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Date: November 30, 1998
Refer to: EM/ER:98-452

Mr. Benito Garcia
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SUBJECT: SUBMITTAL OF SWMU GROUP 73-2 SAP FOR PRSs 73-003, 73-004 (a, b), 73-005, 73-006, 73-007, & C-73-005 (a-f) (FORMER OU 1071, FU 1)

Dear Mr. Garcia:

Enclosed please find your copy of the Sampling and Analysis Plan (SAP) for Solid Waste Management Unit Group 73-2, which addresses Potential Release Sites (PRSs) 73-003, 73-004 (a, b), 73-005, 73-006, 73-007, and C-73-005 (a-f). This SAP fulfills the 1998/1999 Work Schedule for PRSs 73-004 (a, b) and 73-006. PRSs 73-005 and 73-007, which are on the HSWA Permit, are included in this SAP for review and implementation efficiency. PRSs 73-003 and C-73-005 (a-f) are not on the HSWA Permit and have been included for information only.

If you have any questions, please contact Dave McInroy at (505) 667-0819 or Joe Mose at (505) 667-5808.

Sincerely,

Julie A. Canepa, Program Manager
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Theodore J. Taylor, Program Manager
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Enclosure: Sample and Analysis Plan for SWMU Group 73-2

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Sampling and Analysis Plan for SWMU Group 73-2

73-003
73-004(a)
73-004(b)
73-005
73-006
73-007
C-73-005(a through f)

Environmental Restoration Project
A Department of Energy Environmental Cleanup Program

Los Alamos
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Produced by the Remedial Actions Focus Area Town Sites Team

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ACRONYMS

AA	administrative authority
AEC	Atomic Energy Commission
AOC	area of concern
AP	administrative procedure
ATSDR	Agency for Toxic Substances and Disease Registry
BCF	bioconcentration factor
bgs	below ground surface
BV	background value
CFR	Code of Federal Regulations
COPC	chemical of potential concern
D&D	decontamination and decommissioning
DOE	Department of Energy
DQO	data quality objective
EM	Environmental Management
EPA	Environmental Protection Agency
EQL	estimated quantitation limit
ER	Environmental Restoration
FIMAD	Facility for Information Management, Analysis, and Display
FR	Federal Register
FSF	Field Support Facility
HSWA	Hazardous and Solid Waste Amendments of 1984
IWP	Installation Work Plan
J	The analyte was positively identified, and the associated numerical value is estimated to be more uncertain than would normally be expected for that analysis.
J+	The analyte was positively identified, and the reported value is an estimate and likely biased high.
J-	The analyte was positively identified, and the reported value is an estimate and likely biased low.
Koc	adsorption coefficient
LANL	Los Alamos National Laboratory
MDL	method detection limit
MK/PMC	Morrison Knudson/Program Management Company

NA	not analyzed
N/A	not applicable
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMSA	New Mexico Statutes Annotated
NR	not requested
NRA	not readily available
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PID	photoionization detector
PRS	potential release site
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RAD	radiological analysis
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
SAP	sampling and analysis plan
SMO	Sample Management Office (formerly Sample Management Facility)
SOP	standard operating procedure
SOW	statement of work
SSHASP	site-specific health and safety plan
SVOC	semivolatile organic compound
SWDA	Solid Waste Disposal Act
SWMU	solid waste management unit
TAL	target analyte list (EPA)
TBD	to be determined
TS	town site
U	The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.
UST	underground storage tank
VCA	voluntary corrective action
VCP	vitrified clay pipe
VOC	volatile organic compound

1.0 INTRODUCTION

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

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

This sampling and analysis plan (SAP) describes a Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) for Potential Release Sites (PRSs) 73-003 (steam cleaning facility), 73-004(a) (a septic system that served the incinerator building [TA-73-02]), 73-004(b) (a septic system associated with the steam cleaning facility), 73-005 (a surface disposal area in an area formerly known as Contractor's Row), 73-006 (two drainlines that served the incinerator building), 73-007 (a septic tank and its outfall also in Contractor's Row), and Areas of Concern (AOCs) C-73-005(a through f) (six unlined septic pits).

These twelve PRSs are presented in this SAP primarily because they are located at or near the Los Alamos Airport (Figure 1.0-1 and Appendix A, Photograph 1). Several of these PRSs were similarly grouped as Solid Waste Management Unit (SWMU) Group 73-2 in the RFI Work Plan for Operable Unit (OU) 1071 (LANL 1994, ER ID 7667). These PRSs are discussed in Sections 2.0 through 5.0 of this report. The PRSs are aggregated based on proximity and continuity of site process (such as a process and its associated septic tank and drainline). The sites aggregated are: PRSs 73-003 steam cleaning facility and 73-004(b) associated septic tank, discussed in Section 2.0; PRS 73-004(a) septic tank and PRS 73-006 drainline, both from the incinerator building and about 10 ft apart, discussed in Section 3.0; 73-005 surface disposal area and the 73-007 septic tank which falls within the 73-005 area, discussed in Section 4.0; and septic pits AOCs C-73-005(a through f) which are discussed in Section 5.0 because they presumably served structures within the former Contractor's Row. Table 1.0-1 provides a summary of the PRSs discussed in this document.

This SAP specifically follows the most current SAP Outline from the New Mexico Environment Department (NMED). In each of the Sections 2.0 through 5.0, for each PRS aggregate, the following are included: (1) a description of the environmental setting, (2) a description of the structures or systems, (3) the operational history, (4) existing data, (5) a conceptual model, and (6) the proposed sampling activities.

Guidance for the ER Project's overall approach to site investigation, as well as the general history of the Laboratory, is available in the Laboratory's ER Project Installation Work Plan (IWP) (LANL 1996, ER ID 55574). The IWP also includes the ER Project's Quality Assurance Project Plan (QAPP), which describes the requirements for personnel training, sample handling and custody, and data management review, validation, and verification. When appropriate, this SAP will reference the administrative procedures (APs), quality procedures, and standard operating procedures (SOPs) included in the QAPP.

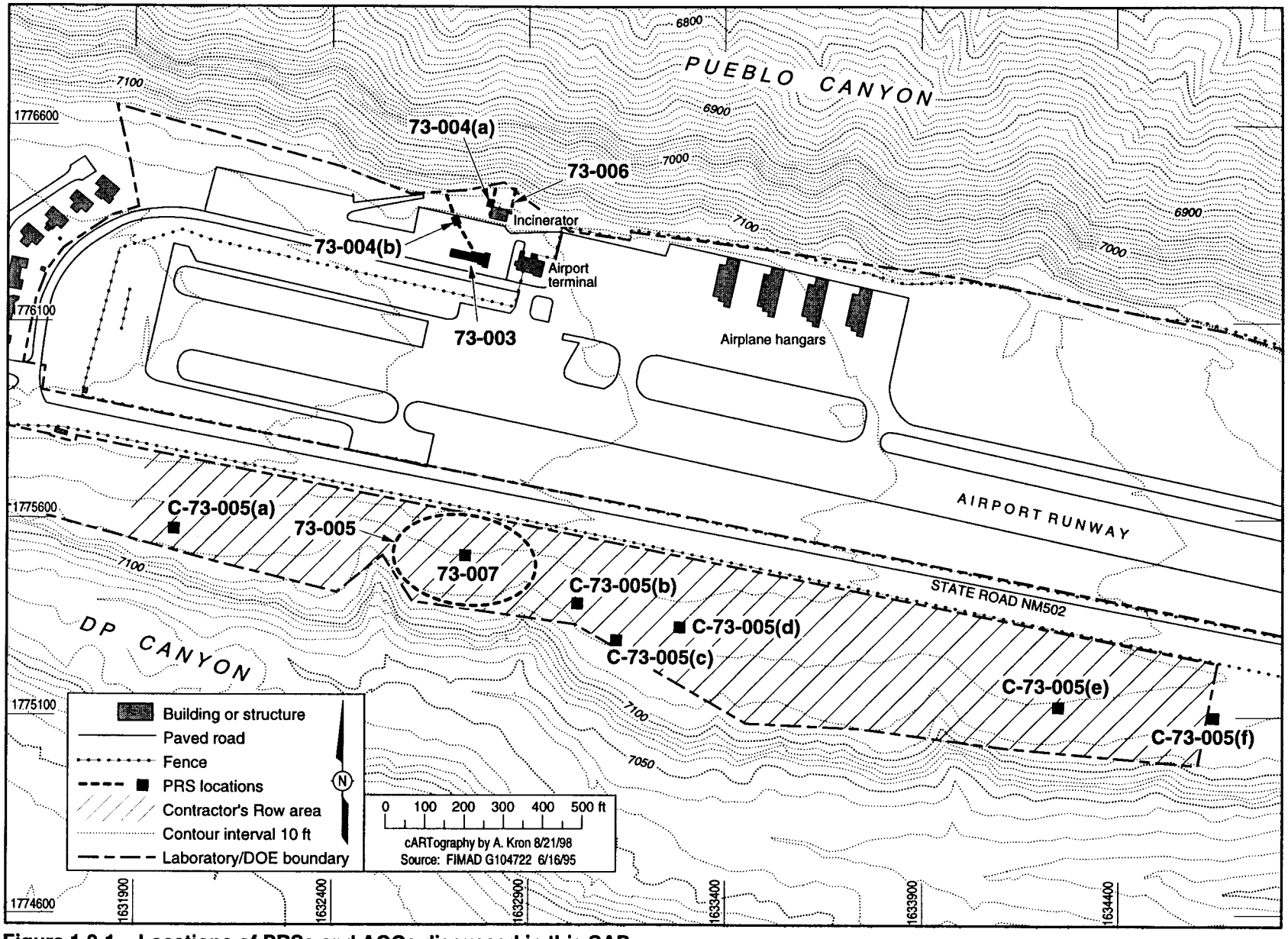

Figure 1.0-1. Locations of PRSs and AOCs discussed in this SAP.

TABLE 1.0-1

SUMMARY OF THE PRSs IN THIS SAP

PRS No.	PRS Type	Description	HSWA*	Section No.
73-003	SWMU	Steam Cleaning Facility	No	Section 2.0
73-004(a)	SWMU	Septic Tank	Yes	Section 3.0
73-004(b)	SWMU	Septic Tank	Yes	Section 2.0
73-005	SWMU	Surface Disposal Area	Yes	Section 4.0
73-006	SWMU	Drainlines	Yes	Section 3.0
73-007	SWMU	Septic Tank	No	Section 4.0
C-73-005(a–f)	AOC	Septic Pits	No	Section 5.0

*HSWA = Hazardous and Solid Waste Amendments of 1984

Previous investigations and corrective actions include the Phase I RFIs and voluntary corrective actions (VCAs) that were completed at PRSs 73-004(a and b), 73-007, and AOCs C-73-005(a through f). A VCA report was prepared and submitted to DOE on 09-30-96 (LANL 1996, ER ID 59374). However, it was determined that additional sampling was required to define extent of contaminants at those sites. A Phase I RFI was completed at PRS 73-006 that included drainline removal. No previous investigations have been performed at PRSs 73-003 or 73-005.

There is no history of requests for supplemental information, notices of deficiency, or correspondence received from the administrative authority (AA) for the PRSs in this SAP (Shanley 1998, ER ID 58982).

All of the items referenced in this document will be included in the LANL ER Reference Library that will be provided to the DOE, NMED, and the LANL public reading room upon submittal of this document. Reference items that relate specifically to former OU 1071 will be included in the OU 1071 Reference Set. Items that relate to the entire ER Project are included in the general ER Project Reference Set.

1.1 Objective and Scope

There are four primary sampling objectives for the proposed investigations:

- Determine the presence or absence of contamination, if not previously determined (for example at PRS 73-003 and 73-005 where no previous sampling has occurred).
- Define the extent of potentially affected media.
- Provide sufficient data to complete human health and ecological risk screening assessments, and/or to develop cleanup standards, if remediation is required.
- Provide investigation results, including a discussion of uncertainty in the human health and ecological screening assessments, to risk managers for decision-making.

Data from this investigation may be used to support risk management recommendations that may include the selection and implementation of a remedy. This SAP is designed to answer the following questions:

- What is the nature, extent, and concentration of contaminants in the media associated with PRSs 73-003, 73-004(b), 73-004(a), 73-006, 73-005, 73-007, and C-73-005(a through f)?

- What is the revised site conceptual model for contaminant fate and transport?
- Do concentrations of contaminants pose a potential unacceptable risk to ecological or human receptors?

1.2 Approach and Implementation

Although the PRSs discussed in this SAP represent several different types of sites, the investigation approaches will be similar. In every case, soil and/or tuff samples will be collected from successively deeper or horizontally more distant intervals until vertical and horizontal extent can be defined. Definition of extent of contamination is achieved when there is a clear decreasing trend and no sample values exceed the risk screening level for human health. Sediment samples will be collected from first-order drainage pathways defined during geomorphologic mapping tasks. These samples will also be collected in a manner allowing definition of horizontal and vertical extent, therefore satisfying the objectives of the investigation. The specific frequency of soil, tuff, and sediment sample collection are discussed in the appropriate sections for each PRS.

Soil, tuff, and sediment grab samples will be collected using the least intrusive and most cost-effective method available as determined based on site conditions, sample depth, and media being sampled. Specific sampling methods are discussed in the appropriate sections for each PRS.

Target analyte suites for PRSs for which a Phase I RFI was completed will be based on those chemicals detected during the Phase I investigation. In most cases, these will include metals, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), and polychlorinated biphenyls (PCBs)/pesticides. Other potential analyte suites are discussed in the appropriate sections for each PRS.

1.3 Background Issues

1.3.1 Regulatory Requirements

This investigation, including sampling and analysis, is conducted under the requirements of the Module VIII Hazardous and Solid Waste Amendments (HSWA) of the Laboratory's hazardous waste facility permit (EPA 1990, ER ID 1585), which was issued on May 23, 1990, and modified on May 19, 1994.

An additional standard for radiological contaminants is DOE Order 5400.5, "Radiation Protection of the Public and the Environment." In 1993 this DOE order was issued as a Proposed Rule (proposed 10 Code of Federal Regulations [CFR] 834) in the Federal Register and covers, among other topics, establishment of dose limits to the public from radiation and radionuclides associated with DOE operations (58 Federal Register [FR] 16268). Although radionuclides are regulated by the DOE and are not regulated under RCRA, it is more efficient and cost effective to investigate all types of potential contamination during a single site characterization. Therefore, radiochemical concerns are addressed as part of this SAP.

Underground storage tank (UST) regulations do not apply to these sites because there are no USTs present.

1.3.2 Other Issues

The Laboratory's ER Project has developed a procedure (LANL-ER-AP-4.5 surface water assessments) to assess sediment transport and erosion concerns at individual PRSs. It provides a basis for prioritizing

and scheduling actions to control erosion of potentially contaminated soils at specific PRSs. The procedure is a two-part evaluation. Part A is a compilation of existing PRS analytical data, site maps, and knowledge-of-process information. Part B is an assessment of the erosion/sediment transport potential at the PRS. Erosion potential is numerically rated from 1 to 100 using a matrix system. PRSs that score below 40 have a low erosion potential; those that score from 40 to 60 have a medium erosion potential; and those that score above 60 have a high erosion potential. LANL-ER-AP-4.5 surface water assessments have been conducted for the PRSs in this SAP. These assessments are discussed in the nonsampling existing data section of the investigatory approach for each PRS (Section X.2.2.1.1) and presented in Appendix C. No groundwater issues have been identified at the sites.

It is anticipated that this land eventually will be transferred from DOE to a new owner.

No other regulatory issues are applicable for the PRSs presented in this SAP at this time.

1.4 Data Quality Objectives Process

The data quality objective (DQO) process was applied in the context of the RCRA corrective action process that requires the development of work plans and reports that lead to corrective action to mitigate risk to humans and the environment.

According to Environmental Protection Agency (EPA) guidance (EPA 1994, ER ID 44324), the outcome of the DQO process is to:

1. clarify the investigation objectives;
2. define what data (number, location, and types of samples) should be collected (or data gaps);
3. define the conditions (or spatial and temporal boundaries) from which to collect data; and
4. specify tolerable limits on decision errors that will be used as the basis for establishing the quantity and quality of data needed to support the decision.

The investigation objectives are included in the data assessment and evaluation process that will be followed for these PRSs.

- Locate samples to determine the nature, extent, and concentration of contamination associated with releases from the PRSs through comparison of sample data to established background data or media-specific detection limits.
- Use sample results to test key assumptions or hypotheses of the preliminary site model.
- Revise the fate/transport/exposure site conceptual model based on the new understanding of nature, extent, and concentration of contamination.
- Apply human health and ecological risk screening procedures that are based on the "worst-case" contamination conditions for exposure media sample data.
- Provide investigation results, including a discussion of uncertainty in the human health and ecological screening assessments, to risk managers for decision-making.

Data gaps for each PRS were identified based on the following steps: (1) gather archival information on the PRSs, (2) compile and evaluate existing data for nature/rate/extent of contamination, and (3) develop a preliminary conceptual model of fate/transport/exposure. The data gap section for each PRS aggregate will address the specific conditions (or boundaries) from which to collect data.

Quantitative limits on decision errors were not specified for these PRS aggregates to determine the number of samples. The number of samples and analytical suites are judgmental and were based on sampling specific locations to test hypotheses about the nature and extent of contamination. In addition, specific samples will be collected to test key assumptions underlying the site model. This information will be used to qualitatively evaluate if the data collected are adequate to support the nature, extent, and concentration evaluation and screening assessments.

2.0 PRS 73-003 STEAM CLEANING FACILITIES AND PRS 73-004(b) SEPTIC TANK

2.1 Characterization and Setting

2.1.1 Site Description

PRS 73-003 was a former steam cleaning facility, and PRS 73-004(b) was the septic system that exclusively served the steam cleaning facility. Both PRSs are inactive SWMUs located on DOE property. The steam cleaning facility was demolished in 1971, and the septic tank was removed during a VCA in 1996. PRS 73-004(b) is listed on the HSWA Module VIII, Table A (EPA 1990, ER ID 1585). There are no above-ground structures remaining at this site, and the entire site, with the exception of the septic tank outfall and a short section of drainline associated with PRS 73-004(b), is now overlain by the asphalt parking lot for the Los Alamos Airport.

PRS 73-003 was located approximately 80 ft west of the current Los Alamos Airport terminal building and 85 ft south of the incinerator building (Figure 2.1.1-1) (Appendix A, Photographs 1, 2, 3, and 4). The facility was constructed of concrete block on a concrete slab with overall dimensions of approximately 50 by 30 ft and a finished floor elevation of 7154 ft. It consisted of a drive through bay for cleaning garbage trucks, a fully enclosed and automated system for cleaning garbage cans, a patio area for unloading garbage cans to be cleaned, a heater room, and an office. Connected to the west side of the facility was a 50 by 20 ft, gravel covered storage yard for storing clean garbage cans. Wash water from the plant entered one of three 14-in.-diameter floor drains that connected to the PRS 73-004(b) septic tank via a 6-in. vitrified clay pipe (VCP) (Zia Company 1949, ER ID 717). The facility was demolished in 1971 (Junge 1971, ER ID 654; Junge 1971, ER ID 655; Sander 1971, ER ID 701; Sander 1971, ER ID 702; and Parker 1971, ER ID 697).

The septic tank associated with PRS 73-004(b) was located approximately 90 ft northwest of the steam cleaning facility and discharged to Pueblo Canyon via a 6-in. VCP (Figure 2.1.1-1). During phase I RFI activities conducted in July and August 1996, the septic tank was exposed using a backhoe (Appendix A, Photograph 5). The top of the tank was found to be intact at a depth of approximately 5 ft below the surface. The tank was constructed, at a minimum, of 4-in. thick concrete and was approximately 10.5 ft long, 6 ft wide, and 7.5 ft deep. The entire tank was poured in place with the tuff as the outer form. There was no evidence that the tank had been constructed with interior baffles. The tank inlet and outlet were constructed of 6-in.-diameter cast iron pipe that connected to 6-in.-diameter VCP drainlines. During the Phase I RFI, the outlet drainline was exposed for sampling purposes in a trench approximately 34 ft northwest of the tank, and again at the outfall to Pueblo Canyon, approximately 65 ft northwest of the tank. The outfall had been covered by 2 to 2.5 ft of fill material during construction activities in the area. The septic tank was found in excellent condition with no cracks or other indications of structural flaws. When the tank was removed as a VCA in 1996 (LANL 1996, ER ID 59374) (Appendix A, Photograph 6), no visual evidence of leaks or releases from the tank was noted. The inlet and outlet drainlines were not removed as part of the VCA.

Combined, the two PRSs occupy an area of approximately 3200 ft^2. Even though the horizontal and vertical extent of contamination at PRS 73-004(b) was not conclusively defined by the Phase I RFI and there are no data for PRS 73-003, the areal extent of contaminant releases is not expected to exceed the total area occupied by the PRSs because contaminants are not expected to move laterally. Determining the areal extent of contamination is the purpose of this SAP.

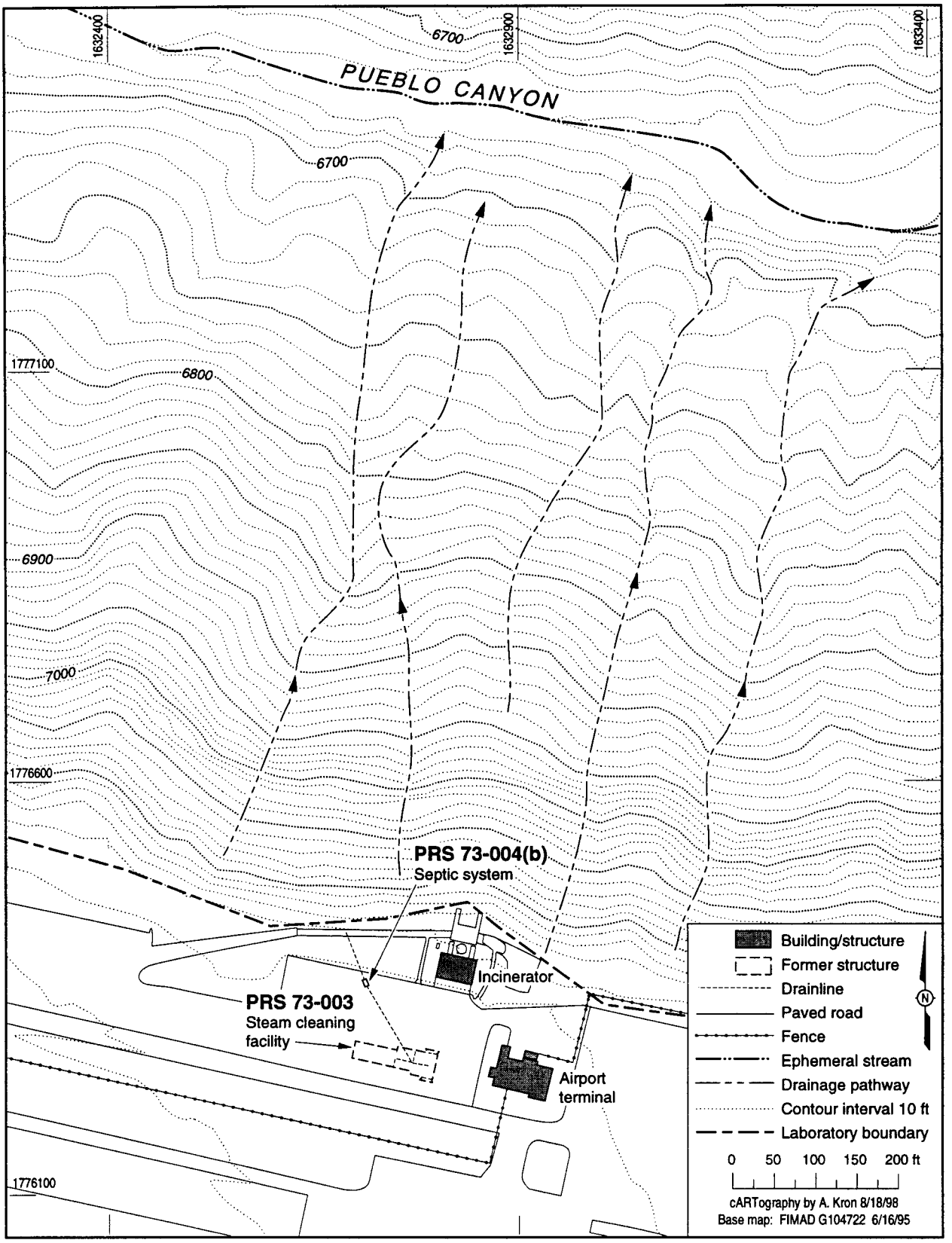

Figure 2.1.1-1. Locations of PRSs 73-003 (steam cleaning facility) and 73-004(b) (septic system).

A PRS that potentially affects the recommendations for PRSs 73-003 and 73-004(b) is the former incinerator building and associated ash disposal area (PRS 73-002). PRSs 73-003 and 73-004(b) are located approximately 85 ft from the former incinerator building and 150 ft from its associated smoke stack and ash disposal area (PRS 73-002). The incinerator began operation in 1947, but because of incomplete combustion problems, only operated for a short period of time. Stack emissions and other activities (see Section 3.0) around the incinerator building may have affected the surrounding vicinity including the PRS 73-004(b) outfall area. PRS 73-002 will be addressed separately, most likely as part of a VCA to be proposed for the ash disposal area (see also Section 3.0).

Current and anticipated future operations and land use at both PRSs are to remain industrial (part of the airport). It is anticipated that this land eventually will be transferred from DOE to a new owner for continued use as an airport.

PHYSICAL DESCRIPTION: Geomorphology, Topography, and Surface Geology

Geology

The PRS-specific geomorphology, topography, and surface geology for PRSs 73-003 and 73-004(b) can be divided into three areas: (1) the asphalted mesa top, (2) the area between the asphalt and the steep slope of the canyon edge, and (3) the canyon slope.

The mesa top (in the area of these PRSs) is currently covered with the asphalt parking lot for the Los Alamos Airport terminal building (Appendix A, Photograph 7). The area between the asphalt and the steep slope of the Pueblo Canyon has exposed soils/fill. Soils in the vicinity of these PRSs are composed predominantly of reworked soil and fill material. Construction of the airport facilities resulted in significant disturbance of the natural soils and introduction of fill material into the site. Airport construction activities have left little, if any, of the original soil profile exposed at the surface. In general, natural soils, where they still exist, are very thin and sandy with relatively low clay content. The area where the outfall for PRS 73-004(b) discharged is relatively steep with drainage channels that initiate at or near the edge of the mesa. In each channel, changes in gradient create areas of deposition (catchments) where sediment and other materials may collect.

Geodetic surveys were conducted to provide accurate state plane coordinate information for the sample locations and selected site features.

Vegetative cover on the north-facing slope of Pueblo Canyon is dominated by grasses and ponderosa pine, with a mix of junipers, piñon, and scrub oak. Except for Bandelier tuff outcrops, the slope is 95 to 100 % vegetated (see Appendix B, Ecological Scoping Checklist)

Hydrology

Surface Water Hydrology. The outfall of PRS 73-004(b) is on the mesa edge, approximately 380 ft above and 1000 ft south of the Pueblo Canyon floor. Stormwater drainage from the vicinity of the outfall flows directly north into the canyon via a drainage channel (Figure 2.1.1-1). Near the top of the channel, there is no evidence of active erosion and there is no visible debris in the watercourse. It is likely that surface water runoff does not reach the canyon floor because it infiltrates colluvium mantling the canyon slope (see Appendix B, Ecological Scoping Checklist, and Appendix C, LANL-ER-AP-4.5 Surface Water Assessments, for a discussion of the terminal point of storm water discharge). Interflow within the soil and the sediment mantling portions of the drainage channel may be a transport mechanism, but it is not expected to be a major contaminant migration pathway since the site drainage patterns indicate that little if any stormwater runoff is directed to this drainage channel. Other than the curb bordering the asphalt parking lot and the parking lot, there are no man-made or natural hydraulic structures that affect the site

hydrology. The curb has the effect of preventing parking lot runoff from entering the drainage channel associated with these PRSs, and thus acts as a runon control for the unpaved portion of this PRS aggregate. Mainly because of the parking lot surface water diversion and infiltration into the colluvium, surface water flow from these PRSs is not expected to reach the active channel in Pueblo Canyon.

Subsurface Water Hydrology. The regional aquifer beneath the TA-73 mesa top is approximately 1100 ft below the surface. An area of tuff and volcaniclastic sediments separate the surface from the regional aquifer. The elevation of the aquifer was determined in Test Well 2 in Pueblo Canyon (approximately 6000 ft) and by Otowi 4 in Los Alamos Canyon. The regional aquifer is within sediments of the Puyé and Tesuque Formations (Purtymun 1995, ER ID 45344; LANL 1998, ER ID 59373). In addition to the regional aquifer, shallow alluvial and perched bedrock aquifers are present in DP, Los Alamos, and Pueblo Canyons (LANL 1998, ER ID 59373). There are no relevant groundwater and surface water monitoring stations, nor active and inactive local water supply and production wells near these PRSs. No springs have been observed in Pueblo Canyon near the airport.

ASSESSMENT OF ECOLOGICAL, CULTURAL, AND BIOLOGICAL RESOURCES

There are no specific climatic influences or cultural resources that will affect the conceptual model for these PRSs.

Ecological scoping (Appendix B) identified that Pueblo Canyon is a nesting area of the peregrine falcon, a federally listed species. These PRSs are contained within the potential foraging area and nesting/roosting habitat for the peregrine falcon and Mexican spotted owl (see Appendix B, Ecological Scoping Checklist). However, the surface of the mesa has undergone heavy commercial and urban development. Comprehensive plant and animal inventories were not performed for the mesa top because it is heavily developed. The wildlife habitats on the mesa top can be characterized as urban plant and animal communities.

Pursuant to the National Historic Preservation Act of 1966 (amended), a cultural resource survey was conducted at OU 1071 during the summer of 1991 (McGehee 1992, ER ID 28310). The methods and techniques used for this survey conformed to those specified in the Secretary of the Interior's standards and guidelines for archeology and historic preservation. There are no archeological sites in the area of PRSs 73-003 and 73-004(b) that are eligible for inclusion in the National Register of Historic Places.

2.1.2 Operational History

The steam cleaning plant and septic system began operation in 1949. There are no operational records for this property prior to that time. The facility was used to clean garbage trucks and cans that contained municipal and residential waste (IT Corporation 1991, ER ID 1905), including LANL sanitary waste. No information is available regarding maintenance activities at the facility. Operations ceased before October 31, 1970, at which time the building was used by the Railway Express Company (Nottrott 1970, ER ID 9708; Sander 1970, ER ID 700). The Zia Company demolished the building and its concrete slab in June 1971 (Junge 1971, ER ID 654 and 655; Sander 1971, ER ID 701 and 702; Parker 1971, ER ID 697). The entire site, other than the PRS 73-004(b) outfall and a short section of the septic tank discharge drainline, is now overlain by the asphalt parking lot for the airport terminal building, and is inaccessible for any human exposure. The outfall is located on a steep, densely vegetated portion of the north facing slope of Pueblo Canyon and is also essentially inaccessible for human exposure.

Historical information indicates no treatment, storage, or disposal of hazardous wastes at these PRSs. The steam cleaning process itself should not have contributed to contamination at the site. The primary source of potential contamination would have been materials disposed in the garbage trucks and cans.

The sampling proposed for PRS 73-003 in this SAP will be the first sampling to occur at this PRS. Phase I sampling occurred at PRS 73-004(b) in August 1996. Based on the Phase I sampling results, the septic tank and its contents were removed, and the inlet and outlet drainlines were abandoned in place. The septic tank was removed in August 1996.

There were no known releases or discharges at these PRSs except at the outfall. The septic tank ceased operation prior to October 1970.

2.1.3 Waste Characteristics

This section addresses the potential contaminants that may be present at these PRSs based on the information contained in Section 2.1.1, Site Description, and Section 2.1.2, Operational History. This information is potentially relevant to "waste" only to the extent that "solid waste," as that term is defined under RCRA, is subsequently generated at these PRSs. Solid waste may be generated at a future time if remediation is required. This discussion of potential contaminants in no way implies that the materials present at these PRSs are "solid waste" or "hazardous waste" as those terms are defined under the New Mexico Statutes Annotated (NMSA), the New Mexico Administrative Code (NMAC), RCRA, HSWA, Solid Waste Disposal Act (SWDA), or other statutes or regulations.

The PRSs' operational histories provide little or no specific information regarding the potential contaminants that may currently be present at the PRSs. Any substance or chemical that was contained in a garbage truck or that could have been present in wash water entering the steam cleaning facility floor drains and flowing through the septic system to the outfall may be present. The Phase I RFI and VCA conducted in July and August, 1996, provided information regarding contaminants at PRS 73-004(b) and potential contaminants at PRS 73-003 (see Section 2.2.1.2, Sampling).

2.2 Investigatory Approach

2.2.1 Existing Data

2.2.1.1 Nonsampling

This section describes nonsampling investigations (e.g., geophysical surveys, threatened and endangered species surveys, LANL-ER-AP-4.5 Surface Water Assessments) that have occurred at these PRSs.

A site survey was conducted to determine the locations and boundaries of pertinent site features, buried structures, and outfall points. Historic aerial photographs and engineering drawings were examined, and the entire site was visually inspected.

A geophysical survey was conducted to confirm the location of the septic tank associated with PRS 73-004(b). Survey data indicated that the tank was located precisely where shown on the available engineering drawings.

Geomorphologic mapping was conducted to locate first-order drainage channels that originated at or transected the PRSs and that may have carried discharges from the outfalls.

Geodetic surveys were conducted to provide accurate state plane coordinate information for the sample locations and selected site features.

A LANL-ER-AP-4.5 Surface Water Assessment Erosion Matrix score was calculated for these PRSs (see Appendix C). The outfall of PRS 73-004(b) had a total erosion matrix score of 39.8. The total erosion matrix score for PRS 73-003 was 10.6. These scores indicate a low erosion potential. The terminal point

of surface water flow was identified as a bench on the north-facing slope of Pueblo Canyon. This indicates that surface water runoff does not reach the floor of Pueblo Canyon.

An ecological scoping checklist was completed for this PRS aggregate and is included in Appendix B. The checklist was used to identify ecological receptors present and potential pathways to those receptors. The information obtained from the checklist was incorporated into the Conceptual Model (Section 2.2.2). The ecological scoping process identified pathways to terrestrial plant and animal receptors. Based on current site knowledge, no pathways to aquatic receptors were identified. Pueblo Canyon has been identified as containing nesting/roosting habitat for Mexican spotted owl and peregrine falcon, both federally listed species. Both species can be expected to forage at a relatively high frequency in Pueblo Canyon.

2.2.1.2 Sampling

This section describes sampling investigations that have occurred at the PRSs, including previous sampling efforts (e.g., RFI, environmental surveillance, fixed-point [discrete sample] radiological surveys, etc.).

No previous sampling has occurred at PRS 73-003.

Previous sampling and tank removal was conducted at PRS 73-004(b) by the ER Project as part of a Phase I RFI (LANL 1994, ER ID 7667) and a VCA (LANL 1996, ER ID 59374), both conducted in July and August, 1996. Work conducted and sampling results are located in the 73-004(b) VCA Report (LANL 1996, ER ID 59374). The septic tank was found to be in excellent condition with no cracks or other indications of structural flaws. During VCA implementation, the tank was observed to contain 1 to 2 ft of sediment that consisted of a hard, dry, dense layer of sand, silt, and clay particles with some gravel. Two sediment samples (0173-96-0241 and 0173-96-0244) and a duplicate sample (0173-96-0242) were collected from within the tank. To determine if releases may have occurred from the septic system components, several characterization samples were collected. Sample 0173-96-0243 was collected from immediately beneath the connection of the 6-in.-diameter cast iron inlet drainline to the septic tank. After receiving preliminary results for this sample, two additional inlet samples were collected approximately 10 ft south of the tank, one above (0173-96-0504) and one below (0173-96-0505) the drainline. Sample 0173-96-0249 was collected beneath a joint in the 6-in.-diameter VCP outlet drainline approximately 34 ft north of the septic tank. Two samples were also collected from the end of the outlet drainline; one (0173-96-0245) from within the end of the VCP and a second (0173-96-0246) from the head of the outfall channel, approximately one foot downgradient of the end of the drainline. Following tank removal, no visual evidence of leaks or releases was noted. The inlet and outlet drainlines were not removed as part of the VCA. Two confirmatory samples (0173-96-0501 and 0173-96-0502) were collected below the tank. Figure 2.2.1.2-1 illustrates all Phase I RFI and VCA sampling locations, and Table 2.2.1.2-1 summarizes all sample information including the location ID, sample number, and analyses requested. Because the confirmation sampling performed after the VCA did not define extent, this SAP is designed to define extent for PRS 73-004(b) and to sample drainlines in PRS 73-003.

Analytical results for PRS 73-004(b) characterization samples are presented in Table 2.2.1.2-2 and Table 2.2.1.2-3. Data were compared with background values (BVs) for inorganic chemicals (LANL 1996, ER ID 59374), or detection levels (estimated quantitation limits [EQLs]) for organic chemicals. Both the BVs and EQLs are provided in the data tables. Several inorganic chemicals were reported at concentrations exceeding their BVs. Several organic chemicals including benzo(a)pyrene and the pesticides alpha and gamma chlordane, DDD, DDE, and DDT were detected at low or trace levels. Gross alpha, beta, and gamma radiological and tritium analyses measured no elevated radiological activity. These organic, inorganic, and radiological data are used to support a revised conceptual model. However, more data need to be collected to define the extent of contamination as noted in Section 2.2.2.3.

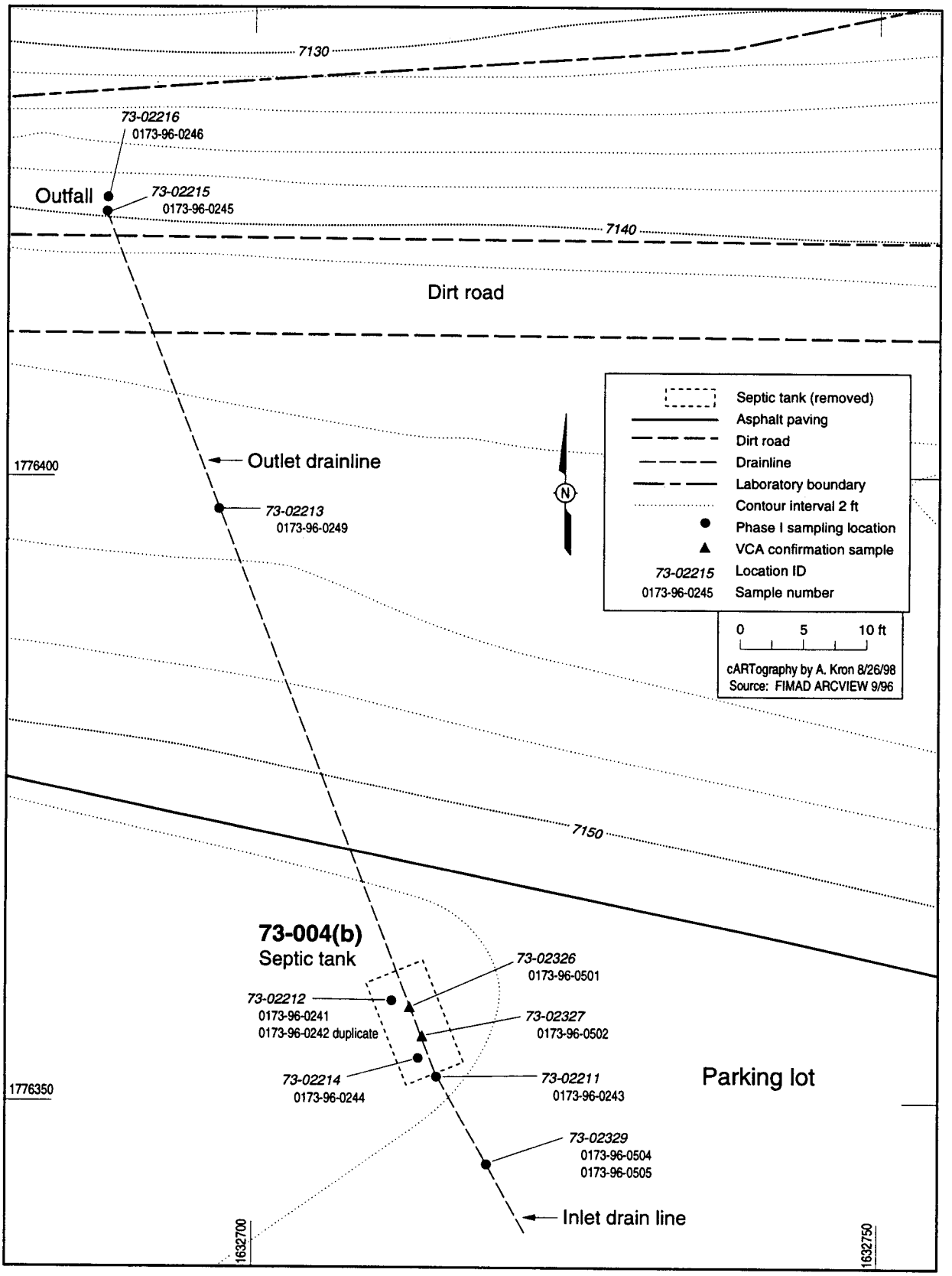

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Figure 2.2.1.2-1. PRS 73-004(b) Phase I and VCA sampling locations.

TABLE 2.2.1.2-1

PRS 73-004(b)
SUMMARY OF SAMPLES COLLECTED[a]

Location ID	Sample ID	Location Description and Depth	Matrix	VOCs	SVOCs	PCBs/ Pest.	TAL[b] Metals	RAD[c]
73-02211	0173-96-0243	Below inlet pipe at junction with septic tank at 7.2–7.4 ft	Soil	2391	2391	2391	2390	2392
73-02212	0173-96-0241	Inside septic tank, northwest quadrant	Soil	2391	2391	2391	2390	2392
73-02212	0173-96-0242	Duplicate of 0173-96-0241	Soil	2391	2391	2391	2390	2392
73-02213	0173-96-0249	Below outlet pipe, 34 ft north of tank at 4.2–4.5 ft	Soil	2391	2391	2391	2390	2392
73-02214	0173-96-0244	Inside septic tank, southwest quadrant	Soil	2391	2391	2391	2390	2392
73-02215	0173-96-0245	Inside end of outlet pipe	Soil	2487	2487	2487	2488	2490
73-02216	0173-96-0246	Head of outfall channel at 2.2–2.5 ft	Soil	2487	2487	2487	2488	2490
73-02329	0173-96-0504	Above inlet pipe, 10 ft south of tank at 3–4 ft	Soil	NA[d]	NA	2611	NA	NA
73-02329	0173-96-0505	Below inlet pipe, 10 ft south of tank at 7–7.5 ft	Soil	NA	NA	2611	NA	NA
73-02326	0173-96-0501	Confirmatory sample below tank	Soil	2568	2568	2568	2569	2570
73-02327	0173-96-0502	Confirmatory sample below tank	Soil	2568	2568	2568	2569	2570

a. Numbers in the cells for each analytical suite are request numbers.
b. TAL metals = target analyte list metals: aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, silver, thallium, and uranium
c. RAD = radiological analyses: gross alpha/beta/gamma and tritium
d. NA = not analyzed

TABLE 2.2.1.2-2

PRS 73-004(b)
INORGANIC CHEMICALS WITH CONCENTRATIONS EXCEEDING BACKGROUND VALUES (BVs)[a]

Location ID	BV	73-02211	73-02213	73-02216	73-02326	73-02327
Location Description	N/A[b]	Under inlet pipe	Below outlet pipe, 34 ft north of tank at 4.2–4.5 ft	Outfall sample	Confirmation sample under north end of tank	Confirmation sample under south end of tank
Sample ID	N/A[b]	0173-96-0243	0173-96-0249	0173-96-0246	0173-96-0501	0173-96-0502
Arsenic	8.17	3.2	4.7	**13 (J-)[c,d]**	2.4	2.4
Chromium	19.3	5.3	5.7	**36**	3.9	4.5
Copper	14.7	4.6	6.3	**23 (J+)[e]**	4.7	4.8
Lead	22.3	13	15	**190**	21	7.4
Mercury	0.1	**0.11(U)[f]**	**0.11**	**0.93**	**0.12(U)**	**0.12(U)**
Vanadium	39.6	13	15	**42**	8.4	8.5
Zinc	48.8	**80**	37	**150**	**260**	**61**

a. Concentrations are in units of mg/kg.
b. N/A = not applicable
c. Bolded values are above BV, as revised on January 30, 1998 (Ryti et al. 1998, ER ID 58093).
d. (J-) = estimated value, possibly biased low
e. (J+) = estimated value, possibly biased high
f. (U) = not detected

TABLE 2.2.1.2-3

PRS 73-004(b)
ORGANIC CHEMICALS WITH DETECTED CONCENTRATIONS[a]

Location ID	EQL[b]	73-02211	73-02213	73-02215	73-02216	73-02326	73-02327
Location Description	N/A[c]	Under inlet pipe	Under outlet pipe	Outfall sample	Outfall sample	Confirmation sample under north end of tank	Confirmation sample under south end of tank
Sample ID	N/A	0173-96-0243	0173-96-0249	0173-96-0245	0173-96-0246	0173-96-0501	0173-96-0502
4,4'-DDD	0.0033	37 (U)[d]	**4.7**[e]	**1.3**	**1.5**	**0.31**	**0.042**
4,4'-DDE	0.0033	37 (U)	0.73 (U)	**0.18**	**0.13**	**0.089**	**0.01**
4,4'-DDT	0.0033	**170**	**0.15**	**0.054**	**0.34**	**0.11**	**0.021**
alpha-Chlordane	0.0017	**1**[f]	**0.066**	**0.21**	**0.46**	**0.028**	0.002 (U)
gamma-Chlordane	0.0017	**0.84**[f]	**0.069**	**0.26**	**0.52**	**0.038**	0.002 (U)
Toxaphene	0.165	**7.4**	0.004 (U)[g]	**2.7**	**2.1**	0.19 (U)	0.19 (U)
Benz(a)anthracene	0.33	0.14 (J)	0.28 (J)	**0.33**	**0.39**	0.19 (U)	0.19 (U)
Benzo(a)pyrene	0.33	0.13 (J)	0.32 (J)	**0.36**	**0.35**	0.19 (U)	0.19 (U)
Benzo(b)fluoranthene	0.33	0.27 (J)	**0.56**	**0.38**	**0.37**	0.19 (U)	0.19 (U)
Benzo(g,h,i)perylene	0.33	0.089 (J)	0.17 (J)			0.19 (U)	0.19 (U)
Benzo(k)fluoranthene	0.33	0.27 (J)	**0.56**	**0.36**	0.29 (J)	0.19 (U)	0.19 (U)
Bis(2-ethylhexyl) phthalate	0.33	**0.64**	**0.34**	0.27 (U)	0.21 (U)	0.19 (U)	0.19 (U)
Chrysene	0.33	0.16 (J)	0.29 (J)	**0.46**	**0.46**	0.19 (U)	0.19 (U)
Fluoranthene	0.33	**0.36**	0.27 (J)	**0.67**	**0.7**	0.19 (U)	0.19 (U)
Indeno(1,2,3-cd)pyrene	0.33	0.077 (J)	0.17 (J)	0.27 (U)	0.21 (U)	0.19 (U)	0.19 (U)
Phenanthrene	0.33	0.17 (J)	0.37 (U)	0.28 (J)	**0.38**	0.19 (U)	0.19 (U)
Pyrene	0.33	0.28 (J)	0.25 (J)	**0.56**	**0.54**	0.19 (U)	0.19 (U)

a. Concentrations are in units of mg/kg.
b. Estimated quantitation limits (EQLs) obtained from the Sample Management Office's Laboratory contract.
c. N/A = not applicable
d. (U) = not detected
e. Bolded values are detected values.
f. Results from analysis with dilution factor of 200.
g. Results from analysis with dilution factor of 1.
h. (J) = Results for this analyte should be regarded as estimated because the result was below the EQL but above the method detection limit (MDL).

2.2.2 Conceptual Model

2.2.2.1 Nature and Extent of Contamination

The preliminary model of contaminant occurrence and distribution is provided by the Phase I sample data and knowledge of site operations. The Phase I investigation identified seven inorganic chemicals present above BVs and 18 detected organic chemicals, mainly pesticides, and polycyclic aromatic hydrocarbons (PAHs). No elevated radiological activity was detected. The steam cleaning process is not expected to have contributed to contamination at the site since it is likely that only hot water was used as a cleaning agent. Potential contaminants at the site are expected to have originated from municipal waste carried by the trucks and cans cleaned at the facility. Samples from all sample locations except the two samples collected above and below the inlet pipe (Location ID 73-02329) were analyzed for complete suites of

VOCs, SVOCs, PCBs/pesticides, and target analyte list (TAL) metals (Table 2.2.1.2-1). These analyses captured the nature of the contamination for these suites at these sites. Laboratory radiological analyses for gross alpha/beta/gamma and tritium were conducted on all samples except the two mentioned above. Based on the levels of pesticides detected below the inlet pipe, the two inlet pipe samples mentioned above were tested only for pesticides (Location ID 73-02329).

PRSs 73-003 and 73-004b comprised an engineered drainline and septic system with an outfall on the south rim of Pueblo Canyon. The volume of water flowing through the system is unknown. The most likely points of contaminant releases to the environment are at the outfall, and at pipe joints and connections with the septic tank. The drainline system which received discharge from PRS 73-003 was gravity driven, with a downward slant to ensure proper discharge to the septic tank and outfall (Zia Company 1949, ER ID 717). The outlet drainline was constructed of two foot sections of 6-in.-diameter VCP. A VCA performed on similar lines at the neighboring PRS 73-006 found that the sections were grouted together, so it is assumed that these drainline sections were also grouted. Because of the gravity driven nature of the system and the assumed grouting of pipe joints, the volume of any leak is expected to be small. Therefore, the volume of the media impacted is expected to be small. Furthermore, contamination resulting from leaks at the inlet line connection with the septic tank impacts only tuff under the asphalt of the airport parking lot. Although the majority of the outlet drainline is not covered by asphalt, the contamination detected is in the subsurface. The main area of contamination is expected to be in the area of the outfall.

