Glaucidium gnoma	Northern pygmy owl
Vireonidae	*Vireo gilvus*	Warbling vireo
	V. solitarius	Solitary vireo

(Travis 1992, 12015; Bird surveys of Los Alamos National Laboratory 1986, 1987, and 1988; Foxx et al. 1987)

TABLE B-5

MAMMAL CHECKLIST FOR LOS ALAMOS CANYON AND PUEBLO CANYON

Family	Scientific Name	Common Name	Source
Canidae	*Canis latrans*	Coyote	b
	Vulpus vulpus	Red fox	b
Cervidae	*Cervus elaphus*	Elk	b
	Odocoileus hemionus	Mule deer	b
Cricetidae	*Clethrionomys gapperi*	Boreal redback vole	d
	Neotoma mexicana	Mexican woodrat	a,b,d,e,f,g
	Microtus longicaudus	Long-tailed vole	f,g
	M. montanus	Montane vole	d
	M. pennsylvanicus	Meadow vole	a,e
	Peromyscus boylii	Brush mouse	d
	P. difficilis	Rock mouse	
	P. leucopus	White-footed mouse	d,f
	P. maniculatus	Deer mouse	a,d,e,f,g
	P. truei	Pinon mouse	a,e,f
	Reithrodontomys megalotis	Western harvest mouse	a,d,e,f
	Sigmodon hispidus	Cotton rat	a
Erethizontidae	*Erethizon dorsatum*	Porcupine	b
Felidae	*Felis concolor*	Mountain lion	b
	Lynx rufus	Bobcat	b
Geomyidae	*Thomomys bottae*	Bottae's pocket gopher	a,e
Heteromyidae	*Perognathus flavus*	Silky pocket mouse	f
	Perognathus intermedius	Rock pocket mouse	f
Leporidae	*Sylvilagus audubonii*	Desert cottontail	b
	Sylvilagus nuttallii	Nuttall's cottontail	e
	Sylvilagus spp.	Cottontail rabbit	a
Muridae	*Mus musculus*	House mouse	a
Mustelidae	*Mustela frenata*	Long-tailed weasel	b
	Taxidae taxus	Badger	b
Sciuridae	*Eutamius minimus*	Least chipmunk	a,d,e,g
	E. quadrivittatus	Colorado chipmunk	d,f,g
	Sciurus aberti	Abert's squirrel	a,d,e
	Spermophilus lateralis	Golden-mantled sqirrel	a
	Spermophilus variegatus	Rock squirrel	a,d,f
	Tamiasciurus hudsonicus	Red squirrel	d
Soricidae	*Sorex vagrans*	Vagrant shrew	e
	S. nanus	Dwarf shrew	a,e
	S. palustris	Northern water shrew	d
Ursidae	*Ursus americanus*	Black bear	b
Verspertilionidae	*Eptesicus fuscus*	Big brown bat	c
	Lasionycteris noctivagans	Silver-haired bat	c
	Lasiurus cinereus	Hoary bat	c
	Myotis evotis	Long-eared myotis	c
	M. volans	Long-legged myotis	c

a. Ferenbaugh et.al. 1982, 6393
b. Biological Resource Evaluation Team database
c. Biological Resource Evaluation Team mist netting 1991
d. Bird surveys of Los Alamos National Laboratory 1986, 1988, and 1989
e. Hakonson 1974
f. Kent 1986, 04-0322
g. Martin et. al. 1971, 04-0323

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Appendix C

Risk Calculations

Exposure Assessment

The exposure to a chemical of potential concern (COPC) is related to the risk of a particular effect by

$$Risk \propto \frac{Intake\ \ of\ \ COPC}{RFD}$$

where RFD is a toxicological reference dose for the particular effect, and intake is a measure of the amount of chemical ingested. A reference dose is an estimated threshold dose, usually in $mg_{chemical}/kg_{body\ mass}/day$, for toxicological effects. The readily available reference doses are more conservative than those usually desired for ecotoxicological risk assessment; therefore, literature-based estimates of toxicological dose-response curves may be necessary.

Intake of contaminants via several pathways is estimated by various means that are described as an exposure assessment. The basic parameters of an exposure assessment are

$$Intake = \frac{DMI \cdot C_{FOOD} \cdot f_{FOOD} + SI \cdot C_{SOIL} \cdot f_{SOIL} + WI \cdot C_{WATER} \cdot f_{WATER}}{BM}$$

where

DMI = dry matter ingestion of food (kg/d),

SI = soil ingestion (kg/d),

WI = water ingestion (L/d),

C_{FOOD} = chemical concentration in food (mg/kg),

C_{SOIL} = chemical concentration in soil (mg/kg),

C_{WATER} = chemical concentration in surface water (mg/L),

f_{FOOD} = fraction of DMI obtained from contaminated area,

f_{SOIL} = fraction of SI obtained from contaminated area,

f_{WATER} = fraction of WI obtained from contaminated area,

BM = live body mass (kg), and

$Intake$ = mg/kg/d.

Risk to Populations

Contaminants affect the persistence of wildlife populations by altering reproduction and survival rates in ways that are analogous to other environmental disturbances. To understand and predict the population consequences of environmental disturbances (such as habitat conversion and fragmentation) natural resource managers use risk assessment models (Soulé 1987, 50115; Burgman et al. 1993, 50261). Several of these models will be applied to ecological risk assessment. For example, Ginzburg et al. (1982, 50267) suggested using the probability that a population is extirpated or falls below a threshold level (*quasi-extinction)* as a measure of impact to a population. The index is

$$I = \frac{(P_{impact} - P)}{P}$$

where P is the probability of extirpation or quasi-extinction in the absence of any anthropogenic impact. The background quasi-extinction rate, P, is included because local populations may die out and be recolonized at a later time, which is true even for populations that have been modeled using exponential growth models (Mangel and Tier 1994, 50266). Alternative forms of the index may be used, such as $I = P_{impact} - P$; however, the important point is that probability of an impact is weighed against a background measure. How P_{impact} and P are calculated depends on the sophistication of the population models used to describe the target population. For the simple exponential population model, $N_t = N_C e^{rt}$. The risk (probability) of an initial population of size, N_O, falling below a critical size, N_C, is

$$P = \left(\frac{N_C}{N_O}\right)^{2r/s^2}$$

where r equals *(births – deaths)* and s^2 is the variance of r, (Burgman et al. 1993, 50269). Population birth and death rates are variable because of environmental variability and because of demographic stochasticity in birth and death processes (low or high rates due to chance). The effects that r and its variance have on the probability of quasi-extinction for the exponential model of population growth can be approximated using the equation above.

