HSWA LANL 3/1082/16/16-003(k)#16-021(c)
LA-02-98-3918

Environmental Restoration
University of California
Environmental Restoration Project, MS M992
Los Alamos, New Mexico 87545
505-667-0808/FAX 505-665-4747

U. S. Department of Energy
Los Alamos Area Office, MS A316
Environmental Restoration Program
Los Alamos, New Mexico 87544
505-667-7203/FAX 505-665-4504

Date: September 30, 1998
Refer to: EM/ER:98-392

SEP 1998
RECEIVED

Mr. Benito Garcia
NMED-HRMB
P.O. Box 26110
Santa Fe, NM 87501

SUBJECT: SUBMITTAL OF CMS PLAN FOR PRS 16-021(c) (FORMER OU 1082, FU 3) TO FULFILL THE FY98 WORK SCHEDULE COMMITMENT

Dear Mr. Garcia:

Enclosed please find two copies of the Corrective Measures Study Plan for Potential Release Site 16-021(c) and the Certification, which are being submitted to the New Mexico Environment Department to fulfill the Fiscal Year 1998 Work Schedule commitment.

If you have any questions or comments, please contact Victoria George at (505) 666-6953.

Sincerely,

Julie A. Canepa, Program Manager
LANL/ER Project

Sincerely,

Theodore J. Taylor, Program Manager
DOE/LAAO

JC/TT/DB/dm

Enclosures: (1) Two CMS Plans for PRS 16-021(c) (Former OU 1082, FU 3)
(2) Certification

TL

6121

Cy (w/ encs.):
D. Hickmott, EES-1, MS E525
R. Michelotti, CST-7, MS E525
D. Neleigh, EPA, R.6, 6PD-N
J. Newlin, CST-7, MS M992
C. Rodriguez, CIO/ER, MS M992
T. Taylor, LAAO, MS A316
T. Trujillo, DOE-AL, MS A906
J. White, ESH-19, MS K490
S. Dinwiddie, NMED-HRMB
M. Leavitt, NMED-GWQB
J. Parker, NMED-AIP
S. Yanicak, NMED-AIP, MS J993
RPF, MS M707, Records Package 306

Information Only (w/o encs.):
T. Baca, EM, MS J591
D. Boak, TSA-10, MS M992
T. George, EM/ER, MS M992
R. Hutton, SAIC, MS J521
M. Kirsch, EM/ER, MS M992
T. Longo, DOE-HQ, EM-453
D. McInroy, EM/ER, M992
J. Mose, LAAO, MS A316
H. Orr, EM/ER, MS M992
S. Rae, ESH-18, MS K497
G. Rael, DOE-AL, MS A906
J. Vozella, LAAO, MS A316
EM/ER File (CT # C284), MS M992
EM/ER File, MS M992

CERTIFICATION

I certify under penalty of law that these documents and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violation.

Document Title: CMS Plan for PRS 16-021(c) (Former OU 1082 , FU 3)

Name: _____ Date: 9/29/98

Julie A. Canepa, Program Manager
Environmental Restoration Project
Los Alamos National Laboratory

or

Tom Baca, Program Director
Environmental Management
Los Alamos National Laboratory

Name: _____ Date: 9/29/98

Joseph Vozella,
Acting Assistant Area Manager of
Environmental Projects
Environment, Safety, and Health Branch
DOE-Los Alamos Area Office

or

Theodore J. Taylor, Program Manager
Environmental Restoration Program
DOE-Los Alamos Area Office

LIBRARY COPY

LIBRARY COPY

LA-UR-98-3918
September 1998

CMS Plan for Potential Release Site

16-021(c)

Environmental Restoration Project
A Department of Energy Environmental Cleanup Program

Los Alamos
NATIONAL LABORATORY
Los Alamos, NM 87545

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36.

TABLE OF CONTENTS

EXECUTIVE SUMMARY 1

1.0 INTRODUCTION 1
- 1.1 Purpose and Regulatory Context 1
- 1.2 Facility Location and Background 3
  - 1.2.1 Facility History and Operations 3
  - 1.2.2 PRS Description 5
  - 1.2.3 Land Use and Nearby PRSs 7
- 1.3 Conceptual Understanding and Approach 7
- 1.4 Special Problems 9
- 1.5 Plan Organization 10

2.0 SUMMARY OF RFI DATA 11
- 2.1 Source Area 11
- 2.2 Cañon de Valle Alluvial System 16
  - 2.2.1 Contaminant of Potential Concern Summary 16
  - 2.2.2 Contaminant Distribution 18
- 2.3 Subsurface Tuff and Subsurface Saturated System 18
  - 2.3.1 COPC Identification 18
  - 2.3.2 Extent of Contamination 20
  - 2.3.3 Spring & Well Dynamics 20
- 2.4 COPC Screening 21

3.0 CORRECTIVE MEASURES OBJECTIVES AND SCOPE 22
- 3.1 Setting 22
  - 3.1.1 Areal Extent and Administrative Boundary 22
  - 3.1.2 Four Component Conceptual Model 22
- 3.2 Remedial Approach 25
  - 3.2.1 Parallel Tracks of Action and Monitoring 25
- 3.3 Objectives of the Corrective Measures Study 26
  - 3.3.1 Investigation Objectives 26
- 3.4 Institutional Considerations 29
  - 3.4.1 Land Use 29
  - 3.4.2 Establishment of Media Cleanup Standards 29
  - 3.4.3 Points of Compliance 31
  - 3.4.4 Risk-Based Decision Approach 33
  - 3.4.5 Applicable Regulation and Requirement Evaluation 33

4.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES 34
- 4.1. Identification of Potential Remediation Technologies 36
- 4.2 Baseline Treatment Technologies 38
  - 4.2.1 Thermal Treatment (Incineration) 38
  - 4.2.2 Stabilization 39
  - 4.2.3 Containment Options 40
  - 4.2.4 Water Treatment with Granular Activated Carbon 40
- 4.3 Assessment of Additional Soil Treatment Technologies 41
  - 4.3.1 In Situ Anaerobic and Aerobic Biotreatment Options 41
  - 4.3.2 In Situ Natural Attenuation Applications 43
  - 4.3.3 In Situ Phytoremediation Applications 43
  - 4.3.4 In Situ Soil Flushing 44
  - 4.3.5 In Situ Chemical Oxidation 44
  - 4.3.6 In Situ Base Hydrolysis 45

4.3.7 In Situ Thermal Treatment 45
4.3.8 Ex Situ Soil Composting/Biopile Applications 46
4.3.9 Ex Situ Bioslurry Reactors....47
4.3.10 Ex Situ Soil Chemical Treatment Options 47
4.4 Assessment of Surface/Groundwater Treatment Technologies 48
4.4.1 Advanced Catalytic and Chemical Treatment....48
4.4.2 Reactive Treatment Material Applications 49
4.4.3 Reactive Barriers 49
4.4.4 Phytoremediation for Water Treatment 50
4.4.5 Bioreactors....50
4.6 Summary and Recommendations for Innovative Treatment Technology Studies....51

5.0 PROCESS AND CRITERIA FOR EVALUATION OF REMEDIATION ALTERNATIVES 52
5.1 Process 52
5.2 Potential Remediation Alternatives....52
5.3 Criteria 53
5.3.1 Performance and Reliability 54
5.3.2 Reduction of Toxicity, Mobility, or Volumes of Contaminants or Wastes....54
5.3.3 Effectiveness of Remedy in Achieving Target Concentrations....54
5.3.4 Timing of the Potential Remedy 54
5.3.5 Ease of Implementation 54
5.3.6 Long-Term Reliability....54
5.3.7 Impacts of Institutional Requirements on Remedy Implementation....54
5.3.8 Mitigation of Human Health and Environmental Exposures 54
5.3.9 Costs....55

6.0 PHASE III RFI INVESTIGATIONS 55
6.1 Objectives and Scope....55
6.1.1 Connectivity 56
6.1.2 Residence Times 56
6.1.3 Spring and Seep Dynamics 56
6.1.4 Alluvial Water Dynamics 56
6.1.5 Alluvial Sediment Dynamics....57
6.1.6 Other Data Campaigns....57
6.2 Approach and Implementation 57
6.3 Phase III Sampling and Analysis Plans....59
6.3.1 Connectivity 59
6.3.2 Residence Times 63
6.3.3 Spring and Seep Dynamics 66
6.3.4 Alluvial Water Dynamics 72
6.3.5 Alluvial Sediment Dynamics 78
6.4 Data Collection Procedures 80
6.4.1 Field Activities....80
6.4.2 Field Analytical Procedures....82
6.4.3 Sample Handling and Tracking 82
6.4.4 Laboratory Analytical Procedures....82

7.0 MONITORING PLAN APPROACH 83

8.0 REFERENCES 87

9.0 APPENDIX A A-1

10.0 APPENDIX B B-1

11.0 APPENDIX C **C-1**

12.0 APPENDIX D **D-1**

13.0 APPENDIX E **E-1**

14.0 APPENDIX F **F-1**

15.0 APPENDIX G **G-1**

LIST OF TABLES

Table 2.1-1. Average Concentration and Percent of Total Contamination in the TA-16-260 Outfall Drainage by Section and Medium 13

Table 4.1-1 Initial Technologies Identified for Consideration at LANL 37

Table 4.2-1 Cost and Performance of Common Baseline Treatment Technologies 39

Table 4.3-1 Summary Applicability of Soil Treatment Technologies 42

Table 4-4-1 Summary Applicability of Innovative Surface and Groundwater Treatment Technologies 50

Table 4.6-1 Technologies Recommended for Laboratory and Pilot Scale Application at LANL and Pantex 51

Table 6.3-1 Summary of Sampling and Analysis for the Connectivity Investigation at the TA-16-260 Outfall Source Area 63

Table 6.3-2 Summary of Annual Sampling and Analysis for the Residence Times Investigation at the TA-16 Springs and Seeps 66

Table 6.3-3 Summary of Annual Sampling and Analysis for the Investigation of Spring and Seep Dynamics[a] 71

Table 6.3-4 Summary of Annual Sampling and Analysis for the Investigation of Alluvial Water Dynamics* 78

Table 6.3-5 Summary of Sampling and Analysis for the Inventory Estimation in Cañon de Valle (Example only) 80

Table 6.4-1 LANL ER SOPs 81

Table 6.4-2 Summary of Requirements for Soil and Water Sampling 82

Table 6.4-3 Analyte Suites, Methods, and Protocols for Analysis of Soil and Water Samples 83

LIST OF FIGURES

Figure 1.2-1. Location of TA-16 with respect to Laboratory technical areas and surrounding landholdings. Building TA-16-260 is also shown. 4

Figure 1.2-2. Location of PRS 16-021(c) and associated physical features. 6

Figure 1.2-3. PRSs in the vicinity of PRS 16-021(c) 8

Figure 2.1-1. Phase I and phase II sampling locations for the TA-16-260 outfall source area. 12

Figure 2.1-2. Stratigraphy beneath the TA-16-260 outfall drainage. HE screening results in tuff below drainage channel are shown. 14

Figure 2.2-1. Sampling locations in Cañon de Valle. 17
Figure 2.3-1. Location map for deep boreholes and springs. 19
Figure 3.1-1. Administrative boundaries for PRS 16-021(c) CMS/CMI. 23
Figure 3.1-2. Simplified conceptual model for TA-16-260, PRS 16-021(c) contaminant dispersal. 24
Figure 6.3-1. Trench and vertical profile locations in the 260 pond. 62
Figure 6.3-2. (a) Cumulative rainfall plot for summer 1997 monsoon season; (b) hydrographic record for SWSC Spring, summer 1997 monsoon season. 64
Figure 6.3-3. Precipitation station location and isotope sampling locations (Cañon de Valle springs). 67
Figure 6.3-4. Extent of Peter Seep. 68
Figure 6.3-5. Perennial reach of Martin Spring Canyon and location of wetlands. 73
Figure 6.3-6. Temporary flume locations in Cañon de Valle. 76
Figure 6.3-7. Temporary flume locations in Martin Spring Canyon. 77

EXECUTIVE SUMMARY

This document is the Corrective Measures Study (CMS) Plan for proceeding with the selection of remedial alternatives for Potential Release Site (PRS) 16-021(c) (the 260 outfall), for evaluating the transport pathways that carry contaminants from that PRS to Cañon de Valle and Martin Spring Canyon, and for designing a long term monitoring program for active contaminant transport pathways. This PRS is located at Technical Area (TA)-16 at Los Alamos National Laboratory (LANL). Two phases of RCRA Facility Investigations (RFI) have been conducted for PRS 16-021(c) and environs. The information in these reports form the basis for scoping the issues to be addressed by the CMS and for identifying remedial alternatives that are likely to be effective in reducing potential impacts to human health and the environment to acceptable levels. This CMS Plan is an element of the RCRA Corrective Action Process, which typically consists of a RCRA Facilities Assessment (RFA), an RFI, the CMS Plan, the CMS, and the Corrective Measures Implementation (CMI).

TA-16 is located on a mesa in the southwest corner of LANL. The TA-16-260 facility is a High Explosives (HE) machining building that processes production quantities of high explosives. Machine turnings and HE washwater are routed as waste to thirteen sumps associated with the building. Historically, discharges from the sumps were routed to an outfall that was permitted under LANL's National Pollutant Discharge Elimination System (NPDES) by the Environmental Protection Agency (EPA). Discharge from this outfall contaminated with HE waste and barium was reportedly as high as several million gallons per year. Consequently, the outfall and drainage channel from the outfall are contaminated with high levels of HE, and barium, and with low levels of many other constituents. Waters in nearby springs — SWSC Spring, Burning Ground Spring, and Martin Spring — and Cañon de Valle are also contaminated with HE and other constituents.

The impacts of the discharges from TA-16-260 have extended beyond the boundaries of the PRS necessitating that investigations and remedial actions be considered at scales larger than the PRS. The administrative boundary for this CMS includes the entire Cañon de Valle basin, which extends east to the confluence of Canon de Valle and Water Canyon and south to Martin Spring Canyon, The conceptual model for contaminant dispersal from PRS 16-021(c) includes four components: the contaminant source area, the subsurface, the transport pathways and springs, and the alluvial system in the canyon bottom. The four components are combined into one conceptual model because transport mechanisms result in interactions among the components. Contaminants in the source area impact the unsaturated subsurface, which impacts the springs and seep, which impact the alluvial system. Changes in one component of the model is likely to affect other downgradient components as well.

Actions have been proposed for TA-16-260 that dovetail with the site conceptual model components. The source area is proposed for an Interim Measure (IM) removal in the Phase II RFI Report to remove this major contaminant source at TA-16 from further opportunity for transport into the physical system. This CMS Plan focuses on those portions of the conceptual model that will remain in the environment following the IM.

This CMS Plan provides:

1. A preliminary evaluation of technologies that can be applied to the source area contaminated soils, alluvial sediments, spring waters and surface water,

2. A process and criteria for evaluating remedial alternatives

3. A Phase III sampling and analysis plan to characterize contaminant transport through the mesa, to the springs and to the alluvial system,

4. A design strategy for long-term monitoring to assess trends in contaminant concentrations and fluxes over time.

HE treatment technologies were evaluated through an Innovative Treatment Remediation Demonstration (ITRD) project. The ITRD panel evaluated both baseline and innovative technologies. Baseline technologies under consideration include granular activated carbon (GAC) for water. Technologies recommended for further investigation, including site-specific laboratory and bench scale studies, include: ex-situ stabilization, zero-valent iron and other chemical treatments, and anaerobic bioslurry for sediments, and passive barriers and phytoremediation for waters. LANL will also share the results of laboratory and pilot scale studies performed at Pantex as part of the ITRD project.

Phase III sampling focuses on five issues: 1) connectivity between the TA-16-260 source region and nearby springs and seeps; 2) residence times of water in the saturated subsurface at TA-16; 3) the dynamics of flow and contaminant concentrations in springs and seeps; 4) the dynamics of the alluvial water system; and 5) contaminant inventories in the alluvial sediment system. These issues are being addressed via extensive sampling for contaminants, stable isotopes and geological/geophysical parameters in springs, seeps, alluvial waters, and alluvial sediments in the Cañon de Valle basin.

Questions remain regarding the impacts of the 260 outfall upon perched aquifers and the regional aquifer. Impacts to deeper groundwater will be estimated using the Phase III sampling results. The scale of these questions exceeds TA-16 and is being addressed in collaboration with the site-wide hydrogeological investigations for the laboratory. A deep well is being drilled on the mesa east of PRS 16-021 (c) and another is planned for the confluence of Cañon de Valle and Water Canyon. Information gained from these wells and larger scale modeling may also be used to assess the impacts PRS 16-021(c) upon groundwater resources.

1.0 INTRODUCTION

This document presents an evaluation of possible remediation alternatives and describes additional data needs for potential release site (PRS) 16-021(c), which is located at Los Alamos National Laboratory's (LANL's) Technical Area (TA) 16. This site, and the associated hydrogeologic system including Cañon de Valle, represents a significant potential risk to human health and the environment; hence, it is being evaluated in a corrective measures study (CMS) and will undergo a corrective measure implementation (CMI) (LANL 1996, 55077). The high explosives- (HE) contaminated source region at PRS 16-021 (c) will be removed in an interim measure (IM) during fiscal years (FYs) 1999 and 2000. The IM plan will be delivered as a separate document during FY99. The IM will be conducted independently of, and concurrently with, the CMS. However, results of the CMS technology evaluations may be used as part of the IM waste management design. If source removal during the IM is successful, the CMS will focus primarily on surface water and the alluvial system in Cañon de Valle.

LANL is a multidisciplinary research facility owned by the Department of Energy (DOE) and managed by the University of California. LANL is located in north-central New Mexico, approximately 60 miles northeast of Albuquerque and 20 miles northwest of Santa Fe. The LANL site covers 43 square miles of the Pajarito Plateau, which consists of a series of fingerlike mesas separated by deep canyons that contain ephemeral and intermittent streams running from west to east. Mesa tops range in elevation from approximately 6200–7800 ft. The eastern portion of the plateau stands 300–900 ft above the Rio Grande.

LANL's Environmental Restoration (ER) Project is involved in a national effort by the DOE to clean up facilities that were historically involved in weapons production. The goal of the ER Project is to ensure that DOE's past operations do not threaten human health, safety, or the environment in and around Los Alamos County, New Mexico. To achieve that goal, the ER Project is currently investigating sites potentially contaminated by past operations.

1.1 Purpose and Regulatory Context

This multi-phase investigation, including sampling and analysis, is being conducted under the requirements of the Resource Conservation and Recovery Act (RCRA). Los Alamos National Laboratory's ER Project is implementing a corrective action program for PRS 16-021(c) in accordance with requirements stipulated in the Hazardous and Solid Wastes Amendments (HSWA) of 1984, Permit (Module VIII). Appendix F presents a crosswalk of HSWA Permit requirements and the locations in this CMS plan (or other documents) where these requirements are satisfied or addressed.

The RCRA corrective action program at PRS 16-021(c) is being implemented in phases. The following is a list of the activities that have been, or will be, accomplished in each phase.

- RCRA facility assessment (RFA) – initial site assessment
- RCRA facility investigation (RFI) – site characterization
- Interim measure– control or abatement of ongoing risks
- Corrective measures study– evaluation of alternatives
- Corrective measure implementation–implementation of the selected alternative

This document is the CMS plan for proceeding with the selection of remedial alternatives for PRS 16-021(c) (the 260 outfall) and for evaluating the transport pathways that carry contaminants from that PRS to Cañon de Valle and the informally-named Martin Spring Canyon. The RFA and two phases of RFI have been conducted for PRS 16-021(c) (LANL 1996, 55077; Environmental Restoration Project 1998 in preparation). The information in these reports forms the basis for scoping the issues to be addressed by the CMS and for identifying remedial alternatives that are likely to be effective in reducing potential impacts to human health and the environment to acceptable levels. The purposes of the CMS plan are to:

- delineate the area under consideration for the CMS,
- describe current conditions at the facility,
- describe the general approach to investigation and potential remedies,
- define the overall objectives of the study,
- identify specific remedies to be studied that have a high likelihood of being effective given site-specific conditions,
- describe any pilot- or bench-scale studies necessary,
- describe a process for detailed evaluation of alternatives,
- identify additional data needs,
- present a Phase III investigation sampling plan to satisfy those needs,
- propose the schedule for conducting the studies, and
- propose the outline of the CMS report.

A major component of the CMS will be to collect contaminant data for active transport pathways that support the human health and ecological site-specific risk assessments. If remediation is necessary, these data will be used to develop specifications for remedial technologies.

The CMS will also provide a design for a long-term monitoring program for the Cañon de Valle basin. Long-term monitoring is necessary because contamination will likely remain in the subsurface and Cañon de Valle alluvial system after the PRS 16-021(c) remediations are completed. In addition, there are other contaminant sources to Cañon de Valle that may be impacting the active transport pathways. Monitoring will show the effects of the source removal and support site management decisions regarding the need for further actions.

The 260 outfall, pond area, and drainage are a major contaminant source for the active transport pathways. This source area is proposed for an IM in the Phase II RFI Report (Environmental Restoration Project 1998, in preparation). Consequently, the planning and design for the IM will occur separately from the CMS and CMI. The IM plan will describe a post-removal characterization of the outfall area that will be used during the CMS and CMI.

1.2 Facility Location and Background

TA-16 is located in the southwest corner of the Laboratory (Figure 1.2-1). It contains 2 410 acres or 3.8 square miles. The land is a portion of that acquired by the Department of Army for the Manhattan Project in 1943. TA-16 is bordered by Bandelier National Monument along State Road 4 to the south and the Santa Fe National Forest along State Road 501 to the west. To the north and east, it is bordered by TAs 8, 9, 14, 15, and 49. TA-16 is fenced and posted along State Road 4. Water Canyon, a 200-ft-deep ravine with steep walls, separates State Road 4 from active sites at TA-16. Cañon de Valle forms the northern border of TA-16. Security fences surround the production facilities. A complete discussion of the environmental setting for TA-16 is presented in Appendix B of the Phase II RFI Report for TA-16-260 (Environmental Restoration Project 1998, in preparation).

TA-16-260 is located on the north side of TA-16 (Figure 1.2-1). The structure was originally built in 1951, with only minor modifications to the structure since then.

1.2.1 Facility History and Operations

TA-16 was established during World War II to develop explosive formulations, cast and machine explosive charges, and assemble and test explosive components for the US nuclear weapons program. Almost all of the work was conducted in support of the development, testing, and production of explosive charges for the implosion method. Current use of this site is essentially unchanged, although facilities have been upgraded and expanded as explosive and manufacturing technologies have advanced.

The TA-16-260 facility is an HE machining building that processes large quantities of HE. Machine turnings and HE washwater are routed as waste to 13 sumps associated with the building. Historically, discharges from the sumps were routed to an outfall that the Environmental Protection Agency (EPA) permitted under the Laboratory's National Pollutant Discharge Elimination System (NPDES). The outfall and drainage channel from the outfall are contaminated with HE waste and barium. The NPDES outfall was deactivated in November 1996, and its NPDES permit (EPA 05A056) was deleted in January 1998. The sumps, drain lines, and troughs of this facility have been designated as PRS 16-003(k), and the outfall, pond area, and drainage as PRS 16-021(c). PRS 16-021(c) is the focus of this report. PRS 16-003(k) was addressed in the Phase I RFI report for this facility, as discussed in Section 1.3, Previous Investigations.

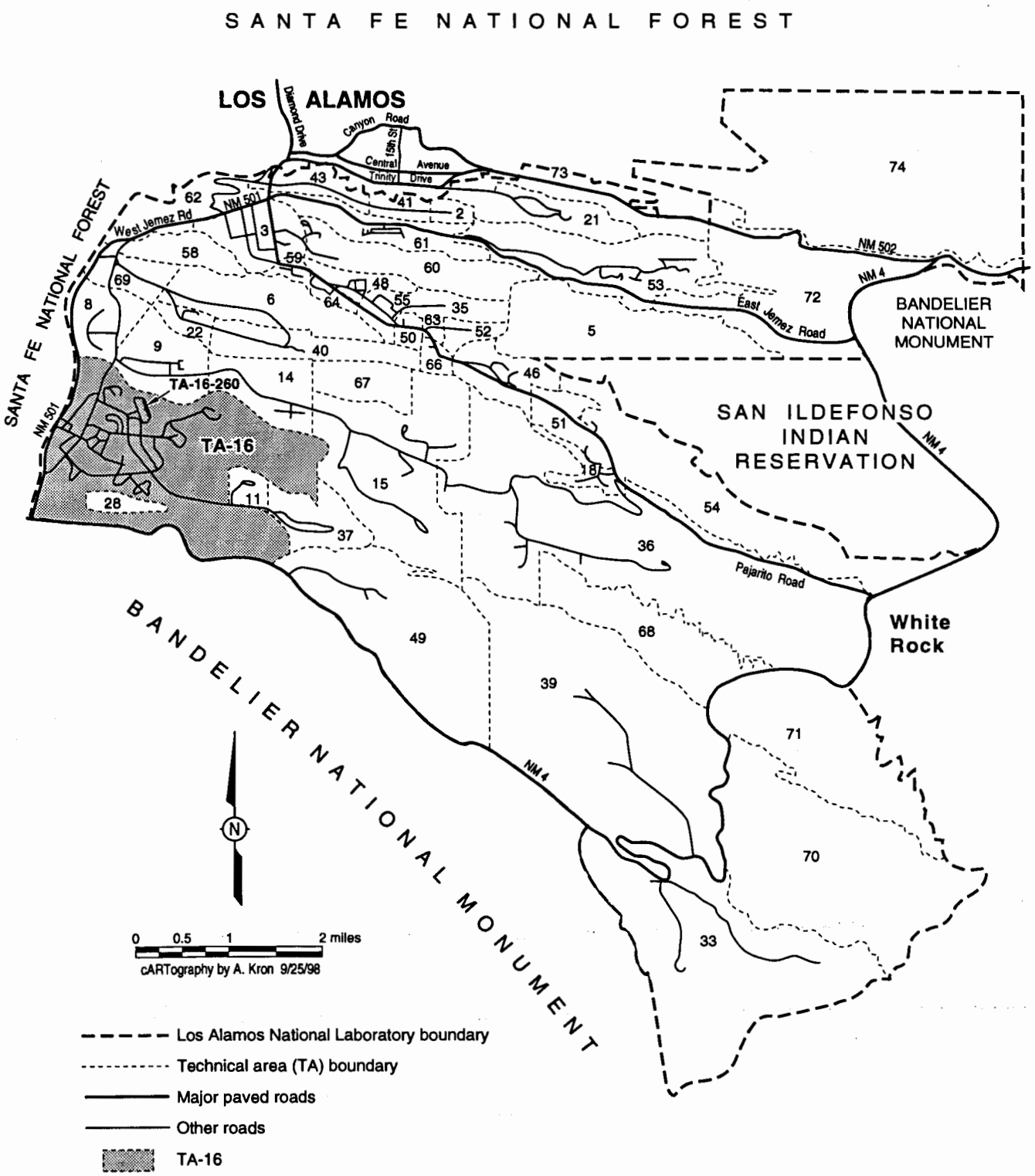


Figure 1.2-1 Location of TA-16 with respect to Laboratory technical areas and surrounding landholdings. Building TA-16-260 is also shown.

1.2.2 PRS Description

The PRS consists of the outfall and the drainage associated with PRS 16-003(k), the 13 HE sumps on the northeast side of TA-16-260 (Figure 1.2-2). HE-contaminated water from the outfall entered a pond about 40 ft from the outfall. The small pond is approximately 55 ft long and was formed by a rock dam located 93 ft from the outfall. The longitudinal axis of the former pond is oriented east-west, with flow in the easterly direction. The dam is about 9-ft thick, but only the first 2 ft of rock are closely packed. At present there is no perennial water in the pond, although the soil and sediment are wet sporadically. Rainwater from the roadway on the northeast side of TA-16-260 also flowed into the pond before an interim action was performed in 1995 and 1996 to divert all runoff to and from the pond area. The drainage channel from the outfall flows approximately 600 ft to the bottom of Cañon de Valle over a drop in elevation of 80 ft. The drainage channel from the outfall is well defined, with apparent high-water marks. The water flows over a 15-ft-high cliff approximately 400 ft from the outfall.

HE contamination in the outfall and drainage area has been recognized since at least 1960, when the first known soil samples from the outfall were analyzed. Contaminants known to be present before RFI investigations included barium, and the HEs RDX, TNT, and HMX. RFI investigations confirmed these constituents and identified additional constituents of concern. These additional constituents include: DNT, amino-DNT, TNB, acetone, chloromethane, dichloroethane, isopropyltoluene, tetrachloroethene, trichloroethene, anthracene, bis(2-ethylhexyl)phthalate, butylbenzylphthalate, copper, cadmium, chromium, cobalt, lead, nickel, silver, vanadium, uranium, and zinc.

Stressed vegetation is evident within the PRS boundaries between the rock dam and the cliff. There are a few dead trees in Cañon de Valle, possibly associated with TA-16-260 discharge, downstream from PRS 16-021(c).

HE, barium, and low levels of other constituents have been observed in waters at Sanitary Wastewater System Consolidation (SWSC) Spring, Burning Ground Spring, and Martin Spring, in surface and alluvial waters in Cañon de Valle, and in intermittent perched waters observed during drilling (Figure 1.2-3). RDX is observed most frequently and presents the most significant potential risk to human health. Constituent concentrations in water vary significantly with season and with flow rates of the springs and surface water.

A series of best management practices (BMPs) were instituted at PRS 16-021(c) during 1995 and 1996 as an Interim Action (LANL 1996, 53838). These BMPs were implemented when a significant amount of inorganic and HE contamination became evident in nearby springs and surface waters. The BMPs consist of four engineered controls:

- a sandbag dam and diversion pipe upgradient from the former HE pond,
- a sandbag dam east of the parking lot behind TA-16-260,
- geotextile fabric matting in the former HE pond area, and
- straw-bale check dams within the PRS drainage between the rock dam and the 15-ft-high cliff.

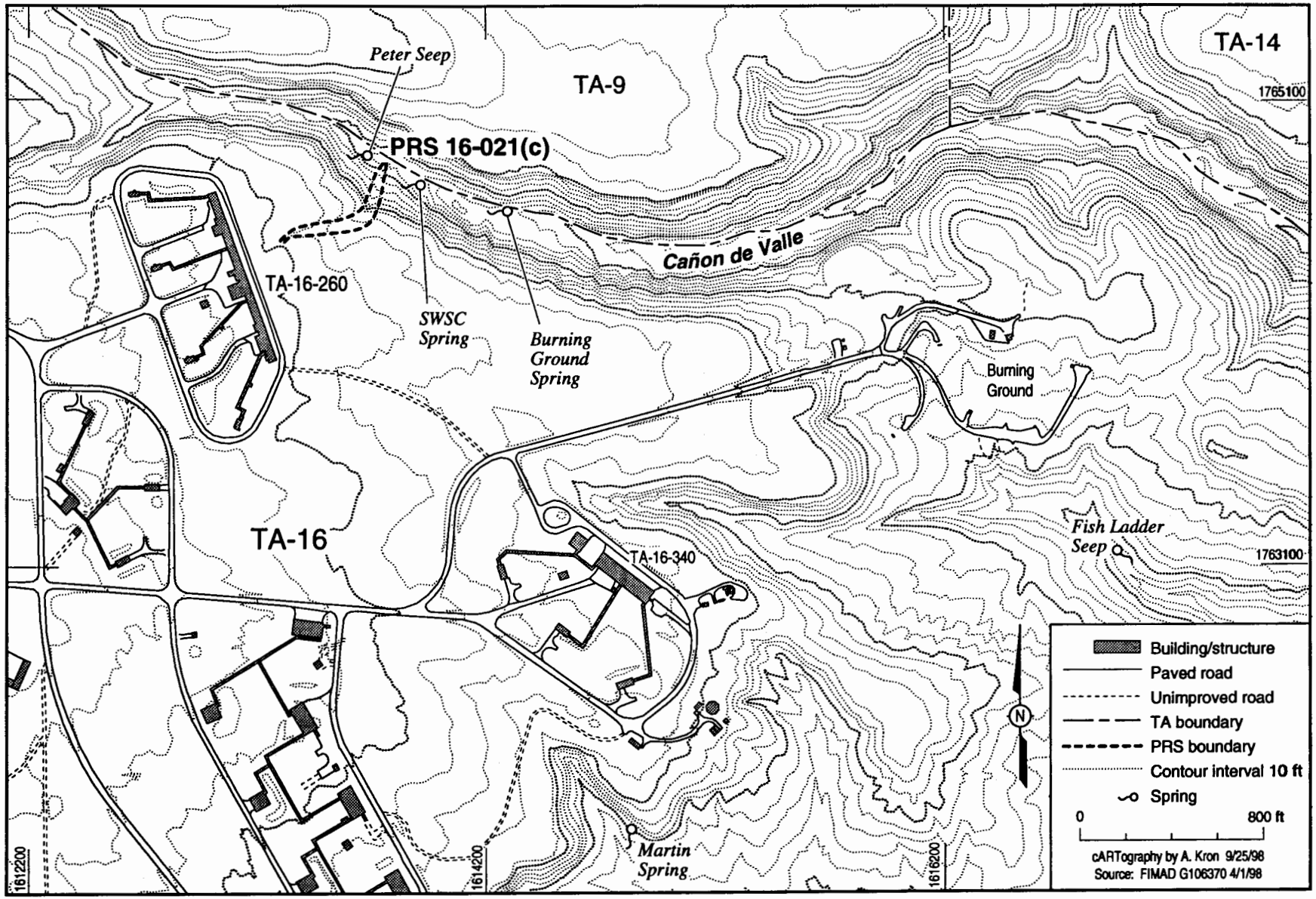


Figure 1.2-2 Location of PRS 16-021(c) and associated physical features.

The rationale for these BMPs is to minimize infiltration in the 260 pond area and runoff from the PRS, thereby decreasing contaminant migration to surface water and groundwater. Casual contact with contaminants by the public or workers is extremely unlikely because the outfall is in a restricted access area and all activity behind the 260 building is forbidden during operations. These BMPs are inspected regularly (at least quarterly) and are maintained and upgraded to ensure that runoff from this site are minimized.

1.2.3 Land Use and Nearby PRSs

The land adjacent to PRS 16-021(c) is dedicated to continued Laboratory operations. PRSs in the vicinity of the 260 outfall are shown in Figure 1.2-3. Several sites with the greatest potential influence on the 260 outfall investigation include the following:

- MDA-R (PRS 16-019). This site is a material disposal area (MDA) located north of the TA-16-260 outfall area. MDA-R was constructed in the mid-1940s and used as a burning ground for waste explosives and possibly other debris. Potential contaminants at this disposal area include HE, HE byproducts, and metals (particularly barium). The site was abandoned in the early 1950s.

- TA-16 Burning Ground [PRSs 16-010(a–n), 16-016(c)]. This site is located on a level portion of the mesa in the northeast corner of TA-16. The burning ground was constructed in 1951 for HE waste treatment and disposal. Over the years many hundreds of thousands of pounds of HE and HE-contaminated waste material have been burned at this location. The remaining noncombustible material was subsequently placed in the MDA-P landfill north of the burning ground (through 1984) or taken to TA-54 for disposal (1984 to present). A barium nitrate pile was located at the TA-16 Burning Ground for many years.

- MDA-P (PRS 16-018). This site is a material disposal area that contains wastes from the synthesis, processing, and testing of HE, residues from the burning of HE-contaminated equipment, and construction debris. HE waste disposal activities at this site started in the early 1950s and ceased in 1984. The site is located on the south slope of Cañon de Valle. MDA-P is currently subject to RCRA clean closure activities, and will be removed by 1999.

These three sites may contain similar contaminants to those found in PRS 16-021(c), and all drain into Cañon de Valle.

1.3 Conceptual Understanding and Approach

Overall, the approach to the RFI/CMS process at the 260 outfall has focused on source identification, including delineation of soil and sediment contamination, and confirmation of groundwater and surface water contamination. In this process data were evaluated to determine if contamination is present, if contamination presents a threat to human health or the environment, if contamination has been sufficiently delineated, and what further action is needed. Because data evaluation presented in both the Phase I RFI report (LANL 1996, 55077) and the Phase II RFI report (Environmental Restoration Project 1998, in preparation) shows contaminant concentrations in the outfall area to be a source of ongoing potential risk, an IM will be conducted to mitigate further contaminant transport from the source area. Once the IM is complete and the source area is removed, potential impacts to groundwater and/or surface water quality will continue to be evaluated during the CMS process and in a site-specific risk assessment (SSRA).

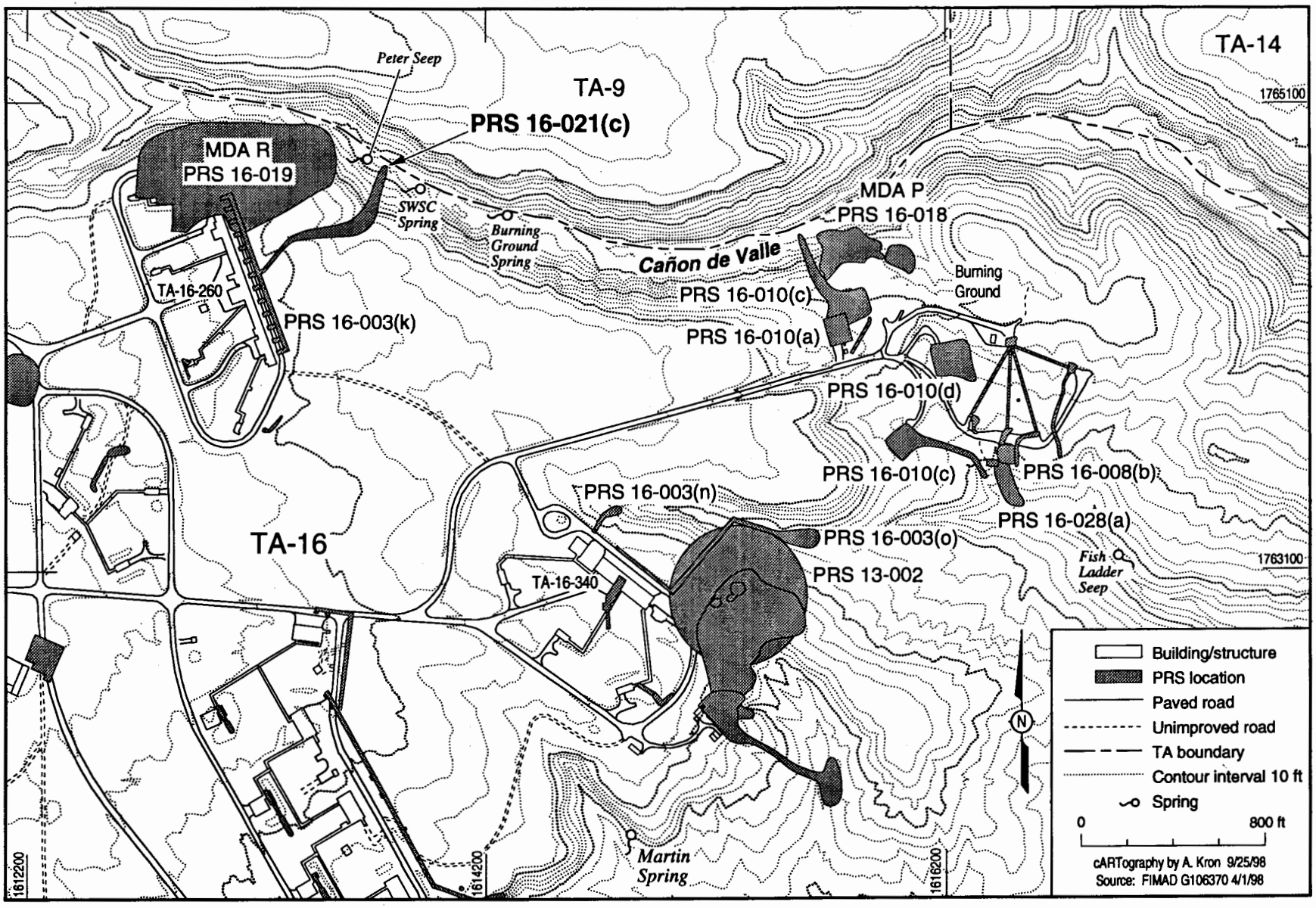


Figure 1.2-3 PRSs in the vicinity of PRS 16-021(c).