Decommissioning of the steam cleaning facility and subsequent construction activities have had significant impacts on the site. The steam cleaning facility was razed and the area paved during the construction of the airport parking lot. It is not known whether the cast iron drainlines which connected the floor drains with the VCP septic tank inlet line were removed or left in place during the razing of the steam cleaning facility. The septic tank was removed as a VCA in 1996. Approximately 6 to 8 ft of the outlet drainline was removed during installation of buried utility lines and during the septic tank VCA. The outfall has been buried to a depth of 2 to 2.5 ft by construction activities in the area (see Section 2.1.1, Site Description).

There are no relevant hydrologic features which could be impacted by contamination at this site (Section 2.1.1, Hydrology). The outfall has a LANL-ER-AP-4.5 Surface Water Assessment total erosion matrix score of 39.8, indicating a low erosion potential. The surface water runoff terminates on a bench on the north-facing slope of Pueblo Canyon (see Appendix C). Runoff from the airport parking lot is diverted away from the site by an asphalt curb. The regional aquifer is located approximately 1100 ft below the surface of the mesa top. Alluvial and perched bedrock aquifers are present in Pueblo Canyon, but there are no monitoring stations or supply and production wells near these PRSs.

The nature of the contamination is fairly well defined at these PRSs. Samples collected under the junction of the septic tank and the inlet line, under the outlet drainline, and at the outfall all show similar suites of organic contaminants (Table 2.2.1.2-3). Samples collected from the sediments inside the septic tank when it was removed showed high concentrations of several pesticides and PAHs, and 14 inorganic chemicals above BV. However, samples from beneath the tank contained only low levels of zinc, DDT and its metabolites, and chlordane, indicating that leakage from the tank itself was minimal.

Extent of contamination at the site is not defined, and defining extent is one of the purposes of this SAP. Contamination from drainline leaks is expected to be totally subsurface, with very low possibility of affecting human or ecological receptors. The extent of contamination at the outfall is not known. Only one sample was collected at the head of the outfall channel approximately one foot downgradient from the end of the drainline, and one was collected within the end of the VCP drainline (Figure 2.2.1.2-1). Both

samples showed identical suites of contaminants. A trend in decreasing concentrations of chemicals of potential concern (COPCs) was not demonstrated (Tables 2.2.1.2-2 and 2.2.1.2-3).

2.2.2.2 Fate and Transport

The Phase I sampling of PRS 73-004(b) identified seven inorganic chemicals (arsenic, chromium, copper, lead, mercury, vanadium, zinc) present at concentrations greater than BVs (Table 2.2.1.2-2). Eighteen organic chemicals were also detected (Table 2.2.1.2-3). General chemical and physical properties that relate to the fate of these contaminants in the environment are provided in Appendix D. Arsenic, chromium, copper, lead, vanadium, and zinc are all natural components of the soil of the Pajarito Plateau. Mercury is also a natural constituent of the soil of the Pajarito Plateau, but it is present at levels less than the detection limit of 0.1 mg/kg.

The fate and distribution of chemicals in the environment are determined by chemical-specific properties, geochemistry of the contaminated media, and physical transport systems such as runoff. The asphalt parking lot covering PRS 73-003 and portions of PRS 73-004(b) greatly reduces surficial erosional processes. At other Laboratory PRSs it has been noted that asphalt acts to reduce evapotranspiration and tends to accumulate moisture in the near subsurface. However, the airport parking lot may not be acting to accumulate moisture as the field notes for the PRS 73-004(b) VCA clearly state that fill underlying the asphalt parking lot was dry. Thus, transport to groundwater seems unlikely based on the distance to the regional aquifer and the likely low moisture conditions observed for the near subsurface. Contamination at the outfall of PRS 73-004(b), however, may be subject to erosional transport processes. The soil in the area of the outfall is Hackroy sandy loam. This consists of shallow, well-drained soils formed in material weathered from tuff. Hackroy sandy loam exhibits low available water capacities and low permeability. It ranges from mildly alkaline at depths less than 25 cm to neutral at depths greater than 25 cm (Nyhan 1978, ER ID 5702). Soil pH is a key factor affecting the ability of many chemicals to adsorb to soil.

Phase I data provide no information on the valence states of the inorganic chemicals detected at this site. Arsenic, chromium, copper, lead, vanadium, and zinc are not volatile in any of their forms, so volatilization is not an exposure or redistribution pathway for these chemicals. Certain organic forms of mercury (e.g., dimethylmercury) can volatilize to the air. However conversion of inorganic mercury to organic mercury occurs only under reducing chemical conditions that are not expected to occur at this site. Appendix D, Chemical Properties, contains a discussion of the conditions necessary for a reducing environment in the section on potential uptake of mercury.

Arsenic is insoluble in water, and many arsenic compounds adsorb to soils and sediments; therefore, transport in soil is expected to occur only over short distances. Likewise, most lead and copper chemical forms are strongly sorbed to soil organic matter, and downward movement via leaching is very slow. Although chromium speciation was not conducted in the Phase I analyses, it is expected that chromium(III) is predominant at the site. Chromium(VI) reduces to chromium(III) fairly rapidly under oxidizing chemical conditions. Such equilibrium chemical conditions are expected for PRSs that have been inactive for at least 28 years. Most chromium(III) in soil is immobilized due to adsorption and complexation with soil materials. Vanadium and zinc are potentially more mobile in soil than arsenic, lead, copper, and chromium due to higher solubilities, but concentrations of vanadium and zinc at this site are near BVs. The highest concentration of vanadium detected was less than 12% above BV. Mercury is highly sorbed to both organic and inorganic soil particles, and leaching is a relatively insignificant transport process in soils. Sediments deposited by surface runoff can be important repositories for inorganic mercury. The bioconversion of inorganic mercury to organic mercury can be of importance in aquatic systems where chemical reducing conditions are more typically encountered (e.g., lake bottom

sediments). There is no evidence that COPCs from these PRSs reach aquatic settings, which include the ephemeral stream channel in Pueblo Canyon directly down hill approximately 1000 ft from the PRS.

All of the organic compounds detected have low water solubilities and low vapor pressures, indicating that dissolution in water and vaporization to the air are not likely transport or exposure pathways. Appendix D, Chemical Properties, presents the solubilities and vapor pressures of organic compounds. The most-likely transport pathways would be wind and water erosion at the outfall. All of the organic chemicals detected, as well as three of the inorganics (copper, lead, and mercury), are on the NMED list of potentially bioaccumulating chemicals (see Appendix B, Ecological Scoping Checklist). As already mentioned, there is no transport to aquatic receptors suggested by the current understanding of the nature and extent of COPCs at this PRS. If the total area impacted by the PRS 73-004(b) outfall is small, it is expected that the potential for persistent bioaccumulation in terrestrial systems is likewise small.

A generalized conceptual transport model for contamination at PRS 73-003 and 73-004(b) is shown in Figure 2.2.2.2-1. The conceptual site model is consistent with the exposure model presented in the ecological scoping checklist. Contamination originating from the steam cleaning building and the septic tank and associated drainlines affects subsurface soil and tuff, and much of it occurs under the asphalt of the airport parking lot. Migration to groundwater is not a concern at this site (See Section 2.1.1, Hydrology), and no mechanisms are present to release this contamination to surface soil or water; therefore, no human or ecological exposure pathways are present for subsurface contamination. Contamination in the area of the outfall is expected to affect surface and near surface soils. Potential transport mechanisms are surface water runoff/soil erosion and air entrainment of potentially contaminated particulate matter. The primary exposure pathways and their potential significance to human and ecological receptors are detailed in Figure 2.2.2.2-1. Although surface water is listed as a potential secondary contaminant medium, it is assumed that no runoff reaches the canyon floor. The LANL-ER-AP-4.5 Surface Water Assessment identifies the terminal point of runoff as a bench on the north-facing slope of Pueblo Canyon (see Appendix C). The results of all the sampling will be provided to the Canyons Focus Area for cumulative assessments of the Pueblo Canyon watershed.

2.2.2.3 Data Gaps

The conceptual model for this drainline and septic system associated with the former steam cleaning plant at TA-73 (PRSs 73-003 and 73-004[b]) suggests that releases to the environment were engineered to occur at the outfall. Other release points include pipe joints, and pipe connections at the septic tank, or leakage from the septic tank itself. The volume of liquid released at the outfall is unknown, but is suspected to be much greater than the quantity of liquid released at leaks within the engineered septic system.

Although much is known about these PRSs from engineering drawings, the primary structure [the steam cleaning facility] that could provide a direct landmark has been demolished. There is uncertainty of whether none, some, or all of the drainlines under the steam cleaning facility were removed during demolition. Thus, the location and presence of some drainlines represents a data gap.

The releases from this PRS aggregate were liquid in nature. However, based on the solubility of the COPCs discussed in the environmental fate section, these COPCs are expected to readily come out of solution and become associated with reactive components of the soil matrix (like ferric hydroxides or organic material). Thus, subsequent transport of COPCs released at the outfall is expected to be primarily through erosion of surface soils. Quantities of COPCs released at other points along the engineered system are expected to be minimal, and the volume of subsurface soil or tuff contaminated by leaks along the drainline is expected to be small.

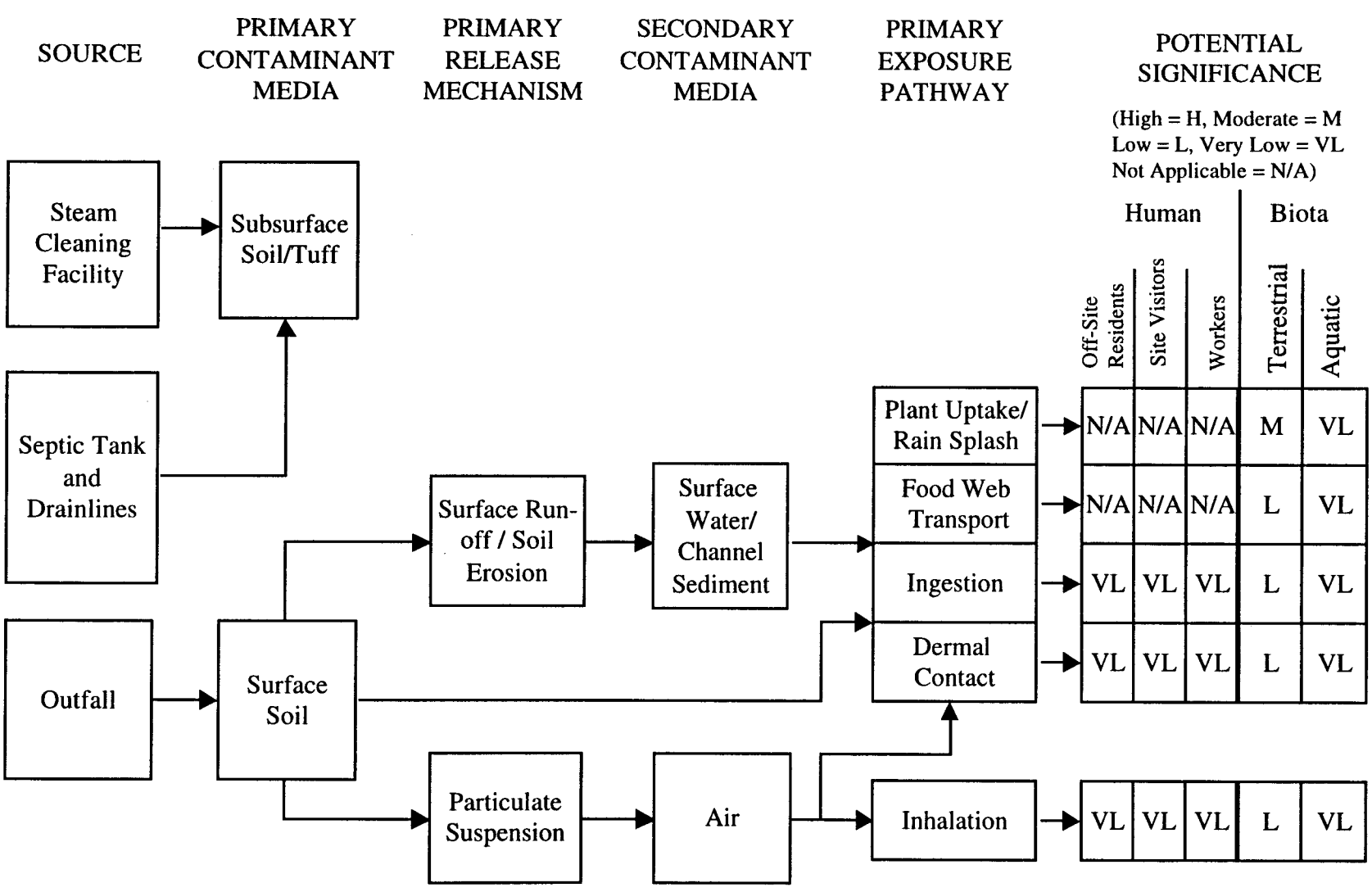


Figure 2.2.2.2-1. Conceptual model of contaminant transport at PRS 73-003 aggregate.

The full suite laboratory analyses for organics and inorganics provides adequate information to determine the nature of contaminant releases. In addition, the COPCs exhibit similar concentration ratios from the septic tank contents to the outfall sample results. This suggests a common, known contaminant source for these COPCs. Gross alpha, beta, and gamma radiological and tritium analyses measured no elevated radiological activity.

Contaminant releases were detected in samples collected inside the end of the outfall pipe and at the outfall. There is no information on trends in COPC concentrations at the outfall. Therefore, one data gap for this PRS aggregate is the horizontal and vertical extent of contamination at the outfall. Because of the uncertainty associated with the volume of water released at the outfall, estimates of the suspected extent of contamination below the outfall cannot be provided. Sample data must be collected to address this uncertainty.

Phase I data indicate that there were leaks along the engineered system. However, there is no information on the vertical extent of such leaks. As discussed above, the volume of subsurface media impacted by leaks is expected to be minimal, and sample data could be used to confirm this expectation.

Once information to provide trends in the extent of contamination is provided, these data are expected to be adequate for human health and ecological risk screening. Based on the concentrations observed for COPCs identified in the VCA and Phase I RFI, this information is also expected to provide adequate information for making risk management decisions for this PRS aggregate.

2.2.3 Sampling Activities

The sampling design presented here was discussed with NMED on 02-04-98. Subsequent conversations led to agreement on a final design (Shanley 1998, ER ID 58982). This section describes the sampling design and the rationale for the design based on the site conceptual model presented in Section 2.2.2, and based on the discussions and agreements with NMED.

For PRS 73-003, the initial task is to determine the exact location and orientation of the former steam cleaning facility. If coordinates are available for building corners or other facility features, these points will be geodetically surveyed and marked on the asphalt pavement. If coordinates are not available, distances from existing structures such as the incinerator and terminal buildings to steam cleaning facility features will be scaled from engineering drawings and measured in the field.

The second task is to verify that the steam cleaning facility drainlines were removed when the building was demolished in 1971. This is necessary in order to determine how and where to collect samples. To verify removal of the drainlines, individuals who were involved in the removal will be interviewed. Small holes may also be drilled through the asphalt parking lot to allow probing of the underlying area.

Having determined the position of the former steam cleaning facility, locations most likely to have released potentially contaminated liquids to the environment will be located. These locations primarily include the floor drains and subsurface drainlines. It is assumed that the floor drains may have been poorly sealed and that the drainline connections may have leaked. It is unknown if the cast iron drainlines leading from the floor drains to the septic tank inlet line were removed with the building foundation. If these drainlines are still in place, an effort will be made to collect the proposed samples directly beneath drainline connections. Otherwise, these samples will be collected at locations and depths below where the drainlines would have been located. Areas where soil is exposed by sampling activities will be

examined for visual evidence of contamination. If visual evidence indicates contamination, additional samples will be collected to determine the horizontal and vertical extent of the contaminated area.

For PRS 73-004(b), several locations will be sampled at the locations judged likely to have received contaminant releases and other locations to test key assumptions of the conceptual model, per the sampling design discussed with the NMED (Shanley 1998, ER ID 58982). Several key assumptions led to this sampling design. It was assumed that the volume of media impacted by drainline leaks was small. The gravity-driven construction of the drainlines required a downward slope to ensure proper drainage. This prevented water from backing up in the drainlines and creating a pressurized situation that might have caused leaks through cracks and poorly sealed pipe connections. The drainline connections were also assumed to have been sealed with cement grout to prevent leakage. Finally, the nature of the operations at PRS 73-003 would have resulted in intermittent flows, thus decreasing the opportunity for drainline leaks.

Lateral samples at the outfall are being collected to ensure that contaminants are not present outside of the drainage channel. Downstream samples are being collected far enough downgradient to look for spatial trends in COPCs. Surface and depth samples will be collected at the bench that is the surface water runoff termination point. Depths will be determined from geomorphological observations in the field and documented at the time of sampling. The depths will be biased towards sediments that are likely to contain contamination.

The sampling design will not be influenced by field kits or other on-site analytical tools. There is no plan to use contaminant collocation or correlation of field measurements to estimate results for any analytes. The same analytical suites analyzed during the Phase I RFI will be requested for all samples except for VOCs at PRS 73-004(b) and radiochemical analysis. All solid media samples (fill, soil, and tuff) will be analyzed for TAL metals, VOCs (as appropriate), SVOCs, organochlorine pesticides, and PCBs.

Analytical data collected from both PRSs will be compared to the local LANL BVs for inorganic chemicals, as described in the paper "Inorganic and Radionuclide Background Data for Soils, Canyons Sediments, and Bandelier Tuff at Los Alamos National Laboratory" (Ryti et al. 1998, ER ID 58093), and to EQLs for organic chemicals.

Based on the sampling design discussion above, the samples to be collected are presented in Table 2.2.3-1 and Table 2.2.3-2 with special detection limits for metals shown in Table 6.1-1. The proposed sampling locations are shown on Figures 2.2.3-1, 2.2.3-2, and 2.2.3-3.

2.2.3.1 Contaminant Source

There are no known contaminant sources present at either PRS 73-003 or 73-004(b). Therefore, no contaminant source sampling is planned. The 73-004(b) septic tank was removed as a VCA in 1996, but the inlet and outlet drainlines were left in place.

2.2.3.2 Media Characterization

This section presents the details of the field and sampling activities to be performed. Citations of SOPs and other procedures to be followed in implementing the sampling activities are presented in Section 6.0.

TABLE 2.2.3-1

PRS 73-003

PROPOSED SAMPLE LOCATIONS AND ANALYTICAL SUITES[a]

Location ID	Location Description and Depth	Matrix	VOCs	SVOCs	PCBs/ Pest.	TAL Metals[b]
TBD[c]	Beneath floor drain location 1	Soil	X	X	X	X
TBD	Depth sample beneath drain location 1	Soil	X	X	X	X
TBD	Beneath floor drain location 2	Soil	X	X	X	X
TBD	Depth sample beneath drain location 2	Soil	X	X	X	X
TBD	Connection of 73-003 cast iron pipe and 73-004(b) VCP[d]	Soil	X	X	X	X
TBD	Depth Sample beneath connection of 73-003 cast iron pipe and 73-004(b) VCP	Soil	X	X	X	X
TBD	Beneath collection box	Soil	X	X	X	X
TBD	Depth sample beneath collection box	Soil	X	X	X	X
TBD	QA/QC[e] sample (field duplicate)	Soil	X	X	X	X

a. All samples are grab samples.
b. See Table 6.1-1 for special required detection limits.
c. TBD = to be determined
d. VCP = vitrified clay pipe
e. QA/QC = quality assurance/quality control

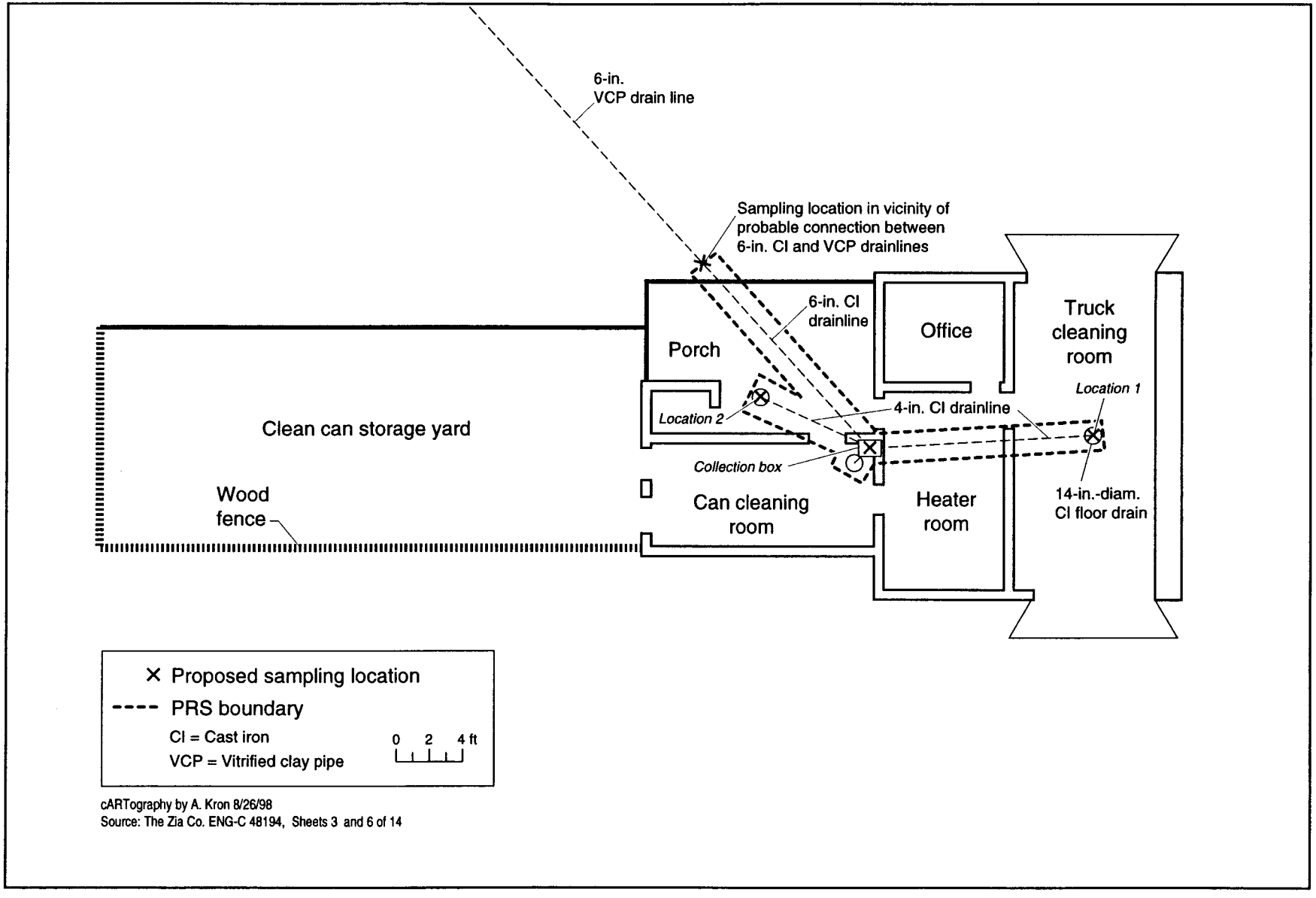
TABLE 2.2.3-2

PRS 73-004(b)

PROPOSED SAMPLE LOCATIONS AND ANALYTICAL SUITES[a]

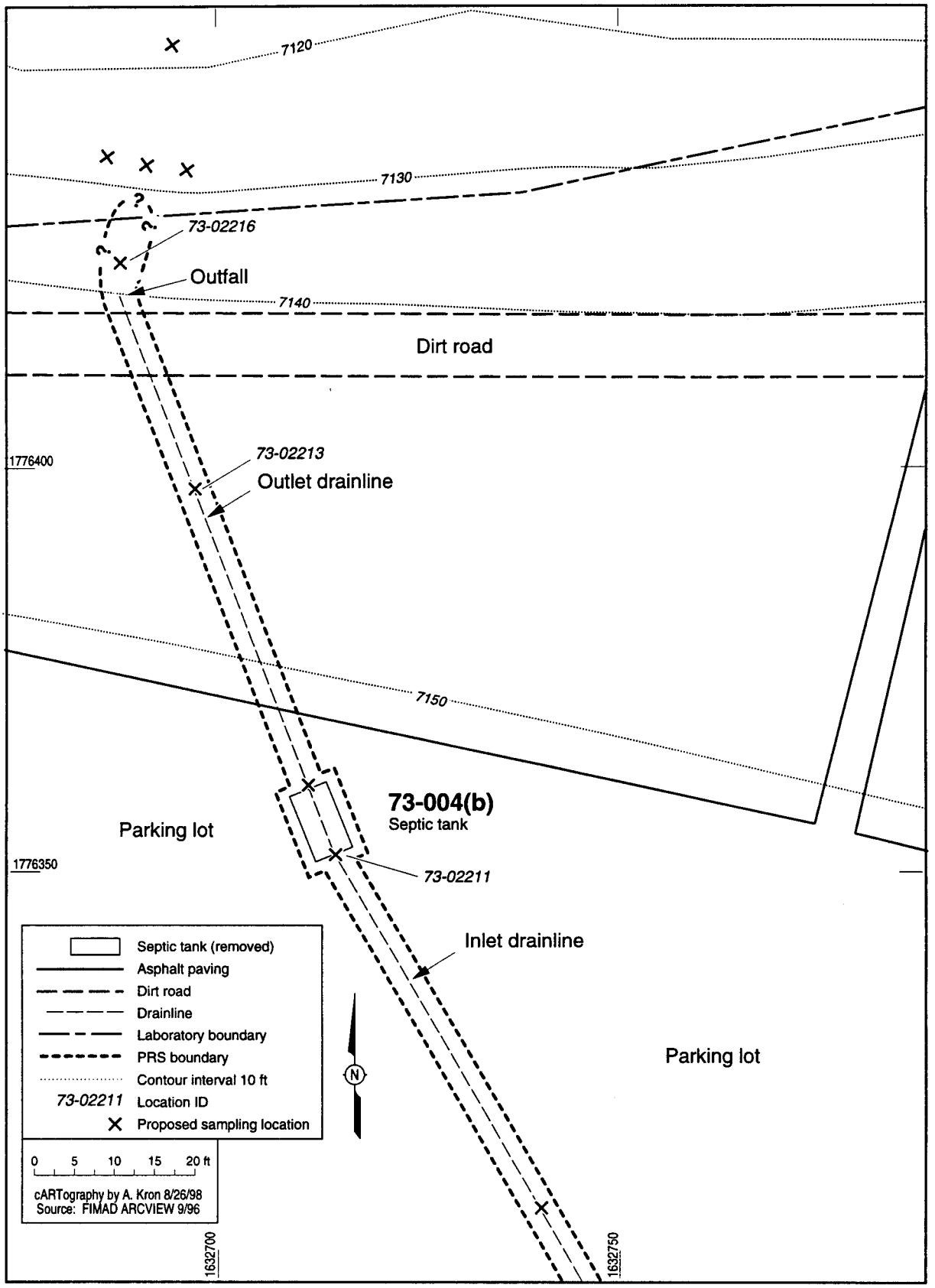
Location ID	Location Description and Depth	Matrix	SVOCs	PCBs/ Pest.	TAL Metals[b]
TBD[c]	Beneath the drainline approximately midway between the septic tank and the connection to the cast iron pipe of PRS 73-003	Soil	X	X	X
TBD	Depth sample beneath drainline approximately midway between the septic tank and the connection to the cast iron pipe of PRS 73-003	Soil	X	X	X
73-02211	Depth sample beneath sample 0173-96-0243 (under septic tank connection with the inlet pipe)	Soil	X	X	X
TBD	Under the septic tank connection to the outlet pipe	Soil	X	X	X
TBD	Depth sample under the septic tank connection to the outlet pipe	Soil	X	X	X
73-02213	Depth sample beneath Phase I sample 0173-96-0249 (under septic tank outlet pipe approximately midway between the septic tank and outfall)	Soil	X	X	X
73-02216	Depth sample beneath sample 0173-96-0246 (outfall sample)	Soil	X	X	X
TBD	Surface downgradient from sample 0173-96-0246 (outfall sample)	Soil	X	X	X
TBD	Depth sample at downgradient sample from sample 0173-96-0246 (outfall sample)	Soil	X	X	X
TBD	Lateral surface samples on either side of outfall sample (2)	Soil	X	X	X
TBD	Surface further downgradient from sample 0173-96-0246 (outfall sample)	Soil	X	X	X
TBD	Surface and depth samples on the bench that is the surface water runoff termination point	Soil	X	X	X
TBD	QA/QC sample (field duplicate)	Soil	X	X	X

a. All samples are grab samples.
b. See Table 6.1-1 for special required detection limits
c. TBD = to be determined



F2.2.3-1 / TA-73 SAP / 092598

Figure 2.2.3-1. PRS 73-003 proposed sampling locations.



F2.2.3-2 / TA-73 SAP / 112298

Figure 2.2.3-2. PRS 73-004(b) proposed sampling locations.

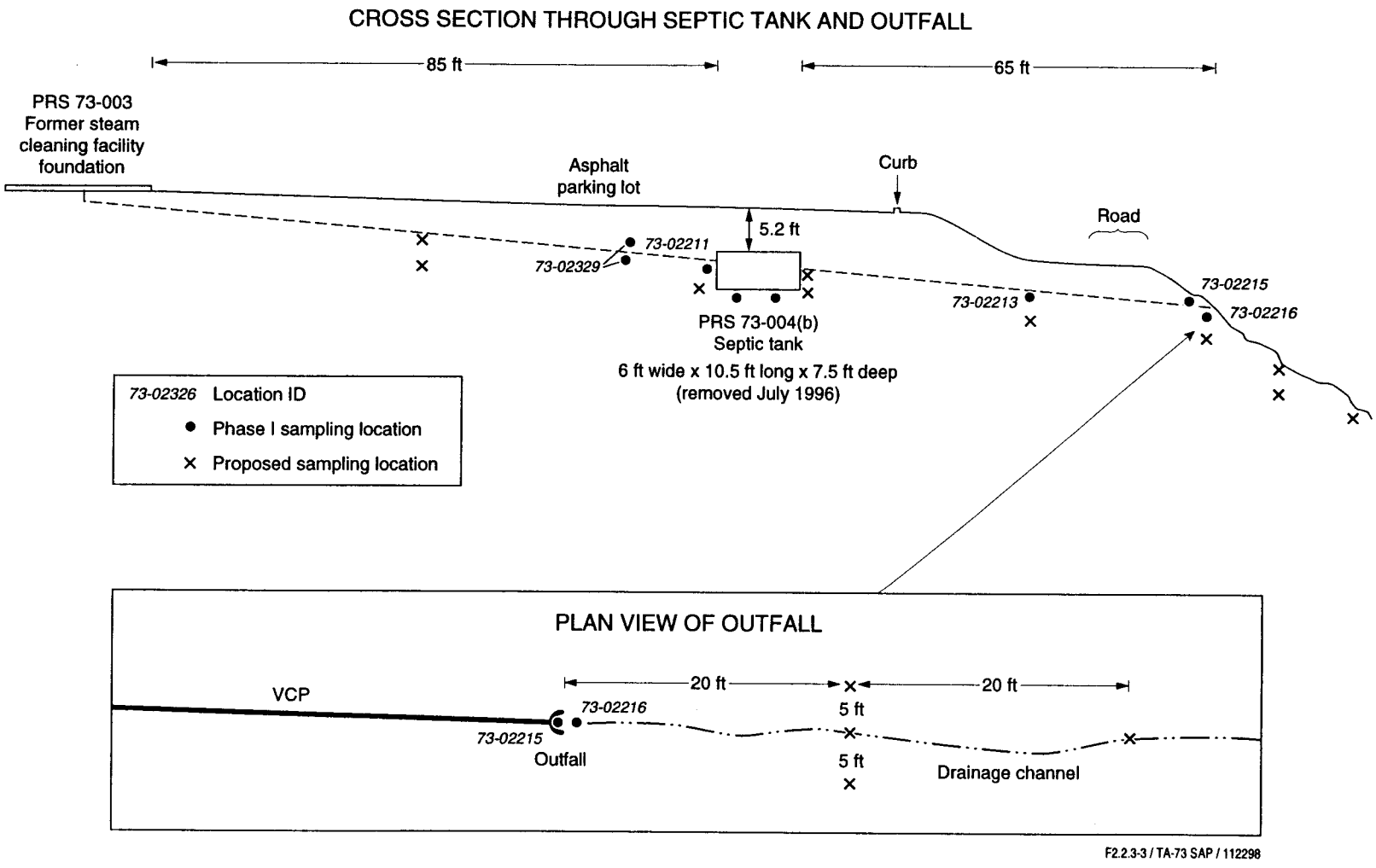


Figure 2.2.3-3. PRS 73-004(b) proposed sampling locations.

Media characterization at PRS 73-003 will be performed to determine the presence or absence of contaminants and to bound the extent of contamination or establish trend of contamination. Once the locations of the steam cleaning facility foundation, floor drains, and drainlines are established to the extent possible, samples will be collected from areas where leaks were most likely to have occurred (at floor drain and drainline connections). Samples will be collected from four locations: beneath two of the three floor drains, at the connection of the cast iron pipe coming from PRS 73-003 and the VCP, and beneath the collection box where the where the floor drains converged before leaving the building (see Figures 2.2.3-1 and 2.2.3-2). To facilitate sample collection, holes will be drilled or cut through the asphalt to expose the base course that will be removed to its contact with the underlying soil. A minimum of two soil samples will be collected at each location, the first from a depth most likely to correspond to soil that would have been beneath the floor drain, collection box, or drainline connection being sampled, and a second from 2 ft deeper. As required, additional deeper samples will be collected at 2-ft intervals to define extent (see Section 1.2). See Table 2.2.3-1 for proposed sample locations.

Media characterization for PRS 73-004(b) will be performed to determine the presence or absence of contaminants and to bound the extent or establish trend of contamination. At a location approximately midway between the septic tank and the connection to the cast iron drainline of PRS 73-003, the soil beneath the PRS 73-004(b) inlet drainline will be sampled. An additional sample will be collected deeper at the same location in order to define extent. Samples will be collected at other locations as follows: one sample beneath Phase I sample 0173-96-0243 (under septic tank connection with the inlet pipe); two samples (one deeper than that other) under the septic tank connection to the outlet pipe; one sample beneath Phase I sample 0173-96-0249 (under septic tank outlet pipe approximately midway between the septic tank and outfall); and as many as eight samples at locations beneath and downgradient from Phase I sample 0173-96-0246 (outfall sample) (see Figures 2.2.3-2 and 2.2.3-3). Additional deeper samples will be collected at 2-ft intervals at any location requiring further definition of extent.

Sampling locations will be chosen as described in Section 2.2.3. Sampling locations and other pertinent site features will be geodetically surveyed using established survey monuments and coordinates published in the LANL Survey Monument Network Manual (LANL 1994, ER ID 55599).

An attempt will be made to collect all samples with a hand auger. Powered augering equipment may be utilized to advance the boreholes depending upon the depth to tuff and the difficulties encountered in using the hand auger. A backhoe may also be used to collect the proposed samples if the methods described above are ineffective.

3.0 PRS 73-004(a) SEPTIC SYSTEM AND PRS 73-006 DRAINLINES

3.1 Characterization and Setting

3.1.1 Site Description

Both PRSs are inactive SWMUs located on DOE property near the Los Alamos County Airport terminal building (Figure 3.1.1-1). Both are listed on the HSWA Module VIII, Table A (EPA 1990, ER ID 1585).

PRS 73-004(a), a septic system that served the former incinerator building (TA-73-02), is located approximately 10 ft northwest of the incinerator building's northwest corner (Figure 3.1.1-1 and Appendix A, Photograph 1). Phase I RFI activities, conducted in July 1996, were initiated by exposing the septic tank using a backhoe. The tank was constructed of concrete and was roughly 6 ft long, 3 ft wide, and 6.8 ft deep. The tank was poured in place using the tuff as the outer form, and was designed with removable baffles, but none were present. The tank discharged through a 6-in.-diameter VCP outfall directly onto the ash disposal area (PRS 73-002) north of the incinerator building (Kruger 1947, ER ID 657). The septic tank was removed as a VCA in August 1996 (Appendix A, Photograph 8). At that time, no visual evidence of leaks or releases was noted beside or below the tank. However, it was noted that there were two inlet and two outlet openings, one approximately 1 ft below the other at each end of the tank (Appendix A, Photograph 9). The upper set of openings was within 6 in. of the top of the tank. It was determined that the lower openings were the functional inlet and outlet openings. Although the upper openings were not being used, they had not been plugged and could allow infiltrating water to enter the tank. The inlet and outlet drainlines were not removed as part of the VCA.

The two drainlines (PRS 73-006) that served the former incinerator building, discharged through separate outfalls to Pueblo Canyon (Kruger 1947, ER ID 657) (Figure 3.1.1-1). The west drainline, constructed of 5-in.-diameter cast iron pipe, originates at two floor drains, now plugged with concrete, one on the west side of the charging floor and the other on the west side of the stoking floor. The first floor of the two-story building was referred to as the stoking floor, and the second floor as the charging floor (Kruger 1947, ER ID 657). The cast iron pipe extends below and three ft beyond the building's northwest corner foundation, at which point it connects to 6-in.-diameter VCP for the remaining 40-ft distance to the outfall. The east drainline, also constructed of 5-in.-diameter cast iron pipe, originates at similar concrete plugged floor drains located on the east side of the charging and stoking floors. This drainline supposedly extends below and five ft beyond the building's east foundation, where it turns 90 degrees north, and connects to a 6-in.-diameter VCP for the remaining distance to the outfall. The floor drains are now plugged with concrete to prevent water or fluids of any kind from entering the drainlines. Both outfalls discharged directly onto the ash disposal area. In July 1997, the west drainline was removed as part of a Phase I RFI. At that time, no visual evidence of leaks or releases was noted beneath any of the drainline connections. The east drainline was not located during the Phase I RFI despite efforts to locate it. It is possible that this drainline was removed during installation of buried telephone and electric lines in this area.

Although functionally and geographically connected to PRSs 73-004(a) and 73-006, the ash disposal area (PRS 73-002) associated with the former incinerator will not be addressed as part of this SAP as this area will be sampled separately, most likely as part of a VCA plan to be proposed for the ash disposal area. PRS 73-002 will impact recommendations for PRSs 73-004(a) and 73-006 because the outfall area of both PRSs are colocated with the ash material. Both outfalls and the portions of the discharge drainlines within the PRS 73-002 boundary will be sampled as part of the actions for PRS 73-002. Figure 3.1.1-1 shows the ash boundary and the approximate area to be addressed with PRS 73-002.

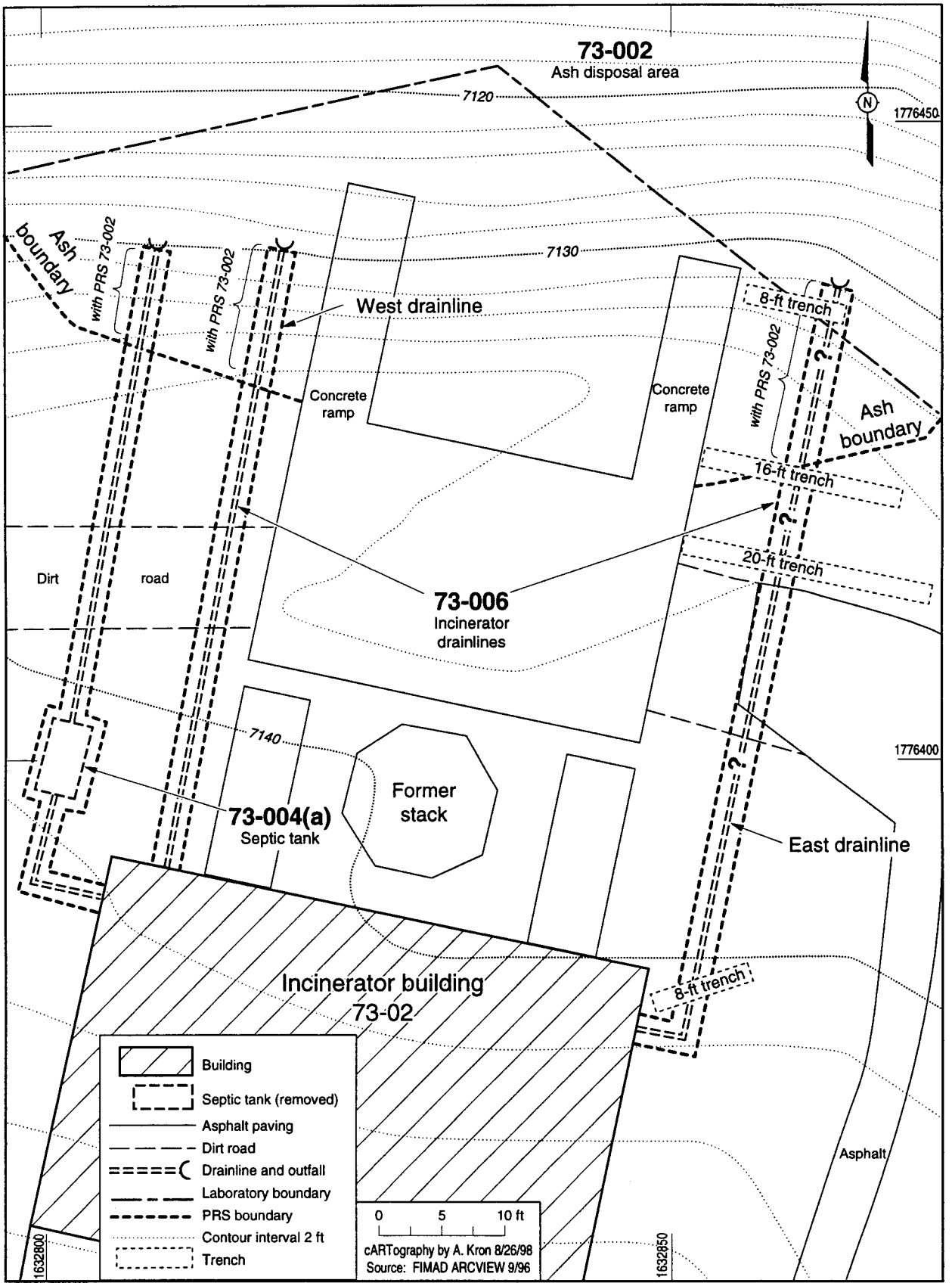


Figure 3.1.1-1. Site map for PRSs 73-004(a) and 73-006.

Combined, the two PRSs occupy an area estimated to be approximately 600 ft^2, excluding the portions that are located within the boundary of PRS 73-002. The horizontal and vertical extent of contamination at both the PRSs was not conclusively defined by the Phase I RFI. The areal extent of contaminant releases is not expected to exceed the total area occupied by the PRSs. Determining the areal extent of contamination is the purpose of this SAP.

Current and anticipated future operations and land use at both PRSs are to remain industrial (part of the airport). The incinerator building is currently used for storage by a sporting-goods store, and the area containing PRSs 73-004(a) and 73-006 is vacant and provides access to the lower level of the incinerator building and the utility boxes behind the building. It is anticipated that this land will eventually be transferred from DOE to a new owner.

PHYSICAL DESCRIPTION: Geomorphology, Topography, and Surface Geology

Geology

PRSs 73-004(a) and 73-006 are mesa top sites that are partially located beneath the dirt access road behind the incinerator building. There are no natural geomorphologic or topographic features in this area that have any relevance to the investigation. An asphalt rundown diverts stormwater from the parking lot around the PRS. The adjacent south slope of Pueblo Canyon, onto which the outfalls of both PRSs discharged, is covered by the ash disposal area and is included within that PRS (73-002).

Vegetative cover on the north-facing slope of Pueblo Canyon is dominated by grasses and ponderosa pine, with a mix of juniper, piñon, and scrub oak. Bandelier tuff outcrops and the ash disposal area account for a large portion of bare ground in the immediate vicinity of the outfall areas of PRSs 73-004(a) and 73-006.

Hydrology

Surface Water Hydrology. Both PRSs 73-004(a) and 73-006 outfall at the mesa edge onto the ash disposal area (PRS 73-002), approximately 380 ft above and 1000 ft south of the Pueblo Canyon floor. Surface drainage in this area is currently diverted to channels on either side of the ash disposal area, in part through the use of sand bags. Prior to the use of the sand bags, runon to the ash disposal area was limited due to the natural contours of the area and the construction of asphalt rundowns from the airport terminal parking lot that directed runoff to the drainages on either side of the ash disposal area. These drainage channels carry ephemeral flow into Pueblo Canyon (Figure 2.1.1-1). Hydrology related to the slope is not relevant to this current investigation. (See also Appendix C, LANL-ER-AP-4.5 Surface Water Assessment.)

Subsurface Water Hydrology. The regional aquifer beneath the TA-73 mesa top is at approximately 1100 ft below the surface. An area of tuff and volcaniclastic sediments separate the surface from the regional aquifer. The elevation of the aquifer was determined in Test Well 2 in Pueblo Canyon (approximately 6000 ft) and by Otowi 4 in Los Alamos Canyon. The regional aquifer is within sediments of the Puyé and Tesuque Formations (Purtymun 1995, ER ID 45344; LANL 1998, ER ID 59373). In addition to the regional aquifer, shallow alluvial and perched bedrock aquifers are present in DP, Los Alamos, and Pueblo Canyons (LANL 1998, ER ID 59373). There are no relevant groundwater and surface water monitoring stations, nor active and inactive local water supply and production wells near these PRSs. No springs have been observed in Pueblo Canyon near the airport.

ASSESSMENT OF ECOLOGICAL, CULTURAL, AND BIOLOGICAL RESOURCES

There are no specific climatic influences or cultural resources that will affect the conceptual model for these PRSs.

Ecological scoping (Appendix B) identified that Pueblo Canyon is a nesting area of the peregrine falcon, a federally listed species. These PRSs are contained within potential nesting/roosting habitat for the peregrine falcon and Mexican spotted owl (see Appendix B, Ecological Scoping Checklist). However, the surface of the mesa has undergone heavy commercial and urban development. Comprehensive plant and animal inventories were not performed for the mesa top because it is heavily developed. The wildlife habitats on the mesa top are characterized as urban plant and animal communities.

Pursuant to the National Historic Preservation Act of 1966 (amended), a cultural resource survey was conducted at OU 1071 during the summer of 1991 (McGehee 1992, ER ID 28310). The methods and techniques used for this survey conformed to those specified in the Secretary of the Interior's standards and guidelines for archeology and historic preservation. There are no archeological sites in the area of PRSs 73-004(a) and 73-006 that are eligible for inclusion in the National Register of Historic Places.

3.1.2 Operational History

The incinerator's primary use was to destroy classified documents from the Laboratory. It was used for this purpose for only about one year because it did not function properly because of incomplete combustion (IT Corporation 1991, ER ID 1905). The incinerator was also used to incinerate municipal trash. In June 1948, The Zia Company acquired the incinerator building, and used it until September 1973. Before 1973, but sometime after incineration had ceased, the building was used by the Los Alamos Dog Obedience Club (Larson 1973, ER ID 662). The incinerator equipment and stack have been removed, but no information on the removal operation is available. The building is currently used by a sporting goods store for inventory storage.

The period of operation of the septic system was concurrent with the occupation of the incinerator building (1947 to 1973). The septic tank received only sanitary waste from the toilet and shower facilities located on the charging floor of the incinerator building (Kruger 1947, ER ID 657). The incinerator floor drains presumably received water used to wash down the charging and stoking floors. The floor drains are now plugged with concrete to prevent water or fluids of any kind from entering the drainlines.

Historical information indicates no treatment, storage, or disposal of hazardous wastes at the incinerator building. The primary source of potential contamination would have been materials disposed in the garbage that was brought for incineration. There were no known releases at these PRSs except at the outfalls. Both outfalls ceased operation prior to the enactment of permitting regulations.

Phase I RFIs were conducted at PRSs 73-004(a) and 73-006 in July 1996, and July 1997, respectively. Following the Phase I sampling results for PRS 73-004(a), the decision was made to remove the tank and its contents and abandon the inlet and outlet drainlines in place. The septic tank was removed as a VCA in August 1996. At PRS 73-006, the west drainline was removed as part of the Phase I investigation. Section 3.2.1.2, Sampling, presents a discussion of Phase I investigations at PRSs 73-004(a) and 73-006.

3.1.3 Waste Characteristics

This section addresses the potential contaminants that may be present at these PRSs based on the information contained in Section 3.1.1, Site Description, and Section 3.1.2, Operational History. This information is potentially relevant to "waste" only to the extent that "solid waste," as that term is defined under RCRA, is subsequently generated at these PRSs. Solid waste may be generated at a future time if remediation is required. This discussion of potential contaminants in no way implies that the materials present at these PRSs are "solid waste" or "hazardous waste" as those terms are defined under the NMSA, NMAC, RCRA, HSWA, SWDA, or other statutes or regulations.

The PRS descriptions and operational histories provide little or no specific information regarding the potential contaminants that may currently be present at the PRSs. Any substance or chemical that was disposed in trash being handled at the incinerator could have spilled on the incinerator building floors and thus could have been present in wash water entering the floor drains and flowing to the outfalls. As previously stated, the septic system was intended to serve only for sanitary waste from the toilet and shower facilities located on the charging floor. There is no record of potentially hazardous or other materials being disposed into the septic system.

3.2 Investigatory Approach

3.2.1 Existing Data

3.2.1.1 Nonsampling

This section describes nonsampling investigations (e.g., geophysical surveys, threatened and endangered species surveys, key elements of LANL-ER-AP-4.5 Surface Water Assessments) that have occurred at these PRSs.

A site survey was conducted to help determine the locations and boundaries of pertinent site features, buried structures, and outfall points. Historic aerial photographs and engineering drawings were examined, and the entire site was visually inspected.