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Appendix D

Field and Laboratory Investigation Methods

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1.0 INTRODUCTION

1.1 Approach

This appendix describes the common elements that apply to the conduct of field investigations within Los Alamos Canyon and Pueblo Canyon. The objectives and technical approach for the Los Alamos Canyon and Pueblo Canyon task/site investigation are described in Chapters 5 and 7 of this work plan. Key concepts presented there include the following.

- Canyons-wide investigations that focus on general environmental characteristics and ambient levels of contaminant indicators. These investigations provide the framework within which site-specific data will be evaluated.
- Site-specific characterization that focuses on the nature and extent of contamination and the potential for future migration of contamination.
- Evaluation of analytical data and reassessment of data needs at intermediate stages (according to the decision analysis and observational approaches).

Listed below are several general concepts that apply to most of the canyons field investigation.

- Radionuclide contamination is a general characteristic of the canyons and a primary focus of the investigation.
- In the canyons, release of hazardous constituents would have been generally associated with release of radioactive materials.
- Field surveys and field screening of samples can be used to identify gross contamination and focus the collection of samples for chemical and radiochemical analysis.
- Mobile laboratory facility analyses can be used to quickly provide analytical data to help guide field operations.

1.2 Field Operations

This appendix identifies certain aspects of the Laboratory's implementation of the investigation, which include the following standard activities that will be used to support field operations:

- Laboratory-required preliminary activities and support procedures,
- identification and documentation of sampling locations,
- sample handling and laboratory coordination procedures,
- equipment decontamination procedures, and
- management of wastes generated by sampling activities.

1.3 Investigation Methods

The field investigation methods for Los Alamos Canyon and Pueblo Canyon are addressed in Section 5.0 and are tiered to the Laboratory's Installation Work Plan (IWP) (LANL 1995, 49822). Standard operating procedures (SOPs) for methods to be used during the investigation are summarized in Table II-8 in Annex II of this work plan. The methods presented in this appendix are specific examples of the options identified in the IWP. In addition, this appendix references the Laboratory ER Project's SOPs (LANL 1991, 21556). Each of the brief method descriptions given herein refers to the applicable SOPs for detailed methodology. The methods described in Sections 4.0 through 8.0 include

- sampling methods,
- field sample screening methods to identify grossly contaminated samples at the point of collection,
- *in situ* field survey methods to identify gross contamination areas,
- mobile laboratory measurement methods to provide rapid quantitative or semiquantitative sample analyses, and
- fixed-site analytical laboratory methods.

The method descriptions are brief and provide some specific information that defines the application. The method descriptions presented here are not intended to supplant or reduce the importance of the Quality Assurance Project Plan (Annex II of this work plan) and the governing SOPs (LANL 1991, 21556).

2.0 FIELD OPERATIONS

As indicated in the project schedule (Annex I of this work plan), several investigations may be conducted concurrently within Los Alamos Canyon and Pueblo Canyon. Field investigation teams will have individual responsibilities for health and safety, sample identification, sample handling and chain of custody, and related activities. Other operations may be shared across field teams, such as the mobile laboratory or an equipment decontamination facility.

A mobile laboratory facility will perform all mobile laboratory analyses required by the site characterization plans described in Chapter 7 of this work plan.

In this section, several aspects of field operations are described that are part of many Los Alamos Canyon and Pueblo Canyon field operations.

2.1 Health and Safety

Annex III of this work plan presents the Health and Safety (H&S) Plan for Los Alamos Canyon and Pueblo Canyon field activities. The H&S plan gives information regarding known or suspected contaminants within Los Alamos Canyon and Pueblo Canyon and personal protection required for different activities. All samples acquired during this investigation will be screened at the point of collection to detect gross contamination or conditions that may pose a threat to the health and safety of field workers. The techniques listed in Section 6.0 will be used. In particular, gross-alpha, -beta, and -gamma radiation surveys will be conducted. Applicable SOPs are contained in the ER Project SOP document (LANL 1991, 21556) and are referenced in Table II-8 in Annex II of this work plan.

2.2 Archaeological, Cultural, and Ecological Evaluations

Before beginning field work, as part of the Laboratory's Environment, Safety, and Health (ES&H) Questionnaire process, archaeological and ecological evaluations will be performed in all areas where the ground surface is to be disturbed, vegetation is to be removed, or invasive sampling is to be performed. After the archaeological and ecological evaluations, a DOE environmental checklist is expected to be issued. It is anticipated that the checklist will lead to a recommendation for a categorical exclusion before field work begins in Los Alamos Canyon and Pueblo Canyon.

2.3 Support Services

Physical services support during the field investigation will be provided by support groups in the Facilities, Security, and Safeguards Division, Johnson Controls World Services, Inc., or Laboratory subcontractors. Existing job ticket procedures will be used. The services these groups will provide include, but are not limited to, excavating with backhoes and front-end loaders, moving pallets of drummed auger cuttings and decontamination solutions, and setting up signs and other warning notices along the perimeter of the working area.

2.4 Excavation Permits

As part of the ES&H Questionnaire process, excavation permits are required by the Laboratory before any excavation, drilling, or other invasive activity. Acquisition of the permits will be coordinated with the Facility Risk Management Group (ESH-3) and Johnson Controls World Services, Inc. Acquisition of excavation permits will be scheduled as appropriate for each phase of field work. All areas intended for excavation, drilling, or sampling deeper than 18 in. will be marked in the field for formal clearance before the work begins.

2.5 Sample Control and Documentation

Guidance for sample handling is provided in Section 4.4 in Chapter 4 of the IWP (LANL 1995, 49822). Sample packaging, handling, chain of custody, and documentation procedures are provided in the following ER Project SOPs (LANL 1991, 21556).