According to the 1995 Update of the LANL Site Development Plan (LANL 1995, 57224) future land use at TA-16 is designated for industrial operations, such as HE research and development and testing. Most of the areas of TA-16 are active sites for the Engineering Sciences and Applications Division of the Laboratory, and construction of new buildings and other facilities in the area is possible. On-site workers (individuals who work on or near the site) and construction workers (individuals who would be exposed to near-surface and subsurface soils through various activities, including excavation) are considered the most likely individuals to be exposed. They are therefore used in the exposure scenarios that will be evaluated in the human-health screening assessment and the SSRA.

In order to complete the CMS process at the site, the following activities and associated documents are proposed:

1. The Phase II RFI report (FY98). The Phase II RFI report includes data assessment, conceptual model development, and both human-health and ecological screening assessments. This report will also include a recommendation for a source removal IM, targeted for completion in FY2000. Removal of the highly contaminated source material at this outfall will alleviate additional transport of contaminants into the subsurface and alluvial systems in Cañon de Valle. Because additional data will be required to complete the conceptual model and SSRA, the SSRA for the site will be delayed until this information is available.

2. The CMS plan and Phase III sampling plan. This document, the CMS plan, proposes an approach for selecting remedial approaches that will mitigate potential risks to human health and the environment and proposes Phase III investigations at the site to further evaluate contaminant pathways and prepare for the human-health and ecological site-specific risk assessments.

3. IM plan and implementation. A plan detailing the source removal effort will be prepared to accomplish an IM source removal of several thousand cubic yards of highly contaminated material in FY99 and FY2000. This plan will consider both risk-based cleanup levels and practical engineering approaches. The plan will include a sampling and analysis plan (SAP) to characterize the extent of contamination remaining in the environment following source removal. This information will be included in the risk assessment and CMS efforts to follow.

4. Phase III RFI/IM report. A report documenting the results of the Phase III data collection, conceptual model refinement, and IM efforts will be prepared. This report will include both human-health and ecological risk SSRAs to be used during the final CMS process to follow. This report may be submitted concurrently with the CMS report.

5. CMS report. A CMS report will be prepared that evaluates the remedial alternatives for contaminants remaining in the unsaturated subsurface, the alluvial system in Cañon de Valle (both surface and alluvial water), and groundwater. Long-term monitoring requirements will also be addressed in this report.

1.4 Special Problems

Based on current understanding of the site, the conceptual model for the 260 outfall includes a highly complex set of contaminant transport pathways and hydrogeologic features. Contaminant transport pathways are structurally controlled in the underlying Bandelier Tuff by fractures and other preferential

pathways such as surge beds between tuff units. Major uncertainties in the conceptual model result from this complexity, particularly regarding the location of saturated zones in the subsurface and associated contaminant pathways at the site. The presence of these saturated zones may also be seasonal or episodic. Further study of the site is warranted to understand the dynamics of contaminant transport and to demonstrate the effects of remedial actions. Even as more data are collected at the site, significant uncertainties may remain in the conceptual model. It is not necessary or feasible to determine the exact extent of contamination at the site in a detailed and spatially explicit manner. Extent can only be described in a gross sense based on current understanding and on monitoring data as it is obtained. Sufficient understanding of the site will be obtained for the purposes of selecting and implementing remedial approaches that will mitigate risks to human and ecological receptors.

1.5 Plan Organization

This CMS plan is organized into seven chapters and seven appendices. The first chapter is this introduction. The second chapter is a summary of the RFI investigations that have been performed and reported to-date. Chapter 3, The Corrective Measure Objectives and Scope, defines the objectives of the CMS and delineates the setting and institutional considerations.

Chapter 4 of this document identifies and selects remedial approaches that are likely to be successful in meeting corrective action objectives. Technologies for treating source area wastes generated during the IM are also evaluated in Chapter 4. Information on the effectiveness of these technologies will be provided to the IM project.

Chapter 5 provides the criteria to be used for comparing and selecting remedial approach alternatives. Most of the criteria are taken from Module VIII of the HSWA Permit (EPA 1990, 01585). Additional criteria relevant to site management decisions at the Laboratory are identified.

Chapter 6 addresses additional data needs for characterization of the active transport pathways, including connections from the source area to the seep and springs, dynamics of the seep and springs, discharge profiles of Cañon de Valle surface water, surface water–alluvial water interactions, and contaminant concentrations and inventories in sediments. Results of the sampling and analysis program will be used for the human-health and ecological SSRAs and for designing the monitoring program.

Chapter 7 presents an approach for designing the long-term monitoring program. It is not possible to develop a specific design for the monitoring program without analyzing and interpreting the data collected through implementation of the SAP described in Chapter 6. The considerations outlined in Chapter 7 can be used to guide the analysis and interpretation of the data.

Appendix A is a glossary and list of acronyms. Appendix B is a schedule for the CMS/CMI process at PRS 16-021(c). Appendix C is a proposed outline for the CMS report. Appendix D describes project management roles and responsibilities. Appendix E describes cost/benefit and risk/benefit considerations that will be applied in the CMS report. Appendix F contains excerpts from LANL's HSWA Module to the RCRA permit. Appendix G contains hard copies of the references cited in this report.

2.0 SUMMARY OF RFI DATA

The summary of the RFI data are broken into three subsections that correspond to the more detailed results that were reported in the Phase II RFI report (Environmental Restoration Project 1998, in preparation). The three subsections are entitled:

- Source Area,
- Cañon de Valle Alluvial System, and
- Subsurface Tuff and Subsurface Saturated System.

2.1 Source Area

Sampling at the source area included collection of surface and near-surface samples of drainage sediments in the outfall area from the outfall itself to Cañon de Valle and also sampling in 15 boreholes drilled in or near the drainage (Figure 2.1-1). The main contaminants identified in the drainage sediments were the major constituents of HE, including barium, HMX, RDX, and TNT, at percent levels, particularly in the ponded area, and other HE, including DNT, amino-DNT, and TNB, at lower levels. In addition, a number of other chemicals were found in these sediments with trends similar to those of the major contaminants. Inorganic chemicals included copper, cadmium, chromium, cobalt, lead, nickel, silver, vanadium, uranium, and zinc, and possibly arsenic, mercury, and manganese. These inorganic chemicals were compared with BVs and were present at levels up to five times BVs in the sediment samples, but some only appear above background in subsurface samples from the boreholes, and generally at less than twice the BVs. The significant non-HE organics in the surface/near-surface were bis(2-ethylhexyl)phthalate and anthracene. Other phthalates and polycyclic aromatic hydrocarbons(PAHs) were detected at much lower levels in subsurface samples where detection levels were not inflated (as they were for some of the sediment samples) by extremely high concentrations of HE. Other organics in the subsurface were detected sporadically and/or at very low levels, although acetone was reported in many samples.

The highest concentrations of HE and barium, as well as of the other chemicals mentioned above, were found in samples collected down the center of the drainage above the soil/tuff interface, particularly within 300 ft of the outfall. Lateral bounding samples within 12 ft of the centerline were sometimes contaminated, especially with HE and barium, but at much lower levels. Almost no surface contamination was found outside the drainage proper.

Collocation among almost all of the contaminants was pronounced in the surface/near-surface samples; exceptions are the inorganics more tentatively identified above (arsenic, manganese, and mercury). Most showed a marked decrease between the pond area and the lower end of the drainage. Barium, however, was found in the 1–3% range all the way down into Cañon de Valle. The average levels of HMX, although not as high as in the pond area, are close to 1% even at the lower end of the drainage, which is more than 400 ft from the outfall. The area affected by the outfall also widens lower in the drainage (approximately 300–400 ft from the outfall); percent levels of barium, as well as HMX at concentrations exceeding 1000 mg/kg, were reported in some of the lateral bounding samples 200–600 ft from the outfall.

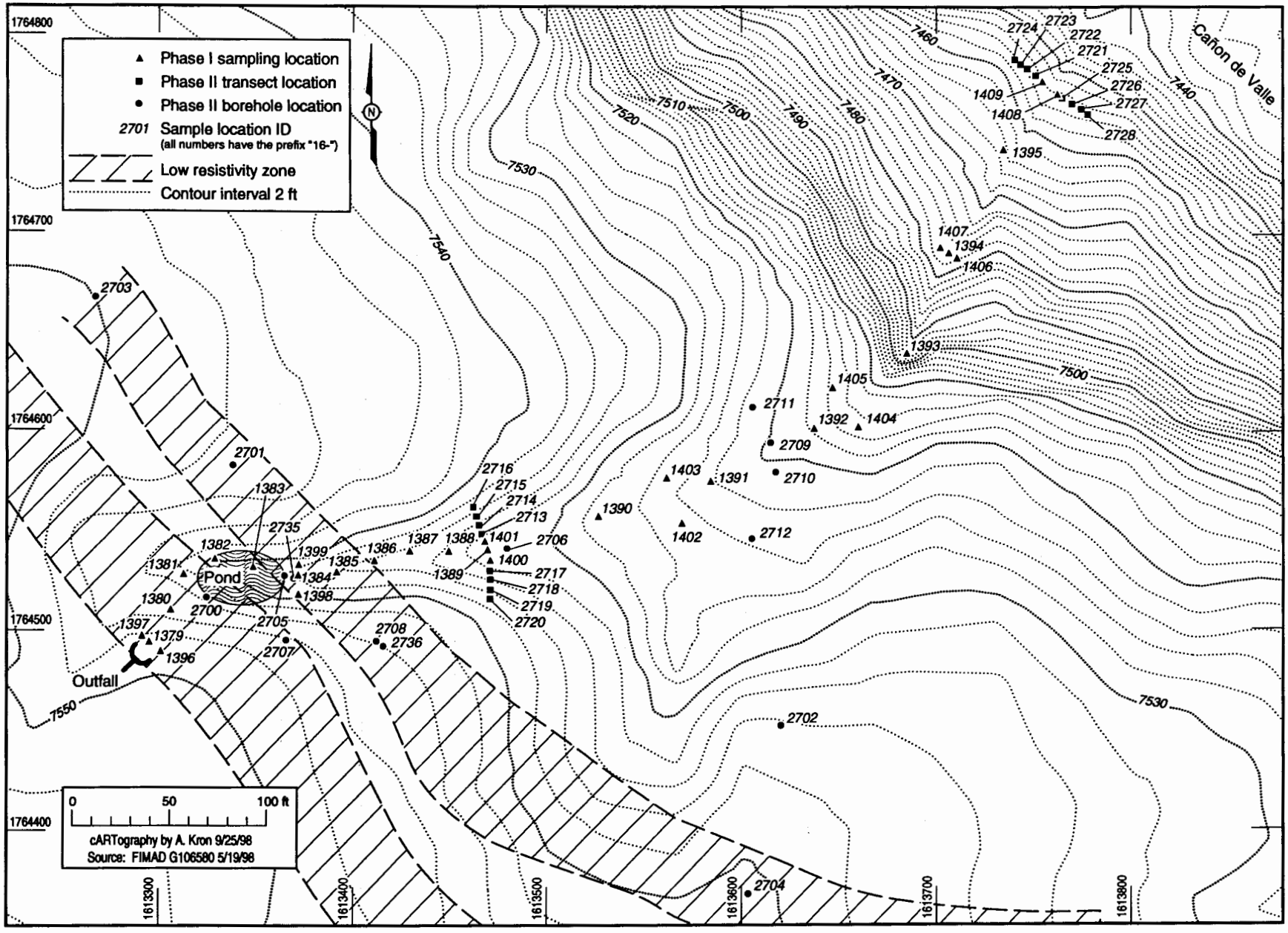


Figure 2.1-1 Phase I and Phase II sampling locations for the TA-16-260 outfall source area.

Collocation of contaminants is not so readily demonstrated in the subsurface data, in part because most of the minor contaminants are found only sporadically and at low levels, if at all, in these data. However, the six boreholes drilled within the drainage account for the great majority of detected or above-background subsurface results for both HE and other chemicals.

The trends seen in these data suggest that the planned IM removal action, targeting sediments in the first 400 ft of the drainage, plus up to 20 ft of tuff beneath the pond or an additional 100 ft down drainage from the pond, will be highly effective. Not only will the IM remove the bulk of the HE and barium contamination, but also most of the contamination associated with other organic and inorganic compounds. The numbers in Table 2.1-1 are approximate, but they show that 80–95% of the major contaminants at the TA-16-260 outfall reside in the sediments between the outfall and the 15-ft cliff where the drainage drops into Cañon de Valle, approximately 420 ft below the outfall. Most of the remaining barium and HMX is in the sediments on the slope of Cañon de Valle, while the remaining RDX and TNT is largely in the tuff beneath the pond.

Table 2.1-1. Average Concentration and Percent of Total Contamination in the TA-16-260 Outfall Drainage by Section and Medium

	Volume (yd^3)	Barium (mg/kg)		HMX (mg/kg)		RDX (mg/kg)		TNT (mg/kg)	
		Average	%	Average	%	Average	%	Average	%
Sediments: Outfall to pond	90	8 700	5.4	4 700	1.1	20 400	9.9	9 500	10.4
Sediments: Pond to 260 ft from outfall	570	15 100	57.8	60 300	88.3	27 500	83.2	11 600	79.0
Qbt5: Pond to 260 ft from outfall	180	240	2.8	270	1.2	660	6.0	510	10.4
Sediments: 260– 420 ft from outfall	200	16 200	19.4	9 800	4.5	550	0.5	70	0.1
Qbt5: 260– 420 ft from outfall	1710	90	0.8	2	0.0	1	0.0	0	0.0
Sediments: more than 420 ft from outfall	1330	10 300	13.9	9 600	5.0	350	0.4	21	0.0

For conceptual model development, the key stratigraphic features noted in source area boreholes are the soil/tuff interface, the upper surge bed that separates unit Qbt4 from unit Qbt5, the powder unit within the Qbt4 unit, and, in the deepest holes, another surge bed near the bottom of the Qbt4 (Figure 2.1-2). Consolidated strata between the soil/tuff interface and the upper surge bed, between this surge bed and the top of the powder unit, and below the powder unit include partially, moderately, and densely welded tuffs. These variations in welding appear to influence the transport of contaminants away from the outfall. In particular, each of the layers of moderately to densely welded tuff appears to correspond to at least 1 order of magnitude drop in levels of HE contamination: from percent levels to less than 1000 mg/kg across the soil/tuff interface, to less than 5 mg/kg below the upper surge bed, and finally to below detection levels at the bottoms of the deeper boreholes.

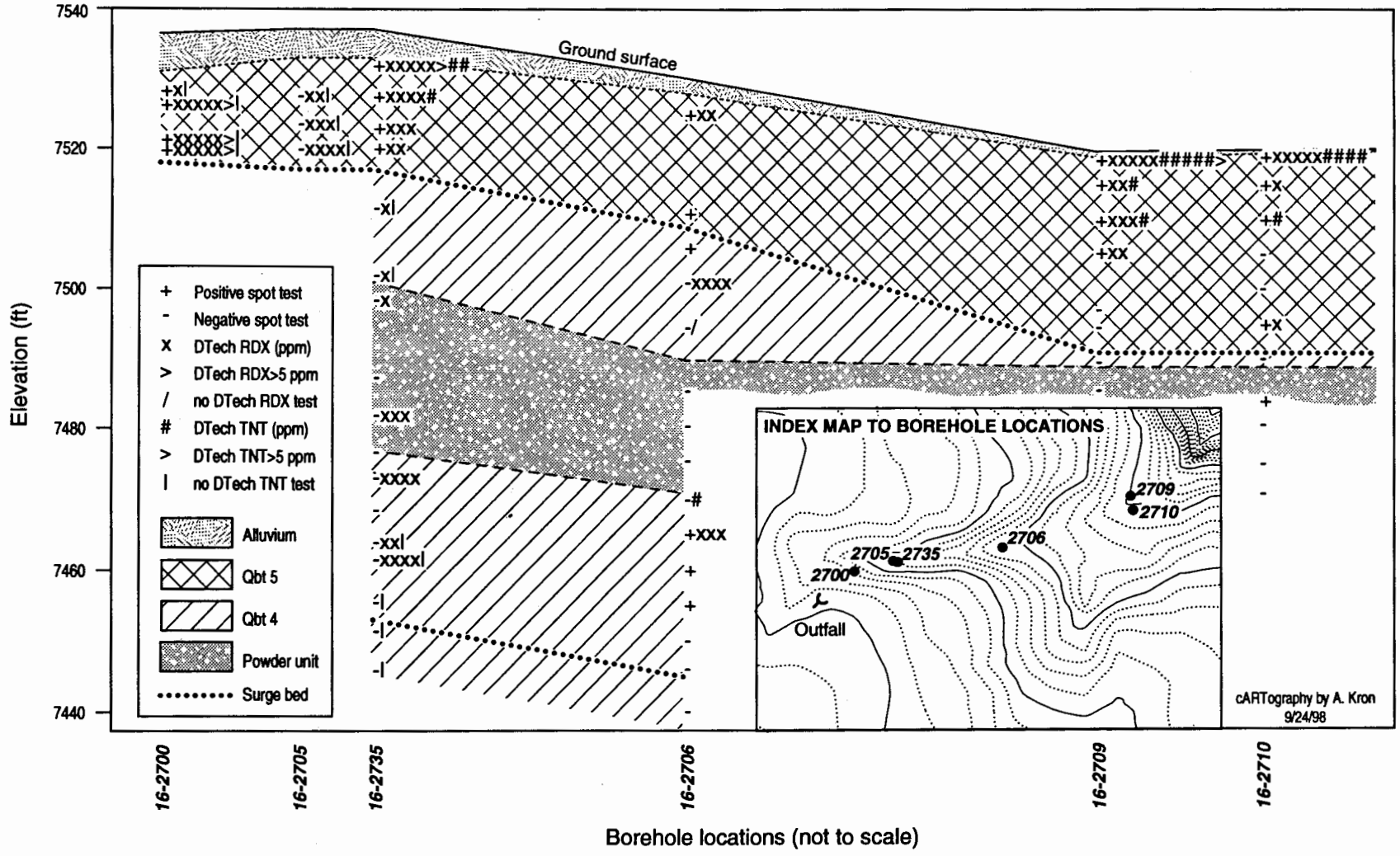


Figure 2.1-2 Stratigraphy beneath TA-16-260 outfall drainage. HE screening results in tuff are also shown.

Field HE screening samples, collected at the rate of approximately one sample per five feet of core, provide the most complete set of downhole observations, although the results are only semiquantitative and exhibit a fairly high false positive rate. These results suggest the following:

- significant levels of HE contamination between the soil/tuff interface and the upper surge bed in the six boreholes within the drainage, particularly in the boreholes drilled in and just below the ponded area,
- some contamination, but at much lower levels, at the top of Qbt4 below the upper surge bed, both within the drainage and in some of the holes to the south and east of the pond,
- relatively few positive readings in the powder unit, even in the drainage boreholes,
- a rise in contamination at the base of the powder unit, again in holes to the south of the drainage, as well as in the two holes within the drainage that penetrate to this depth, and
- clean intervals at the bottom of most boreholes.

The laboratory data are much sparser than field data, but they provide additional information. Screening results, whether positive or negative, are not always confirmed, but positive results in which the screening results were negative (relative to a nominal detection level of 0.5 mg/kg for the field screening kits) do not exceed 3.5 mg/kg and are generally less than 1.5 mg/kg. These results provide some confidence that the vertical extent of contamination near the source area has, in fact, been bounded at 70–100 ft below the surface.

Based largely on samples from a single borehole at the upper end of the ponded area, the upper surge bed appears to be a preferential pathway for contamination, with connections to the surface that were not intercepted during drilling. One of these samples was a saturated sample from which the liquid evaporated before analysis, and the analytical results showed not only very high levels of HE and other previously-identified contaminants but also several PAHs not found in any other sample. Unfortunately, no other laboratory samples were collected from this important geological interface because core in this interval was lost at the other drilling locations. One important exception to the statement that most of the positive laboratory results come from drainage boreholes is the observation of RDX, TNB, and butylbenzylphthalate in two samples collected near the bottom of the powder unit in Borehole 16-2707, located about 30 ft south of the pond. RDX was also found in a sample (0316-97-0390 at 54-55' depth) from a comparable depth in Borehole 16-2735 to the north within the drainage. Butylbenzylphthalate was reported in sample 0316-97-0391 from a depth of 63-3.8' in the same hole, (Recall that the top of borehole 16-2375 is about 10 feet below the top of Borehole 16-2707.) These paired observations provide one of the main indications of stratigraphic control of lateral migration, in this case at a depth that appears to correspond to the top of a welded stratum.

Evidence for interflow migration along the soil/tuff interface is inconclusive. HE was reported at 1–2 mg/kg in two soil/tuff interface samples from Boreholes 16-2711 and 16-2712 that are about 30 ft north and south of the center of the drainage, respectively. However, the drainage at this point is broad and fairly level and the presence of HE in these samples could be the result of both surface transport and interflow along the soil/tuff boundary.

In summary, the available evidence suggests that HE and other contaminants have generally penetrated the upper layer of tuff (above the upper surge bed), but at concentrations that are 1 order of magnitude

smaller than contaminants observed in sediments above the soil/tuff interface. Sporadic hits below the upper surge bed, both under and south of the drainage, indicate that further distribution of contamination, particularly near the pond area, has occurred along pathways that may be determined by vertical fractures and dense horizontal strata. While laboratory evidence is quite limited, there is nothing in the data to suggest the presence of pockets with high levels of contaminants in the deep subsurface, that is, below the level of the upper surge bed at the Qbt4/Qbt5 contact.

2.2 Cañon de Valle Alluvial System

2.2.1 Contaminant of Potential Concern Summary

Sampling in the Cañon de Valle alluvial system included collection of surface and subsurface sediments, three pairs of overbank sediment samples, filtered and unfiltered surface water, and one quarterly round of filtered and unfiltered alluvial well water. These samples were collected during three different investigations: 1994, 1996, and 1997/98. All sampling locations are shown in Figure 2.2-1.

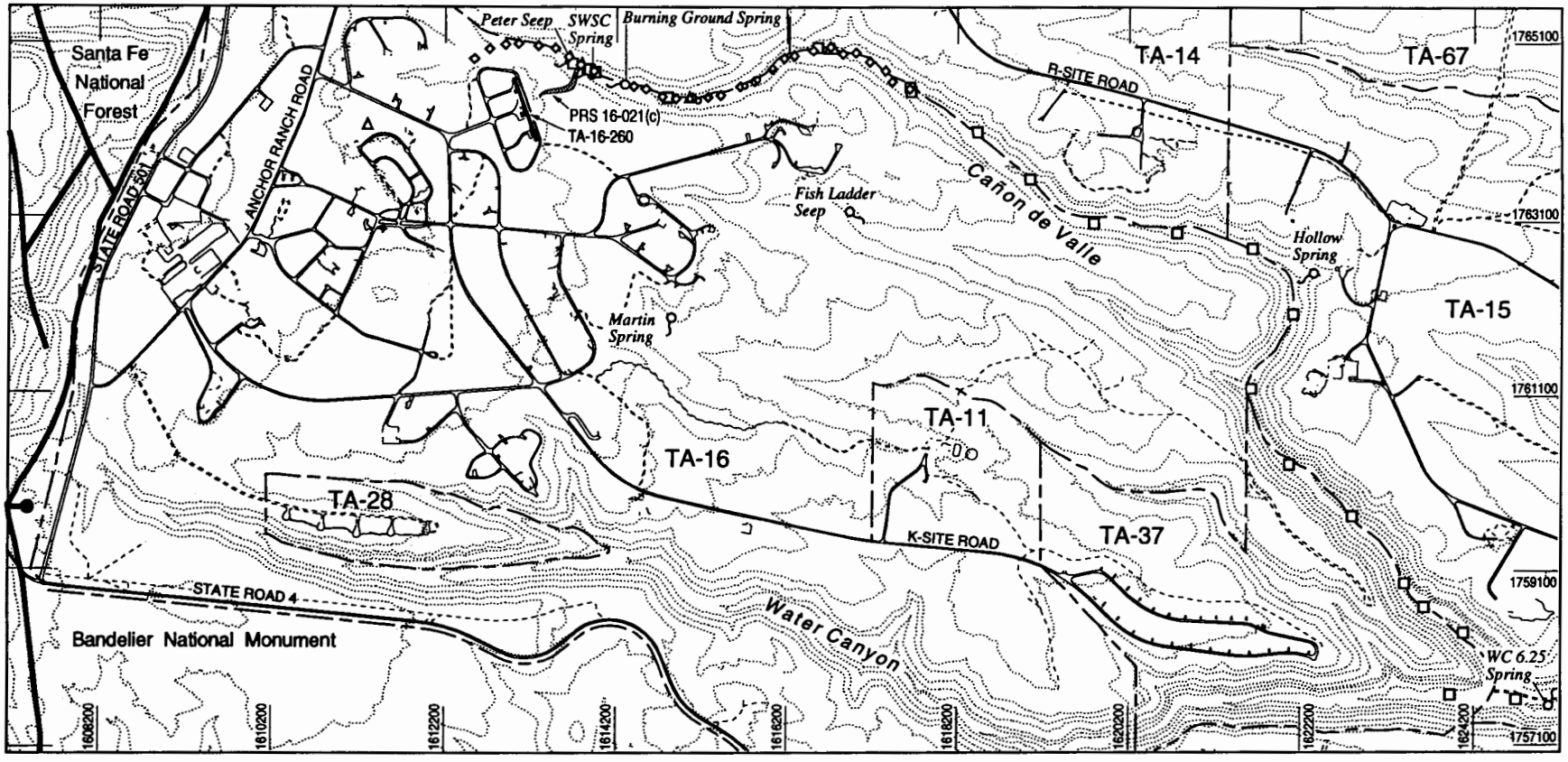
The sediment samples from all three investigations were primarily collected from the 0–6-in. depth in the center of the channel. However, in the 1997/98 campaign, three pairs of overbank samples were collected and eight subsurface samples were collected while drilling five alluvial wells.

Barium is the most abundant inorganic contaminant of potential concern (COPC) in sediments. For the surface samples, the range of barium concentrations is 130–40 300 mg/kg. Other inorganics above BVs include arsenic, cadmium, chromium, cobalt, copper, lead, manganese, mercury, selenium, silver, vanadium, zinc, and possibly antimony and cyanide. Concentrations of these chemicals are generally less than two times the BVs. Cesium-137 (1.06 pCi/g) is the only radionuclide reported above the BV in any of the surface or subsurface samples.

Several HE were found at concentrations greater than the detection limits: 2,6- amino-DNT, 4,6-amino-DNT, HMX, nitrobenzene, 3-nitrotoluene, RDX, TNB, and TNT. HMX and RDX were the two HE greatest in abundance and highest in concentration with maximums of 170 mg/kg and 42 mg/kg, respectively. The highest RDX value comes from an overbank sample collected approximately 6200 ft below the 260 outfall/Cañon de Valle confluence. The significant non-HE organics detected were bis(2-ethylhexyl)phthalate and di-n-butylphthalate.

Surface water samples and water from the five alluvial wells were collected in Cañon de Valle. For the purposes of comparison, Peter Seep was grouped with the alluvial well water samples. Peter Seep may simply be the westernmost expression of the alluvial groundwater system, or it may be fed by one or more sources from the adjacent mesas. Data were compiled during the three different investigations: filtered/unfiltered sample pairs were collected in 1994 and 1997/98, and primarily unfiltered samples were collected in 1996. However, there are only small differences in concentrations between the filtered and unfiltered samples, suggesting that most of the observed constituents are dissolved

For the Phase II RFI report the TA-16 water samples are compared with preliminary background water data sets (note that NMED-approved statistical BVs for springs are not available). A simple statistical test (Gehan 1965, 55611) was used to determine whether the TA-16 data set was greater than this background data set at a specific confidence level. The inorganics determined to be above background



Paved road
Unimproved road
TA boundary
Contour interval 50 ft
1994 sample location
1996 sample location
1997/98 surface sample location
1997/98 alluvial borehole sample location
Spring or seep
Pajarito Fault Zone (bar and ball on downthrown side)

N

0 1000 2000 ft

cARTography by A. Kron 9/25/98
Source: FIMAD G106370 4/1/98

Figure 2.2-1 Sampling locations in Cañon de Valle.

and carried forward as COPCs are antimony, arsenic, barium, calcium, chromium, iron, lead, magnesium, manganese, mercury, nickel, potassium, sodium, vanadium, and zinc. Barium is the most abundant COPC in this list, with concentrations ranging from 99–16 000 µg/L. The highest barium value was in alluvial well 16-2658 located just upgradient from MDA-P. In fact, all of the samples collected from the alluvial wells in Cañon de Valle have barium concentrations higher than those in the surface water samples. However, the alluvial well samples were collected in winter when flow in the canyon was very low, and the majority of the surface water samples were collected during higher flow conditions.

As in the sediment data, HE appears to be the other major contaminant in Cañon de Valle water. The HE identified are 2,6- amino-DNT, 4,6-amino-DNT, HMX, nitrobenzene, 2-nitrotoluene, RDX, TNB, and TNT. RDX is the HE highest in concentration with a maximum concentration of 818 µg/L. Acetone, 1,2-dichloroethane, and methylene chloride are all low in concentration.

2.2.2 Contaminant Distribution

When considering Cañon de Valle from Peter Seep to the confluence with Water Canyon, the data suggest that contaminants decrease in concentration downgradient. However, when looking at the upper canyon in smaller scale, concentrations of many of the COPCs fluctuate. These fluctuations may be attributed to contaminant sources other than the TA-16-260 outfall, sediment packages where COPCs accumulate, or the sampling events occurring during different flow conditions. Constituent transport in Cañon de Valle appears to be largely due to the input of Peter Seep, SWSC Spring, and Burning Ground Spring, with the additional input of surface runoff during precipitation events and snowmelt. No other discrete sources of water to this system have been identified. Flow rates in Cañon de Valle range up to 0.178 cfs. (Dale 1997, 57286)

2.3 Subsurface Tuff and Subsurface Saturated System

2.3.1 COPC Identification

Sampling in the subsurface hydrologic system included collection of tuff samples from four intermediate-depth borehole locations, sampling of intermittent perched water from two of those boreholes, and quarterly sampling at three springs—SWSC, Burning Ground, and Martin—that tap the shallow perched zone at TA-16 (Figure 2.3-1).

Subsurface tuff outside of the source region contained few constituents at levels greater than background. Semiquantitative D-Tech screening of tuff samples showed no HE present in the cores. Constituents retained as COPCs include the inorganics antimony, calcium, mercury, selenium, and silver. Of these, only calcium was detected at levels greater than tuff background levels; the other constituents had detection limits greater than the tuff background values. No HE constituents were detected in the tuff samples. Detected organic constituents included bis(2-ethylhexyl)phthalate and acetone, both of which are common laboratory constituents and blank contaminants. Intermittent perched water, that was observed in Boreholes 16-2665 and 16-2669 (Figure 2.3-1) contained aluminum, barium, calcium, iron, magnesium, manganese, nickel, potassium, in unfiltered samples at levels greater than the background range (note that NMED-approved statistical background values for springs are not available). Borehole waters also contained the HE constituents 2,4-DNT, HMX, RDX, and 2,4,6-TNT.

Spring waters contained many analytes at levels greater than background distributions. Inorganic constituents detected at levels greater than the background distribution based on statistical tests

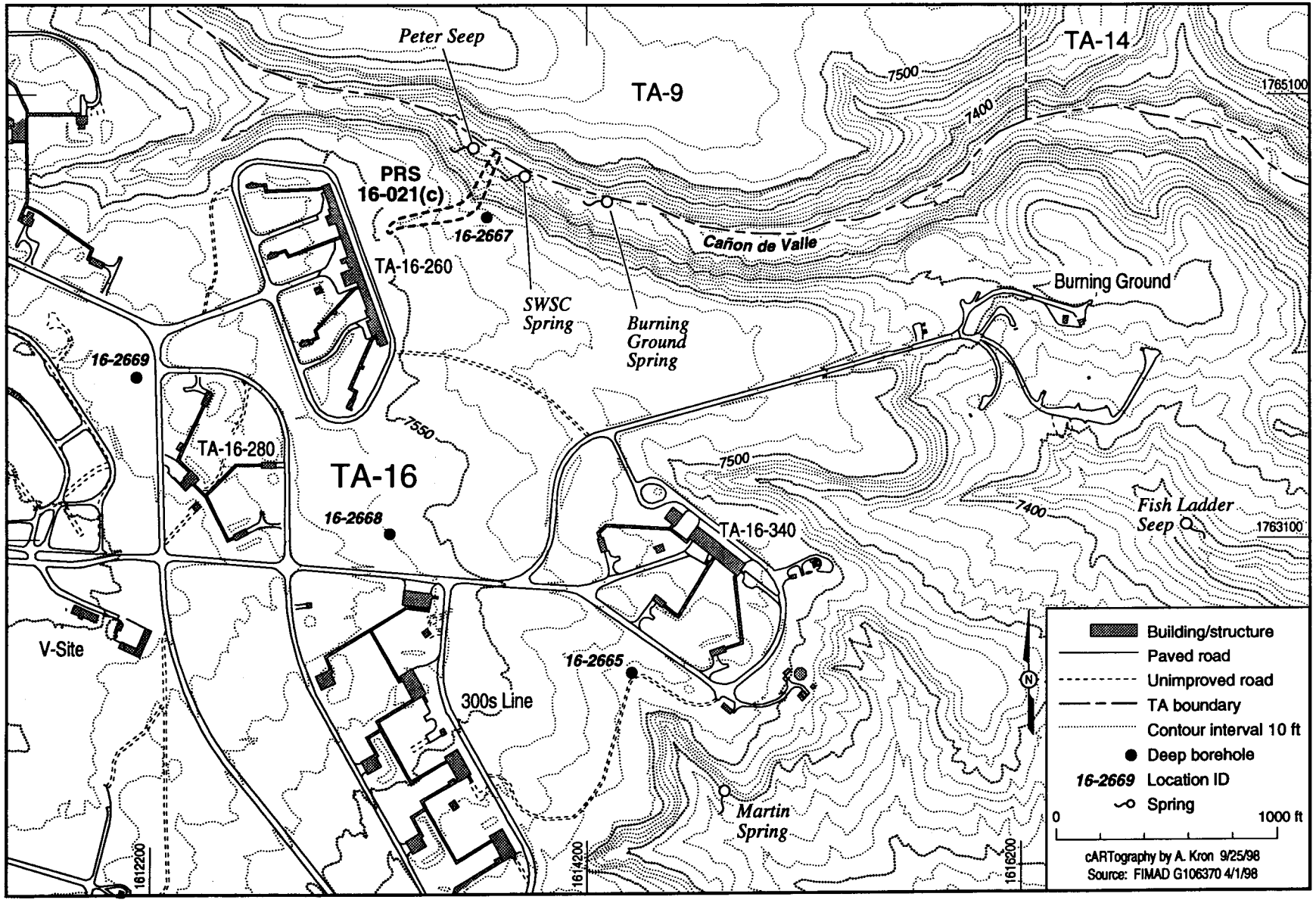


Figure 2.3-1 Location map for deep boreholes and springs.

included: aluminum, ammonium, barium, boron, bicarbonate, calcium, chloride, fluoride, iron, magnesium, manganese, nitrate, phosphate, silicon dioxide, sodium, strontium, and sulfate. Of these inorganic constituents barium, boron, nitrate, and phosphate are almost certainly related to anthropogenic discharges. Barium levels were higher in SWSC and Burning Ground Springs than in Martin Spring. HE constituents detected in springs were 4-amino-2,6-dinitrotoluene, 2-amino-4,6-dinitrotoluene, 1,3-dinitrobenzene, 2, 4-dinitrotoluene, HMX, 3-nitrotoluene, RDX, tetryl, 1,3,5-TNB, and 2,4,6-TNT. RDX was the most frequently detected HE constituent; also it was detected at the highest total concentration. HE constituents were detected at the highest levels in Martin Spring. Other organic constituents detected were acetone, bromomethane, chloromethane, 1,2-dichloroethane, di-n-butylphthalate, tetrachloroethene, and trichloroethene. Of these organic constituents only acetone was detected in more than half of the spring water samples.

Many of these constituents were also identified as COPCs in the TA-16 source region, suggesting that a hydrogeologic link between the TA-16-260 outfall and the springs is likely. Of the constituents identified, HE and barium are probably the constituents of greatest potential concern to human health and the environment.

2.3.2 Extent of Contamination

The analytical data from the deep borehole tuff and water suggest that the standard notion of extent of contamination, in which a plume of steadily decreasing constituent concentration is observed in the environment radiating out from a source of anthropogenic contamination, is not relevant for the subsurface at TA-16. High levels of HE were observed in water samples collected in intermittently saturated zones in two hydrologic boreholes (16-2665 and 16-2669). These waters with high HE concentrations were each found at the bottom of greater-than-100-ft-deep, clean tuff boreholes near the QBt3/Qbt4 contact. Constituent transport in the TA-16 subsurface appears to be dominated by transport along fast, saturated pathways such as surge beds and heavily fractured units. Saturation in these pathways is most likely to be either seasonal or intermittent.

2.3.3 Spring & Well Dynamics

Quarterly sampling of all three springs showed significant variability in constituent concentrations and flow with time. Flow rates for springs ranged up to 0.023 cfs for SWSC spring, to 0.157 cfs for Burning Ground Spring and to 0.009 cfs for Martin Spring. In addition, RDX in Martin Spring varied from greater than 150 µg/L during December 1996 sampling to less than 10 µg/L during March 1997 sampling. Inorganic constituent abundances also vary by up to a factor of 5. Three modes of variation in constituent abundance with flow were observed: (1) decreases followed by increases in abundance with increases in flow, e. g., barium, major cations, (2) a continuous increase in concentration with flow, e.g., iron, aluminum, and (3) a decrease followed by both increases and decreases with flow, apparently depending on the season, e.g., HE.

The observations of variability in constituent abundance with flow suggest

- that the hydrogeologic systems that feed SWSC and Burning Ground Springs are similar to each other and different from that for Martin Spring,
- that multiple recharge sources are active for the springs, and

- spring of the year and monsoon recharge occur by different flow paths. This dynamic is suggested by high HE during monsoonal high-flow intervals in SWSC and Martin Spring relative to low HE during snowmelt high-flow intervals.