A geophysical survey was conducted to confirm the location of the septic tank, 73-004(a). Geophysical survey data indicated that the tank was probably located precisely where shown on the available engineering drawings. However, the geophysical anomaly created by the tank was indistinguishable from the incinerator building, and it was difficult to discern one from the other.

Geomorphologic mapping was conducted to locate first-order drainage channels that originated at or transected the PRSs and that may have carried discharges from the outfalls.

Several backhoe trenches were excavated to help locate the east drainline at PRS 73-006. These trenches verified that the east drainline was not located where it was shown to be in the engineering drawings. This information led to the conclusion that the drainline was removed at some time prior to the RFI, and thus no samples were collected.

Geodetic surveys were conducted to provide accurate state plane coordinate information for the sample locations and selected site features.

A LANL-ER-AP-4.5 Surface Water Assessment Erosion Matrix score was calculated for PRSs 73-004(a) and 73-006 (see Appendix C). PRS 73-004(a) had a low total erosion matrix score of 38, and PRS 73-006

had a medium total erosion matrix score of 56. However, these scores include the outfall areas, which are being addressed as part of the PRS 73-002 VCA Plan. The terminal point of surface water flow was identified as a bench on the north-facing slope of Pueblo Canyon. This indicates that surface water runoff does not reach the floor of Pueblo Canyon.

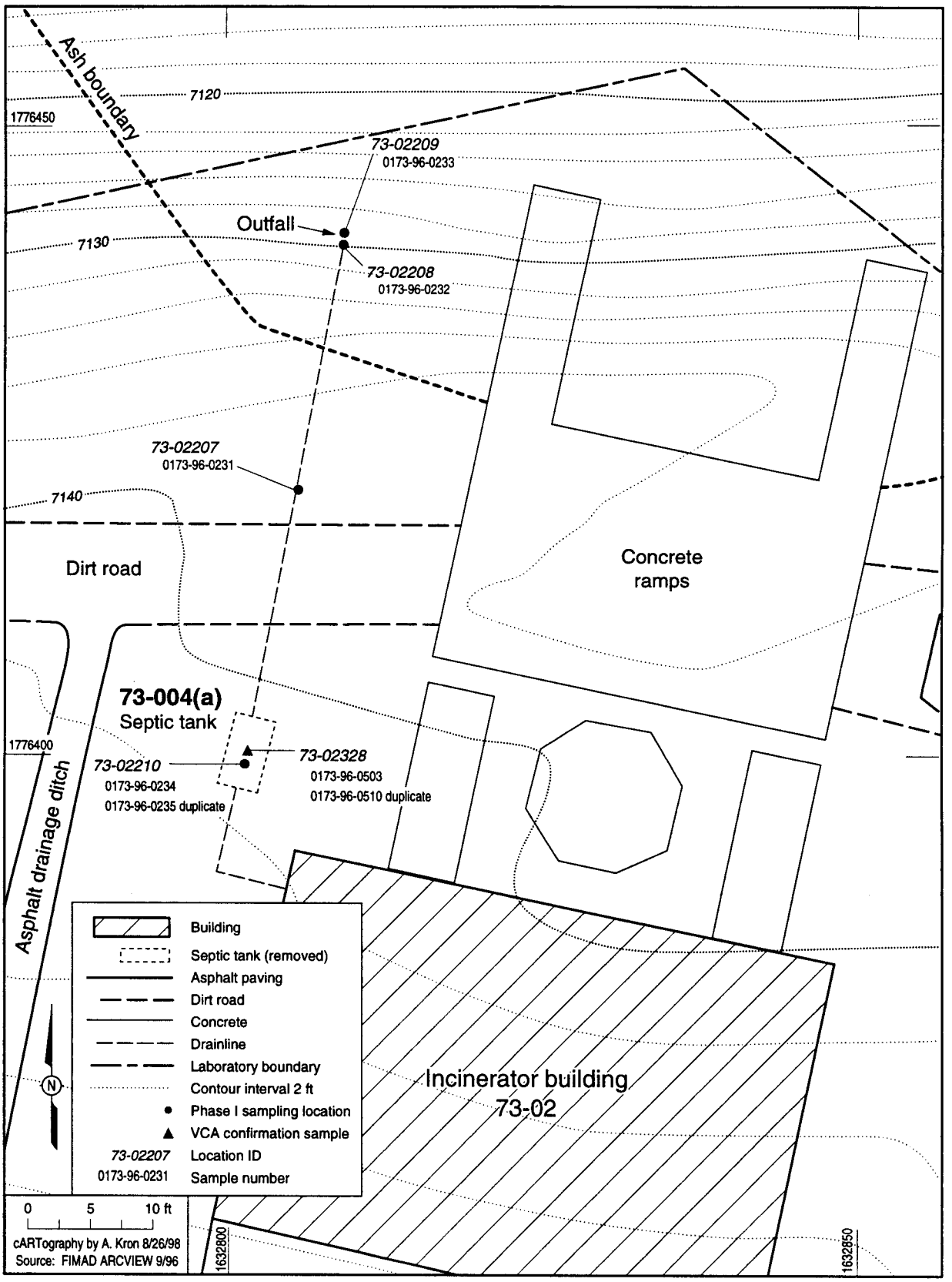
An ecological scoping checklist was completed for this PRS aggregate and is included in Appendix B. The ecological scoping process includes PRS 73-002 in this aggregate because of geographical and functional proximity. However, 73-002 is not included in this SAP because it is the subject of a separate action, most likely part of a VCA plan to be proposed for the ash disposal area. The checklist was used to identify ecological receptors present and potential pathways to those receptors. The information obtained from the checklist was incorporated into the Conceptual Model (Section 2.2.2). The ecological scoping process identified pathways to terrestrial plant and animal receptors. Based on current site knowledge, no pathways to aquatic receptors were identified. Pueblo Canyon has been identified as containing nesting/roosting habitat for Mexican spotted owl and peregrine falcon, both federally listed species. Both species can be expected to forage at a relatively high frequency in Pueblo Canyon.

3.2.1.2 Sampling

This section describes sampling investigations that have occurred at the PRSs (e.g., RFI, environmental surveillance, fixed-point [discrete sample] radiological surveys, etc.).

Phase I RFI activities were conducted at PRS 73-004(a) in June and July 1996 by the ER Project. The potential for chemical or radiological contamination within this septic system was considered to be low. The septic tank was subsequently removed as a VCA in August 1996 (LANL 1996, ER ID 59374) (see Appendix A, Photograph 8). Description of VCA sampling results are documented in the VCA Report for 73-004(a) (LANL 1996, ER ID 59374). The inlet and outlet drainlines were left in place. Because the confirmation sampling performed after the VCA did not define extent, this SAP is designed to define extent for PRS 73-004(a) and to sample drainlines in PRS 73-006.

The septic tank was found to be in excellent condition with no cracks or other indications of structural flaws. The tank contained approximately 3 to 3.5 ft of sediment and 1 to 1.5 ft of water (see Appendix A, Photograph 9). Because of the relatively small size of the tank and the fact that the baffles appeared to have been missing for some time, it was decided to collect one sediment sample (0173-96-0234) and a duplicate (0173-96-0235), and one water sample (0173-96-0238). The water sample was collected prior to collecting the sediment sample to avoid excessive water turbidity. To determine if releases may have occurred from the septic system, additional characterization samples were collected. Sample number 0173-96-0231 was collected from beneath a joint in the VCP outlet drainline, approximately 17 ft north of the septic tank. Because of poor access and the proximity of buried utilities, no attempt was made to collect a sample below the inlet drainline. Two samples were collected from the end of the outlet drainline located within the boundary of the ash disposal area (PRS 73-002). One sample (0173-96-0232) was collected from within the end of the VCP and the second sample (0173-96-0233) was collected from the head of the outfall channel, approximately one foot downgradient of the end of the drainline. Both samples appeared to be composed of ash material rather than soil. Therefore, the chemical nature of these samples may have more to do with the ash disposal area than with discharges from the septic tank. Accordingly, these sample data will be combined with 73-002 sample data, but are included in this discussion for completeness. Following tank removal, no visual evidence of leaks was noted. One confirmatory sample (0173-96-0503) and a duplicate (0173-96-0510) were collected below the tank. Figure 3.2.1.2-1 illustrates all Phase I RFI and VCA sampling locations, and Table 3.2.1.2-1 summarizes all sample information including the sample number.



F3.2.1.2-1 / TA-73 SAP / 092598

Figure 3.2.1.2-1. PRS 73-004(a) Phase I and VCA sampling locations.

TABLE 3.2.1.2-1

PRS 73-004(a)
SUMMARY OF SAMPLES COLLECTED[a]

Location ID	Sample ID	Location Description and Depth	Matrix	VOCs	SVOCs	PCBs/ Pest.	TAL Metals	RAD[b]
73-02207	0173-96-0231	Below outlet pipe 17.5 ft north of tank at 3.5–3.8 ft	Soil	2385	2385	2385	2384	2389
73-02208	0173-96-0232	Inside end of outlet pipe	Soil/ash	2385	2385	2385	2384	2389
73-02209	0173-96-0233	Head of outfall channel at 0.3–0.8 ft	Ash	2385	2385	2385	2384	2389
73-02210	0173-96-0234	Inside septic tank, slightly south of middle	Sediment	2385	2385	2385	2384	2389
73-02210	0173-96-0235	Duplicate of 0173-96-0234	Sediment	2385	2385	2385	2384	2389
73-02210	0173-96-0238[c]	Inside septic tank	Water	2385	2385	2385	2384	2389
73-02328	0173-96-0503	Confirmatory sample at 9–10 ft	Tuff	2568	2568	2568	2569	2570
73-02328	0173-96-0510	Duplicate of 0173-96-0503	Tuff	2568	2568	2568	2569	2570

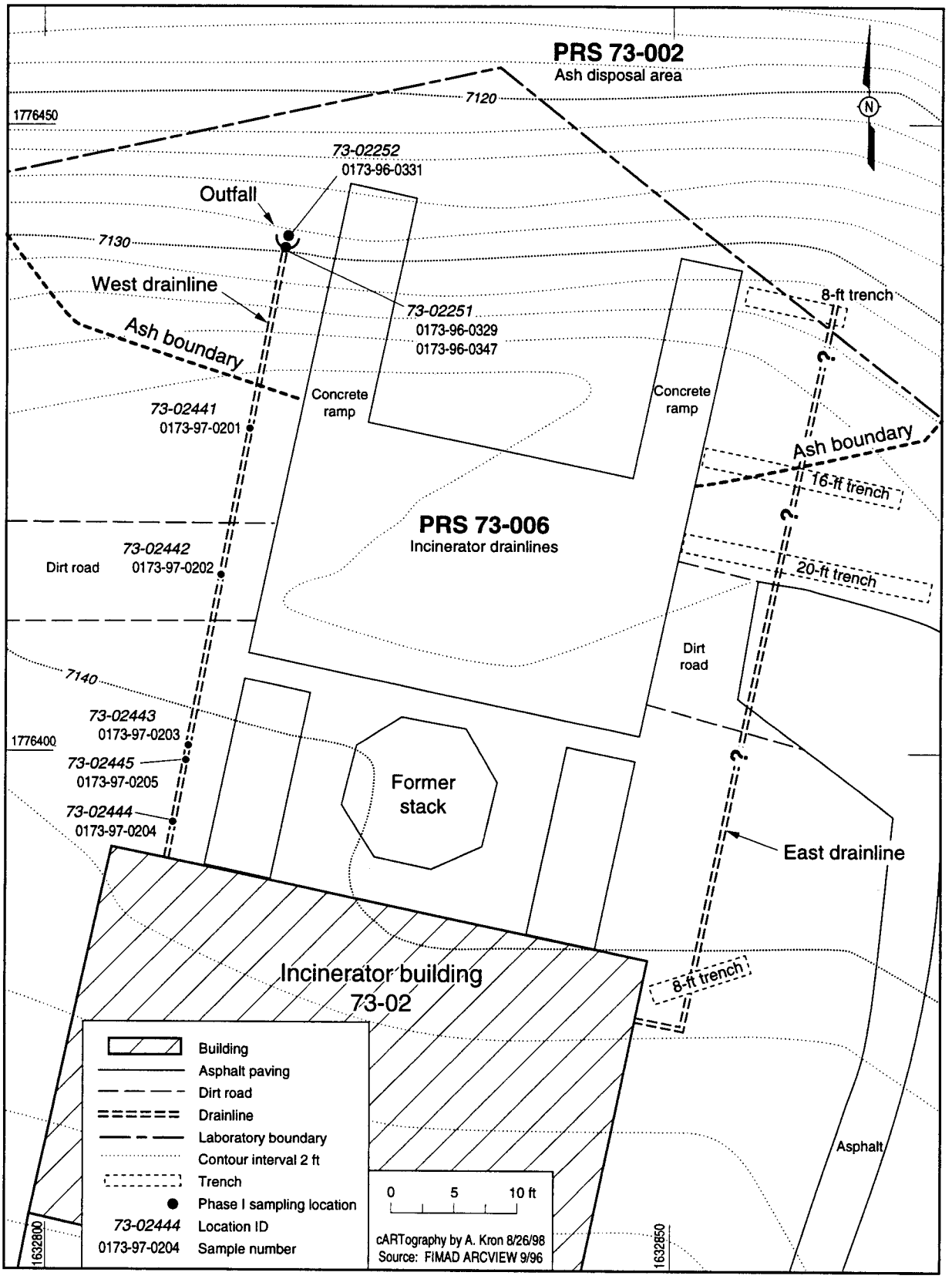
a. Numbers in the cells for each analytical suite are request numbers.

b. RAD = radiological analyses: gross alpha/beta/gamma and tritium

c. This sample was also analyzed for total petroleum hydrocarbons under request no. 2385.

The investigation of PRS 73-006 was completed by the ER Project in several phases between July 1996, and July 1997. Initially, one sample and a duplicate (0173-96-0329 and 0173-96-0347) were collected from within the end of the west drainline and a third sample (0173-96-0331) was collected from the outfall approximately 1 ft downgradient from the end of the drainline. The inside-the-drainline samples were composed of predominantly ash debris, and the outfall sample was entirely ash debris. As with the 73-004(a) outfall samples, the chemical nature of these samples may have more to do with the ash disposal area than with discharges from the septic tank. Accordingly, these sample data will be combined with 73-002 sample data, but are included in this discussion for completeness. The inside-the-drainline sample data were used for waste characterization purposes. The last two outfall drainline sections were dislodged during the sampling event and each was found to be plugged with sediment that looked less like ash debris as distance increased from the outfall. Each drainline section was 2 ft long with a bell joint to the adjacent section. Each joint had been sealed with cement grout.

The second part of the 73-006 Phase I investigation involved removal of the west drainline and 2 to 4 in. of underlying soil to permit the collection of additional samples at locations potentially not affected by other contaminant sources. The entire drainline, approximately 47 ft in length, was 70 to 100 % full of sediment, the majority of which was thinly layered, indicating that it had been deposited over time as sediment-laden water flowed through the drainline. Two additional samples (0173-97-0201 and 0173-97-0205) of this sediment were collected at distances of 8 and 35 ft from the incinerator building. Both were representative of the type of sediment filling the drainline. Following drainline removal, three confirmatory samples (0173-97-0202, 0173-97-0203, and 0173-97-0204) were collected beneath drainline joints at distances of 3, 9, and 23 ft from the building. Figure 3.2.1.2-2 illustrates the Phase I RFI sampling locations, and Table 3.2.1.2-2 summarizes the sample information including location ID, sample number, and analyses requested.



F3.2.1.2-2 / TA-73 SAP / 112598

Figure 3.2.1.2-2. PRS 73-006 Phase I sampling locations.

TABLE 3.2.1.2-2

PRS 73-006
SUMMARY OF SAMPLES COLLECTED[a]

Location ID	Sample ID	Location Description and Depth	Matrix	VOCs and SVOCs	PCBs/ Pest.	Metals	Dioxins/ Furans	Gross α,β,γ	H3	RAD[c]
73-02251	0173-96-0329	Inside drainline/ waste charac.	Sediment/ ash	2286	2286	2287	NR[b]	2288	2288	NR
73-02251	0173-96-0347	Duplicate of 0173-96-0329	Sediment/ ash	2286	2286	2287	NR	2288	2288	NR
73-02252	0173-96-0331	Head of outfall channel at 0.1–0.3 ft	Ash	2286	2286	2287	NR	2288	2288	NR
73-02441	0173-97-0201	Inside drainline/ waste charac.	Sediment	3464R	3464R	3465R	3464R	NR	NR	NR
73-02442	0173-97-0202	Confirmatory sample at 2.8–3.0 ft	Soil	3464R	3464R	3465R	3464R	NR	NR	NR
73-02443	0173-97-0203	Confirmatory sample at 3.2–3.4 ft	Soil	3464R	3464R	3465R	3464R	NR	NR	NR
73-02444	0173-97-0204	Confirmatory sample at 3.0–3.2 ft	Soil	3464R	3464R	3465R	3464R	NR	NR	NR
73-02445	0173-97-0205	Inside drainline/ waste charac.	Sediment	3464R	3464R	3465R	3464R	3466R	NR	3466R

a. Numbers in the cells for each analytical suite are request numbers.
b. NR = not requested
c. Gamma scan, Sr-90, Iso Pu, Iso U

Analytical results for the 73-004(a) and 73-006 characterization samples are presented in Tables 3.2.1.2-3, 3.2.1.2-4, 3.2.1.2-5, 3.2.1.2-6, and 3.2.1.2-7. Data for PRS 73-004(a) were compared with BVs for inorganic chemicals (LANL 1996, ER ID 59374), or detection levels (EQLs) for organic chemicals.

Based on data review for PRS 73-004(a), several pesticides, PAHs, and metals were identified as COPCs. These organic and inorganic data are adequate to support a revised conceptual model. More data need to be collected to define the extent of contamination.

Based on data review for PRS 73-006, several pesticides, PAHs, radionuclides, and metals were identified as COPCs. These organic and inorganic data are adequate to support a revised conceptual model. However, more data were needed to define the extent of contamination.

TABLE 3.2.1.2-3

PRS 73-004(a)
INORGANIC CHEMICALS WITH CONCENTRATIONS EXCEEDING BACKGROUND VALUES (BVs)[a]

Location ID	BV	73-02207	73-02208	73-02209
Location Description	N/A[b]	Below outlet pipe	Inside end of outlet pipe	Head of outfall channel
Sample ID	N/A	0173-96-0231	0173-96-0232	0173-96-0233
Arsenic	8.17	3.7	7.2	**45**[c]
Barium	295	170 (J-)[d]	**3300 (J-)**	**4400 (J-)**
Cadmium	0.4	**0.61 (U)**[e]	**2.5**	**4.6**
Calcium	6120	**18000**	**7400**	**9100**
Chromium	19.3	5.4	**36**	**110**
Copper	14.7	12	**220**	**960**
Iron	21,500	6800	17000	**120,000**
Lead	22.3	17 (J-)	**1300 (J-)**	**2700 (J-)**
Manganese	671	120	380	**790**
Mercury	0.1	**0.12 (U)**	**0.55 (J+)**[f]	**1.0 (J+)**
Nickel	15.4	4.4	**17**	**76**
Silver	1.0	**2.4**	**160**	**220**
Sodium	915	210	**2200**	**1200**
Vanadium	39.6	11	19	**62**
Zinc	48.8	44	**1100**	**2000**

a. Concentrations are in units of mg/kg.
b. N/A = not applicable
c. Bolded values are above BVs, as revised on January 30, 1998 (Ryti et al. 1998, ER ID 58093).
d. (J-) = estimated value, possibly biased low
e. (U) = not detected
f. (J+) = estimated value, possibly biased high

TABLE 3.2.1.2-4

PRS 73-004(a)
ORGANIC CHEMICALS WITH DETECTED CONCENTRATIONS[a]

Location ID	EQL[b]	73-02207	73-02208	73-02209
Location Description	N/A[c]	Below outlet pipe	Inside end of outlet pipe	Head of outfall channel
Sample ID	N/A	0173-96-0231	0173-96-0232	0173-96-0233
4,4'-DDD	0.0033	**0.173**[d]	**6.8**	**1.3**
4,4'-DDE	0.0033	**0.14**	**4.38**	**0.78**
4,4'-DDT	0.0033	**0.5**	**35.4**	**3.19**
Chlordane (technical grade)	0.0017	0.004 (U)[e]	**0.415**	**0.235**
Alpha-chlordane	0.0017	0.001 (U)	**0.0345**	**0.019**
Gamma-chlordane	0.0017	0.001 (U)	**0.0382**	**0.028**
2-Methylnaphthalene	0.33	0.22 (J)	0.71 (U)	0.25 (J)
Benzo(b)fluoranthene	0.33	0.77 (U)	**0.21**	1.8 (U)
Benzoic acid	0.33	7.7 (U)	**0.19**	1.8 (U)
Chrysene	0.33	0.77 (U)	**0.12**	1.8 (U)
Di-n-butylphthalate	0.33	0.77 (U)	0.71 (U)	**0.25**
Fluoranthene	0.33	0.77 (U)	0.16 (J)	**0.36**
Naphthalene	0.33	0.16 (J)	0.08 (J)	**0.36**
Phenanthrene	0.33	0.1 (J)	0.092 (J)	0.28 (J)
Phenol	0.33	0.77 (U)	0.71 (U)	**0.52**
Pyrene	0.33	0.77 (U)	0.14 (J)	1.8 (U)
Trichlorofluoromethane	0.005	**0.007**	0.012 (U)	0.005 (U)

a. Concentrations are in units of mg/kg.
b. EQLs obtained from the Sample Management Office's Laboratory contract.
c. N/A = not applicable
d. Bolded values are detected values.
e. (U) = not detected
f. (J) = Results for this analyte should be regarded as estimated because the result was below the EQL but above the MDL.

TABLE 3.2.1.2-5

PRS 73-006
INORGANIC CHEMICALS WITH CONCENTRATIONS EXCEEDING BACKGROUND VALUES (BVs)[a]

Location ID	BV	73-02442	73-02443	73-02444
Location Description	N/A[b]	Confirmation sample beneath drainline	Confirmation sample beneath drainline	Confirmation sample beneath drainline
Sample ID	N/A	0173-97-0202	0173-97-0203	0173-97-0204
Cadmium	0.4	**0.69 (J-)**[c,d]	**1.6 (J-)**	**3.4 (J-)**
Copper	14.7	**16**	**46.1**	**83.1**
Lead	22.3	18.9	**38.3**	**22.9**
Mercury	0.1	**0.82**	**1.5**	**7.9**
Nickel	15.4	6.7	15.2	**30.3**
Silver	1.0	0.92	**4.1**	**2.2**
Zinc	48.8	**57.8**	**270**	**1250**

a. Concentrations are in units of mg/kg.
b. N/A = not applicable
c. Bolded values are above BV, as revised on January 30, 1998 (Ryti et al. 1998, ER ID 58093).
d. (J-) = estimated quantity, possibly biased low

TABLE 3.2.1.2-6

PRS 73-006
ORGANIC CHEMICALS WITH DETECTED CONCENTRATIONS[a]

Location ID	EQL[b]	73-02442	73-02443	73-02444
Location Description	N/A[c]	Confirmation sample beneath drainline	Confirmation sample beneath drainline	Confirmation sample beneath drainline
Sample ID	N/A	0173-97-0202	0173-97-0203	0173-97-0204
4,4'-DDD	0.0033	**0.0048**[d]	0.008 (U)[e]	**0.022**
4,4'-DDE	0.0033	**0.035**	0.008 (U)	0.008 (U)
4,4'-DDT	0.0033	**0.230**	0.047	**0.220**
Benzo(a)pyrene	0.33	0.370 (U)	0.052 (J)[f]	0.410 (U)
Benzo(b)fluoranthene	0.33	0.370 (U)	0.046 (J)	0.410 (U)
Benzo(g,h,i)perylene	0.33	0.370 (U)	0.120 (J)	0.410 (U)
bis(2-Ethylhexyl)phthalate	0.33	0.370 (U)	0.069 (J)	0.410 (U)
Chrysene	0.33	0.370 (U)	0.050 (J)	0.410 (U)
Diethylphthalate	0.33	0.067 (J)	0.160 (J)	0.160 (J)
Fluoranthene	0.33	0.370 (U)	0.077 (J)	0.410 (U)
HpCDD	0.0002	0.00068 (U)	**0.00024 (J)**	0.0002 (U)
Indeno(1,2,3-cd)pyrene	0.33	0.370 (U)	0.051 (J)	0.410 (U)
OCDD	0.0004	0.00038 (U)	**0.00078 (J)**	**0.001 (J)**
Pyrene	0.33	0.370 (U)	0.072 (J)	0.410 (U)
Trichlorotrifluoroethane	0.005	0.002 (J)	0.002 (J)	**0.006 (U)**

a. Concentrations are in units of mg/kg.
b. EQLs obtained from the Sample Management Office's Laboratory contract.
c. N/A = not applicable
d. Bolded values are above EQLs.
e. (U) = not detected
f. J values are all less than the EQL, except for possibly the dioxin concentrations.

TABLE 3.2.1.2-7

PRS 73-006
DETECTED RADIONUCLIDES[a]

Location ID	73-02445
Location Description	Inside drainline
Sample ID	0173-97-0205
Americium-241	0.137
Cesium-137	0.163
Pu-239	0.685
U-234	23.2
U-235	0.967
U-238	20.5
Gross Alpha	60.6 (J)[b]
Gross Beta	42.6 (J)

a. Activities are in units of pCi/g.
b. (J) = estimated value

3.2.2 Conceptual Model

3.2.2.1 Nature and Extent of Contamination

The preliminary conceptual model for the nature and extent of contamination at this site is provided by the Phase I sample data and knowledge of site operations. Phase I sampling of PRS 73-004(a) identified 15 inorganics occurring above BVs and 17 detected organics (Tables 3.2.1.2-3 and 3.2.1.2-4). Phase I sampling of PRS 73-006 identified seven inorganics occurring above BVs, 15 detected organics, and six radioisotopes (Tables 3.2.1.2-5, 3.2.1.2-6, and 3.2.1.2-7). PRS 73-004(a) received only sanitary waste from toilet and shower facilities in the incinerator building, and there are no records of other materials being disposed into the septic system. Potential contaminants at 73-006 are expected to have originated from material burned in the incineration process and washed down the floor drains of the incinerator building. This conceptual model will deal only with nature and extent of contamination due to potential releases along the length of the drainline/septic systems. Potential releases at the outfall occur within the boundary of PRS 73-002, and will be addressed as part of that VCA Plan. All samples taken at PRS 73-004(a) were analyzed for complete suites of VOCs, SVOCs, PCBs/Pesticides, and TAL metals, as well as gross alpha/beta/gamma and tritium radiological analyses (Table 3.2.1.2-1). It is likely that these analyses captured the nature of contamination resulting from this PRS. Based on the operational history of this PRS (sanitary septic system) contamination by radioisotopes is not expected. Samples taken from PRS 73-006 included three confirmatory samples taken below the west drainline (Location IDs 73-02442, 73-02443, 73-02444), and two waste characterization samples taken inside the west drainline (Location IDs 73-02441 and 73-02445). All of these samples were analyzed for VOCs, SVOCs, PCBs/pesticides, TAL metals and dioxins/furans (Table 3.2.1.2-2). Radiological analyses, including gross alpha/beta/gamma and tritium, gamma spectrometry, and analyses for Sr-90 and isotopic U and Pu were conducted on one sample taken from inside the drainline (Location ID 73-02445). Three additional samples were taken in the end of the drainline and at the outfall, but these fall within the 73-002 ash debris pile and will be addressed as part of that VCA plan. Any additional COPCs identified in those samples will be considered part of the nature of contamination of 73-002, and not part of the 73-004(a) aggregate. It is likely that the analyses mentioned above adequately define the nature of the contamination at this site.

PRSs 73-004(a) and 73-006 both comprise engineered drainline systems with outfalls on the south rim of Pueblo Canyon. The volume of water which flowed through the systems is not known, but given the nature of operations at the site, and the brief period of operation of the incinerator, flow is not expected to have been significant. However, because 73-006 was simply a drainline with no septic tank, any water flowing into the floor drains would discharge at the outfall. Both drainline systems were gravity driven, with downward slants to ensure proper drainage to the septic tank and outfalls. The most likely points of contaminant releases to the environment would be at pipe joints and, in the case of 73-004(a), at pipe connections with the septic tank. Releases at the outfall will be addressed as part of PRS 73-002. The west drainline of PRS 73-006 was removed as part of a Phase I investigation in 1997. The entire length of the drainline was removed back to the foundation of the incinerator building. The drainline consisted of two foot sections of vitrified clay pipe connected with bell joints sealed by cement grout. Two to 4 in. of the underlying soil was also removed at the same time. The east drainline was not found, despite extensive efforts to locate it. The septic tank of PRS 73-004(a) was removed as a VCA in 1996 (LANL 1996, ER ID 59374). The tank was in excellent condition (see Section 3.2.1.2, Sampling), with no evidence of leakage having occurred from the tank itself. The inlet and outlet drainlines were left in place, but it is assumed that their construction is similar to the drainlines of 73-006. Contamination resulting from leaks in the drainlines associated with these two PRS would not affect surface soil. Based on the gravity-driven construction of the system and the nature of the operations at the site, it is assumed that the volume of media impacted by such leaks would be small.

There are no relevant hydrologic features that could be impacted by contamination at this site (Section 3.1.1, Hydrology). Although PRSs 73-004(a) and 73-006 have LANL-ER-AP-4.5 Surface Water Assessment Erosion Matrix Scores of 56 and 38, indicating a medium and low erosion potential, respectively. The terminal point of surface water runoff is a bench on the north-facing slope of Pueblo Canyon. No waterways or aquatic communities are impacted by these PRSs. The regional aquifer is located approximately 1100 ft below the mesa top. Alluvial and perched bedrock aquifers are present in Pueblo Canyon, but there are no monitoring stations or supply and production wells near these PRSs.

The nature of contamination has been well defined by the Phase I sampling activities at these PRSs, with the exception of any possible contamination from the east drainline of PRS 73-006, which was not located. Analyses were conducted for all analytical suites thought likely to occur given the operational history of the incinerator facility, and samples were collected where releases were most-likely to occur (i.e., pipe joints, outfall). Of the organic contaminants detected under the west drainline of PRS 73-006 (Location IDs 73-02442, 73-02443, and 73-02444), 16 of the 22 detected values were J-qualified. However, this is not likely to be a data quality issue since all of the J-qualified values (with the possible exception of the two dioxins detected) are less than the EQL.

Extent of contamination at these two PRSs is not well defined, and determining extent is the purpose of this SAP. Contamination from drainline leaks is not expected to impact surface soil, and is expected to impact only a small volume of soil or tuff. Samples taken from under the 73-004(a) septic tank showed no signs that the septic tank had leaked. However, the vertical extent of contamination from drainline leaks is unknown. Also, although samples from inside the 73-006 west drainline indicated the presence of radionuclides, the extent of contamination by those isotopes is unknown, because radiological analyses were not conducted on any other samples from PRS 73-006.

3.2.2.2 Fate and Transport

The Phase I sampling of PRS 73-004(a) and 73-006 identified 15 inorganic chemicals present at concentrations greater than BVs (Tables 3.2.1.2-3 and 3.2.1.2-5). Twenty-five organic chemicals were also detected (Tables 3.2.1.2-4 and 3.2.1.2-6). Waste characterization samples from inside the 73-006 drainline also detected elevated levels of U-234, U-238, and Pu-239 (Table 3.2.1.2-7). General chemical and physical properties which relate to the fate of these contaminants in the environment are provided in Appendix D.

The fate and distribution of chemicals in the environment are determined by chemical-specific properties, geochemistry of the contaminated media, and physical transport systems such as runoff. The contamination from the drainlines of 73-004(a) and 73-006 does not affect surface soils, making it less likely to be affected by surficial erosion processes. Contamination at the outfalls of 73-004(a) and 73-006 is subject to erosional transport processes, but the outfalls are being addressed as part of the VCA plan for PRS 73-002.

Phase I data provide no information on the valence states of the inorganic chemicals detected at these sites. The inorganics detected, with the exception of mercury, are not volatile in any of their forms, so volatilization is not a viable exposure or redistribution pathway for these chemicals. Certain organic forms of mercury are volatile, but the reducing chemical conditions necessary for the conversion of inorganic mercury to organic mercury are not expected to occur at this site. Appendix D, Chemical Properties, presents a discussion of the conditions necessary for a reducing environment in the section on potential for uptake of mercury. The radionuclides detected are not volatile. Several of the detected organic chemicals (diethylphthalate, phenol, trichlorofluoromethane, benzoic acid, and trichlorotrifluoroethane) have relatively high vapor pressures, indicating that volatilization could be an exposure/transport

pathway. The subsurface nature of the contamination and the relatively low concentrations of volatile COPCs limits this pathway potential.

Several of the organic chemicals detected (benzoic acid, diethylphthalate, phenol, trichlorofluoromethane) have high water solubilities, and infiltration is a possible transport mechanism. However, downward movement of chemicals in dissolved phase would affect only subsurface tuff, as migration to groundwater is not likely from releases associated with this site (See Section 3.1.1, Hydrology). The radionuclides detected belong to the group of elements known as actinides. These elements form relatively insoluble compounds in the environment, and are not considered biologically mobile.

PRS 73-004(a) and PRS 73-006 have LANL-ER-AP-4.5 Surface Water Assessment Erosion Matrix scores of 38.0 (low erosion potential) and 56.0 (medium), respectively. However, these scores include the outfalls, which are being addressed as part of PRS 73-002. Surface runoff will have little effect on the subsurface contamination beneath the drainlines, which is the limited scope of this investigation.

Eighteen of the organic contaminants, five of the inorganics, and all of the radionuclides are listed on the NMED list of potentially bioaccumulating chemicals. There is no transport to aquatic receptors suggested by the current understanding of the nature and extent of COPCs at these sites. It is expected that the total area impacted by these PRSs is small and the contamination is not surficial, so it is expected that the potential for persistent bioaccumulation is minimal.

The primary impacted media from contamination originating from drainline or septic tank leaks is subsurface soil and tuff. Thus, surface water runoff and air entrainment of fugitive dust are not likely transport or exposure pathways at this site. Migration to groundwater is also not a concern at this site. Given the mesa edge location of the PRS, mass wasting could be considered a mechanism by which contamination could be released to surface soil or water. The radionuclides detected are alpha emitters. External exposure to low level alpha emissions is not a concern as alpha particles are not penetrating and can be blocked by even thin barriers (i.e. soil, skin). The main exposure pathways relevant to alpha emitting radionuclides are inhalation or ingestion of contaminated material. The lack of exposure pathways, the small size of the affected area, and the subsurface nature of contamination make the potential significance to human and ecological receptors very low. An ecological scoping checklist was completed for this PRS aggregate (including PRS 73-002) and is included in Appendix B.

3.2.2.3 Data Gaps

The conceptual model for PRSs 73-004(a) and 73-006 emphasizes that these sites represent engineered systems that were designed to release contaminants through drainlines and a septic tank to an outfall. The outfall area of both PRSs is contained within PRS 73-002 and is not included as part of this sampling and analysis plan. Thus, data gaps at the outfall area of these PRSs will be identified as part of the VCA plan for PRS 73-002.

Potential release points that are relevant to this plan are pipe joints, and pipe connections at the septic tank, or leakage from the septic tank itself. The releases from these PRSs were liquid in nature. However, based on the solubility of the COPCs discussed in the environmental fate section, these COPCs are expected to readily come out of solution and become associated with reactive components of the soil matrix (like ferric hydroxides or organic material). Quantities of COPCs released at points along the engineered system are expected to be minimal and the volume of subsurface soil or tuff contaminated by leaks along the drainline is expected to be small.

The full suite laboratory analyses for organics and inorganics provides adequate information of the nature of contaminant releases for these analyte groups. However, radiological analysis were limited to the

drainline contents and not the environmental media below the pipe. Because radionuclides were detected within the pipe, radiological analyses will be requested on samples collected to identify the nature and extent of contamination in environmental media.

Phase I data indicate that there were contaminant releases associated with leaks along the engineered system. However, there is no information on the vertical extent of such releases. As discussed above, the volume of subsurface media impacted by such releases is expected to be minimal, and sample data could be used to confirm this expectation.

Another data gap is the lack of sample data to determine if the east drainline of PRS 73-006 had leaked. Although trenching did not reveal this pipe, the engineering "as-built" diagram of building TA-73-02 suggest that this east drainline was installed. The location of the east drainline could be estimated from the engineering "as-built" diagram of building TA-73-02.

No data have been collected from either within or beneath the cast iron portion of PRS 73-006. Because the cast iron pipe is underneath building TA-73-02, it is not easy to sample. This also suggests that there are no pathways and thus no current day risk posed by any contaminants associated with the cast iron portion of PRS 73-006. For the purposes of the human health and ecological risk assessments for PRS 73-006, it is assumed that the amount of environmental media impacted by leaks from the unsampled cast iron portion of PRS 73-006 is similar to the accessible part of PRS 73-006.

Once information to provide trends in the extent of contamination are provided, these data are expected to be adequate for human health and ecological risk screening. Based on the concentrations observed for COPCs identified in the VCA and Phase I RFI, this information is also expected to be provide adequate information for making risk management decisions for these PRSs.

3.2.3 Sampling Activities

This section describes the sampling design and the rationale for the design based on the site conceptual model presented in Section 3.2.2.

The volume of media impacted by drainline leaks at PRSs 73-004(a) and 73-006 is expected to be small based on three factors. The first factor is the gravity-driven construction of the drainlines that required a downward slope to ensure proper drainage. This prevented water from backing up in the drainlines and creating a pressurized situation that might have caused leaks through cracks and poorly sealed pipe connections. The second factor is that the drainline connections were sealed with cement grout to prevent leakage. The third factor is the nature of the operations at both PRSs that would have resulted in low and intermittent flows. The restroom facilities would only have been used periodically throughout the workday, and floor-washing activities would only have taken place as needed.

The proposed samples will be collected directly beneath the drainlines where the potential leaks would have occurred. Locations identified during the Phase I RFI where COPCs exceeded BVs or EQLs will be resampled at deeper depths for the purpose of determining concentration trends with distance and depth from the drainlines. As part of the Phase II RFI, including 73-004(a), drainlines will be removed to facilitate the investigation. Additional locations may then be sampled based on visual evidence of leaks.

The sampling design will not be influenced by field test kits or other on-site analytical tools. There is no plan to use contaminant collocation or correlation to estimate results for any analytes. The same analytical suites analyzed during the Phase I RFI will be requested for all samples collected during the planned sampling activities. These include TAL metals, VOCs (only below a 6-in. depth), SVOCs, organochlorine pesticides, and PCBs. The only exceptions are that dioxins and furans and radiological

analyses will be requested for PRS 73-006. The radiological analyses will include isotopic uranium and plutonium, gamma spectrometry, and alpha spectrometry.

Analytical data generated by these sampling activities will be compared to the appropriate LANL BVs for inorganic chemicals and radionuclides, as described in the paper "Inorganic and Radionuclide Background Data for Soils, Canyons Sediments, and Bandelier Tuff at Los Alamos National Laboratory" (Ryti et al. 1998, ER ID 58093), and EQLs for organic chemicals (LANL 1995, ER ID 49738). Field duplicate samples will be collected to evaluate data quality.

Based on the sampling design discussion above and in Sections 3.2.3.1 and 3.2.3.2, the samples to be collected are presented in Tables 3.2.3-1 and 3.2.3-2. The proposed sampling locations are shown on Figure 3.2.3-1.

TABLE 3.2.3-1

PRS 73-004(a)
PROPOSED SAMPLE LOCATIONS AND ANALYTICAL SUITES[a]

Location ID	Location Description and Depth	Matrix	VOCs	SVOCs	PCBs/ Pest.	TAL Metals[b]
73-02207	Deeper sample beneath sample 0173-96-0231	Soil	X	X	X	X
TBD[c]	Confirmation sample below outlet drainline	Soil	X	X	X	X
TBD	Confirmation sample below inlet drainline	Soil	X	X	X	X
TBD	Additional samples for definition of extent	Soil	X	X	X	X
TBD	QA/QC sample (duplicate)	Soil	X	X	X	X

a. All samples will be grab samples.
b. See Table 6.1-1 for special required detection limits
c. TBD = to be determined

TABLE 3.2.3-2

PRS 73-006
PROPOSED SAMPLE LOCATIONS AND ANALYTICAL SUITES[a]

Location ID	Location Description and Depth	Matrix	VOCs	SVOCs	PCBs/ Pest.	TAL Metals[b]	Dioxins/ Furans	RAD[c]
73-02442	Deeper sample beneath sample 0173-97-0202	Soil	X	X	X	X	X	X
73-02443	Deeper sample beneath sample 0173-97-0203	Soil	X	X	X	X	X	X
73-02444	Deeper sample beneath sample 0173-97-0204	Soil	X	X	X	X	X	X
TBD[d]	Samples beneath estimated east drainline location	Soil	X	X	X	X	X	X
TBD	Additional samples for definition of extent	Soil	X	X	X	X	X	X
TBD	QA/QC sample (duplicate)	Soil	X	X	X	X	X	X

a. All samples will be grab samples.
b. See Table 6.1-1 for special required detection limits.
c. RAD = radiological analyses: isotopic uranium and plutonium, and gamma and alpha spectrometry
d. TBD = to be determined

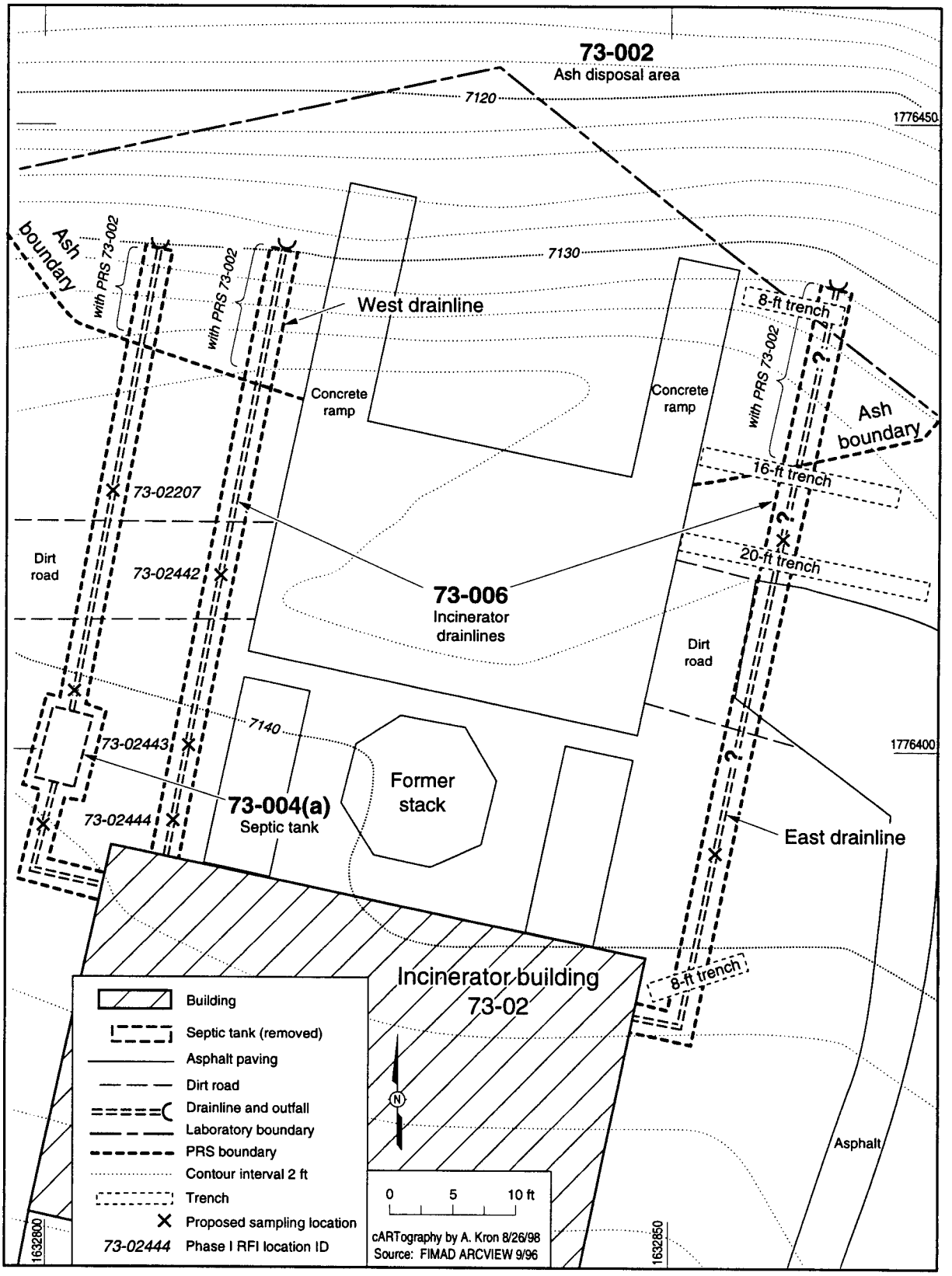


Figure 3.2.3-1. Proposed sampling locations for PRSs 73-004(a) and 73-006.

3.2.3.1 Contaminant Source

There are no known contaminant sources present at either PRS 73-004(a) or 73-006. Therefore, no contaminant source sampling is planned. The 73-004(a) septic tank was removed as a VCA in 1996, but the inlet and outlet drainlines were left in place. The 73-006 west drainline was removed in 1997 as part of a Phase I RFI. The east drainline is thought to have been previously removed during buried utility installation.

3.2.3.2 Media Characterization

PRS 73-004(a)

At PRS 73-004(a), the initial task will be to collect a deeper sample at Location ID 73-02207. This will be followed by removal of the outlet drainline to the point at which it becomes incorporated with PRS 73-002, and removal of the inlet drainline back to the incinerator building foundation. As the drainlines are removed, the underlying soil or tuff will be visually inspected for staining or other signs of leaks. If visual evidence indicates potential contamination, a sample will be collected to further define the extent of contamination. The underlying material will also be periodically screened with a photoionization detector (PID) and radiation detection instruments for worker health and safety purposes. Two confirmatory samples will be collected from immediately beneath portions of the drainlines not sampled for other reasons, one beneath the inlet drainline and one beneath the outlet drainline.

The deeper sample at Location ID 73-02207 will be collected at a depth of two feet below the original sample (sample 0173-96-0231). The original sample was collected approximately 17 ft north of the septic tank and at a depth of approximately 3.5 ft below ground surface (bgs), directly beneath an outlet drainline pipe connection. The original sample was described as brown, silty, sandy soil. A backhoe will again be used to expose the drainline at this location. A hand auger will subsequently be used to drill to a depth of two feet below the original sample interval. The next 6-in. interval will then be sampled and analyzed for the proposed analytical suites. As required, additional deeper samples will be collected at two-foot intervals to define extent (see Section 1.2). Powered augering equipment may be used to advance the borehole depending upon the depth of contamination and the difficulties encountered in using the hand auger. A backhoe also may be used to obtain the deeper sample(s) if the methods described above are ineffective. The final selection of a sampling method will be made in the field based on soil and site conditions.

The same basic procedure for collecting deeper samples will be followed at any of the additional sampling locations in order to define extent or establish a decreasing concentration trend. No more than two consecutive samples will be collected at a location until it is confirmed by fixed-site laboratory data that additional deeper sampling is required. The only exception to this will be if visual observations clearly indicate that the deepest sample interval is obviously contaminated.

PRS 73-006

The initial task at PRS 73-006 will be to collect deeper samples at the three Phase I confirmatory sample locations (Location IDs 73-02442, 73-02443, and 73-02444) where the analytical data indicated inorganic chemicals exceeding BVs and organic chemicals exceeding EQLs. These location IDs correspond to samples 0173-97-0202, 0173-97-0203, and 0173-97-0204, respectively. All three of these samples were composed of fill material with abundant tuff fragments, and it was determined that the fill/tuff contact was immediately below these sample intervals at depths of 3 to 3.5 ft bgs. The proposed sampling will be accomplished using a backhoe to expose the bottom of the drainline trench at each of the three

confirmatory sample locations. The backhoe will then excavate an additional 2 ft. Samples will be collected from the next 6-in. interval at each location using a hand auger. Deeper samples will be collected, as necessary, to define extent of contamination or a decreasing concentration trend.

Based on the as-built engineering drawing of Building TA-73-02, any of the four Phase I exploratory trenches excavated for the purpose of locating the east drainline should have successfully located the line if it were still in place. The former location of the east drainline will be estimated from the as-built drawing, and two locations will be sampled beneath this estimated drainline location.

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4.0 PRS 73-005 SURFACE DISPOSAL AREA AND PRS 73-007 SEPTIC TANK

4.1 Characterization and Setting

4.1.1 Site Description

PRSs 73-005 and 73-007 are both in an area formerly known as Contractor's Row. This DOE-owned land is located directly south of the Los Alamos Airport terminal building between state road NM 502 and the southern edge of East Mesa, in TA 73, OU 1071 (Appendix A, Photographs 1, 3, and 4). The former Contractor's Row extended from near the west end of the runway to the east for approximately 2800 ft. Both PRSs are inactive, and PRS 73-005 is a SWMU listed on the HSWA Module VIII Table A (EPA 1990, ER ID 1585).

PRS 73-005 consists of a surface disposal area near the north edge of DP Canyon (Figure 4.1.1-1). As defined in the RFI Work Plan for OU 1071 (LANL 1994, ER ID 7667), the area is roughly 400 ft long and 200 ft wide, extending from the highway right-of-way fence line to the north rim of DP Canyon, and between two small drainages. It consists of discrete piles of concrete and other construction debris (Appendix A, Photographs 10, 11, and 12). The entire area is undeveloped, heavily vegetated, and appears similar to surrounding undisturbed areas not included in the PRS.