- LANL-ER-SOP-01.01, "General Instructions for Field Investigations"
- LANL-ER-SOP-01.02, "Sample Containers and Preservation"
- LANL-ER-SOP-01.03, R1, "Handling, Packaging, and Shipping of Samples"
- LANL-ER-SOP-01.04, R2, "Sample Control and Field Documentation"

2.6 Sample Coordination

The Sample Management Office has been established by the ER Project to provide consistency for all investigations. The system is described in Section 4.4.1.2 in Chapter 4 of the IWP (LANL 1995, 49822). The applicable SOP is LANL-ER-SOP-01.04, R2, "Sample Control and Field Documentation."

2.7 Quality Assurance Samples

Field quality assurance (QA) samples of several types are collected during a field investigation. The definition for each kind of sample and the purpose it is intended to fulfill are given in Annex II of this work plan.

2.8 Equipment Decontamination

Decontamination is performed as a QA measure and a safety precaution. The process prevents cross contamination among samples and helps maintain a clean working environment for the safety of workers. Sampling tools are decontaminated by washing, rinsing, and drying. The effectiveness of the decontamination process is documented by rinsate blanks submitted for laboratory analysis. Steam cleaning is used for large machinery, vehicles, auger flights, and coring tools used in borehole sampling. Decontamination fluids, including steam-cleaning fluids, are considered wastes and must be collected and contained for proper disposal. The applicable SOP is LANL-ER-SOP-01.08, "Field Decontamination of Drilling and Sampling Equipment."

2.9 Waste Management

This discussion is based on the guidance provided in Section 3.4 in Chapter 3 of the IWP (LANL 1995, 49822). Wastes produced during characterization sampling activities may include borehole auger cuttings, excess sample, excavated soil from trenching, decontamination and steam-cleaning fluids, and disposable materials such as wipes, protective clothing, and spoiled sample bottles. In different areas of Los Alamos Canyon and Pueblo Canyon, several of the following waste categories may be encountered: hazardous wastes, low-level radioactive wastes, transuranic waste, and mixed waste (either low-level or transuranic mixed waste). Requirements for segregating, containing, characterizing, treating, and disposing of each type and category of waste are provided in the applicable SOP, LANL-ER-SOP-01.09, "Management of Environmental Restoration Program Radioactive Material Management Areas."

3.0 SURVEY, SCREENING, AND ANALYSIS METHODS

Consistent language has been adopted in this work plan to refer to four categories of measurements as defined below, to avoid confusion regarding the type of measurement being discussed.

3.1 Field Surveys

Field surveys are also referred to as "surveys." Direct reading or recording instruments may be used to scan the ground surface to make measurements of *in situ* conditions. Gamma radioactivity is a common measurement in radiological surveys. Land surveys, geophysical surveys, and borehole logging also are included in this category.

3.2 Field Screening

Field screening is also referred to as "field sample screening" or "screening." Instruments or observations are applied to samples at the point of collection to measure the presence of gross contamination or to determine other properties of the sample. Gross-alpha radioactivity is a common field screening measurement. Lithological logging of core samples also is included in this category.

3.4 Mobile Laboratory Facility Analysis

Mobile laboratory facility measurements are also referred to as "mobile laboratory analyses." These are sample analysis methods that require minimal sample preparation and are readily adaptable to mobile laboratory analytical equipment. These methods measure contaminants or other sample properties at better detection limits, with better precision, or different contaminants than can be obtained with field screening techniques. Examples of typical field screening techniques are gross-alpha, -beta, and -gamma radiation measurements on dried soil samples.

3.5 Fixed-Site Laboratory Analysis

Routine analyses performed at ER Project approved fixed-site laboratories are described in the ER Project analytical services statement of work (LANL 1995, 49738). This category represents the primary analysis for which samples are collected, preserved, and sealed.

4.0 FIELD SURVEYS

Field surveys (defined above in Section 3.1) typically are scans of the ground surface using direct reading or recording instruments. For this work plan, the surveys include radiological and geomorphic surveys to identify sampling locations. Field surveys also may be used for preliminary assessment of areas where contaminants are not expected. Although negative field survey results are not necessarily conclusive evidence of the absence of contaminants, these results can greatly minimize the probability that gross contamination has been overlooked and can allow timely redirection of field sampling.

4.1 Radiological Surveys

Radiological field surveys are usually scans of the ground surface using direct reading or recording instruments. For the Los Alamos Canyon and Pueblo Canyon investigation, radiological surveys will be used to identify and refine locations where contamination may exist. Although negative field survey results are not necessarily conclusive evidence for the absence of elevated levels of radioactive contaminants, the probability that such contamination exists can be minimized with the proper design and execution of radiological surveys. When elevated contamination levels are detected, survey equipment allows the precise location of "hot spots" to be determined for subsequent discrete soil sampling.

Radiological surveys to detect surface contamination are exceptionally convenient and rapid to accomplish. Survey methods have the disadvantage that the x-ray and gamma-ray signatures are strongly attenuated by solid matter; therefore, contamination below the surface (in most cases at depths greater than 1 to 2 in.) are not detected reliably. A second disadvantage is that minimum detection limits are highly isotope specific, depending on the nuclear characteristics of the decaying isotope.

4.1.1 Gross-Gamma Radiation Surveys

Several instruments are suitable for gross-gamma radiation surveys: μR meters, NaI detectors of various sizes (with ratemeters and scalars), and Geiger-Müller detectors. The preferred instruments are μR meters with the ability to measure 5 μR/hr and 2-in. by 2-in. NaI detectors with a ratemeter capable of displaying 100 cpm. Some discrete-measurement or continuous-measurement instruments also are available using the same detectors. Surveys typically are conducted by carrying these instruments at waist height, walking slowly, and observing and recording the ratemeter response. Measurement also may be made at the ground surface to aid in identifying the presence of localized contamination. The applicable SOP is LANL-ER-SOP-06.23, "Measurement of Gamma-Ray Fields Using a Sodium Iodide Detector."

4.1.2 Low-Energy Gamma Radiation Surveys

Field instruments for detecting low-energy radiations (FIDLER) and Phoswich (NaI[TI]/CsI[TI]) instruments are most commonly used to detect radionuclides that emit low-energy gamma- and x- radiation. Both instruments are optimized to detect low-energy photons, such as the 60 keV gamma emission from ^{241}Am or the x-rays that accompany the decay of most heavy radionuclides including uranium, plutonium, and other transuranics. Discrete- or continuous-measurement recording options are available. Surveys typically are conducted by carrying the instruments close to the ground surface or attaching the instruments to tripods and observing the ratemeter or scalar. Also, measurements may be made at the ground surface to identify and precisely locate highly localized contamination. The applicable SOP is LANL-ER-SOP-10.04, R1, "Fidler Instrument System."