Examination of detailed hydrographs for the springs provides additional insights into recharge at the springs, and hence into the subsurface hydrogeologic conceptual model. Spring response to rainfall occurs on up to three timescales. For example, following an initial rainfall event of greater than 0.5 in. during the summer monsoon season at SWSC spring:

- initial response of spring flow is seen less than 2 hours,
- a slightly larger response is seen less than 20 hours later, and finally,
- the mass of monsoon water impacts the spring baseflow a few days to weeks later.

These data suggest that at least three distinct recharge sources impact the springs. Three plausible candidates for these recharge sources are (1) direct runoff into the spring catchments with a response time of a few hours, (2) an interflow pathway with a response time of 1–2 days, and (3) a subsurface pathway with a response time of several weeks.

Two out of four intermediate-depth (less than 200 ft) boreholes drilled during the Phase II investigation intersected ephemeral perched water that was contaminated by HE constituents. These water-bearing zones were located near the contact between Qbt3 and Qbt4. Each borehole contained water for less than a month, and no additional water has been seen. This observation supports a hydrogeologic conceptual model in which subsurface contaminant transport is controlled by intermittently-saturated ribbons that are structurally controlled by surge beds and/or fractured intervals, particularly near the Qbt3/QBt4contact, which is also the elevation of the springs and seep The ribbons appear to be seasonally or episodically saturated because of the changes in contaminant concentrations at the springs described above.

2.4 COPC Screening

As described in the previous sections, extensive data evaluation was performed during the RFI to identify those constituents associated with various media that should be carried forward into a screening level assessment for human health and ecological effects. The screening assessment included a combination of comparison to medium-specific risk-based criteria and applicable water quality standards. For a given medium, the maximum reported concentration of each analyte was compared to the corresponding screening value. If the maximum reported concentration is less than the screening concentration, the contaminant is not selected as a COPC.

Constituents of greatest concern that wee identified as COPCs as a result of the screening assessment for both human health and ecological effects are barium, bis(2-ethylhexyl)phthalate, HMX, RDX, and trinitrotoluene[2,4,6-]. These constituents are consistently found in the highest concentrations in all the media considered in the RFI, but particularly in the surface soil. The site-specific risk assessment and CMS process to follow will focus on this set of constituents. Bis(2ethylhexyl)phthalate will receive the least attention because it is concentrated almost entirely in the HE pond, which will be removed during the interim measure.

3.0 CORRECTIVE MEASURES OBJECTIVES AND SCOPE

3.1 Setting

3.1.1 Areal Extent and Administrative Boundary

The administrative boundary for the CMS is shown in Figure 3.1-1. The boundary runs along State Route 501, which coincides with the Pajarito Fault to the west, and follows the basin divides between Water Canyon and Cañon de Valle to the south, as far as Martin Spring Canyon and Pajarito Canyon, and Cañon de Valle to the north. These basin divides converge at the confluence of Cañon de Valle and Water Canyon. This area will be referred to as the Cañon de Valle basin. The areal extent of the study includes all of the surface and subsurface terrain within the boundary except (1) individual PRSs and associated downgradient areas to the edge of Cañon de Valle and (2) Fish Ladder Seep and its sub-basin. These potential contaminant sources are being addressed within the scope of other ER Project activities.

The administrative boundary is designed to incorporate contaminant sources and the fate and transport mechanisms of the Cañon de Valle basin. The TA-16-260 outfall is considered the major source of contaminants in the basin. Monitoring and data analysis at the basin scale will support decisions on whether to conduct remedial activities at other potential contaminant source locations as well.

3.1.2 Four Component Conceptual Model

The conceptual model used in the CMS is composed of four components: the contaminant source area, the subsurface, the transport pathways and springs, and the alluvial system in the canyon bottom (Figure 3.1-2). Sources of recharge to the mesa, springs, and canyon alluvial system are inputs to the model. Structuring the conceptual model in this manner identifies and separates the parts of the physical system that warrant individual remediation or monitoring approaches. For example, approaches to addressing the contaminant source area are different from approaches to addressing contaminants in the springs. The four components are combined into one conceptual model because transport mechanisms result in interactions among the components. Contaminants in the source area impact the unsaturated subsurface, which impacts the springs and seep, which impact the alluvial system. As the conceptual model shows, anything that affects one component of the model is also likely to affect other downgradient components.

The source area will be addressed by the IM proposed in the Phase II RFI report that is being submitted concurrently with this CMS plan. The details of the IM will be provided in a separate IM plan to be submitted during FY99. The IM will require removal of all highly contaminated soil and tuff in the TA-16-260 outfall, pond, and drainage and characterization of low levels of contamination present in the residual soil and tuff. The subsurface consists of the volume of the mesa that connects the source area to the seep, springs, and the canyon alluvial system. This is a physically complex system including multiple geologic units, fracture sets, and porous media. Phase II drilling results show that there are low levels of HE (less than 10 mg/kg) in this part of the system. These data suggest that transport occurs along preferential flow paths controlled by stratigraphy and fractures rather than through a large plume in porous media.

The transport pathways and springs component of the conceptual model specifically addresses contaminant transport in the subsurface from source areas and the unsaturated subsurface. Sources of

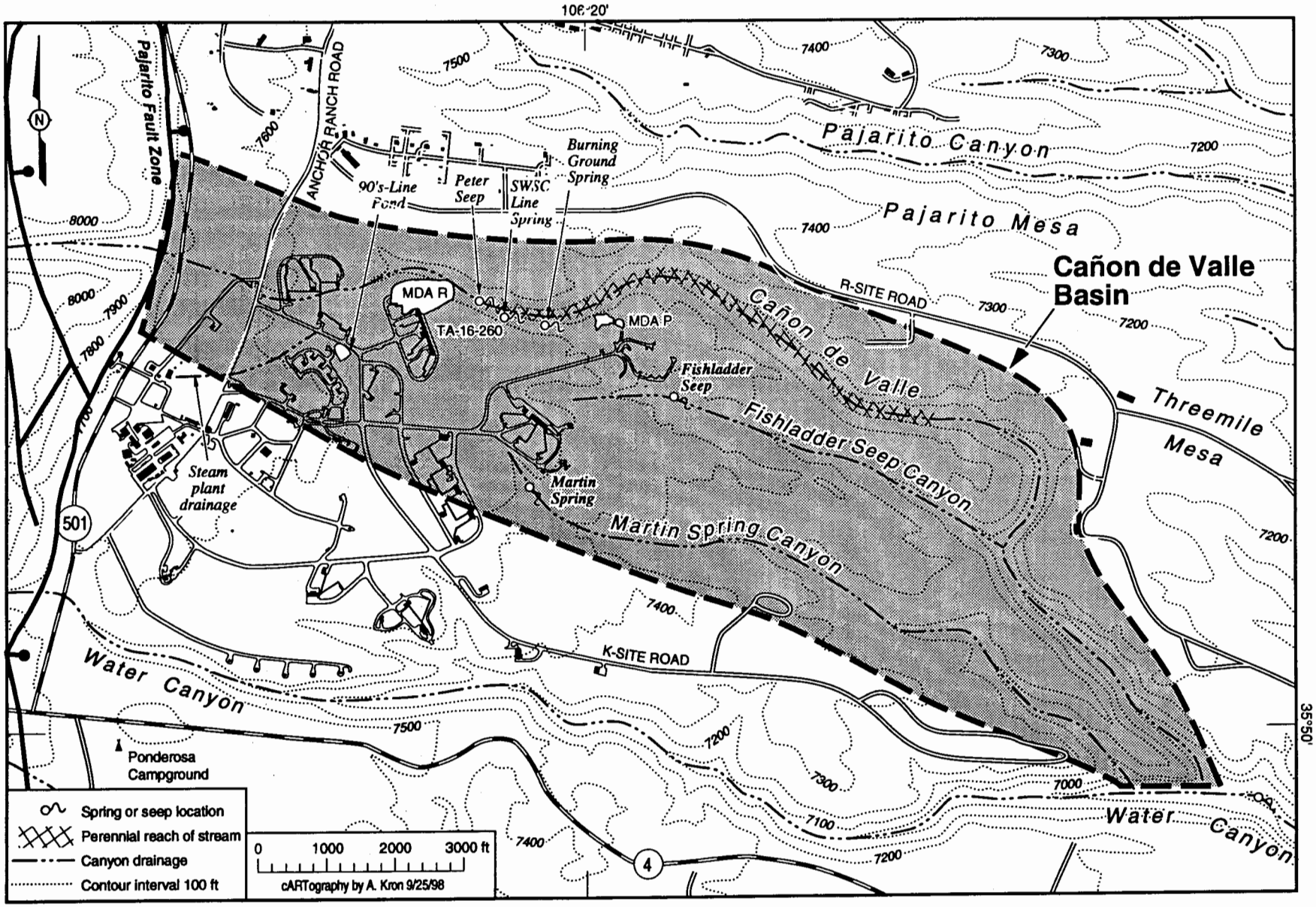


Figure 3.1-1 Administrative boundaries for PRS 16-021(c) CMS/CMI.

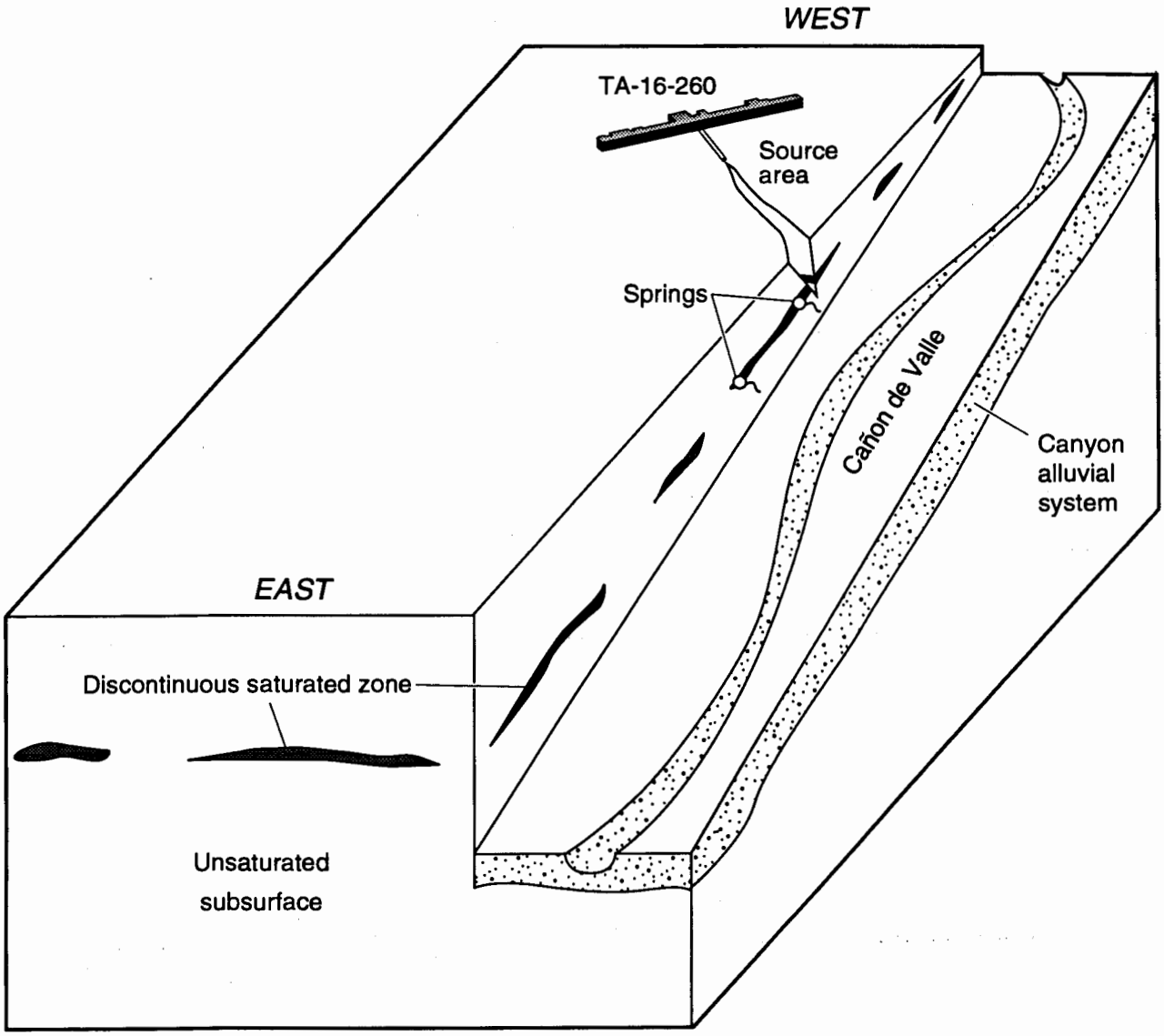


Figure 3.1-2 Simplified conceptual model for TA-16-260, PRS 16-021(c) contaminant dispersal.

recharge to these pathways and the interactions between recharge and primary or secondary contaminant sources are essentially unknown. Data from the Phase II RFI show that these pathways are highly dynamic. Rates of spring flows range over 1 order of magnitude. The hydrographs show multiple responses to individual storms, as well as changes in base flow rates with season. Contaminant abundances and types also change as discharge changes. The alluvial system is presently considered a receiving system for contaminants transported from the mesa. Concentrations of contaminants vary among the different components of the alluvial system: surface water, alluvial aquifer, and sediments.

The connection between the alluvial system, the deeper perched aquifer(s), and the regional aquifer is an important issue that is in part being addressed by the site-wide hydrogeologic investigation (LANL 1996, 55430). Well R-25 will be drilled approximately 2000 ft to the east of the TA-16-260 outfall during late FY98 and early FY99. Well R-27 is currently scheduled to be drilled at the confluence of Cañon de Valle and Water Canyon during FY2000. Both wells could potentially provide useful information on subsurface transport phenomena near PRS 16-021(c) and may identify other perched aquifer systems. LANL will include a detailed discussion of results from these wells in a future report focused on PRS 16-021(c), either the Phase III RFI report or the CMS report. The results of R-25 and R-27 drilling could potentially drive further sampling of the deeper subsurface system in association with the CMS/CMI for PRS 16-021(c).

3.2 Remedial Approach

The proposed remedial approach for the TA-16-260 outfall is to perform a CMS/CMI for the residual contamination left in the source area and the remainder of the hydrogeologic system contaminated by discharges at PRS 16-021(c). The source area is contaminated at levels up to 20% HE by weight and 3% barium by weight. It is estimated that removal of approximately 2500 $yd^3$of material in the source area would eliminate 80–95% of the contaminated media in the 260 outfall region. Conducting a SSRA to justify the IM removal is not useful or necessary.

The IM will be performed according to what is feasible in terms of engineering rather than to remediation concentration goals because the contaminant concentrations drop quickly with depth. To achieve the best possible results, remedial approach evaluations conducted in the CMS will support selection of waste treatment options used in the IM. There are known to be low levels (less than 10 mg/kg) of contaminants at depths to 70 ft below ground surface. These contaminated locations cannot be reliably predicted and will be left in the unsaturated subsurface when the IM is complete. The CMS treatability studies and the CMS Phase III sampling will focus on evaluating remediation options for the remainder of the hydrogeologic system. Remediation for other components of the physical system will depend upon monitoring results for transport pathways, including the springs, seep, surface water, and alluvial water. Decisions to remediate water will depend upon concentrations, potential exposures, observable biological effects, and applicable relevant and appropriate regulations (ARARs). Methods to be considered will include active and passive treatment systems, phyto-remediation, and natural monitored attenuation.

3.2.1 Parallel Tracks of Action and Monitoring

The physical system addressed by the CMS consists of four components that are related by transport pathways (see Subsection 3.1.2). Changing the contaminant mass in one component of the system eventually affects the contaminant mass in other components downstream. Routine monitoring will be established for the springs and alluvial system before remedial actions are taken. This monitoring will

make it possible to evaluate trends in the types and levels of contaminants present over time and to assess the efficacy of the remediation, particularly the impact of the IM on contaminants in the remainder of the hydrogeologic system. Analysis of the baseline monitoring data will be used to finalize the long-term monitoring program.

3.3 Objectives of the Corrective Measures Study

The overall objective of the CMS and subsequent CMI is to ensure that contaminant concentrations within the four components of the site conceptual model (as discussed in Section 3.1.2) meet acceptable levels relative to human health and ecological criteria. The primary objective of the CMS is to select the remedial technologies that will be used to achieve media cleanup standards (MCSs) in each of the four components of the site conceptual model. A fundamental component of this selection process will be the evaluation of candidate technologies in bench-scale and pilot-scale studies. An additional objective of the CMS is to define preliminary MCSs for each of the four conceptual model components. These cleanup standards will be based extensively on human health and ecological risk criteria. The CMS will also define regulatory points of compliance (POCs) for the four components of the site conceptual model. POCs are developed and negotiated with the AA as monitoring locations to determine if MCSs have been achieved. Preliminary POCs are proposed in Section 3.4.2 of this CMS plan.

Existing data from previous investigations and additional site characterization data will be used to meet the objectives of the CMS outlined above. This plan discusses in the following subsections the fundamental data objectives, the adequacy and source of existing data, and the need for additional data for each component of the site conceptual model. Chapter 6 of this plan also presents PRS 16-021(c) RFI Phase III sampling investigations for collecting the majority of the required additional data.

3.3.1 Investigation Objectives

The objectives of investigation to support the CMS are (1) to define the extent of contamination, and (2) to characterize the behavior of active transport pathways for specific components of the site conceptual model. Sufficient data generated in previous investigations may already meet one or both of these objectives for certain components of the site model. For example, the nature of contamination has been adequately addressed in previous RFI reports. The following subsections discuss the existing data and the need for additional data relative to these two objectives for each model component. The sections also discuss explicitly how the additional objectives support the CMS. The individual objectives are numbered investigation objective (IO) 1 , IO2, etc. This numbering scheme is then used in Chapter 6 to show the correlation of the investigation objectives presented here to the site investigations presented in Chapter 6.

3.3.1.1 The Contaminated Source Area

Nature and Extent, IO1

As stated previously, an IM will be implemented at the source area prior to the CMS. The extent of residual contamination remaining in the source area will require characterization. This investigation will be designed in conjunction with the IM plan and is, therefore, not included in the RFI Phase III investigation presented in this report. The data generated in the post-IM investigation will be used to support the selection of a remedial technology for the post-IM source area. The nature of contamination has been adequately characterized by previous investigations.

The post-IM sampling plan will focus on determining the mean contaminant concentrations remaining in the area. This data will then be used to support the risk-based contaminant concentrations proposed as MCSs in the CMS report. The sampling plan will also focus on identifying points of maximum contaminant concentration to support the definition of the POC for the source area.

Transport Pathways, IO2

The drainage channel associated with the source area will remain a potential surface contaminant transport pathway following the IM. The extent data generated during the post-IM sampling, along with existing extent data, will be used to estimate contaminant inventories remaining in the drainage channel and will be used to support the selection of remedial technologies for the drainage channel and POCs for the entire source area. The surface transport pathway within the source area is well understood and the nature and extent data should be sufficient to make meaningful calculations of future risk to potential receptors.

The subsurface transport pathways are discussed in subsection 3.3.1.3

3.3.1.2 Unsaturated Mesa Subsurface

Nature and Extent of Contamination, IO3

The nature and extent of subsurface contamination in the unsaturated subsurface has been evaluated in both the source area and the intermediate-depth subsurface phases of the PRS 16-021(c) RFI Phase II investigation. An additional borehole will be drilled in the source area to a total depth of 80 ft as part of the post-IM investigation. Data from this borehole and previous investigation data are expected to be sufficient to finalize the evaluation of the unsaturated mesa system. This data will support the remedial technology decision for this component of the site conceptual model. It is currently anticipated that due to the low expected contaminant concentrations and the lack of a viable exposure route to receptors, MCSs and POCs will not need to be defined for this conceptual model component.

Transport Pathways, IO4

Transport pathways connecting the unsaturated subsurface to groundwaters, such as intermediate perched aquifers or the regional aquifer, will be evaluated following the same phased approach proposed in Section 3.4.2.3. The phased approach will be used to support decisions on whether remediation of deeper groundwater is necessary and, if so, the selection of remedial technologies for this component of the site conceptual model.

3.3.1.3 Transport Pathways and Associated Springs

Nature and Extent of contamination, IO5

Dynamics in the physical behavior of the springs are expected to have significant impacts on contaminant concentrations and fluxes observed at the springs. As a result, the physical behavior of the springs and the relationships between flow rate and contaminant concentration must be understood in order to evaluate the nature of contamination observed at the springs and the short- and long-term trends in springs contaminant data. Understanding trends in spring contaminant data, in turn, directly effects all three objectives of the CMS. Trends in springs' contaminant data must be evaluated in order to assess the viability of natural attenuation as a remedial alternative. Furthermore, trend data must be

understood in order to assess the effectiveness of the source removal. This has implications for establishing MCSs at the source area. MCSs at the springs themselves may also be based on a set of data that more accurately measure maximum expected contaminant concentrations or fluxes. In addition, the physical behavior of the springs must be understood in order to establish an effective monitoring strategy. This, then, is of paramount importance for demonstrating compliance with MCSs.

The nature and extent of contamination as observed at the springs has been evaluated in several investigations, most recently in association with the PRS 16-021(c) Phase II investigation. Significant additional investigations are proposed in Chapter 6 that primarily focus on establishing the physical behavior of the springs.

Transport Pathways, IO6

Understanding the transport pathways connecting the source area to the seeps and springs is necessary for evaluating exposures to potential receptors at the seeps and springs. This information will then be used directly to support the CMS objective of selecting an appropriate remedial technology for the seeps and springs. Source-to-springs transport pathways are currently being evaluated in an ongoing potassium bromide tracer study. The results of the study to date are discussed in the Phase II RFI (LANL 1998 in preparation). However, because only a small mass of tracer has been observed in the springs, additional sampling in support of the tracer study is presented in Chapter 6.

3.3.1.4 Alluvial System Surface and Groundwaters

Nature and Extent of Contamination, IO7

The nature and extent of contamination in surface and groundwaters in both Cañon de Valle and Martin Spring Canyon is needed to support the remedial technology decision for this component of the site conceptual model. This data is also necessary to define the groundwater POCs for both Martin Spring Canyon and Cañon de Valle. In addition, the nature of the physical system and the interactions between the surface water and groundwater component of this system need to be defined. This will provide the basis for developing long-term monitoring strategies for the alluvial surface and groundwater systems that will be required for demonstrating compliance with MCSs.

Cañon de Valle has been sampled several times, most recently as part of the PRS 16-021(c) RFI Phase II investigation. Martin Spring Canyon has not been sampled to date. Current data does not adequately define the nature and extent of contamination in this component of the conceptual model. This plan describes additional sampling to be conducted as part of the RFI Phase III investigation presented in Chapter 6.

Transport Pathways, IO8

Transport pathways connecting alluvial groundwaters to other groundwaters, such as intermediate perched aquifers or the regional aquifer, will be evaluated following the same phased approach proposed in Section 3.4.2.3. The subsurface transport pathways between the source region and the alluvial system and deeper groundwaters will probably be indistinguishable, given the scale of hydrogeologic processes. The phased approach will be used to support the selection of remedial technologies for this component of the site conceptual model. Some preliminary information on the potential impacts of the alluvial groundwater systems on deeper systems will be generated in the water mass balance studies proposed in Chapter 6.

Alluvium

Nature and Extent of Contamination, IO9

The nature and extent of contamination present in canyon alluvium is necessary to select the appropriate remedial technology for this component of the site conceptual model. The data will also be used to perform risk assessments to establish MCSs and establish compliance with the negotiated cleanup standards.

The alluvium in Cañon de Valle has been investigated previously, most recently during the PRS 16-021(c) RFI Phase II sampling campaign. The existing data is not sufficient to determine the mass of contaminants stored in the alluvium; sampling proposed in Chapter 6 is designed to address this concem.

Transport Pathways, IO10

Interactions between contaminants stored in canyon alluvium and surface and groundwaters is not currently understood. It is not known if a large mass of contaminants stored in alluvium can act as a continual source impacting the surface water and groundwater transport pathways. The alluvium contaminant inventory investigation proposed in Chapter 6 will provide data that can be used to predict the impacts of stored contamination on these transport mechanisms.

3.4 Institutional Considerations

3.4.1 Land Use

TA-16 is planned for continued operation as an HE production and machining facility. Consequently, the area within the administrative boundary is subject to controlled access. Industrial land use is being used as the driver for exposure scenarios in human-health risk assessments, as documented in a letter from DOE to the NMED Hazardous and Radioactive Materials Board (HRMB), {"Request To Use Industrial Exposure Scenarios In Lieu Of Residential Scenarios For Human Health Risk Assessment In 260 Outfall [PRS 16-021(c)] RFI/CMS Process (Former OU 1082, FU 3).(LANL:1998, 59173).

3.4.2 Establishment of Media Cleanup Standards

MCSs will be developed as part of the CMS and recommended to the AA in the CMS report. Following the CMS, MCSs will be included in the LANL permit modification as constituent concentrations in soil and water that must be achieved for successful completion of the corrective action [proposed 40 CFR 264.525(d)] unless a determination is made under proposed 40 CFR 264.525(d)(2) that remediation to MCSs is not required.

As stated in *The General Standards for Corrective Measures* [proposed 40 CFR 264.525(a)], there are several types, and uses, of MCSs that need to be clarified. Target MCS s are not cleanup goals or action levels, but "...are preliminary cleanup goals established during the CMS to provide a benchmark for evaluating the effectiveness of the alternatives for the corrective measure." The final MCSs are actual remediation goals that must be attained for release of the site from the RCRA corrective action process. Section 3.4.3.1 describes the derivation and identification of target MCSs. Final MCSs, recommended to the AA, will be determined in the CMS process following completion of the IM, Phase III investigation,

and the site-specific human and ecological risk assessments. This process is discussed briefly in Section 3.4.3.2.

Site constituents for which MCSs will be developed were identified in the Phase II RFI report (FY98) as COPCs to be carried forward into the CMS. These COPCs were determined from the following activities:

- a human-health screen to site-specific action levels (SSALs),
- an ecological screen to ecological benchmark values, and
- other applicable regulations (where appropriate).

3.4.2.1 Target MCSs

Target MCSs are generally derived by calculating concentrations in specific media that are protective of human health. These calculations are performed according to standard approved methodology provided by EPA and NMED. This approach was used to calculate SSALs for screening purposes in the Phase II RFI report (LANL 1998, in preparation). Therefore, it is proposed that these SSALs be used in the CMS as target MCSs. Complete details on derivation of these levels are provided in the Phase II RFI report.

Table 3.4.3-1 provides a list of constituents, by medium, that were identified as COPCs, based on human health screening, to be considered in the CMS along with the target MCS. The site-specific persistent bioaccumulators are also listed in this table.

Table 3.4.3-1

TARGET MCSs FOR COPCs BASED ON HUMAN HEALTH RISK SCREENING

COPC	Target MCS
Soil	mg/kg
Barium	5320
Bis(2-ethylhexyl)phthalate	48.7
HMX	639
RDX	6.19
2,4,6-Trinitrotoluene	227
Water	µg/L
Barium	1620
Lead	[a]
RDX	72.6

[a]No risk-based MCS for lead in water has been determined at this time.

3.4.2.2 Final MCSs

The CMS report will propose final MCSs for each site conceptual model component, media, and COPC. Many factors will be taken into consideration when establishing final MCSs during the CMS. These include the results of SSRAs for human health and ecological receptors, exposure issues specific to TA-16, and applicable regulations or promulgated standards. Other issues that will be considered, as set forth in proposed 40 CFR 264.525(d), include:

- effects of multiple contaminants in each environmental medium,
- environmental receptors that are threatened by the release,
- evaluation of the cumulative risk when populations may be exposed to multiple sources or through multiple pathways, and
- factors specific to the corrective measure under consideration, including reliability, effectiveness, practicality, and other factors.

The CMS report will also provide a petition to the AA to make a determination that remediation to a site conceptual model component-, media-, and contaminant-specific MCS is not required if:

- there is no threat of exposure to the contamination,
- remediation to MCSs will not result in any significant reduction in risk to humans or the environment, or
- remediation to MCSs is technically impracticable [proposed 40 CFR 264.525(d)(2)]

This petition will provide a careful evaluation of the technical circumstances involved and clear and convincing information supporting this recommendation.

3.4.3 Points of Compliance

Under 40 CFR 264.525(e)(1)(i)-(v) of the proposed Subpart S rule, the POC is the point(s) or area(s) where a facility must demonstrate compliance with MCSs. The location of the POC is medium-specific and depends on factors such as the potential for exposure of human or ecological receptors, the potential for migration, the potential for impact to sensitive ecosystems, and accessibility. In the absence of final corrective action regulations specifically addressing points of compliance, POCs are developed on a site-specific basis. It should be noted that a POC can be defined as an area with the potential for exposure to receptors (CFR 1995, 56034). Specific locations within these areas that are representative of the exposure to specific receptors are then selected as sampling locations to demonstrate compliance with the MCS.

Four preliminary POCs are proposed in this CMS plan. Each POC covers a different medium or system. The preliminary POCs will be refined during the CMS as additional information is obtained and remedial approaches are selected. Final POCs will be proposed to the Administrative Authority (AA) in the CMS report.

3.4.3.1 Soils and Alluvium

The preliminary POC for soils is any point where direct contact with a receptor may occur. This will extend within the 260 outfall drainage from the outfall to the confluence with Cañon de Valle. The preliminary POC for alluvium is any point in Cañon de Valle and Martin Spring Canyon within the area of contamination defined in Chapter 2 where direct contact with a receptor may occur. The POCs for the soils and alluvium are distinct because they have different exposure scenarios due to very different topography and ecosystems. EPA has established that the POC for soils (and by extension, alluvium) is limited to near-surface soils because subsurface soils have limited likelihood of exposure to receptors.

3.4.3.2 Surface Water

The preliminary POC for surface water is any point in Cañon de Valle and Martin Spring Canyon within the area of contamination defined in Chapter 2 where direct contact with a receptor may occur. This includes water from Burning Ground Spring, SWSC Spring, Martin Spring, and Peter Seep. EPA has established that the POC for surface water is generally the point where releases enter the surface water. However, in Cañon de Valle and possibly Martin Spring Canyon, contamination may enter by way of Burning Ground Spring, SWSC Spring, Martin Spring, Peter Seep, alluvial sediments, and surface runoff from sources other than the TA-16-260 outfall (i.e., MDA-P, MDA-R, and the Burning Ground). EPA recognizes that the point may not be clearly defined and the POC reflects the uses of the water and the environmental and ecological importance of the water body. Hence, a POC that is downgradient from all sources to alluvial water will also be considered during the CMS. Defining such a POC will require a detailed understanding of sources and sinks of water in Canon de Valle, which will be investigated in Phase III studies outlined in Chapter 6.

3.4.3.3 Groundwater

For the purposes of this CMS, the preliminary POC for groundwater will be defined as the alluvial water in Cañon de Valle and Martin Spring Canyon within areas of contamination defined in Chapter 2, or as indicated by results from the Phase III investigation. Under the Subpart S rule, the POC for remediation of groundwater generally will be the entire region of contaminated groundwater, or plume. EPA recommends consideration of the following factors when developing site-specific groundwater POCs:

- Proximity of sources of contaminants,
- Technical practicability of groundwater remediation,
- Vulnerability of groundwater and its uses, and
- Exposure and likelihood of exposure.

Other groundwaters, such as intermediate perched aquifers or the regional aquifer, will be evaluated under the following phased approach. The CMS will evaluate the potential risk to the nearest human and ecological receptors under the following conservative scenarios.

1. That the alluvial groundwater, subsurface saturated areas, and unsaturated flow through the mesas flow directly to the main aquifer and subsequently to the nearest human or ecological receptor.

2. That the alluvial groundwater and subsurface saturated areas flow directly to the nearest downgradient spring or seep to the human or ecological receptors at that location.

Should these conservative risk assessments indicate the potential for unacceptable human or ecological risk, an additional investigation will be designed and implemented that will provide the information necessary to refine the risk assessments. Such investigations will probably require detailed modeling of the hydrogeologic system at TA-16.

Another consideration for selecting POCs is sensitivity of biological systems in the canyon to contaminants in the seep, springs, and alluvial system. The ecological screening assessment for surface and alluvial waters in the Phase II RFI suggests that these biological systems are not seriously disturbed by the contaminants (LANL 1998, in preparation). If this is the case, then monitoring, treatment, and remediation to achieve compliance should be designed to minimize the impacts these engineered components may have on the natural system.

3.4.4 Risk-Based Decision Approach

The corrective measures study and implementation process is risk based. This is consistent with the HRMB's risk-based decision tree, EPA's 40 CFR Chapter 1, Subpart S, Part V, and DOE Order 5400.1, which includes the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and RCRA by reference for environmental remediation of hazardous wastes.

3.4.5 Applicable Regulation and Requirement Evaluation

This section presents an overview of laws and regulations that may apply to the PRS 16-021(c) CMS under the proposed EPA Subpart S and Module VIII of LANL's Hazard Waste Facility Permit. The medium (e.g., surface water or soil) that each relevant regulation applies to is also discussed.

Generator and Transporter Requirements Any action resulting in the generation of hazardous and solid wastes under the CMS will comply with the regulations under 40 CFR Part 260 et seq. for hazardous waste management. These requirements will also apply to the hazardous and solid wastes generated during the treatment of soils and water. These requirements will apply to the IM and will be addressed in the IM plan.

Land Disposal Restrictions The restrictions on the land disposal of hazardous wastes address the mitigation of hazards posed by waste constituents. All PRS 16-021(c) activities that generate hazardous waste as part of the RCRA corrective action will comply with the land disposal restriction (LDR) requirements of 40 CFR Part 268. If a media is treated in situ and a waste is not generated, the LDRs do not apply, as stated in the Federal Register Volume 63, pages 28556-28634, published May 26, 1998. However, any ex-situ CMS treatment (soil or water) that generates a waste will comply with LDR requirements, pending approval of these requirements by NMED.

Public Participation and Community Relations RCRA § 7004 encourages public participation in the development, revision, implementation, and enforcement of any regulation, guideline, information, or program activities. The Public Participation and Community Relations regulation is currently implemented in the LANL ER Project through community meetings and meetings with stakeholders in the community such as the Northern New Mexico pueblos, the County of Los Alamos, and officials of the community. LANL currently complies with the DOE public participation policy that is outlined in *Public Participation Policy for Environmental Restoration and Waste Management, US DOE (October, 1992).*

Public Participation activities specific to PRS 16-021(c) are included in the CMS/CMI schedule found in Appendix B.

The National Environmental Policy Act Section 102(2)(c) of the **National Environmental Policy Act** (NEPA) requires that all federal agencies prepare an environmental impact statement (EIS) for all major federal actions significantly affecting the quality of the human environment. The DOE has established a procedure for compliance with NEPA defined in 10 CFR 1021 and 40 CFR 1500–1508. Before implementing the IM and the CMS, all NEPA procedures will be completed. The environmental safety and health (ESH) questionnaire will be completed and reviewed by the LANL Environmental Assessments and Resource Evaluations Group, ESH-20, NEPA team. All NEPA concerns will be addressed before implementing intrusive activities.

The Clean Water Act The Clean Water Act requirements apply to the CMS and IM at PRS 16-021(c) if additional discharges, impacts to stormwater, or lease of treatment agents result from implementing the IM or CMS.

The Clean Air Act The Clean Air Act is not applicable for the CMS or the IM at PRS 16-021(c) because there are no anticipated air releases. Dust will be mitigated for health and safety reasons during field activities, and the air will be continuously monitored with Miniram™ personal air monitors.

The Toxic Substances Control Act The Toxic Substances Control Act (TSCA) is not applicable to the CMS at 16-021(c) because no TSCA constituents will be released or removed from any soil or water treated.

The New Mexico Water Quality Control Commission and Drinking Water Regulations The New Mexico Water Quality Control Commission (NMWQCC) standards and The New Mexico Drinking Water standards for barium are applicable to the corrective action at PRS 16-021(c). Barium is the only COPC present at the site that exceeds human health, domestic water supply, wildlife habitat, or irrigation use standards that have been set under these regulations. The New Mexico Drinking Water Standard (2 000 µg/L) and the NMWQCC Ground Water Standard for Human Health for Barium (1 000 µg/L) will be applied to the nearest drinking water well under the groundwater evaluations described in Section 3.4.2.3. The NMWQCC Surface Water Standard for domestic water supply does not apply to the PRS 16-021(c) corrective action because the surface waters are not, and will not, be used for domestic water supply purposes.

4.0 IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section of the CMS plan presents the identification and screening of remediation alternatives under consideration for the 260 outfall and Cañon de Valle. Remediation technologies will be identified and screened and will address each compartment comprising the conceptual model: the contaminant source area, the unsaturated subsurface, the transport pathways and springs, and the alluvial system in the canyon bottom. The discussion of each potentially viable remediation approach will include:

- how the alternative works,
- results from previous usage under similar site conditions,
- anticipated technology limitations of the alternative, given waste characteristics,

- an estimate of the time required to implement the alternative, and
- recommendations.

The identification and screening process of remediation approaches has been ongoing since January 1998 through participation in an Innovative Treatment Remediation Demonstration (ITRD) Project. This ITRD project was designed to study HE and barium remediation technologies in both soils and water focusing on the unique problems associated with DOE HE processing facilities such as LANL and Pantex. Contamination at these sites differs from many Department of Defense (DoD) sites because of the occurrence of barium and because the principal HEs used were HMX and RDX (the nitrosamines) rather than TNT and DNT (the nitroaromatics).

In the ITRD program, DOE facilities work cooperatively with EPA, industry, national laboratories, and state and federal regulatory agencies to identify applicable, innovative technologies for use at their sites. Selected technologies are used to remediate small, representative areas as technology demonstrations; and then hopefully move to full-scale corrective actions. During the technology demonstrations, operating, treatment, performance, and cost data are generated. The ITRD technology screening was deemed to be more than sufficient for meeting the CMS technology screening requirements. The format of an ITRD project is to invite a panel of experts from government, industry, and regulatory agencies to form a team with site technical personnel. The team uses a combination of experience and brainstorming to generate a list of technologies that may be applicable to the conditions and challenges at the site. At this stage, approaches that have yet to be proven at full scale are given equal weight with mature technologies. After the list of technologies is assembled, individuals on the team take technologies and collect information on their maturity, cost, and likelihood of effectiveness for the site in question. The full panel then uses the information assembled to sort the technologies by applicability and maturity. The ITRD program is interested in fostering the demonstration of new technologies, provided that the technology development has progressed sufficiently to be evaluated for full-scale application within approximately two years. Good ideas and conceptual technologies that will require more than two years to get to pilot-scale demonstration exceed the time horizon for ITRD.

Active and passive treatment technologies for soil and water contaminated with HE were reviewed for both in situ and ex situ applications. These remediation approaches address all four compartments within the conceptual model. The general maturity, cost, and performance characteristics of the technologies were reviewed in detail. The major factors considered included protection of human health and the environment, technology implementation costs and ease of implementation, technology maturity, life cycle costs and overall cost effectiveness, ability to reduce the contaminants of concern to likely regulatory levels, time required for completion, safety issues, permitting, and remediation operations. These criteria were all applied in the context of: (1) the TA-16-260 site characteristics, (2) the TA-16-260 waste characteristics, and (3) technology limitations. To ensure that they hold some potential advantage over existing methods, remediation approaches or innovative technologies are screened against mature, or baseline, technologies. These criteria both meet and exceed the screening criteria established in EPA proposed 40 CFR Part 264.525.