PRS 73-007, a cylindrical steel septic tank and its outfall and two cast iron riser pipers (probably the inlet to the tank [see Appendix A, Photograph 13]), were discovered in June 1996, during a field reconnaissance visit to the former Contractor's Row area. PRS 73-007 is located within the boundary of PRS 73-005 (Figure 4.1.1-1). The tank and its contents were removed as a VCA in 1996 by the ER Project (LANL 1996, ER ID 59374) and the inlet and outlet drainlines were abandoned in place. It is assumed that this septic system served a facility located in the former Contractor's Row. However, there is no historical information to document the identity of the facility or the contents of the waste discharged to this septic system. Only a single set of aerial photographs dated 1949 show buildings within the former Contractor's Row (see Appendix A, Photograph 4). These photographs were all taken at oblique angles, and it was impossible to see the septic system or determine which buildings it might have served.

The 73-007 septic tank was constructed of a steel cylinder set vertically into a hole dug in the tuff. The tank was 4.3 ft in diameter by 5 ft deep and had an integral steel bottom. The cover was also steel with a narrow lip that fit over the edge of the tank when the lid was placed into position. Narrow steel tabs, welded to the outside of the tank, were bent over the lid to hold it in position. There were no baffles other than pieces of steel plate welded into position over both the inlet and outlet openings. The tank walls and floor were badly rusted, but appeared to be intact (Appendix A, Photograph 14). There were no visible corrosion holes or other openings through which fluids might have leaked from the tank. The tank contained approximately 1 to 2 in. of sediment and no water. The sediment appeared to primarily consist of rusted metal fragments. The inlet drainline was constructed of 4-in.-diameter cast iron pipe. The cast iron riser pipe could be the source for liquids in the tank (Figure 4.1.1-1). The outlet drainline was constructed of 4-in.-diameter VCP. Both drainline openings were positioned 6 in. below the top of the tank. The outfall was located 67 ft south of the tank at a depth of 1.5 ft covered with fill material containing construction debris (Appendix A, Photograph 15). The total surface area of the PRS and the extent of contamination will be determined during the execution of this SAP.

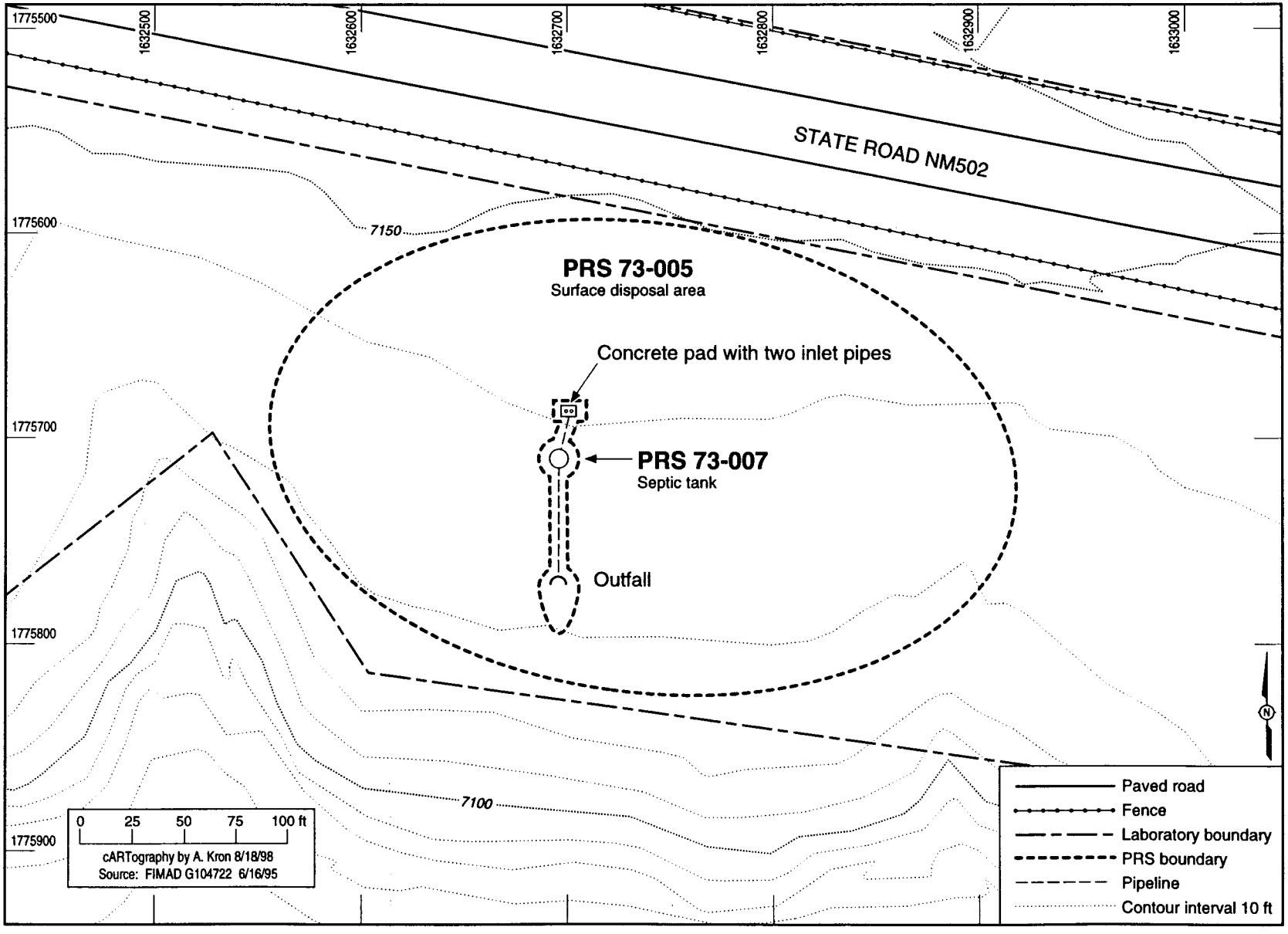


Figure 4.1.1-1. Site map for PRSs 73-005 and 73-007.

The former Contractor's Row is currently vacant land, separated from state road NM 502 right-of-way by a 4-ft high barbed-wire fence. The future land use has not been determined. There are no other PRSs that potentially affect the recommendations for these PRSs. There are no environmental management (EM)/ER, decontamination and decommissioning (D&D), or facility management activities that will impact these PRSs. It is anticipated that this land eventually will be transferred to a new owner.

PHYSICAL DESCRIPTION: Geomorphology, Topography, and Surface Geology

Geology

Soils in the vicinity of Contractor's Row are composed predominantly of reworked soil. Construction and demolition of the surrounding facilities resulted in significant disturbance of the natural soils. In general, natural surficial soils, where they still exist, are very thin and sandy with relatively low clay content. With depth, more well-developed soils occasionally may be encountered with relatively high percentages of reddish clay. Depth to bedrock at these PRSs has not been well defined. There are outcrops of Bandelier tuff on the surface. During earlier sampling activities, soil as thick as 2 ft was encountered.

The vegetative cover consists of native grasses, piñon, juniper, oak and pine that covers approximately 75 to 100% of the land. The average slope of this mesa top land is approximately 10%.

Hydrology

Surface Water Hydrology. Runon to this area is from the north, in the form of sheetflow flowing south toward DP Canyon. The average slope of this mesa top land is less than 10%. The runoff from this area drains into two large and some small natural channels. There is no debris in the watercourse. (See also Appendix C, LANL-ER-AP-4.5 Surface Water Assessment.) The two larger channels also drain an area along state road NM 502 and a portion of the airport. The channels eventually drain south into DP Canyon, a 1.5 mile long canyon that begins in the Los Alamos townsite and extends east to the confluence with Los Alamos Canyon. Topographic features where contaminants might collect would be sediment catchment areas within the drainage channels. The stream at the bottom of DP Canyon is ephemeral. The stream flow consists of industrial effluent from permitted outfalls and storm water and snowmelt runoff from DP Mesa, the townsite, and East Mesa.

Subsurface Water Hydrology. DP Canyon contains alluvial wells LAUZ-1, and LAUZ-2 (Figure 4.1.1-2). These two wells are located approximately 750 ft southeast of PRS 73-005. The total depth of each well is 15 ft. Alluvial water was encountered in both wells at approximately 4.5 ft below the surface. The saturated zone at the time was approximately 3.5 ft thick. This alluvial water is thought to be a source for DP Spring. This spring flows from the south-facing slope of DP Canyon, approximately 4000 ft downstream to the east from PRS 73-005 and 73-007 (Figure 4.1.1-2).

The deep well LADP-4 was drilled in 1993 in DP Canyon to the depth of 800 ft to determine whether there is perched groundwater beneath DP Canyon. It is located approximately 750 ft south of PRS 73-005 (Figure 4.1.1-2). No perched groundwater was found beneath DP Canyon (LANL 1998, ER ID 59373).

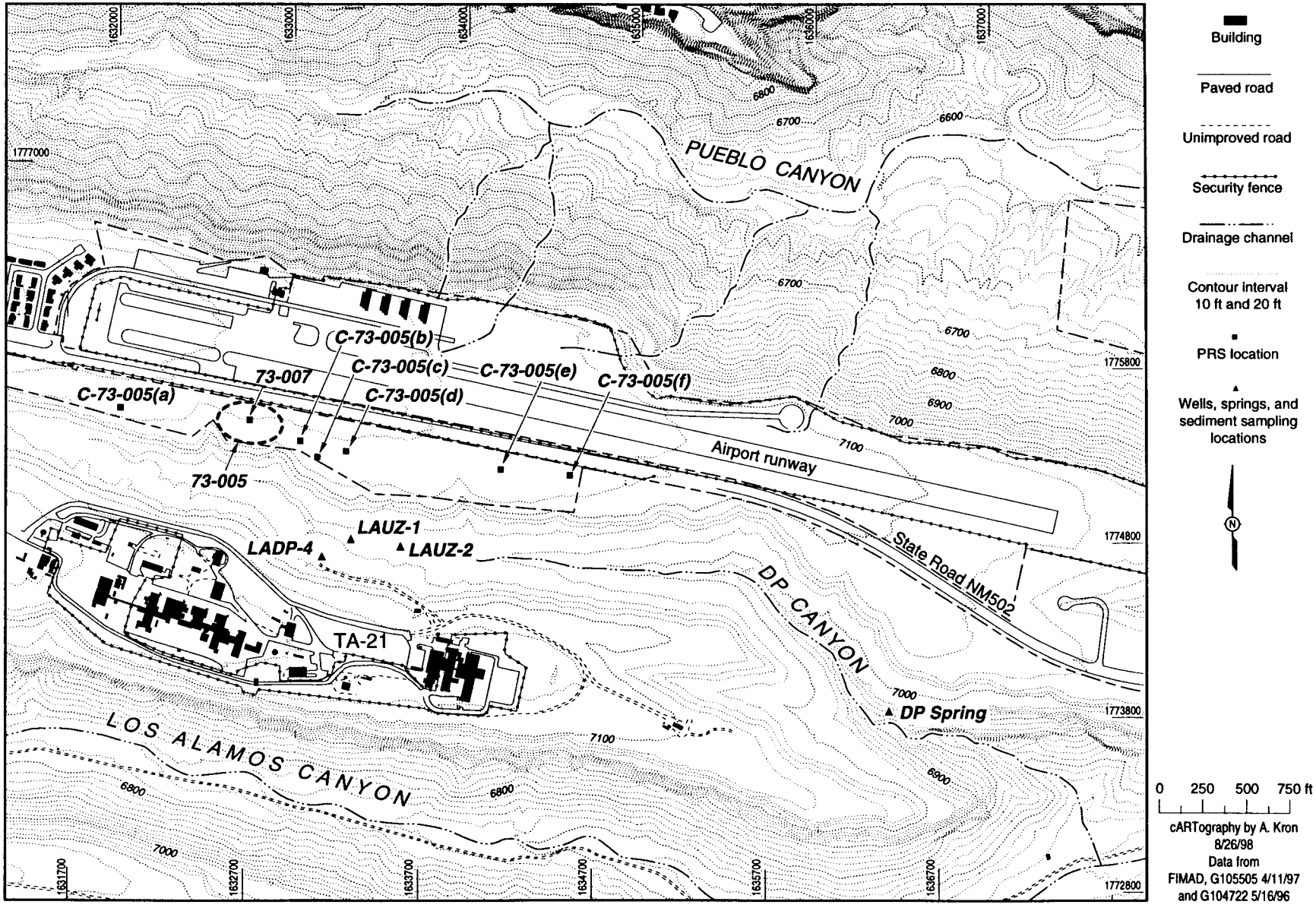


Figure 4.1.1-2. Location of alluvial wells, deep wells, springs, and sediment sampling locations in DP Canyon.

ASSESSMENT OF ECOLOGICAL, CULTURAL, AND BIOLOGICAL RESOURCES

There are no specific climatic influences or cultural resources that will affect the conceptual model for these PRSs.

Ecological scoping (Appendix B) identified that DP Canyon is a potential foraging area for peregrine falcon and Mexican spotted owl, both federally listed species. However, the surface of the mesa has undergone heavy development historically, but has regrown in the nearly 50 years since the site was used for contractor activities. Comprehensive plant and animal inventories have not yet been performed for the mesa top.

Pursuant to the National Historic Preservation Act of 1966 (amended), a cultural resource survey was conducted at OU 1071 during the summer of 1991 (McGehee 1992, ER ID 28310). The methods and techniques used for this survey conformed to those specified in the Secretary of the Interior's standards and guidelines for archeology and historic preservation. There are no archeological sites in the area of PRSs 73-005 and 73-007) that are eligible for inclusion in the National Register of Historic Places.

4.1.2 Operational History

Construction contractors occupied the area to the south of state road NM 502, between the road and the edge of the mesa, from 1947 until early 1950 (Francis 1996, ER ID 58984). This area parallels state road NM 502 for approximately 2800 ft. Contractor's Row area was occupied by general contractors, timekeeping and dispatching offices where craftsmen reported for work, material storage sheds, parking areas for heavy equipment, and aggregate stockpiles. No laboratory operations were conducted in this area (IT Corporation 1991, ER ID 1905). In 1951, the Atomic Energy Commission (AEC) ordered the contractors to relocate and clean up the area before they vacated. However, certain types of construction or demolition debris are relatively abundant at the site. The majority of the debris is clearly nothing more than road aggregate. Occasional chunks of concrete appear to represent pieces of building foundations or footings. Much of the asphalt debris appears to be the weathered remains of roads or parking lots. The majority of the metal debris is composed of nails, wire, pieces of cast iron pipe, and sheet metal fragments.

There are no records available from the Contractor's Row area to describe maintenance activities, cleaning and storing of equipment, and waste management practices (including whether there was treatment, storage, or disposal of hazardous wastes at the PRS) or any processes and the chemicals used that may have contributed to contamination. There are also no records available giving a description of site accessibility or authorized and unauthorized human use of the site. However, because this area was used by non-laboratory personnel, most likely site access was not restricted. The RCRA corrective action status of PRS 73-005 is Phase I; no sampling has been conducted.

PRS 73-007 was discovered in June 1996, during a field reconnaissance visit to the former Contractor's Row area. The RCRA corrective action status of PRS 73-007 is Phase II after a VCA. The tank and its contents were removed in a VCA conducted by the ER Project. The inlet and outlet drainlines were abandoned in place. There is no information regarding releases or discharges at PRS 73-007. The septic tank, associated drainlines, and outfall point were investigated during the site characterization activities to determine if contamination was present.

4.1.3 Waste Characteristics

This section addresses the potential contaminants that may be present at these PRSs based on the information contained in Section 2.1.1, Site Description, and Section 2.1.2, Operational History. This information is potentially relevant to "waste" only to the extent that "solid waste," as that term is defined under RCRA, is subsequently generated at these PRSs. Solid waste may be generated at a future time if remediation is required. This discussion of potential contaminants in no way implies that the materials present at these PRSs are "solid waste" or "hazardous waste" as those terms are defined under the NMSA, NMAC, RCRA, HSWA, SWDA, or other statutes or regulations.

The PRS descriptions and operational histories provide little or no specific information regarding the potential contaminants that may currently be present at the PRSs. The results presented in Section 4.2.1.2, Sampling, provide information about the potential contaminants that may be at these PRSs.

4.2 Investigatory Approach

4.2.1 Existing Data

4.2.1.1 Nonsampling

This section describes nonsampling investigations that have occurred at these PRSs. Plant and animal inventories, as well as the cultural resource survey have been discussed in the site description Section 4.1.1.

A site survey was conducted as part of a Phase I investigation in 1997. A preliminary review of historic aerial photographs provided no information regarding the location of the area. Several site visits were conducted during which the entire Contractor's Row area was visually examined. In the vicinity of PRS 73-005, (which included PRS 73-007), as it was defined in the work plan, certain types of construction or demolition debris are relatively abundant. However, similar debris is scattered throughout the Contractor's Row area. The mounds referred to in the 1986 field survey are very subtle and essentially blend in with the surrounding topography. The majority of the debris appears to be road aggregate (Appendix A, Photographs 10 and 12). Occasional chunks of concrete appear to represent pieces of building foundations or footings (Appendix A, Photograph 11). Occasional small piles of concrete and asphalt chunks are obviously the result of excess construction materials being dumped to empty the trucks upon their return from the job site. Much of the asphalt debris appears to be the weathered remains of roads or parking lots. The majority of the metal debris is composed of nails, wire, pieces of cast iron pipe, and sheet metal fragments. These last two items were probably from plumbing and heating contractors that were known to have occupied the area.

Geodetic surveys were conducted to provide accurate state plane coordinate information for sample locations and selected site features.

A LANL-ER-AP-4.5 Surface Water Assessment Erosion Matrix score was calculated for this PRS aggregate. The aggregate has a low total erosion matrix score of 27.6. The terminal point of surface water flow is DP Canyon.

An ecological scoping checklist was completed for this PRS aggregate and is included in Appendix B. The checklist was used to identify ecological receptors present and potential pathways to those receptors. The information obtained from the checklist was incorporated into the Conceptual Model (Section 4.2.2).

The ecological scoping process identified potential pathways to terrestrial plant and animal receptors. Ephemeral aquatic communities exist in DP Canyon, but pathways to those receptors are dependent upon a contamination source being identified at PRS 73-005. DP Canyon is listed as foraging habitat for peregrine falcon and Mexican spotted owl, both federally listed.

4.2.1.2 Sampling

This section describes the sampling investigation that has occurred at the PRS 73-007. No sampling has been done at PRS 73-005.

A Phase I RFI investigation and VCA were conducted at PRS 73-007 in June and August 1996. VCA activity and sampling results are documented in the VCA report (LANL 1996, ER ID 59374). The VCA work plan called for the collection of characterization samples from within the tank, beneath associated drainlines, and from the outfall (Figure 4.2.1.2-1). Due to the small size of the tank and the lack of baffles, a single sediment sample (sample 0173-96-0252) and a duplicate (sample 0173-96-0282) were collected from the tank. The samples were collected using a garden hoe to scrape the sludge from the bottom and raise it out of the tank. To determine if a release occurred from the outlet drainline, a single sample (sample 0173-96-0251) was collected from the end of the drainline. Table 4.2.1.2-1 presents the summary of sample information and analyses requested.

TABLE 4.2.1.2-1

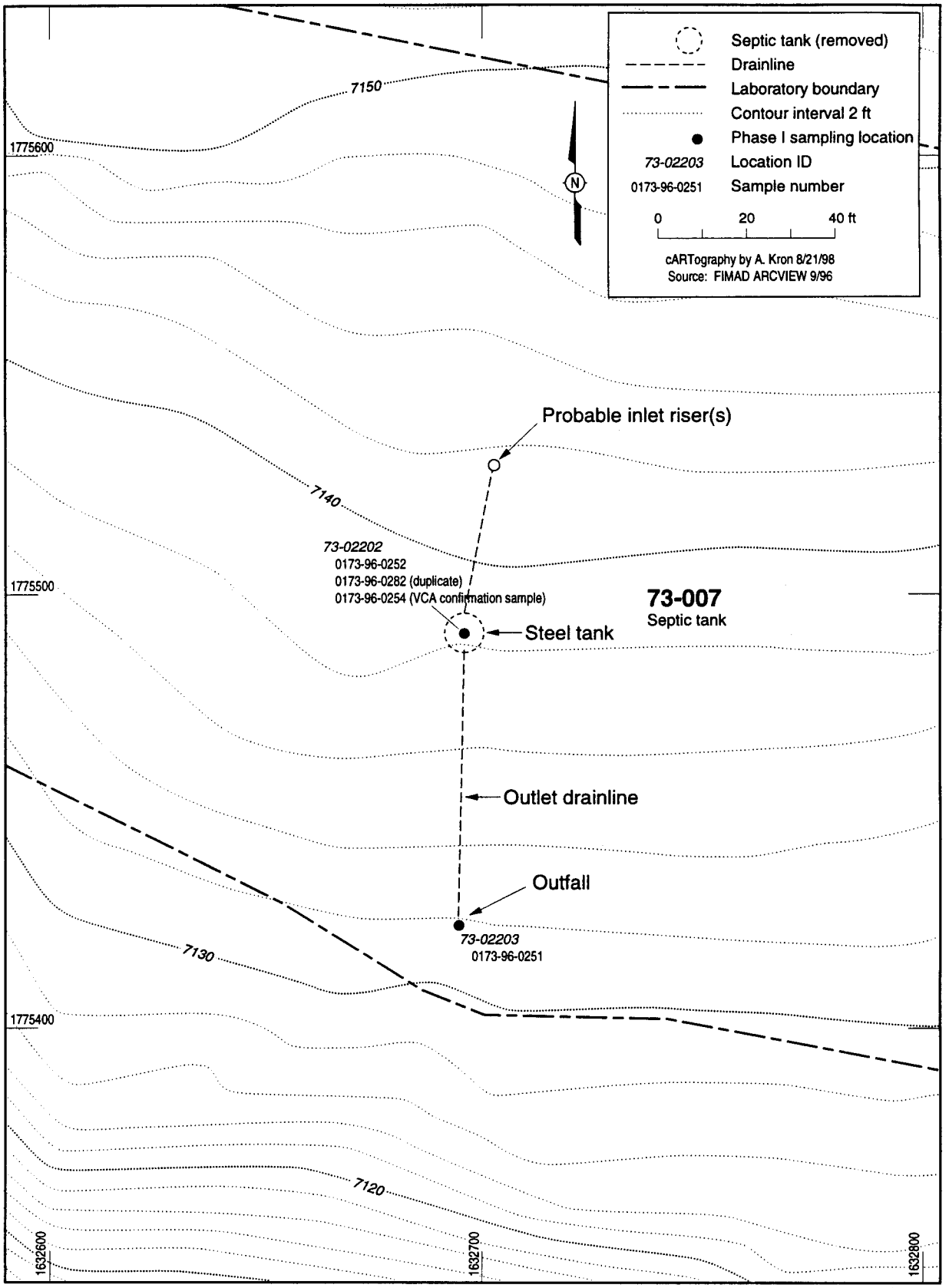
PRS 73-007
SUMMARY OF SAMPLES COLLECTED

Location ID	Sample ID	Location Description and Depth	Matrix	VOCs	SVOCs	PCBs/ Pest.	TAL Metals	RAD[a]
73-02202	0173-96-0252	Inside septic tank	Sediment	2286	2286	2286	2287	2288
73-02202	0173-96-0282	Duplicate of 0173-96-0252	Sediment	2286	2286	2286	2287	2288
73-02203	0173-96-0251	End of outlet pipe at 1.8–2.1 ft	Soil	2286	2286	2286	2287	2288
73-02202	0173-96-0254	Confirmatory sample below tank (5–5.3 ft)	Tuff	2496	2496	2496	2497	NA[b]

a. RAD = radiological analyses: gross alpha/beta/gamma and tritium
b. NA = not analyzed

On August 13, 1996, removal of the septic tank by the ER Project commenced. A backhoe was used to dig down along three sides of the tank. A strap was then threaded through the inlet and outlet openings and used to pull the tank out of the ground (Appendix A, Photograph 16). In spite of the heavy corrosion, there did not appear to be any holes in the tank other than holes knocked through the side during excavation activities.

After removing the septic tank, one confirmation sample (sample 0173-96-0254) was collected from the approximate mid-point beneath the tank. Table 4.2.1.2-1 summarizes the sample information including location ID, sample ID, and analyses requested.



F4.2.1.2-1 / TA-73 SAP / 112598

Figure 4.2.1.2-1. PRS 73-007 Phase I and VCA sampling locations.

Analytical results for the 73-007 characterization and confirmation samples are presented in Table 4.2.1.2-2 and Table 4.2.1.2-3. The data assessment approach was to first compare the preliminary analytical data to BVs. These organic and inorganic data are adequate to support a revised conceptual model. No organic chemicals were detected, and no inorganic chemicals were detected above BVs in the confirmation sample from under the tank. Lead, silver, thallium, and zinc were all detected above BVs in the outfall sample. Additionally, di-n-butylphthalate was detected in the outfall sample. Therefore, extent in the outfall has not been adequately defined. This is discussed in Section 4.2.2.3, Data Gaps. Gross alpha, beta, and gamma radiological and tritium analyses measured no elevated radiological activity.

TABLE 4.2.1.2-2

PRS 73-007
INORGANIC CHEMICALS WITH CONCENTRATIONS EXCEEDING BACKGROUND VALUES (BVs)[a]

Location ID	BV	73-02203	73-02202
Location Description	N/A[b]	Outfall sample	Confirmation sample
Sample ID	N/A	0173-96-0251	0173-96-0254
Lead	22.3	**50**[c]	8.6
Silver	1.0	**2.2**	2 (U)[d]
Thallium	0.73	**1.4**	1.3 (U)
Zinc	48.8	**120**	29

a. Concentrations are in units of mg/kg.
b. N/A = not applicable
c. Bolded values are above BVs, as revised on January 30, 1998 (Ryti et al. 1998, ER ID 58093).
d. (U) = not detected

TABLE 4.2.1.2-3

PRS 73-007
ORGANIC CHEMICALS WITH DETECTED CONCENTRATIONS[a]

Location ID	EQL	73-02203
Location Description	N/A[b]	Outfall Sample
Sample ID	N/A	0173-96-0251
Di-n-butylphthalate	0.33	**0.96**[c]

a. Concentrations are in units of mg/kg.
b. N/A = not applicable
c. Bolded value is a detected value..

4.2.2 Conceptual Model

4.2.2.1 Nature and Extent of Contamination

Although PRSs 73-005 and 73-007 have different release mechanisms and potential contaminant sources, the areal extent of PRS 73-007 is suspected to be entirely contained within the boundary of PRS 73-005. Thus, one nature and extent of contamination evaluation will apply to this PRS aggregate.

The only data available for determining the nature and extent of the PRS 73-005/007 aggregate is provided by the PRS 73-007 Phase I sample data. The two samples taken at PRS 73-007 were analyzed for complete suites of VOCs, SVOCs, PCBs/Pesticides, TAL Metals, and Gross Alpha/Beta/Gamma and Tritium (Table 4.2.1.2-1). No historical information is available to determine what facility was served by the 73-007 septic system, or what materials may have been discharged to the system. No sampling has been conducted to address the nature and extent of contamination for the remainder of the PRS 73-005/007 aggregate.

PRS 73-005 is the major areal component of the PRS 73-005/007 aggregate. PRS 73-005 is defined as a surface disposal area located in the former Contractor's Row along the north edge of DP Canyon. The area housed general contractors and dispatching offices from 1947-1950. No laboratory operations were conducted in the area (See Section 4.1.2, Operational History). Concrete debris present in the area likely originated from demolition activities associated with the relocation of Contractor's Row offices in 1951. Widely scattered piles of asphalt were obviously deposited while still hot, indicating that they may be the result of excess construction materials being dumped from trucks upon return from job sites. Additional asphalt debris appears to be the weathered remains of roads or parking lots. Widely scattered metal debris composed of wire, nails, cast iron pipe, and sheet metal fragments can also be found within this PRS. This metal debris is probably from plumbing and heating contractors that occupied the area, and/or from demolition activities associated with the relocation of the contractors. Although scattered debris can be found along the entire 2800 ft length of Contractor's Row, it seems to be more concentrated within the 400 ft by 200 ft oval defined in the RFI Work Plan for OU 1071 (LANL 1994, ER ID 7667). Individual debris aggregates are small and widely scattered. The entire area is heavily vegetated and appears similar to surrounding undisturbed areas. No records are available to describe activities or waste management practices which may have contributed to contamination.

PRS 73-007 encompasses a small area within the PRS 73-005/007 aggregate. PRS 73-007 was defined as a septic system, including a cylindrical steel septic tank, drainlines, and outfall. The septic tank was removed as a VCA in 1996 (LANL 1996, ER ID 59374) and the outlet and inlet lines were left in place. No records exist to determine what structure was served by this septic system. The inlet line was constructed of 4-in.-diameter cast iron pipe, while the outlet drainline was constructed of 4 in. VCP. The system was engineered so that overflow from the tank would be released at the outfall. One sample was taken at the outfall of PRS 73-007, and one confirmation sample was taken beneath the septic tank after VCA activities in 1996 (Table 4.2.1.2-1). The outfall sample for 73-007 detected one SVOC (di-n-butylphthalate), and four inorganic chemicals (lead, silver, thallium, and zinc) above BV. The four inorganic contaminants were all present at levels approximately twice BVs. No contaminants were detected in the confirmation sample taken below the septic tank, indicating that the tank had not leaked.

Hydrologic features which could be impacted by contamination from these PRSs are discussed in Section 4.1.1, Hydrology. Both PRS 73-005 and 73-007 have a LANL-ER-AP-4.5 Surface Water Assessment Erosion Matrix score of 27.6, indicating a low erosion potential, with a Surface Water Runoff subscore of 24.0. The terminal point of water flow is DP Canyon. Two alluvial wells in DP Canyon (LAUZ-1 and

LAUZ-2) are located approximately 750 ft southeast of PRS 73-005. PRS 73-005 is bounded by two large surface drainage channels which receive runoff from portions of the airport and state road NM 502. Given their location relative to PRS 73-007 it is unlikely that any discharge from the 73-007 outfall would flow directly into these drainage channels.

The nature of the contamination at PRS 73-007 septic system is provided by the Phase I sample data cited above. The complete chemical suites for which analyses were conducted capture the nature of contamination present. In addition to the contaminants detected at the outfall, several VOCs were detected within the tank itself. Further investigation may prove these detects to be a data quality issue, as it seems unlikely that volatile chemicals would remain in a tank that was dry and rusty, and had been inactive for almost 50 years. The extent of contamination at PRS 73-007 has not been identified. Although there was no evidence that the septic tank leaked, no samples were taken beneath the inlet and outlet drainlines. The vertical and horizontal extent of contamination at the outfall has not been characterized.

4.2.2.2 Fate and Transport

The Phase I sampling of PRS 73-007 identified four inorganic chemicals (lead, silver, thallium, zinc) at the outfall present at concentrations greater than BVs (Table 4.2.1.2-2). One SVOC (di-n-butylphthalate) was also detected. No radiochemicals were detected. General chemical and physical properties which relate to the fate of these chemicals in the environment are provided in Appendix D. No sampling has been conducted in the surface disposal area of PRS 73-005.

Phase I sampling data provide no information on the valence states of the inorganic chemicals detected at this site. Lead, silver, thallium, and zinc are not volatile in any of their forms, so volatilization is not an exposure or redistribution pathway for these chemicals. Concentrations of all of the inorganic chemicals detected in the 73-007 outfall occur at levels 2 to 2.5 times BVs. Di-n-butylphthalate is moderately soluble in water and could be transported horizontally via surface water runoff and vertically via infiltration. The PRS 73-005 aggregate has a LANL-ER-AP-4.5 Surface Water Assessment Erosion Matrix score of 27.6 (low erosion potential), with a surface water runoff subscore of 24. The terminal point of water transport is DP Canyon.

A generalized conceptual transport model for contamination at PRS 73-005 and 73-007 is provided in Figure 4.2.2.2-1. Contamination at the 73-007 outfall and the 73-005 surface disposal area is expected to affect surficial soils. Potential transport mechanisms are surface water runoff/soil erosion and air entrainment of potentially contaminated particulate matter. The primary exposure pathways and their potential significance to ecological and human receptors are presented in Figure 4.2.2.2-1. An ecological scoping checklist was completed for this PRS aggregate and is included in Appendix B. The stream in DP Canyon is ephemeral, flowing only in response to storm events, and ephemeral aquatic communities are present. Alluvial water is also present in the canyon directly downslope from these PRSs (Section 4.1.1, Hydrology). Alluvial wells LAUZ-1 and LAUZ-2 detected water 4.5 ft below the surface in DP Canyon. Contamination from these PRSs could potentially reach alluvial or surface water in DP Canyon, although the completion of this transport pathway is dependent on identifying a large, soluble contaminant source term for the PRS 73-005 and 73-007 aggregate. The results of the Phase II sampling will be provided to the Canyons Focus Area for use in cumulative assessments of the DP Canyon watershed.

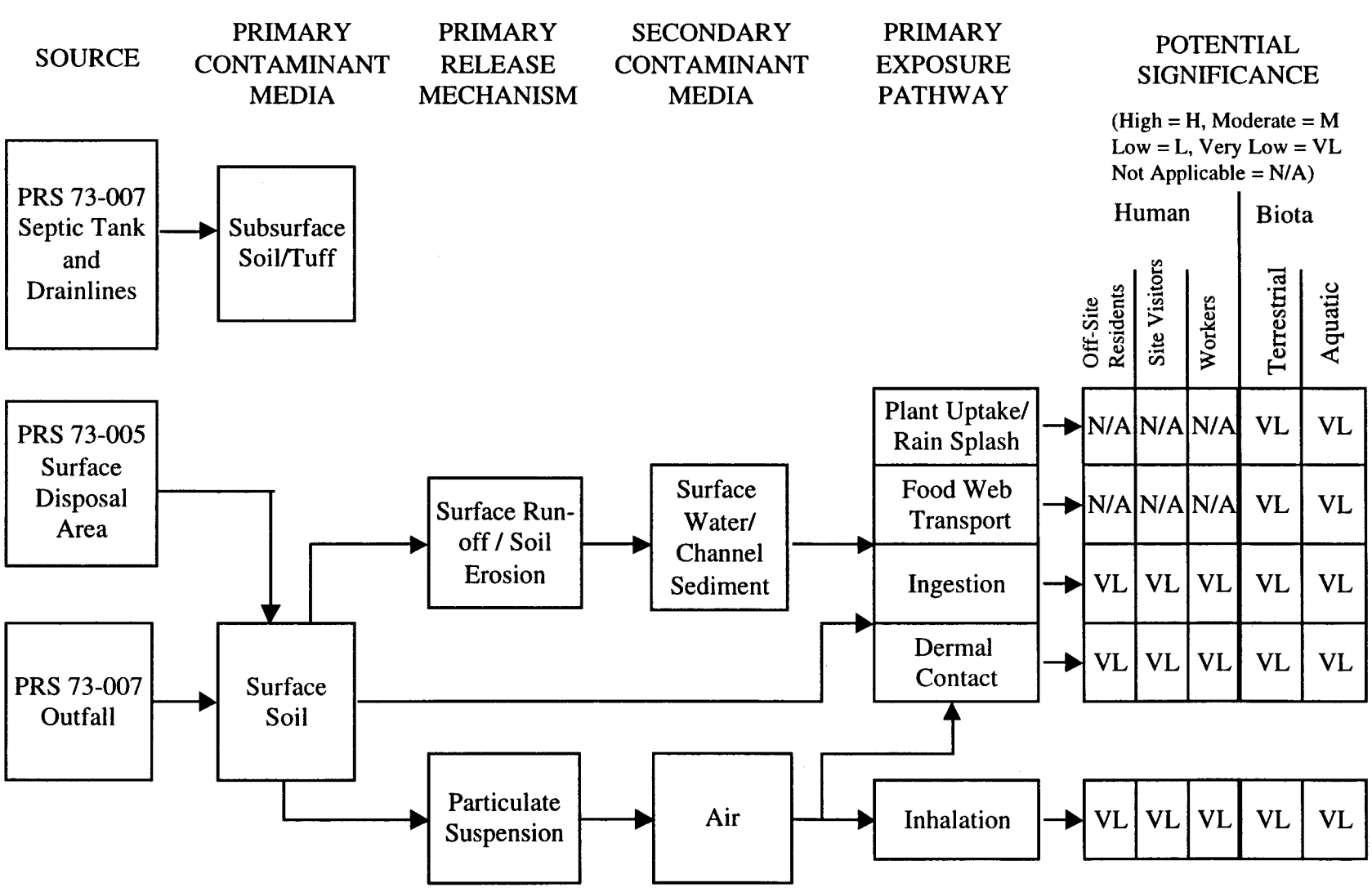


Figure 4.2.2.2-1. Conceptual model of contaminant transport at PRS 73-005 aggregate.

4.2.2.3 Data Gaps

In the Phase I RFI for PRS 73-007, samples were collected within the septic tank, below the septic tank, and at the outfall. No characterization was conducted to evaluate whether the drainlines may have leaked and potentially contaminated the soil or tuff below the drainlines.

The data collected from inside of the septic tank and below the septic tank are judged to be adequate to evaluate releases from this part of the septic system. This information and the visual observation of the apparent structural integrity of the septic tank would suggest that there were no releases from the steel septic tank itself (no detected chemicals below the tank).

To evaluate releases from an engineered septic system, we should consider how liquids were intended to flow through this system. The most likely point of release to the environment would be at the outfall. Because VCP drainlines were grouted, releases at pipe joints may have occurred, but are less likely than at the outfall. As mentioned above, visual inspection of the septic tank and evaluation of Phase I sample data provide no evidence that the septic tank itself had leaked. The major data gap for the septic system is the lack of data at the outfall that would suggest trends in contaminant concentration from this potential release point. As this outfall area is contained within the surface debris part of the PRS 73-005 and 73-007 aggregate, sample sites at the outfall must be chosen carefully and the sample results evaluated relative to other potential contaminant sources (i.e., surface debris). See Section 4.2.3.2, Media Characterization.

The other major data gap for the PRS 73-005 and 73-007 aggregate is an evaluation of the nature and extent of chemical contamination in surface soil that can be associated with visible debris. Thus, one data gap is the spatial mapping of the major surficial debris in the former Contractor's Row area. Once the extent of debris has been delineated, samples can be collected to determine the nature and extent of soil contamination associated with specific concentrated areas of debris.

4.2.3 Sampling Activities

This section describes the sampling design and the rationale for the design based on the site conceptual model presented in Section 4.2.2.

The sampling design at both PRSs will not be influenced by field test kits or other on-site analytical tools. There is no plan to use contaminant collocation or correlation to estimate results for any analytes. The analytical suites to be requested for all samples collected during the planned sampling activities include TAL metals, VOCs (only below a 6-in. depth), SVOCs, organochlorine pesticides, and PCBs.

Analytical data generated by these sampling activities will be compared to the appropriate LANL BVs for inorganic chemicals and radionuclides (Ryti et al. 1998, ER ID 58093) and EQLs for organic chemicals (LANL 1995, ER ID 49738). Field duplicate samples will be collected to evaluate data quality.

Based on the sampling design discussion above and in Sections 4.2.3.1 and 4.2.3.2, the samples to be collected are presented in Tables 4.2.3-1 and 4.2.3-2, and the proposed sampling locations are shown on Figure 4.2.3-1.

TABLE 4.2.3-1

PRS 73-007
PROPOSED SAMPLE LOCATIONS AND ANALYTICAL SUITES[a]

Location ID	Location Description and Depth	Matrix	VOCs[b]	SVOCs	PCBs/ Pest.	TAL Metals[c]
73-02203	Deeper sample beneath outfall sample 0173-96-0251	Soil	X	X	X	X
TBD[d]	Additional outfall samples (3)	Soil	X	X	X	X
TBD	Confirmation sample below outlet drainline	Soil	X	X	X	X
TBD	Confirmation sample below inlet drainline	Soil	X	X	X	X
TBD	Sample adjacent to inlet risers	Soil	X	X	X	X
TBD	Additional samples for horizontal and vertical extent	Soil	X	X	X	X
TBD	QA/QC sample (duplicate)	Soil	X	X	X	X

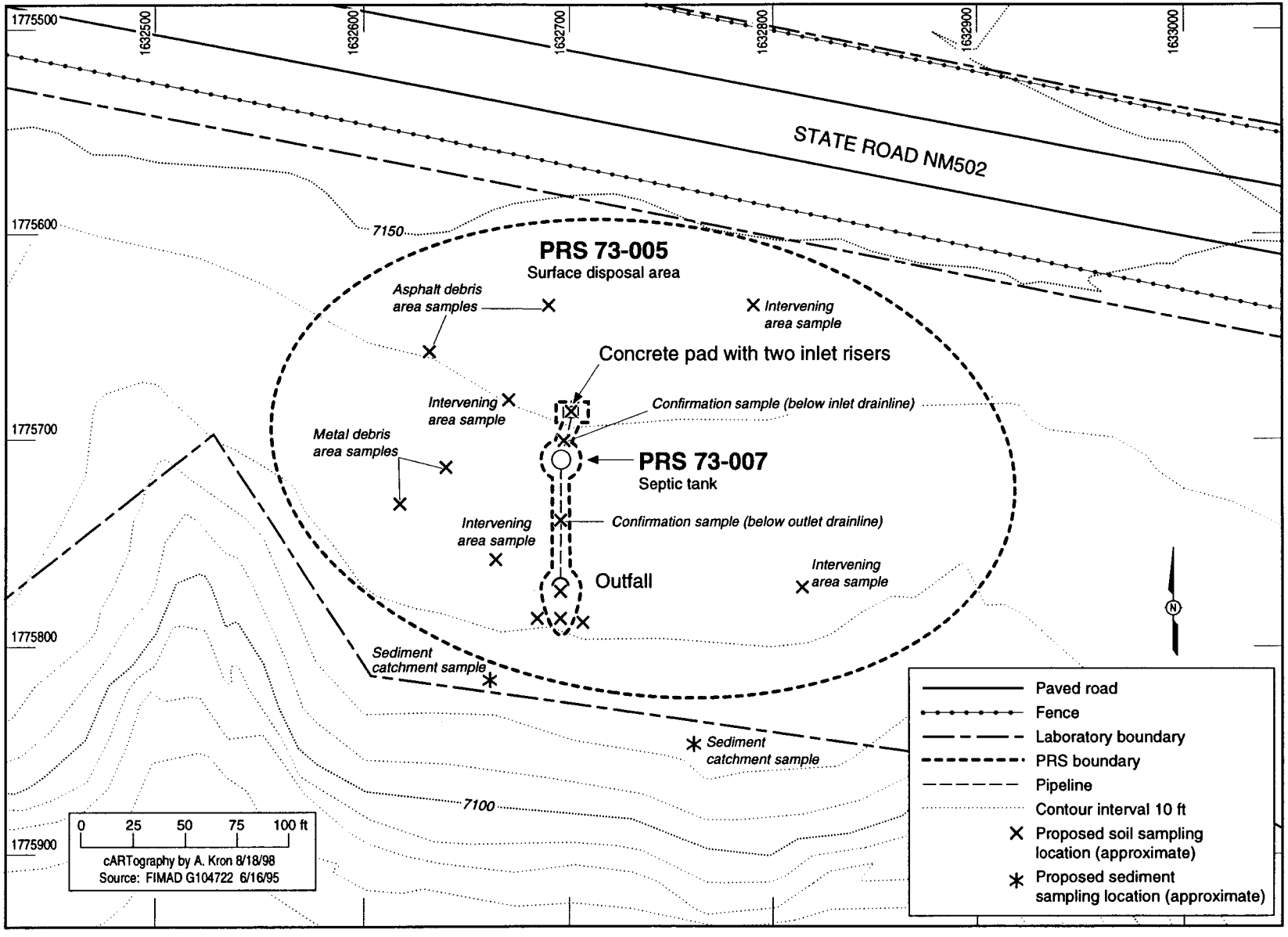
a. All samples will be grab samples.
b. VOCs greater than 6 in. deep
c. See Table 6.1-1 for special required detection limits.
d. TBD = to be determined

TABLE 4.2.3-2

PRS 73-005
PROPOSED SAMPLE LOCATIONS AND ANALYTICAL SUITES[a]

Location ID	Location Description and Depth	Matrix	VOCs[b]	SVOCs	PCBs/ Pest.	TAL Metals[c]
TBD[d]	Samples in asphalt debris area (2 locations, 2 depths each)	Soil	X	X	X	X
TBD	Samples in metal debris area (2 locations, 2 depths each)	Soil	X	X	X	X
TBD	Samples in intervening areas (3 locations, 2 depths each)	Soil	X	X	X	X
TBD	Samples in sediment catchments (2 locations, 2 depths each)	Soil	X	X	X	X
TBD	Additional samples for definition of extent	Soil	X	X	X	X
TBD	QA/QC sample (duplicate)	Soil	X	X	X	X

a. All samples will be grab samples.
b. VOCs greater than 6 in. deep
c. See Table 6.1-1 for special required detection limits.
d. TBD = to be determined



F4.2.3-1 / TA-73 SAP / 112298

Figure 4.2.3-1. Proposed sampling locations for PRSs 73-005 and 73-007.

PRS 73-007

It is expected that the volume of media impacted by potential leaks from the PRS 73-007 inlet and outlet drainlines is small. The gravity-driven construction of the drainlines that required a downward slope would have ensured proper drainage to the outfall, the most likely point of release. This prevented water from backing up in the drainlines and creating a pressurized situation that might have caused leaks through cracks and poorly sealed pipe connections. Although there are no records to indicate what structure(s) was served by this septic system, it is assumed, based on the relatively small size of the tank and the 4-in. diameter of the drainlines, that the volume of liquid waste received by the system would have been small. It is also assumed that flow through the drainlines would have been intermittent. It is certain that the septic system functioned for no more than three years.

The proposed samples will be collected at the outfall and directly beneath the drainlines where potential leaks may have occurred. The single outfall location identified during the Phase I RFI where COPCs exceeded BVs or EQLs will be resampled at a deeper depth(s) for the purpose of defining vertical extent of contamination. Samples will also be collected downgradient of the outfall for the purpose of defining horizontal extent. To facilitate the Phase II RFI, the inlet and outlet drainlines will be removed, including the cast iron riser pipes that are thought to be the origin of the inlet drainline. At least one sample will be collected in the vicinity of the cast iron riser pipes. Additional locations may be sampled based on visual evidence of leaks.

PRS 73-005

There is no historical data regarding the nature and extent of potential contamination at PRS 73-005 that is defined as a surface disposal area located in the former Contractor's Row. However, it is believed that the scattered debris in this area likely originated from demolition and restoration activities associated with the relocation of Contractor's Row in 1951. The majority of the debris is composed of gravel, concrete fragments, asphalt piles and fragments, and metal fragments.

It is expected that the spatial distribution of potential contamination would be related to the distribution of debris, particularly the metal and asphalt debris since these materials can be potential sources of inorganic and organic chemicals. The working hypothesis is that the gravel and concrete fragments would not have acted as a source of contamination since these materials do not inherently contain chemicals of concern.

Sampling locations at PRS 73-005 will be chosen to evaluate selected areas of visible debris, selected intervening areas with little or no debris, and selected drainage channels that receive storm water runoff only from the site.

4.2.3.1 Contaminant Source

At PRS 73-007, the only potential contaminant source is sediment that may be present in the drainlines. The septic tank and its contents were removed as a VCA in 1996. If sediment is encountered in the drainlines, samples will be collected for waste characterization purposes. The results of these samples will also help to further define the nature of potential contamination at this PRS.

At PRS 73-005, the asphalt and metal debris are believed to constitute the contaminant source. There are no plans to sample these materials; however, soils in the areas containing the debris will be sampled (Section 4.2.3.2, Media Characterization).

4.2.3.2 Media Characterization

PRS 73-007

At PRS 73-007, the initial task will be to define the extent of contamination at the outfall. A deeper sample will first be collected 2 ft below the original sample at Location ID 73-02203. Additional samples will be collected downgradient of this location. The precise number and location of these samples will be determined based on a careful examination of the outfall channel. As it exists, the channel is subtle and has been partially infilled, presumably by the site restoration activities carried out when Contractor's Row was relocated. This presumption is reinforced by the fact that the outfall was found to be covered by 1.5 ft of fill material containing asphalt debris. An estimated configuration of the former outfall channel will be determined and the additional sampling locations will be selected. Initially, one sampling location will be positioned within the axis of the former channel and two locations will be positioned perpendicular to the axis of the channel, one per side. The initial distance of these samples from the outfall and from the axis of the channel will be approximately 20 ft and 5 ft, respectively. Additional samples, as needed to define horizontal extent, will be added at similar distance increments from the previous samples. Samples will be collected at depths determined to roughly correspond to the original bed of the outfall channel. Additional samples will also be collected at 2 ft depth intervals, as needed, to define vertical extent (see Section 1.2).

The entire inlet and outlet drainlines will be removed to facilitate the investigation. As the drainlines are removed, the underlying soil or tuff will be visually inspected for staining or other signs of leaks. If visual evidence indicates potential contamination, a sample will be collected at that location. Two confirmatory samples will be collected from immediately beneath the portions of the drainlines not sampled for other reasons, one beneath the inlet drainline and one beneath the outlet drainline. One location, immediately below the concrete pad surrounding the cast iron riser pipes, will also be sampled. The initial biased and confirmatory samples will be examined for visual evidence of contamination. If evidence of possible contamination is noted, a deeper sample will be immediately collected at that location, 2 ft below the initial sample.

Samples will be collected using a spade, hand auger, or powered hand augering equipment to advance the borehole, depending upon the type of material being removed and the depth of contamination. A fourth option will be to use a backhoe to obtain the deeper sample(s). The final selection of a sampling method will be made in the field based on soil conditions.

PRS 73-005

The initial task at PRS 73-005 will be to conduct a site survey that will consist of mapping and physically marking the locations of debris within the PRS boundary as established in the RFI Work Plan (LANL 1994, ER ID 7667). In conjunction with the site survey, a geomorphologic survey will also be conducted to identify drainage channels that only receive storm water runoff from the area of the PRS. Sediment catchments that would provide suitable sampling locations will be identified within these drainage channels.