4.1.3 Gamma Spectrometry Systems

The Energy Measurements Division of EG&G-Las Vegas operates the DOE's Remote Sensing Laboratory. This laboratory maintains state-of-the-art ground- and airborne-vehicle based gamma spectrometry systems that have been valuable during a number of environmental studies involving radioactive contamination at DOE, Department of Defense, and other sites (see Table D-1).

Ground-based (*in situ*) gamma spectrometry systems use liquid nitrogen-cooled high-purity germanium detectors mounted on an easily moved tripod, on a backpack field unit, or on a retractable arm attached to a four-wheel drive vehicle. The retractable arm on the vehicle-based system allows the detector's height above ground to be varied from essentially ground level to about 10 m. A height of about 7.5 m typically is used, and lead collimators can be used to vary the cone angle available to the detector's sensor.

The vehicle also contains a computer processing facility so that raw data processing and preliminary contamination mapping can be performed in real time in the field. Subsequent refinement of the data occurs off-site, which results in a map of individual radionuclides (or groups of radionuclides emitting gamma rays of similar energy). Airborne gamma spectrometry systems differ from ground-based systems in that they use arrays of sensitive detectors.

Minimum detectable activities (MDAs) for several radionuclides of interest for the Los Alamos Canyon and Pueblo Canyon investigation are listed in Table D-2. MDAs are listed for both ground-based (*in situ*) and aerial-based systems. Because gamma rays are strongly attenuated by solid matter, gamma survey methods are useful only for the

TABLE D-1

PAST ENVIRONMENTAL APPLICATIONS OF THE REMOTE SENSING LABORATORY'S GAMMA SPECTROMETRY SYSTEMS

Site	Survey Location	Date	Isotopes of Interest	Application
Enewetok Atoll	Western Pacific	7/77–12/79	^{241}Am	Cleanup
Gnome	Carlsbad, NM	8/77–9/77	^{137}Cs	Assessment
Johnston Atoll	Western Pacific	4/80–8/80	^{241}Am	Mapping
Middlesex Plant	Middlesex, NJ	7/80–11/80	^{226}Ra	Cleanup
Kellex	Jersey City, NJ	9/80–11/80	^{235}U, ^{238}U, ^{232}Th	Assessment
Area 11	Nevada Test Site	6/81–9/81	^{241}Am	Cleanup
Areas 2, 15, and 21	Los Alamos National Laboratory	9/82	^{241}Am, ^{137}Cs, ^{238}U	Mapping
Areas 1–13, 15–20, 25, 26, and 30	Nevada Test Site	6/81–3/86	All measurable	Mapping/ Inventory
Maralinga	South Australia	5/87–7/87	^{241}Am, ^{137}Cs, ^{238}U	Survey support
Rocky Flats Plat	Golden, CO	12/90	^{241}Am, ^{235}U, ^{238}U	Assessment

(Tipton et al. 1981, 0695)

TABLE D-2

TYPICAL MINIMUM DETECTABLE ACTIVITIES FOR SURFACE SOILS USING THE REMOTE SENSING LABORATORY'S IN SITU AND HELICOPTER-BASED GAMMA SPECTROMETRY SYSTEMS[a]

Isotope	Helicopter[b] ($\mu Ci/m^2$)	In Situ[c] ($\mu Ci/m^2$)
^{241}Am	0.1	0.006
^{239}Pu	400	30
^{235}U	0.03	0.003
^{238}U	1.0	0.04
^{137}Cs	0.02	0.002
^{131}I	0.02	0.002
^{60}Co	0.01	0.001

a. An infinite (uniform) surface distribution of radionuclides is assumed. Minimum detectable activities are from the EG&G reports cited in the reference list. Actual values can vary by a factor of two or more at specific sites, depending on background.

b. Altitude 30 m, speed 60 knots, 20 NaI (Tl) detectors (12.7 cm x 5.1 cm), 1 second acquisition time

c. Height 1 m, 20% n-type high-purity germanium detector, 10 min acquisition time

(Boyns 1990, 0696; Reiman 1991, 0722; Tipton et al. 1981, 0695) uppermost portion of the soil horizon. For example, 95% of the 60 keV signal attributable to ^{241}Am originates within the top 6 cm of soil (assuming uniform distribution of ^{241}Am in soil) and 99% of the signal originates within the top 9 cm.

MDAs also are strongly isotope dependent, as indicated in Table D-2. Isotope dependency is due to both the energy of the emission (lower energies are more strongly attenuated and give lower detector response) and the branching factor (fraction of radioactive decays that give rise to gamma-ray emission). Of particular relevance to the Los Alamos Canyon and Pueblo Canyon investigation is the relatively low sensitivity to plutonium emissions, primarily due to the low branching factor. However, sensitivity is excellent to ^{137}Cs, ^{235}U, ^{238}U, and ^{241}Am (the daughter product of the relatively short-lived isotope, ^{241}Pu). All of these are important contaminants of concern for the canyons investigation. The spectrometer system can be optimized for specific isotopes of interest in the survey.

The usual approach for deducing plutonium distributions from gamma-ray techniques is to measure the easily detected signature from ^{241}Am and to apply a factor accounting for the americium/plutonium ratio at the site. This approach assumes that the ratio does not vary over the site due to either partitioning of americium and plutonium by environmental processes or the existence of plutonium at various ages and initial isotopic mixtures.

Fractionation of americium and plutonium in the environment has rarely been observed, and past studies generally have shown the process to be negligible at arid or semiarid sites. In addition, the plutonium and americium source history at Technical Area (TA) -2 and TA-41 within Los Alamos Canyon is unusually well defined. Therefore, the Los Alamos Canyon and Pueblo Canyon investigation is especially well suited to use americium surface survey results to deduce plutonium levels. The plutonium and americium levels will be measured from discrete sampling at all canyon work sites to confirm that the americium/plutonium ratio is adequately well known and the ratio is invariant across the canyons investigation.