Based on available technical information, the most promising technologies (those alternatives that meet the above criteria) have been proposed for in-depth assessment, laboratory treatability and pilot studies, and detailed engineering evaluations of expected site application costs and performance. These include pilot-scale and laboratory studies of several conceptual designs for soil and groundwater remediation.

Technologies such as zero-valent iron, granular activated carbon, and phytoaccelerated natural attenuation are proposed to be evaluated for use on LANL surface water and groundwater. These technologies address both the transport pathways and springs and the alluvial system compartments of the conceptual model. Technologies applicable to stream sediments and the source removal are also being evaluated. These include zero-valent iron, zero-valent iron enhanced by microbial activity, and stabilization. These remediation approaches address both the contaminated soil/tuff and the alluvial system compartments of the conceptual model. Natural attenuation or no action are to be evaluated for the unsaturated subsurface compartment. Information from the evaluations of technologies for treating soil/tuff will be utilized in the IM design. Initial treatment studies will be conducted through the summer, fall, and winter of FY98/99. The results of these studies will be compared with common remediation strategies such as incineration, composting, and capping to identify possible benefits and suggest cost-effective remediation alternatives.

Subsection 4.1 identifies all of the technologies evaluated. Many of these were discarded as impractical without detailed discussions. Subsections 4.2 through 4.4 describe those technologies that were evaluated in detail during the ITRD process.

Each technology described in Subsections 4.2 through 4.4 includes a recommendation for the LANL site derived from the ITRD participants. In those cases where further site-specific studies are recommended, a brief implementation strategy is provided.

For the more mature technologies, such as composting, direct reference to the literature is provided. For many innovative technologies references are not available. The recommendations below represent the consensus of the ITRD participants, many of whom are currently performing bench-scale and pilot-scale studies for the innovative technologies.

4.1. Identification of Potential Remediation Technologies

At the initial Pantex/LANL Explosives Project meeting in January 1998, approximately 40 active or passive treatment technologies were identified by the participants for in situ or ex situ applications, each with the potential to improve the schedule or costs of remediating the LANL and Pantex sites. Technologies focused on HE and its principal co-contaminant at LANL, barium. Approximately 30 participants representing DOE, EPA, DoD, industry, and other regulatory agencies attended this meeting, and formed the HE Advisory Group. The technologies identified and their potential application at these two sites are shown in Table 4.1-1.

Based on this initial technology identification effort, the HE Advisory Group proceeded to assess the applicability of each technology at the LANL and Pantex sites. To help in this evaluation effort, Pantex and LANL provided detailed information about site monitoring, contaminant distribution, and geotechnical data to the HE Advisory Group. Additionally, a meeting was held at Santa Fe in March 1998 so participants could tour the LANL site.

During several subsequent meetings, the HE Advisory Group discussions focused on assessing the applicability of each technology identified in Table 4.1-1 to the technical needs and concerns, and cost and performance goals of each site. Each technology was evaluated on the basis of maturity, cost, and implementation feasibility. Sections 4.2 through 4.4 discuss the assessment of the suggested technologies and summarize the findings of the HE Advisory Group on the applicability of these

technologies to enhance soil and groundwater remediation at LANL and Pantex. Only the more promising technologies listed in Table 4.1-1 are described in detail in subsections 4.2 through 4.4.

Table 4.1-1 identifies whether a technology is an in-situ or ex-situ technology. In-situ technologies have the advantage of minimal disruption of the local ecosystem, which supports a threatened and endangered species. The disadvantages of in-situ approaches are potentially leaving contaminants or their byproducts in the environment and difficulties with demonstrating effectiveness and completion. Ex-situ technologies, particularly when combined with off-site disposal, have the advantage of full removal of contaminants from the environment, and the disadvantage of significant disruption of the local ecosystem.

TABLE 4.1-1
Initial Technologies Identified for Consideration at LANL

Technology	Technology Class	In-situ/Ex-situ
Bioaugmentation Biosep/DuPont process	Biological	In-situ soils
Biodegradation(aerobic, anaerobic) with gas and liquid phase additions	Biological	In-situ soils
Biodegradation with thermal enhancement	Biological	In-situ soils
Biodegradation with natural attenuation	Biological	In-situ soils
Biodegradation – phytoextraction	Biological	In-situ soils
Soil flushing	Physical Chemical	In-situ soils
KM_nO_4 treatment	Physical Chemical	In-situ soils
Solidification/stabilization	Physical Chemical	In-situ soils
Co_{60} irradiation	Physical Chemical	In-situ soils
Fenton's reactions	Physical Chemical	In-situ soils
Chemoxidation	Physical Chemical	In-situ soils
Soil heating with soil vapor extractions	Thermal	In-situ soils
Soil vitrification	Thermal	In-situ soils
Radio frequency heating	Thermal	In-situ soils
Steam stripping	Thermal	In-situ soils
Downhole burner (disco)	Thermal	In-situ soils
RCRA cap/cover	Other	In-situ soils
Containment (slurry wall)	Other	In-situ soils
Composting	Biological	Ex-situ soils
Bioslurry – white rot fungi, Bioslurry – indigenous microbes	Biological	Ex-situ soils
Bioslurry—gas phase additions	Biological	Ex-situ soils
Zero Valent iron abiotic reduction	Physical Chemical	Ex-situ soils
Soil washing	Physical Chemical	Ex-situ soils
Solidification/stabilization	Physical Chemical	Ex-situ soils

TABLE 4.1-1 (continued)
Initial Technologies Identified for at LANL

Technology	Technology class	Applicability
Solvent extraction	Physical Chemical	Ex-situ soils
Fenton's reagent	Physical Chemical	Ex-situ soils
Base hydrolysis with humic acid	Physical Chemical	Ex-situ soils
Solvated electrons	Physical Chemical	Ex-situ soils
Gamma irradiation	Physical Chemical	Ex-situ soils
Molten salt	Physical Chemical	Ex-situ soils
Electron beam	Physical Chemical	Ex-situ soils
Thermal oxidation (incineration)	Thermal	Ex-situ soils
High-temperature thermal desorption	Thermal	Ex-situ soils
Low-temperature thermal desorption	Thermal	Ex-situ soils
Granular activated carbon (GAC)	Physical Chemical	Ex-situ surface and groundwater
UV/peroxide	Physical Chemical	Ex-situ surface and groundwater
Peroxone	Physical Chemical	Ex-situ surface and groundwater
Titanium oxide/UV	Physical Chemical	Ex-situ surface and groundwater
Phytoremediation	Biological	In-situ surface and groundwater
Electron beam	Physical Chemical	Ex-situ surface and groundwater
Zero valent iron	Physical Chemical	Ex-situ surface and groundwater
Supercritical water oxidation	Physical Chemical	Ex-situ surface and groundwater
Biotreatment	Biological	Ex-situ surface and groundwater
Reactive barriers	Physical Chemical	Ex-situ/in-situ surface and groundwater

4.2 Baseline Treatment Technologies

Several treatment technologies are considered as baseline technologies for the treatment of explosives-contaminated soil and water. These technologies are generally mature but often have limitations regarding application and cost-effectiveness at a specific site. Any innovative technology needs to be compared with these baseline technologies to determine the overall benefits to schedule, performance, cost, or regulatory acceptability. This section provides a short overview of the cost and performance of the baseline technologies. The information is summarized in Table 4.2-1 at the end of this section.

4.2.1 Thermal Treatment (Incineration)

Incineration was first demonstrated on explosives-contaminated soil in 1982 at the Savannah Army Depot (Sisk 1998, 58940). Projects have been completed at four sites, with costs that range from $250–$600 per ton. Pilot-scale feed rates were 200–400 lb/hour and full--scale rates are estimated to be 20–40 ton/hour. Advantages of incineration are that it is a process that can handle a wide range of waste characteristics and contaminant concentrations, has a large treatment rate, has little downtime, is not affected by the weather, and can treat both liquids and solids.

Disadvantages of incineration include a negative public perception, the need for air pollution control equipment and air permitting to control byproducts, high mobilization and demobilization costs ($2–3.5 million), and the energy-intensive nature of the process. It takes two years, on average, to obtain regulatory approval for incineration. Incineration has been used to treat explosive compounds down to

Table 4.2-1
Cost and Performance of Common Baseline Treatment Technologies

Treatment Technology	Unit Cost	Treatment Rate	Demonstrated Performance	Explosives Treated	Implementation Issues
Soils Treatment					
Incineration (ex situ)	$250–700/ton	20–40 ton/hour	1µg/g 80% uptime liquids and solids	All HE	Public perception, high mobilization & demobilization costs, ~2 years to get approvals
Stabilization (ex situ)	$150–200/ton	80 ton/hour	Meets LDRs	HE & mixed metals	None identified
Caps (in situ)	$1–2/ft^2	NA	Permeable barrier	NA	Long-term performance maintenance & liability
Covers (in situ)	$2.50–$7.50/ft^2	NA	Impermeable barrier, leachate collection	NA	Long-term performance maintenance & liability
Slurry walls (in situ)	$5–10/ft^2	NA	Minimize horizontal migration	NA	Long-term performance maintenance & liability
Water Treatment					
GAC (ex situ)	$0.40–1.00/1000 gal.	Scale dependent	<5 µg/L	All HE	Operation & Maintenance costs

levels of 1 mg/kg. The small volumes of soil to be treated at LANL probably do not warrant the high mobilization costs incineration requires.

Recommendation: Do not pursue laboratory- or pilot-scale studies for PRS 16-021(c) at this time due to small volumes of soil requiring treatment.

4.2.2 Stabilization

Stabilization of explosives-contaminated soil has been demonstrated at the Umatilla Army Depot Site (EPA1995, 58942; Channel 1996, 58943). Stabilization was the selected remedy for the Umatilla Army Depot Burning Ground because the soil contained metals as well as explosives. Incineration was also evaluated, but addressing the metals would have required stabilization after incineration, for a total cost of $15 million. The cost of stabilization alone was estimated at $4 million. An on-site landfill accepted the stabilized soil, which had to meet toxicity characteristic leaching procedure (TCLP) criteria for metals and separate leaching criteria for HE. Lab- and pilot-scale tests were performed using combinations of the

amendments Portland cement, fly ash, and GAC. Carbon in the cement mix improves performance, with 5% GAC providing optimum performance. The full-scale recipe used only 10% Portland cement, no fly ash and 1–1.5% GAC. This reduced recipe caused about 10% of the waste to fail TCLP, requiring breakup and retreatment. Approximately 30 000 tons of soil were processed at a cost of approximately $5 million.

The Umatilla Army Depot stabilization operation had a capacity of 80 ton/hour and cost $170 per ton (turnkey). It is estimated that costs at other sites would range from approximately $150–$200 per ton (turnkey costs). There is about a 50% increase in volume over the starting amount. Stabilization amendments could also include sulfates, in order to better stabilize barium as insoluble barium sulfate.

Stabilization could be a good option for soil contaminated with mixed metals and explosives, such as the soils at LANL.

Recommendation: Pursue as an option for soils at LANL. During the IM, PRS 16-021(c) outfall soils will need to be treated to meet LDRs before disposition in an approved landfill. Perform laboratory-scale studies on LANL wastes under ITRD program.

Laboratory-scale study implementation strategy : Provide soils from outfall area to a vendor experienced in soil stabilization. US Army Engineer Waterways Environmental Station (WES) in Vicksburg, Mississippi, performed the treatability studies for Umatilla Army Depot. The vendor will determine optimum mixes of carbon, Portland cement, sulfate, and fly ash to minimize leaching of HE and barium from the treated mixtures. Performance criteria will be determined by the waste characteristics and waste acceptance criteria of the treatment, storage, and disposal (TSD) facilities selected to receive IM wastes.

4.2.3 Containment Options

Much of industry uses caps and covers as a method of containing contaminants at a site. Caps or covers are used in conjunction with slurry walls to contain contaminants while a site is in operation. This option requires maintenance of the cap or cover and commonly requires a leachate collection system. This type of system provides an effective interim method to limit contaminant migration. DuPont, for example, uses these types of systems routinely at their facilities. Given the relatively small volume of highly contaminated material at LANL's PRS 16-021(c), removal is probably preferable to capping. After excavation capping might be warranted to hydrologically isolate residual contaminants in the subsurface directly beneath the excavation footprint.

Recommendation: Laboratory- or pilot-scale studies are not required. If capping is required at PRS 16-021(c) during the IM, use results from studies performed by the MDA focus area.

4.2.4 Water Treatment with Granular Activated Carbon

GAC treatment is the most common method for remediation of surface or pumped groundwater contaminated with explosives. For example, pump and treat units using GAC systems have been deployed at both the Umatilla Army Depot Site and at the Pantex site (EPA 1995, ER ID 58941). Estimated costs are $0.40–$1.00 per 1000 gal. of water treated. Pump and treat units for HE are typically scheduled for deployment for 15–30+ years, depending on the size of the HE plume and the concentration of HE in the groundwater. GAC units do not remove significant amounts of barium; however, they can be combined with other treatment methods (passive barriers, reverse osmosis) in a

treatment train. This treatment method should continue to be evaluated for the contaminated surface waters at LANL.

Recommendation: Do not pursue laboratory- or pilot-scale studies at LANL at this time. This technology is sufficiently mature that implementation at LANL should be feasible with minimal or no laboratory- or pilot-scale studies.

4.3 Assessment of Additional Soil Treatment Technologies

Several in situ and ex situ treatment technologies were identified for the treatment of explosives-contaminated and mixed explosives/metals contaminated soil. In situ treatment technologies, such as bioremediation, chemical treatment, chemical flushing, or thermal treatment are often attractive options because of the ability to treat the soil in place, thereby reducing excavation costs. Excavation at LANL is expected to be somewhat complicated because of the difficult terrain and because work schedules are restricted by HE machining operations at the site. In situ techniques also minimally impact local ecosystems, including threatened and endangered species. Ex situ treatment technologies, such as composting, bio- or chemical-treatment reactors are attractive because they provide improved flexibility in treatment options, allowing optimum contaminant degradation performance. The type or combination of technologies used at a site should be based on the overall cost-effectiveness and performance of a system.

The HE Advisory Group assessed each technology option that was initially identified. Many were quickly determined to be at too immature a stage for use, not applicable to explosives-contaminated media, or not applicable at these sites. Several technologies appeared to have potential applicability at these two sites and were retained for more detailed evaluation. Based on these detailed evaluations several are being considered for site-specific laboratory treatment and pilot studies, as summarized in Table 4.3-1. This section provides an overview of the most appropriate in situ and ex situ treatment technologies identified by the HE Advisory Group.

4.3.1 In Situ Anaerobic and Aerobic Biotreatment Options

As the factors that control microbial degradation of contaminants become better understood, in situ biological treatment of contaminated soil is becoming recognized as a feasible remedial technology (Craig et al. 1995, 58939). This technology is finding use throughout the world and has significant potential as a low-cost remediation technology. For these reasons, the HE Advisory Group worked closely with the DOE, EPA, and DoD to assess the applicability of this technology at LANL.

The Idaho National Environmental Engineering Laboratory has found that gas-phase delivery of ethanol or acetic acid stimulates bioremediation of RDX and TNT, although high-concentration, solid-phase explosive contamination does not seem to be degraded. Laboratory tests have found increasing biological activity in soils at increasing depth, and anaerobic conditions showed higher activity than aerobic conditions. Microcosm experiments conducted at the University of Texas, Austin using Pantex soil also demonstrate that anaerobic conditions are related to significant RDX reduction. The lab results showed significant reductions in as little as two months. Therefore, it appears that anaerobic bioremediation would be appropriate for the contaminants of concern at LANL.

For applications in the vadose zone, it would be necessary to introduce nutrients to stimulate bacterial degradation of the explosives. It may be necessary to use an inert gas or a liquid in conjunction with

nutrient enhancement to achieve anaerobic conditions. This process would require a robust nutrient injection system. Therefore, vapor phase applications are expected to be easier to control and probably would be applicable at any depth. Other types of biological injection systems may have application at

Table 4.3-1
Summary Applicability of Soil Treatment Technologies

In situ Treatment of Soils			
Treatment Technology	Source	Alluvium	Subsurface
Biological			
Aerobic	No	No	No
Anaerobic	Uncertain	Uncertain	Uncertain
Natural Attenuation	No	Yes	Yes
Phytoextraction	No	Uncertain	No
Physical/Chemical			
Soil Flushing	No	No	No
Stabilization	No	No	No
Chemical Oxidation	No	No	No
Thermal			
Gas Heating	No	No	No
Ex situ Treatment of Soils			
Treatment Technology	Source	Alluvium	Subsurface
Biological			
Composting	Yes, With barium stabilization	Uncertain	No
Solid Phase	Yes, With barium stabilization	Uncertain/no	No
Bio Slurry	Yes, With barium stabilization	Uncertain/no	No
Physical/Chemical			
Soil Washing	No	No	No
Stabilization	Yes	Uncertain/no	No
Chemical Treatment	Yes	No	No

Note: LANL locations have barium that must be considered in any treatment process.

shallow or deeper depths, depending on how cost effectively the nutrients can be applied. Both vapor phase and other nutrient amendment applications, such as land farming applications, were identified for

laboratory and pilot studies. This treatment technology is insufficiently mature to estimate a time for treatment. Biotreatment options do not remediate barium, and high metal levels are often antagonistic to bioremediation processes. The complex hydrogeology at LANL would complicate implementation of this technology. Despite these concerns, this technology is being retained for consideration at LANL

Recommendation: Do not pursue laboratory- or pilot-scale studies at LANL at this time. LANL will use results from the proposed pilot-scale study being performed at Pantex under the auspices of ITRD.

4.3.2 In Situ Natural Attenuation Applications

Empirical evidence exists at many HE-contaminated sites for natural attenuation of HE contaminants in the environment. For example, inspection of highly contaminated soil at numerous US Army ammunition plants over decades has shown that denuded areas have gradually reduced in size (McCutcheon personal communication, 1998). Plants, microbes, contaminant migration, and photodegradation reactions are probably responsible for reclaiming contaminated areas. TNT in denuded areas is often present at an average of about 5000 µg/g in the unvegetated soil, with hundreds of micrograms per gram of TNT in the soil on the fringe where grasses are growing and tens of micrograms per gram in the soil where the trees have established (that used to be part of the denuded areas). DoD/DOE/EPA's Strategic Environmental Research and Development Program is funding natural attenuation work on HE, in which kinetic reactions are being evaluated at Joliet Army Ammunition Plant and Crane Naval Weapon Station. Accurate characterization is vital for natural attenuation studies, and a conceptual model should be developed to describe the processes involved. US Army Engineer WES has developed a protocol for natural attenuation studies.

Natural attenuation is probably occurring at LANL, but verification of such processes will be difficult to quantify. Ongoing studies at LANL suggest that TNT breaks down readily in the environment, but that RDX and HMX do not (DuBois and Baytos 1991, 06994). This treatment technology is immature, treatment durations cannot be estimated at this time. Leachable barium levels are probably naturally attenuating due to conversion of barium to barium sulfate. Natural attenuation should not be discounted and should continue to be considered at LANL, especially in combination with active efforts to remove source terms and other significant contaminant concentration areas.

Recommendation: Do not pursue laboratory- or pilot- scale soil studies at LANL at this time. In-situ natural attenuation may be successfully implemented as part of the IM strategy.

4.3.3 In Situ Phytoremediation Applications

Empirical evidence for phytoremediation of soils has been observed at several army ammunition plants (McCutcheon 1998, 59170). Several types of phytoremediation have been observed: phytodegradation, phytostimulation, phytoaccumulation, phytovolatilization, and phytostabilization. Cellular enzymes are responsible for chemical reactions eliminating HE from natural systems. Nitroreductase enzyme has been shown to reduce nitro groups to amino groups on the structures of RDX and TNT. Lactase enzyme has been shown to participate in ring cleavage reactions. Experiments with several plant species have shown significant reductions in concentrations of aqueous phase HE. TNT reaction rates are apparently faster than those for RDX by approximately a factor of 10. For soil or sediments containing HE, the mass transfer from the solid to aqueous phase will likely be the rate-limiting step for in situ phytoremediation applications. The treatment depth of this technique is limited to the root zone and varies seasonally. Poplar trees produce nitroreductase and could treat the soil from 2–15 ft deep. Yucca plants have been

shown to uptake explosives. Other native plants may also be effective at bioremediation of HE. The end product of the phytoremedation reactions is typically plant biomass. However, if the plants are bioaccumulating toxic byproducts or metals, biomass may need to be harvested to avoid ecotoxicity problems. High concentrations of HE have been shown to be toxic to plants.

Phytoremediation probably could be used as a polishing step for remediation processes at some of the shallow alluvial areas at LANL. Native plants may be capable of uptaking HE; uptake of HE by existing plants may be the reason for the apparent natural reduction of the explosive contaminants along Cañon de Valle. Barium sulfate particles have been observed in the xylem of ponderosa pine in Cañon de Valle, suggesting that plants may also be effective at sequestering barium. However, sequestration of metals such as barium still leaves a metal-bearing material in the environment. Phytoremediation and phytosequestration technology is immature, treatment durations cannot be estimated at this time. Because phytoremediation technologies may be appropriate for removal of HE and barium from soils and waters at LANL, the technology should be reviewed further.

Recommendation: Do not pursue as option for source area soils at LANL at this time. Consider as an option for the canyon alluvial sediments and soils.

4.3.4 In Situ Soil Flushing

Soil flushing with surfactants to treat dense non-aqueous phase liquids (DNAPLs) has been actively pursued by both the EPA and DOE for several years. The DoD is beginning to look at the use of soil flushing to treat explosives-contaminated soils and groundwater. At the DoD's Umatilla Army Depot, source term remediation efforts removed lagoon bottoms plus about 20 ft of subsoils, then the lagoon areas were used for a re-infiltration gallery for a pump and treat system, setting up a recirculation, or soil flushing cell (Defense Environmental Restoration Program 1994, 59172). The soils are a high hydraulic-conductivity gravel/sand mix. About 300 gal./min is flushed through the soils over a 1-acre area. The pump and treat system is remediating a 350-acre plume. In situ soil flushing has resulted in the following reductions in leachate concentrations: TNT 92%, TNB 68%, RDX 87%, and HMX 94%. This pump and treat soil flushing operation is expected to continue for approximately 20 years.

The principal concerns with soil flushing are: (1) controlling the flushing of the soil, (2) avoiding the possibility of increasing the mobility of contaminants in the vadose zone, (3) determining the technology's ability to reduce all the contaminants of concern, and (4) applying the technology cost-effectively. The injection of treated water to help flush RDX from the soil in situ is potentially feasible from a technical standpoint, but control of the injected water and verifying compliance are issues that need to be better understood. Soil flushing could also be used to mobilize soluble barium. The complexity of the hydrologic system at LANL is not conducive to soil flushing because of fractures in the subsurface and because of potential flushing media loss to a perched aquifer or the regional aquifer.

Recommendation: Do not pursue as an option for LANL at this time.

4.3.5 In Situ Chemical Oxidation

Oak Ridge National Laboratory (ORNL) has explored the use of potassium permanganate for the chemical oxidation of trichloroethene. Reagents cost approximately \$30–\$40 yd^3. There are no data for explosives; however, ORNL has operational lab facilities that are capable of performing lab tests if requested. WES has performed ex situ chemical oxidation lab and pilot tests. Fenton's Reagent is

another potential oxidant for in situ chemical oxidation. Achieving the correct soil/contaminant/water/H_2O_2 ratios are critical, and the reactions work better at higher temperatures. The reaction takes place in the aqueous phase; therefore, it is likely to be water solubility limited and hence is not recommended for in situ use. This treatment technology is immature, treatment durations cannot be estimated at this time. This approach is not feasible at LANL because of the high barium concentrations that would still be present in the surface and because of concerns with mobilizing oxidation byproducts via surface and groundwater pathways.

Recommendation: Do not pursue as an option for LANL at this time.

4.3.6 In Situ Base Hydrolysis

Base hydrolysis methods have been developed in the laboratory as an alternative to open burning/open detonation of bulk explosive materials. The process requires considerable time (4–5 hours) and elevated temperatures (60–150°C), it requires a biotreatment step for the nonenergetic aqueous wastes generated, and the kinetics are thought to be mass transfer limited. The principal advantage of base hydrolysis is that it can accept high concentrations of HE. The disadvantages are that it is not appropriate for in situ applications, byproducts of TNT treatment may be problematic, and the technology has not matured sufficiently for field applications. This treatment technology is immature; treatment lengths cannot be estimated at this time. This approach is not feasible at LANL because of the high barium concentrations that would still be present in the surface and because of concerns with mobilizing byproducts via surface and groundwater pathways.

Recommendation: Do not pursue as an option for LANL at this time.

4.3.7 In Situ Thermal Treatment

The in situ HE catalytic oxidation process uses a downhole burner developed for oil field applications to raise the soil temperature sufficiently to thermally decompose explosive residues. Differential thermal analysis of pure RDX shows thermal decomposition occurs at approximately 250°C (400° F). Heated air from a burner is directed into a treatment zone using traditional soil vapor extraction technology. Calculations show that for each 1000 $yd^3$of contaminated soil it will take about 75 days at 450 ft^3/min to raise soil temperature to 400° F, using approximately 4500 gal. of propane (at a cost of about $3300).

Energy balance estimates indicate that it will take

- 90 288 BTU per $yd^3$to heat soil to 100°,
- 41 040 BTU per $yd^3$to heat the soil water to 100°C,
- 262 710 BTU per $yd^3$to evaporate the soil water, and
- 106 920 BTU per $yd^3$to heat the soil to 250°C,
- for a total of 500 960 BTU per yd^3.

The time required to heat the soil (33 days), heat the soil water to boiling (6 days), and the time to evaporate the soil water (38 days) are dependent on the burner temperature (estimated to be 1400° F) and flow rate (200 standard ft^3/min). While these figures indicate that the cost of propane is small ($4.6

per yd^3), the boreholes to perform the hot air injection and extraction are estimated to cost about $30 per yd^3. This method might be cost-effective for deep applications.

The previous use of low-temperature thermal desorption on explosives indicated that TNT transformation products might include aniline, which is of concern for toxicity reasons. The army has evaluated the use of hot gas decontamination of buildings. Temperatures of 500–700° F are required for effective treatment. The major issues with in situ thermal systems are the temperatures required to achieve decontamination to a reasonable radius, and the safety issues of heating explosives. Both concerns could significantly drive the remediation costs above those estimated above. This treatment technology is immature; treatment lengths cannot be estimated at this time. Barium would not be effectively remediated using this technique. LANL's safety group has concerns with using such a system at sites where detonable quantities of HE are present. The HE Advisory Group recommended that these safety issues must be addressed before the application of this technology can be realistically considered at LANL.

Recommendation: Do not pursue as an option for LANL at this time.

4.3.8 Ex Situ Soil Composting/Biopile Applications

Composting has been implemented at pilot- and full-scale at several army sites (Craig et al. 1995, 58939). Composting requires the blending of about 30% soil and 70% amendments (typically manure or waste agricultural products) to generate thermophilic conditions (indicated by temperatures greater than 40°C). Biopile treatments are similar, but are considered mesophilic (occurring at less than 40°C). At Umatilla Army Depot about 11 000 yd^3 of TNT-contaminated soils (averaging 1200 µg/g after sieving to 1 in.) were treated for about 15 days to reach the preliminary remediation goal (PRG) of 30 µg/g. Turnkey cost was about $300–$350 per yd^3. It is estimated that costs would be about $250–$300 per yd^3 today. There appear to be commercial groups capable of performing full-scale work (six bids received, five were capable). Bench-scale tests are needed to assess amendment proportions.

Evaluation of composting at Hawthorne Army Depot found that it was necessary to use a substantial amount of water (1.7 gal. per yd^3 per day). Daily mixing was required. A building housing the operation was not required (although the process still required windbreaks to maintain thermophilic temperatures). Four recipes containing various proportions of soil, hay, potato, cow manure, and wood chips were evaluated. Soils contained TNT and RDX starting at about 5700 µg/g (after blending), and the PRGs of 233 µg/g for TNT and 67 µg/g for RDX were reached. Full-scale turnkey costs were about $163 per $yd^3$for 40 500 yd^3.

At Toule Army Depot, soils containing about 1000 µg/g of HE were composted in 20 days and were able to reach the PRGs of 95 µg/g for TNT, 34 µg/g for RDX, and 18 000 µg/g for HMX. This work found that the SW-846 Method 8330 detection limits in compost were 2 µg/g for TNT and 4 µg/g for RDX. The soil volume was found to increase by about 85%.

The windrow composting method appears to apply an aerobic/anaerobic cycling and an effective method for adding water. In areas that did not receive adequate amounts of water, thermophilic conditions were not achieved. Biopile applications are similar to composting, however, soil is not mixed and water is not added, which limits treatment rates because in the absence of water, thermophilic conditions will be lost. Composting is thought to be available in the range of $200-$350 per yd^3. It is estimated that at

approximately 30 000 yd^3, incineration becomes more cost-effective than composting. The US Army Corps of Engineers is developing a guidance document on composting.

Composting implementation times have ranged from 30–235 days in pilot studies (Craig et al. 1995, 58939). There are concerns about use of composting at LANL because soil also has high barium levels, which could be toxic to composting organisms. Also, barium-contaminated residues would require treatment before disposal.

Recommendation: Do not pursue laboratory- or pilot-scale studies at LANL at this time. LANL will utilize results of Pantex studies as needed. Ex-situ soil composting/biopile may be implemented as part of the IM strategy.

4.3.9 Ex Situ Bioslurry Reactors

Much of the work on ex situ bioslurry reactors for HE has been done by the DoD and DOE (Craig et al. 1995, ER ID 58939; Manning et al. 1996, 58937). A slurry reactor demonstration was recently performed at Joliet Army Depot. In this demonstration, a semibatch process was used that required a six- to eight-week startup period, used a 10–15% replacement method, and achieved 99.6% TNT reduction. The demonstration used aerobic/anoxic cycling, found molasses as an optimal co-substrate, and recycled the process water. At the Iowa Army Ammunition Plant, a 10 000 yd^3 demonstration was performed to develop cost and performance guidelines. The process used a 40% slurry in an open lagoon. Batch treatment times were about six to eight weeks to reach PRGs of 196 µg/g for TNT and 53 µg/g for RDX. After 11 weeks, the free release criteria were reached (47 µg/g for TNT and 2 µg/g for RDX). The system could not be operated in cold weather; at less than 20°C treatment slowed almost to a stop.

Dewatering of the slurry appears to be a major issue. The water will require treatment because it has high biological oxygen demand (BOD) and high suspended solids. Cost evaluations found that the aerobic tank method was about $345 per yd^3, the aerobic lagoon method was about $307 per yd^3, and the SABRE lagoon method was about $408 per yd^3. These costs are similar to composting ($300 $350per yd^3), but lower than incineration ($700 per yd^3). In conclusion, the ex situ bioslurry systems appear feasible for excavated materials, but there does not seem to be a clear advantage over composting. In composting waste volumes increase, while with slurry reactors, the volume of water that has to be treated and handled increases. Both composting and the bioreactors should be compared for specific application performance and costs at each site. Barium treatment of soil residues would be required at LANL. This technology is promising for the LANL site.

Recommendation: Pursue laboratory-scale studies at LANL. Bioslurry processes may successfully be implemented as part of the IM strategy.

Implementation Strategy: Provide PRS 16-021(c) soils to a vendor that can implement laboratory-scale treatability studies.

4.3.10 Ex Situ Soil Chemical Treatment Options

In the early 1980s the Army Environmental Center performed successful ex situ soil-slurry chemical-oxidation tests on HE and found that this process was pH dependent. However, the effluent failed the microtoxicity test, requires dewatering the slurry (with a high BOD load), and did not appear to be any more economical than incineration.

A commercial company claims to have an ex situ mixing system that can apply chemical oxidants. They have experience with PAHs, pesticides, and wood-treatment compounds and claim the process will work for TNT. They have a one-sixth scale treatability testing system. Another vendor has a solvated electron technology using ammonium that has recently been used for treatment of explosive soils. The system also is claimed to remove metals, such as barium. The costs for the system appear to be high relative to other types of technologies. Three firms have been identified that have capabilities and interest for chlorinated hydrocarbon treatments, but these companies voiced reluctance to work with explosives.

Reduction of HE in soil with zero-valent iron (ZVI) has been demonstrated in the lab (Agrawal and Tratnyek 1995, 58938). However, more work is needed to assess the reaction products and evaluate methods to recover the iron from the soils. Labwork found that adding hydrogen peroxide after ZVI treatment resulted in the oxidation of TNT ZVI reduction products, and that with time, the products became strongly sorbed and were not susceptible to further oxidation. Work with RDX found that the initial ZVI reduction products were not strongly sorbed and were more readily susceptible to oxidation. ZVI treated TNT was found to be more susceptible to biodegradation than untreated TNT in liquid media inoculated with a microbial consortium obtained from TNT-contaminated soil. However, even with pretreatment with ZVI, the rate of biodegradation was slow. These treatment technologies are immature; treatment lengths cannot be estimated at this time. Barium chemical treatment can be incorporated into some of these chemical treatment methods, primarily by including sulfates in the treatment process.

The data suggest that these types of systems may be technically feasible, depending on the application. However, the technical group needs to closely assess and compare the cost-effectiveness of the systems relative to other technologies before being suggested for full-scale implementation. Further evaluation for LANL soils is recommended.

Recommendation: Pursue laboratory-scale studies at LANL. Chemical treatment processes may successfully be implemented as part of the IM strategy.

4.4 Assessment of Surface/Groundwater Treatment Technologies

Another set of technologies reviewed by the HE Advisory Group were alternatives for the treatment of surface and groundwater. The technologies reviewed included biological reactors, iron filings treatment concepts, and phytoremediation options. The purpose was to identify treatment technologies capable of treating water containing RDX more cost-effectively than traditional chemical treatment processes, such as GAC units.

Based on a review of and assessment of the identified technologies, the HE Advisory Group identified several treatment technologies with the potential to reduce groundwater treatment costs and minimize generated wastes, while still achieving likely remediation goals. These technologies are being evaluated in more detail to better assess expected cost-effectiveness and overall performance at LANL. The assessment of each identified technology is discussed below and is summarized in Table 4.4-1.

4.4.1 Advanced Catalytic and Chemical Treatment

WES has performed ex situ chemical oxidation lab and pilot tests for extracted groundwater (Toro et al. 1995, 58936). Traditional advanced oxidation processes (AOPs), such as ultraviolet/peroxide and ultraviolet/ozone, have been evaluated by WES and shown to be effective for TNT. Production of the TNB intermediate was not a problem after a five-minute treatment in a 1-L reactor. Non-traditional AOPs,

such as peroxone with and without ultrasound, were also evaluated by WES. These require more treatment time (25 min) to completely remove the TNB intermediate. Geocleanse has performed similar

work for RDX in water using Fenton's reagent with reasonably good results. Barium would not be degraded by these treatments.

The cost-effectiveness and performance of the technologies depend on the contaminant levels and flow rates. The application of these technologies, therefore, is site-specific. These technologies will be further reviewed, but their application may be limited at LANL.

Recommendation: Do not pursue as an option for LANL at this time.

4.4.2 Reactive Treatment Material Applications

ZVI has been investigated for removal of HE from water. Treating an aqueous solution of TNT (70 mg/L) with 1% ZVI completely removed TNT from solution after eight hours of contact time. High Performance Liquid Chromatography (HPLC) analysis showed production of monoaminodinitrotoluenes during the initial 30 min, but these later disappeared indicating further transformation or sorption to the iron surface. Treating an aqueous solution of RDX (32 mg/L) with 1% ZVI completely removed RDX from solution after 96 hours of contact time. The issues with this treatment include assessment of the reduction products, and determination of the reaction kinetics, material longevity, and other design parameters. ZVI would not effectively remove barium from water.

In summary, ZVI has potential for use in treatment of HE in groundwater. However, the maturity of the technology is low, and much more work is needed to assess the viability for field applications. Because this treatment technology is immature, treatment lengths cannot be estimated at this time. The major advantage of this material is the passive applications that it may support; these passive applications could significantly reduce operations and maintenance costs for surface water and springs treatment.

Recommendation: Do not pursue as an option for LANL at this time.

4.4.3 Reactive Barriers

Reactive walls are passive, low maintenance systems that can be used to treat some types of groundwater contamination. Laboratory bench-scale tests and large-scale field demonstrations have focused on the chlorinated hydrocarbon groundwater contaminants such as trichloroethylene (TCE), perchloroethylene (PCE), and uranium/technetium inorganic ions. Treatment materials are typically characterized by the degradation half-life, as this impacts the amount of material used in field systems. Funnel and gate installations are often employed to direct groundwater flow through the reactive zone. Ideally the reactive wall should be tied into a confining unit so that water must pass through the reactive zone before moving downgradient. If a hanging wall is used, it should be installed to a depth 4 to 5 times the depth of the plume to avoid bypass. Various reactive materials have been used in reactive walls: sorbents, biological treatment zones, and ZVI. Reactive barrier materials that remove barium are available. These kinds of passive systems could have application at LANL, with the biggest issue being installation. This treatment technology is immature; treatment lengths cannot be estimated at this time. The technology appears feasible at LANL where the shallow nature of surface water may be cost-effectively treated by this technology.

Recommendation: Pursue laboratory-scale studies at LANL. Reactive barriers may be implemented for treatment of transport media.

Implementation Strategy: Cañon de Valle waters will be provided to a vendor with experience implementing this technology. A range of barrier materials will be evaluated to determine the optimum materials for HE and barium removal.

4.4.4 Phytoremediation for Water Treatment

Plants containing the nitroreductase enzyme are capable of treating HE-contaminated solutions with half-lives of 1– 70 hours (McCutcheon 1998, 59170). The applications of this technology for surface waters would be as constructed wetlands. Tests are being conducted at Iowa Army Ammunition Plant, Milan Army Ammunition Plant, and Volunteer Army Ammunition Plant of these types of systems. A cost and performance study of constructed wetlands will soon be available from Darlene Bader (AEC) from the Milan Army Ammunition Plant pilot studies. Barium may either pass through the treatment system or become sequestered in the plant material. If the latter occurs, harvesting the plant material may be necessary. This treatment technology is immature; treatment lengths cannot be estimated at this time. This type of system has potential applications at LANL.

Recommendation: Pursue laboratory-scale studies at LANL.

Implementation Strategy: Provide HE-contaminated LANL waters to EPA, WES, or another institute with experience in investigating phytoremediation of HE. Evaluate plant uptake of HE both in the laboratory and in the field.

4.4.5 Bioreactors

Several types of bioreactors were considered for application at LANL. The best concept would depend upon the overall cost of the process and factors such as total waste generated and operating and maintenance requirements. Anaerobic reactors would probably be most appropriate for effective operations. Barium would not be treated by a bioreactor. This option does not seem especially attractive at LANL. Based on the technology review, the HE Advisory Group believed that a passive, rather than an active, treatment system would be more appropriate for these sites because the passive systems appear to be more cost-effective and have similar performance characteristics. This treatment technology is immature; treatment lengths cannot be estimated at this time.

Recommendation: Do not pursue as an option for LANL at this time.