A total of 10 sampling locations will be selected: two within areas containing abundant asphalt debris; two within areas containing abundant metal debris; four within intervening areas containing little or no debris; and two within sediment catchments (one within each of the two primary runoff drainage channels). Two samples will be collected at each location, one from the surface (0 to 6 in.) and a second from 2.5 to 3 ft bgs. Samples will be examined for visual evidence of contamination. If evidence of possible

contamination is noted in the deep sample, deeper samples will be immediately collected at that location until there is no visual evidence of contamination. Additional deeper samples will be collected if it is determined by fixed-site laboratory data that deeper sampling is required. No horizontal offset locations will be sampled until the initial sampling results are available. If necessary, a strategy will then be developed for a second phase of sampling during which the horizontal extent of contamination will be addressed.

Samples will be collected using a spade, hand auger, or powered hand augering equipment to advance the borehole, depending upon the type of material being removed and the depth of contamination. A backhoe may be used to obtain the deeper sample(s) if the methods described above are ineffective. The final selection of a sampling method will be made in the field based on soil conditions.

5.0 AOCs C-73-005(a through f) SEPTIC PITS

5.1 Characterization and Setting

5.1.1 Site Description

During a 1996 site survey, six unlined pits of various dimensions ranging from 3 to 6 ft wide, 5 to 12 ft long, and 2.5 to 6 ft deep were discovered on DOE property on East Mesa south of state road NM 502, between the road and the north edge of DP Canyon, in TA 73, OU 1071 (Figure 5.1.1-1). They are located within the former Contractor's Row that extended from near the west end of the runway to the east for approximately 2800 ft (Appendix A, Photograph 1). It is likely these pits received sanitary waste from facilities within the former Contractor's Row during the period from approximately 1947 to 1951. However, there are no available records of their construction or operation, and no engineering drawings or other historical information that illustrate former facility or septic pit locations within this area. Only a single set of aerial photographs dated 1949 were discovered that show Contractor's Row (Appendix A, Photograph 4). This photograph was taken at an oblique angle, and it is not possible to see any of the pits or determine with certainty which buildings they might have served. These pits were designated as AOCs C-73-005(a through f) and tentatively identified as septic pits.

The septic pits were all excavated directly into tuff with no secondary walls or floors. The excavated material was piled next to the pits. There was no evidence that any of the pits had contained baffles. Pit C-73-005(a) was constructed with a 4-in.-diameter VCP inlet drainline and was also connected to the edge of the mesa by a shallow trench that may have contained an outlet drainline at one time, or may have acted directly as an open drainage ditch (Appendix A, Photographs 17 and 18). The C-73-005(b) pit was constructed with a VCP outlet drainline, but no visible inlet drainline (Appendix A, Photographs 19 and 20). The other four pits contained no visible inlet or outlet lines or trenches (Appendix A, Photographs 21, 22, 23 and 24). The pits contained fill material ranging from 1 to approximately 3.8 ft thick when they were discovered. For the most part, the fill material consisted of natural soil and tuff fragments that appeared to have washed into the pits over the years. Some of the fill material contained abundant organic debris, and occasional glass, metal, and charred wood fragments that may have been disposed in the pits when they were abandoned. The total surface area of the PRSs and the extent of contamination will be determined during the execution of this SAP.

The former Contractor's Row area is currently vacant land, separated from the state road NM 502 right of way by a 4-ft high barbed wire fence. No use is presently being made of this land, and the future land use has not been determined. There are no other PRSs that potentially affect the recommendations for these AOCs. There are no EM/ER, D&D, or facility management activities that will impact these AOCs. It is anticipated that this land will be transferred to a new owner.

PHYSICAL DESCRIPTION: Geomorphology, Topography, and Surface Geology

Geology

Soils in the vicinity of Contractor's Row are composed predominantly of reworked soil. Construction and demolition of the surrounding facilities resulted in significant disturbance of the natural soils. In general, natural surficial soils, where they still exist, are very thin and sandy with relatively low clay content. With depth, more well-developed soils may occasionally be encountered with relatively high percentages of reddish clay. Depth to bedrock at these PRSs has not been well defined. There are outcrops of Bandelier tuff on the surface. During earlier sampling activities, soil as thick as 2 ft was encountered.

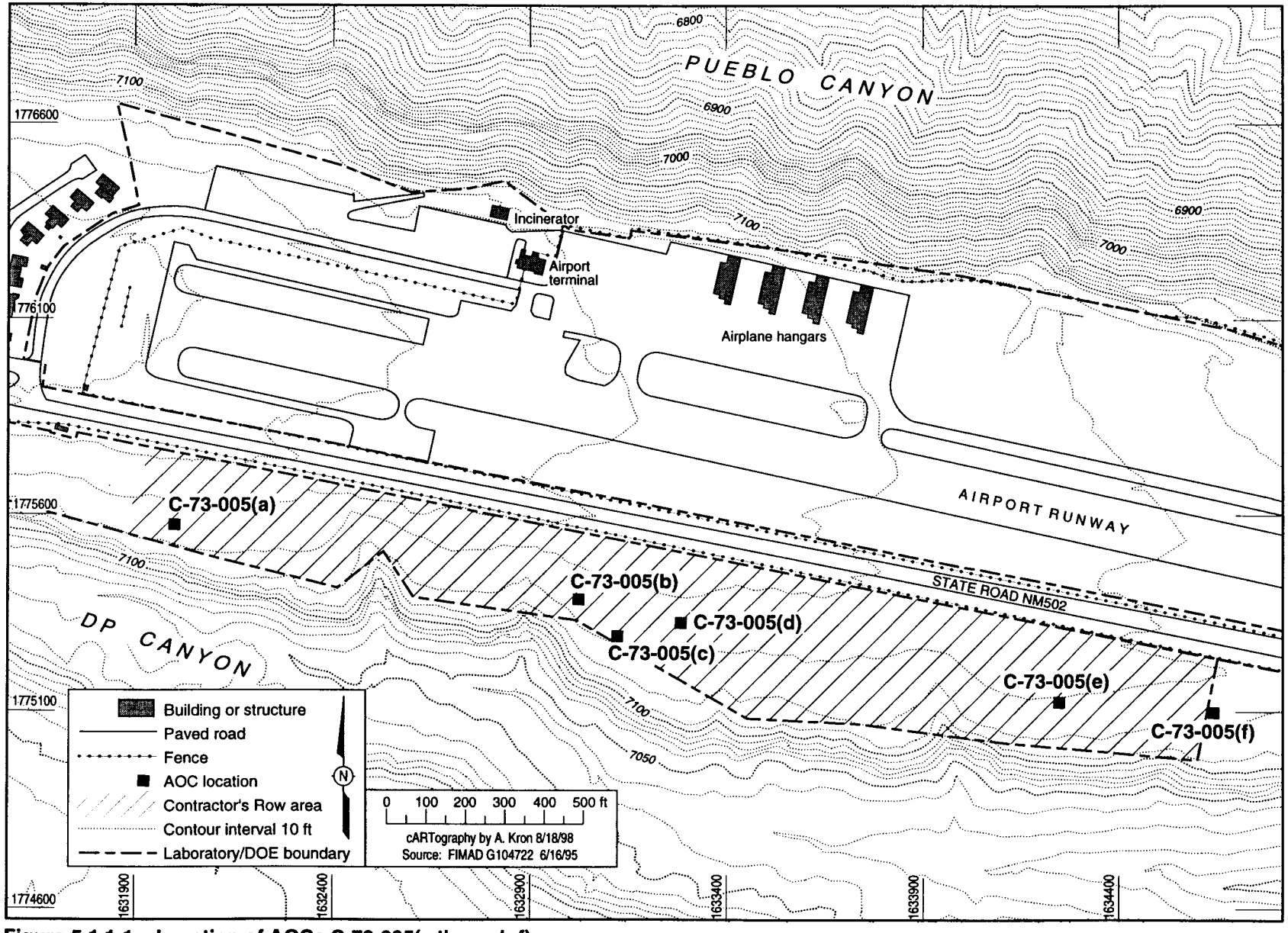


Figure 5.1.1-1. Location of AOCs C-73-005(a through f).

The vegetative cover consists of native grasses, piñon, juniper, oak and pine that covers approximately 75 to 100% of the land. The average slope of this mesa top land is approximately 10%.

Hydrology

Surface Water Hydrology. Runon to the areas surrounding the AOCs is from the north, in the form of sheetflow toward DP Canyon. The average slope of these areas is less than 10%. Runoff flows into natural, first-order drainage channels, some of which may also receive runoff from areas along state road NM 502 and the airport. (See also Appendix C, LANL-ER-AP-4.5 Surface Water Assessment.) These drainage channels flow directly south into DP Canyon. Sediment catchments within these drainage channels represent areas in which potential contaminants may collect. During the 1996 site survey, no debris was noted in these watercourses. The stream at the bottom of DP Canyon is ephemeral.

Subsurface Water Hydrology. DP Canyon contains alluvial wells LAUZ-1 and LAUZ-2 (Figure 4.1.1-2). These two wells are located approximately 750 ft southeast of AOC C-73-005(d). The total depth of each well is 15 ft. Alluvial water was encountered in both wells at approximately 4.5 ft below the surface. The saturated zone at the time was approximately 3.5 ft thick. Alluvial water is thought to be the source for DP Spring. This spring flows from the north canyon wall in the lower portion of DP Canyon, approximately 4000 ft downstream from AOC C-73-005(d) (Figure 4.1.1-2).

The deep well LADP-4 was drilled in 1993 in DP Canyon to the depth of 800 ft to determine whether there is perched ground water beneath DP Canyon. It is located approximately 750 ft south of AOC C-73-005(d) (Figure 4.1.1-2). No perched ground water was found beneath DP Canyon (LANL 1998, ER ID 59373).

ASSESSMENT OF ECOLOGICAL, CULTURAL, AND BIOLOGICAL RESOURCES

There are no specific climatic influences or cultural resources that will affect the conceptual model for these PRSs.

Ecological scoping (Appendix B) identified that DP Canyon is a potential foraging area for peregrine falcon and Mexican spotted owl, both federally listed species. However, the surface of the mesa has undergone heavy development historically, but has regrown in the nearly 50 years since the site was used for contractor activity.

Pursuant to the National Historic Preservation Act of 1966 (amended), a cultural resource survey was conducted at OU 1071 during the summer of 1991 (McGehee 1992, ER ID 28310). The methods and techniques used for this survey conformed to those specified in the Secretary of the Interior's standards and guidelines for archeology and historic preservation. There are no archeological sites in the area of the AOCs that are eligible for inclusion in the National Register of Historic Places.

5.1.2 Operational History

Construction contractors occupied the area to the south of state road NM 502, between the road and the edge of the mesa, from 1947 until early 1950 (Francis 1996, ER ID 58984). Contractor's Row area was occupied by general contractors, timekeeping and dispatching offices where craftsmen reported for work, material storage sheds, parking areas for heavy equipment, and aggregate stockpiles. This area parallels state road NM 502 for approximately 2800 ft between the road and the edge of the mesa. No laboratory operations were conducted in this area (IT Corporation 1991, ER ID 1905). In 1951, the AEC ordered the contractors to relocate and clean up the area before they vacated. During a 1996 site survey, shallow pits

excavated into the tuff were discovered at the site. Based on the fact that at least two had inlet and/or outlet drainlines, these pits were assumed to have received liquid (sanitary) waste from facilities within the former Contractor's Row.

There are no records available from the Contractor's Row area to describe maintenance activities, cleaning and storing of equipment, and waste management practices (including whether there was treatment, storage, or disposal of hazardous wastes at the AOCs) or any processes and the chemicals used that may have contributed to contamination. Information regarding releases or discharges is unknown. There are also no records available giving a description of site accessibility or authorized and unauthorized human use of the site. However, because this area was used by non-laboratory personnel, most likely site access was not restricted.

5.1.3 Waste Characteristics

This section addresses the potential contaminants that may be present at these AOCs based on the information contained in Section 2.1.1, Site Description, and Section 2.1.2, Operational History. This information is potentially relevant to "waste" only to the extent that "solid waste," as that term is defined under RCRA, is subsequently generated at these AOCs. Solid waste may be generated at a future time if remediation is required. This discussion of potential contaminants in no way implies that the materials present at these AOCs are "solid waste" or "hazardous waste" as those terms are defined under the NMSA, NMAC, RCRA, HSWA, SWDA, or other statutes or regulations.

The AOC descriptions and operational histories provide little or no specific information regarding the potential contaminants that may currently be present at the AOCs. The Phase I RFI results presented in Section 5.2.1.2 provide the only direct information about the potential contaminants that may be at these AOCs.

5.2 Investigatory Approach

5.2.1 Existing Data

5.2.1.1 Nonsampling

This section describes nonsampling investigations that have occurred at the AOCs. Plant and animal inventories, as well as the cultural resource survey have been discussed in Section 5.1.1.

A site survey was conducted as part of a Phase I RFI investigation in 1997. A preliminary review of historic aerial photographs provided no information regarding the location of the area. Several site visits were conducted during which the entire Contractor's Row area was examined visually. Certain types of construction or demolition debris are scattered throughout the Contractor's Row area. The majority of the debris is nothing more than road aggregate. Occasional chunks of concrete appear to represent pieces of building foundations or footings. Occasional small piles of concrete and asphalt chunks are obviously the result of excess construction materials being dumped to empty trucks upon their return from the job site. Much of the asphalt debris appears to be the weathered remains of roads or parking lots. The majority of the metal debris is composed of nails, wire, pieces of cast iron pipe, and sheetmetal fragments. These last two items were probably from plumbing and heating contractors that were known to have occupied the area.

Geodetic surveys were conducted to provide accurate state plane coordinate information for the sample locations and selected site features.

LANL-ER-AP-4.5 Surface Water Assessment was calculated for this PRS aggregate. The aggregate has a total erosion matrix score of 27.6. The terminal point of surface water flow is DP Canyon.

An ecological scoping checklist was completed for this AOC aggregate and is included in Appendix B. The checklist was used to identify ecological receptors present and potential pathways to those receptors. The information obtained from the checklist was incorporated into the conceptual model (Section 2.2.2). The ecological scoping process identified potential pathways to terrestrial plant and animal receptors. Ephemeral aquatic communities exist in DP Canyon, but pathways to those receptors are dependent upon a contamination source being identified at PRS 73-005. DP Canyon is listed as foraging habitat for peregrine falcon and Mexican spotted owl, both federally listed species.

5.2.1.2 Sampling

Two samples were collected from the bottom of each septic pit (Figures 5.2.1.2-1 and 5.2.1.2-2). To determine if releases occurred from the outlet drainline, one sample (sample 0173-96-0264) was collected from the C-73-005(b) outfall. One sample (sample 0173-96-0260) was also collected from the C-73-005(a) outlet trench. The fill material was sampled with a stainless steel hand auger (Appendix A, Photograph 21). The pits were subsequently backfilled to eliminate any physical hazards presented by their continued existence. Table 5.2.1.2-1 summarizes the characterization sample information for the AOCs including the sample numbers and analyses requested.

Analytical results for the characterization samples are presented in Table 5.2.1.2-2 and Table 5.2.1.2-3. The data assessment approach was to compare the analytical data to BVs or EQLs. These organic and inorganic data are adequate to support a revised conceptual model (see Section 5.2.2.1).

The inorganic chemicals copper, lead, manganese, mercury, silver, thallium, and zinc were detected at concentrations greater than background values. The organic chemicals DDT, 4-isopropyl toluene, acetone, toluene, and a class of chemicals, PAHs, were detected. Extent of these chemicals has not been adequately defined. This is discussed in Section 5.2.2.3, Data Gaps.

5.2.2 Conceptual Model

5.2.2.1 Nature and Extent of Contamination

The preliminary conceptual model for the nature and extent of contamination at this site is provided by the Phase I sample data. Phase I sample data of AOC C-73-005(a through f) identified seven inorganic chemicals present above background values. Thirteen organic chemicals were also detected at these AOCs. All samples collected from these AOCs were analyzed for complete suites of VOCs, SVOCs, PCBs/pesticides, TAL metals, and gross alpha/beta/gamma and tritium. Although knowledge of the operational history of the site is insufficient to suggest what types of waste may have been disposed into these pits, it is likely that the sampling location density and the laboratory analyses conducted adequately define the nature of contamination at these sites.

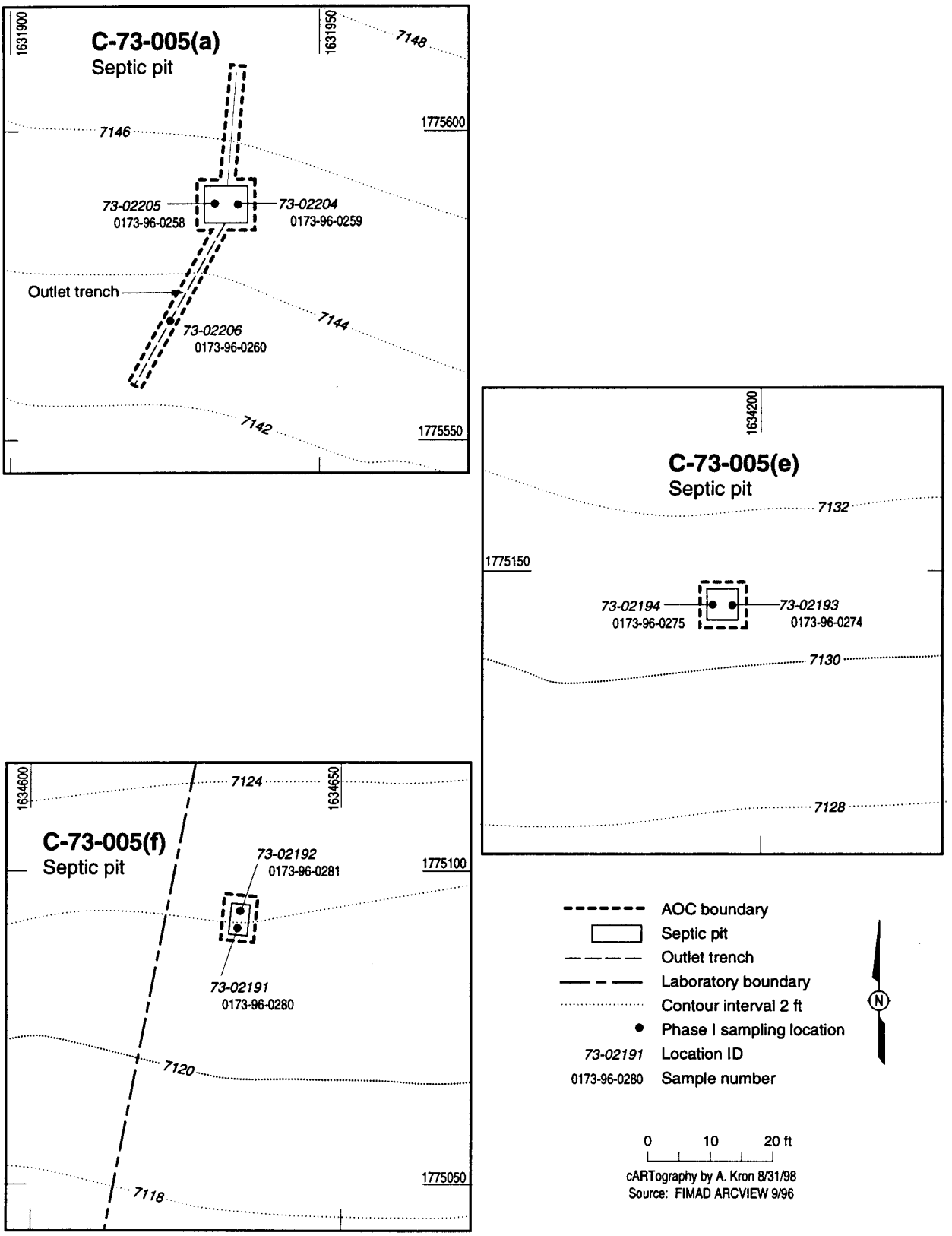


Figure 5.2.1.2-1. Phase I sampling locations for AOCs C-73-005(a, e, and f).

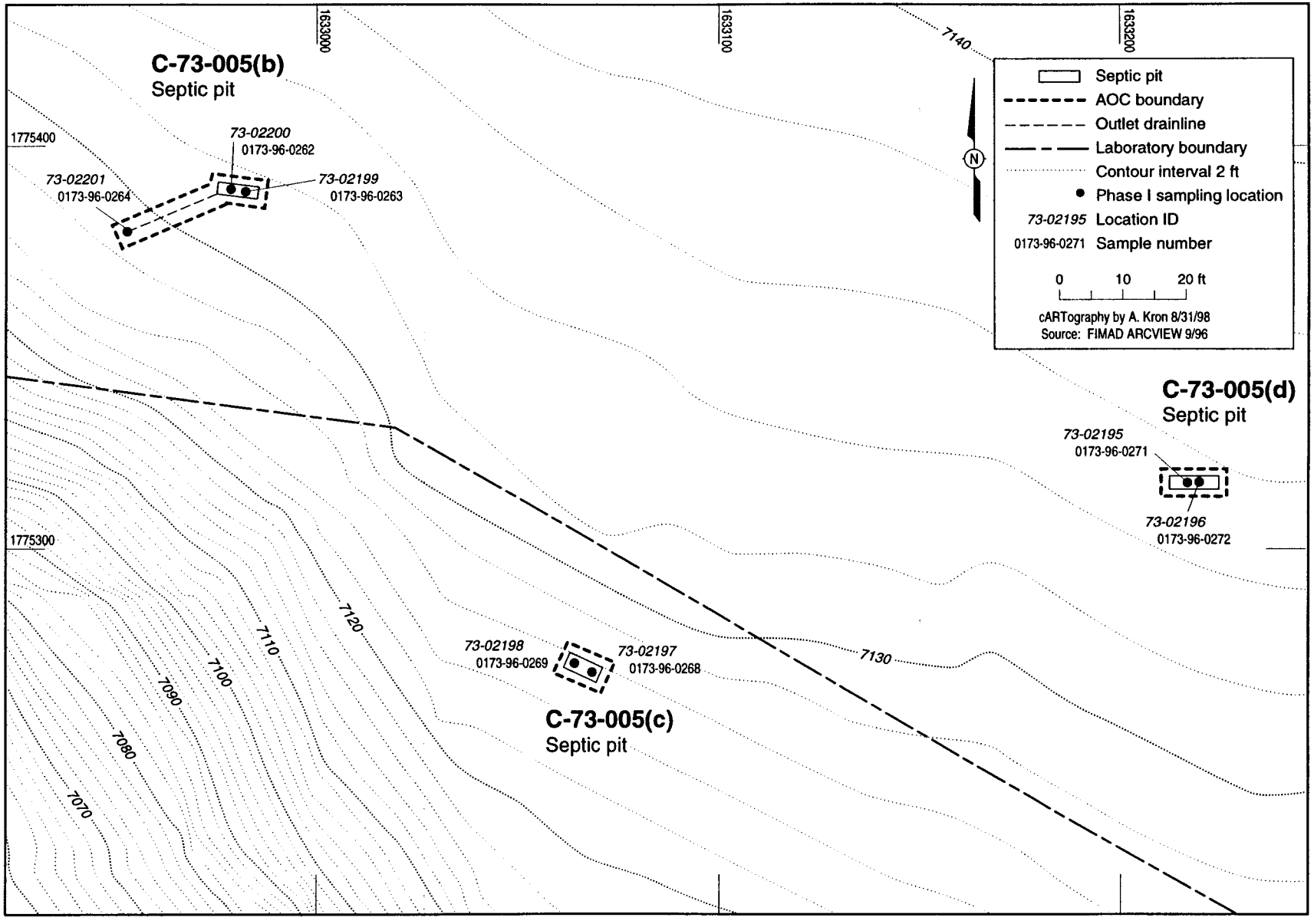


Figure 5.2.1.2-2. Phase I sampling locations for AOCs C-73-005(b, c, and d).

F5.2.1.2-2 / TA-73 SAP / 092598

TABLE 5.2.1.2-1

AOCs C-73-005(a through f)
SUMMARY OF SAMPLES COLLECTED[a]

Location ID	Sample ID	Location Description and Depth	Matrix	VOCs	SVOCs	PCBs/ Pest.	TAL Metals	RAD[b]
73-02204	0173-96-0259	C-73-005(a) - Inside Septic Pit at 2.6–3.7 ft	Soil	2286	2286	2286	2287	2288
73-02205	0173-96-0258	C-73-005(a) - Inside Septic Pit at 2.7–3.8 ft	Soil	2286	2286	2286	2287	2288
73-02206	0173-96-0260	C-73-005(a) - Outlet Trench at 0.0–0.7 ft	Soil	2286	2286	2286	2287	2288
73-02199	0173-96-0263	C-73-005(b) - Inside Septic Pit at 1.3–2.1 ft	Soil	2286	2286	2286	2287	2288
73-02200	0173-96-0262	C-73-005(b) - Inside Septic Pit at 1.0–2.0 ft	Soil	2286	2286	2286	2287	2288
73-02201	0173-96-0264	C-73-005(b) - End of Outlet Pipe at 0.0–0.2 ft	Soil	2286	2286	2286	2287	2288
73-02197	0173-96-0268	C-73-005(c) - Inside Septic Pit at 0.0–0.8 ft	Soil	2271	2271	2271	2272	2273
73-02198	0173-96-0269	C-73-005(c) - Inside Septic Pit at 0.4–1.2 ft	Soil	2271	2271	2271	2272	2273
73-02195	0173-96-0271	C-73-005(d) - Inside Septic Pit at 1.9–2.9 ft	Soil	2271	2271	2271	2272	2273
73-02196	0173-96-0272	C-73-005(d) - Inside Septic Pit at 1.5–2.5 ft	Soil	2271	2271	2271	2272	2273
73-02193	0173-96-0274	C-73-005(e) - Inside Septic Pit at 1.0–1.9 ft	Soil	2271	2271	2271	2272	2273
73-02194	0173-96-0275	C-73-005(e) - Inside Septic Pit at 1.0–2.0 ft	Soil	2271	2271	2271	2272	2273
73-02191	0173-96-0280	C-73-005(f) - Inside Septic Pit at 1.5–2.5 ft	Soil	2271	2271	2271	2272	2273
73-02192	0173-96-0281	C-73-005(f) - Inside Septic Pit at 1.5–2.5 ft	Soil	2271	2271	2271	2272	2273

a. Numbers in the cells for each analytical suite are request numbers.

b. RAD = Radiological analyses: gross alpha/beta/gamma and tritium

TABLE 5.2.1.2-2

AOCs C-73-005(a through f)
INORGANIC CHEMICALS WITH CONCENTRATIONS EXCEEDING BACKGROUND VALUES (BVs)[a]

Location ID	Sample ID	Copper	Lead	Manganese	Mercury	Silver	Thallium	Zinc
	BV	14.7	22.3	671	0.1	1.0	0.73	48.8
73-02205	0173-96-0258	**20**[b]	**41**	**1100**	**0.42**	**2.2**	**1.4**	**110**
73-02204	0173-96-0259	**16**	**41**	95	**0.26**	**2.2**	**1.4**	**110**
73-02206	0173-96-0260	6.8	**29**	340	**0.11 (U)**[c]	**2.1**	**1.3**	44
73-02200	0173-96-0262	6.6	9.9	190	**0.1 (U)**	**2 (U)**	**1.3**	23
73-02199	0173-96-0263	6.9	18	200	**0.1 (U)**	**2.1**	**1.3 (U)**	31
73-02201	0173-96-0264	12	**31**	210	**0.1 (U)**	**2 (U)**	**1.3**	43
73-02197	0173-96-0268	6.9	**24**	390	**0.11**	**2.1 (U)**	**1.3 (U)**	**110**
73-02198	0173-96-0269	7.7	16	400	**0.11 (U)**	**2.1 (U)**	**1.3 (U)**	39
73-02195	0173-96-0271	14	**200**	380	**0.11 (U)**	**2.2 (U)**	**1.3 (U)**	**290**
73-02196	0173-96-0272	9.7	**90**	400	**0.11**	**2.1 (U)**	**1.3 (U)**	**150**
73-02193	0173-96-0274	7.1	**26**	240	**0.11**	**2.1 (U)**	**1.3 (U)**	**70**
73-02194	0173-96-0275	6.5	18	250	**0.11**	**2.2 (U)**	**1.4 (U)**	36
73-02191	0173-96-0280	9.5	**30**	320	**0.11**	**2.2 (U)**	**1.3 (U)**	**61**
73-02192	0173-96-0281	6.4	19	330	**0.11**	**2.1 (U)**	**1.3 (U)**	37

a. Concentrations are in units of mg/kg.

b. Bolded values are above BVs, as revised on January 30, 1998 (Ryti et al. 1998, ER ID 58093).

c. (U) = not detected

TABLE 5.2.1.2-3

AOCs C-73-005(a through f)
ORGANIC CHEMICALS WITH DETECTED CONCENTRATIONS[a]

Part 1

Location ID	Sample ID	4,4'-DDT	4-Isopropyl-toluene	Acetone	Benz(a) anthracene	Benzo(a) pyrene	Benzo(b) fluoranthene
	EQL	0.0033	0.005	0.02	0.33	0.35	0.33
73-02205	0173-96-0258	0.0036(U)[b]	0.0055(U)	0.022(U)	0.18(U)	0.18(U)	0.18(U)
73-02204	0173-96-0259	0.0036(U)	0.0054(U)	0.022(U)	0.18(U)	0.18(U)	0.18(U)
73-02206	0173-96-0260	0.0035(U)	0.0054(U)	0.022(U)	**0.29[c] (J)**	**0.23 (J)**	**0.3 (J)**
73-02199	0173-96-0263	**0.01**	0.0052(U)	**0.024**	0.17(U)	0.17(U)	0.17(U)
73-02201	0173-96-0264	0.0034(U)	**0.012**	**0.08**	0.17(U)	0.17(U)	0.17(U)
73-02197	0173-96-0268	0.0035(U)	0.0053(U)	0.021(U)	0.18(U)	0.18(U)	0.18(U)
73-02198	0173-96-0269	0.0033(U)	0.0051(U)	0.02(U)	0.17(U)	0.17(U)	0.17(U)
73-02195	0173-96-0271	**0.0088 (J-)[d]**	0.0053(U)	0.021(U)	0.18(U)	0.18(U)	0.18(U)
73-02196	0173-96-0272	**0.0083 (J-)**	0.0053(U)	0.021(U)	1.1(U)	1.1(U)	1.1(U)
73-02193	0173-96-0274	0.0035(U)	0.0053(U)	**0.054**	0.17(U)	0.17(U)	0.17(U)
73-02194	0173-96-0275	0.0035(U)	**0.0086**	**0.041**	0.18(U)	0.18(U)	0.18(U)
73-02191	0173-96-0280	**0.0059**	0.0053(U)	0.021(U)	0.18(U)	0.18(U)	0.18(U)
73-02192	0173-96-0281	0.0035(U)	0.0053(U)	0.021(U)	0.17(U)	0.17(U)	0.17(U)

Part 2

Location ID	Sample ID	Benzo(k) fluoranthene	Chrysene	Fluoranthene	Methylene Chloride	Phenanthrene	Pyrene	Toluene
	EQL	0.33	0.33	0.33	0.005	0.33	0.33	0.005
73-02205	0173-96-0258	0.18(U)	0.18(U)	0.18(U)	0.0055(U)	0.18(U)	**0.2 (J)**	0.0055(U)
73-02204	0173-96-0259	0.18(U)	0.18(U)	**0.2 (J)**	0.0054(U)	0.18(U)	**0.21 (J)**	0.0054(U)
73-02206	0173-96-0260	**0.23 (J)**	**0.35**	**0.63**	0.0054(U)	**0.26 (J)**	**0.42**	0.0054(U)
73-02199	0173-96-0263	0.17(U)	0.17(U)	0.17(U)	0.0052(U)	0.17(U)	0.17(U)	0.0052(U)
73-02201	0173-96-0264	0.17(U)	0.17(U)	0.17(U)	**0.01(J+)[e]**	0.17(U)	0.17(U)	**0.0061(J+)**
73-02197	0173-96-0268	0.18(U)	0.18(U)	0.18(U)	0.0053(U)	0.18(U)	0.18(U)	0.0053(U)
73-02198	0173-96-0269	0.17(U)	0.17(U)	0.17(U)	0.0051(U)	0.17(U)	0.17(U)	0.0051(U)
73-02195	0173-96-0271	0.18(U)	0.18(U)	0.18(U)	0.0053(U)	0.18(U)	0.18(U)	0.0053(U)
73-02196	0173-96-0272	1.1(U)	1.1(U)	1.1(U)	0.0053(U)	1.1(U)	1.1(U)	0.0053(U)
73-02193	0173-96-0274	0.17(U)	0.17(U)	0.17(U)	0.0053(U)	0.17(U)	0.17(U)	0.0053(U)
73-02194	0173-96-0275	0.18(U)	0.18(U)	0.18(U)	0.0054(U)	0.18(U)	0.18(U)	**0.0065**
73-02191	0173-96-0280	0.18(U)	0.18(U)	0.18(U)	0.0053(U)	0.18(U)	0.18(U)	0.0053(U)
73-02192	0173-96-0281	0.17(U)	0.17(U)	0.17(U)	0.0053(U)	0.17(U)	0.17(U)	0.0053(U)

a. Concentrations are in units of mg/kg.

b. (U) = not detected

c. Bolded values are detected values.

d. (J-) = estimated quantity possibly biased low

e. (J+) = estimated quantity possibly biased high

f. (J) = Results for this analyte should be regarded as estimated because the result was below the EQL but above the MDL.

AOCs C-73-005(a through f) are unlined pits excavated into the tuff. They were discovered during a site survey in 1996. It is assumed that these pits received sanitary waste from facilities within the former Contractor's Row, although there is no historical information to document this. AOC C-73-005(a) had an inlet drainline constructed of 4-in. VCP. It also had a shallow outlet trench which connected the pit to the edge of the mesa. AOC C-73-005(b) had a 4-in. VCP outlet pipe, but no inlet line. None of the other pits had evident inlet or outlet drainlines. All pits when sampled contained 1 to 3.8 ft of fill material that had washed into the pits over the years. As all pits were unlined, any contamination present in material disposed into the pits could have infiltrated the tuff walls and floors. Potential contamination could also be present in the outlet trench and outfall of C-73-005(a) and the outfall of C-75-005(b) if discharge was greater than the capacity of the pits. Phase I data suggest that this was the case, as levels of PAH contamination in the C-73-005(a) outlet trench exceed the levels of contamination in the septic pit, and contaminants were detected at the end of the C-73-005(b) outlet pipe that were not detected in the septic pit. Potential contamination could also exist beneath the VCP inlet pipe of C-73-005(a) if leaks occurred along this inlet line. No samples were taken under this line during the Phase I investigation, and no attempt was made to determine the length or origin of the inlet line.

Relevant hydrologic features which could be impacted by contamination at these sites are discussed in Section 5.1.1, Hydrology. The sites have LANL-ER-AP-4.5 Water Assessment Erosion Matrix scores of 27.6, indicating a low erosion potential, with Surface Water Runoff subscores of 24. The terminal point of runoff is DP Canyon. Two alluvial wells (LAUZ-1 and LAUZ-2) are located in DP Canyon approximately 750 ft south of the east end of AOC C-73-005(d) (Figure 4.1.1-2). After the Phase I sampling, all pits were backfilled and compacted, making any contamination present in the pits less likely to be transported by surface water runoff.

Phase I sampling identified the nature of contamination at these sites. When detected, inorganic contaminants were less than two and a half times the BVs with the following exceptions: Mercury was detected in the C-73-005(a) pit at four times background levels, lead was detected at AOC C-73-005(d) at levels approximately nine times background, while zinc was detected at six times BV in the same pit. Detection limits for mercury and thallium were slightly elevated for the samples where these analytes were not detected, being equal to or slightly above BV.

Contamination by organic chemicals was not consistent from pit to pit. Several PAHs were detected at low or trace levels in the C-73-005(a) septic pit and outlet trench, but this is the only site at which PAHs were detected. Very low concentrations of several VOCs were detected at C-73-005(b) and C-73-005(e), and low levels of 4,4'-DDT were detected at C-73-005(d) and C-73-005(f). No organic COPCs were detected in C-73-005(c). The full suite analyses conducted on all samples adequately define the nature of contamination at these sites.

Vertical and horizontal extent of contamination has not been characterized at these AOCs. Characterization of extent of contamination at these sites is the purpose of this SAP.

5.2.2.2 Fate and Transport

Phase I sampling at AOCs C-73-005(a through f) detected seven inorganic contaminants occurring above background values (Table 5.2.1.2-2). Thirteen organic COPCs were also detected (Table 5.2.1.2-3). The fate and distribution of chemicals in the environment are determined by chemical-specific properties, geochemistry of the contaminated media, and physical transport systems. General chemical and physical properties which relate to the fate of these contaminants in the environment are provided in Appendix D.

Phase I data provide no information on the valence states of the inorganic chemicals detected at these AOCs. With the exception of mercury, none of the inorganic COPCs detected are volatile in any of their forms, so volatilization is not a potential transport or exposure pathway. Certain organic forms of mercury can volatilize to the air, but reducing chemical conditions necessary to convert inorganic mercury to organic mercury are not expected to occur at this site. Appendix D, Chemical Properties, contains a discussion of conditions necessary for a reducing environment in the section on potential for uptake of mercury. Sediments deposited by surface runoff, the most likely transport pathway for surficial contamination at this site, can be important repositories for inorganic mercury. Mercury was detected only in samples taken from the bottom of the septic pits, and not from the sample taken in the C-73-005(a) outlet trench or at the C-73-005(b) outfall. These pits were backfilled in 1997 so the contamination is now subsurface. This makes it unlikely that the mercury would reach potential aquatic settings in the bottom of DP Canyon. All of the organic COPCs detected have low vapor pressures and low water solubilities, indicating that they are not likely to volatilize to the air and are likely to be immobilized due to soil adsorption.

All of the organic chemicals and three of the inorganic chemicals are listed on the NMED list of potentially bioaccumulating chemicals. It is expected that the total area impacted by these PRSs is small. Therefore, it is expected that the potential for persistent bioaccumulation is minimal.

A generalized conceptual transport model for contamination at AOCs C-73-005(a through f) is provided in Figure 5.2.2.2-1. Contamination at the outlet trench of C-73-005(a) and the outfall of C-73-005(b) is expected to affect surficial soils, while contamination in the septic pits is expected to affect subsurface soil/tuff. Potential transport mechanisms are surface water runoff/soil erosion and air entrainment of potentially contaminated particulate matter. The AOC C-73-005 aggregate has a LANL-ER-AP-4.5 Surface Water Assessment Erosion Matrix score of 27.6 (low erosion potential), with a surface water runoff subscore of 24. The terminal point of water transport is DP Canyon. The primary exposure pathways and their potential significance to ecological and human receptors are presented in Figure 5.2.2.2-1. An ecological scoping checklist was completed for this AOC aggregate and is included in Appendix B. The stream in DP canyon is ephemeral, flowing only in response to storm events, and ephemeral aquatic communities are present. Alluvial water is also present in the canyon directly downslope from these PRSs (Section 4.1.1, Hydrology). Alluvial wells LAUZ-1 and LAUZ-2 detected water 4.5 ft below the surface in DP Canyon. Surficial contamination from these AOCs could potentially reach alluvial or surface water in DP Canyon. However, since the backfilling of the septic pits, surficial contamination associated with these AOCs is limited to the C-73-005(a) outlet trench and C-73-005(b) outfall. The results of the Phase II sampling will be provided to the Canyons Focus Area for use in cumulative assessments of the DP Canyon watershed.

5.2.2.3 Data Gaps

The Phase I RFI data for these minimally engineered septic pits suggested that there were releases to the environment at the septic pits located in the former Contractor's Row area. Because of the limited areal and depth coverage of the Phase I RFI data, strong arguments cannot be made regarding the extent of contamination at two septic pits.

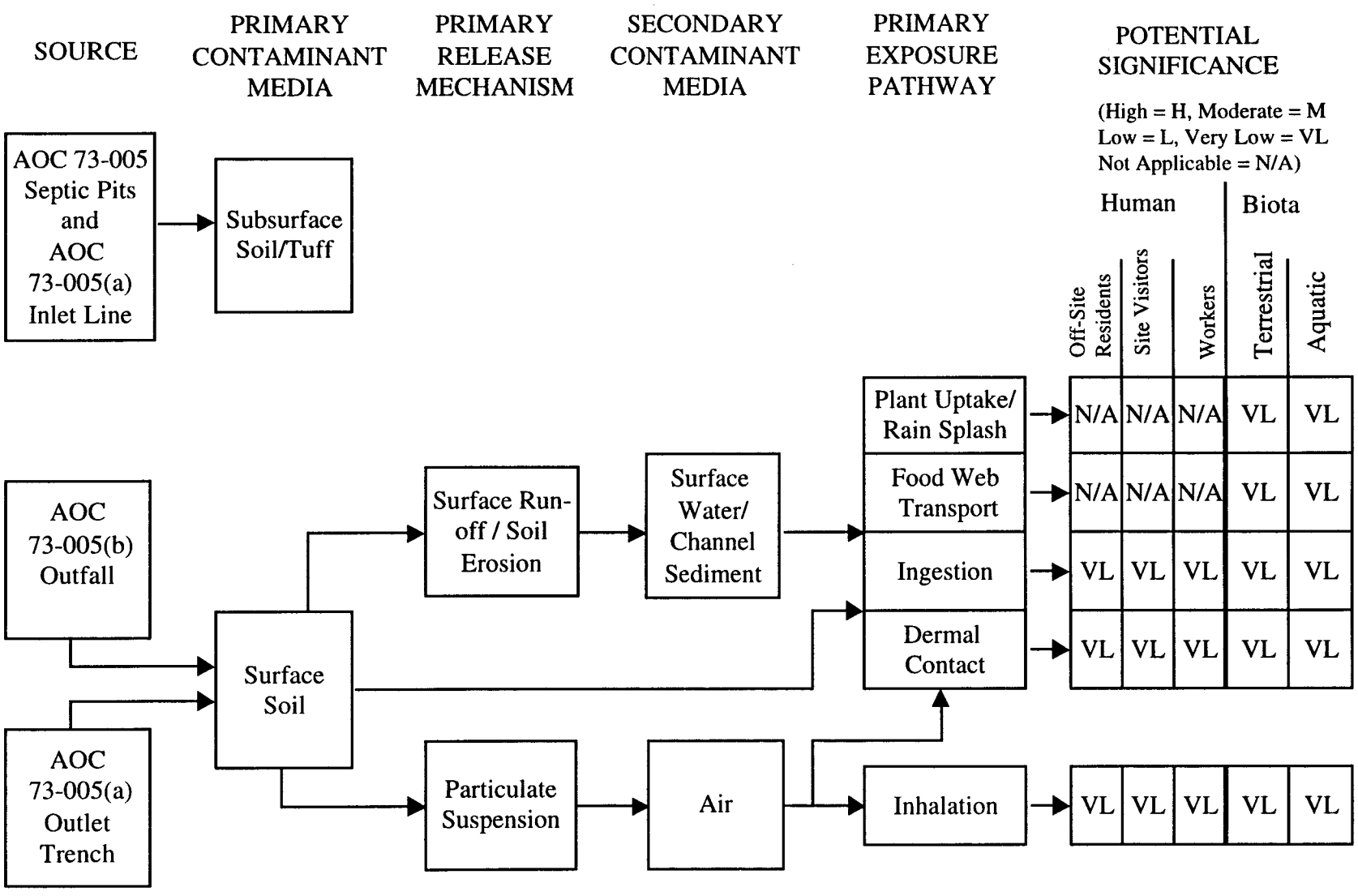


Figure 5.2.2.2-1. Conceptual model of contaminant transport at AOC C-73-005 aggregate.

The construction of the septic pits suggests that the most likely point of release to the environment may have been at the pit. In particular, C-73-005(a) was constructed with an inlet drainline and an outlet trench, which may suggest that liquid contamination accumulated in the unlined pit and drained into the underlying tuff. Overflow from the C-73-005(a) pit was directed to surface soil at the outfall through the trench. It is assumed that the inlet drainline was cement grouted VCP, and thus the likelihood of releases from the inlet drain line are small. C-73-005(b) was constructed with an outlet drainline that led to an outfall. It is expected that the most likely point of release to the environment for C-73-005(b) is at the outfall. It is assumed that the outlet drainline was cement grouted VCP, making the likelihood of releases small from the outlet drainline. C-73-005(c, d, e, and f) were constructed with no inlet line and no outlet line or trench. Thus, releases to the environment are likely at only the septic pits for C-73-005(c, d, e, and f). It is also possible that the C-73-005(c, d, e, and f) pits may have overflowed and contaminated the surface soil downslope of the pits.

Thus, additional sampling would focus on determining the extent of contamination at the six septic pits and the outfall area of C-73-005(a and b). As noted in the site description, the area around these AOCs may have some surface debris associated with either operations at the former Contractor's Row or the demolition of the Contractor's Row structures. Thus, the presence of surface debris near any sample locations should be noted to help better interpret the sample results obtained from this next sampling phase.

Another data gap is how the inlet line for C-73-005(a) and outlet line for C-73-005(b) were constructed. If these inlet lines were grouted, as stated above, releases from these pipes are unlikely and media characterization beneath the lines therefore unnecessary.

5.2.3 Sampling Activities

This section describes the sampling design and the rationale for the design based on the site conceptual model presented in Section 5.2.2.

The sampling design at all AOCs will not be influenced by field test kits or other on-site analytical tools. There is no plan to use contaminant collocation or correlation to estimate results for any analytes. The analytical suites to be requested for all samples collected during the planned sampling activities include TAL metals, VOCs (only below a 6-in. depth), SVOCs, organochlorine pesticides, and PCBs.

Samples will be collected using a spade, hand auger, or power hand auger, depending upon the type of material being sampled.

Analytical data generated by these sampling activities will be compared to the appropriate LANL BVs for inorganic chemicals and radionuclides (Ryti et al. 1998, ER ID 58093) and EQLs for organic chemicals (LANL 1995, ER ID 49738). Field duplicate samples will be collected to evaluate data quality.

Based on the sampling design discussion below and in Sections 5.2.3.1 and 5.2.3.2, the samples to be collected are presented in Tables 5.2.3-1 and 5.2.3-2, and the proposed sampling locations are shown on Figures 5.2.3-1 and 5.2.3-2.

TABLE 5.2.3-1

AOCs C-73-005(a and b)
PROPOSED SAMPLE LOCATIONS AND ANALYTICAL SUITES[a]

AOC	Location ID	Location Description and Depth	Matrix	VOCs	SVOCs	PCBs/ Pest.	TAL Metals[b]
73-005(a)	73-02205	Deeper sample beneath sample 0173-96-0258	Soil	X	X	X	X
73-005(a)	73-02204	Deeper sample beneath sample 0173-96-0259	Soil	X	X	X	X
73-005(a)	73-02206	Deeper sample beneath sample 0173-96-0260	Soil	X	X	X	X
73-005(a)	TBD[c]	Confirmation sample(s) below inlet drainline	Soil	X	X	X	X
73-005(a)	TBD	Downgradient outlet trench sample	Soil	X	X	X	X
73-005(a)	TBD	Additional samples for definition of extent	Soil	X	X	X	X
73-005(b)	73-02199	Deeper sample beneath sample 0173-96-0263	Soil	X	X	X	X
73-005(b)	73-02200	Deeper sample beneath sample 0173-96-0262	Soil	X	X	X	X
73-005(b)	73-02201	Deeper sample beneath sample 0173-96-0264	Soil	X	X	X	X
73-005(b)	TBD	Confirmation sample below outlet drainline	Soil	X	X	X	X
73-005(b)	TBD	Downgradient outfall sample	Soil	X	X	X	X
73-005(b)	TBD	Additional samples for definition of extent	Soil	X	X	X	X
	TBD	QA/QC sample(s) (duplicate)	Soil	X	X	X	X

a. All samples will be grab samples.

b. See Table 6.1-1 for special required detection limits.

c. TBD = to be determined

TABLE 5.2.3-2

AOCs C-73-005(c, d, e, and f)
PROPOSED SAMPLE LOCATIONS AND ANALYTICAL SUITES[a]

AOC	Location ID	Location Description and Depth	Matrix	VOCs	SVOCs	PCBs/ Pest.	TAL Metals[b]
73-005(c)	73-02197	Deeper sample beneath sample 0173-96-0268	Soil	X	X	X	X
73-005(c)	73-02198	Deeper sample beneath sample 0173-96-0269	Soil	X	X	X	X
73-005(c)	TBD[c]	Additional samples for horizontal and vertical extent	Soil	X	X	X	X
73-005(d)	73-02195	Deeper sample beneath sample 0173-96-0271	Soil	X	X	X	X
73-005(d)	73-02196	Deeper sample beneath sample 0173-96-0272	Soil	X	X	X	X
73-005(d)	TBD	Additional samples for horizontal and vertical extent	Soil	X	X	X	X
73-005(e)	73-02193	Deeper sample beneath sample 0173-96-0274	Soil	X	X	X	X
73-005(e)	73-02194	Deeper sample beneath sample 0173-96-0275	Soil	X	X	X	X
73-005(e)	TBD	Additional samples for horizontal and vertical extent	Soil	X	X	X	X
73-005(f)	73-02191	Deeper sample beneath sample 0173-96-0280	Soil	X	X	X	X
73-005(f)	73-02192	Deeper sample beneath sample 0173-96-0281	Soil	X	X	X	X
73-005(f)	TBD	Additional samples for horizontal and vertical extent	Soil	X	X	X	X

a. All samples will be grab samples.

b. See Table 6.1-1 for special required detection limits.

c. TBD = to be determined

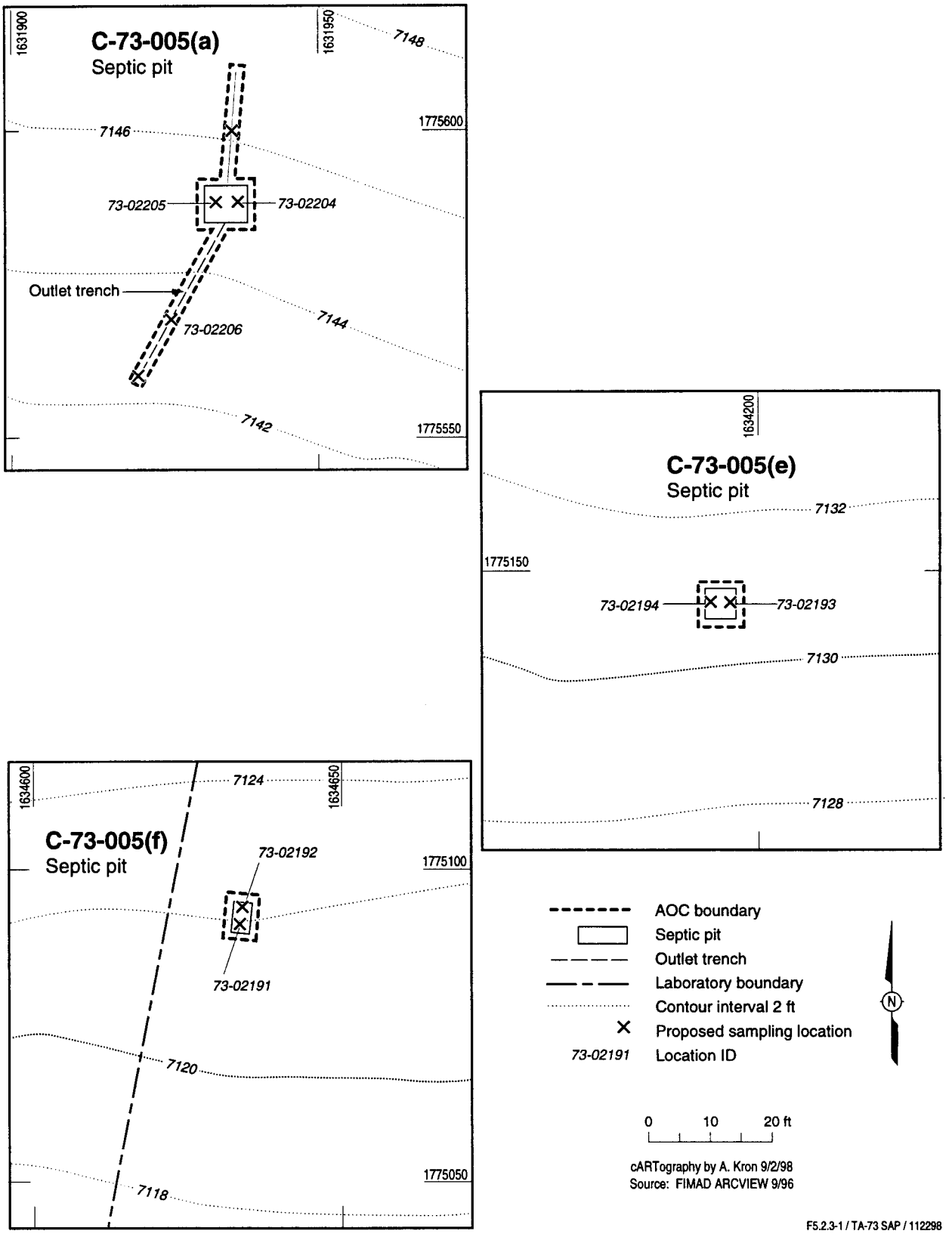


Figure 5.2.3-1. Proposed sampling locations for AOCs C-73-005(a, e, and f).