Results from radiological surveys usually are expressed in units of $\mu Ci/m^2$. Conversion to units of pCi/g requires some knowledge or assumptions about the vertical and lateral distribution of the radionuclide in the soil.

Source term size also has a strong impact on lower detection limits. Tables D-3 and D-4 give some conversion factors and illustrate the lower sensitivity for point versus uniformly distributed sources. For example, consider a typical *in situ* system configuration with a detector height of 7.4 m and a corresponding field of view of about 300 m^2 (20 m diameter). For a uniform surface distribution of ^{241}Am, the MDA is about 11 pCi/g, or 0.36 mCi for a point source. This sensitivity is comparable to, or better than, that of FIDLER or Phoswich systems (not radionuclide-specific) operating at a height of about 1 m above ground surface, with a corresponding survey area of several square meters.

4.2 Geophysical Surveys

When required, field surveys will be performed with a metal detector to confirm the location of buried pipes. The selected geophysical instrument will be able to detect all types of metal (ferrous and nonferrous) and will be capable of detecting a 2-in.-diameter metal pipe buried at a depth of 5 ft. A geophysical survey to locate buried metal pipes is typically performed by continuously observing the instrument meter response while walking along traverse lines that cross at a right angle over the suspected trend

TABLE D-3

FINITE AMERICIUM-241 SOURCE CORRECTION FACTORS vs. AREA OF CONTAMINATION

Sources Diameter (m)	Correction Factor	Diameter of Contaminated Circular Area (m)	Correction Factor
10	37	5	300
20	9	10	100
40	3.5	25	10
60	2.2	50	6.5
80	1.6	100	2.5
100	1.3	200	1.2
140	1.1	300	1.0
>140	1.0	∞	1.0

(Boyns 1990, 0690)

TABLE D-4

TYPICAL MDAs AND DISTRIBUTED SOURCE MDA CURVE FOR ROCKY FLATS BUFFER ZONE SURFACE SOILS

Isotope	MDA[a] (pCi/g)
^{241}Am	0.9
^{137}Cs	0.1
^{238}U	4.1
^{226}Ra	0.2
^{232}Th	0.2
^{40}K	0.2

a. MDA = minimum detectable activity = A/B where
A = activity read on graph (pCi/g) for B=1
B = branching rates (gamma/disintegration)
For
- three standard deviation statistical uncertainty of typical background spectrum
- 15 min acquisition time
- 20% Bare N-type HPGe detector
- 7.5 m detector elevation
- 46 m grid
- uniform distribution averaged over top 3 cm

(Reiman 1991, 0722)

of the buried pipe. A typical spacing of the parallel traverse lines is 20 ft. The applicable SOP is LANL-ER-SOP-03.02, R1, "General Surface Geophysics."

4.3 Engineering Surveys

Engineering surveys will be used to document all sampling locations and to locate either former or buried structures (where needed). In all cases, the minimum precision requirements for the surveys are the same: ± 1 ft horizontal and vertical. The conventional survey procedures used are documented by groups in the Laboratory Facilities, Security, and Safeguards Division.

5.0 FIELD SAMPLING METHODS

For the sampling and analysis plans used in this work plan, a suite of specific sampling methods has been selected, and the details of their use and application in the field have been defined. For example, a "surface soil sample" in this work plan is specifically defined as representing a 0- to 12-in. layer of soil collected by a hand scoop (see Section 5.1.1), and a "core sample" is generally defined as a 5-ft core interval of a specified length (see Section 5.2).

Setting these common definitions and using them uniformly in all the Los Alamos Canyon and Pueblo Canyon sampling and analysis plans provides several benefits: consistency of field operations, comparability of sample analysis results from location to location, and the ability to have each sampling and analysis plan refer to a method defined in this appendix without reproducing the information in each plan. For each method identified below, the specifically defined portion is detailed. However, complete specification of the method requires additional information that is referenced to the applicable SOP or provided in the sampling and analysis plan (for example, nominal or target depth for a borehole).

5.1 Soil and Sediment Sampling Methods

5.1.1 Surface Sample

Surface soil samples are defined as samples collected from the first 12 in. of soil. This type of soil sample will be collected using a stainless steel or Teflon scoop. Care will be used to collect the sample to a full 12-in. depth and to cut the sides of the hole vertically to ensure that equal volumes of soil are taken over the full 12-in. depth. The applicable SOP is LANL-ER-SOP-06.09, "Spade and Scoop Method for Collection of Soil Samples."

5.1.2 Undisturbed Surface Soil Sample

Undisturbed soil samples will be collected from the first 6 in. of soil using the ring sampler method. This method involves driving a 4-in.-diameter stainless steel tube (ring sampler) vertically into the area to be sampled. The soil around the ring sampler is then excavated so that the tube can be removed. An undisturbed core sample is obtained by pushing out the soil in the ring sampler. The applicable SOP is LANL-ER-SOP-06-11, "Stainless Steel Surface Soil Sampler."

5.1.3 Manual Shallow Core Sample

Small-volume soil samples can be collected from depths approaching 10 ft with a hand auger or a thin-wall tube sampler. The thin-wall tube sampler provides a less disturbed sample than that collected with a hand auger. However, it may not be possible to force the thin-wall tube sampler through some soil or tuff, and sampling with the hand auger may be a more viable alternative. Usually it is not practical to use a hand auger or thin-wall sampler at depths below 10 ft. The applicable SOP is LANL-ER-SOP-06.10, "Hand Auger and Thin-Wall Tube Sampler."

5.2 Core Sampling Methods and Borehole Stopping Criteria

Split-barrel core sampling will be accomplished using an auger rig that drives a 4.25-in. internal diameter hollow-stem auger with 7.5-in. outer diameter auger flights. Soil samples will be collected using a 3.125-in. internal diameter, 5-ft continuous split-barrel sampler. The borehole will be sampled to at least the nominal depth given in the sampling and analysis plan. If contamination is detected by field screening measurements in the last core interval above the nominal depth, drilling will continue until field screening shows no anomalies in two successive sample intervals. This stopping criterion will be applied as a means of ensuring that the maximum information on contaminant depth is acquired. Each sampling and analysis plan specifies an analytical plan for cores down to the nominal depth. The pattern set by the sampling and analysis plan will be followed for the complete depth of the borehole as determined by the stopping criterion.