Table 4-4-1
Summary Applicability of Innovative Surface and Groundwater Treatment Technologies

Treatment Technology	LANL
Advanced Oxidation	No
Passive Treatment Walls	Yes
Zero Valent Iron	No
Phytoremediation	Possibly
Bioreactors	No

4.6 Summary and Recommendations for Innovative Treatment Technology Studies

Based on the technologies identified and reviewed by the HE Advisory Group for the Pantex/LANL Explosives ITRD Project, several technologies were identified that are capable of enhancing the remediation efforts. These technologies, or remedial approaches using the technologies, meet the screening criteria established in EPA proposed 40 CFR Part 264.525. The screening criteria are as follows:

- be protective of human health and the environment,
- attain likely media cleanup standards,
- control the sources of releases so as to reduce or eliminate, to the extent practicable, further releases that may pose a threat to human health and the environment, and
- comply with standards for management of wastes.

The screened technologies that meet the above standards, as well as other criteria discussed in Section 4.0, have been selected for site-specific laboratory treatment or pilot studies (Table 4.6-1). These studies will be conducted over the next several months to identify technology performance and costs in applications at the two sites, and to help define optimum operating parameters for possible full-scale remediation efforts. Pantex laboratory pilot studies are also identified in this table because LANL may directly utilize the results of the Pantex studies.

The site-specific treatment studies being considered for LANL include approaches for three compartments comprising the conceptual model: the contaminant source area (soils), transport pathways and springs pathway (water), and alluvial system (soil and water). Monitored natural attenuation or no action are considered for the unsaturated subsurface compartment. Treatment studies for excavated soils will include stabilization, chemical treatment, ZVI, and ZVI augmented in a bioslurry. The treatment studies for the seep and spring waters will include passive barrier surface water treatment and phyto-remediation. The alluvial waters will be evaluated for the same technologies as the seep and springs in addition to evaluating monitored natural attenuation through phytodegradation. The default technology for the seep, springs, and alluvial waters is an active pumping system using GAC. This technology is mature and does not require a treatability study.

Table 4.6-1
Technologies Recommended for Laboratory and Pilot Scale Application at LANL and Pantex

Technology	Site of Pilot Study	Media	Nature of Pilot Study
Stabilization	LANL	Soil	Laboratory scale
Chemical Treatment/ZVI	LANL	Soil	Laboratory scale
Bioslurry with ZVI	LANL/Pantex	Soil	Laboratory scale
Phytoremediation	LANL	Water	Pilot scale
Passive Barrier	LANL	Water	Laboratory and Pilot scale
Bioremediation– vapor phase augmented	Pantex	Soil	Pilot scale
Composting	Pantex	Soil	Pilot scale

As the results of the laboratory-scale and pilot studies are finalized, engineering evaluations of expected performance and cost of several possible remediation options and concepts at each site will be developed by the HE Advisory Group. The results of the HE Advisory Group engineering and cost evaluations, as well as the results of each treatability study, will be available to all project participants. Based on the current treatability study schedule, suggested remediation options for each site from the HE Advisory Group should be finalized in calendar year 1999. The suggested remediation approaches will be evaluated according to the process presented in Section 5.

5.0 PROCESS AND CRITERIA FOR EVALUATION OF REMEDIATION ALTERNATIVES

5.1 Process

Section 5 discusses the process for evaluating remediation technologies/alternatives, selected in Section 4, to determine the most appropriate remedy(s) for the site. Four components comprising the site conceptual model, have been identified for the 260 outfall and Cañon de Valle. These site conceptual model components include: the contaminant source area, the unsaturated subsurface, the transport pathways and springs, and the alluvial system in the canyon bottom. Remediation approaches that have been successfully screened for each component are discussed in Section 5.2. The process and criteria for evaluating these remediation approaches is the same regardless of the actual remedy or component. These criteria are discussed in Section 5.3.

5.2 Potential Remediation Alternatives

Remediation alternatives are based on corrective measure objectives, discussed in Section 3, and analysis of technologies, presented in Section 4. The remediation approaches represent either a single technology, combination of technologies, or no action. The approaches represent workable options that will adequately address the site problems. Potential remediation alternatives for each component of the conceptual model are discussed below.

Contaminated Source Area

The soil in the 260 pond source area will be removed during the IM. The remediation alternatives for this IM activity include technologies that are presented in Section 4. These alternatives will not be discussed here; however they will be evaluated according to the criteria discussed in Section 5.3. The contaminated source area included in this CMS is comprised of: soil and tuff beneath the excavated or remediated pond soils and soil in the drainage from the pond to Cañon de Valle. Because there will be no exposure to the soil and tuff remaining after the pond is remediated, the most likely alternative for this part of the source area is no action. Three alternatives are likely for any additional contaminated source area soils in the drainage that are not removed in the IM: (1) biodegradation/monitored natural attenuation, (2) no action, and (3) removal followed by treatment (for soil presenting unacceptable human health or ecological exposures).

Unsaturated Subsurface

Two likely remediation alternatives are considered for the unsaturated subsurface soils. One option, biodegradation/monitored natural attenuation, is presented in Section 4.. The second option is no action.

Transport Pathway and Springs

Four likely remediation alternatives are considered for the surface water and groundwater and springs. Four principal treatment options are presented as technologies in Section 4; passive barrier surface water treatment, GAC treatment, phytoremediation, and biodegradation/monitored monitored natural attenuation. The fifth alternative is no action. Pilot-scale studies will be conducted for the relevant technologies, as needed. These studies will determine the feasibility of removing contaminants specific to the site. Dependent on the results of the studies, a single technology or combination of technologies may be selected.

Alluvial System – Soil

Three likely remediation alternatives are considered for the alluvial system soils: (1) biodegradation/monitored natural attenuation, (2) no action, and (3) removal followed by treatment (for soil presenting unacceptable human health or ecological exposures).

Alluvial System – Water

Four likely remediation alternatives are considered for the alluvial water. Four treatment options are presented as technologies in Section 4; passive barrier surface water treatment, GAC treatment, phytoremediation, and biodegradation/monitored natural attenuation. The fifth alternative is no action. Pilot-scale studies will be conducted for the technologies, as needed. These studies will determine the feasibility of removing contaminants specific to the site. Dependent on the results of the studies, a single technology or combination of technologies may be selected.

5.3 Criteria

Remediation approaches retained for evaluation beyond the initial screening (those approaches presented in Section 4 and presented above) will be compared and contrasted using criteria established in Task VIII of Module VIII of the HSWA Permit for Los Alamos National Laboratory (NM0890010515) and in EPA proposed 40 CFR Part 264.522(a). These applicable regulations are presented in Appendix F. The intent of this evaluation is to determine the most plausible remedy(s) specific to each component. Each of the retained remediation approaches will be evaluated based on the following criteria:

- performance and reliability,
- reduction of toxicity, mobility, or volumes of contaminants or wastes,
- effectiveness of remedy in achieving target concentrations,
- timing of the potential remedy,
- ease of implementation,
- long-term reliability,
- impacts of institutional requirements on remedy implementation,

- mitigation of human health and environmental exposures, and
- costs.

5.3.1 Performance and Reliability

The CMS will assess the effectiveness of considered remedial approaches in controlling the source of release and the impacts associated with the potential remedy. The effectiveness of remedial approaches at similar sites and under analogous conditions will be evaluated.

5.3.2 Reduction of Toxicity, Mobility, or Volumes of Contaminants or Wastes

The CMS will evaluate if the considered remedies are effective at reducing the contamination at the site and determine if the remedy will successfully eliminate or reduce the toxicity, reduce the ability of the contaminant(s) to move, or substantially decrease the volume.

5.3.3 Effectiveness of Remedy in Achieving Target Concentrations

The CMS will assess each potential remedy in terms of its effectiveness and ability to achieve the target MCS.

5.3.4 Timing of the Potential Remedy

The CMS will evaluate the time required to implement each potential remedy and the time anticipated to see the results. The setup and implementation of a remedy includes the design, mobilization, demobilization, construction, permitting, and waste acceptance for off-site disposal. For hazardous waste treatment, permits will be required prior to construction.

5.3.5 Ease of Implementation

The CMS will evaluate the ease of implementation of the considered remedial approaches. Some examples of site conditions that may affect the ease of implementation include depth to water table, heterogeneity of surface and subsurface materials, terrain, and site location. Other conditions include the need for special permits or agreements, equipment availability, and location of suitable off-site treatment or disposal facilities.

5.3.6 Long-Term Reliability

The CMS will evaluate the useful life of the considered remedies in terms of the length of time that the remedy can effectively be maintained and whether the remedy will deteriorate with time.

5.3.7 Impacts of Institutional Requirements on Remedy Implementation

The CMS will evaluate federal, state, local, public health regulations, or permitting requirements that may substantially impact the implementation of the investigated remedies.

5.3.8 Mitigation of Human Health and Environmental Exposures

The CMS will assess each remedy in terms of the extent that it mitigates short- and long-term potential exposure to any human health or ecological receptors both during and after implementation of the remedy.

5.3.9 Costs

The CMS will evaluate each potential remedial approach in terms of cost. The cost estimate will include costs for each phase of the remedy and will include capital, operation, and maintenance costs. Capital costs include the direct construction costs and indirect non-construction and overhead costs. Operation and maintenance costs are post-construction costs necessary to ensure continued effectiveness of the corrective measure.

Additional criteria have been identified that are important to the successful completion of a corrective measure. These criteria will be used in the evaluation process and are as follows:

- public acceptance of feasible technologies,
- pollution prevention and waste minimization, including the relative quantities of waste generated by competing technologies, energy efficiency, and resource conservation,
- progress toward nature systems recovery, and
- mitigating conditions that could result in natural resource damage assessments.

Remedial approaches will be selected based on the above criteria and process of evaluation. The approaches will be recommended to the Administrative Authority in the CMS Report.

6.0 PHASE III RFI INVESTIGATIONS

6.1 Objectives and Scope

This section presents the objectives and scope of the CMS data needs addressed by the Phase III RFI. These data needs support the investigation objectives described in Chapter 3. The scope of the investigation required to sufficiently satisfy these objectives may be classified into five components:

- connectivity,
- residence times,
- spring and seep dynamics,
- alluvial water dynamics, and
- alluvial sediment dynamics.

The investigations that are associated with the first and last of the components will be one-time events. Sampling and analysis to address the second, third, and fourth components will continue for the duration of Phase III, nominally three years. As a point of reference, previous ER data associated with the TA-16-260 outfall are summarized in Chapter 2 of this document.

This Phase III investigation will nominally span three years and will be reviewed after the first year of data collection. Any refinement to the plan at that time will be discussed with the Administrative Authority. Ecological risk assessment approaches are under development in concert with the

Administrative Authority. As ecological data needs for the PRS 16-021(c) CMS/CMI become evident, they too will be discussed with the Administrative Authority and appended to the CMS Plan.

6.1.1 Connectivity

How is the TA-16-260 outfall source area connected to the TA-16 springs and seeps? This question must be answered in order to identify potential monitoring locations, as well as points for remediation beyond the source removal IM. Are there other transport pathways that connect directly with the main aquifer, not expressed in the springs or seeps? This question may not be answered, but is considered in the groundwater point of compliance discussion in Section 3.4.2.3. This question will also be partially addressed by the R-25 and R-27 deep-groundwater well investigations.

6.1.2 Residence Times

How long does it take for water to travel from the point or points of recharge to the TA-16 springs and seeps? The answer to this question will evaluate the association of the contamination in the springs and seep with the 260 outfall and is also related to the design of short- and long-term monitoring plans.

6.1.3 Spring and Seep Dynamics

How do contaminant fluxes change with discharge, season, and (in the case of Peter Seep) location at the TA-16 springs and seeps? Do contaminants at the various springs and seeps represent the same sources or different subsets of sources at TA-16? As discussed at length in Section 6.3.3, understanding the dynamics of springs and seeps that are potential monitoring points is essential for the interpretation of monitoring data. These data will also begin to identify sources of contamination other than PRS 16-021(c), if any, and address the potential impact of residual contamination in the subsurface. Understanding these dynamics will also provide information needed to evaluate certain remedial alternatives, such as the feasibility of hydrologic isolation and the viability of monitored natural attenuation for this site.

6.1.4 Alluvial Water Dynamics

Does the perennial reach of Cañon de Valle act as a simple "pipe," conducting all water that enters it (surface runoff, springs, and seeps) past MDA-P to the point where it disappears near the Qbt3/Qbt2 contact via its surface and alluvial groundwater components? Or are there unidentified losing stretches in intermediate reaches? The answer to this question has implications for selecting points of remediation of surface water, if necessary, and the selecting monitoring points and points of compliance. In particular, understanding the alluvial water dynamics is important in determining the number of monitoring points and points of compliance that may be required to address not only PRS 16-021(c), but other contaminant sources that impact Cañon de Valle. This understanding also has direct application for modeling the potential impact of these PRSs on deeper groundwater aquifers and for siting potential future deeper monitoring wells.

Virtually nothing is known about the alluvial system associated with Martin Spring. Martin Spring and its canyon may or may not be impacted by PRS 16-021(c), but investigation of its alluvial system will be initiated as part of the Phase III investigations.

6.1.5 Alluvial Sediment Dynamics

What are the inventories of contaminants in active channel and overbank deposits? Are these sediments an active source of contamination to alluvial waters? How are contaminants associated with sediments redistributed within the alluvial system? How will this redistribution affect future contaminant concentrations and future contaminant inventories in areas both within the administrative boundaries and downstream of the administrative boundaries? The answers to these questions will be used directly to evaluate the impact of residual contamination on assessment endpoints, as well as to address the feasibility and selection of remediation alternatives if alternatives are called for.

6.1.6 Other Data Campaigns

The inventory and distribution of residual contamination at the TA-16-260 outfall source area will be addressed in a separate sampling and analysis plan (SAP), included in the IM plan scheduled for completion in 1999.

For the purposes of the CMS, receptor exposure to groundwater will be limited to the areas in Cañon de Valle and Martin Spring Canyon that contain contaminated perched alluvial groundwater. The CMS will evaluate the potential risk to the nearest human and ecological receptors under the conservative scenarios described in Section 3.4.2.3.

Should these conservative risk assessments indicate the potential for unacceptable human or ecological risk, an additional investigation will be designed and implemented that will provide the information necessary to refine the risk assessments. Information gained from the hydrologic boreholes R-25 (scheduled to be completed in 1998) and R-27 (scheduled to be completed in 2000) will be useful in performing these risk assessments.

6.2 Approach and Implementation

This section provides a brief overview of the information that will be collected to address the five components of the Phase III investigation listed in Section 6.1. Much more detail, including specific problem histories, is provided in Section 6.3. Field implementation procedures are discussed in Section 6.4.

1. Connectivity

   This sampling plan is designed to estimate the mass of a potassium bromide tracer that still remains near its point of deployment, which was the ponded area of the TA-16-260 outfall. Very little of this tracer has been recovered to date, although it was deployed in April 1997. Grab samples of soil and tuff will be collected and analyzed for bromide and percent moisture during the source removal IM. Both field and laboratory analyses will be performed; a statistical design will be used to select the subset of samples for laboratory analysis.

   The sampling program to detect the tracer in the TA-16 springs and seeps (see the Phase I RFI report, (LANL 1996, 55077) will continue during the Phase III investigations.

2. Residence times

   Unfiltered grab samples will be collected from the TA-16 springs and seeps in coordination with the continuing tracer sampling at those points. Precipitation samples will also be collected at a

central TA-16 location. Subsets of these samples will be selected for laboratory determination of stable isotope ratios that reflect seasonal atmospheric conditions. Additional samples will be archived and may be analyzed later. Isotopic signatures in springs will be compared with those of individual precipitation events to estimate the apparent ages of waters emerging at the springs and seeps. This will provide a lower bound for the residence times of contaminants in the subsurface.

3. Spring and seep dynamics

Discharge records and flow-integrated filtered water samples will be collected at the springs. The Isco autosamplers at Burning Ground, SWSC, and Martin Spring will be instrumented with data loggers for pH, conductivity, and temperature. Paired filtered grab samples will be collected at Peter Seep in Cañon de Valle, and additional observations will also be made to characterize the migration of Peter Seep (location, discharge, and concurrent water levels in the alluvial wells). A standard suite of field measurements will be used for all samples. Laboratory analyses of a standard suite of contaminants (HE and inorganics) and water quality parameters will be obtained for a subset of weekly flow-integrated samples and Peter Seep samples, selected to represent a range of hydrologic conditions. Some monthly composites of remaining flow-integrated samples will also be analyzed for inorganics and water quality parameters.

The data will be used to establish dynamic baselines for future monitoring (i.e., concentration–discharge relationships, with possible dependence on seasonal factors as well). The data may also be used to estimate seasonally-dependent parameters of a mixing model for each spring. The quarterly sampling program for water in the springs (see the Phase I RFI report, ref.) (Environmental Restoration Project 1996, 55077) will be continued for the duration of Phase III. These samples include both filtered and unfiltered samples for HE, metals, VOCs, SVOCs, and water quality parameters.

4. Alluvial water dynamics

Surface and subsurface discharge profiles will be estimated for the perennial reach of Cañon de Valle and the upper reach of Martin Spring Canyon. Concurrent filtered grab samples of surface water, alluvial water, and springs will be collected. The standard field parameters, plus a field HE measurements, will be provided for all samples, and laboratory contaminant and water quality analyses will obtained for subsets selected to represent high and low baseflow conditions.

The data will be used to determine whether there are sources to the alluvial system other than those already identified and to identify reaches where significant exchange between the surface water and alluvial groundwater components of the system occur.

The quarterly sampling program for water in the alluvial wells (see the Phase I RFI report, (LANL 1996, 55077) will be continued for the duration of Phase III. These samples include both filtered and unfiltered samples for HE, metals, VOCs, SVOCs, and water quality parameters.

5. Alluvial sediment dynamics

Geomorphic mapping of the sediments in restricted reaches of Cañon de Valle and Martin Spring Canyon will be completed following the procedures used in the Core Document for Canyons Investigations (LANL 1997, 55622). The mapping will focus on identifying and subdividing post-

1940 sediments into geomorphic units with different characteristics (i.e., age, thickness, particle size) that may relate to varying contaminant concentrations and inventories. Following this, a statistical sampling plan will be designed to sample the post-1940 floodplain sediments. Field HE measurements will be made on all sediments, and subsets will be selected, again according to a statistical design, for analysis for the full suite of contaminants associated with PRS 16-021(c). Data will be used to estimate the spatial distribution and inventory of contamination in the sediments of Cañon de Valle and Martin Spring Canyon. Additional biased sampling may be necessary to evaluate hypotheses concerning sediment dynamics, such as defining how COPC concentrations vary with distance, time (gained by sampling sediment with variable age), and particle size.

6.3 Phase III Sampling and Analysis Plans

The following subsections provide background for each of the components of the Phase III investigation. Each subsection identifies the types of data needed and the proposed use of these data, together with the assumptions and physical and temporal constraints that affect the design of the data collection plan. The specific investigation objective (as defined in Chapter 3) that the data supports is explicitly identified for each of the Phase III investigation components. Finally, a sampling and analysis plan is proposed for each component. Procedural and other implementation aspects of these plans are described in Section 6.4.

6.3.1 Connectivity

6.3.1.1 Overview

In April 1997, 100 kg of potassium bromide tracer dissolved in 450 gal. of water was deployed at the head of the TA-16-260 outfall pond. The tracer was followed by 200 gal. of water on two consecutive days for a total of 400 gal. The purpose of the tracer was to test the hypothesis that the 260 outfall is the source of contamination in Peter Seep, SWSC Spring, Burning Ground Spring, and Martin Spring.

Thus far, tracer has been detected in SWSC Spring at low microgram per liter levels and possibly in Burning Ground Spring. The total amount of tracer recovered to date is estimated to be less than 1% of what was deployed in 1997.

There are several possible explanations for why tracer concentrations in the springs are low or at background levels.

- There may be insufficient water impacting the pond area to transport the tracer away from the point of origin, given that the outfall is no longer in service and that BMPs are placed to prevent runoff to the pond area.

- The tracer may be moving through the subsurface, but at a slow rate. The tracer may have primarily intersected slower flow paths during and following deployment. In general, residence times for water in the hydrologic system are not well understood.

- The subsurface flow paths from the point of tracer deployment may not be connected to some of the springs. The tracer is migrating through the hydrologic system, but not to the locations being monitored for breakthrough.

This subsection describes an investigation to test the first of the above hypotheses. Subsection 6.3.2 describes investigations of residence times of water in the subsurface, the results of which will impact the second hypothesis. The third hypothesis is not being directly evaluated in this investigation. The data generated in the investigation presented in this subsection will directly support investigation objective IO6.

6.3.1.2 Investigation Design

An investigation will be conducted to determine the mass of tracer remaining in and near the source area. The remainder of the tracer will be assumed to have migrated into the subsurface system, although little of it has been recovered to date. This investigation will be conducted in two parts.

1. During the IM, before removal of pond sediments, soil and tuff samples will be collected at or near the point of tracer deployment within the TA-16-260 outfall pond area.

2. Following the IM, after the source area has been removed, a borehole will be drilled to collect data on the extent of contamination and bromide in tuff below the ponded area. Data generated during the drilling of this borehole will also be used to determine bromide concentrations at or near the source area.

Samples generated during this two-part investigation will be analyzed for bromide and moisture content at the field support facilities. A subset of soil and tuff samples will be selected from the screening samples and analyzed for bromide at an off-site analytical laboratory. Bromide will be measured by drying the samples to get sample weights, and then leaching the samples with deionized water and measuring bromide concentrations with an ion-specific electrode; soil moisture content will be measured using American Society of Testing and Materials (ASTM) methods. Laboratory analyses will be conducted in accordance with contract-specified procedures.

The field and analytical laboratory data will be used to determine the following information.

1. An estimate of the total inventory of tracer at the source area will be obtained. The extent and trend of bromide concentrations in pond sediments and tuff will be estimated based on the field screening data. Estimates of mean contamination in soil and tuff will be based on the laboratory sample results. These estimates will be combined to produce the total bromide inventory estimate.

   A statistical approach, ranked set sampling (RSS) (Patil et al., 1994, 59113, pp. 57-97 will be used to select the subset of soil and tuff samples for laboratory analysis. This method will improve the accuracy and precision for the mean bromide concentration estimate. At most, bromide concentrations on the order of 500–2000 mg/kg may remain in the sediments near the point of deployment. However, some tracer has clearly left the source area, so much lower concentrations may be observed.

2. The data will show whether bromide, as a conservative tracer, is collocated with relatively high moisture in soil and tuff samples. The data could be used to improve the estimate of the mass remaining at the source area.

3. The data will show how well the field bromide analytical methods perform.

6.3.1.3 Sampling Activities

During the IM, a trench will be excavated through the outfall pond sediments to the soil/tuff interface. (Figure 6.3-1). The trench will be excavated along the center axis of the pond from the point just below where the drainage channel intersects the pond, downgradient to the top of the rock dam. The trench should be approximately 30 ft long (the estimated length of the pond), up to 8 ft deep and at least one backhoe bucket wide. Eight vertical profiles, spaced approximately four feet apart, will be sampled along the trench. Each profile will extend to the soil/tuff interface, and four screening samples will be collected from each vertical profile. The depth intervals that the samples will be collected on are expected to vary from profile to profile. A tighter, but evenly spaced, sampling interval will have to be used where the depth to tuff is shallower and a larger (again, evenly spaced) interval will have to be used where the depth to tuff is greater. This will require particular care during trenching activities to control the sampling depth. Initially, provisional samples may also need to be collected on a tight interval (as little as 0.5 ft) to ensure that four samples are collected on even intervals from each profile, particularly at profile locations where the depth to tuff is expected to be very shallow. This will produce a total of 32 systematic (unbiased) field-screening samples.Eight samples for laboratory analysis will be selected from the 32 field screening samples following the RSS strategy outlined below.

The four samples from each profile will be ranked from one (low concentration) to four (high concentration) based on the field bromide results. Selection of samples for laboratory analysis will begin with the lowest ranked sample in the first profile, the next lowest in the second profile, through the highest in the fourth profile, and then again the lowest in the fifth profile through the highest in the eighth profile.

After the IM removal of outfall sediments has been completed, a borehole located at the center of the (removed) pond will be advanced to a total depth of 80 ft. The borehole will be continuously cored and sampled on five-foot intervals. This will generate sixteen unbiased (systematic) field screening samples. The core samples will be field screened for bromide concentration and percent moisture.

An RSS strategy will again be used to select four samples for laboratory analysis from the 16 screening samples. The systematic (unbiased) samples will be assigned at random to four subgroups of four samples each. The samples will be ranked one through four (again based on lowest to highest bromide concentration) within each of the four subgroups. Finally, the sample ranked number one in the first subgroup, two in the second subgroup, and so on will be submitted for laboratory analysis.

Additional screening samples may be selected to target moist strata or fractures if any are encountered, but these biased samples will be kept separate from the unbiased samples and will not be used in the RSS estimate of the mean bromide concentration. Up to six of these biased samples will be submitted for laboratory analysis for bromide and moisture content.

Table 6.3-1 summarizes the field screening and laboratory analyses.

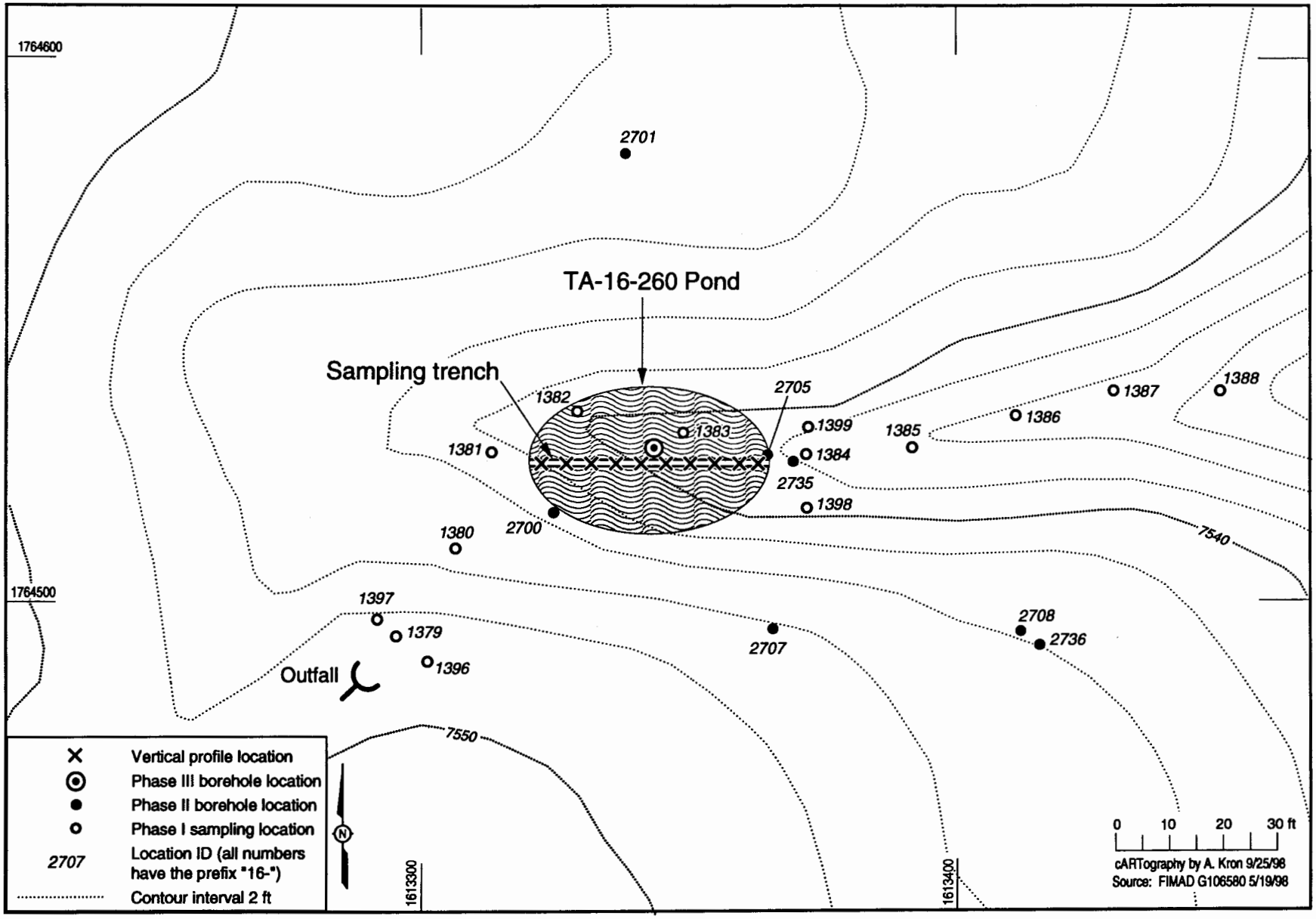


Figure 6.3-1 Trench and vertical profile locations in the 260 pond.

Table 6.3-1
Summary of Sampling and Analysis for the Connectivity Investigation at the TA-16-260 Outfall Source Area

Sample or Survey Measurement	Number collected	Number Analyzed	Field Measurements and Analytical Suites
During IM: sediment samples from trench	32	32 field 8 laboratory	Field bromide, % moisture Laboratory bromide
After IM: tuff samples from borehole	16 + additional biased	16 + additional biased 4-+up to 6 biased	Field Br-, % moisture Laboratory bromide
After IM: tuff samples from borehole	16 + additional biased	16 + additional biased 4-+up to 6 biased	Field bromide, % moisture Laboratory bromide

6.3.2 Residence Times

6.3.2.1 Overview

The characteristics of the subsurface transport system, as represented by the discharge records for the springs, show significant variations with seasons and rainfall events. Comparison of the rainfall records for TA-16 with spring discharge plots, as in Figure 6.3-2, suggests three separate and distinct responses by the springs to precipitation. There is a rapid response that occurs within a few hours of an individual event, a slightly delayed response observed within days, and a seasonal response observed as overall higher baseflow discharge rates during the monsoon season.

These response times do not necessarily reflect actual residence times in the subsurface. The early responses to significant precipitation events, in particular, may represent the displacement of water already in the system by the influx of new water, rather than the immediate transport of the new water to the springs. However, these relatively rapid response times suggest that fast pathways exist between recharge points and the springs.

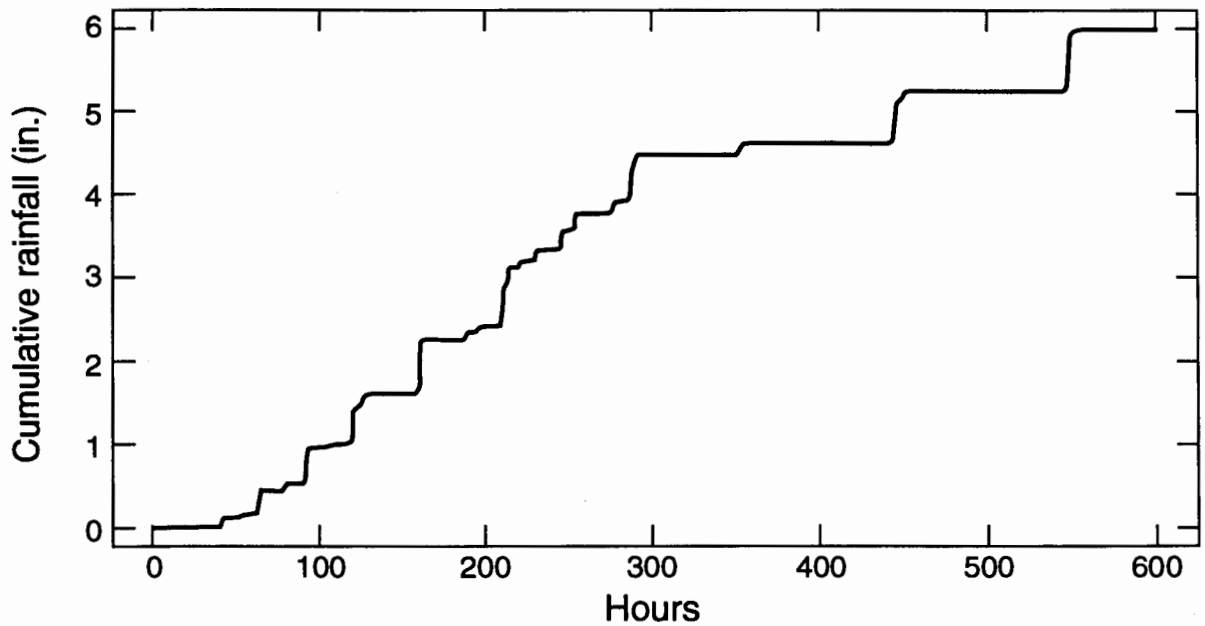
Residence times for contaminants are generally longer than the residence times for water or a conservative tracer, such as bromide, because of various retardation mechanisms. Nevertheless, monitoring for the effects of source removals and other remedial actions at the springs and seeps can be improved by estimating the anticipated time lag to response expected to be effective.

This subsection describes investigations intended to provide data to estimate the range of residence times for water in the subsurface hydrological system. The investigations described in Section 6.3.3 will also have some bearing on the question of multiple pathways. The data generated in the investigation presented in this subsection will directly support investigation data objectives IO6.

6.3.2.2 Investigation Design

Residence times will be estimated by analyzing oxygen and hydrogen stable isotope ratios ($\delta^{18}O$ and δD) in the spring and seep waters and comparing these data with the corresponding isotope signatures in

(a)



(b)

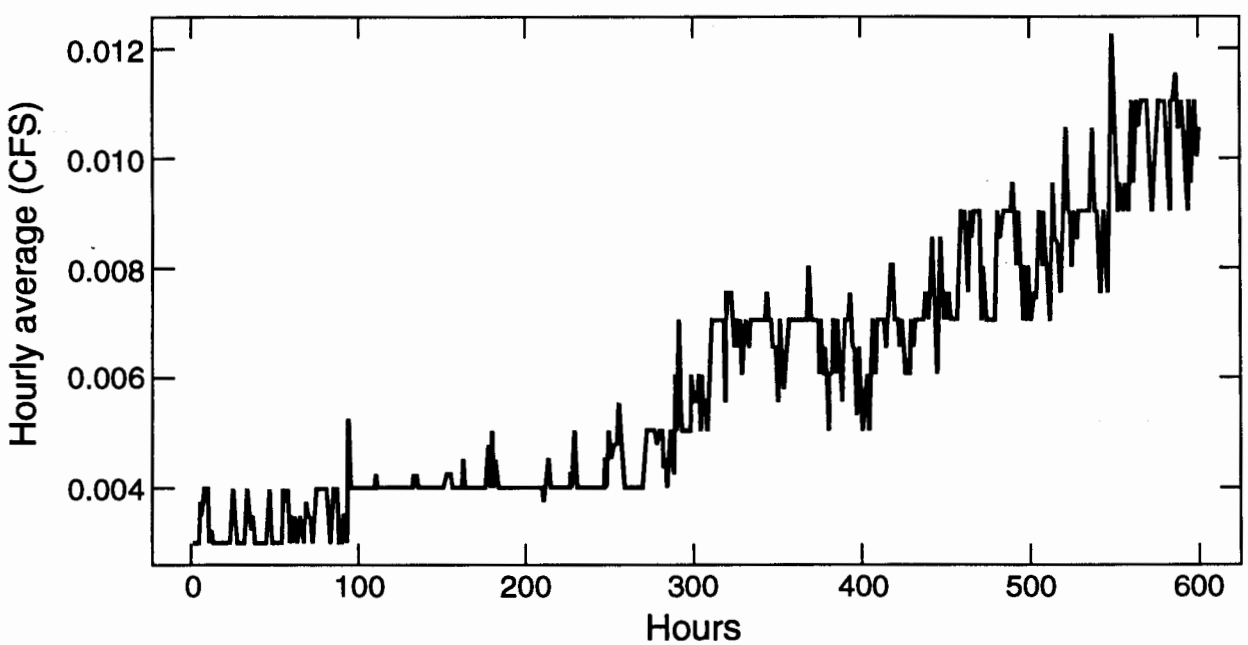


Figure 6.3-2 (a) Cumulative rainfall plot for summer 1997 monsoon season; (b) hydrographic record for SWSC Spring, summer 1997 monsoon season.

precipitation. Large shifts in $\delta^{18}O$ and δD in precipitation are associated with changes in atmospheric temperatures. Annually recurring transition periods are fairly predictable and frequently abrupt, including the monsoon onset and spring and autumn temperature shifts. Precipitation recharges the system, and these shifts in isotope ratios can be detected in the springs and seep after transport-related lag periods. The lag period for each spring and the seep provides an estimate of the associated transport residence time in the hydrologic system.

The stable isotope approach has been used with success at the ponderosa pine hillslope near TA-16 (Newman 1998, 54399) and for springs at the Nevada Test Site (Ingraham et al. 1991, 59171). To the extent that samples from Peter Seep represent emergence of alluvial groundwaters that may have been in the alluvial system for some time (see the discussion in Section 6.3 below), this technique may not be as useful for this location as for the springs.

Because the atmospheric signal does not vary significantly over spatial scales on the order of kilometers, a single precipitation sampling station located at TA-16 will be sufficient for this investigation. However, wide variations in the arrival times of the isotopic signals at the various springs and seeps can be anticipated, and quite a large number of analyses may be required to estimate the associated lag times. Because the isotopic ratio will not alter in a properly stored, archived sample, a sequential approach to the selection of samples for analysis is proposed.

Comparison of stable isotope data from individual precipitation events to the timing of change points in ratios measured in samples from the springs will be used to estimate the apparent age (or possibly, a range of apparent ages, if multiple breakthroughs of an identifiable signature are observed) of waters emerging at each of the sampled springs and seeps. This in turn will provide a lower bound for the time between source removal and changes in contaminant signatures at these points.

If the residence times of the springs are too long (i.e., longer than the three-year period allocated for the Phase III investigations), the stable isotope approach will not provide the resolution in ages that is anticipated. However, even this result would provide a lower bound for when we might expect changes in contaminant signatures at the springs following the IM source removal. Based on the response time data discussed above, it is more likely that the springs have a fairly short residence time that can be estimated based on a sampling period of one to two years.

6.3.2.3 Sampling Activities

Samples for stable isotope analysis will be collected every-other day with auto-samplers at three springs and at Peter Seep for a period of three years as unfiltered aliquots of the samples collected for the bromide tracer under the ongoing Phase II program. Concurrently during the Phase III sampling period (nominally two to three years), precipitation samples will be collected for isotope analysis at a station located near the TA-16 field trailers (Figure 6.3-3). Precipitation sampling will be event driven. Initially, the spring and seep samples will be submitted for $\delta^{18}O$ analysis at the rate of 1 in 10 samples collected from the autosamplers (one every three weeks) during atmospherically stable periods. During seasonal transition (e.g., snowmelt, monsoon, and early fall post-monsoon), one in four samples (one a week) will be submitted for $\delta^{18}O$ analysis. A total of approximately 25 samples per spring per year will be submitted for $\delta^{18}O$ analysis. The remaining samples will be archived. Additional samples will be extracted from the archives to pinpoint more precisely the timing of shifts in the results, once these have been bracketed, so the total number of samples analyzed may rise to as many as 50 per spring. Every fifth laboratory sample will also be analyzed for δD so that the impact of evaporation can be assessed.

δN, which is more of an indicator of contamination than of atmospheric changes, will be requested for every tenth sample. All precipitation samples will be analyzed for the stable isotopes, $\delta^{18}O$ and δD (Table 6.3-2). Nitrogen isotopes (δN) will also be analyzed for a subset of these samples, two per season; although these are more relevant to the investigations described in Section 6.3 below. The precipitation data will be used to establish isotope signatures of storms and the timing of atmospheric transitions.