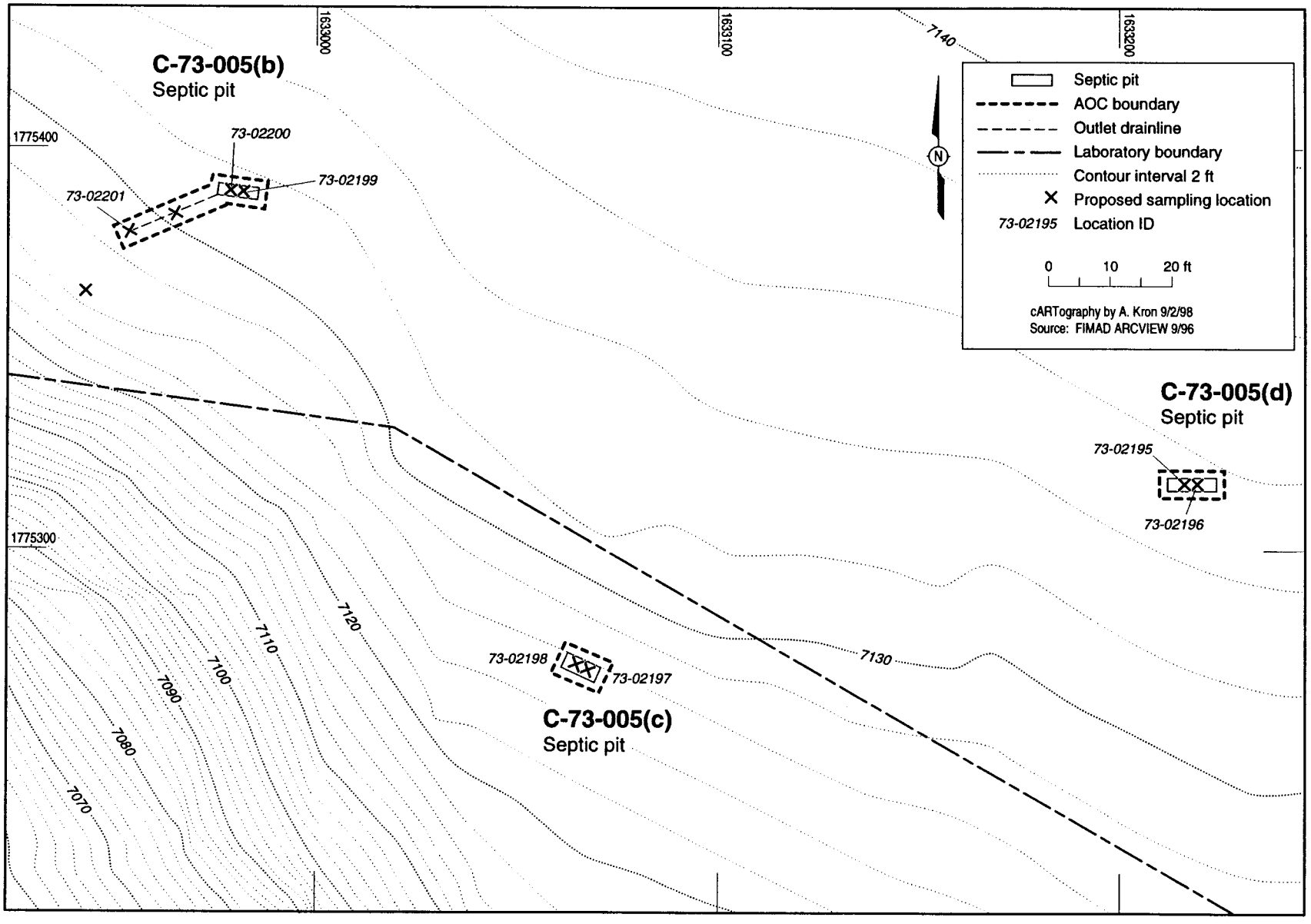


Figure 5.2.3-2. Proposed sampling locations for AOCs C-73-005(b, c, and d).

AOCs C-73-005(a and b)

Both of these AOCs were also excavated into tuff. C-73-005(a) was constructed with a 4-in.-diameter VCP inlet drainline and a shallow outlet trench. C-73-005(b) was constructed with a short 4-in.-diameter VCP outlet drainline. The aspects of their construction suggests that these pits also received relatively small, intermittent volumes of waste. It is expected that the volume of media potentially impacted by leaks from the inlet and outlet drainlines is small. Their gravity-driven construction would have ensured proper drainage. Some of the liquid in the pits would have infiltrated downward into the vadose zone under the influence of gravity, and to a lesser degree, horizontal infiltration would have been taking place. It is expected that the maximum volume of potentially impacted tuff will be beneath the pits. Some of the liquid flowing intermittently through the outlet trench of C-73-005(a) would also have infiltrated into the underlying tuff through the same mechanism for vertical and horizontal migration.

Phase I samples were collected from the soil and sediment at the bottom of each pit, the outfall for C-73-005(b), and the outlet trench for C-73-005(a). The initial Phase II samples will be collected from the tuff below the original sample locations. An additional soil sample will be collected using a hand auger from the C-73-005(a) outlet trench, downgradient from the original sample. An additional sample will also be collected downgradient from the original C-73-005(b) outfall sample. Deeper samples will be collected at 2-ft intervals, as necessary, to determine vertical extent of contamination (see Section 1.2). Since vertical liquid movement would have been the predominant direction of infiltration, horizontal offset samples will not be collected until it is demonstrated that the underlying tuff is contaminated. To facilitate the investigation, both drainlines will be removed and additional locations may be sampled based on visual evidence of leaks. If there is no visual evidence of leaks, one confirmatory sample will be collected below each line at a joint.

AOCs C-73-005(c, d, e, and f)

It is assumed that these pits received liquid waste from facilities within the former Contractor's Row. The construction of the pits provides some information regarding their potential function. All four of these AOCs were excavated into tuff and had no inlet or outlet drainlines or trenches. Because of this, it is assumed that they received only small, intermittent volumes of waste. It is possible that they served latrines that were constructed directly over the pits and were pumped out, as necessary, to prevent them from overflowing. If the pits had periodically overflowed, it would seem that drainlines or drainage trenches to direct the overflow to the edge of the mesa would have been constructed.

It is expected that the maximum volume of potentially impacted tuff will be beneath the pit with some degree of horizontal infiltration. It is expected that vertical liquid movement driven by gravity would have been the predominant direction of infiltration. Lesser degrees of horizontal spreading might be expected depending on factors such as stratification within the tuff, variations in hydraulic conductivity, and fracturing of the tuff.

The Phase I samples were collected from the soil and sediment at the bottom of the pits. Therefore, the initial Phase II samples will be collected from the tuff below the original sample locations. As required, deeper samples will be collected at 2-ft intervals to define extent of contamination (see Section 1.2). Horizontal offset samples may be collected to define horizontal extent as discussed in Section 5.2.3.2, Media Characterization.

5.2.3.1 Contaminant Source

At all AOCs the only potential contaminant source is the soil and sediment on the bottom of the pits. This material was sampled during the Phase I RFI, and additional contaminant source sampling is not needed. If sediment is encountered in the C-73-005(a) inlet drainline or the C-73-005(b) outlet drainline, samples will be collected for waste characterization purposes. The results of these samples, if collected, will also help to further define the nature of potential contamination at these AOCs.

5.2.3.2 Media Characterization

AOCs C-73-005(a through f)

All proposed Phase II samples will be collected from tuff at depths greater than the bottom of the pit. Therefore, sampling will be performed using either powered hand augering equipment or a backhoe. In the unlikely event that the depth of contamination exceeds the capabilities of the backhoe or powered hand auger, a truck mounted drilling rig will be utilized to complete the definition of extent.

AOCs C-73-005(a and b)

The initial task will be to define the extent of contamination at the Phase I sampling locations. At each of these locations, a sample will first be collected 2 ft below the original sample. Additional sampling for the definition of horizontal and vertical extent will be conducted, as necessary, following the same procedures outlined for AOCs C-73-005(c, d, e, and f). A surface sample will be collected from the C-73-005(a) outlet trench 20 ft downgradient of location 73-02206. A surface sample will also be collected from the C-73-005(b) outfall 20 ft downgradient of location 73-02201. Additional downgradient samples will be collected at 20-ft intervals, if needed, to define horizontal extent in the outlet trench and outfall area. Deeper samples will be collected at 2-ft intervals, as necessary, to define vertical extent of contamination (see Section 1.2).

To facilitate the investigations, the entire C-73-005(a) inlet and C-73-005(b) outlet drainlines will be removed. As the drainlines are removed, the underlying soil or tuff will be visually inspected for staining or other signs of leaks. The underlying material will also be periodically screened for worker health and safety purposes with a PID and radiation detection instruments. If evidence indicates potential contamination, a sample will be collected at that location. Depending on the length of the drainlines, one to two confirmatory samples (one per 30 ft of drainline) will be collected from immediately beneath the portions of the drainlines not sampled for other reasons. All samples will be examined for visual evidence of contamination. If evidence of possible contamination is noted, a deeper sample will be immediately collected at that location, 2 ft below the initial sample. If there is no evidence to support the collection of a deeper sample, none will be collected until the initial sample results are compared to the screening values. As before, no more than two consecutive samples will be collected at a location until it is confirmed by fixed-site laboratory data that additional deeper sampling is required.

Samples will be collected using a spade, hand auger, or powered hand augering equipment to advance the borehole, depending upon the type of material being removed and the depth of contamination. A fourth option will be to use a backhoe to obtain the deeper sample(s). In the event that the depth of contamination exceeds the capabilities of the backhoe or powered hand auger, a truck mounted drilling rig will be utilized to complete the definition of extent. The final selection of a sampling method will be made in the field based on soil and site conditions.

AOCs C-73-005(c, d, e, and f)

Initially, the vertical extent of contamination will be defined at the Phase I sampling locations at each AOC. This will be accomplished by collecting a sample from the first 6-in. interval, 2 ft below the original sample at each location. These samples will be examined for visual evidence of contamination. If evidence of contamination is noted at a location, deeper samples will be immediately collected until there is no visual evidence of contamination. Additional deeper samples will be collected if it is determined by fixed laboratory data that deeper sampling is required.

Although horizontal infiltration of liquid from the pit may have been occurring, it is expected that vertical liquid movement driven by gravity would have been the predominant direction of infiltration. Therefore, it is proposed that horizontal offset sampling be performed only if two deeper samples are collected at a location and both contain COPCs above screening values. The rationale for this approach is twofold. First, if only one deep sample is collected and it is clean, it will be assumed that no significant vertical or horizontal migration of contaminants occurred. Second, if two deep samples are collected and the shallowest is contaminated but the deepest is clean, the extent of vertical migration will have been limited to a zone less than 4.5 feet deep below the pit. Therefore, it is expected that the extent of horizontal migration would be somewhat less given the predominant vertical direction of infiltration.

If horizontal offset sampling is required, it will initially be performed at a distance of 5 ft from the sides of the pit in two directions, one downgradient of the pit based on the observed slope of the bedrock surface, and one at 90 degrees to that direction. The first samples will be collected at a depth of 4 ft below the bottom of the pit, and sampling will continue at 2-ft intervals, as needed. The remaining two directions at 90 degrees around the pit will be sampled in a similar manner if it is determined that samples from the original two offset locations contained COPCs above screening values. If they did not, no additional sampling will be performed to define horizontal extent.

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6.0 DATA COLLECTION DESIGN AND PROCEDURES

6.1 Data Quality Objectives

The general protocols for evaluating data adequacy for meeting the SAP objectives are provided in Chapter 4, Section D of the ER Project QAPP (LANL 1996, ER ID 55574).

To meet the objective of determining the nature and extent of contamination, data collected from all PRSs will be compared to the local LANL BVs for inorganic chemicals and radionuclides, as described in the paper "Inorganic and Radionuclide Background Data for Soils, Canyons Sediments, and Bandelier Tuff at Los Alamos National Laboratory" (Ryti et al. 1998, ER ID 58093). Data for organic chemicals will be compared with the EQLs for organic chemicals (LANL 1995, ER ID 49738). To be able to distinguish PRS-related contaminant concentrations to the level of some of the BVs, minimum detection limits and special analytical techniques are requested for five metals (Table 6.1-1).

TABLE 6.1-1

SPECIAL REQUIRED DETECTION LIMITS IN SOILS

Chemical	Minimum Detection Limit Required (mg/kg)[a]
Antimony[b]	<0.5
Cadmium	<0.4
Copper	<4.0
Mercury	<0.1
Nickel	<6.0
Selenium	<0.3
Silver	<1
Thallium	<0.7

a. Ryti et al. 1998, ER ID 58093

b. At least 60% recovery is required for antimony.

To satisfy the requirements of the screening assessments, data collected must be able to reasonably represent the "worst-case" or maximum media-specific contamination conditions. This will be assessed by testing the key assumptions of the site model and by understanding the possible importance of laboratory measurement bias. The routine data qualification process and the focussed data validation process will provide information on potential laboratory bias. Bias will be assessed through the evaluation of average recoveries from laboratory spike samples, duplicate analyses, and laboratory control samples.

6.2 Quality Assurance/Quality Control

All sampling and analysis activities will be conducted according to the requirements in Chapter 4 of the ER Project QAPP (LANL 1996, 55574.1). All field measurements and surveys will follow the quality assurance/quality control (QA/QC) procedures outlined in the SOPs specified in Section 6.3.

Field duplicate samples will be collected at each PRS aggregate at a frequency of 1 duplicate for every 20 samples collected. If fewer than 20 samples are collected at a PRS, one duplicate will be collected.

Data from the analytical laboratories will comply with the ER Project Statement of Work for Analytical Services (LANL 1995, ER ID 49738) and will include all of the normal QA/QC parameters specified by the statement of work (SOW).

All samples will require lower detection limits for six of the TAL metals than those specified in the ER Project Statement of Work for Analytical Services (LANL 1995, ER ID 49738) (see Table 6.1-1). In addition, since there are often problems with antimony using inductively coupled plasma emission spectroscopy, the laboratory must have at least a 60% recovery for antimony to insure data usability. To assure that these special detection limits and recoveries are met, the field team will coordinate the sample analyses with the sample management office (SMO) and the analytical lab. The following procedure is suggested:

1. Prior to sampling, contact the SMO and find an analytical laboratory that can achieve the detection limits and recoveries required.

2. After samples are collected, take samples to the SMO and include the special analytical requirements on the analytical request form.

3. Call the analytical laboratory to alert them that the samples are in transit and remind them of the special requirements.

4. If the laboratory has any problems meeting the special requirements, have them notify the field team as soon as possible so that the situation can be handled while the samples are still available and within analytical holding times.

6.3 Field Activities

This section provides the details of how the sampling activities and related field tasks are to be performed.

General LANL ER guidelines for conducting field investigations will be followed. The following LANL ER Project SOPs will be utilized during completion of the field activities:

LANL-ER-SOP-1.01 General Instructions for Field Investigations
LANL-ER-SOP-3.12 Field and Laboratory Notebook Documentation for Environmental Restoration Earth Science Studies

A licensed New Mexico surveyor will perform geodetic surveying. Geodetic surveying will be utilized to accurately locate pertinent site features. Surveying will also be conducted to precisely locate sampling locations. All locations will be recorded in New Mexico state plane coordinates and location identification numbers will be assigned for submission to the Facility for Information Management, Analysis, and Display (FIMAD). The following LANL ER Project SOP will be utilized during completion of this task:

LANL-ER-SOP-3.01 Land Surveying Procedures

A geomorphic survey will be conducted at PRS 73-005 to identify the primary drainage channels that receive runoff only from the area of the PRS. Within these channels, sediment catchments will be identified that are appropriate for collecting samples. The following LANL ER Project SOP will be utilized during completion of this task:

LANL-ER-SOP-3.08 Geomorphic Characterization

Two primary sampling methods will be used, as appropriate. For relatively shallow soil samples, the spade and scoop method will be used. For deeper soil samples, a hand auger may be used if the soil is relatively free of large rocks and debris that make hand augering difficult. At locations where hand augering is ineffective or where tuff is encountered, powered hand augering equipment may be utilized. Another option is to use a backhoe to dig a small sampling trench from which the sample can be collected. The following LANL ER Project SOPs will be utilized during completion of this task:

LANL-ER-SOP-6.09 Spade and Scoop Method for Collection of Soil Samples
LANL-ER-SOP-6.10 Hand Auger and Thin-Wall Tube Sampler

During completion of the field investigation, direct screening for volatile organic vapors will be performed using a Thermo Environmental Instruments, Inc., organic vapor monitor Model 580B, or equivalent PID with an 11.8 eV bulb. The PID will be calibrated and checked by the site safety officer, as recommended by the manufacturer. Calibration records will be kept in the field log book. PID readings will be recorded in the field log book and/or the sample collection logs. Screening for ionizing radiation will be performed using a Ludlum Model 139 rate meter, or equivalent, with an air proportional (alpha) probe and an Eberline ESP-1 rate meter, or equivalent, with a beta/gamma probe. The measured radioactivity levels will be recorded in the field log book and/or the sample collection logs. The following LANL ER Project SOP will be utilized:

LANL-ER-SOP-10.07 Field Monitoring for Surface and Volume Radioactivity Levels

The following laboratory analytical methods will be used for routine analytical services:

- VOCs – Method 8260A
- SVOCs – Method 8270B
- PCBs/Pest. – Method 8081
- Dioxins/Furans – Method 8280
- TAL Metals – Method 6010B (Axial view), Hg by 7471
- Isotopic Uranium – Alpha Spectroscopy
- Isotopic Plutonium – Alpha Spectroscopy
- Gamma Spectrometry
- Gross Alpha, Beta, and Gamma at TA-21 for DOT shipping purposes

Special analytical techniques may be required for antimony, cadmium, mercury, selenium, silver, and thallium in order to achieve the desired detection levels (see Table 6.1-1).

All sampling will be conducted in accordance with LANL ER Project procedures for sample control and documentation, and sample handling, packaging, and shipping. All sample containers will be

appropriately labeled and assigned unique LANL sample identification numbers with bar codes for tracking purposes. The samples will be documented on sample collection logs, placed in coolers with blue ice, and transported to the SMO under chain-of-custody. The following LANL ER Project SOPs will be followed:

LANL-ER-SOP-1.02 Sample Containers and Preservation
LANL-ER-SOP-1.03 Handling, Packaging, and Shipping of Samples
LANL-ER-SOP-1.04 Sample Control and Field Documentation

QA/QC samples, primarily consisting of field duplicates, will be collected. Equipment rinsate blanks may also be collected if certain pieces of sampling equipment such as hand auger buckets must be decontaminated and reused. The following LANL ER Project SOP will be followed:

LANL-ER-SOP-1.05 Field Quality Control Samples

Management of investigation derived wastes will follow the guidelines and requirements discussed in the Waste Characterization Strategy Form and in the following LANL ER Project SOP:

LANL-ER-SOP-1.06 Management of Environmental Restoration Project Wastes

When possible, disposable sampling equipment will be utilized to avoid the necessity of decontamination and the possibility of cross contamination. However, if decontamination of certain pieces of sampling equipment is required, it will be performed according to the following LANL ER Project SOP:

LANL-ER-SOP-1.08 Field Decontamination of Drilling and Sampling Equipment

All original field documents will be transferred to the ER Project Records Processing Facility in accordance with the following administrative procedure:

LANL-ER-AP-02.1 Procedure for LANL ER Records Management

Data generated by the analytical laboratories will be submitted to the Field Support Facility (FSF) in accordance with the requirements of the ER Project analytical services statement of work (LANL 1995, ER ID 49738). The reporting requirements include electronic and hard-copy deliverables for routine analyses. The FSF is responsible for data verification, validation, and transmittal to FIMAD.

7.0 PROJECT MANAGEMENT

7.1 Project Scheduling and Reporting Requirements

These activities will be directed by the Remedial Actions Town Sites (TS) Team of the ER Project at LANL. A proposed schedule of the activities is presented in Table 7.1-1. A contract has been awarded for the conduct of the field sampling activities; the organization responsible for performing the sampling activities is Morrison Knudson/Program Management Company (MK/PMC).

A report for the activities described in this SAP may be combined with the results of the VCA for the ash disposal area at 73-002. Because commencement of the field sampling activities is dependent on approval of this SAP by the AA, it is not known when the field activities will start; therefore, a specific date for submittal of a report is unavailable at this time. The projected schedule shown in Table 7.1-1 shows the timeline for TS Team activities.

7.2 Health and Safety Plan

A site-specific Health and Safety Plan will be developed in accordance with the Environmental Restoration Project Site-Specific Health and Safety Plan (SSHASP), LANL EM/ER:95-PCT-012, April 13, 1995 (Glatzmaier 1995, ER ID 56448).

7.3 Investigation-Derived Waste Plan

Investigation-derived waste, if any, will be handled in accordance with LANL-ER-SOP-1.06 (Tillery 1996, ER ID 57923).

7.4 Community Relations Plan

Community Relations are governed by the Public Involvement Plan in Chapter 7 of 1996 IWP (LANL 1996, ER ID 55574).

TABLE 7.1-1

PROPOSED SCHEDULE OF ACTIVITIES

Activity	Schedule
Field work preparation	Jan 99
Start field work	Feb 99
End field work	Apr 99
Sample analysis	Feb 99–June 99
Data analysis and assessment	June 99–Aug 99
Report preparation	Aug 99–Sep 99
Submit Report to AA	Nov 99

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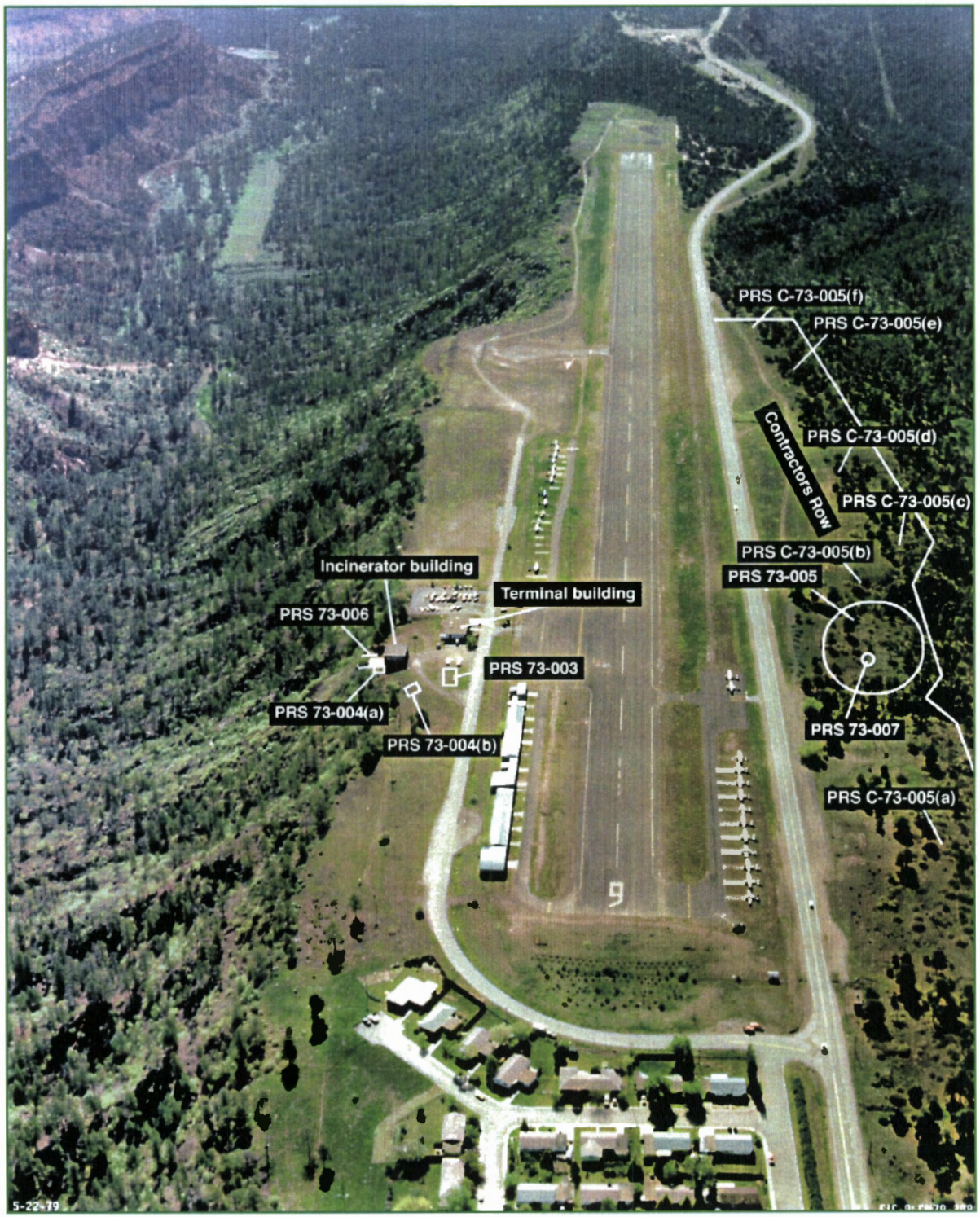
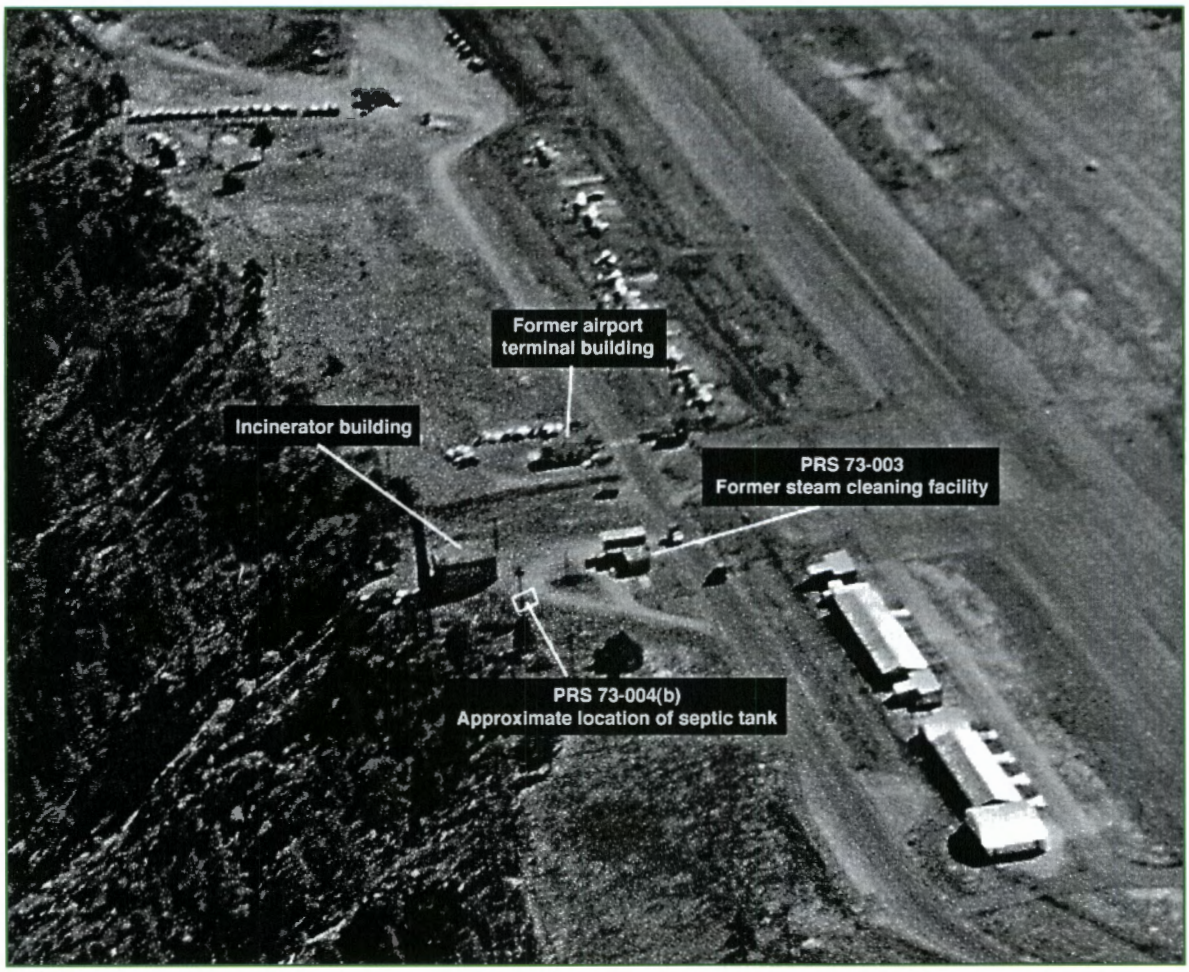
Appendix A

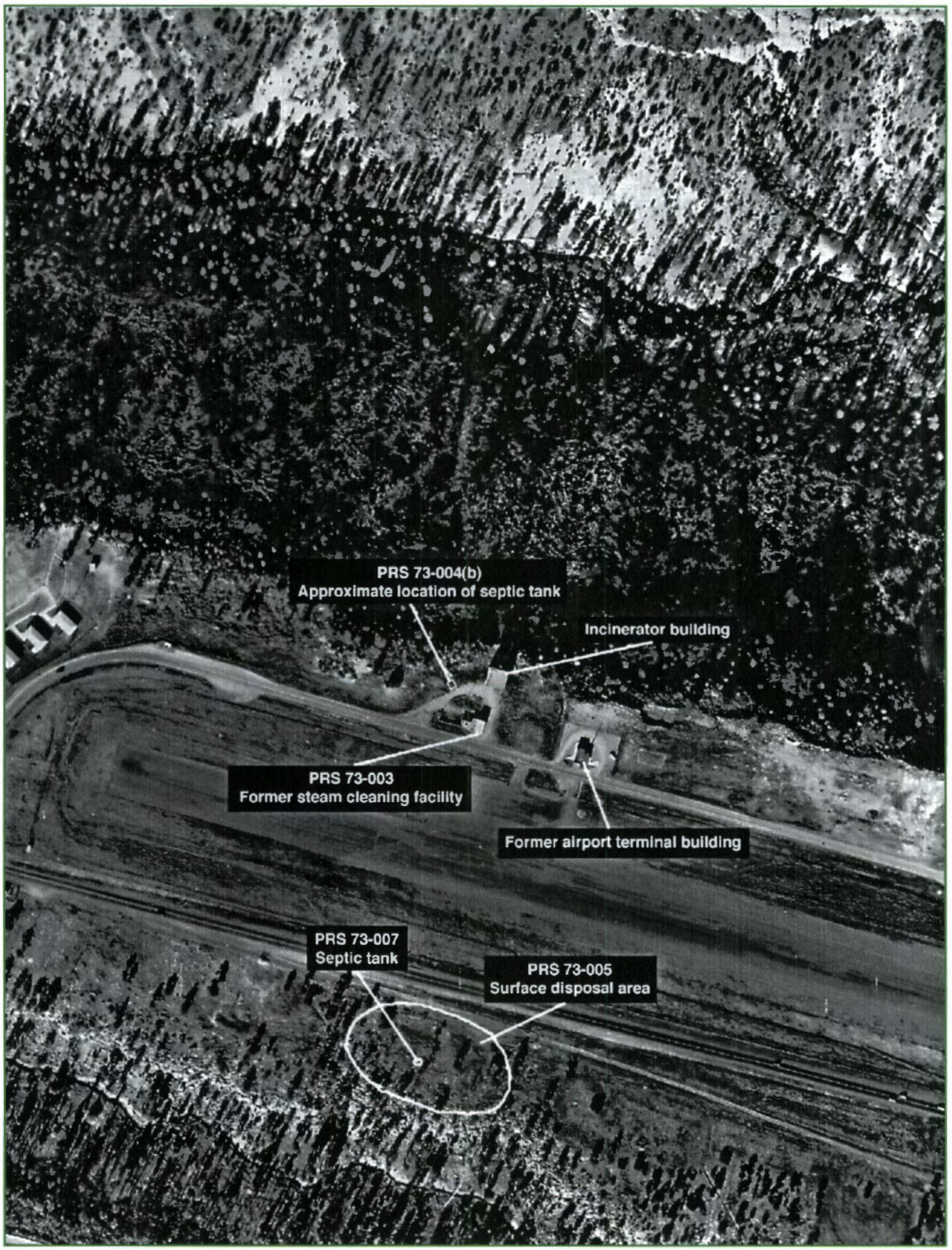
Photographs



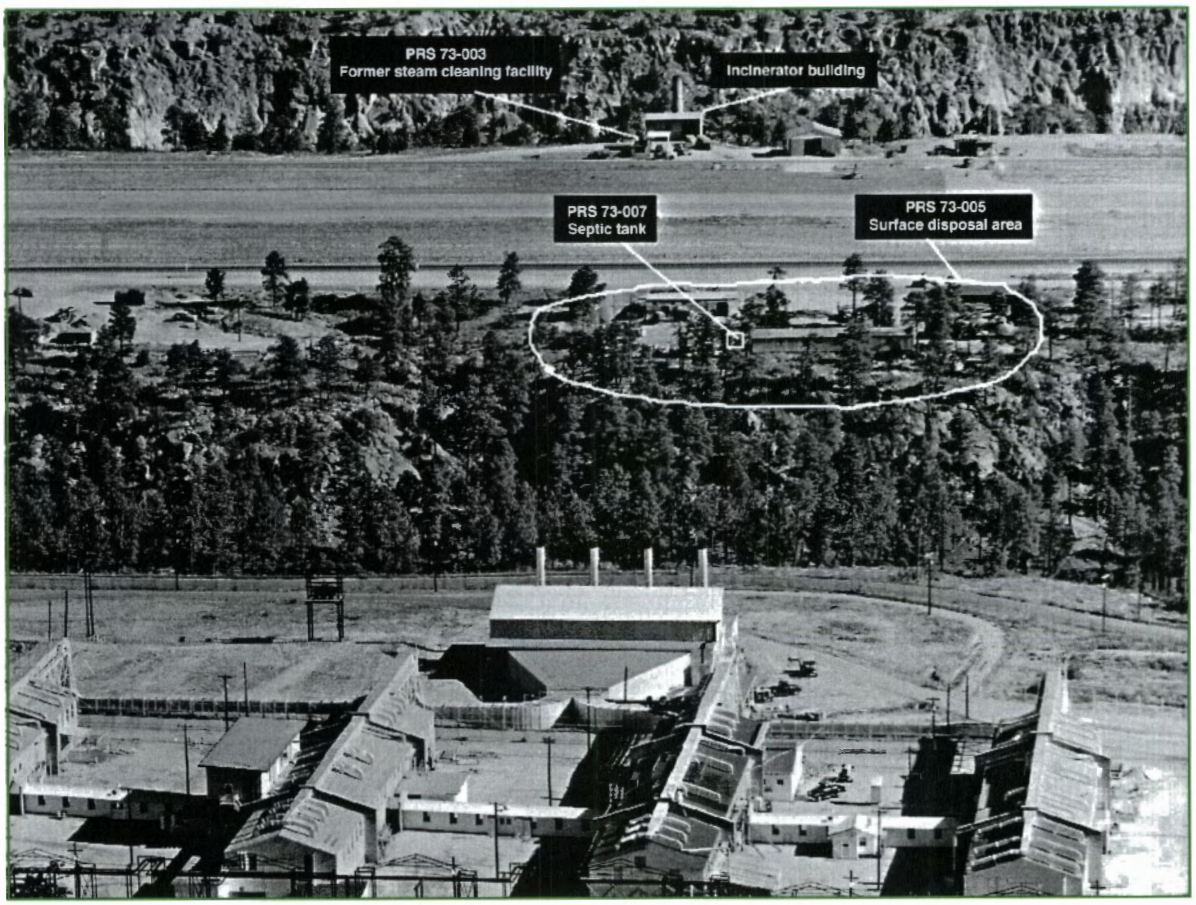
Photograph 1. SWMU Group 73-2 aggregate.



Photograph 2. SWMU Group 73-2 aggregate.



Photograph 3. SWMU Group 73-2 aggregate.



Photograph 4. SWMU Group 73-2 aggregate. Oblique view showing PRSs.

Photograph 5. PRS No. 73-004(b) septic tank. Tank being removed during VCA, August 1996.

Photograph 6. PRS No. 73-004(b) septic tank. Tank being removed during VCA, August 1996.

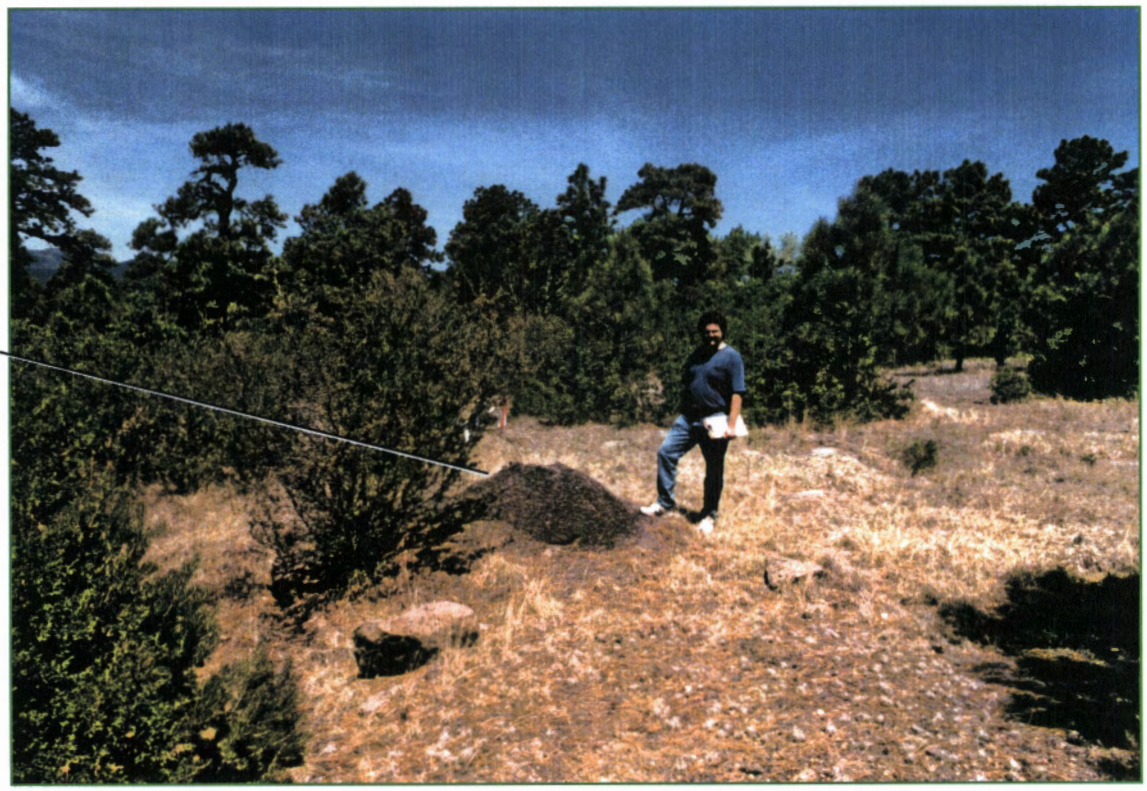
Photograph 7. Current condition of PRS 73-004(b) following VCA.

Photograph 8. 73-004(a) septic tank. Tank being removed during VCA, August 1996.

Photograph 7. Current condition of PRS 73-004(b) following VCA.

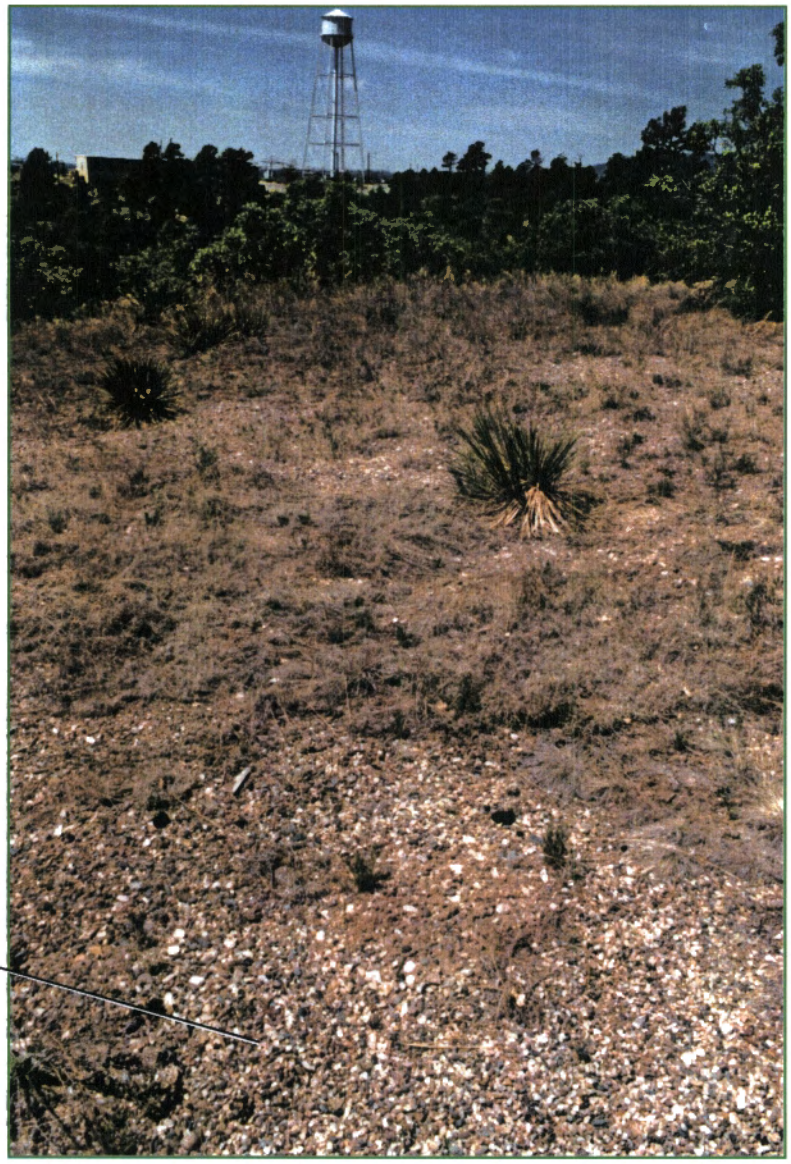
Photograph 8. 73-004(a) septic tank. Tank being removed during VCA, August 1996.

Photograph 9. PRS 73-004(a) septic tank. During Phase I RFI.



Photograph 10. PRS 73-005 surface disposal area. Asphalt debris.

Photograph 11. PRS 73-005 surface disposal area. Concrete debris.



Photograph 12. PRS 73-005 surface disposal area. Road aggregate debris.

Photograph 13. PRS 73-007 septic system. Cast iron inlet riser pipe.

Photograph 14. PRS 73-007 septic tank. During Phase I RFI.

Photograph 15. PRS 73-007 septic tank outfall.

Photograph 16. PRS 73-007 septic tank being removed during VCA.

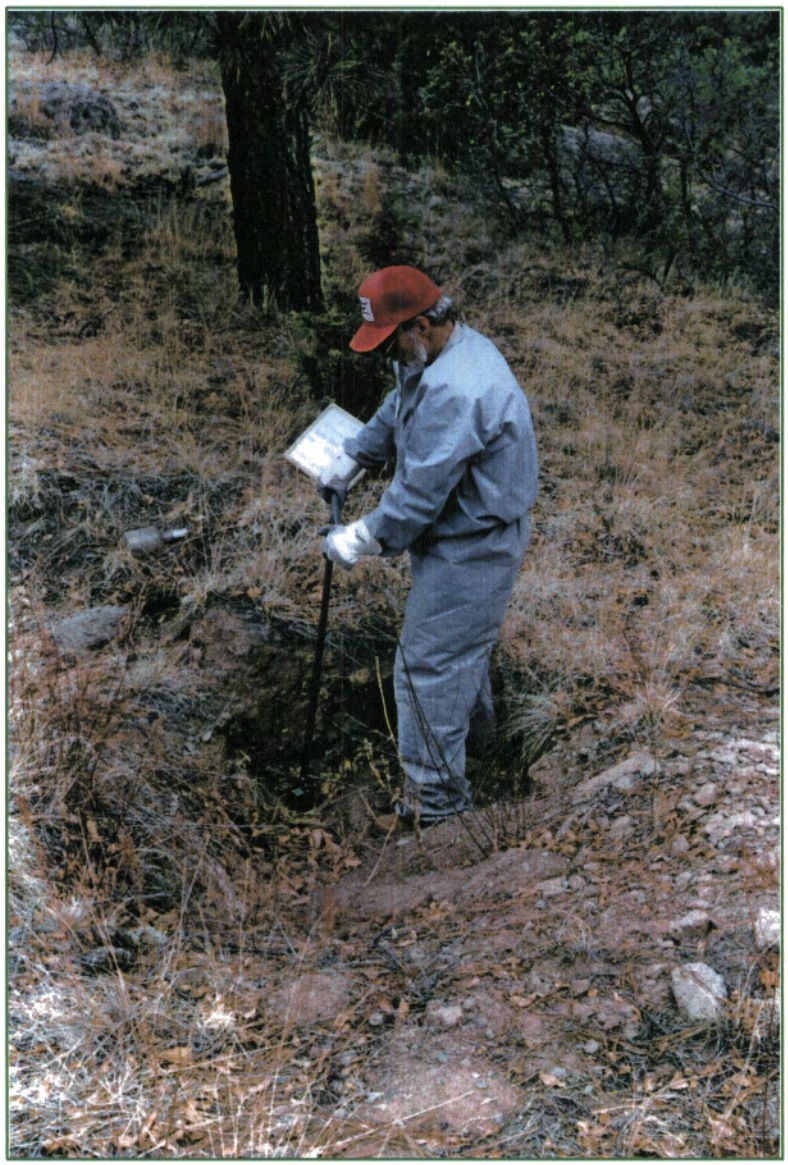
Photograph 17. PRS C-73-005(a) septic pit.

Photograph 18. PRS C-73-005(a) septic pit.

Photograph 19. PRS C-73-005(b) septic pit.

VCP drainline outfall

Photograph 20. PRS C-73-005(b) VCP drainline outfall.



Photograph 21. PRS C-73-005(c) septic pit.

Photograph 22. PRS C-73-005(d) septic pit.

Photograph 23. PRS C-73-005(e) septic pit.

Photograph 24. PRS C-73-005(f) septic pit.