5.2.1 Shallow Boreholes

Several Los Alamos Canyon and Pueblo Canyon sampling and analysis plans call for core samples to be collected from shallow boreholes limited to depths of about 50 ft in the alluvium. A 5-ft core interval is specified as the standard sample. For ease of setup and rapid drilling of shallow boreholes, the use of a light-weight drill rig may be preferred over other methods. The applicable SOP for shallow boreholes is LANL-ER-SOP-04.01, "Drilling Methods and Drill Site Management."

5.2.2 Deep Core Sampling

For tuff coring deeper than 250 to 300 ft, a drill rig is needed with capabilities greater than those used for the hollow-stem auger rigs described above. Initial plans presented in Chapter 7 of this work plan call for nine boreholes deeper than 200 ft. Section 7.3.3.1.3 describes the drilling and sampling strategy for these nine boreholes. For deep drilling methods, the applicable SOP is LANL-ER-SOP-04.01, "Drilling Methods and Drill Site Management."

5.3 Surface Water Sampling Methods

A Geotech Model 0700 peristaltic pump, or its equivalent, will be used to collect surface water samples. The Geotech Model 0700 allows the union of the filtration assembly with the pump and the sample container so that collection of a representative sample is simplified and the possibility of sample contamination is reduced. In this method, surface samples are filtered and collected directly with minimal elapsed time.

An alternate method is to collect surface water as grab samples. This method involves dipping a beaker, flask, or some other transfer device into the surface water to retrieve samples. The water sample also can be collected directly by dipping the sample container into the water and filling, removing, and capping it. This method is less useful when sampling shallow waters such as seeps, springs, or shallow streams. The applicable SOP is LANL-ER-SOP-06.13, "Surface Water Sampling."

5.4 Ground Water Sampling

The sampling of the shallow and intermediate characterization boreholes within Los Alamos Canyon and Pueblo Canyon is included in Chapter 7 of this work plan. If perched water zones, springs, or seeps are encountered, they also will be sampled. The applicable SOPs for ground water sampling are LANL-ER-SOP-06.01, "Purging of Wells for Representative Sampling of Ground Water," and LANL-ER-SOP-06.02, "Field Analytical Measurements on Groundwater Samples."

6.0 FIELD SAMPLE SCREENING

Field screening is defined earlier in Section 3.3. Screening measurements are applied to samples at the point of surface sample collection to assess conditions affecting the health or safety of field workers. Application of screening for worker health and safety is described in Annex III of this work plan. Samples taken will be screened for gross-alpha, -beta, and -gamma radioactivity. In addition, a noninstrumental form of sample screening, lithological logging, will be performed for all borehole samples.

6.1 Radiological Screening

6.1.1 Gross-Alpha

Field screening of samples for gross-alpha contamination will be conducted using a hand-held alpha detector and a ratemeter. The detector is held close to the sample and is capable of detecting approximately 100 to 200 cpm for an undried sample. However, the instrument cannot identify specific radionuclides. The applicable SOP is LANL-ER-SOP-10.07, "Field Monitoring for Surface and Volume Radioactivity Levels."

6.1.2 Gross-Gamma

Field screening of samples for gamma radioactivity will be conducted using a hand-held gamma detector probe and ratemeter as a gross indicator of potential contamination. The detector is held close to the sample and is capable of identifying elevated concentrations of certain radionuclides as an increased ratemeter reading above instrument background levels. The applicable SOP is LANL-ER-SOP-06.23, "Measurement of Gamma-Ray Fields Using a Sodium Iodide Detector."

6.2 Nonradioactive Screening

6.2.1 Organic Vapor Detectors

Organic vapor detectors may be used to screen specified borehole cores and soil samples at the point of collection. Two purposes are addressed: worker safety and the identification of grossly contaminated samples. Two types of detectors, photoionization detectors (PIDs) and flame ionization detectors (FIDs), are used to detect a wide range of vapors.

6.2.1.1 Photoionization Detector

A Model PI 101 PID, or its equivalent, will be used as needed to detect organic vapors. This general survey instrument is capable of detecting real time concentrations of many complex organic compounds and some inorganic compounds in air. The instrument can be calibrated to a particular compound. However, the instrument cannot distinguish among detectable compounds in a mixture of gases.

6.2.1.2 Flame Ionization Detector

A Foxboro Model OVA-128, or its equivalent, will be used. This FID can be used as a general screening instrument to detect the presence of many organic vapors. The instrumental response is relative to the response to a gas of known composition to which the instrument has been calibrated.

6.2.2 Combustible Gas and Oxygen Detectors

A Gastech Model 1314, or its equivalent, may be used to determine the potential for combustion or explosion of unknown atmospheres. A typical combustible gas indicator determines the level of organic vapors and gases present in an atmosphere as a percentage of the lower explosive limit or lower flammability limit. The Gastech Model 1314 also contains an oxygen detector to determine atmospheres that are deficient or enriched in oxygen.

6.2.3 Lithologic Logging

Lithological logging of recovered core will be performed to describe the physical nature of borehole cores. Lithological logging will be performed by a geologist qualified to describe subsurface lithologies and differentiate the various strata of the Bandelier Tuff. The applicable SOP is LANL-ER-SOP-04.04, "General Borehole Logging."

7.0 MOBILE LABORATORY MEASUREMENTS

The scope and nature of mobile laboratory measurements to be used in support of the Los Alamos Canyon and Pueblo Canyon investigation are defined in this section. The mobile laboratory will provide fast turnaround analysis of samples for a limited number of analytical methods. The mobile laboratory methods provide better quality information or lower detection limits than can be obtained with field screening or surveys. In some cases, mobile laboratory methods provide the type of information that cannot be obtained with field screening or survey techniques. The intended uses of the mobile laboratory results are discussed in the following sections.

7.1 Uses of Mobile Laboratory Results

7.1.1 Guidance to Field Operations

The use of a mobile laboratory can provide fast turnaround results to aid in directing the course of field work, thus increasing the efficiency of field operations. An example is the use of mobile laboratory measurements to determine when to cease borehole drilling.

7.1.2 Judgmental Sample Selection

Mobile laboratory analyses of knowledge-based (judgmental) samples can enhance the effectiveness of the investigation. Based on mobile laboratory analyses, additional samples having the following particular characteristics can be selected:

- those with no detectable contaminants (to define the edge of a plume) and

- those with the highest levels (to identify contaminants during source characterization).