Table 6.3-2
Summary of Annual Sampling and Analysis for the Residence Times Investigation at the TA-16 Springs and Seeps

Sample or Survey Measurement	Number collected	Number analyzed	Field Measurements and Analytical Suites
Precipitation samples collected at a central TA-16 station	25–50	25–50 8	$\delta^{18}O$, δD δN
Burning Ground Spring, unfiltered water grab samples	180	25–50 5–10 2–5	$\delta^{18}O$ δD δN
SWSC Spring, unfiltered water grab samples	180	25–50 5–10 2–5	$\delta^{18}O$ δD δN
Martin Spring, unfiltered water grab samples	180	25–50 5–10 2–5	$\delta^{18}O$ δD δN
Peter Seep, unfiltered water grab samples	180	25–50 5–10 2–5	$\delta^{18}O$ δD δN

6.3.3 Spring and Seep Dynamics

6.3.3.1 Overview

Elevated levels of barium, HE, and other contaminants associated with PRS 16-021(c), as well as with a number of other TA-16 PRSs, are observed in all TA-16 springs and seeps (Figure 6.3-3) Data from quarterly grab samples indicate that contaminant concentrations vary with changes in discharge for these springs. More relevant for the establishment of baselines for long-term monitoring would be estimates of contaminant fluxes, which also can be expected to change as a function of discharge, season, and (in the case of Peter Seep) possibly location. Existing data from grab samples cannot provide reliable estimates of contaminant fluxes and are completely inadequate for estimating the dynamic baseline (that is, a function that relates contaminant flux to discharge, season, and seep location) that will be required for long-term modeling and monitoring.

The location of Peter Seep fluctuates within a reach of Cañon de Valle that is approximately 600-ft long (Figure 6.3-4. While the lower end of this reach (the "foot" of Peter Seep) is east of the TA-16-260 outfall, the upper end (the "head") is upgradient from the outfall. Understanding the mechanism that controls the migration of Peter Seep is important to understanding the source of contaminants observed at the seep, as well as for establishing a baseline for future monitoring. One conceptual model is that the seep location changes simply reflect changes in head in the alluvial aquifer; when the water table in the alluvium is higher, then the seep emerges higher up the canyon reach than when the water table is lower.

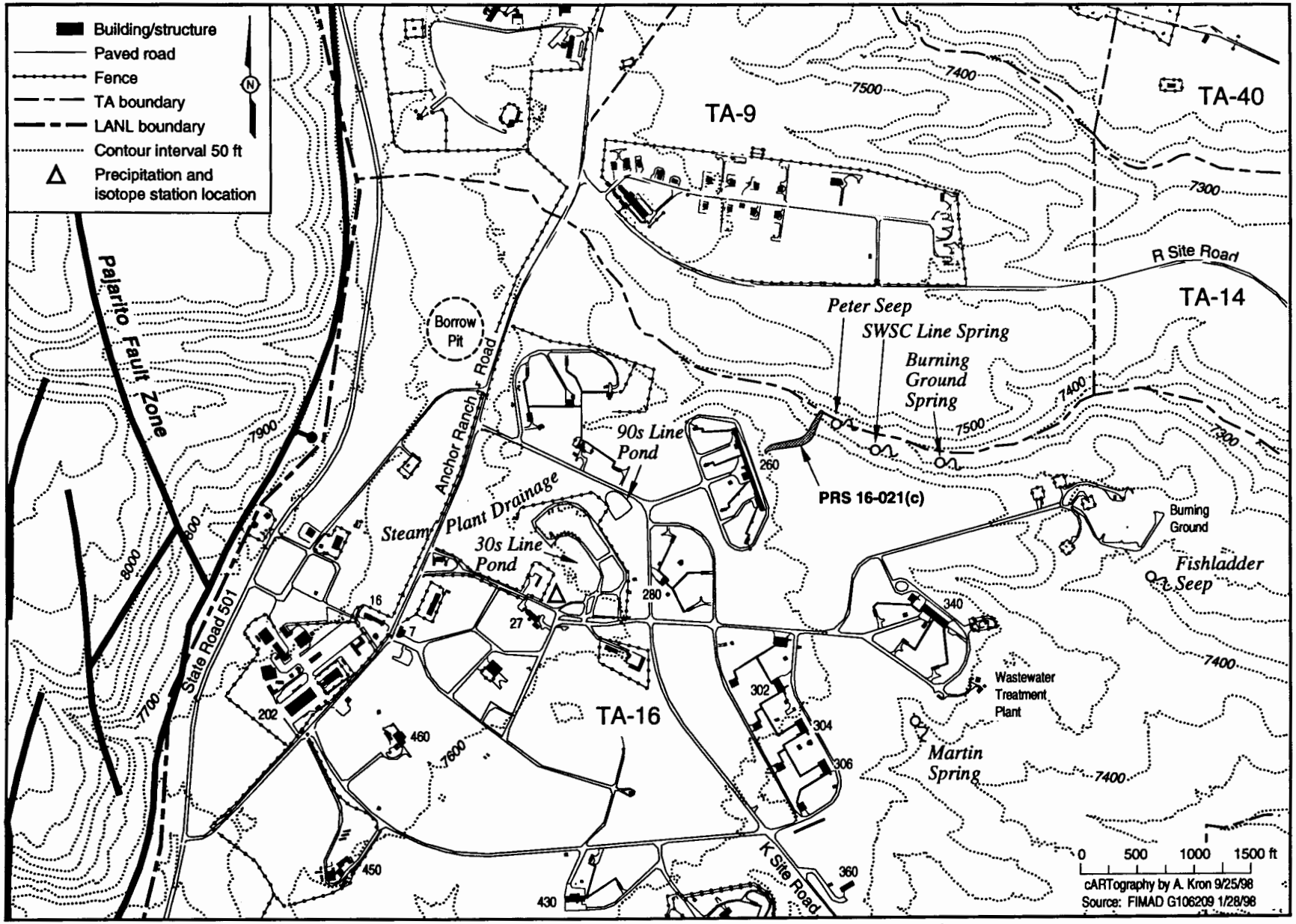


Figure 6.3-3 Precipitation station location and isotope sampling locations (Cañon de Valle springs).

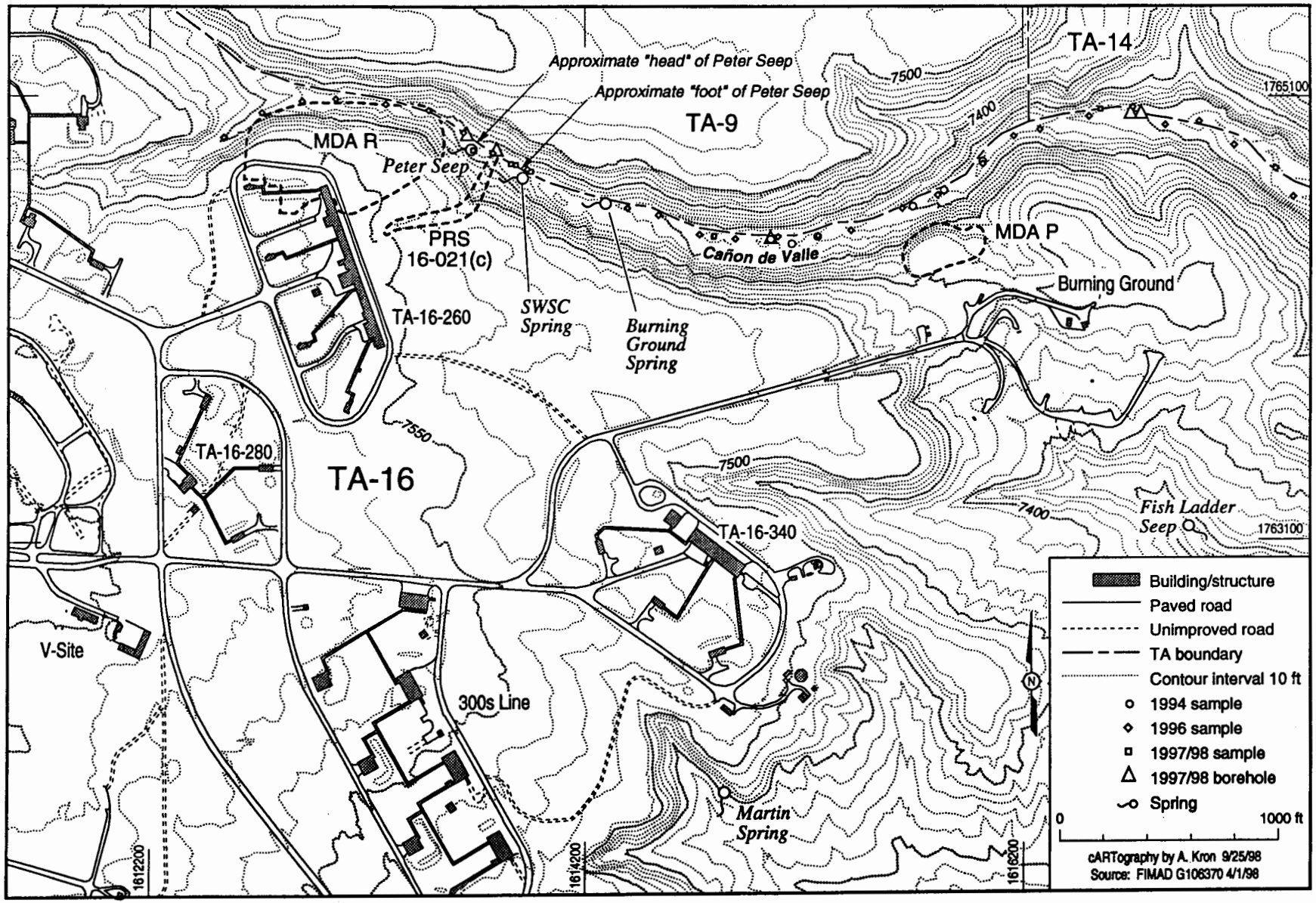


Figure 6.3-4 Extent of Peter Seep.

Alternatively, Peter Seep may be fed by discharges from the adjacent mesas. In this case, its location could be controlled by fractures and the seep may emerge only at discrete locations, or its head might not be well correlated with head in the alluvial aquifer.

The interactions of the subsurface hydrologic system with the PRS 16-021(c) source area, secondary contaminant sources related to PRS 16-021(c), and additional TA-16 PRSs, as well as the timing of those interactions, are unknown. Several sources of recharge for the springs, seeps, and the canyon alluvial systems have been suggested. These include: (1) diffuse recharge, (2) surface flow into the Cañon alluvial system, (3) interflow along the soil-tuff interface into Cañon de Valle or the spring systems; (4) localized recharge into the alluvial fans and borrow pit near Route 501, and (5) fracture-controlled recharge along the Pajarito Fault. Significant former and current sources of process water include the steam plant drainage, the 90s line pond, and former 30s line lagoons in the World War II area, the former wastewater treatment plant through which TA-16 sanitary wastes are still routed to the new SWSC line, and, of course, the TA-16-260 outfall (see Figure 6.3-3).

Because of the complexity of the TA-16 hydrogeologic system, it is likely that these sources combine in different proportions to generate the discharge at any given spring. For example, flow and chemistry data for Martin Spring suggest that recharge and contaminant sources for this spring may be different than those for the Cañon de Valle springs [see Section 2 and also Chapter 4 of the Phase II RFI report for PRS 16-021(c), (LANL 1998, in preparation). These relationships can never be perfectly modeled, but some of the information collected during the Phase III investigations may provide preliminary answers to such questions as:

- Do discharges at the SWSC Line Spring and the Burning Ground Spring represent essentially the same sources, although possibly with different transport times? Is the TA-16-260 outfall the dominant source of contamination in these springs? The water chemistries of these two springs are very similar.

- Is Peter Seep connected to this same system? Or do discharges at Peter Seep represent predominantly an alluvial groundwater component, and does its contaminant signature more closely resemble that observed in the nearby alluvial wells? Is the TA-16-260 outfall the dominant source of contamination at this seep, or are there significant contributions from other upgradient sources?

- Does the TA-16-260 outfall area contribute to the discharge at Martin Spring? Or are contaminants in this spring derived predominantly from other sources at TA-16?

- The investigations described in Subsections 6.1 and 6.2 are also relevant to these questions, while investigations of the alluvial groundwater system are described in Subsection 6.4 below. Complete answers to these questions also require information from other source investigations at

  TA-16, not all of which have been completed. However, the analysis of contaminant fluxes at the springs and seeps that is described in this subsection, and is required in order to establish baselines for future monitoring of the effectiveness of remedial actions at PRS 16-021(c), also provides an essential piece of the answer. The data generated in the investigation presented in this subsection will directly support investigation objective IO5.

6.3.3.2 Investigation Design

Weekly and monthly flow-integrated samples from each of the three springs will be analyzed for the major PRS 16-021(c) contaminants (HE and inorganics) and water quality parameters (major cations and anions and bicarbonate in the laboratory, plus pH, temperature, and conductance in the field). Paired grab samples from Peter Seep (one being collected at the migrating location of the head of the seep, and the other at the foot of the seep) will be analyzed for the same constituents.

Data from quarterly grab samples indicate that contaminant concentrations vary with changes in discharge for these springs. Therefore, analyzing trends in the spring data will depend upon collecting samples that are comparable with one another, given these dynamics. That is, flow-integrated sampling is required. An appropriate integration time interval for trend estimation is approximately one week; integration over shorter durations will be influenced by individual events, while longer durations may mask the relationship being evaluated.

Eventual long-term monitoring may be conducted using flow-integrated sampling over longer periods. Therefore some one-month flow-integrated samples will also be collected. However, because of the short holding time for HE (seven days between collection and extraction), the monthly composite samples cannot be effectively analyzed for HE.

Spring sampling will cover the range of spring discharge, which varies on both short- and medium-term time scales as noted in Subsection 6.2. At least two years of data will be required to span the range of flow conditions that are observed at the springs and seeps, as well as potential seasonal variations. However, it is particularly important that as much data as possible be collected before the IM source removal, since one of the first goals of monitoring will be to measure the effectiveness of that action.

Sampling at Peter Seep will cover the range of locations of the head of the seep, and will attempt to provide information for estimates of the seasonal effect that are not confounded with estimates of the effect of location.

The concentration data contrasted with the discharge data for the one-week integrated samples will be plotted to evaluate the form of the relationships between concentration and flow data for significant contaminants, and to determine whether seasonal and location effects are significant. The parameters of the functions that describe these relationships should be estimated with sufficient precision so that changes in the contaminant flux/discharge relationship on the order of 50% can be detected with high probability. How much data this will require will depend in part on the complexity of the observed relationships (i.e., on the number of parameters required to describe them). The simplest function would be a constant (i.e., either concentration or flux is independent of discharge). Finding this level of simplicity is unlikely, but it is possible that the relationship may be reasonably linear, and also that the seasonal or location components may be relatively unimportant.

The behavior of Peter Seep will be observed by means of frequent measurements of location and of discharge at the foot of Peter Seep, together with concurrent measurements of water levels in the alluvial wells that were installed during RFI Phase II investigations. The resulting spatial patterns and correlations will be analyzed to determine whether the location of Peter Seep varies along a continuum or is confined to discrete locations, and whether or not it is correlated with water elevation in the alluvial wells.

Based on the contaminant data, as well as tracer and stable isotope data, mixing models that attempt to explain the observations in terms of contributions from identifiable sources (e.g., uncontaminated groundwater, HE production process water, leakage from sanitary discharges) will be proposed for each spring. The parameters of such models may also depend on season or discharge. While it is unlikely that such models can be estimated with a high degree of accuracy, they may be useful in optimizing a monitoring plan specific to PRS 16-021(c).

6.3.3.3 Sampling Activities

One-week flow-integrated filtered samples will be collected from each spring for trend analysis (Table 6.3-3). Samples will be collected weekly and field measurements of pH, temperature, and conductance will be reported for all samples daily using a logger connected to the Isco autosampler. A subset of 8–15 samples per year representing the flow range of the springs, as determined using historic hydrographs and the range of field measurements, will be submitted for laboratory analysis for trend estimation. (Fifteen samples should be collected during the first year of the Phase III investigation. Thereafter 8–10 per year should be adequate.) The remaining samples will be used to create additional flow-weighted monthly composites.

Table 6.3-3
Summary of Annual Sampling and Analysis for the Investigation of Spring and Seep Dynamics[a]

Sample or Survey Measurement	Number Collected	Number Analyzed	Field Measurements and Analytical Suites
Burning Ground Spring, filtered one-week flow-integrated samples	50	50 50 8–15	Discharge record Field temperature, pH, conductance HE, metals, major anions/cations, HCO_3
Burning Ground Spring, filtered one-month flow-weighted composite samples	6	6	Metals, major anions/cations, HCO_3
SWSC Spring, filtered one-week flow-integrated samples	50	50 50 8–15	Discharge record Field temperature, pH, conductance HE, metals, major anions/cations, HCO_3
SWSC Spring, filtered one-month flow-weighted composite samples	6	6	Metals, major anions/cations, HCO_3
Martin Spring, filtered one-week flow-integrated samples	50	50 50 8–15	Discharge record Field temperature, pH, conductance HE, metals, major anions/cations, HCO_3
Martin Spring, filtered one-month flow-weighted composite samples	6	6	Metals, major anions/cations, HCO_3
Record Peter Seep location	50	NA	Discharge record
Record alluvial water elevations	50	NA	NA
Filtered grab samples from head of Peter Seep	50	50 8–15	Field temperature, pH, conductance HE, metals, anions, HCO_3
Filtered grab samples from foot of Peter Seep	50	50 8–15	Field temperature, pH, conductance HE, metals, anions, HCO_3

[a]Where a range of sample sizes is reported, the upper end corresponds to the first year of the Phase III investigations, the lower end to subsequent years.

The one-week flow-integrated laboratory samples will be analyzed for HE, metals, and water quality parameters (including anions and HCO_3). The flow-weighted monthly composites will be analyzed for the same suites, except HE.

Peter Seep reach will be staked at 75 ft (22 m) intervals and the elevations of these markers will be surveyed to provide measurement control (Figure 6.3-4). The location of Peter Seep will be measured relative to the nearest stake +/- 2 in. (5 cm). Measurement frequency will be at least biweekly. Up to three measurements per week will be made during hydrologic transition times (snowmelt, monsoon onset, and post-monsoon) and at least weekly measurements will be reported throughout the summer monsoon season.

Concurrently with Peter Seep location measurements, water levels will be measured in the alluvial wells and discharge at the foot of the seep will be recorded. These locations will be instrumented with automatic data recorders that provide ongoing measurements of pH, conductivity, pressure, and temperature.Filtered grab water samples at the head and foot of the seep extent will be also collected at the above-indicated frequencies, and the standard field measurements (pH, temperature, and conductance) will be performed on each of these samples. Approximately 15 pairs of these samples, representing the range of Peter Seep locations, as well as seasonal variations, will be submitted for laboratory analysis of HE, metals, and water quality parameters during the first year of the Phase III investigation; thereafter eight pairs per year will be submitted for laboratory analysis.

6.3.4 Alluvial Water Dynamics

The perennial reach of Cañon de Valle extends from Peter Seep to a point approximately 4500 ft downgradient from MDA-P (Figure 6.3-5. The extent of the saturated alluvium, however, has not been determined. The surface and alluvial groundwater systems are thought to be connected, but insufficient data have been collected to establish this connection. As mentioned in the previous section, Peter Seep may simply be the westernmost expression of the alluvial groundwater system, or it may be fed by one or more sources from the adjacent mesas. SWSC Spring and Burning Ground Spring contribute substantial amounts of water to the system. At one time the TA-16-260 outfall also contributed a significant fraction of the water in the system (up to 50% in the earlier decades of its operations), but this decreased to about 15% of the total before flow from the outfall was shut off completely in 1996. (No other discrete sources of water to this system have been identified. Cañon de Valle also receives runoff from the adjacent slopes and mesa tops during snowmelt and precipitation events.

At its eastern end, the surface water system terminates near the point where the canyon floor intersects the stratigraphic contact between units Qbt3 and Qbt2 of the Tshirege Member of the Bandelier Tuff. The fate of waters leaving the alluvial system at this point is unknown. No other regions where losses to the subsurface occur have been identified along the perennial reach of Cañon de Valle, but neither can it be demonstrated with current information that no such regions exist. Even less is known about Martin Spring Canyon, in which no alluvial investigations have been conducted. Perennial surface water is observed for only about 100 ft below Martin Spring. Below that point, flow is ephemeral until a relatively wet area near K-Site (Figure 6.3-5).

The springs and seeps that feed the alluvial systems of Cañon de Valle and Martin Spring Canyon are known to be contaminated with HE, barium, and other contaminants released at PRS 16-021(c). Martin

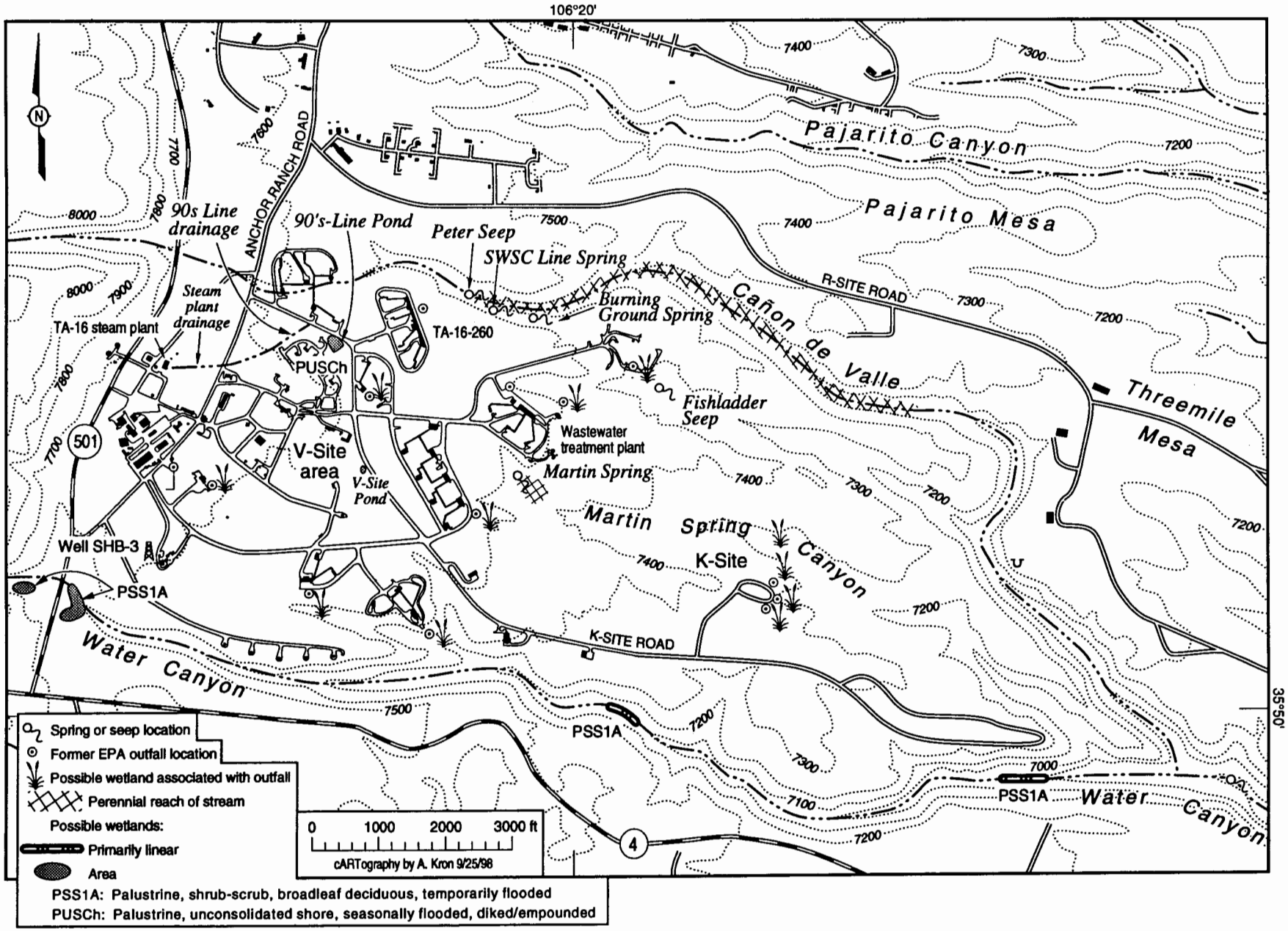


Figure 6.3-5 Perennial reach of Cañon de Valle and Martin Spring Canyon and location of wetlands.

Spring waters also contain a significant number of contaminants that are not associated with PRS 16-021(c), including boron.

In Cañon de Valle, anomalies have been observed in the concentration patterns of these contaminants which are not easily explained in terms of these known sources. One such anomaly is the jump in barium concentrations at a point about 4000 ft below the TA-16-260 outfall and 500 ft below MDA-P. Jumps, both upward and downward, are found in the concentrations of other chemicals as well—potassium shifts upward, and RDX downward. It is not known whether this effect is the result of the surfacing of part of the alluvial system at this point, an unobserved contribution from the adjacent mesas, or a change in water chemistry.

Only a handful of samples have been collected to date from the alluvial wells installed in Cañon de Valle, but they suggest unexpected levels of heterogeneity between wells. No information about levels or patterns of contamination in the surface and alluvial waters of Martin Spring Canyon has been collected. The data generated in the investigation presented in this subsection will directly support investigation objectives IO7 and IO8.

6.3.4.1 Investigation Design

Water and contaminant mass balance studies will be performed in both Cañon de Valle and Martin Spring Canyon. Surface water discharges will be measured at several locations in order to construct discharge profiles representing both low-flow and high-flow conditions. Alluvial discharge will also be estimated at the same times and locations. Filtered grab samples will be collected from surface water, alluvial groundwater, springs, and Peter Seep at the same times and, in the case of surface water, from the same locations. Spring discharge will also be reported when the spring samples are collected, as all contaminant measurements will be converted to fluxes. Field measurements for all samples will include pH, temperature, conductance, and RDX. Two sets of samples, one from high baseflow and one from low baseflow conditions, will be submitted for laboratory analysis for the usual contaminant and water quality suites (HE, inorganics, major anions and cations, HCO_3). A total of five shallow piezometers will be installed in Cañon de Valle near the Qbt 3/2 contact using a pneumatic hammer to determine the extent of saturated alluvium in the canyon. The shallow piezometers will be sited based on geophysical investigations.

Data will be used to determine the extent of saturation in the alluvium of Cañon de Valle and Martin Spring Canyon. Data will also be used to determine whether water and contaminant masses are conserved along the perennial reach of Cañon de Valle and in Martin Spring Canyon between Martin Spring and K-Site. Specific conservation questions include:

1. Does the surface water discharge in Cañon de Valle below Burning Ground Spring equal the summed discharges from Peter Seep, SWSC Spring, and Burning Ground Spring?

2. Does the surface water in Cañon de Valle have gaining reaches (other than those already identified) or losing reaches (upstream of the loss of flow at the Qbt3/Qbt2 contact)? If so, are such gains or losses accounted for by corresponding losses or gains in the alluvial groundwater system?

3. Are observed contaminant fluxes consistent with what would be predicted using a mixing model at points where springs enter or water is exchanged between the surface and alluvial groundwater systems?

4. Are the contaminant fluxes constant below Burning Ground Spring? Should answers to the second and third questions above be negative, one possible explanation might be that contaminants are being exchanged between water and alluvial sediments. Contaminants in alluvial sediments are discussed in Section 6.5 below.

6.3.4.2 Sampling Activities

Discharge profiles for surface water will be constructed from data collected using portable flumes. Precise locations will be specified by reconnaissance to include flow transition points (in particular, the points where the springs join the main channel). Six representative locations for Cañon de Valle are illustrated on Figure 6.3-6 Profiles will be constructed to represent the range of low baseflow and high baseflow conditions. Potential locations for Martin Spring Canyon are illustrated on Figure 6.3-7 , although it is possible that no surface water will be found in Martin Spring Canyon more than 100 ft below the spring at any time of year. Five discharge profiles are proposed per canyon per year, to be collected during recession after snowmelt, dry season, early monsoon, late monsoon, and mid-fall post monsoon (See Table 6.3-4).

Three alluvial wells will be installed in Martin Spring Canyon, one below the spring, one in the wet area below K-Site, and one down-drainage from the wet area (see Figure 6.3-7). These alluvial wells will be instrumented with automated data loggers for pH, conductivity, pressure, and temperature. They will be sampled quarterly for HE, inorganics, VOCs, SVOCs, and water quality parameters in both filtered and unfiltered samples.

Filtered surface water grab samples will be collected at the discharge measurement times and points. Filtered groundwater samples will be collected from the alluvial wells, and filtered grab samples will be collected from the springs, concurrent with the discharge profile measurements and surface water sampling. Field measurements for temperature, pH, conductance, and RDX will be made on all samples.

All samples from two of the five sampling times in each canyon, one representing low flow conditions (spring or fall dry seasons) and one representing high flow conditions (monsoon or snowmelt), will be analyzed for HE, metals, major cations and anions, and HCO_3-.

Five shallow piezometers will be installed using a pneumatic hammer in the Cañon de Valle alluvium. The locations in the perennial reach portion of the canyon will be determined after the geomorphic survey. Because it is believed much of the alluvial and surface water is lost at the Qbt3/Qbt2 contact, one hole will be drilled beyond the contact within unit Qbt2. The remaining locations in the "dry" stretch of Cañon de Valle will be set at approximately a 3 000 ft interval beyond the Qbt3/2 contact. As they are being drilled, they will be measured for moisture content and HE using field HE analyses.

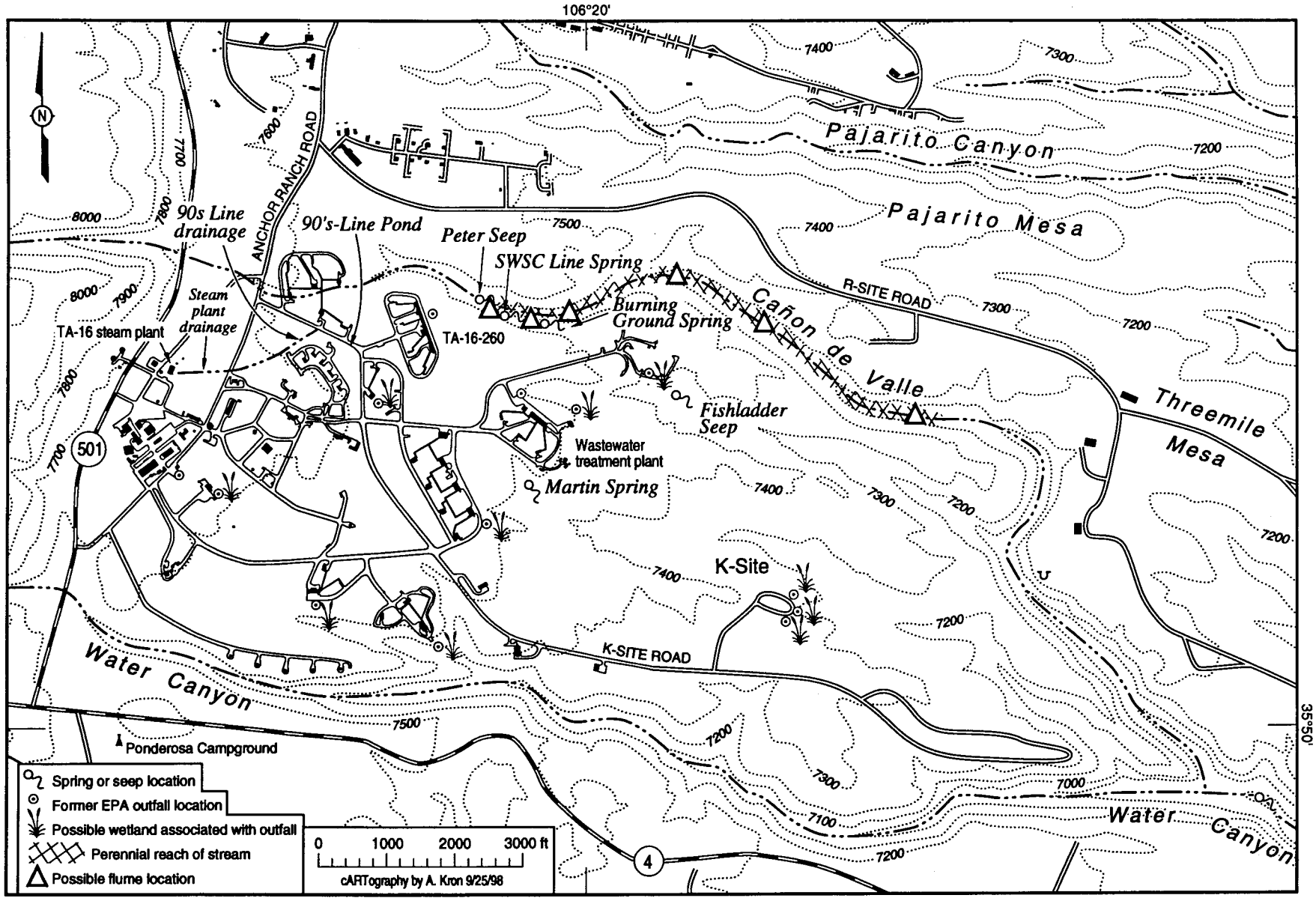


Figure 6.3-6 Temporary flume locations in Cañon de Valle.

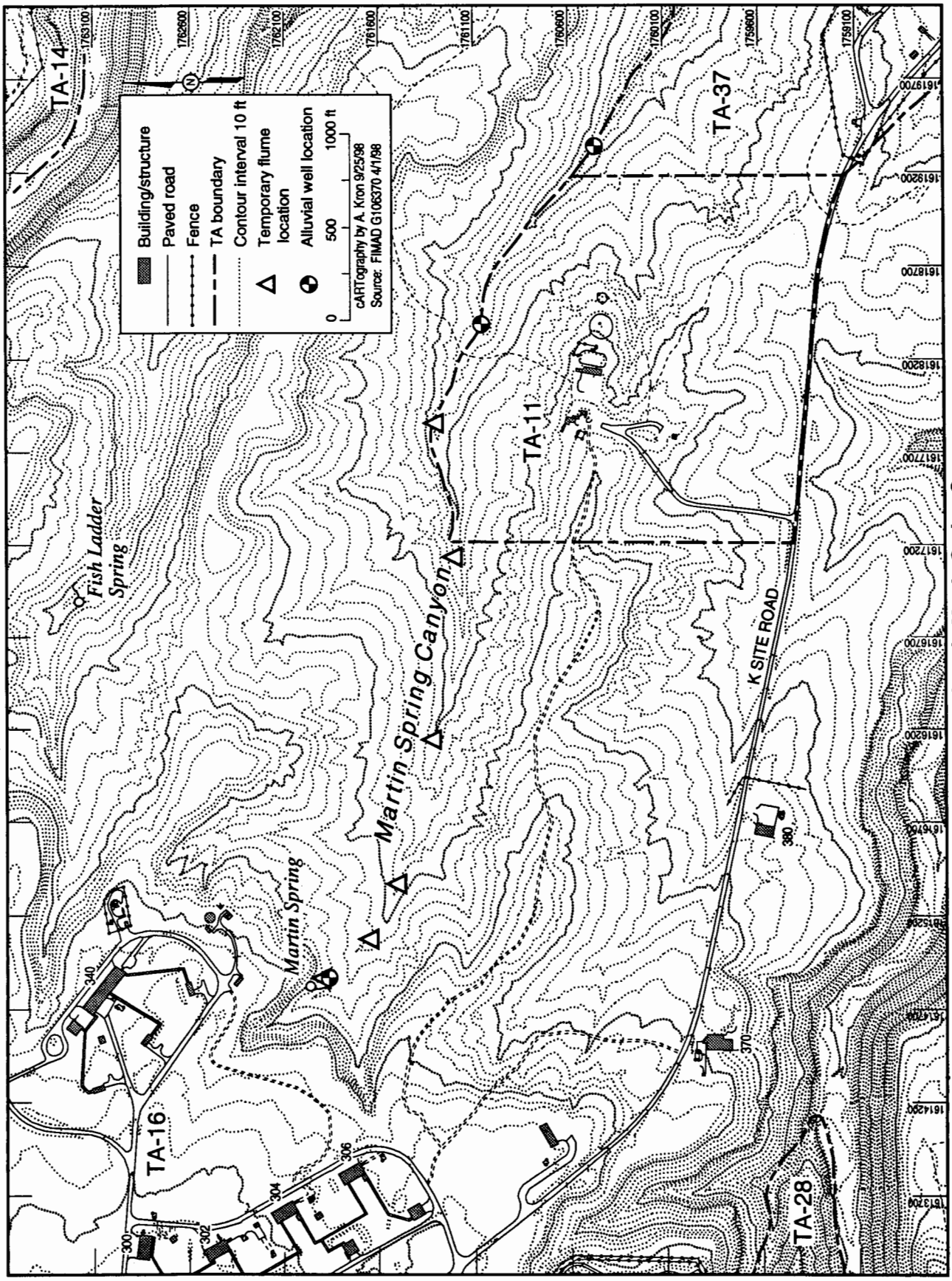


Figure 6.3-7 Temporary flume and proposed alluvial well locations in Martin Spring Canyon.

Table 6.3-4
Summary of Annual Sampling and Analysis for the Investigation of Alluvial Water Dynamics*

Sample or Survey Measurement	Number Collected	Number Analyzed	Field Measurements and Analytical Suites
Cañon de Valle surface water discharge profile	5	NA	NA
Cañon de Valle filtered surface water grab samples	30[a]	30 12	Field temperature, pH, conductance, RDX HE, metals, anions, HCO_3
Cañon de Valle alluvial groundwater discharge	5 profiles	NA	NA
Cañon de Valle filtered alluvial groundwater grab samples	25[b]	25 10	Field temperature, pH, conductance, RDX HE, metals, anions, HCO_3
Martin Spring Canyon surface water discharge profile	5	NA	NA
Martin Spring Canyon filtered surface water grab samples	15[c]	15 6	Field temperature, pH, conductance, RDX HE, metals, anions, $HCO3_3$
Martin Spring Canyon alluvial groundwater discharge	5 profiles	NA	NA
Martin Spring Canyon filtered alluvial groundwater grab samples	15	15 6	Field temperature, pH, conductance, RDX HE, metals, anions, HCO_3
SWSC Spring instantaneous discharge	5	NA	NA
SWSC Spring filtered grab water samples	5	5 2	Field temperature, pH, conductance, RDX HE, metals, anions, HCO_3
Burning Ground Spring instantaneous discharge	5	NA	NA
Burning Ground Spring filtered grab water samples	5	5 2	Field temperature, pH, conductance, RDX HE, metals, anions, HCO_3
Martin Spring instantaneous discharge	5	NA	NA
Martin Spring filtered grab water samples	5	5 2	Field temperature, pH, conductance, RDX HE, metals, anions, HCO_3

[a]Assuming that discharge is measured at six points for each profile.

[b]Assuming that five alluvial wells are sampled.

[c]Assuming that discharge is measured at three points for each profile.