Appendix B

Ecological Scoping Checklist

APPENDIX B ECOLOGICAL SCOPING CHECKLIST

B-1.0 PART A—SCOPING MEETING DOCUMENTATION

Site ID	PRSs 73-003, 73-004(b)
Nature of PRS releases **(indicate all that apply)**	**Solid** – Yes **Liquid** – Yes **Gaseous** – No **Other, explain**
List of Primary Impacted Media **(indicate all that apply)**	**Surface soil** – Yes SURFACE WATER/SEDIMENT – **NO** **Subsurface** – Yes **Groundwater** – No **Other, explain**
FIMAD vegetation class **(indicate all that apply)**	**Water** – No **Bare Ground/Unvegetated** – No **Spruce/fir/aspen/mixed conifer** – No **Ponderosa pine** – Yes **Piñon juniper/juniper savannah** – No **Grassland/shrubland** – No **Developed** – Yes
Is T&E Habitat Present? **list species if applicable**	Yes Yes, potential nesting and foraging habitat for the Peregrine falcon and the Mexican spotted owl.
Provide list and description of Neighboring/ Contiguous/ Upgradient PRSs **(consider need to aggregate PRS for screening)**	PRS 73-004(b) was a septic tank which received wash water from floor drains of PRS 73-003, a steam cleaning facility used to clean garbage trucks and cans. The steam cleaning facility was demolished in 1971, and the septic tank was removed as a VCA in 1996. Both sites are overlain by the asphalt parking lot for the Los Alamos Regional Airport. An overflow pipe from the septic tank discharged into Pueblo Canyon. This pipe is still in place. For the purpose of scoping these sites will be treated in aggregate.
AP 4.5 Part B Information **Run-off score (out of 46)** **Terminal point of surface water transport**	PRS 73-004(b) has an AP4.5 Total Erosion Matrix Score of 39.8. The terminal point of surface water transport is a bench on the north-facing slope of Pueblo Canyon.
Other Scoping Meeting Notes	None.

B-1.1 Part B—Site Visit Documentation

Site ID	PRS 73-003, 73-004(b)
Date of Site Visit	2 June 1998
Site Visit Conducted by	G. McDermott

Receptor Information:

Estimate cover	**% vegetated** = ~5% **% wetland** = none **% structures/asphalt, etc.** = ~80%
Field notes on the FIMAD vegetation class	The mesa top area of this site that is not paved is largely bare ground with scattered grasses and forbs. FIMAD lists the north-facing slope of Pueblo Canyon as Ponderosa pine, but on the rim of the north-facing slope there are nearly equal numbers of firs and Gambel oaks.
Field notes on T&E Habitat, if applicable	Pueblo Canyon is core foraging/roosting habitat for Peregrine falcon and Mexican spotted owl.
Are ecological receptors present at the PRS? **(yes/no/uncertain)** **Provide explanation**	Yes. There are scattered grasses, forbs and Gambel oaks growing over the area of the outlet drainline from the septic tank. The outfall area of the drainline contains Gambel oak, scattered shrubs, and Ponderosa pine and Douglas fir directly downslope of the outfall.

Contaminant Transport Information:

Surface water transport **Field notes on the terminal point of surface water transport (if applicable)**	Run-off from the airport parking lot is prevented from flowing over the PRS 73-004(b) outfall by an asphalt berm which diverts water to an asphalt drainage ditch approximately 100 ft east of the outfall.
Are there any off-site transport pathways? **(yes/no/uncertain)** **Provide explanation**	Yes. The amount of bare ground present makes the area vulnerable to wind erosion. The PRS 73-004(b) outfall area is subject to erosion from surface water runoff.

Ecological Effects Information:

Physical Disturbance **(provide list of major types of disturbances)**	PRS 73-003 and the inlet line and area of the septic tank VCA of PRS 73-004(b) have been asphalted over. The ground around the outlet line was disturbed for electric and telephone line installation. An asphalt and dirt road crosses over the outlet line approximately 5 ft south of its terminus.
Are there obvious ecological effects? **(yes/no/uncertain)** **Provide explanation**	Yes. The ground between the parking lot and the asphalt and dirt road is largely unvegetated, probably due to the disturbance from the septic tank VCA and the electric and telephone line installation.

No Receptor/No Pathways:

If there are no receptors and no offsite transport pathways the remainder of the checklist should not be completed. Stop here and provide any additional explanation/justification for proposing an ecological No Further Action recommendation (if needed). This section does not apply.

Data Adequacy:

Do existing data provide information on the nature, rate and extent of contamination? **(yes/no/uncertain)** **Provide explanation** **(consider if the maximum value was captured by existing sample data)**	No. Only one sample was taken under the approximately 58 ft of outlet drain that remains in place. Since this sample yielded a number of inorganic and organic contaminants, other samples should be taken beneath the outlet pipe to determine the extent of contamination. Only one sample was taken under the inlet line to the septic tank, and no samples were taken from PRS 73-003, the site of the former Steam Cleaning Facility. Most importantly, more samples needs to be taken in the outfall area to determine the vertical and horizontal extent of contamination in this area, as this is the area most likely to be subject to erosional forces.
Do existing data for the PRS address potential pathways of site contamination? **(yes/no/uncertain)** **Provide explanation** **(consider if other sites could be impacting this PRS)**	No. The vertical profile of contamination in the outfall needs to be characterized so that the risk posed by wind and water erosion can be better determined.

Additional Field Notes:

Provide additional field notes on the site setting and potential ecological receptors.

B-1.2 Part C—Ecological Pathways Conceptual Exposure Model

Provide answers to Questions A to R and use this information to complete the Ecological Pathways Conceptual Exposure Model

Question A:

Could soil contaminants reach receptors via vapors?

- **Volatility of the hazardous substance (volatile chemicals generally have Henry's Law constant >10^{-5} atm-me/mol and molecular weight <200 g/mol).**

Answer (likely/unlikely/uncertain) Unlikely

Provide explanation:

No volatile chemicals were detected at the site. Low concentrations of the semivolatile bis(2-ethylhexyl)phthalate were detected under the inlet drain, which is currently asphalted over, and under the outlet drain, which is not covered by asphalt. Given that the samples under the outlet drain were detected at a depth of 4.2–4.5 ft, and that bis(2-ethylhexyl)phthalate has a Henry's Law constant <10^{-5} atm-me/mol, the risk of contaminants reaching receptors via vapors is very minimal.

Question B:

Could the soil contaminants identified above reach receptors through fugitive dust carried in air?

- **Soil contamination would have to be on the actual surface of the soil to become available for dust.**
- **In the case of dust exposures to burrowing animals, the contamination would have to occur in the depth interval where these burrows occur.**

Answer (likely/unlikely/uncertain) Uncertain

Provide explanation:

Fourteen organic and seven inorganic contaminants were detected in the outfall and in the end of the outlet pipe. The outfall samples were taken at a depth of 2.2–2.5 ft. Since there is a large proportion of bare ground in the outfall area that is subject to wind erosion, samples should be taken to quantify the vertical and horizontal extent of contamination in the outfall area.

Question C:

Can contaminated soil be transported to aquatic ecological communities (use AP 4.5 run-off score and terminal point of surface water runoff to help answer this question)?

- **If the AP 4.5 run-off score* equal to zero, this suggests that erosion at PRS is not a transport pathway. (* note that the runoff score is not the entire erosion potential score, rather it is a subtotal of this score with a maximum value of 46 points)**

- **If erosion is a transport pathway, evaluate the terminal point to see if aquatic receptors could be affected.**

Answer (likely/unlikely/uncertain) Unlikely

Provide explanation:

There are no aquatic ecological communities between the PRS and the terminal point of surface water transport.

Question D:

Is contaminated groundwater potentially available to biological receptors through seeps or springs?

- **Known or suspected presence of contaminants in groundwater.**
- **The potential for contaminants to migrate via groundwater and discharge into habitats and/or surface waters.**
- **Contaminants may be taken up by terrestrial and rooted aquatic plants whose roots are in contact with groundwater present within the root zone (~1 m depth).**
- **Terrestrial wildlife receptors generally will not contact groundwater unless it is discharged to the surface.**

Answer (likely/unlikely/uncertain) Unlikely

Provide explanation:

The main aquifer lies approximately 1100 beneath the mesa top (SAP for Solid Waste Management Plan 73-2), making it unlikely that contaminants from these PRSs would reach the aquifer. There are no known seeps or spring in the vicinity of the PRSs. However the hydrology of the area is not well characterized with regards to shallow alluvial and perched bedrock aquifers present in Pueblo Canyon.

Question E:

Is infiltration/percolation from contaminated subsurface material a viable transport pathway?

- **Suspected ability of contaminants to migrate to groundwater.**
- **The potential for contaminants to migrate via groundwater and discharge into habitats and/or surface waters.**
- **Contaminants may be taken up by terrestrial and rooted aquatic plants whose roots are in contact with groundwater present within the root zone (~1 m depth).**
- **Terrestrial wildlife receptors generally will not contact groundwater unless it is discharged to the surface.**
- **Also consider the importance of mass wasting as a potential release mechanism for subsurface material.**

Answer (likely/unlikely/uncertain) Unlikely

Provide explanation:

See Question D, above.

Question F:

Might erosion or mass wasting events be a potential release mechanism for contaminants from subsurface materials or perched aquifers to the surface?

- **Consider, particularly, the erodability of fill material and the geologic processes of canyon/mesa edges.**

Answer (likely/unlikely/uncertain): Unlikely

Provide explanation:

Since the outfall of PRS 73-004(b) is on the rim of Pueblo Canyon, mass wasting must be considered as a potential, albeit unlikely, release mechanism for subsurface material.

Question G:

Could airborne contaminants interact with receptors through respiration of vapors?

- **Contaminants must be present as volatiles in the air.**
- **Consider the importance of inhalation of vapors for burrowing animals.**
- **Foliar uptake of organic vapors is typically not a significant pathway.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial/Emergent Plants: 0
Terrestrial Animals: 0

Provide explanation:

No volatile organic compounds are present.

Question H:

Could airborne contaminants interact with plants through deposition of particulates or with animals through inhalation of fugitive dust?

- **Contaminants must be present as particulates in the air or as dust for this pathway to be viable.**

- **Exposure via inhalation of fugitive dust is particularly applicable to ground-dwelling species that would be exposed to dust disturbed by their foraging or burrowing activities or by wind movement.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial/Emergent Plants: 2
Terrestrial Animals: 2

Provide explanation:

The large extent of bare ground at the site makes the area subject to wind erosion. This cannot be considered as less than a minor pathway until the vertical extent of contamination in the outfall area has been characterized.

Question I:

Could contaminants interact with plants through root uptake or rain splash from surficial soils?

- **Contaminants in bulk soil may partition into soil solution, making them available to roots.**
- **Exposure of terrestrial plants to contaminants present in particulates deposited on leaf and stem surfaces by rain striking contaminated soils (i.e., rain splash).**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Plants: 3

Provide explanation:

The contaminants in the outfall area occur at a depth where they are available for root uptake by plants in the area. There are scattered grasses, shrubs and trees in the immediate area of the outfall.

Question J:

Could contaminants interact with receptors through food web transport from surficial soils?

- **The chemicals may bioaccumulate in animals (see list of bioaccumulating chemicals presented in Table B.1.2-1).**
- **Animals may ingest contaminated prey.**

TABLE B.1.2-1

BIOACCUMULATING CHEMICALS

Volatile Organic Compounds	**PCBs/Pesticides**
Dichlorobenzene[1,4-]	All aroclors
Trichlorobenzene[1,2,4-]	Beta-BHC and BHC-mixed isomers
Xylene (mixed isomers)	Chlordane
Semivolatile Organic Compounds	Chlorecone (Kepone)
Acenaphthene	DDT and metabolites
Anthracene	Dieldrin
Benz(a)anthracene	Endosulfan
Benzo(a)pyrene	Endrin
Benzo(b)fluoranthene	Heptachlor
Benzo(g,h,i)perylene	Lindane
Benzo(k)fluoranthene	Methoxychlor
Bis(2-ethylhexyl)phthalate	Toxaphene
Butyl benzyl phthalate	**Inorganic Chemicals**
Chrysene	Aluminum
Dibenz(a,h)anthracene	Cadmium
Di-n-butyl phthalate	Copper
Di-n-octyl phthalate	Lead
Fluoranthene	Mercury
Fluorene	Nickel
Indeno(1,2,3-cd)pyrene	Selenium
Phenanthrene	**Radionuclides**
Pyrene	Americium-241
Pentachloronitrobenzene	Cesium-137
Pentachlorophenol	Plutonium-238, -239,240
Dioxins/Furans	Radium-226, -228
Dibenzofuran	Strontium-90
2,3,7,8-tetrachloro-dibenzo(p)dioxin	Thorium-228, -230, -232
2,3,7,8-tetrachloro-dibenzo(p)furan	Uranium-234 -235, -238

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 3

Provide explanation:

Seventeen potentially bioaccumulating contaminants were detected in the outfall area. This area is subject to wind and water erosion, and the vertical extent of contamination has not been quantified. Until this extent is quantified, the nature of the contamination warrants this being considered a major pathway.

Question K:

Could contaminants interact with receptors via incidental ingestion of surficial soils?

- **Incidental ingestion of contaminated soil could occur while animals grub for food resident in the soil, feed on plant matter covered with contaminated soil or while grooming themselves clean of soil.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 2

Provide explanation:

This could be a minor pathway in the outfall area, where contaminants may be close enough to the surface to make themselves available to fossorial vertebrates and invertebrates. It is probably not a viable pathway in other areas of the PRS, where contaminants have either been paved over or occur at depths beyond the range of fossorial animals.

Question L:

Could contaminants interact with receptors through dermal contact with surficial soils?

- **Significant exposure via dermal contact would generally be limited to organic contaminants which are lipophilic and can cross epidermal barriers.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 2

Provide explanation:

Many of the organic compounds detected in the outfall are lipophilic. This cannot be considered less than a minor pathway until the vertical extent of the contamination at the outfall is characterized.

Question M:

Could contaminants interact with plants or animals through external irradiation?

- **External irradiation effects are most relevant for gamma emitting radionuclides.**
- **Burial of contamination severely attenuates radiological exposure.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Plants: 0
Terrestrial Animals: 0

Provide explanation:

No radionuclides were detected at the site.

Question N:

Could contaminants interact with plants through direct uptake from water and sediment or sediment rain splash?

- **Contaminants may be taken-up by terrestrial plants whose roots are in contact with surface waters.**
- **Terrestrial plants may be exposed to particulates deposited on leaf and stem surfaces by rain striking contaminated sediments (i.e., rain splash). in an area that is only periodically inundated with water.**
- **Contaminants in sediment may partition into soil solution, making them available to roots.**
- **Aquatic plants are in direct contact with water.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Plants: 1
Aquatic Plants: 0

Provide explanation:

Surface water is highly ephemeral at the site. Erosion due to surface water run-off could deposit contaminated sediments from the outfall farther downslope in Pueblo Canyon. There are no aquatic communities present between the mesa top and the terminal point of surface water transport.

Question O:

Could contaminants interact with receptors through food web transport from water and sediment?

- **The chemicals may bioaccumulate in animals (see list of bioaccumulating chemicals presented in Table B.1.2-1)**
- **Animals may ingest contaminated prey.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 1
Aquatic Animals: 0

Provide explanation:
Potentially bioaccumulating chemicals are present at the site, but surface water is highly ephemeral. No aquatic receptors are present between the mesa top and the terminal point of surface water transport.

Question P:

Could contaminants interact with receptors via incidental ingestion of water and sediment?

- **If sediments are present in an area that is only periodically inundated with water, terrestrial receptors may incidentally ingest sediments.**
- **Terrestrial receptors may ingest water-borne contaminants if contaminated surface waters are used as a drinking water source.**
- **Aquatic receptors may regularly or incidentally ingest sediment while foraging.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 1
Aquatic Animals: 0

Provide explanation:

Surface water available for ingestion is highly ephemeral at the site. No aquatic communities are present.

Question Q:

Could contaminants interact with receptors through dermal contact with water and sediment?

- **If sediments are present in an area that is only periodically inundated with water, terrestrial species may be dermally exposed during dry periods.**
- **Terrestrial organisms may be dermally exposed to water-borne contaminants as a result of wading or swimming in contaminated waters.**
- **Aquatic receptors may be directly exposed to sediments or may be exposed through osmotic exchange, respiration, or ventilation of sediment pore waters.**
- **Aquatic receptors may be exposed through osmotic exchange, respiration, or ventilation of surface waters.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 1
Aquatic Animals: 0

Provide explanation:

Surface water is highly ephemeral at the site. No aquatic communities are present.

Question R:

Could contaminants interact with plants or animals through external irradiation?

- **External irradiation effects are most relevant for gamma emitting radionuclides.**
- **Burial of contamination severely attenuates radiological exposure.**
- **The water column acts to absorb radiation, thus external irradiation is typically more important for sediment dwelling organisms.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

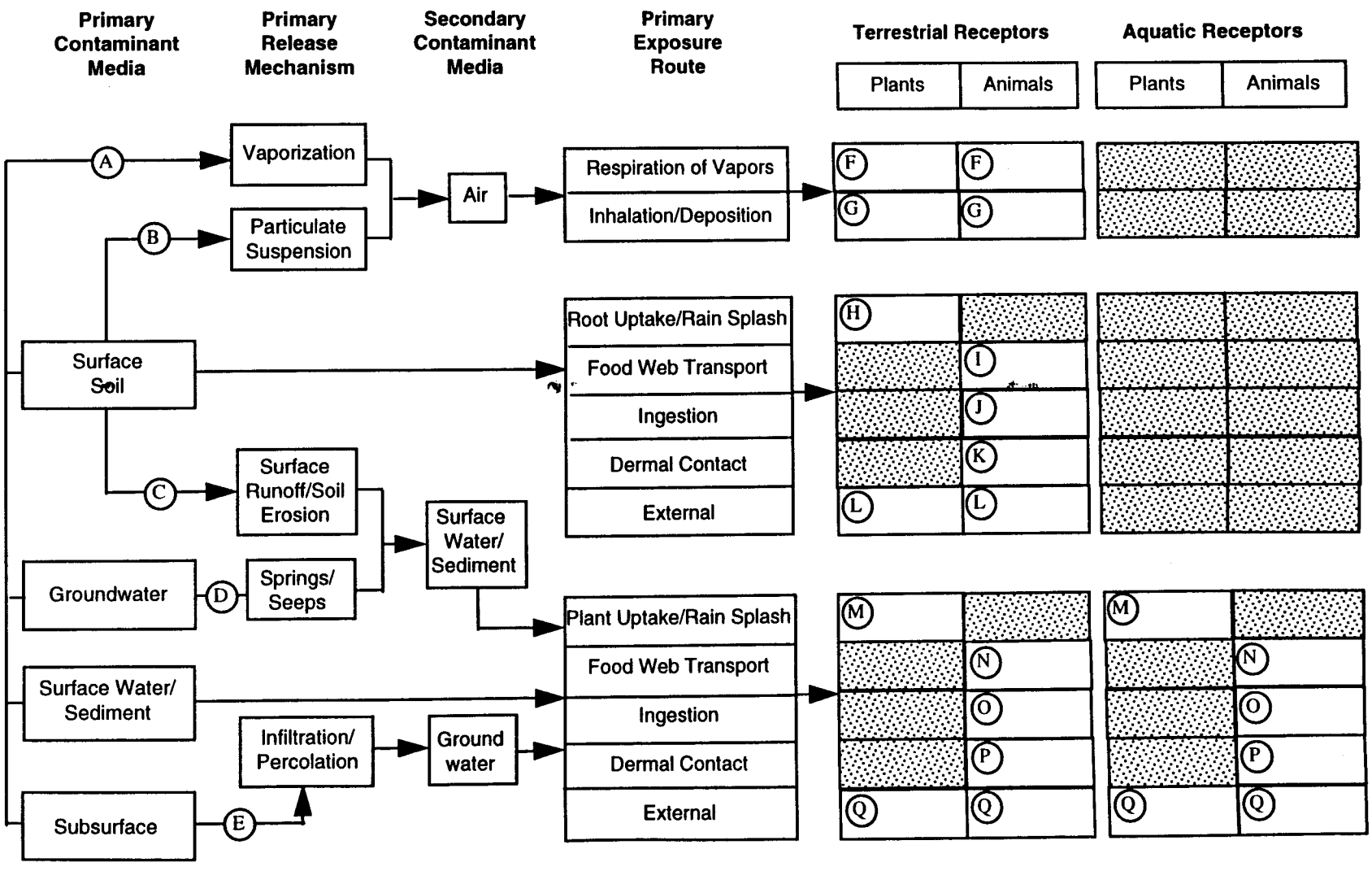
Terrestrial Plants: 0
Aquatic Plants: 0
Terrestrial Animals: 0
Aquatic Animals: 0

Provide explanation:

No radionuclides are present at the site.

Ecological Scoping Checklist: Ecological Pathways Conceptual Exposure Model

KEY
0 - No Pathway
1 - Unlikely Pathway
2 - Minor Pathway
3 - Major Pathway



Signatures and certifications:

Checklist completed by (provide name, organization and phone number)

Name (printed): Gregory McDermott

Name (signature): Gregory J. McDermott

Organization: Neptune and Company, Inc.

Phone number: (505) 662-0730, ext. 21

Date completed: June 8, 1998

Verification by a member of ER Project Ecological Risk Task Team (provide name, organization and phone number)

Name (printed): Randall Ryti

Name (signature): Randall Ryti

Organization: Neptune and Company, Inc.

Phone number: (505) 662-0707 ext. 12

B-2.0 PART A—SCOPING MEETING DOCUMENTATION

Site ID	PRSs 73-002, 73-004(a), 73-006
Nature of PRS releases **(indicate all that apply)**	**Solid** – Yes **Liquid** – Yes **Gaseous** – No **Other, explain**
List of Primary Impacted Media **(indicate all that apply)**	**Surface soil** – Yes SURFACE WATER/SEDIMENT – **NO** **Subsurface** – Yes **Groundwater** – No **Other, explain**
FIMAD vegetation class **(indicate all that apply)**	**Water** – No **Bare Ground/Unvegetated** – No **Spruce/fir/aspen/mixed conifer** – No **Ponderosa pine** – Yes **Piñon juniper/juniper savannah** – No **Grassland/shrubland** – No **Developed** – Yes
Is T&E Habitat Present? **list species if applicable**	Yes Yes, potential nesting and foraging habitat for the Peregrine falcon and the Mexican spotted owl.
Provide list and description of Neighboring/ Contiguous/ Upgradient PRSs **(consider need to aggregate PRS for screening)**	PRS 73-002 is an ash outfall from the incinerator building on the grounds of the Los Alamos Airport. The ash was dumped from the rim of Pueblo Canyon and extends approximately 100 ft down the south wall of the canyon to a bench. The outfall is approximately 150 ft wide where it intersects the bench. PRS 73-004(a) was a concrete septic system which received sanitary waste from the incinerator building. The septic tank was removed as a VCA in 1996, but the inlet and outlet drainlines remain in place. PRS 73-006 consists of two drainlines connected to the floor drains of the incinerator building. The western-most drainline was located and removed, the eastern drainline has not been located. The drainlines for both of these PRSs run parallel with one another, with the PRS 73-004(a) drainline located approximately 5 ft west of the western-most drainline of PRS 73-006. The outfalls from the drainlines of PRS 73-004(a) and PRS 73-006 fall within the boundaries of PRS 73-002 and as such, these two PRSs should be considered in aggregate with 73-002.
AP 4.5 Part B Information **Run-off score (out of 46)** **Terminal point of surface water transport**	PRS 73-004(a) has an AP4.5 Total Erosion Matrix Score of 38. PRS 73-006 has an AP4.5 Total Erosion matrix score of 56. The terminal point of surface water transport is a bench on the north-facing slope of Pueblo Canyon.
Other Scoping Meeting Notes	None.

B-2.1 Part B—Site Visit Documentation

Site ID	PRS 73-004(a), 73-006
Date of Site Visit	29 May 1998, 2 June 1998
Site Visit Conducted by	G. McDermott, R. Ryti (1st visit only)

Receptor Information:

Estimate cover	**% vegetated** = ~10% **% wetland** = none **% structures/asphalt, etc.** = minimal
Field notes on the FIMAD vegetation class	The FIMAD classification lists the mesa top area as developed, with the canyon identified as ponderosa pine forest. PRS 73-004(a) and PRS 73-006 are mostly bare ground with scattered grasses and forbs. PRS 73-002 is also predominantly bare ground with scattered shrubs and trees.
Field notes on T&E Habitat, if applicable	Pueblo Canyon is core foraging/roosting habitat for Peregrine falcon and Mexican spotted owl.
Are ecological receptors present at the PRS? **(yes/no/uncertain)** **Provide explanation**	Yes. Scattered grasses and forbs are growing over the site. The outfall of PRS 73-004(a) occurs within a cluster of juniper and oak trees.

Contaminant Transport Information:

Surface water transport **Field notes on the terminal point of surface water transport (if applicable)**	The terminal point of surface water transport is a bench located approximately 100 ft below the top of the mesa. Surface water runoff in the vicinity is magnified by an asphalt drainage ditch which channels runoff from the airport parking lot into Pueblo Canyon. The drainage ditch is located approximately 12 ft west of PRS 73-004(a).
Are there any off-site transport pathways? **(yes/no/uncertain)** **Provide explanation**	Yes. There is potential for contaminants in the outfall area to be transported into Pueblo Canyon by water (see above, Surface water transport). The amount of bare ground present also suggests wind erosion may be a viable pathway.

Ecological Effects Information:

Physical Disturbance **(provide list of major types of disturbances)**	The area was disturbed for the 73-004(a) septic tank VCA and for the installation of electric and telephone lines. A dirt road runs east-west over the drainlines. These factors account for the large proportion of unvegetated ground at the site.
Are there obvious ecological effects? **(yes/no/uncertain)** **Provide explanation**	Yes. Much of the area is sparsely vegetated.

No Receptor/No Pathways:

If there are no receptors and no offsite transport pathways the remainder of the checklist should not be completed. Stop here and provide any additional explanation/justification for proposing an ecological No Further Action recommendation (if needed). This section does not apply.

Data Adequacy:

Do existing data provide information on the nature, rate and extent of contamination? **(yes/no/uncertain)** **Provide explanation** **(consider if the maximum value was captured by existing sample data)**	Uncertain. Only one sample was taken beneath the 37 ft length of outlet pipe associated with PRS 73-004(a). This sample detected two inorganics above UTL, and seven organics, including four bioaccumulating chemicals. Concentrations of these chemicals may be higher under pipe joints if the joints have leaked. No samples were taken beneath the short inlet pipe, or at the junctions where the inlet and outlet pipes joined the septic tank. It is possible that the sampling failed to adequately characterize the rate of contamination at the site. Three samples were taken under the PRS 73-006 western drainline and found seven inorganics above UTL, including three bioaccumulating metals, and 11 bioaccumulating organic contaminants. Since the eastern drainline was not located, no sampling was done in that area. Since the outfalls from the two drainlines fall within the area of the dumped ash, it is not possible to distinguish between contamination originating from the drainlines and contamination associated with the ash.
Do existing data for the PRS address potential pathways of site contamination? **(yes/no/uncertain)** **Provide explanation** **(consider if other sites could be impacting this PRS)**	Yes. Data seems to have captured the extent of contamination at PRS 73-002. Downslope drainages have been identified and sampled.

Additional Field Notes:

Provide additional field notes on the site setting and potential ecological receptors. PRS 73-004(a) and PRS 73-006 cannot be separated from PRS 73-002 either functionally or geographically. From an ecological risk standpoint, these three sites should be considered as one for the purpose of any future planned actions.

B-2.2 Part C—Ecological Pathways Conceptual Exposure Model

Provide answers to Questions A to R and use this information to complete the Ecological Pathways Conceptual Exposure Model

Question A:

Could soil contaminants reach receptors via vapors?

- **Volatility of the hazardous substance (volatile chemicals generally have Henry's Law constant >10^{-5} atm-me/mol and molecular weight <200 g/mol).**

Answer (likely/unlikely/uncertain) Uncertain.

Provide explanation:

A number of volatile chemicals have been detected in the ash outfall, but mainly at trace levels.

Question B:

Could the soil contaminants identified above reach receptors through fugitive dust carried in air?

- **Soil contamination would have to be on the actual surface of the soil to become available for dust.**
- **In the case of dust exposures to burrowing animals, the contamination would have to occur in the depth interval where these burrows occur.**

Answer (likely/unlikely/uncertain) Yes

Provide explanation:

The area is subject to wind erosion, and much of the contamination in the ash outfall occurs within 1 ft of the soil surface. This also makes it readily available to be inhaled by burrowing vertebrates and invertebrates.

Question C:

Can contaminated soil be transported to aquatic ecological communities (use AP 4.5 run-off score and terminal point of surface water runoff to help answer this question)?

- **If the AP 4.5 run-off score* equal to zero, this suggests that erosion at PRS is not a transport pathway. (* note that the runoff score is not the entire erosion potential score, rather it is a subtotal of this score with a maximum value of 46 points)**
- **If erosion is a transport pathway, evaluate the terminal point to see if aquatic receptors could be affected.**

Answer (likely/unlikely/uncertain) Unlikely

Provide explanation:

There are no aquatic ecological communities between the PRS and the terminal point of surface water transport.

Question D:

Is contaminated groundwater potentially available to biological receptors through seeps or springs?

- **Known or suspected presence of contaminants in groundwater.**
- **The potential for contaminants to migrate via groundwater and discharge into habitats and/or surface waters.**
- **Contaminants may be taken up by terrestrial and rooted aquatic plants whose roots are in contact with groundwater present within the root zone (~1 m depth).**
- **Terrestrial wildlife receptors generally will not contact groundwater unless it is discharged to the surface.**

Answer (likely/unlikely/uncertain) Unlikely

Provide explanation:

The main aquifer lies approximately 1100 beneath the mesa top (SAP for Solid Waste Management Plan 73-2), making it unlikely that contaminants from these PRSs would reach the aquifer. There are no known seeps or spring in the vicinity of the PRSs. However the hydrology of the area is not well characterized with regards to shallow alluvial and perched bedrock aquifers present in Pueblo Canyon.

Question E:

Is infiltration/percolation from contaminated subsurface material a viable transport pathway?

- **Suspected ability of contaminants to migrate to groundwater.**
- **The potential for contaminants to migrate via groundwater and discharge into habitats and/or surface waters.**
- **Contaminants may be taken up by terrestrial and rooted aquatic plants whose roots are in contact with groundwater present within the root zone (~1 m depth).**
- **Terrestrial wildlife receptors generally will not contact groundwater unless it is discharged to the surface.**
- **Also consider the importance of mass wasting as a potential release mechanism for subsurface material.**

Answer (likely/unlikely/uncertain) Unlikely

Provide explanation:

See Question D, above.

Question F:

Might erosion or mass wasting events be a potential release mechanism for contaminants from subsurface materials or perched aquifers to the surface?

- **Consider, particularly, the erodability of fill material and the geologic processes of canyon/mesa edges.**

Answer (likely/unlikely/uncertain): Unlikely

Provide explanation:

Since the outfall of PRS 73-004(b) is on the rim of Pueblo Canyon, mass wasting must be considered as a potential, albeit unlikely, release mechanism for subsurface material.

Question G:

Could airborne contaminants interact with receptors through respiration of vapors?

- **Contaminants must be present as volatiles in the air.**
- **Consider the importance of inhalation of vapors for burrowing animals.**
- **Foliar uptake of organic vapors is typically not a significant pathway.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial/Emergent Plants: 1
Terrestrial Animals: 1

Provide explanation:

Volatile organic compounds were detected mainly at trace levels.

Question H:

Could airborne contaminants interact with plants through deposition of particulates or with animals through inhalation of fugitive dust?

- **Contaminants must be present as particulates in the air or as dust for this pathway to be viable.**
- **Exposure via inhalation of fugitive dust is particularly applicable to ground-dwelling species that would be exposed to dust disturbed by their foraging or burrowing activities or by wind movement.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial/Emergent Plants: 3
Terrestrial Animals: 3

Provide explanation:

This is a major pathway due to the extent of the bare ground subject to wind erosion. There is abundant evidence of fossorial vertebrates in the area, although no tunneling was evident within the small area of PRS 73-004(a) and 73-006.

Question I:

Could contaminants interact with plants through root uptake or rain splash from surficial soils?

- **Contaminants in bulk soil may partition into soil solution, making them available to roots.**
- **Exposure of terrestrial plants to contaminants present in particulates deposited on leaf and stem surfaces by rain striking contaminated soils (i.e., rain splash).**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Plants: 3

Provide explanation:

There are scattered trees, grasses, and forbs growing over the area. The contaminants in the outfall area were detected at depths that would make them available for uptake by plants. Contaminated surface soils in the outfall could be deposited on plant surfaces via rain splash.

Question J:

Could contaminants interact with receptors through food web transport from surficial soils?

- **The chemicals may bioaccumulate in animals (see list of bioaccumulating chemicals presented in Table B.2.2-1).**
- **Animals may ingest contaminated prey.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 3

Provide explanation:

Contaminants detected at the site include 20 bioaccumulating organic chemicals and 5 bioaccumulating inorganics. These chemicals are available for uptake by plants and potentially for uptake by fossorial mammals and invertebrates, and by ground-feeding birds, mammals, reptiles and invertebrates in the area, which could then serve as prey for larger predators.

TABLE B.2.2-1

BIOACCUMULATING CHEMICALS

Volatile Organic Compounds	**PCBs/Pesticides**
Dichlorobenzene[1,4-]	All aroclors
Trichlorobenzene[1,2,4-]	Beta-BHC and BHC-mixed isomers
Xylene (mixed isomers)	Chlordane
Semivolatile Organic Compounds	Chlorecone (Kepone)
Acenaphthene	DDT and metabolites
Anthracene	Dieldrin
Benz(a)anthracene	Endosulfan
Benzo(a)pyrene	Endrin
Benzo(b)fluoranthene	Heptachlor
Benzo(g,h,i)perylene	Lindane
Benzo(k)fluoranthene	Methoxychlor
Bis(2-ethylhexyl)phthalate	Toxaphene
Butyl benzyl phthalate	**Inorganic Chemicals**
Chrysene	Aluminum
Dibenz(a,h)anthracene	Cadmium
Di-n-butyl phthalate	Copper
Di-n-octyl phthalate	Lead
Fluoranthene	Mercury
Fluorene	Nickel
Indeno(1,2,3-cd)pyrene	Selenium
Phenanthrene	**Radionuclides**
Pyrene	Americium-241
Pentachloronitrobenzene	Cesium-137
Pentachlorophenol	Plutonium-238, -239,240
Dioxins/Furans	Radium-226, -228
Dibenzofuran	Strontium-90
2,3,7,8-tetrachloro-dibenzo(p)dioxin	Thorium-228, -230, -232
2,3,7,8-tetrachloro-dibenzo(p)furan	Uranium-234 -235, -238

Question K:

Could contaminants interact with receptors via incidental ingestion of surficial soils?

- **Incidental ingestion of contaminated soil could occur while animals grub for food resident in the soil, feed on plant matter covered with contaminated soil or while grooming themselves clean of soil.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 3

Provide explanation: : The surface contamination in the outfall is readily available for ingestion by ground dwelling animals, or by herbivores feeding on foliage covered with contaminated soil.

Question L:

Could contaminants interact with receptors through dermal contact with surficial soils?

- **Significant exposure via dermal contact would generally be limited to organic contaminants which are lipophilic and can cross epidermal barriers.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 2

Provide explanation:

Several of the organic contaminants are lipophilic in nature, but generally the soil concentrations of these contaminants are low enough to make this a less significant pathway than inhalation and ingestion of the contaminants.

Question M:

Could contaminants interact with plants or animals through external irradiation?

- **External irradiation effects are most relevant for gamma emitting radionuclides.**
- **Burial of contamination severely attenuates radiological exposure.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Plants: 2
Terrestrial Animals: 2

Provide explanation:

Isotopic uranium and plutonium were detected in the area of the PRS 73-006 outfall, with Uranium-238 occurring at a concentration 5-7 times normal background rate.

Question N:

Could contaminants interact with plants through direct uptake from water and sediment or sediment rain splash?

- **Contaminants may be taken-up by terrestrial plants whose roots are in contact with surface waters.**
- **Terrestrial plants may be exposed to particulates deposited on leaf and stem surfaces by rain striking contaminated sediments (i.e., rain splash). in an area that is only periodically inundated with water.**
- **Contaminants in sediment may partition into soil solution, making them available to roots.**
- **Aquatic plants are in direct contact with water.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Plants: 1
Aquatic Plants: 0

Provide explanation:

Surface water is highly ephemeral at the site. Erosion due to surface water run-off could deposit contaminated sediments from the outfall farther downslope in Pueblo Canyon. There are no aquatic communities present between the mesa top and the terminal point of surface water transport.

Question O:

Could contaminants interact with receptors through food web transport from water and sediment?

- **The chemicals may bioaccumulate in animals (see list of bioaccumulating chemicals presented in Table B.2.2-1)**
- **Animals may ingest contaminated prey.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 1
Aquatic Animals: 0

Provide explanation:

Potentially bioaccumulating chemicals are present at the site, but surface water is highly ephemeral. No aquatic receptors are present between the mesa top and the terminal point of surface water transport.

Question P:

Could contaminants interact with receptors via incidental ingestion of water and sediment?

- **If sediments are present in an area that is only periodically inundated with water, terrestrial receptors may incidentally ingest sediments.**
- **Terrestrial receptors may ingest water-borne contaminants if contaminated surface waters are used as a drinking water source.**
- **Aquatic receptors may regularly or incidentally ingest sediment while foraging.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 1
Aquatic Animals: 0

Provide explanation:

Surface water available for ingestion is highly ephemeral at the site. No aquatic communities are present.

Question Q:

Could contaminants interact with receptors through dermal contact with water and sediment?

- **If sediments are present in an area that is only periodically inundated with water, terrestrial species may be dermally exposed during dry periods.**
- **Terrestrial organisms may be dermally exposed to water-borne contaminants as a result of wading or swimming in contaminated waters.**
- **Aquatic receptors may be directly exposed to sediments or may be exposed through osmotic exchange, respiration, or ventilation of sediment pore waters.**
- **Aquatic receptors may be exposed through osmotic exchange, respiration, or ventilation of surface waters.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 1
Aquatic Animals: 0

Provide explanation:

Surface water is highly ephemeral at the site. No aquatic communities are present.

Question R:

Could contaminants interact with plants or animals through external irradiation?

- **External irradiation effects are most relevant for gamma emitting radionuclides.**
- **Burial of contamination severely attenuates radiological exposure.**
- **The water column acts to absorb radiation, thus external irradiation is typically more important for sediment dwelling organisms.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

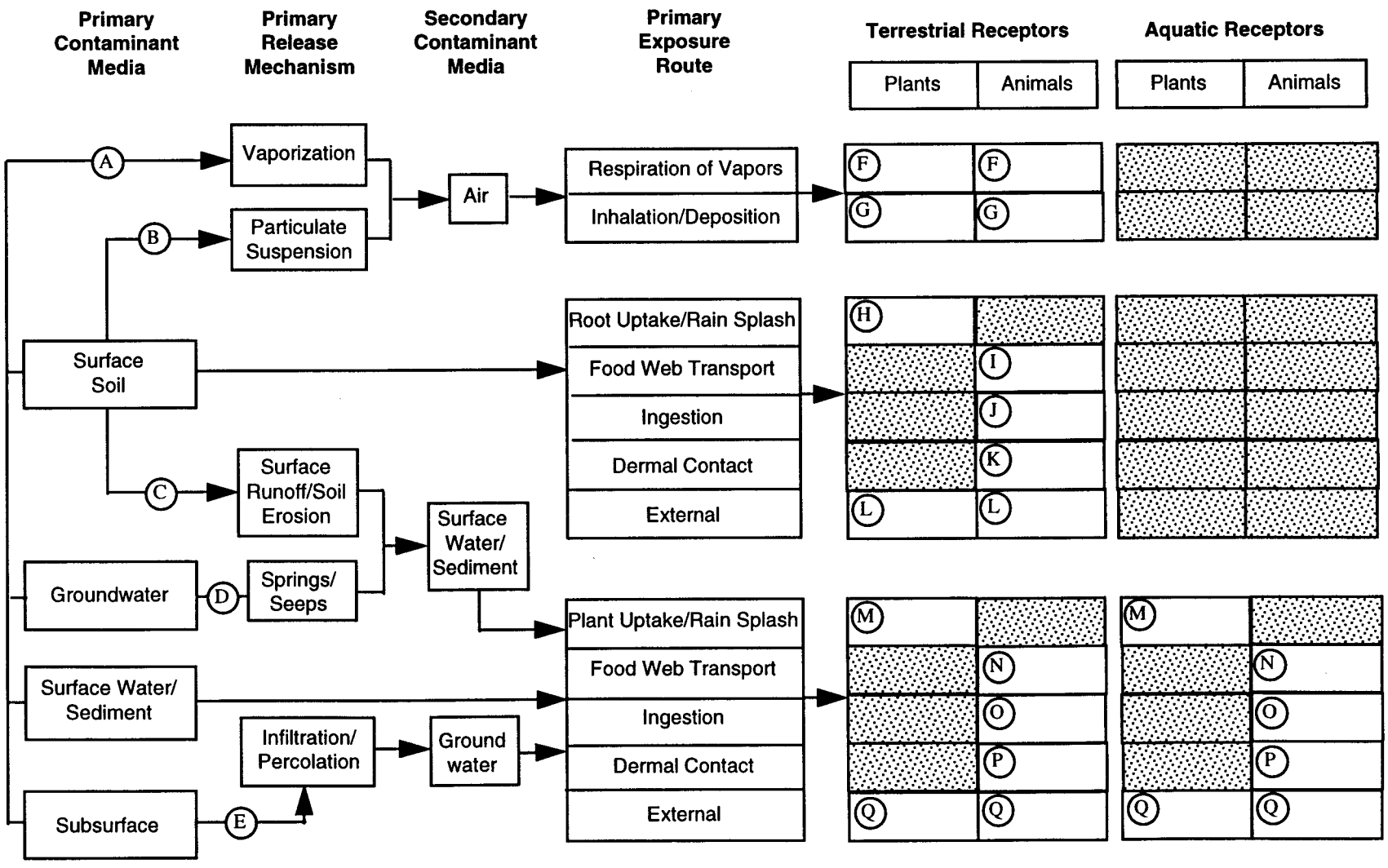
Terrestrial Plants: 1
Aquatic Plants: 0
Terrestrial Animals: 1
Aquatic Animals: 0

Provide explanation:

Although several radionuclides were detected at the site, surface water is highly ephemeral, and no aquatic communities are present.

Ecological Scoping Checklist: Ecological Pathways Conceptual Exposure Model

KEY
0 - No Pathway
1 - Unlikely Pathway
2 - Minor Pathway
3 - Major Pathway



Signatures and certifications:

Checklist completed by (provide name, organization and phone number)

Name (printed): Gregory McDermott

Name (signature): Gregory J. McDermott

Organization: Neptune and Company, Inc.

Phone number: (505) 662-0730, ext. 21

Date completed: June 8, 1998

Verification by a member of ER Project Ecological Risk Task Team (provide name, organization and phone number)

Name (printed): Randall Ryti

Name (signature): Randall Ryti

Organization: Neptune and Company, Inc.

Phone number: (505) 662-0707 ext. 12

B-3.0 PART A—SCOPING MEETING DOCUMENTATION

Site ID	PRSs 73-005, 73-007, AOCs 73-005(a–f)
Nature of PRS releases **(indicate all that apply)**	**Solid** – Yes **Liquid** – Yes **Gaseous** – No **Other, explain**
List of Primary Impacted Media **(indicate all that apply)**	**Surface soil** – Yes SURFACE WATER/SEDIMENT – **YES** **Subsurface** – No **Groundwater** – No **Other, explain**
FIMAD vegetation class **(indicate all that apply)**	**Water** – No **Bare Ground/Unvegetated** – Yes **Spruce/fir/aspen/mixed conifer** – No **Ponderosa pine** – Yes **Piñon juniper/juniper savannah** – Yes **Grassland/shrubland** – Yes **Developed** – No
Is T&E Habitat Present? **list species if applicable**	Yes Yes. DP Canyon is Peregrine falcon foraging habitat and is potential nesting habitat for Mexican spotted owl.
Provide list and description of Neighboring/ Contiguous/ Upgradient PRSs **(consider need to aggregate PRS for screening)**	PRS 73-005 is described as a surface debris area located within the former "Contractors Row" south of the Los Alamos Airport. The area was occupied by general contractors and offices from 1947-1950 and contains various solid debris left behind when the contractors relocated. Located within this area are AOCs C-73-005(a–f), which are six unlined pits excavated into the tuff that served as septic tanks for structures in contractors row. These pits were sampled and backfilled during VCA activities in 1996. PRS 73-007 was a steel septic tank located within the surface debris area of PRS 73-005. This tank was removed as a VCA in 1996 but inlet and outlet drainlines were left in place. The outlet drainline flows into DP Canyon. For screening purposes these sites will be treated in aggregate.
AP 4.5 Part B Information **Run-off score (out of 46)** **Terminal point of surface water transport**	All sites in this aggregate have total AP 4.5 scores of 27.6, with run-off scores of 24.0. Terminal point of water transport is DP Canyon.
Other Scoping Meeting Notes	None.

B-3.1 Part B— Site Visit Documentation

Site ID	PRSs 73-005, 73-007, AOCs 73-005(a–f)
Date of Site Visit	29 May 1998, 2 June 1998
Site Visit Conducted by	G. McDermott, R. Ryti (1st visit only)

Receptor Information:

Estimate cover	**% vegetated** = ~60% **% wetland** = none **% structures/asphalt, etc.** = minimal
Field notes on the FIMAD vegetation class	Vegetation classes correspond to FIMAD classifications.
Field notes on T&E Habitat, if applicable	DP Canyon is foraging habitat for Peregrine falcon and is potential nesting habitat for Mexican spotted owl.
Are ecological receptors present at the PRS? **(yes/no/uncertain)** **Provide explanation**	Yes. There are grasses, forbs, shrubs, and trees growing throughout the site. There are many ant mounds and fossorial vertebrates present at the site. A pair of ash-throated flycatchers and a family group of scrub-jays were noted feeding on the site, indicating they are probably nesting on the PRS.

Contaminant Transport Information:

Surface water transport **Field notes on the terminal point of surface water transport (if applicable)**	The terminal point of surface water transport is DP Canyon
Are there any off-site transport pathways? **(yes/no/uncertain)** **Provide explanation**	Yes. Two culverts divert run-off from the airport under the road and empty into drainage channels which cut across PRS 73-005 and empty into DP Canyon. The entire area contains 35–40% bare ground that is subject to wind erosion.

Ecological Effects Information:

Physical Disturbance **(provide list of major types of disturbances)**	The major physical disturbances are scattered mounds of asphalt, concrete debris, and areas of pea-gravel probably used as a foundation layer or fill material. Also, the areas around the AOCs C-73-005(a–f) and PRS 73-007 were disturbed during VCA activities.
Are there obvious ecological effects? **(yes/no/uncertain)** **Provide explanation**	Vegetation has grown and obscured much of the surface debris present. The debris is scattered along the entire length of Contractor's Row.

No Receptor/No Pathways:

If there are no receptors and no offsite transport pathways the remainder of the checklist should not be completed. Stop here and provide any additional explanation/justification for proposing an ecological No Further Action recommendation (if needed). This section does not apply.

Data Adequacy:

Do existing data provide information on the nature, rate and extent of contamination? **(yes/no/uncertain)** **Provide explanation** **(consider if the maximum value was captured by existing sample data)**	No. No samples were collected beneath the inlet or outlet drainlines of PRS 73-007. No samples have been collected in the surface disposal area. No samples have been taken from drainage channels receiving run-off from the surface debris area. Biased sampling probably resulted in the maximum values being captured in the sampling of AOCs 73-005(a–f).
Do existing data for the PRS address potential pathways of site contamination? **(yes/no/uncertain)** **Provide explanation** **(consider if other sites could be impacting this PRS)**	No. The potential for offsite transport of contaminants exists in the surface debris area due to the amount of bare ground subject to wind erosion, and the possibility of surface runoff into DP Canyon. No samples have been taken in the surface debris to determine if or at what level contaminants are present..

Additional Field Notes:

Provide additional field notes on the site setting and potential ecological receptors.

B-3.2 Part C—Ecological Pathways Conceptual Exposure Model

Provide answers to Questions A to R and use this information to complete the Ecological Pathways Conceptual Exposure Model

Question A:

Could soil contaminants reach receptors via vapors?

- **Volatility of the hazardous substance (volatile chemicals generally have Henry's Law constant >10^{-5} atm-me/mol and molecular weight <200 g/mol).**

Answer (likely/unlikely/uncertain) Uncertain.

Provide explanation:

Two volatiles were detected in the waste characterization samples taken from the PRS 73-007 septic tank, but not in the confirmation samples taken under the tank. No samples were taken beneath the inlet and outlet drainlines. No volatiles were detected in the 73-007 outfall. Three volatiles (acetone, toluene, isopropyltoluene) were detected in septic pit AOC 73-005(e) at depths of 1.0–2.0 ft. Backfilling of these pits probably placed the contamination at a depth where volatility is not an issue.

Question B:

Could the soil contaminants identified above reach receptors through fugitive dust carried in air?

- **Soil contamination would have to be on the actual surface of the soil to become available for dust.**
- **In the case of dust exposures to burrowing animals, the contamination would have to occur in the depth interval where these burrows occur.**

Answer (likely/unlikely/uncertain) Yes

Provide explanation:

Backfilling of the septic pits probably place the areas of contamination beyond the reach of burrowing animals. The five contaminants detected at the outfall of PRS 73-007 could be reached by burrowing mammals. No samples were taken in the surface disposal areas, where bare ground is likely to produce airborne particulate matter.

Question C:

Can contaminated soil be transported to aquatic ecological communities (use AP 4.5 run-off score and terminal point of surface water runoff to help answer this question)?