7.1.3 Analytical Sample Load Reduction

The mobile laboratory provides the capability to relatively quickly and inexpensively assess samples for selected analytes. Therefore, the submittal of a smaller number of samples to a fixed-site analytical laboratory can be justified by a base of lower quality measurements. This approach ensures that high-quality measurements are representative and sufficient for decision making and can limit the number of samples that must be sent for more costly and time-consuming analysis at a fixed-site analytical laboratory.

The selection of samples to be submitted to a fixed-site analytical laboratory, based on mobile laboratory results, is required in this investigation. The criteria to be used for making this selection depends on the focus and goals of the particular investigation, as described in the site-specific sampling and analysis plans (Chapter 7 of this work plan).

7.2 Radiological Measurements

7.2.1 Gross-Alpha and Gross-Beta Radioactivity

Measurements of gross-alpha and -beta radioactivity can be used to assess the presence of plutonium, uranium, and americium in samples; however, identification of the individual radionuclides is not possible by this method. For example, the alpha emissions from ^{238}Pu are indistinguishable from those of ^{241}Am by gross-alpha counting. These measurements can be used to guide field operations or to bias sample selection.

The method uses a thin-walled NaI detector on dried soil samples in a fixed geometry. A measurement time of approximately 15 to 20 min is typical. Additional detail is given in Annex II of this work plan.

7.2.2 Gross-Gamma Radioactivity

Gross-gamma radioactivity will be determined by the gamma spectrometry method.

8.0 FIXED-SITE LABORATORY ANALYSIS

As stated in Section 3.0 above, fixed-site laboratory analyses are used in this work plan. Fixed-site laboratory analyses are intended to provide the highest quality data required. As described above in Section 2.6, samples to be submitted to a fixed-site analytical laboratory will be coordinated, handled, and tracked by the ER Project Sample

Management Office. The standard list of analytes and quantitation limits is given in Annex II of this work plan and in the ER Project analytical services statement of work (LANL 1995, 49738). Standard laboratory procedures will be modified as described in Section 7.2 and in Annex II of this work plan.

Some Los Alamos Canyon and Pueblo Canyon sampling and analysis plans rely exclusively on fixed-site laboratory data to support their objectives. Other plans use screening data for field guidance and use the higher quality results for limited purposes. Identification of methods frequently referenced in the Los Alamos Canyon and Pueblo Canyon sampling and analysis plans include the following.

- Gross-alpha and -beta radiation and 90Sr

  Analyses will be done using a gas flow proportional counter.

- Gross-gamma, ^{241}Am, ^{137}Cs, and ^{60}Co

  Radionuclides will be quantified by measuring gamma ray photon emissions using the gamma spectrometry method.

- Tritium

  Tritium in water samples or in moisture distilled from soil will be quantified by measuring the low-energy beta emission with liquid scintillation counting.

- Total and isotopic uranium

  Analysis will be done by the inductively coupled plasma mass spectrometry (ICPMS) method. Isotopic uranium will be analyzed using alpha spectrometry or ICPMS.

- Isotopic plutonium

  Radiochemical methods will be used to separate plutonium from soil, followed by alpha spectrometry to quantify each isotope of plutonium. Special radiochemical separation methods and counting techniques employing advanced instrumentation may be used to provide plutonium isotopic data in soil and sediment at low activity levels.

The following analyses will be used in the Los Alamos Canyon and Pueblo Canyon investigation.

- Organochlorine pesticides and polychlorinated biphenyl compounds

  The Environmental Protection Agency (EPA) standard method (SW 8081) will be used to quantify polychlorinated biphenyls and pesticides.

- Semivolatile organic compounds

  The EPA standard method (SW 8270) will be used to quantify semivolatile organic compounds.

- Metals

The EPA standard method (SW 6010) will be used to quantify metals.

- Volatile organic compounds

  The EPA standard method (SW 8260) will be used to quantify volatile organic compounds.

9.0 GEOHYDROLOGIC CHARACTERIZATION OF BOREHOLES AND RECOVERED CORE

Methods used for geohydrologic characterization of boreholes during the Los Alamos Canyon and Pueblo Canyon investigation are described in the following section.

9.1 Hydrogeologic Measurements on Recovered Core

Gravimetric water content in intact core samples will be measured quantitatively by weighing moisture loss due to oven drying using the American Society for Testing and Materials (ASTM) method D-4531-86 (ASTM 1988, 0514). This procedure also yields bulk density, dry density, and porosity.

Porosity (He injection) will be measured quantitatively using intact core samples by American Petroleum Institute Method API 40, Section 3.58.

Saturated hydraulic conductivity will be measured using intact core samples by ASTM method D-2434-68 (ASTM 1988, 0514).

Air/water relative permeability will be determined by the method of van Genuchten (1980, 49927) using data from saturated hydraulic conductivity tests and moisture characteristic curves.

9.2 Geochemical Measurements

Standard x-ray diffraction procedures will be applied to powdered rock and soil samples to characterize the type and relative abundance of the following mineral phases.

- Clay mineralogy (kaolinite, illite, and montmorillonite)
- Zeolite mineralogy
- Matrix mineralogy (silica polymorphs, alkali feldspars, and volcanic glass)
- Carbonate mineralogy
- Iron and manganese mineralogy

Other parameters to be measured include the following.

- Total organic carbon

  Total organic carbon in crushed rock samples will be measured by combustion in a muffle furnace by ASTM method D-2974 (ASTM 1988, 0514).

- Cation exchange capacity

  Cation ion exchange capacity will be measured on crushed core samples using EPA method 9080 (EPA 1984, 0409).

9.3 Environmental Isotope Measurements

- Chlorine-35/chlorine-37

  This isotope ratio will be measured by accelerator mass spectrometry on chloride samples obtained by leaching crushed core samples with deionized water.

- Carbon-12/carbon-13

  This isotope ratio will be measured by mass spectrometry on water samples or pore water extracted under vacuum from crushed core samples.

- Hydrogen/deuterium

  This isotope ratio will be measured by mass spectrometry on water samples or pore water extracted from crushed core samples.

- Oxygen-18/oxygen-16

  This isotope ratio will be measured by mass spectrometry on water samples or pore water extracted under vacuum from crushed core samples.