6.3.5 Alluvial Sediment Dynamics

6.3.5.1 Overview

RFI Phase II sampling demonstrated that secondary sources of contaminants reside in both the active channels and in the overbank areas of Cañon de Valle. However, very few samples have been collected

to date outside the active channel, so neither the distribution nor the total inventory of contamination in the alluvial sediments can be reliably estimated.

Alluvial sediments have not been sampled in Martin Spring Canyon.

The data generated in the investigation presented in this subsection will directly support data objectives IO9 and IO10.

6.3.5.2 Investigation Design

Geomorphic units will be mapped in Cañon de Valle and Martin Spring Canyon. In Cañon de Valle, this mapping will be conducted from the head of Peter Seep to below the barium anomaly at the bottom of MDA-P, approximately 4000 ft. In Martin Spring Canyon the mapping will cover a distance of approximately 2000 ft below Martin Spring. (The remainder of the canyons will be mapped as part of the Canyons focus area investigation.)

Geomorphic mapping will identify sediment packages of different age and different particle size characteristics. In particular, sediment packages less than 50 years old may contain contaminants released from PRS 16-021(c) and older TA-16 HE production facilities and finer-grained sediments may have higher concentrations of contaminants than coarse-grained sediments. Contaminant levels could be particularly high in relatively fine-grained sediment packages deposited by unusually high flood events during the period of greatest discharge from the TA-16-260 line outfall, if such packages can be identified.

Subsequent sediment sampling will be confined to areas found to include post-1940 sediment packages, and stratified within such areas according to the results of the geomorphic survey. In particular, as sediments in the active channel have already been extensively sampled, most of the Phase III sampling will be concentrated in floodplain sediments outside the active channel. These floodplain sediments may in turn be stratified into two or more subsets—at a minimum, sediments estimated as having been deposited before and after 1940, with more refined estimates of age if possible.

Within each stratum, the goal is to obtain unbiased estimators of volume and mean contamination for the purposes of estimating total inventory. Volume will be estimated during geomorphic mapping. Contamination will be estimated based on samples collected according to a statistical (ranked set sampling) design, where field ranking is performed using a field HE kit in combination with field descriptions of approximate sediment particle size. The final design of this sampling plan will depend on the results of the geomorphic mapping.

6.3.5.3 Sampling Activities

Geomorphic mapping will be performed in accordance with the methods provided in the Core Document for Canyons Investigations (LANL 1997, 55622).

A sufficient number of sediment samples will be collected to estimate contaminant inventories in the sediment deposits. The numbers provided in Table 6.3-5 are illustrative only. Ranked set sampling (Patil et al. 1994, 59113) will be used, given that a satisfactory field method for one of the contaminants of greatest interest (RDX) is available. Table 6.3-5 suggests a possible design based on the identification of two post-1940 floodplain strata. The first of the two strata is assumed to extend along most of the length of the mapped area and to be geomorphically heterogeneous; no discrete sediment packages can be

identified within it. The second is confined to a relatively short reach, but appears to be a sediment package that was deposited in a single flood event during the period of high volume discharges from the TA-16-260 outfall. A larger number of samples would be allocated by this method to geomorphic units that are either larger or more heterogeneous illustrated in Table 6.3-5.

Table 6.3-5
Summary of Sampling and Analysis for the Inventory Estimation in Cañon de Valle (Example only)

Sample or Survey Measurement	Number collected	Number analyzed	Field Measurements and Analytical Suites
Sediment samples from first (large, inhomogeneous) floodplain stratum	36	36 12 6	Field HE HE, inorganics SVOCs
Sediment samples from second (small, homogeneous) floodplain stratum	9	9 3 1	Field HE HE, inorganics SVOCs

6.4 Data Collection Procedures

This section cites current ER Standard Operating Procedures (SOP)s. As these are revised during the coming year, the new, equivalent procedures will be used.

6.4.1 Field Activities

Fieldwork will be performed at TA-16 from 1999 through 2001. The following field activities will be completed:

- geomorphic survey,
- field sample analysis,
- field sampling activities, and
- land survey.

6.4.1.1 Geomorphic survey

The geomorphic survey will be conducted in Cañon de Valle and Martin Spring Canyon for the purpose of identifying sediment packages of different ages. The survey will be conducted in accordance with procedures presented in the Core Document for Canyons Investigations (LANL 1997, 55622)

6.4.1.2 Field Screening

Field screening will be conducted on soil/sediment/tuff and water samples. Soil/sediment/tuff samples will be screened for bromide, percent moisture, and HE as specified in Section 6.3. Water samples will be screened for temperature, pH, and specific conductance. Field screening of soil/sediment/tuff will be conducted at the field chemistry trailer. Field screening of water will be conducted at the time of sample collection. All field screening results will be documented in a LANL ER document-controlled logbook.

Bromide will be measured using a Tracor Northern Spectrace 9000™ energy dispersive XRF and ion-specific electrodes on extracted bromide solutions. These two field methods will be compared, and the more effective will be implemented. Percent moisture will be measured gravimetrically. RDX and TNT will be measured using a D-Tech™ and, or Ensys™ field analysis kit. Temperature, pH, and conductance will be measured using field portable probes. Screening will be carried out following the Laboratory's ER Project SOPs)and quality procedures (QPs) listed in Table 6.4-1.

Table 6.4-1
LANL ER SOPs

Method	LANL-ER-SOP or QP
XRF	LANL-ER-SOP-10.06
Percent moisture	ASTM, ER SOP is pending
Physical parameters in water	LANL-ER-SOP-06.02

6.4.1.3 Field Sampling Activities

All samples will be collected in accordance with the applicable ER Project SOPs for the collection, preservation, identification, storage, transport, and documentation of environmental samples, as described in the ER Project Quality Assurance Project Plan (QAPP) (LANL 1996, 55298). All samples will be identified in accordance with LANL-ER-SOP-01.04, Sample Control and Field Documentation. Sample media and sample locations will be described, photographed, and documented. Chain-of-custody requirements described in LANL-ER-SOP-01.04 will be implemented. The field support facility (FSF) will be consulted regarding the appropriate sample containers and preservation. Samples will be packaged and shipped in accordance with LANL-ER-SOP-01.03, "Handling, Packaging and Shipping of Samples." All analytical laboratory samples will be shipped from the FSF to off-site laboratories for analysis.

Boreholes will be drilled using hollow stem auger, air rotary, and/or wet rotary drilling methods. All drilling activities will conform to LANL-ER-SOP-04.01, Drilling Methods and Drill Site Management. Samples will be collected from the borehole using a stainless steel, split-spoon sampler according to LANL-ER-SOP-06.24, Sample Collection from Split-Spoon and Shelby Tube Samplers. Trench samples will be collected from the bucket of the backhoe. Collection will conform to LANL-ER-SOP-06.09, Spade and Scoop Method for Collection of Soil Samples. Surface soil and sediment samples will also be collected according to LANL-ER-SOP-06.09, Spade and Scoop Method for Collection of Soil Samples. Subsurface soil/sediment/tuff samples may also be collected using a manually operated hand auger.

Surface water samples will be collected as grab samples using LANL ER-SOP-06.13, "Surface Water Sampling." Filtered water samples will be collected by pumping the water through 0.45 μ filters using a Geotech™ peristaltic pump. Well-water samples will be collected in accordance with LANL-ER-SOP-6.01, Purging of Wells for Representative Sampling of Ground Water. Table 6.4-2 lists the SOPs that will be used for the collection of soil/sediment/tuff and water samples.

Table 6.4-2
Summary of Requirements for Soil and Water Sampling

Sampling Tools and Methods	LANL-ER-SOP
Spade and scoop	06.09
Hand auger	06.10
Trenching	03.10
Surface water sampling	06.13
Alluvial well sampling (look under well development	06.01, 06.02, 06.03
Drilling	04.01
Split spoon sampling	06.24
Well development	05.02

6.4.1.4 Land Survey

Following sample collection, the sample points will be staked, documented and surveyed. A Trimble™ global positioning system (GPS) total station will be used to perform the survey to an estimated accuracy of ± 2 ft. Each sample location will be marked or permanently monumented (where possible), photographed, and assigned a unique ER Project sample location identification number. The data will be recorded on the site base map. The surveying will be performed by licensed professionals working to minimum standards for land surveying in New Mexico, and with oversight by the field team leader (FTL).

6.4.2 Field Analytical Procedures

Section 6.4.1 presented the procedures that will be used to perform the field analyses. Above is a table of the analytical protocols for field screening analyses.

6.4.3 Sample Handling and Tracking

All samples will be managed and tracked in accordance with the applicable ER Project SOPs for the collection, preservation, identification, storage, transport, and documentation of environmental samples, as described in the ER Project QAPP (LANL 1996, 55298). Archived samples for potential stable isotope analysis will be stored in a glass vial with a polyseal cap and refrigerated. An investigation-specific archiving procedure will be developed and presented in the field implementation plan for the Phase III investigation.

6.4.4 Laboratory Analytical Procedures

Analytical methods

All laboratory samples will be analyzed by contract analytical laboratories using methods specified in ER Sample Management Office (SMO) analytical subcontracts (LANL 1995, 1278). Below is a table of the analytical protocols required for laboratory analyses.

Table 6.4-3
Analyte Suites, Methods, and Protocols for Analysis of Soil and Water Samples

Analyte Suite	Analytical Method	Analytical Protocol
HE	HPLC	SW-846, Method 8330
Metals	Inductively coupled plasma emission spectroscopy (ICPES)_	SW-846, Method 6010
Anions (nitrate, sulfate)	Ion Chromatography	EPA Method 300
Fluoride	Ion Chromatography	EPA WW 340 series
Chloride	Ion Chromatography	EPA WW 325 series
Bromide	Ion Chromatography	EPA Method 300EPA Method 320.1
HCO_3 (bicarbonate)	Titration	SW-846, Method 4500-CO_2

Data verification and routine validation procedures are used to determine whether analytical data packages have been generated according to specifications and contain the information necessary to determine data sufficiency for decision-making. Data verification includes ascertaining that data packages are complete, including results for all requested analyses and all supporting information such as chromatograms. It also includes the comparison of results reported in the hard-copy data package with those delivered electronically and uploaded into the Facility for Information Management, Analysis, and Display (FIMAD). All field data and QC results will be verified in FIMAD by comparing electronic data with hard copy reports. Discrepancies will be resolved in favor of the hard copy reports. For analytical data that will be used for decisions, routine data validation will be performed under the auspices of the SMO as described in the ER Project QAPP Requirements for Sampling and Analysis (LANL 1996, 55298). The product of this process is a validation report, including data qualifiers that designate potential deficiencies for affected results. Each data qualifier will be accompanied by a reason code that provides information about how the deficiency might impact data use. Data qualifiers assigned by routine validation, together with their reason codes, will also be recorded in FIMAD. The validation report is used in the decision-making process, and it may also be used to direct a focused validation for evaluating the usability of the data of interest.

7.0 MONITORING PLAN APPROACH

The focus of the IM, CMS, and CMI for the TA-16-260 Outfall and Cañon de Valle is to reduce HE, barium and other constituents in active transport pathways to acceptable levels. As described in Section 6, Additional Data Needs, the hydrologic system defined by the administrative boundary is dynamic, complex, and responds to changes at different time scales. Consequently, assessing the longer-term impacts of the interim measure and determining that contaminant signatures are persistently at or below performance criteria will require a monitoring program.

Monitoring is an activity that involves making periodic measurements over time for the purpose of assessing status and trends. Developing an effective monitoring program depends upon understanding the system to be monitored sufficiently to anticipate what data will be useful in the analysis and when they should be collected. The information collected in Phase III, as specified in Section 6, will

characterize the system sufficiently to support the design of the monitoring plan. The monitoring plan developed in the CMS will be integrated with LANL's Watershed Management Plan.

The monitoring plan cannot be specified at this time because the Phase III information has yet to be collected and analyzed. LANL anticipates that monitoring locations are likely to be selected to coincide with locales that are included in the quarterly sampling described in the Phase I RFI report or in the Phase III sampling plan presented in Chapter 6. These locales might include the springs, the seep, and the further downgradient expression of the alluvial systems in Cañon de Valle and Martin Spring Canyon. Monitoring design criteria can be identified. The following elements should be considered when the plan is developed.

- Identify the specific goals of the monitoring plan. This step is especially important for hydrologic system components, like the springs, where contaminant concentrations change with discharge and the system has several time scales of response to storm events. The measured concentration values will be influenced by the period of integration for the samples. This also means that performance criteria for contaminant concentrations need to be associated with time integration periods.

- Measure both quantity and quality of water. Dynamic nonlinear hydrologic systems often require estimates of contaminant flux before it is possible to assess trends. Discharge measurements of all surface water and springs are necessary for these calculations.

- Monitor at multiple geographic scales. The administrative boundary, as described in Section 3, is designed to include all the fate and transport processes for the Cañon de Valle basin. The monitoring program should be designed to make empirical estimates of the net contaminant export from the basin as a whole. These estimates can then be compared with the individual pathways monitoring data from the springs and seep to check for congruence. If the signatures do not balance, then either another source or an unknown sink may be operating in the system.

- Coordinate surface water and groundwater monitoring in the Cañon de Valle basin. The separation of surface water and groundwater is more a convenience than a system reality, especially for the alluvial aquifer. Sampling of groundwater should correspond to surface water monitoring events to support comparisons of the data.

- Collect water quality parameters. Several sources of water will be sampled and analyzed, including Peter Seep, the three springs, and alluvial groundwater. Having information on parameters such as pH, temperature, and charge balance is important to inferring how these waters combine as a basin output.

- Include biological monitoring as part of the program. Cost efficiencies for monitoring programs often take the form of restricted analyte lists to reduce analytical costs. One way to assess the overall quality of the monitored waters is to conduct toxicity testing with well-documented test organisms. If persistent toxic effects occur without changes in the monitored contaminants, then the waters should be evaluated for additional toxicants.

- Establish a monitoring baseline, then evaluate the program for effectiveness and relevance. Monitoring programs are often susceptible to inertia. Once a program is initiated, the design is rarely revisited. A periodic review should be scheduled as part of the plan implementation. Criteria should also be established that allow reduced monitoring after a stated duration of results without exceeding performance criteria. For example, if the RDX signatures at Burning Ground Spring are below acceptable criteria under the conditions most likely to exceed the criteria, then the monitoring effort could be reduced.

- Integrate the monitoring design with other monitoring programs. Organizations other than the ER Project are conducting monitoring programs at LANL. Coordination of these programs can reduce costs and enhance data usability.

- Commit to a reporting schedule and decision framework. Each measurement in the monitoring program should have an intended use. Periodic reports of data and data interpretations are necessary in order to get information out to the stakeholders. Part of the design of the program should be documenting the decision options that the data and interpretations are likely to support. The lag between sample collection and reporting should be carefully considered. Information should be timely, but the schedule cannot move faster than the infrastructure that returns the data to the investigators.

8.0 REFERENCES

Agrawal, A. and P. G. Tratnyek, 1995. "Reduction of Nitro Aromatic Compounds by Zero-Valent Iron Metal," Environmental Science and Technology paper Vol. 30, No, 1. **(Agrawal and Tratnyek 1995, 58938)**

Channel, M. G., April 1996. "An Evaluation of Solidification/Stabilization for Treatment of Contaminated Soils from the Umatilla Army Depot Activity," U.S. Army Corp of Engineers, Vicksburg, MS. **(Channel 1996, 58943)**

Craig, H. D, W.E. Sisk, M.D. Nelson, and W.H . Dana., 1995. "Bioremediation of Explosives-Contaminated Soils: A Status Review," Proceedings of the 10th Annual Conference on Hazardous Waste Research. **(Craig et al. 1995, 58939)**

Code of Federal Regulations (CFR), July 1, 1995. "Title 40-Protection of Environment, Part 264," Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities. Subchapter 1 Solid Wastes, Washington, D.C. **(CFR 1995, 56034)**

Dale, M. R., 1997. "Water Quality and Flow Characteristics of Perennial Reaches in Pajarito Canyon and Canon de Valle, Los Alamos National Laboratory," New Mexico Environment Department, DOE Oversight Bureau Draft Report, Los Alamos, New Mexico. **(Dale 1997, 57286.2, 1082,VolX)**

Defense Environmental Restoration Program, June 7, 1994. "Umatilla Depot Activity Explosives Washout Lagoons Ground Water Operable Unit," Defense Environmental Restoration Program Final Record of Decision, Hermistou, Oregon. **(Defense Environmental Restoration Program 1994, ER ID 59172).**

DuBois, F. W. and J. F. Baytos, May 1991. "Weathering of Explosives for Twenty Years," Los Alamos National Laboratory Report LA-11931, Los Alamos, New Mexico. **(DuBois and Baytos 1991, 06994)**

Environmental Restoration Project, in preparation. "Phase II RFI Report for Potential Release Site 16-021(c)," Los Alamos National Laboratory Report LA-UR-98-XXXX, Los Alamos, New Mexico. **(Environmental Restoration Project 1998, in preparation)**

Environmental Restoration Project, September 1996. "RFI Report for Potential Release Sites in TA-16: 16-003(k), 16-021(c), Field Unit 3," Los Alamos National Laboratory Report LA-UR-96-3191, Los Alamos, New Mexico. **(Environmental Restoration Project 1996, 55077)**

EPA (US Environmental Protection Agency), March 29, 1990. "Hazardous Waste Management Systems; Identification and Listing of Hazardous Waste; Toxicity Characteristics Revisions," Final Rule, 40 CFR Parts 261, 264, 265, 268, 271, and 302, Federal Register, Vol. 55, No. 61, p. 11798. **(EPA 1990, 0093)**

EPA (U. S. Environmental Protection Agency), February 1995. "EPA Superfund Record of Decision: Umatilla Army Depot (Lagoons), Operable Unit 3, 7/19/1994," EPA/ROD/R10/94/094, Hermiston, Oregon. **(EPA1995, 58942)**

EPA (U. S. Environmental Protection Agency), February 1995. "EPA Superfund Record of Decision: Umatilla Army Depot (Lagoons), Operable Unit 4, 7/19/1994," EPA/ROD/R10/94/095, Hermiston, Oregon. **(EPA 1995, ER ID 58941)** √

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, 01585)**

Gehan, E. A., 1965. "A Generalized Wilcoxan Test for Comparing Arbitrarily Singly-Sensored Samples," *Biometrika,* Vol. 52, Nos. 1 and 2, pp. 203-223. **(Gehan 1965, 55611.1, 1082, Vol.X)**

Ingraham, N. L., B. F. Lyles, R. L. Jacobson, and J. W. Hess 1991. "Stable Isotopic Study of Precipitation and Spring Discharge in Southern Nevada.," Journal of Hydrology, 125 (1991), 125 pp. 243-258. **(Ingraham et al. 1991, 59171, 1082, Vol.X)**

LANL (Los Alamos National Laboratory) 1995. "Site Development Plan, Annual Update 1995," Los Alamos National Laboratory Publication, LALP-95-113, Los Alamos, New Mexico. **(LANL 1995, 57224)**

LANL (Los Alamos National Laboratory), December 6, 1996. "Hydrogeologic Workplan," Revision 1.0, Los Alamos National Laboratory Report, Los Alamos, New Mexico. **(LANL 1996, 55430)**

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, 49738)**

LANL (Los Alamos National Laboratory), January 1996. "Interim Action Report for Solid Waste Management Unit 16-021(c)." **(LANL 1996, 53838)**

LANL (Los Alamos National Laboratory), March 1996. "Quality Assurance Project Plan Requirements for Sampling and Analysis," Los Alamos National Laboratory Report LA-UR-96-441, ER ID No. 53450, Los Alamos, New Mexico. **(LANL 1996, 55298)**

Los Alamos National Laboratory (LANL) April 1997. "Core Document for Canyons Investigations," Los Alamos National Laboratory Report LA-UR-96-2083, Los Alamos, New Mexico. **(LANL 1997, 55622, Canyons)**

Los Alamos National Laboratory (LANL) July 16, 1998. "Request To Use Industrial Exposure Scenarios In Lieu Of Residential Scenarios For Human Health Risk Assessment In 260 Outfall [PRS 16-021(c)] RFI/CMS Process (Former OU 1082, FU 3)," Los Alamos National Laboratory letter to B. Garcia (NMED-HRMB) EM/ER:98-237, Los Alamos, New Mexico. **(LANL 1998, 59173)**

Manning, J. F., R. Boopathy, and E. R. Breyfogle, December 1996. "Field Demonstration of Slurry Reactor Biotreatment of Explosives-Contaminated Soils," Bioremediation Group, Environmental Research Division paper (SFIM-AEC-ER-CR-96178), Argonne, Illinois. **(Manning et al. 1996, 58937)**

McCutcheon, March 1998. "Phytoremediation of High Explosives at Pantex and Los Alamos Facilities," personal communication at ITRD briefing in Santa Fe, New Mexico. **(McCutcheon 1998, 59170)**

Newman, B. D. 1996. Geochemical Investigations of Calcite Fracture Fills and Mesa-Top Water Dynamics on the Pajarito Plateau, New Mexico," Ph.D. Dissertation, New Mexico Tech. pp. 61-109. Los Alamos National Laboratory Report LA-UR-96-1441, Los Alamos, New Mexico. **(Newman 1996, 54399, 1082, Vol.X)**

(Patil, G. P., S. D. Gore and A. K. Sinha. 1994. "Environmental Chemistry, Statistical Modeling, and Observational Economy. Chapter 3 in Environmental Statistics, Assessment and Forecasting (C. R. Cothern and N. P. Ross, eds.), Lewis Publishers, Boca Raton. pp. 57-97. **(Patil, et. al., 1994, 59113)**

Sisk, W. E. 1998. "Incineration of Explosive-Contaminated Soil," presentation by W.E. Sisk, U.S. Army Environmental Center. **(Sisk 1998, 58940)**

Los Alamos National Laboratory (LANL), March 8, 1997. "Summary of Regulatory Water Standards," Los Alamos National Laboratory Environmental Restoration, Los Alamos, New Mexico. **(LANL 1997, 59174)**

Toro, E., J. Miller, and M. Zappi, May 1995. "Assessing Advanced Oxidation Processes for the Treatment of Trinitrotoluene Contaminated Groundwater," Proceedings of the Department of Defense Environmental Technology Workshop, Hershey, Pennsylvania. **(Toro et al. 1995, 58936)**

9.0 APPENDIX A

Acronyms & Glossary

MASTER LIST OF ACRONYMS AND ABBREVIATIONS FOR ER PROGRAM AT LOS ALAMOS

AA	Administrative Authority
AEA	Atomic Energy Act
AEC	US Atomic Energy Commission
ALARA	As low as reasonably achievable
AOP	Advanced oxidation processes
ARAR	Applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
BMP	best management practices
BOD	biological oxygen demand
BV	Background value
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CMI	Corrective measures implementation
CMS	Corrective measures study
COPC	Contaminant of potential concern
CWA	Clean Water Act
DNAPL	Dense nonaqueous phase liquid
DNT	Dinitrotoluene
DoD	US Department of Defense
DOE	US Department of Energy
DOE/LAAO	US Department of Energy /Los Alamos Area Office
DQO	Data quality objective
EA	Environmental assessment (NEPA)
EES	Earth and Environmental Sciences (Division)
EIS	Environmental impact statement
EM	Environmental Management (Division)
EPA	US Environmental Protection Agency
ER	Environmental restoration
ESH	environmental safety and health
FIMAD	Facility for Information Management, Analysis, and Display
FSF	field support facility
FTL	Field team leader
FY	Fiscal year
FWS	US Fish and Wildlife Service
GAC	granular activated carbon
GC	Gas chromatograph(y), Garratt-Callahan
GFAA	Graphite furnace atomic absorption
HE	High explosive
HMX	1,3,5,7-tetranitro-1,3,5,7-tetrazacyclooctane (Cyclotetramethylenetetranitramine)
HPLC	High-performance liquid chromatography

HRMB	Hazardous and Radioactive Materials Board
HSWA	Hazardous and Solid Waste Amendments of 1984
ICPES	Inductively coupled plasma emission spectroscopy
IM	Interim measure
IO	investigation objective
ITRD	Innovative Treatment Remediation Demonstration
LAAO	Los Alamos Area Office (a branch of the Department of Energy)
LANL	Los Alamos National Laboratory
LDR	Land disposal restrictions
MCS	Media cleanup standard
MDA	Material disposal area
MDL	Minimum/method detection limit
MS	Mass spectrometer (spectrometry)
NEPA	National Environmental Policy Act
NFA	No further action
NMED	New Mexico Environment Department (New Mexico Environmental Improvement Division before 1991)
NMWQCC	New Mexico Water Quality Control Commission
NOD	Notice of deficiency
NPDES	National pollutant discharge elimination system
NPL	National Priorities List
ORNL	Oak Ridge National Laboratory
OU	Operable unit
PAH	Polyaromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCE	Perchloroethane
POC	points of compliance
PRG	Preliminary remediation goal
PRS	Potential release site
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality control
QP	Quality procedure
RCRA	Resource Conservation and Recovery Act
RDX	1,3,5-trinitro-1,3,5-triazacyclohexane (Cyclotrimethylenetrinitramine)
RFA	RCRA facility assessment, request for analysis
RFI	RCRA facility investigation
RFP	Request for proposal
RI	Remedial investigation
RI/FS	Remedial investigation/feasibility study
ROD	Record of decision
RSD	Relative standard deviation
RSS	Ranked set sampling
SADA	Spatial analysis and decision assistance
SAL	Screening action level
SAP	Sampling and analysis plan

SARA	Superfund Amendments and Reauthorization Act
SMO	Sample Management Office (formerly Sample Management Facility)
SOP	Standard operating procedure
SSAL	Site-specific action levels
SSRA	Site-specific risk assessment
SVOC	Semivolatile organic compound
SW	Solid waste
SWSC	Sanitary wastewater system consolidation
SWMU	Solid waste management unit
TA	Technical area
TCE	Trichloroethylene
TCLP	Toxicity characteristic leaching procedure
TNB	Trinitrobenzene
TNT	Trinitrotoluene
TRD	Treatment remediation demonstration
TSD	Treatment, storage, disposal
TSDF	Treatment, storage, and disposal facility
TSCA	Toxic Substances Control Act
UTL	Upper tolerance limits
VOC	Volatile organic compound
WES	Waterways Environmental Station
XRF	X-ray fluorescence
ZVI	Zero-valent iron

GLOSSARY

Alluvial Said of materials or features deposited by running water.

Alluvial fan A fan-shaped piedmont accumulation of sediment deposited by a stream.

Applicable, relevant, or appropriate requirement (ARARs) Those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, or that address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

Aquifer A permeable body of geologic material capable of yielding groundwater to wells or springs.

Background value (BV) Background values exist for inorganic chemicals and radionuclides. The background values are the upper tolerance limits (UTLs) of background sample results, calculated as the upper 95% confidence limit for the 95th percentile. In cases where a UTL cannot be calculated, either the detection limit or maximum reported value is used as a BV. Background values are used as simple threshold numbers to identify potentially contaminated site sample results as greater than background levels.

Baseline risk assessment (Also known as ***risk assessment***) A site-specific analysis of the potential adverse effects caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these releases. There are four steps in baseline risk assessment: data collection and analysis, exposure assessment, toxicity assessment, and risk characterization.

Chemical of concern A chemical that is identified as a potential risk as the result of performing a site-specific human health or ecological risk assessment.

Chemical of potential concern (COPC) A chemical detected at a site that has the potential to adversely affect human and or ecological receptors due to its concentration, distribution and mechanism of toxicity. The chemical remains a concern until exposure pathways and receptors are evaluated in a site-specific risk assessment.

Cleanup levels Media-specific target concentration levels for contaminants that must be met by a selected corrective action. Cleanup levels are established using criteria such as protection of human health and the environment; compliance with regulatory requirements; reduction of toxicity, mobility, or volume through treatment; long- and short- term effectiveness; implementability; cost; and public acceptance.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. Amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986. The acts created a special tax that goes into a trust fund, commonly known as Superfund, whose mandate is to investigate and clean up abandoned or uncontrolled hazardous waste sites that may endanger health or the environment. The EPA is responsible for managing Superfund.

Conceptual model See also ***Site conceptual model.***

Conceptual hydrogeologic model Perception of the occurrence, movement and quality of groundwater in an area and the relationship of groundwater to the surface water, soil water and geologic framework there.

Constituent Any compound or element present in environmental media, including both naturally occurring and anthropogenic elements.

Contaminant Any chemical (including radionuclides) present in environmental media or on structural debris at a concentration that may present a risk to human health or the environment.

Controlled area Any Laboratory area to which access is controlled to protect individuals from exposure to radiation and/or hazardous materials.

Corrective Action A measure taken to rectify conditions adverse to human health or the environment.

Corrective measures study If a RCRA facility investigation indicates that further action is required, a "corrective measures study" is performed to identify and evaluate cleanup alternatives for the release. This study assesses risks to human health and the environment, costs, and other factors such as disposal methods.

Corrective measures implementation (CMI) This third step of the corrective action process includes design, construction, maintenance, and monitoring of the chosen remedy.

Data quality objectives (DQOs) The qualitative and quantitative goals that are developed before sampling begins that clarify the investigation objectives and identify the type, quantity and quality of data needed to support decisions.

Discharge or Hazardous Waste Discharge (As defined under RCRA, 40 CFR 260.10) The accidental or intentional spilling, leaking, pumping, pouring, emitting, emptying, or dumping of hazardous waste into or on any land or water.

Ecological Screening Level (ESL) An organism's exposure-response threshold for a given chemical constituent. It is the concentration of a substance in a particular medium that corresponds to a hazard quotient (HQ) of 1.0 for a given organism and below which no risk is indicated.

Effluent A liquid discharged as a waste, such as contaminated water from a factory or the outflow from a sewage works; water discharged from a storm sewer or from land after irrigation.

Ephemeral stream Said of a stream or spring that flows only during and immediately after periods of rainfall or snowmelt.

Grab sample A specimen collected by a single application of a field sampling procedure to a target population, e.g. the surface soil from a single hole collected following the spade and scoop sampling procedure, or a single air filter left in the field for three months.

Groundwater Water in a subsurface saturated zone.

Hazardous and Solid Waste Amendments (HSWA) Amendments to the Resource Conservation and Recovery Act, 1984. HSWA added land disposal restrictions, minimum technology requirements, and expanded corrective action authorities to the RCRA statue.

Hazardous substance (As defined by 40 CFR 302.3) Any substance designated pursuant to 40 CFR 302. 40 CFR 302.4 – Designation of Hazardous Substances:

(a) ***Listed hazardous substances.*** The elements, compounds and hazardous wastes appearing in Table 302.4 are designated as hazardous substances under section 102(a) of the CERCLA.

(b) ***Unlisted hazardous substances.*** A solid waste, defined in 40 CFR 261.2, which is not excluded from regulation as a hazardous waste under 40 CFR 261.4(b), is a hazardous substance under

section 101(14) of the CERCLA if it exhibits any of the characteristics identified in 40 CFR 261.20 through 261.24. See Hazardous Waste. Note: This definition incorporates by reference, substances listed in CWA sections 311 and 307(a); CAA section 112; RCRA section 3001; and TSCA section 7.

Hazardous waste (As defined by RCRA 40 CFR 261.3) Any solid waste is generally a hazardous waste if it is not excluded from regulation as a hazardous waste, is listed in the regulations as a hazardous waste, exhibits any of the defined characteristics of hazardous waste (ignitability, corrosivity, reactivity, or toxicity), or is a mixture of solid waste and hazardous waste.

Holding time The maximum elapse of time that one can expect to store a sample without unacceptable changes in analyte concentrations. Holding times apply under prescribed storage conditions and deviations in storage conditions may affect the holding time. Extraction Holding Time refers to the time lapse from sample collection to sample preparation; Analytical Holding Time refers to the time lapse between sample preparation and analysis.

HSWA module A portion of the Laboratory's permit to operate under RCRA that contains requirements specific to Los Alamos National Laboratory. It is this portion of the permit that contains the list of solid waste management units that must be cleaned up in accordance with RCRA procedures.

Industrial use scenario Industrial use is the future use scenario in which current Laboratory operations continue. Any necessary remediation involves cleanup to standards designed to ensure a safe and healthy work environment for Laboratory workers.

Interflow A runoff process that involves lateral subsurface flow in the soil zone.

Interim measure The actions used to achieve the goal of stabilization at contaminated sites that present serious and immediate health hazards.

Intermittent stream Said of a stream that flows only in certain reaches due to losing and gaining characteristics of the channel bed.

Institutional controls Controls prohibiting or limiting access to contaminated media; may consist of deed restrictions, use restrictions, permitting requirements, etc.

Leachate A liquid that has percolated through waste, soil or rock material and mobilized chemical species in the process.

Materials disposal area An area used any time between the beginning of Laboratory operations in the early 1940s and the present for disposing of chemically and/or radioactively contaminated materials.

Maximum contaminant level Under the Safe Drinking Water Act, the maximum permissible level of a contaminant in water that is delivered to any user of a public water system that serves 15 or more connections and 25 or more people. The standards set take into account the feasibility and cost of attaining the standard.

Medium (environmental) Any material capable of absorbing or transporting constituents including tuffs, soils and sediments derived from these tuffs, surface water, groundwater, air, structural surfaces, and debris.

Migration The movement of inorganic and organic species through unsaturated or saturated materials.

Migration pathway A route (e.g., a stream or subsurface flow path that controls the potential movement of contaminants to environmental receptors (plants, animals, humans).

Monitoring well A well drilled at a specific location on or off a hazardous waste site for the purpose of sampling groundwater or measuring water levels. Typically constructed with a moderate screen interval placed so as to straddle the water table or potentiometric surface associated with the saturated zone of interest.

National Pollutant Discharge Elimination System (NPDES) A federal regulation under the Clean Water Act requiring permits for discharge into surface waterways.

Outfall The vent or end of a drain, pipe, sewer, ditch, or other conduit that carries waste water, sewage, storm runoff or other effluent into a stream.

Perched groundwater Groundwater that lies above the regional water table and is separated from it by an unsaturated zone.

Perennial Stream Said of a stream or reach that flows continuously throughout the year.

Piezometer A well drilled for the purpose of measuring hydraulic head or water level; ideally only open at the bottom but usually constructed with a very short screen interval.

Piezometric Surface Also called potentiometric surface. The level to which water will rise in a well tightly cased into an aquifer.

Potential release site (PRS) A site suspected of releasing contaminants into the environment. PRS is a generic term that includes SWMUs, hazardous waste sites listed in Module VII of the Laboratory's Hazardous Waste Facility Permit, and sites that have been identified as potentially contaminated by radioactivity.

RCRA facility assessment (RFA) Usually the first step in the RCRA corrective action process, to identify potential and actual releases from SWMUs and make preliminary determinations about releases, the need for corrective action, and interim measures. The RFA is generally equivalent to the preliminary assessment/site investigation taken under Superfund.

RCRA facility investigation (RFI) The second step of a RCRA corrective action, to gather enough data to fully characterize the nature, extent, and rate of migration of contaminants to determine the appropriate response action. The RFI is generally equivalent to the RI portion of the Superfund process.

Receptor A person, plant, animal, or geographical location that is exposed to a chemical or physical agent released to the environment by human activities.

Recharge The process by which water is added to the zone of saturation, either directly from the overlying unsaturated zone or indirectly by way of another material in the saturated zone.

Recreational use scenario Recreational use refers to current and future use scenarios in which cleanup of a PRS is completed to a level that permits the public to safely use it on an intermittent basis for activities such as hiking and camping. The standards are more stringent than they are for the industrial use scenario but not as stringent as those for residential use.

Relevant and appropriate requirements Those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate. **(DOE 1991)**

Remediation The process of reducing the concentration of a contaminant (or contaminants) in air, water, or soil media to a level that poses an acceptable risk to human health; the act of restoring a contaminated area to a usable condition based on specified standards.

Remedy or remedial action Those actions consistent with permanent remedy instead of or in addition to removal actions in the event of a release or threatened release of a hazardous substance into the environment, to prevent or minimize the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health or welfare or the environment. The term includes, but is not limited to, such actions at the location of the release as storage, confinement, perimeter protection using dikes, trenches, or ditches, clay cover, neutralization, cleanup of released hazardous substances and associated contaminated materials, recycling or reuse, diversion, destruction, segregation of reactive wastes, dredging or excavations, repair or replacement of leaking containers, collection of leachate and run-off, on-site treatment or incineration, provision of alternative water supplies, and any monitoring reasonably required to assure that such actions protect the public health and welfare and the environment. **[CERCLA 101(24)]** Activities conducted at DOE facilities to reduce potential risks to people and/or harm to the environment from radioactive and/or hazardous substance contamination. **(DOE Order 5820.2A)**

Removal action An immediate action taken over the short term to address a release or threatened release of hazardous substances. **(DOE 1991)**

Residential use scenario The standards for residential use are the most stringent of the three current and future use scenarios being considered by the ER Project and is the level of cleanup EPA is currently specifying for SWMUs located off the Laboratory site and for those released for non-Laboratory use.

Resource Conservation and Recovery Act (RCRA) The RCRA regulations establish a comprehensive hazardous waste management system under the authority of RCRA Subtitle C. RCRA regulates hazardous waste from its point of generation through its point of final disposal. RCRA also regulates solid waste under Subtitle D.

Restricted Area Any area access to which is controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials. "Restricted area" shall not include areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area. **(10 CFR 60.2)**

Risk A measure of a negative or undesirable impact associated with an event.

Risk assessment see also *Baseline Risk Assessment*

Risk assessment, preliminary A risk assessment conducted using conservative assumptions and scenarios and assuming no mitigating or corrective measures beyond those already in place.

Risk characterization The summarization and integration of the results of toxicity and exposure assessments into quantitative and qualitative expressions of risk. The major assumptions, scientific judgments, and sources of uncertainty related to the assessment are also presented.

Risk management Risk management is the integration of risk characterization with other nonscientific considerations specified in applicable statutes to make and justify regulatory decisions. ***(RCRA/CERCLA Update*, June 1992)**

Sample A portion of a material (e.g., rock, soil, water, air), which, alone or in combination with other samples, is expected to be representative of the material or area from which it is taken. Samples are typically sent to a laboratory for analysis or inspection or are analyzed in the field. When referring to samples of environmental media, the term *field sample* may be used.

Screening Action Level (SAL) Medium-specific concentration level for a chemical derived using conservative criteria below which it is generally assumed that there is no potential for unacceptable risk to human health. The derivation of a SAL is based on conservative exposure and land use assumptions. However, if an applicable regulatory standard exists that is less than the value derived by risk-based computations, it will be used for the SAL.

Screening Assessment A process designed to determine whether contamination detected in a particular medium at a site may present a potential unacceptable human health and /or ecological risk. The assessment utilizes screening levels that are either human-health or ecologically-based concentrations derived using chemical specific toxicity information and standardized exposure assumptions below which no additional actions are generally warranted.

Site characterization The program of exploration and research, both in the laboratory and in the field, undertaken to establish the geological, hydrological, and chemical conditions at a site. Site characterization includes borings, surface excavations, excavation of exploratory shafts, limited subsurface lateral excavations and borings and geophysical testing. **(10 CFR 60.2)**

Site conceptual model A qualitative or quantitative description of sources of contamination, environmental transport pathways for contamination, and biota that may be impacted by contamination (called receptors) and whose relationships describe qualitatively or quantitatively the release of contamination from the sources, the movement of contamination along the pathways to the exposure points, and the uptake of contaminant by the receptors.