- Tritium

  Tritium activity will be measured in water samples or pore water extracted under vacuum from crushed core samples by liquid scintillation counting methods.

- Carbon-14

  Carbon-14 age determinations will be carried out by accelerator mass spectrometry on pore water extracted from crushed rock samples.

- Chlorine-36

  Chlorine-36 age determinations will be carried out by accelerator mass spectrometry on water samples or solutions obtained by leaching crushed core samples with deionized water.

9.4 Straddle Packer Tests

Carbon-12/carbon-13 isotope ratio will be measured by mass spectrometry methods on *in situ* gas samples extracted from discrete depths in open boreholes.

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Appendix E

List of Contributors

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NAME AND AFFILIATION	EDUCATION AND EXPERTISE	FUNCTION
Tom Anderson (ERM/Golder)	B.S. Geology 5 years experience in RCRA/CERCLA waste site characterization	ER support contractor
Kathryn Bennett (ESH-20)	M.S. Environmental Science 3 years experience in NEPA biological activities including Laboratory wetlands evaluation, endangered and threatened species studies, and environmental database development	NEPA biological evaluation
Jerry Boak (CST-7)	Ph.D. Geologic Sciences 21 years experience in geologic, geochemical, and petroleum geologic research, exploration, and program management including performance assessment of the high-level radioactive waste repository program	Technical lead
Wesley Bradford (LATA)	Ph.D. Earth Sciences 28 years experience in conducting field investigations in hydrology, hydrogeology, and geochemistry and managing RI/FS environmental contamination assessments and RCRA corrective actions	Technical coordinator
David Broxton (EES-1)	M.S. Geology 7 years experience in petrologic and geochemical studies of volcanic rocks, geologic disposal of high-level nuclear waste, and project management	Principal investigator for geology
Jolene Byers (LATA)	A.A. Liberal Arts 3 years experience in administrative support	Word processor Document production
Florie Caporuscio (ERM/Golder)	Ph.D. Geology/Igneous Petrology 10 years experience in RCRA/CERCLA and federal NESHAPS investigations; expertise in geochemistry as related to high-level and transuranic radioactive waste	Technical consultant
Joe Wanda Cramer (LATA)	39 years experience in records management, document control, and administrative support including environmental restoration	Archival research Technical and quality assurance support
David Dander (CST-7)	B.S. Environmental Sciences/Applied Geology	Technical illustrator
Beverly Dickinson (CST-7)	21 years experience in office management and 10 years experience in word processing	Word processor
Alison Dorries (TSA-11)	Ph.D. Chemistry/M.P.H. Public Health 9 years experience in toxicology, pulmonary health research, regulation development, and human health risk assessment	Technical team leader for human health risk assessment

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Teralene Foxx (ESH-20)	M.S. Biology 18 years field ecology and waste site characterization experience; adjunct professor, University of New Mexico; author of books and publications on plant and fire ecology	NEPA biological evaluation
Bruce Gallaher (ESH-18)	M.S. Hydrology 15 years experience in waste management in contaminant hydrology	Principal investigator for hydrology
Yvonne Herring (CST-7)	9 years experience in office work and word processing	Word processor
Richard Kelley	B.S Geology 16 years experience in geologic and petroleum geologic exploration including 6 years of environmental and hydrological specialization	Geologic/GIS mapping consultant
Kevin Kinsella (ERM/Golder)	B.S. Physical Geography/Environmental Studies 1 year experience in site characterization and investigation	ER support contractor
Beverly Larson (ESH-20)	M.A. Anthropology/Ph.D. Candidate in Anthropology 17 years field experience, including 6 years as a Laboratory archaeologist; adjunct professor, University of New Mexico	NEPA cultural evaluation
Patrick Longmire (CST-7)	Ph.D. Aqueous Geochemistry 17 years experience in field hydrogeochemistry, soil chemistry regulatory oversight (NMEID), the UMTRA project, and RCRA/CERCLA remediation (Roy F. Weston)	Technical lead for aqueous geochemistry
Mary Ann Mullen (ESH-20)	M.S. Statistics 2 years experience with the Laboratory Environmental Restoration Project; expertise in statistical ecology and environmental sciences	Lead statistician
Orrin Myers (EES-15)	Ph.D. Wildlife Biology 10 years experience conducting field investigations on effects of environmental contaminants on wetland and terrestrial wildlife populations, including 4 years in ecological risk assessment	Technical lead for ecological risk assessment
Maureen Oakes (CIC-1)	B.S. Biology 5 years experience writing and editing technical documents, including environment, safety, and health and environmental restoration documentation	Technical writer/editor

NAME AND AFFILIATION	EDUCATION AND EXPERTISE	FUNCTION
Donna O'Donnell (LATA)	6 years experience in project control and data management	Project planning specialist
Deidre´ Plumlee (Ray Rashkin Associates, Inc.)	A.A. Graphic Communication 2 years experience as an electronic publications specialist; 2 years experience creating and publishing a magazine that was distributed in the United States and Canada	Electronic publications specialist
Allyn Pratt (EES-13)	B.S. Environmental Science/M.B.A. 19 years experience in natural resource management, project management, and environmental management	Field Unit 4 project leader
Steven Reneau (EES-1)	Ph.D. Geology 16 years experience in geosciences; 7 years at the Laboratory evaluating surface transport of contaminants for the Environmental Restoration Project	Technical lead for sedimentology
Marja Shaner (EM/P&PI)	B.A. Languages/Paralegal degree 12 years experience at the Laboratory, primarily in environmental law, community involvement, and public outreach	Primary contact for public involvement
Catherine Smith (LATA)	Ph.D. Analytical Chemistry 10 years experience in analytical chemistry with emphasis on environmental characterization; expertise in quality assurance for analytical services and analytical data quality evaluation	Technical consultant
Alan Stoker (SAIC)	Environmental Engineering Degree 20 years experience at the Laboratory with main expertise in hydrogeology, environmental monitoring, water quality, and water resources investigations for NEPA, RCRA, and CERCLA compliance	Technical manager for hydrology
Brad Wilcox (EES-15)	Ph.D. Watershed Management 10 years experience in hydrology and natural resource management and waste site characterization; adjunct professor, University of New Mexico; author of books and publications on plant and fire ecology	Hydrologist