Solid waste management unit (SWMU) 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.

Split sample A sample that has been subdivided into two or more portions expected to be of the same composition. Used to characterize within-sample heterogeneity, sample handling, and measurement variability.

Standard operating procedure (SOP) A written document that details the method for an operation, analysis, or action with thoroughly prescribed techniques and steps, and is officially approved as the method for performing certain routine or repetitive tasks.

Stratigraphy The science dealing with the succession, age, composition and history of strata.

Technical area (TA) The Laboratory established technical areas as administrative units for all its operations. There are currently 49 active TAs spread over 43 square miles.

Topography The physical features of a place or region.

Treatment Any method, technique, or process, including elementary neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste, or so as to recover energy or material resources from the waste, or so as to render such waste non-hazardous, or less hazardous; safer to transport, store, or dispose of; or amenable for recovery, amenable for storage, or reduced in volume.

Treatment, storage, and disposal facility (TSDF) Any building, structure, or installation where a hazardous waste has been treated, stored, or disposed. TSD facilities are regulated by EPA and states under RCRA.

Tuff A compacted deposit of volcanic ash and dust that contains rock and mineral fragments accumulated during an eruption.

Unsaturated zone The zone between the land surface and the regional water table. Generally, fluid pressure in this zone is less than atmospheric pressure, and some of the voids may contain air or other gases at atmospheric pressure. Alternatively, the unsaturated zone generally has moisture contents less than saturation.

Water balance The relationship between water input (precipitation) and output (runoff, evapotranspiration, and recharge) in a hydrological system; the portioning of precipitation into these components of the hydrological cycle.

Water content (also gravimetric moisture content) The amount of water in an unsaturated medium, expressed as the ratio of the weight of water in a sample to the weight of the oven-dried sample; often expressed as a percent.

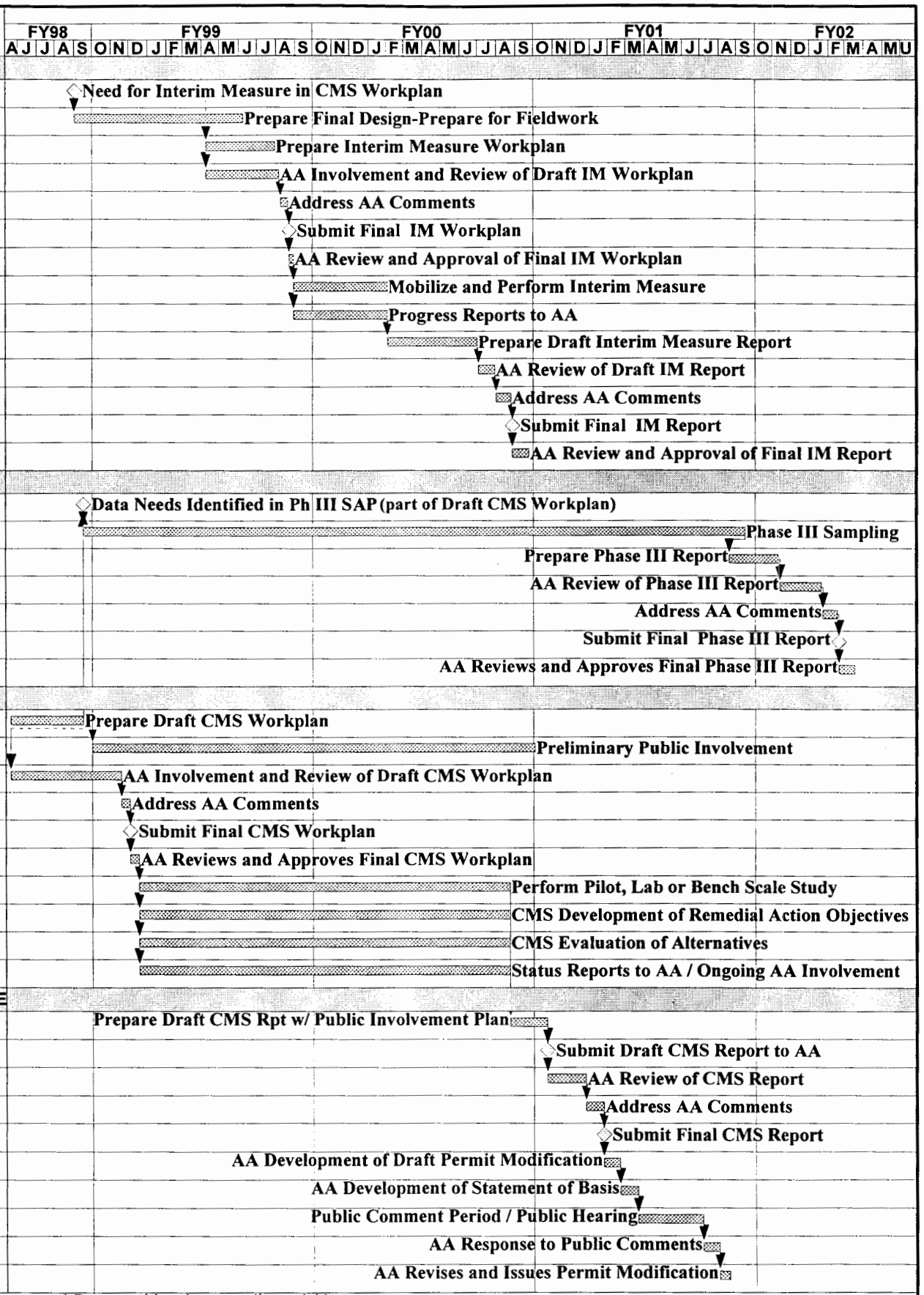
Water table The top of the saturated zone; the water level associated with an unconfined aquifer.

Welded Tuff A volcanic deposit hardened by the action of heat, pressures from overlying material, and hot gases.

10.0 APPENDIX B

Schedule for CMS/CMI at PRS 16-021(c)

Early Start	Early Finish	
INTERIM MEASURE		
01SEP98*		Need for Interim Measure in CMS Workplan
01SEP98	07JUN99	Prepare Final Design-Prepare for Fieldwork
09APR99*	30JUL99	Prepare Interim Measure Workplan
09APR99	06AUG99	AA Involvement and Review of Draft IM Workplan
09AUG99	20AUG99	Address AA Comments
23AUG99		Submit Final IM Workplan
23AUG99	30AUG99	AA Review and Approval of Final IM Workplan
31AUG99	01FEB00	Mobilize and Perform Interim Measure
31AUG99	01FEB00	Progress Reports to AA
02FEB00	30JUN00	Prepare Draft Interim Measure Report
03JUL00	28JUL00	AA Review of Draft IM Report
31JUL00	25AUG00	Address AA Comments
28AUG00		Submit Final IM Report
28AUG00	22SEP00	AA Review and Approval of Final IM Report
PHASE III RFI		
15SEP98		Data Needs Identified in Ph III SAP (part of Draft CMS Workplan)
15SEP98	14SEP01	Phase III Sampling
20AUG01	09NOV01	Prepare Phase III Report
12NOV01	18JAN02	AA Review of Phase III Report
21JAN02	15FEB02	Address AA Comments
18FEB02		Submit Final Phase III Report
18FEB02	15MAR02	AA Reviews and Approves Final Phase III Report
CMS PHASE		
19MAY98*	14SEP98	Prepare Draft CMS Workplan
01OCT98*	03OCT00	Preliminary Public Involvement
19MAY98	17NOV98	AA Involvement and Review of Draft CMS Workplan
18NOV98	03DEC98	Address AA Comments
04DEC98		Submit Final CMS Workplan
04DEC98	17DEC98	AA Reviews and Approves Final CMS Workplan
18DEC98	23AUG00	Perform Pilot, Lab or Bench Scale Study
18DEC98	23AUG00	CMS Development of Remedial Action Objectives
18DEC98	23AUG00	CMS Evaluation of Alternatives
18DEC98	23AUG00	Status Reports to AA / Ongoing AA Involvement
CMS REPORT PHASE		
24AUG00	23OCT00	Prepare Draft CMS Rpt w/ Public Involvement Plan
24OCT00		Submit Draft CMS Report to AA
24OCT00	25DEC00	AA Review of CMS Report
26DEC00	22JAN01	Address AA Comments
23JAN01		Submit Final CMS Report
23JAN01	19FEB01	AA Development of Draft Permit Modification
20FEB01	19MAR01	AA Development of Statement of Basis
20MAR01	04JUL01	Public Comment Period / Public Hearing
06JUL01	02AUG01	AA Response to Public Comments
03AUG01	17AUG01	AA Revises and Issues Permit Modification



* Dates not driven by preceeding activities

Project Start	02MAR98	Early Bar
Project Finish	15MAR02	Progress Bar
Data Date	09MAR98	
Run Date	29SEP98	

© Primavera Systems, Inc.

PRS 16-021(c) CMS Schedule
Los Alamos National Laboratory
Environmental Restoration Project

11.0 APPENDIX C

CMS Report Outline

Corrective Measures Study Report Outline

A. Executive Summary

B. Introduction/Purpose/Applicability

C. Site History

D. Description of Current Conditions

E. Media Cleanup Standards/Points of Compliance/Remedial Action Objectives

F. Selection of Corrective Measure Alternatives

1. Process and Criteria Used to Evaluate Alternatives
2. Identification
3. Development (Threshold Criteria Screening)

a) Protection of Human Health and the Environment
b) Ability to Meet Media Cleanup Standards
c) Ability to Control Releases
d) Compliance with Applicable Standards for Management of Wastes Feasibility Given Existing Waste- and Site-Specific Conditions

G. Evaluation of Selected Corrective Measure Alternatives

1. Long-Term Reliability and Effectiveness
2. Reduction of Toxicity, Mobility, and/or Volume of Wastes
3. Short-Term Effectiveness
4. Potential Impacts
5. Implementability
6. Cost

H. Justification and Recommendation of the Corrective Measure or Measures

1. Summary of the Corrective Measure or Measures and Rationale
2. Design and Implementation Criteria/Precautions
3. Operation and Maintenance Requirements
4. Remedy-Specific Performance Standards and Expectations
5. Cost Estimates and Schedules (Compliance Time Frame)

I. Public Involvement Plan

12.0 APPENDIX D

Roles and Responsibilities for CMS/CMI

The following table outlines key Los Alamos National Laboratory (LANL) and US Department of Energy (DOE) personnel currently involved in the Corrective Measures Study/Corrective Measures Implementation (CMS/CMI) process for PRS 16-021(c), the TA-16-260 outfall. Many other resources from LANL's contractors, particularly ICF Kaiser Engineers and Neptune and Company, have also been intimately involved in the CMS/CMI activities during past years.

Table D-1

Roles & Responsibilities of Key LANL and DOE Personnel Involved in CMS/CMI Activities at PRS 16-021(c)

Name	Affiliation	Role/Responsibility
W. Scott Baldridge	EES-1	Geology
Kathy Campbell	EES-5	Statistics
Julie Canepa	EM/ER	ER Project Leader
Alison Dorries	EES-13	Analysis & Assessment Focus Area Leader
Victoria George	EM/ER	Regulatory Compliance Focus Area Leader
Donald Hickmott	EES-1	Team Leader – HE Production Sites Team, Geology
Elizabeth Kelly	TSA-1	Ecological Risk Assessment
John McCann	CST-7	Team Leader – Firing Sites Team, Risk Assessment
Roy Michelotti	CST-7	Remedial Actions Focus Area Leader
Joe Mose	DOE/LAAO	DOE Contact
Brent Newman	EES-15	Hydrogeology
Karen Schultz-Paige	CST-7	Chemistry

13.0 APPENDIX E

Cost/benefit and risk/benefit considerations

that will be applied in the CMS Report

APPENDIX E COST/BENEFIT AND RISK/BENEFIT CONSIDERATIONS THAT WILL BE APPLIED IN THE CMS REPORT

Cost/benefit and risk benefit methodologies to support the CMS Process

LANL will evaluate remedial alternatives based on risk-benefit, cost-benefit, and applicability selection criteria during the CMS process. In order to meet this objective, LANL will use a proven methodology such as the Laboratory Integration and Prioritization (LIPS) cost/benefit/prioritization model developed by LANL, a modified Kepner-Tregoe Formalism process, or other similar methodology. For example, the modified Kepner-Tregoe process would include the following five steps:

- Step 1 Develop remedial objectives
- Step 2 Quantify remedial objectives
- Step 3 Develop list of potential remedial approaches
- Step 4 Evaluate and rank potential remedial approach
- Step 5 Choose best scoring technology as tentative decision

E.1 Step 1 Develop Remedial Objectives

The remedial objectives developed during the CMS will be based primarily on cost-benefit and risk-benefit criteria, applicability, and related factors relevant to the site, media, or environment. In developing remedial objectives the following factors, described in more detail in Chapter 5, will be evaluated:

- performance and reliability,
- reduction of toxicity, mobility, or volume of contaminants or wastes,
- effectiveness of remedy in achieving target concentrations,
- timing of the potential remedy,
- ease of implementation,
- long-term reliability,
- impacts of institutional requirements on remedy implementation,
- mitigation of human health and environmental exposures, and
- costs.

E.2 Step 2 Quantify Remedial Objectives

The purpose of Step 2 is to address the qualitative remedial objectives and assign a value of low priority to high priority (e.g., a 1ñ10 scale). This quantity (W for illustrative purposes) will be a weighting factor used in subsequent calculations.

E.3 Step 3 Develop List of Potential Remedial Approaches

Step 3 is intended to identify potential remedial approaches that might apply based on Step 1 objectives and site-specific conditions. Potential remedial approaches are identified in Section 5.2.

E.4 Step 4 Evaluation and Ranking of Potential Remedial Approaches

Each potential remedial approach will be assigned a numerical score (rating) based on how it performs in each of the objectives (e.g. a 1Ñ10 scale). The number assigned to the remedial approach will be called S for illustrative purposes.

This score will be multiplied by the weighting factor for the objective (i.e., S*W).

The sum of the scores is calculated.

Rating of the remedial approaches will focus on facility conditions and pathways of contamination actually addressed by each remedial approach.

To evaluate all the criteria (based on remedial approaches), LANL will graphically depict data pertaining to costs/risk, costs/benefits, and risk/benefit for each recommended approach using the Spatial Analysis and Decision Assistance (SADA) software (or similar software). SADA was developed for DOE in 1998, and can graphically reproduce site cost/benefit curves that demonstrate the specific relationship between a given remedial cleanup goal and the corresponding cost. This cleanup goal can be a concentration value or a particular human-health risk scenario. SADA also incorporates a variety of summarization, visualization, and modeling tools to aid in making remedial decisions. We will use such software tools combined with published remedial cost tables and other guidance documents to help evaluate specific approaches.

E.5 Step 5 Recommend Best Remedial Alternatives

In Step 5 the remedial approaches scoring the highest scores will be used as tentative selections. A sensitivity analysis will then be run on the results to verify the scoring elections.

14.0 APPENDIX F

Excerpts from LANL's HSWA module to the RCRA permit Relevant to the CMS Plan and Crosswalk between Permit Requirements and this Document

Table F-1 HSWA Permit Requirements Crosswalk

HSWA Permit Requirements	Where Addressed
L. CORRECTIVE ACTION MEASURE STUDY PLAN	
2a. General approach to investigate and study potential remedies	CMS Plan Secs. 3, 4
2b. Define overall objectives of study	CMS Plan Sec. 3
2c. Plans for evaluating remedies to ensure compliance w/remediation standards	CMS Plan Sec. 5
2d. Schedule for conducting study	CMS Plan App. B
2e. Proposed format	CMS Plan Sec. 1, App. C
2f. Pilot- or bench-scale studies necessary	CMS Plan Sec. 4
R. SCOPE OF WORK FOR A RCRA CORRECTIVE MEASURES STUDY AT LOS ALAMOS NATIONAL LABORATORY	
VI. IDENTIFICATION AND DEVELOPMENT OF THE CORRECTIVE ACTION ALTERNATIVES	
A. Description of current situation	RFI Reports CMS Plan Sec.2
B. Establishment of Corrective Action Objective	CMS Plan Sec. 3
C. Laboratory and Bench-scale Study	CMS Plan Sec. 4
D. Screening of Corrective Measure Technologies	CMS Plan Sec. 4
E. Identification of Corrective Measure Alternatives	CMS Plan Sec. 5
VIII. EVALUATION OF THE CORRECTIVE MEASURE ALTERNATIVE OR ALTERNATIVES	
A. Technical/Environmental/Human Health/Institutional	
1. Technical	CMS Plan Sec. 5, CMS Report
2. Environmental perform EA for each alternative	CMS Plan Sec. 5, CMS Report
3. Human Health mitigation of short-and long-term potential exposure both during and after implementation.	CMS Plan Sec. 5, CMS Report
4. Institutional effect of federal, state, and local environmental and public health standards, regulations, guidance advisories, ordinances, or community relations on the design, operation, and timing of alternatives.	CMS Plan Sec. 5, CMS Report
B. Cost Estimate	CMS Plan Sec. 5, CMS Report
1. Capital costs	CMS Report
2. Operation and maintenance costs, after construction	CMS Report
JUSTIFICATION AND RECOMMENDATION OF THE CORRECTIVE MEASURE OR MEASURES	
A. Technical	CMS Plan Sec. 5, CMS Report
1. Performance	
2. Reliability	
3. Implementability	
4. Safety	
B. Human Health	CMS Plan Sec. 5, CMS Report
C. Environmental	CMS Plan Sec. 5, CMS Report

The following is extracted from the CMS section of the HSWA permit. Any inconsistencies are inadvertent and not intended as modifications.

L. Corrective Action Measures Study Plan

1. If the Administrative Authority has reason to believe that a SWMU has released concentrations of hazardous constituents, or if the Administrative Authority determines that contaminants present a threat to human health and the environment given site-specific exposure conditions, or may present a threat over the lifetime of wastes, the Administrative Authority may require a Corrective Measures Study (CMS) and shall notify the Permittee in writing. The notification may also specify remedial alternatives and pilot or bench scale studies to be evaluated by the Permittee during the CMS.

2. The Permittee shall submit a draft CMS Plan to the Administrative Authority within ninety (90) calendar days from notification of the requirement to conduct a CMS. The Scope of Work for a Corrective Measure study (CMS) is in Section R.

The CMS Plan shall provide the following information:

a. A description of the general approach to investigation and potential remedies;

b. A definition of the overall objectives of the study;

c. The specific plans for evaluating remedies to ensure compliance with remedy standards;

d. The schedules for conducting the study;

e. The proposed format for the presentation of information; and

f. Any pilot or bench scale studies necessary.

3. After the Permittee submits the draft CMS plan, the Administrative Authority will either approve or disapprove the plan. If the plan is not approved, the Administrative Authority will notify the Permittee in writing of the plan's deficiencies and specify a due date for submittal of the, revised plan. If this plan is not approved, the Administrative Authority will revise the Plan and notify the Permittee of the revisions. This Administrative Authority revised Plan becomes the approved Plan.

M. CORRECTIVE MEASURES STUDY IMPLEMENTATION

No later than fifteen (15) calendar days after the Permittee has received written approval from the Regional Administrator for the CMS Plan, the Permittee shall begin to implement the Corrective

Measures Study according to the schedules specified in the CMS Plan. The CMS shall be conducted in accordance with the approved Plan.

N. CORRECTIVE MEASURES STUDY FINAL REPORT

1. Within sixty (60) calendar days after the completion of the CMS, the Permittee shall submit a CMS Final Report. The CMS Final Report shall summarize the results of the investigations for each remedy studied and of any bench-scale or pilot tests conducted. The CMS Report must include an evaluation of each remedial alternative. The CMS Report shall present all information gathered under the approved CMS Plan. The final report must contain adequate information to support the Regional Administrator in the remedy selection decision making process.

2. If the Regional Administrator determines that the CMS Final Report does not fully satisfy the information requirements specified under Permit condition N.1., the Regional Administrator may disapprove the CMS Final Report. If the Regional Administrator disapproves the Final Report, the Regional Administrator will notify the Permittee in writing of deficiencies in the Report and specify a due date for submittal of a revised Final Report (e.g., thirty (30) days after notification).

3. Based on preliminary results and the final CMS report, the Administrative Authority may require the Permittee to evaluate additional remedies or particular elements of one or more proposed remedies.

P. FACILITY SUBMISSION SUMMARY – RELEVANT SECTION ONLY

Interim Measures Plan for interim measures required after permit issuance	thirty (30) calendar days after notification
Revised Interim Measure Plan	as determined
CMS Plan	ninety (90) calendar days after notification of the requirement to perform a CMS
Revised CMS Plan	as determined
CMS Report	sixty (60) calendar days after completion of CMS
Revised CMS Report	thirty (30) calendar days after notification of deficiency

R. SCOPE OF WORK FOR A RCRA CORRECTIVE MEASURE STUDY (CMS) AT LOS ALAMOS NATIONAL LABORATORY

PURPOSE

The purpose of this Corrective Measure Study (CMS) is to develop and evaluate the corrective action alternative or alternatives and to recommend the corrective measure or measures to be taken at Los Alamos National Laboratory. The Permittee will furnish the personnel, materials, and services necessary to prepare the CMS, except as otherwise specified.

If the Permittee believes that certain requirements of the scope of work are not applicable, the specific requirements shall be identified and the rationale for inapplicability shall be provided. This scope of work should be modified as necessary to require only that information necessary to complete the RCRA CMS.

SCOPE

The CMS consists of four tasks. Those tasks, and the ER Program documents/activities that are equivalent to the CMS documents/, activities are listed on the following page. The permittee shall prepare a single installation-wide work plan, which shall be updated annually, and task specific RI/FS documents for each task. The installation wide work plan shall contain programmatic operating procedures, tabular summaries of the potential release sites, prioritization of the site/tasks, and a work schedule by task (including a current year work plan). The task specific RI/FS documents/activities shall be prepared as tasks are implemented. The detailed outlines for the task specific RI/FS documents shall be provided in the installation-wide work plan.

TASK VI: IDENTIFICATION AND DEVELOPMENT OF THE CORRECTIVE ACTION ALTERNATIVE(S)

Based on the results of the RCRA Facility Investigation (RFI) and consideration of the identified Preliminary Corrective Measure Technologies (Task I) the Permittee shall identify, screen, and develop the alternative(s) for removal, containment, treatment and/or other remediation of the contamination based on the objectives established for the corrective action.

A. Description of Current Situation

The Permittee shall submit an update to the information describing the current situation at the facility and the known nature and extent of the contamination as documented by the RFI report. The Permittee shall provide an update to information presented in Task I of the RFI to the Administrative Authority regarding previous response activities and any interim measures which have or are being implemented at the facility. The Permittee shall also make a facility-specific statement of the purpose for the response, based on the results of the RFI. The statement of purpose should identify the actual or potential exposure pathways that should be addressed by corrective measures.

B. Establishment of Corrective Action Objectives

The Permittee, in conjunction with the Administrative Authority, shall establish site specific objectives for the corrective action. These objectives shall be based on public health and environmental criteria, information gathered during the RFI, EPA guidance and the requirements of any applicable Federal statutes. At a minimum, all corrective actions concerning groundwater releases from solid waste management units must be consistent with, and as stringent as, those required under 40 CFR 264.100.

C. Laboratory and Bench-Scale Study

When a new technology is being proposed or similar waste streams have not routinely been treated or disposed using the technology the Permittee shall conduct laboratory and/or bench-scale studies to determine the applicability of a corrective measure technology or technologies to the facility conditions. The Permittee shall analyze the technologies, based on literature review, vendor contracts, and past experience to determine the testing requirements.

The Permittee shall develop a testing plan identifying the type(s) and goal(s) of the study(ies), the level of effort needed, and the procedures to be used for data management and interpretation.

Upon completion of testing, the Permittee shall evaluate the testing results to assess the technology or technologies with respect to the site-specific questions identified in the test plan.

The Permittee shall prepare a report summarizing the testing program and its results, both positive and negative.

D. Screening of Corrective Measure Technologies

The Permittee shall review the results of the RFI and reassess the technologies specified in Task II and identify any additional technologies which are applicable to the facility. The Permittee shall screen the preliminary corrective measure technologies identified in Task II of the RFI and any supplemental technologies to eliminate those that may prove not feasible to implement, that rely on technologies unlikely to part form satisfactorily or reliably, or that do not achieve the corrective measure objective within a reasonable time period. This screening process focuses on eliminating those technologies which have severe limitations for a given set of waste and site-specific conditions. The screening step may also eliminate technologies based on inherent technology limitations.

Site, waste, and technology characteristics which are used to screen inapplicable technologies are described in more detail below:

1. Site Characteristics
   Site data should be reviewed to identify conditions that may limit or promote the use of certain technologies. Technologies whose use is clearly precluded by site characteristics should be eliminated from further consideration;

2. Waste Characteristics
   Identification of waste characteristics that limit the effectiveness or feasibility of technologies is an important part of the screening process. Technologies clearly limited by these waste characteristics should be eliminated from consideration. Waste characteristics particularly affect the feasibility of in-situ methods, direct treatment methods, and land disposal (on/off-site); and

3. Technology Limitations
   The level of technology development, performance record, and inherent construction, operation and maintenance problems shall be identified for each technology considered. Technologies that are unreliable, perform poorly, or are not fully demonstrated may be eliminated in the screening process. For example, certain treatment methods have been developed to a point where they can be implemented in the field without extensive technology transfer or development.

E. Identification of the Corrective Measure Alternatives

The permitting shall develop the corrective measure alternatives based on the corrective measure objectives and analysis of Preliminary Corrective Measure Technologies, as presented in Task I of the RFI as supplemented following the preparation of the RFI report. The Permittee shall rely on engineering practice to determine which of the previously identified technologies appear most suitable for the site. Technologies can be combined to form the overall corrective action alternatives. The alternatives developed should represent a workable number of options that each appear to adequately address all

site problems and corrective action objectives. Each alternative may consist of an individual technology or a combination of technologies. The Permittee shall document the reasons for excluding technologies, identified in Task I, as supplemented in the development of the alternative.

TASK VIII EVALUATION OF THE CORRECTIVE MEASURE ALTERNATIVE(S)

The Permittee shall describe each corrective measure alternative that passed the initial screening in Task VI and evaluate each corrective measure alternative and its components. The evaluation shall be based on technical, environmental, human health and institutional concerns. The Permittee shall also develop cost estimates for each corrective measure.

A. Technical Environmental/Human Health/Institutional

The Permittee shall provide a description of each corrective measure alternative which includes but is not limited to the following: preliminary process flow sheets; preliminary sizing and type of construction for buildings and structures; and rough quantities of utilities required. The Permittee shall evaluate each alternative in the four following areas:

1. Technical

The Permittee shall evaluate each corrective measure alternative based on performance. reliability, implementability and safety.

a. The Permittee shall evaluate performance based on the effectiveness and useful life of the corrective measure:

i) Effectiveness shall be evaluated in terms of the ability to perform intended functions such as containment, diversion, removal, destruction, or treatment. The effectiveness of each corrective measure shall be determined either through design specifications or by performance evaluation. Any specific waste or site characteristics which could potentially impede effectiveness shall be considered. The evaluation should also consider the effectiveness of combinations of technologies; and

ii) Useful life is defined as the length of time the level of effectiveness can be maintained. Most corrective measure technologies, with the exception of destruction, deteriorate with time. Often, deterioration can be slowed through proper system operation and maintenance, but the technology eventually may require replacement. Each corrective measure shall be evaluated in terms of the projected service lives of its component technologies. Resource availability in the future life of the technology, as well as appropriateness of the technologies, must be considered in estimating the useful life of the project.

b. The Permittee shall provide information on the reliability of each corrective measure including their. operation and maintenance requirements and their demonstrated reliability:

i) Operation and maintenance requirements include the frequency and complexity of necessary operation and maintenance. Technologies requiring frequent or complex operation and maintenance activities should be regarded as less reliable than technologies requiring little or straightforward operation and maintenance. The availability of labor and materials to meet these requirements shall also be considered; and

ii) Demonstrated and expected reliability is a way of measuring the risk and effect of failure. The Permittee should evaluate whether the technologies have been used effectively under analogous conditions; whether the combination of technologies have been used together effectively; whether failure of any one technology has an immediate impact on receptors; and whether the corrective measure has the flexibility to deal with uncontrollable changes at the site.

c. The Permittee shall describe the implementability of each corrective measure including the relative ease of installation (constructibility) and the total time required to achieve a given level of response:

i) Constructibility is determined by conditions both internal and external to the facility conditions and include. such items as location of underground utilities, depth to water table, heterogeneity of subsurface materials, and location of the facility (e.g., remote location vs. a congested urban area). The Permittee shall evaluate what measures can be taken to facilitate construction under these conditions. External factors which affect implementation include the need for special permits or agreements, equipment availability, and the location of suitable off-site treatment or disposal facilities;

ii) Time has two components that shall be addressed: the time it takes to implement a corrective measure and the time it takes to actually see beneficial results. Beneficial results are defined as the reduction of contaminants to some acceptable, pre—established level.

d. The Permittee shall evaluate each corrective measure alternative with regard to safety. This evaluation shall include threats to the safety of nearby communities and environments as well as those to workers during implementation. Factors to consider include fire, explosion, and exposure to hazardous substances.

2. Environmental

The Permittee shall perform an Environmental Assessment for each alternative. The Environmental Assessment shall focus on facility conditions and pathways of contamination actually addressed by each alternative. The Environmental Assessment f or each alternative will include, at a minimum, an evaluation of: the short— and long-term beneficial and adverse effects of the response alternative; any adverse effects on environmentally sensitive areas; and an analysis of measures to mitigate adverse impacts.

3. Human Health

The Permittee shall assess each alternative in terms of the extent which it mitigates short and long-term potential exposure to any residual contamination and protects human health both during and after implementation of the corrective measure. The assessment will describe the levels and characterizations of contaminants on—site, potential exposure routes, and potentially affected populations. Each alternative will be evaluated to determine the level of exposure to contaminants and the reduction over time. For management of mitigation measures, the relative reduction of impact will be determined by comparing residual levels of each alternative with existing criteria, standards, or regulations acceptable to the Administrative Authority.

4. Institutional

The Permittee shall access relevant institutional needs for each alternative specifically the effects of Federal state, and local environmental and public health standards, regulations, guidance, advisories, ordinances, or community relations on the design, operation, and timing of each alternative.

B. Cost Estimate

The Permittee shall develop an estimate of the cost of each corrective measure alternative (and for each phase or segment of the alternative). The cost estimate shall include capital, and operation and maintenance costs.

1. Capital costs consist of direct (construction) and indirect (nonconstruction and overhead) costs.
   a. Direct capital costs include:
      i) Construction costs: Cost of materials, labor (including fringe benefits and worker's compensation), and equipment required to install the corrective measure alternative.
      ii) Equipment costs: Costs of treatment, containment, disposal and/or service equipment necessary to implement the action; these materials remain until the corrective action is completed;
      iii) Land and site development costs: Expenses associated with purchase of land and development of existing property; and
      iv) Building and services coats: Costs of process and nonprocess buildings, utility connections, purchased services, and disposal costs.

   b. Indirect capital costs include:
      i) Engineering expenses: Costs of administration, design construction supervision, drafting and testing of corrective measure alternatives;
      ii) Legal fees and license or permit costs:
      Administrative and technical costs necessary to obtain licenses and permits for installation and operation;
      iii) Start-up and shakedown Costa: Cost incurred during corrective measure start-up; and
      iv) Contingency allowances: Funds to cover costs resulting from unforeseen circumstances, such as adverse weather conditions, strikes, and inadequate facility characterization.

2. Operation and maintenance costs are post-construction costs necessary to ensure continued effectiveness of a corrective measure. The Permittee shall consider the following operation and maintenance cost components:

    a. Operating labor costs: Wages, salaries, training, overhead, and fringe benefits associated with the labor needed for post-construction operation;
    b. Maintenance materials and labor casts: Costa for labor, parts, and other resources required for routine maintenance of facilities and equipment;
    c. Auxiliary materials and energy: Costs of such items as chemicals and electricity for treatment plant operations, water and sewer service, and fuel;
    d. Purchased services: Sampling costs, laboratory fees, and professional fees for which the need can be predicted;
    e. Disposal and treatment: Costs of transporting, treating, and disposing of waste materials, such a. treatment plant residues generated during operation;
    f. Administrative costs: Costs associated with administration of corrective measure operation and maintenance not included under other categories;
    g. Insurance, taxes, and licensing costs: Costs of such items as liability and sudden accidental insurance; real estate taxes on purchased land or rights-of-way; licensing fees for certain technologies; and permit renewal and reporting costs;
    h. Maintenance reserve and contingency funds: Annual payments into escrow funds to cover (1) costs of anticipated replacement or rebuilding of equipment and (2) any large unanticipated operation and maintenance costs; and
    i. Other costs: Items that do not fit any of the above categories.

TASK VIII. JUSTIFICATION AND RECOMMENDATION OF THE CORRECTIVE MEASURE OR MEASURES

The Permitting shall justify and recommend a corrective measure alternative using technical, human health, and environmental criteria. This recommendation shall include summary tables which allow the alternative or alternatives to be understood easily. Trade off among health risks, environmental effects, and other pertinent factors shall be highlighted. At a minimum, the following criteria will be used to justify the final corrective measure or measures.

A. Technical

1. Performance - corrective measure or measures which are most effective at performing their intended functions and maintaining the performance over extended periods of time will be given preference;
2. Reliability — corrective measure or measures which do not require frequent or complex operation and maintenance activities and have proven effective under waste and facility conditions similar to those anticipated will be given preference;
3. Implementability — corrective measure or measures which can be constructed and operated to reduce levels of contamination to attain or exceed applicable standards in the shortest period of time will be preferred; and
4. Safety - corrective measure or measures which pose the least threat to the safety of nearby residents and environments as well as workers during implementation will be preferred.

B. Human Health

The corrective measure or measures must comply with existing U.S. EPA criteria, standards, or regulations for the protection of human health. Corrective measures which provide the minimum level of exposure to contaminants and the maximum reduction in exposure with time are preferred.

C. Environmental

The corrective measure or measures posing the least adverse impact (or greatest improvement) on the environment over the shortcut period of time will be favored.

TASK IX: REPORTS

The Permittee shall prepare a Corrective Measure Study Report presenting the results of Tasks VII through IX recommending a corrective measure alternative. Two (2) copies and one compatible disk copy of the draft and final reports shall be provided to the Administrative Authority by the Permittee.

A. Progress

The Permittee shall at a minimum provide the Administrative Authority with signed monthly management status reports containing:

1. A description and estimate of the percentage of the 018 completed;
2. Summaries of contacts relevant to corrective action with representatives of the local community, public interest groups or State government during the reporting period;
3. Summaries of problems or potential problems relevant to corrective action encountered during the reporting period;
4. Actions being taken to rectify problems;
5. changes in key project personnel during the, reporting period; and
6. Projected work for the next reporting period.

B. Draft

The Report shall at a minimum include:

1. A summary of the corrective measure or measures and rationale:
   a. Description of the corrective measure or measures and rationale for selection;
   b. Performance expectations;
   c. Preliminary design criteria and rationale;
   d. General operation and maintenance requirements; and
   e. Long-term monitoring requirements.

2. Design and implementation precautions:
   a. Special technical problems;
   b. Additional engineering data required;
   c. Permits and regulatory requirements;
   d. Access, easements, right-of-way;
   e. Health and safety requirements; and
   f. Community relations activities.

3. Cost Estimates and Schedules:
   a. Capital cost estimate;
   b. Operation and maintenance cost estimate; and
   c. Project schedule (design, construction, operation).

C. Technical Quarterly Process Reports

The Permittee shall submit quarterly progress reports which summarize environmental data collected during the previous quarter.

A. Final

The Permittee shall finalize the Corrective Measure Study Report incorporating comments received from the Administrative Authority on the Draft Corrective Measure Study Report.

15.0 APPENDIX G

Relevant Documents

APPENDIX G. RELEVANT DOCUMENTS

G-1.0 DOCUMENTATION OF REGULATORY HISTORY

G-1.1 Corrective Action History

The history of regulatory interaction concerning the TA-16-260 outfall site is extensive and has involved a close working relationship with EPA and NMED. This working relationship has included numerous site tours and briefings on the progress of investigations. A summary of the key corrective action interactions with the regulators is provided in Table G-1.1-1.

Table G-1.1-1

Corrective Action History Summary TA-16 260 Outfall, PRS 16-021(c)

Date	Description of Corrective Action Activity
July 1993	RFI Work Plan for OU 1082 submitted to EPA
7/18/94	DOE received letter from EPA describing NODs on the Work Plan (letter dated 7/13/94)
8/11/94	LANL sent letter to DOE responding to NODs received on the Work Plan, Part 1 – 30 day
8/17/94	DOE sent letter to EPA responding to NODs received on the Work Plan, Part 1
11/21/94	LANL sent letter to DOE responding to NODs received on the Work Plan, Part 2
11/30/94	DOE sent letter to EPA responding to NODs received on the Work Plan, Part 2
12/22/94	DOE received letter from EPA approving the Work Plan, Part 1
1/9/95	LANL received letter from DOE on approval of the Work Plan, Part 1
1/12/95	DOE received letter from EPA approving the Work Plan, Part 2
1/18/95	LANL received letter from DOE on approval of the Work Plan, Part 2
2/12/96	Interim Action Report for SWMU 16-021(c) submitted to NMED
2/16/96	IA Report re-submitted to NMED
9/17/96	DOE received letter from NMED recommending CMS for this site and requesting a CMS Plan submittal by October 1, 1996 (letter dated 4/3/96)
9/23/96	RFI Report for PRSs in TA-16, 16-003(k) and 16-021(c), submitted to NMED (included Phase II SAP)
9/26/96	LANL/DOE sent letter to NMED requesting permission to submit the CMS Plan following completion of the Phase II RFI Report for the site.
12/5/96	LANL/DOE received letter from NMED describing comments on RFI Report for Potential Release Sites in TA-16
1/9/97	LANL/DOE sent letter to NMED acknowledging 12/5/96 letter above
2/26/97	LANL/DOE sent letter responding to NMED comments on RFI Report for Potential Release Sites in TA-16
8/6/97	LANL/DOE received letter from NMED requesting supplemental information (RSI) on RFI Report for Potential Release Sites in TA-16 (letter dated 8/4/97)
8/26/97	LANL/DOE sent letter requesting extension for submittal of response to RSI on RFI Report for Potential Release Sites in TA-16
9/15/97	LANL/DOE received letter from NMED approving request for extension for submittal of response to RSI on RFI Report for Potential Release Sites in TA-16 (letter dated 9/11/97)
11/14/97	Response to RSI on RFI Report for Potential Release Sites in TA-16 submitted to NMED

Table G-1.1-1 (concluded)

Date	Description of Corrective Action Activity
1/26/98	LANL/DOE received letter from NMED approving RFI Report for Potential Release Sites in TA-16 upon modification (letter dated 1/20/98)
2/26/98	Response to Approval upon Modification RFI Report for Potential Release Sites in TA-16 submitted to NMED
3/31/98	LANL/DOE received letter from NMED approving RFI Report for Potential Release Sites in TA-16 (letter dated 3/26/98)

G-1.2 Other Regulatory Documents

None.

G-2.0 Referenced Documents

Referenced documents specific to this CMS Plan may be found in the TA-16 reference set, which is being submitted with the Phase II RFI Report for PRS 16-021(c). All other documents referenced in this report can be found in the ER Project Reference Library.