- **If the AP 4.5 run-off score* equal to zero, this suggests that erosion at PRS is not a transport pathway. (* note that the runoff score is not the entire erosion potential score, rather it is a subtotal of this score with a maximum value of 46 points)**

- **If erosion is a transport pathway, evaluate the terminal point to see if aquatic receptors could be affected.**

Answer (likely/unlikely/uncertain) Uncertain.

Provide explanation:

The AP 4.5 runoff score is 24.0. Ephemeral aquatic communities probably are present in DP Canyon during wet periods.

Question D:

Is contaminated groundwater potentially available to biological receptors through seeps or springs?

- **Known or suspected presence of contaminants in groundwater.**
- **The potential for contaminants to migrate via groundwater and discharge into habitats and/or surface waters.**
- **Contaminants may be taken up by terrestrial and rooted aquatic plants whose roots are in contact with groundwater present within the root zone (~1 m depth).**
- **Terrestrial wildlife receptors generally will not contact groundwater unless it is discharged to the surface.**

Answer (likely/unlikely/uncertain) Uncertain

Provide explanation:

Alluvial wells LAUZ-1 and LAUZ-2 are present in DP Canyon directly downslope from the east end of these PRSs. Alluvial water is present in both wells 4.5 ft below the surface, and is thought to be the source for DP Spring. The SAP for PRS C-0-021 will test the hypothesis of connection between this alluvial water and DP Spring.

Question E:

Is infiltration/percolation from contaminated subsurface material a viable transport pathway?

- **Suspected ability of contaminants to migrate to groundwater.**
- **The potential for contaminants to migrate via groundwater and discharge into habitats and/or surface waters.**
- **Contaminants may be taken up by terrestrial and rooted aquatic plants whose roots are in contact with groundwater present within the root zone (~1 m depth).**
- **Terrestrial wildlife receptors generally will not contact groundwater unless it is discharged to the surface.**
- **Also consider the importance of mass wasting as a potential release mechanism for subsurface material.**

Answer (likely/unlikely/uncertain) Unlikely

Provide explanation:

See Question D, above.

Question F:

Might erosion or mass wasting events be a potential release mechanism for contaminants from subsurface materials or perched aquifers to the surface?

- **Consider, particularly, the erodability of fill material and the geologic processes of canyon/mesa edges.**

Answer (likely/unlikely/uncertain): Unlikely

Provide explanation:

The PRSs are generally not near enough to the mesa edge for this to be a likely pathway.

Question G:

Could airborne contaminants interact with receptors through respiration of vapors?

- **Contaminants must be present as volatiles in the air.**
- **Consider the importance of inhalation of vapors for burrowing animals.**
- **Foliar uptake of organic vapors is typically not a significant pathway.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial/Emergent Plants: 1
Terrestrial Animals: 1

Provide explanation:

Volatile organic compounds present were detected mainly at low levels and were mainly subsurface, making this an unlikely pathway.

Question H:

Could airborne contaminants interact with plants through deposition of particulates or with animals through inhalation of fugitive dust?

- **Contaminants must be present as particulates in the air or as dust for this pathway to be viable.**

- **Exposure via inhalation of fugitive dust is particularly applicable to ground-dwelling species that would be exposed to dust disturbed by their foraging or burrowing activities or by wind movement.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial/Emergent Plants: 1
Terrestrial Animals: 1

Provide explanation:

The only surficial contaminants were at the outlet trench from AOC 73-005(a). These could be available for air entrainment, but the outlet trench affects only a small area. Contaminants present at the 73-007 outfall could be inhaled by burrowing animals. No samples were taken from the surface debris areas.

Question I:

Could contaminants interact with plants through root uptake or rain splash from surficial soils?

- **Contaminants in bulk soil may partition into soil solution, making them available to roots.**
- **Exposure of terrestrial plants to contaminants present in particulates deposited on leaf and stem surfaces by rain striking contaminated soils (i.e., rain splash).**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Plants: 2

Provide explanation:

Contaminants at the PRS 73-007 outfall could be taken up by roots of grasses, shrubs, and trees in the immediate vicinity. AOCs 73-005(a–f) are all immediately bordered by trees whose root zones almost certainly extend down to the zone of contamination.

Question J:

Could contaminants interact with receptors through food web transport from surficial soils?

- **The chemicals may bioaccumulate in animals (see list of bioaccumulating chemicals presented in Table B3.2-1).**
- **Animals may ingest contaminated prey.**

TABLE B.3.2-1

BIOACCUMULATING CHEMICALS

Volatile Organic Compounds	**PCBs/Pesticides**
Dichlorobenzene[1,4-]	All aroclors
Trichlorobenzene[1,2,4-]	Beta-BHC and BHC-mixed isomers
Xylene (mixed isomers)	Chlordane
Semivolatile Organic Compounds	Chlorecone (Kepone)
Acenaphthene	DDT and metabolites
Anthracene	Dieldrin
Benz(a)anthracene	Endosulfan
Benzo(a)pyrene	Endrin
Benzo(b)fluoranthene	Heptachlor
Benzo(g,h,i)perylene	Lindane
Benzo(k)fluoranthene	Methoxychlor
Bis(2-ethylhexyl)phthalate	Toxaphene
Butyl benzyl phthalate	**Inorganic Chemicals**
Chrysene	Aluminum
Dibenz(a,h)anthracene	Cadmium
Di-n-butyl phthalate	Copper
Di-n-octyl phthalate	Lead
Fluoranthene	Mercury
Fluorene	Nickel
Indeno(1,2,3-cd)pyrene	Selenium
Phenanthrene	**Radionuclides**
Pyrene	Americium-241
Pentachloronitrobenzene	Cesium-137
Pentachlorophenol	Plutonium-238, -239,240
Dioxins/Furans	Radium-226, -228
Dibenzofuran	Strontium-90
2,3,7,8-tetrachloro-dibenzo(p)dioxin	Thorium-228, -230, -232
2,3,7,8-tetrachloro-dibenzo(p)furan	Uranium-234 -235, -238

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 2

Provide explanation:

Eight bioaccumulating semivolatile chemicals were found near the surface of the outlet trench of AOC 73-005(a), but at fairly low concentrations. Six of these chemicals were only found in the outlet trench, and were not detected in the septic pit. Although apparently confined to a very small area, these chemicals are close enough to the surface to be ingested by receptors. Lead, a potentially bioaccumulating inorganic compound, was detected above BV at all six of the septic pits and at the PRS 73-007 outfall. Copper and mercury were detected above BV at AOC 73-005(a). With the exception of the 73-005(a) outlet trench mentioned above, the contaminants were subsurface in nature, limiting their availability to receptors.

Question K:

Could contaminants interact with receptors via incidental ingestion of surficial soils?

- **Incidental ingestion of contaminated soil could occur while animals grub for food resident in the soil, feed on plant matter covered with contaminated soil or while grooming themselves clean of soil.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 1

Provide explanation: : This could be considered a minor pathway in the very small area of the AOC 73-005(a) outlet trench, but the subsurface nature of the contamination over the rest of the site would make this an unlikely pathway.

Question L:

Could contaminants interact with receptors through dermal contact with surficial soils?

- **Significant exposure via dermal contact would generally be limited to organic contaminants which are lipophilic and can cross epidermal barriers.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 1

Provide explanation:

Most of the contamination is subsurface in nature, making this an unlikely pathway.

Question M:

Could contaminants interact with plants or animals through external irradiation?

- **External irradiation effects are most relevant for gamma emitting radionuclides.**
- **Burial of contamination severely attenuates radiological exposure.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Plants: 0
Terrestrial Animals: 0

Provide explanation:

No radionuclides were detected at the site.

Question N:

Could contaminants interact with plants through direct uptake from water and sediment or sediment rain splash?

- **Contaminants may be taken-up by terrestrial plants whose roots are in contact with surface waters.**
- **Terrestrial plants may be exposed to particulates deposited on leaf and stem surfaces by rain striking contaminated sediments (i.e., rain splash). in an area that is only periodically inundated with water.**
- **Contaminants in sediment may partition into soil solution, making them available to roots.**
- **Aquatic plants are in direct contact with water.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Plants: 1
Aquatic Plants: 1

Provide explanation:

Surface water at the site is highly ephemeral. There is no evidence that contaminated sediments have been washed downslope, but no samples have been taken in the major drainages which pass through the site.

Question O:

Could contaminants interact with receptors through food web transport from water and sediment?

- **The chemicals may bioaccumulate in animals (see list of bioaccumulating chemicals presented in Table B.3.2-1)**
- **Animals may ingest contaminated prey.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 1
Aquatic Animals: 1

Provide explanation:

Although some potential bioaccumulators exist at the site, contamination is mainly subsurface and surface water is highly ephemeral, making this an unlikely pathway.

Question P:

Could contaminants interact with receptors via incidental ingestion of water and sediment?

- **If sediments are present in an area that is only periodically inundated with water, terrestrial receptors may incidentally ingest sediments.**
- **Terrestrial receptors may ingest water-borne contaminants if contaminated surface waters are used as a drinking water source.**
- **Aquatic receptors may regularly or incidentally ingest sediment while foraging.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 1
Aquatic Animals: 1

Provide explanation:

Surface water available for ingestion and aquatic communities in DP Canyon are highly ephemeral at the site

Question Q:

Could contaminants interact with receptors through dermal contact with water and sediment?

- **If sediments are present in an area that is only periodically inundated with water, terrestrial species may be dermally exposed during dry periods.**
- **Terrestrial organisms may be dermally exposed to water-borne contaminants as a result of wading or swimming in contaminated waters.**
- **Aquatic receptors may be directly exposed to sediments or may be exposed through osmotic exchange, respiration, or ventilation of sediment pore waters.**
- **Aquatic receptors may be exposed through osmotic exchange, respiration, or ventilation of surface waters.**

Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Animals: 1
Aquatic Animals: 1

Provide explanation:

Surface water and aquatic communities are highly ephemeral at the site.

Question R:

Could contaminants interact with plants or animals through external irradiation?

- **External irradiation effects are most relevant for gamma emitting radionuclides.**
- **Burial of contamination severely attenuates radiological exposure.**
- **The water column acts to absorb radiation, thus external irradiation is typically more important for sediment dwelling organisms.**

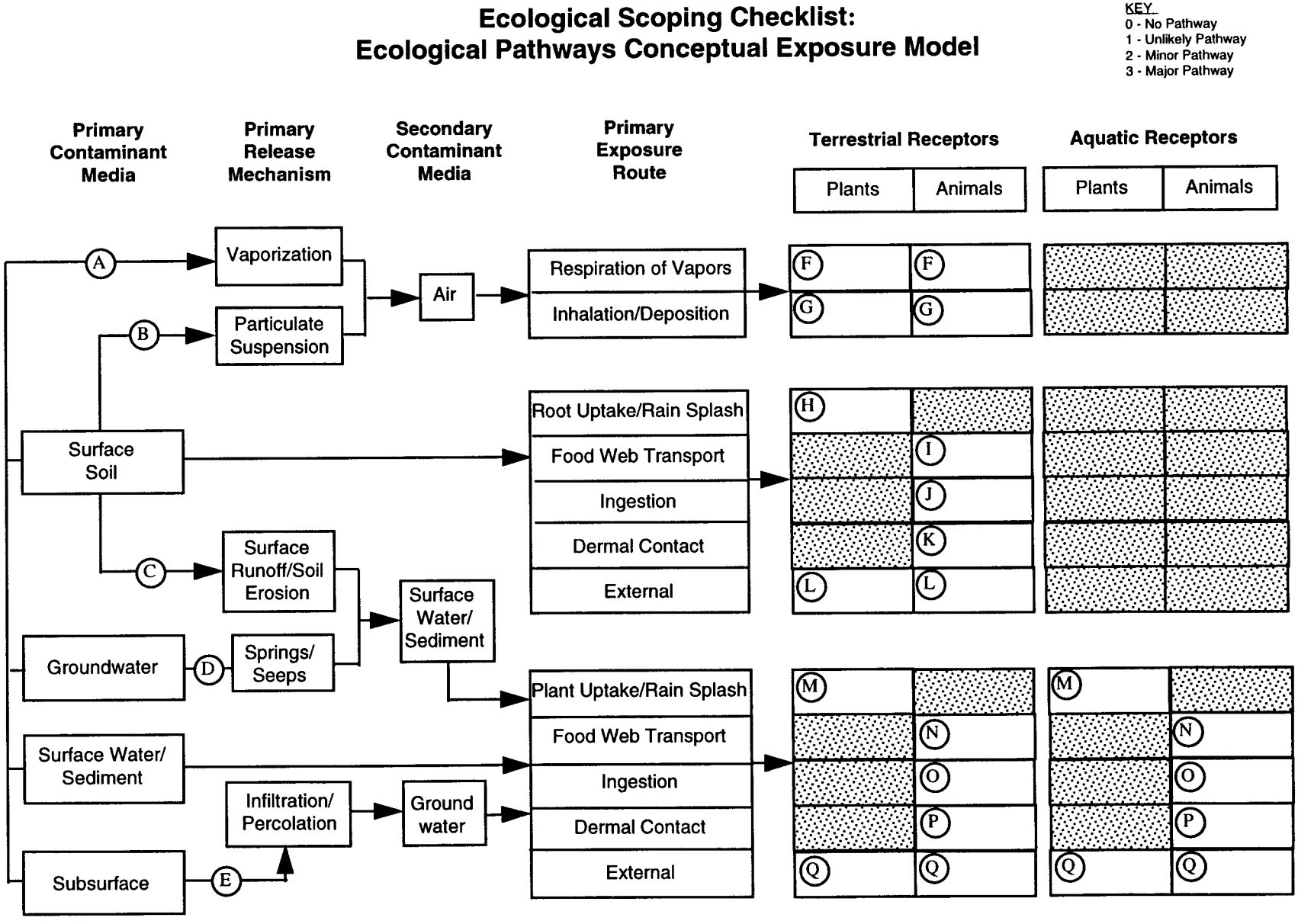
Provide quantification of pathway (0=no pathway, 1=unlikely pathway, 2=minor pathway, 3=major pathway)

Terrestrial Plants: 0
Aquatic Plants: 0
Terrestrial Animals: 0
Aquatic Animals: 0

Provide explanation:

No radionuclides were detected at the site.

Ecological Scoping Checklist: Ecological Pathways Conceptual Exposure Model



Signatures and certifications:

Checklist completed by (provide name, organization and phone number)

Name (printed): Gregory McDermott

Name (signature): Gregory L. McDermott

Organization: Neptune and Company, Inc.

Phone number: (505) 662-0730, ext. 21

Date completed: June 9, 1998

Verification by a member of ER Project Ecological Risk Task Team (provide name, organization and phone number)

Name (printed): Randall Ryti

Name (signature): Randall Ryti

Organization: Neptune and Company, Inc.

Phone number: (505) 662-0707 ext. 12

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Appendix C

LANL-ER-AP-4.5 Surface Water Assessment

APPENDIX C LANL-ER-AP-4.5 SURFACE WATER ASSESSMENT

The Laboratory's ER Project has developed a surface water assessment procedure (formerly known as Administrative Procedure 4.5) to assess sediment transport and erosion concerns at specific PRSs. The surface water assessment provides a basis for prioritizing and scheduling actions to control erosion of potentially contaminated soils at specific PRSs. The procedure is a two-part evaluation. Part A is a compilation of existing PRS analytical data, site maps, and knowledge-of-process information. Part B is an assessment of the erosion/sediment transport potential at the PRS. Erosion potential is numerically rated from 1 to 100 using a matrix system. PRSs that score below 40 have a low erosion potential; those that score from 40 to 60 have a medium erosion potential; and those that score above 60 have a high erosion potential.

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Los Alamos National Laboratory
Environmental Restoration Program
CONSTITUENT ASSESSMENT

LANL-ER-AP-4.5
Part A

SITE INFORMATION

1. PRS Number: 73-003
2. Date (M/D/Y): 11/18/97 Time (am/pm) 5:00:00 PM
3. ER Point of Contact: Carl Newton
4. FMU/Responsible Party Contact: Ed Hoth
5. HSWA: No
6. Site Ranking System (SRS): #28
7. Description of the historical operations of this PRS:

Per the approved OU 1071 RFI work plan, the former steam cleaning plant for garbage trucks, cans, and dumpsters that contained municipal waste was located immediately west of the existing airport terminal building, approximately 30 ft south of the incinerator. The trucks were cleaned in the east side of the plant and garbage cans in a concrete-block-enclosed area to the west. An open storage yard, approximately 50 by 18 ft with a 6-in . curb, was also located on the west side of the plant. The wash water from the plant discharged to a septic tank (PRS 73-004(b)). The plant operated from 1949 until sometime before October 31, 1970, at which time the building was used by the Railway Company. The building and its concrete slab were demolished in June 1971.

8. Description of the current operations of this PRS (if any):

No current operations. The site of the former steam cleaning plant is currently paved and is used as a parking lot for the Los Alamos County Airport.

PRS STATUS

9. Action/Status to Date (check all that apply)

☒ None

Date Completed or Anticipated

☐ Field Investigation ☐ Phase I ☐ Phase II

☐ Interim Measures ☐ IM ☐ BMP

IM:

BMPs:

☐ VCA ☐ VCM

☐ Other ☐ Monitoring ☐ CMS

☐ Report Status ☐ SAP ☐ RFI Report SAP: RFI RPTs:

SAP INFO:

☐ NFA/DOU If checked, supply HH NFA criteria number and date:

SAMPLE INFORMATION

○ Yes ◉ No **10. Have surface/sediment (depth less than 12 inches) samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, sample ID, SAL, depth, and media (soil, tuff, etc.)
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **11. Have surface water samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, filtered/non-filtered, & flow data, if available.
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **12. Are data pending?**

If yes: 1) List date data are anticipated: _____
2) Provide list of COPCs identified in RFI Work Plan as an attachment.

Gary McMillan for
13. Signature of ER Representative
Brad Martin

Los Alamos National Laboratory

Environment, Safety and Health Division
ESH-18 Water Quality and Hydrology Group

AP 4.5 Surface Water Assessment
Erosion Matrix for PRS 73-003

CRITERIA EVALUATED	Value	Erosion/Sediment Transport Potential Low 0.1	Medium 0.5	High 1.0	Calculated Score
Site Setting (43)					
On mesa top	1	Defined based on topographic setting			1.0
Within bench of canyon	4				
Within the canyon floodplain but not watercourse	13				
Within bottom of canyon channel in watercourse	17				
Estimated % ground and canopy cover	13	>75%	25-75%	<25%	1.3
Slope	13	0-10%	10-30%	>30%	1.3
Surface Water Factors-Run-off (46)					
Visible evidence of runoff discharging? (Yes/No)	5	If no, score of 0 for runoff section.			0.0
		If yes, score 5 and proceed with section.			
Where does runoff terminate?	19	Other	Bench Setting	Drainage/Wetland	0.0
Has runoff caused visible erosion? (Yes/No)	22	Sheet	Rill	Gully	0.0
		If no, score as 0. If yes, calculate as appropriate.			
Surface Water Factors-Run-on (11)					
Structures adversely affecting run-on (Yes/No)	7*	If yes, score as 7. If no, score as 0.			7.0
Current operations adversely impacting (Yes/No)	4	If yes, score as 4. If no, score as 0.			0.0
Natural drainages onto site (Yes/No)	7*	If yes, score as 7. If no, score as 0.			0.0
**Select either structures or natural drainages.*					
MAX. POSSIBLE EROSION MATRIX SCORE:	**100**			**Total Score**	10.6

Los Alamos National Laboratory
SURFACE WATER
SITE ASSESSMENT

SITE INFORMATION

1a) PRS Number 73-003 **1b) Structure Number** [ ] **1c) FMU Number** [ ]

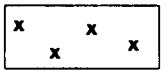
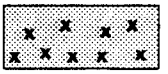
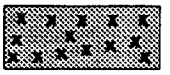
2. Date/Time (M/D/Y H:M am/pm) 10/15/97 1:55:00 PM

SITE SETTING (check all that apply)

3. (●) **On mesa top (a).** ( ) **In the canyon floor, but not in an established channel (c).**
( ) **Within a bench of a canyon (b).** ( ) **Within established channel in the canyon floor (d).**

Explanation: In parking lot adjacent to airport runway, south side of Pueblo Canyon. Former garbage truck, dumpster, and can clean-up area.

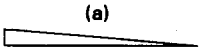
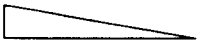
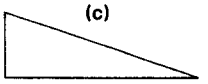
4. Estimated ground and/or canopy cover at site: (deciduous leaves, pine needles, rocks, vegetation, trees, structures, asphalt, etc.)

(illustration) (a)  (b)  (c) 

Estimated % of ground/canopy cover: ( ) 0% to 25% ( ) 25% to 75 (●) 75% to 100

Explanation: Area covered with asphalt.

5. Steepest slope at the area impacted:

(a)  (b)  (c) 

(●) Less than 10% ( ) 10% to 30% ( ) 30% and greater

Explanation:

RUNOFF FACTORS

Y / N

[ ] [X] **6. Is there visible evidence of runoff discharging from site? If yes, answer a) - c) below:**

[ ] [X] **6a) Is runoff channelized? If yes, describe** ( ) **Man-made channel.** ( ) **Natural channel.**

Explanation:

RUNOFF FACTORS, CONT'D

6b) Where does evidence of runoff terminate?

- ◯ Drainage or wetland (name) _____
- ◯ Within bench of canyon setting (name) _____
- ◯ Other (i.e., retention pond, meadow, mesa top) _____

Explanation:

Y / N

☐ ☒ 6c) Has runoff caused visible erosion at the site? If yes, explain below ◯ Sheet ◯ Rill ◯ Gully

Explanation:

RUN-ON FACTORS

Please rate the potential for storm water to run on to this site: (Check EITHER #7 or #9)

☒ ☐ 7. Are structures (i.e., buildings, roof drains, parking lots, storm drains) creating run-on to the site?

Explanation: Run-off from adjacent asphalt areas.

☐ ☒ 8. Are current operations (i.e., fire hydrants, NPDES outfalls) adversely impacting run-on to the site?

Explanation:

☐ ☒ 9. Are natural drainage patterns directing stormwater onto site?

Explanation:

ASSESSMENT FINDING:

☐ ☒ **10. Based on the above criteria and the assessment of this site, does soil erosion potential exist? (REFER TO EROSION POTENTIAL MATRIX.)**

T. Lemke

11. Signature of Water Quality/Hydrology Representative

GW Initials of independent reviewer.

Check here when information is entered in database: ☒

This page is for ESH-18 notes, recommendations, and photos.

	Y / N	
12 a)	○ ◉	Is there visible trash/debris on the site?
b)	○ ◉	Is there visible trash/debris in a watercourse?

Description of existing BMPs:

○ ◉ Are BMPs being properly maintained? If no, describe in "Other Internal Notes."

○ ◉ Are BMPs effectively keeping sediment in place and reducing erosion potential?

OTHER INTERNAL NOTES:

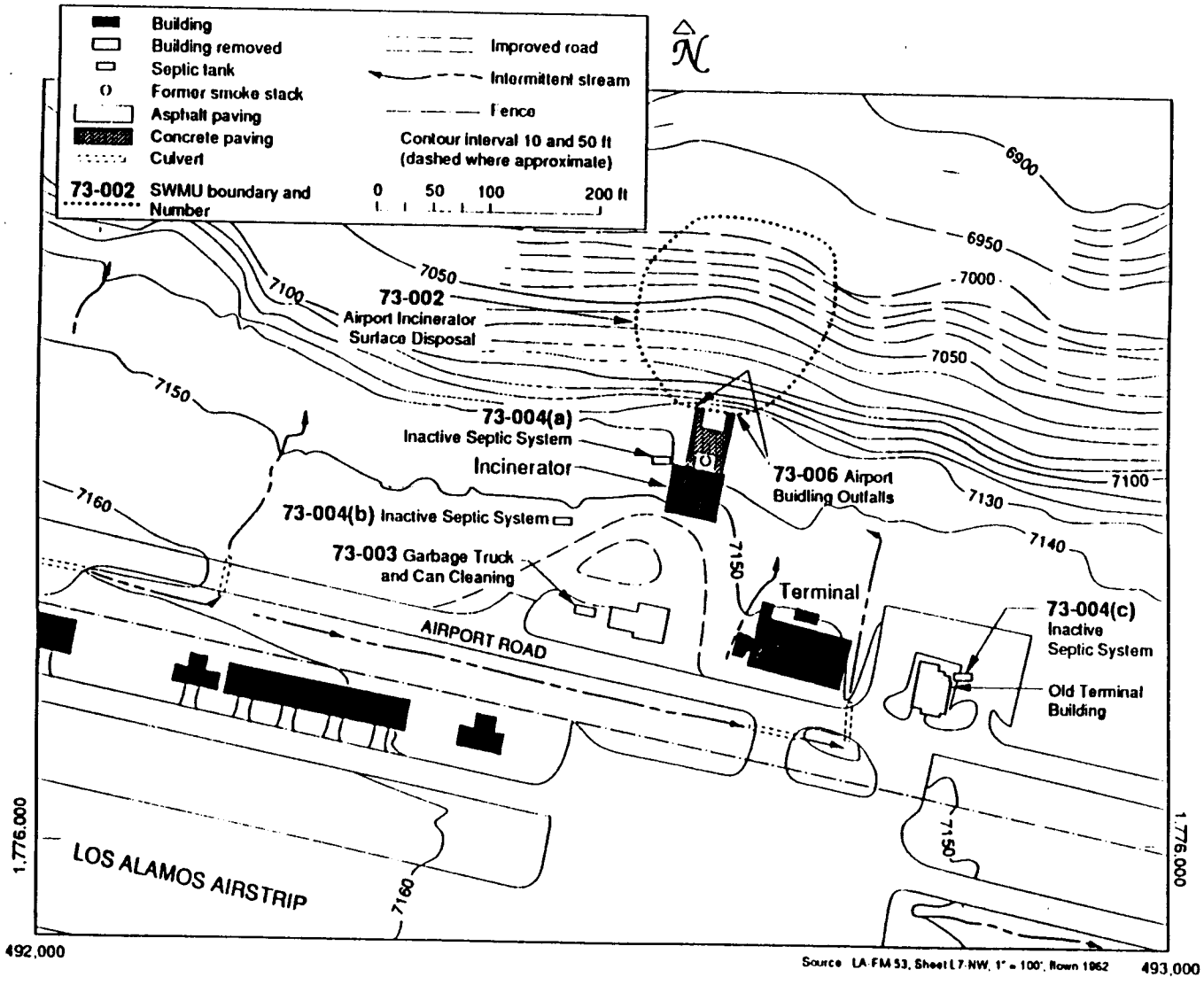


Figure 5-86. SWMU Aggregate 73-B, Los Alamos Airport (West).

Los Alamos National Laboratory
Environmental Restoration Program
CONSTITUENT ASSESSMENT

LANL-ER-AP-4.5
Part A

SITE INFORMATION

1. PRS Number: 73-004(a)
2. Date (M/D/Y): 11/21/97 Time (am/pm) 8:00:00 AM
3. ER Point of Contact: Carl Newton
4. FMU/Responsible Party Contact: Ed Hoth
5. HSWA: Yes
6. Site Ranking System (SRS): #29
7. Description of the historical operations of this PRS:

Per the approved OU 1071 RFI work plan, PRS 73-004(a) was a septic system that served the incinerator (PRS 73-002). The septic tank was located northwest of the incinerator building and the outflow was diverted through a 6-in. VCP to an outfall to Pueblo Canyon. The period of operation of this septic system was concurrent with that of the incinerator (1947 to 1973).

8. Description of the current operations of this PRS (if any):

No current operations. The septic tank was removed as part of a VCA.

PRS STATUS

9. Action/Status to Date (check all that apply)

	Date Completed or Anticipated
☐ None	
☐ Field Investigation ☐ Phase I ☐ Phase II	
☐ Interim Measures ☐ IM ☐ BMP	IM: BMPs:
☒ VCA ☐ VCM	06/20/96
☐ Other ☐ Monitoring ☐ CMS	
☐ Report Status ☐ SAP ☐ RFI Report	SAP: RFI RPTs:
SAP INFO:	
☒ NFA/DOU If checked, supply HH NFA criteria number and date:	5 06/20/96

SAMPLE INFORMATION

○ Yes ◉ No **10. Have surface/sediment (depth less than 12 inches) samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, sample ID, SAL, depth, and media (soil, tuff, etc.)
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **11. Have surface water samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, filtered/non-filtered, & flow data, if available.
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **12. Are data pending?**

If yes: 1) List date data are anticipated: _____
2) Provide list of COPCs identified in RFI Work Plan as an attachment.

Mary McMaster for
13. Signature of ER Representative
Brad Martin

Los Alamos National Laboratory

Environment, Safety & Health Division
ESH-18 Water Quality & Hydrology Group

Surface Water Assessment
Erosion Matrix for PRS 73-004(a)

CRITERIA EVALUATED	Value	Erosion/Sediment Transport Potential Low 0.1	Medium 0.5	High 1.0	Calculated Score
Site Setting (43)					
On mesa top	1	Defined based on topographic setting			
Within bench of canyon	4				4.0
Within the canyon floodplain but not watercourse	13				
Within bottom of canyon channel in watercourse	17				
Estimated % ground and canopy cover	13	>75%	25-75%	<25%	6.5
Slope	13	0-10%	10-30%	>30%	13.0
Surface Water Factors-Run-off (46)					
Visible evidence of runoff discharging? (Yes/No)	5	If no, score of 0 for runoff section.			5.0
		If yes, score 5 and proceed with section.			
Where does runoff terminate?	19	Other	Bench Setting	Drainage/Wetland	9.5
Has runoff caused visible erosion? (Yes/No)	22	Sheet	Rill	Gully	0.0
		If no, score as 0. If yes, calculate as appropriate.			
Surface Water Factors-Run-on (11)					
Structures adversely affecting run-on (Yes/No)	7*	If yes, score as 7. If no, score as 0.			0.0
Current operations adversely impacting (Yes/No)	4	If yes, score as 4. If no, score as 0.			0.0
Natural drainages onto site (Yes/No)	7*	If yes, score as 7. If no, score as 0.			0.0
**Select either structures or natural drainages.*					
MAX. POSSIBLE EROSION MATRIX SCORE:	**100**			**Total Score**	38**

** Indicates BMPs in place. Erosion potential without BMPs may be greater.

REVISED PART B

Report Printed 8/27/98 10:08:44 AM.

Los Alamos National Laboratory
SURFACE WATER
SITE ASSESSMENT

Revised Part B. Please discard previous.

SITE INFORMATION

1a) PRS Number 73-004(a) **1b) Structure Number** 73-2 **1c) FMU Number** 80

2. Date/Time (M/D/Y H:M am/pm) 8/26/98

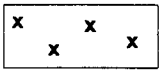
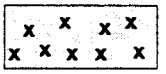
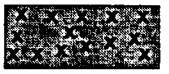
SITE SETTING (check all that apply)

3. ◉ **On mesa top (a).** ○ **In the canyon floor, but not in an established channel (c).**

◉ **Within a bench of a canyon (b).** ○ **Within established channel in the canyon floor (d).**

Explanation: South side of Pueblo canyon behind incinerator building TA-73-2. Site of old septic tank and associated outfall.

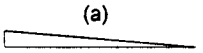
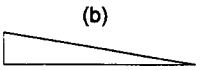
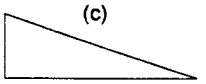
4. Estimated ground and/or canopy cover at site: (deciduous leaves, pine needles, rocks, vegetation, trees, structures, asphalt, etc.)

(illustration) (a)  (b)  (c) 

Estimated % of ground/canopy cover: ○ 0% to 25% ◉ 25% to 75% ◉ 75% to 100%

Explanation: Septic area covered with jute matting and ground cover. Outfall discharges over mesa edge onto ash pile and partially vegetated slope.

5. Steepest slope at the area impacted:

(a)  (b)  (c) 

◉ Less than 10% ○ 10% to 30% ◉ 30% and greater

Explanation: Outfall previously discharged onto steep slope over mesa edge.

RUNOFF FACTORS

Y / N

☑ ☐ **6. Is there visible evidence of runoff discharging from site? If yes, answer a) - c) below:**

☐ ☑ 6a) Is runoff channelized? If yes, describe: ○ Man-made channel. ○ Natural channel.

Explanation: Outfall from septic discharged onto slope below site. Direct rainfall impact is evident in ash occupying slope near outfall (from PRS 73-002).

RUNOFF FACTORS, CONT'D

6b) Where does evidence of runoff terminate?

- ○ **Drainage or wetland (name)** Pueblo Canyon
- ◉ **Within bench of canyon setting (name)**
- ○ **Other (i.e., retention pond, meadow, mesa top)**

Explanation: Runoff terminates into PRS 73-002 located on bench below site.

Y / N

☐ ☑ 6c) Has runoff caused visible erosion at the site? If yes, explain below: ○ Sheet ○ Rill ○ Gully

Explanation: None observed

RUN-ON FACTORS

Please rate the potential for storm water to run on to this site: (Check EITHER #7 or #9)

☐ ☑ **7.** Are structures (i.e., buildings, roof drains, parking lots, storm drains) creating run-on to the site?

Explanation:

☐ ☑ **8.** Are current operations (i.e., fire hydrants, NPDES outfalls) adversely impacting run-on to the site?

Explanation:

☐ ☑ **9.** Are natural drainage patterns directing stormwater onto site?

Explanation:

ASSESSMENT FINDING:

☐ ☑ **10. Based on the above criteria and the assessment of this site, does soil erosion potential exist? (REFER TO EROSION POTENTIAL MATRIX.)**

T. Lemke

11. Signature of Water Quality/Hydrology Representative

Initials of independent reviewer.

Check here when information is entered in database: ☑

This page is for ESH-18 notes, recommendations, and photos.

	Y	N	
12. a)	○	◉	Is there visible trash/debris on the site?
b)	○	◉	Is there visible trash/debris in a watercourse?

Description of existing BMPs:

Jute matting is effective at site. BMPs installed 4/30/96. Run-on diversion is also effective.

◉ ○ Are BMPs being properly maintained? If no, describe in "Other Internal Notes."

◉ ○ Are BMPs effectively keeping sediment in place and reducing erosion potential?

OTHER INTERNAL NOTES:

Site rescored to include septic outfall. The previous assessment (10/15/97) did not include the outfall as part of the assessment.

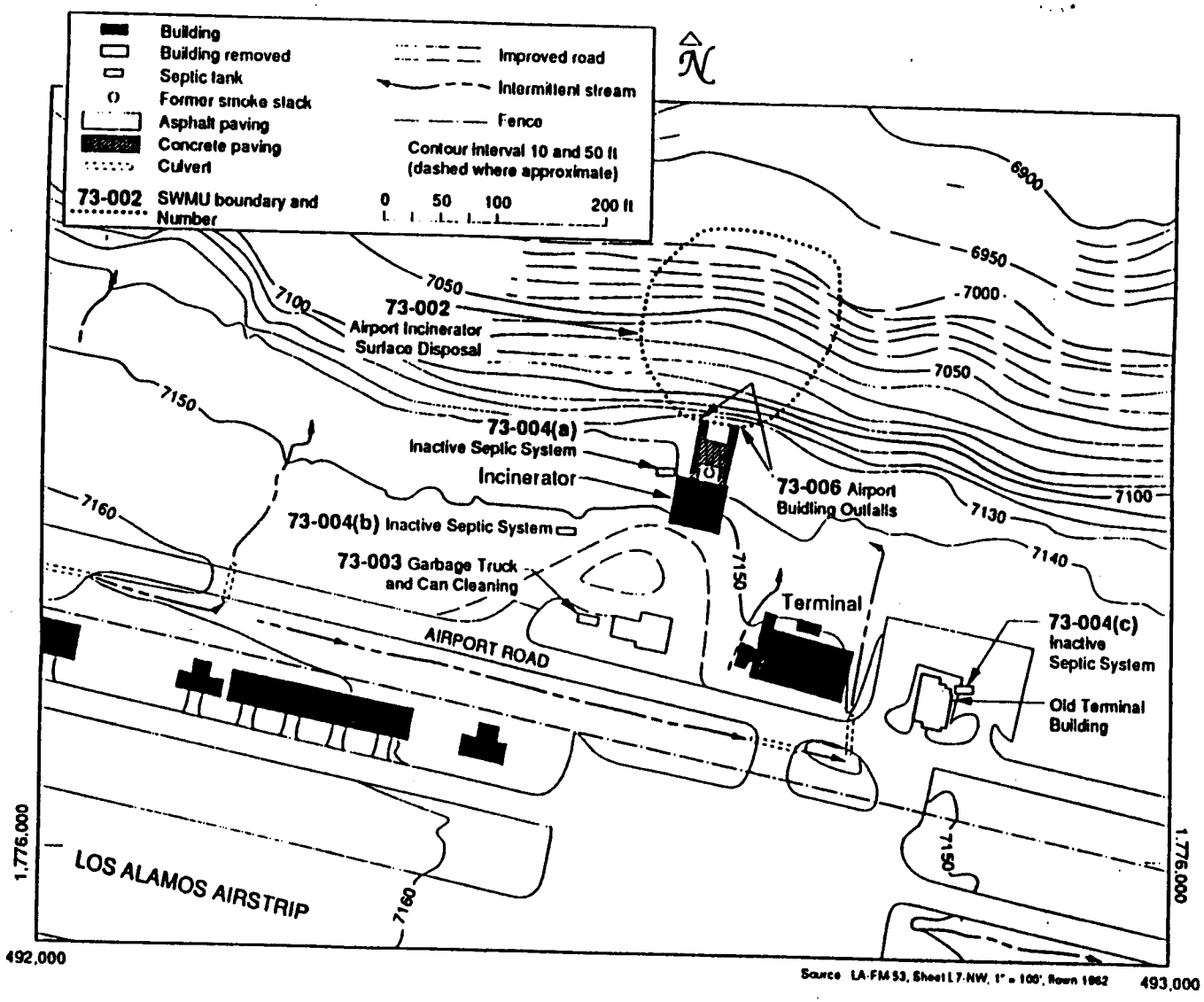


Figure 5-86. SWMU Aggregate 73-B, Los Alamos Airport (West).

Los Alamos National Laboratory
Environmental Restoration Program
CONSTITUENT ASSESSMENT

LANL-ER-AP-4.5
Part A

SITE INFORMATION

1. PRS Number: 73-004(b)
2. Date (M/D/Y): 11/21/97 Time (am/pm) 8:15:00 AM
3. ER Point of Contact: Carl Newton
4. FMU/Responsible Party Contact: Ed Hoth
5. HSWA: Yes
6. Site Ranking System (SRS): #35
7. Description of the historical operations of this PRS:

Per the approved OU 1071 RFI work plan, PRS 73-004(b) was a septic system that serviced the steam cleaning plant, PRS 73-003. The concrete septic tank was located approximately 80 ft to the NW of the steam cleaning building. Wash water from the steam cleaning plant discharged to the septic tank. Overflow was diverted through a 6-in. VCP to an outfall to Pueblo Canyon. The plant operated from 1949 until sometime before October 31, 1970.

8. Description of the current operations of this PRS (if any):

No current operations. The septic tank was removed as part of a VCA.

PRS STATUS

9. Action/Status to Date (check all that apply)

		Date Completed or Anticipated
☐ None		
☐ Field Investigation ☐ Phase I ☐ Phase II		
☐ Interim Measures ☐ IM ☐ BMP	IM:	
	BMPs:	
☒ VCA ☐ VCM		09/30/96
☐ Other ☐ Monitoring ☐ CMS		
☐ Report Status ☐ SAP ☐ RFI Report	SAP: / RFI RPTs:	
SAP INFO:		
☒ NFA/DOU If checked, supply HH NFA criteria number and date:	5	09/30/96

SAMPLE INFORMATION

○ Yes ◉ No **10. Have surface/sediment (depth less than 12 inches) samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, sample ID, SAL, depth, and media (soil, tuff, etc.)
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **11. Have surface water samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, filtered/non-filtered, & flow data, if available.
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **12. Are data pending?**

If yes: 1) List date data are anticipated: _____
2) Provide list of COPCs identified in RFI Work Plan as an attachment.

Amy McMaster for
13. Signature of ER Representative
BRAD MARTIN

Los Alamos National Laboratory

Environment, Safety & Health Division
ESH-18 Water Quality & Hydrology Group

Surface Water Assessment
Erosion Matrix for PRS 73-004(b)

CRITERIA EVALUATED	Value	Erosion/Sediment Transport Potential Low 0.1	Medium 0.5	High 1.0	Calculated Score
Site Setting (43)					
On mesa top	1	Defined based on topographic setting			
Within bench of canyon	4				4.0
Within the canyon floodplain but not watercourse	13				
Within bottom of canyon channel in watercourse	17				
Estimated % ground and canopy cover	13	>75%	25-75%	<25%	1.3
Slope	13	0-10%	10-30%	>30%	13.0
Surface Water Factors-Run-off (46)					
Visible evidence of runoff discharging? (Yes/No)	5	If no, score of 0 for runoff section.			5.0
		If yes, score 5 and proceed with section.			
Where does runoff terminate?	19	Other	Bench Setting	Drainage/Wetland	9.5
Has runoff caused visible erosion? (Yes/No)	22	Sheet	Rill	Gully	0.0
		If no, score as 0. If yes, calculate as appropriate.			
Surface Water Factors-Run-on (11)					
Structures adversely affecting run-on (Yes/No)	7*	If yes, score as 7. If no, score as 0.			7.0
Current operations adversely impacting (Yes/No)	4	If yes, score as 4. If no, score as 0.			0.0
Natural drainages onto site (Yes/No)	7*	If yes, score as 7. If no, score as 0.			0.0
**Select either structures or natural drainages.*					
MAX. POSSIBLE EROSION MATRIX SCORE:	**100**			**Total Score**	39.8**

** Indicates BMPs in place. Erosion potential without BMPs may be greater.

REVISED PART B

Report Printed 8/27/98 10:23:39 AM.

Los Alamos National Laboratory
SURFACE WATER
SITE ASSESSMENT

Revised Part B. Please discard previous.

SITE INFORMATION

1a) PRS Number 73-004(b) **1b) Structure Number** 73-2 **1c) FMU Number** 80

2. Date/Time (M/D/Y H:M am/pm) 8/26/98

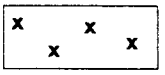
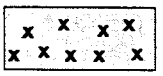
SITE SETTING (check all that apply)

3. ◉ **On mesa top (a).** ○ **In the canyon floor, but not in an established channel (c).**

◉ **Within a bench of a canyon (b).** ○ **Within established channel in the canyon floor (d).**

Explanation: In parking lot between airport runway and Pueblo Canyon. Site of former septic tank and associated outfall.

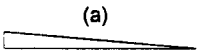
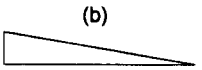
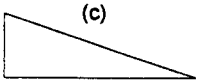
4. Estimated ground and/or canopy cover at site: (deciduous leaves, pine needles, rocks, vegetation, trees, structures, asphalt, etc.)

(illustration) (a)  (b)  (c)

Estimated % of ground/canopy cover: ○ 0% to 25% ○ 25% to 75% ◉ 75% to 100%

Explanation: Area covered with asphalt and thick vegetation on slope below outfall.

5. Steepest slope at the area impacted:

(a)  (b)  (c) 

◉ Less than 10% ○ 10% to 30% ◉ 30% and greater

Explanation: Septic tank is located on mesa top, outfall discharges onto steep slope below site.

RUNOFF FACTORS

Y / N

☑ ☐ **6. Is there visible evidence of runoff discharging from site? If yes, answer a) - c) below:**

☐ ☑ 6a) Is runoff channelized? If yes, describe: ○ Man-made channel. ○ Natural channel.

Explanation: Minor evidence - thick vegetation below outfall site shows some sheet flow movement.

RUNOFF FACTORS, CONT'D

6b) Where does evidence of runoff terminate?

- ○ **Drainage or wetland (name)** Pueblo Canyon
- ◉ **Within bench of canyon setting (name)**
- ○ **Other (i.e., retention pond, meadow, mesa top)**

Explanation: Runoff terminates into the slope alluvium above bench.

Y / N

☐ ☑ 6c) Has runoff caused visible erosion at the site? If yes, explain below: ○ Sheet ○ Rill ○ Gully

Explanation: None observed.

RUN-ON FACTORS

Please rate the potential for storm water to run on to this site: (Check EITHER #7 or #9)

☑ ☐ **7.** Are structures (i.e., buildings, roof drains, parking lots, storm drains) creating run-on to the site?

Explanation: Run-off from adjacent asphalt.

☐ ☑ **8.** Are current operations (i.e., fire hydrants, NPDES outfalls) adversely impacting run-on to the site?

Explanation:

☐ ☑ **9.** Are natural drainage patterns directing stormwater onto site?

Explanation:

ASSESSMENT FINDING:

☐ ☑ **10. Based on the above criteria and the assessment of this site, does soil erosion potential exist? (REFER TO EROSION POTENTIAL MATRIX.)**

Steve Veenis

11. Signature of Water Quality/Hydrology Representative

SV Initials of independent reviewer.

Check here when information is entered in database: ☑

This page is for ESH-18 notes, recommendations, and photos.

	Y	N	
12. a)	○	◉	Is there visible trash/debris on the site?
b)	○	◉	Is there visible trash/debris in a watercourse?

Description of existing BMPs:

Straw bale berms were installed below site to keep sediment in place. Excavated areas were reseeded and jute mat was installed 4/30/96

◉ ○ Are BMPs being properly maintained? If no, describe in "Other Internal Notes."

◉ ○ Are BMPs effectively keeping sediment in place and reducing erosion potential?

OTHER INTERNAL NOTES:

Site rescored to include septic outfall. The previous assessment (10/15/97) did not include the outfall as part of the assessment.

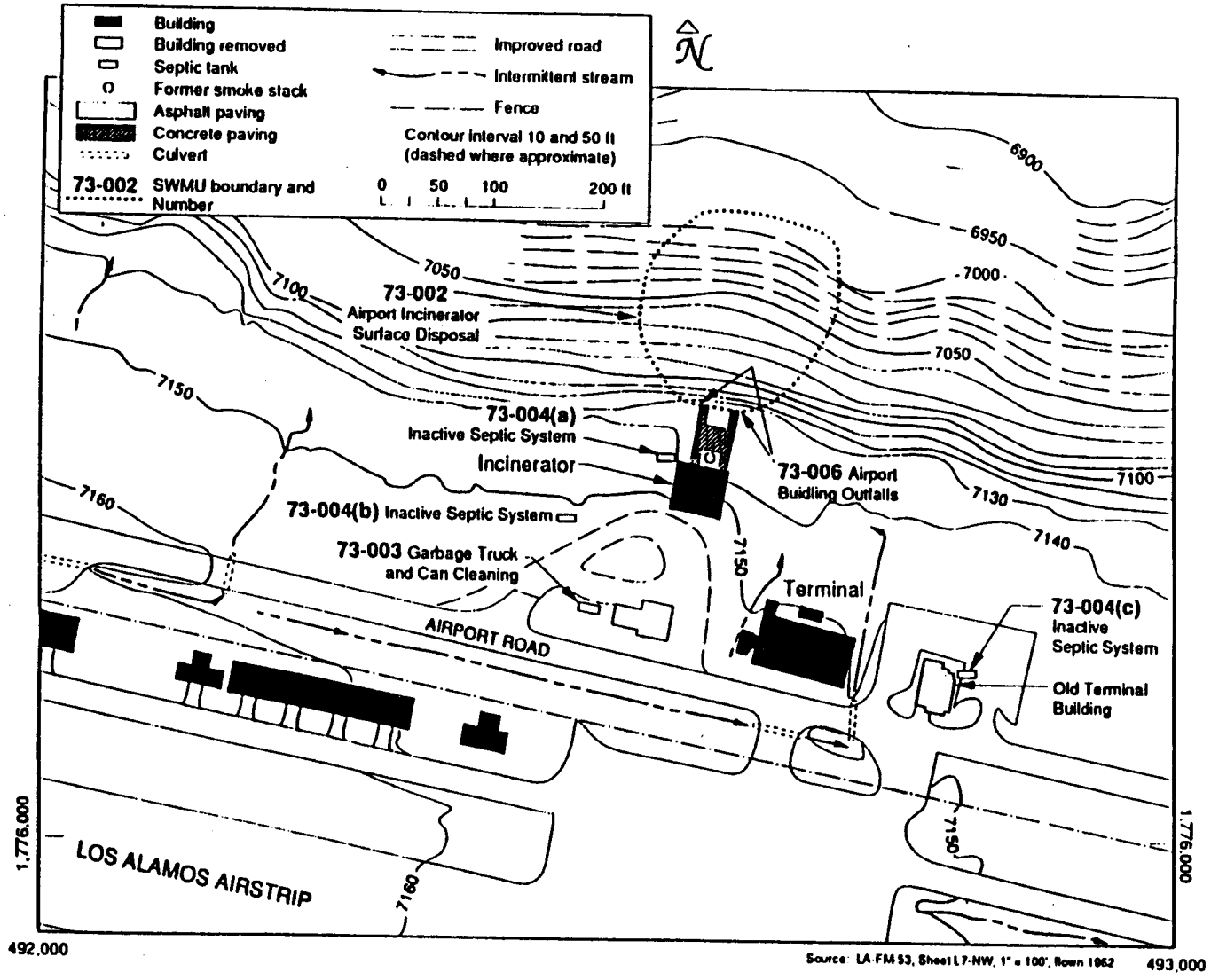


Figure 5-86. SWMU Aggregate 73-B, Los Alamos Airport (West).

Los Alamos National Laboratory
Environmental Restoration Program
CONSTITUENT ASSESSMENT

LANL-ER-AP-4.5
Part A

SITE INFORMATION

1. PRS Number: 73-005 **2. Date (M/D/Y):** 09/24/98 **Time (am/pm):** 4:37:00 PM

3. ER Point of Contact Gabriela Lopez **4. FMU/Responsible Party Contact** _____

5. HSWA Yes **6. Site Ranking System (SRS) #** 31

7. Description of the historical operations of this PRS:

PRS 73-005 is a surface disposal area roughly 400 feet long and 200 feet wide in the Contractor's Row Area. There are no records discussing historical operations of PRS 73-005

8. Description of the current operations of this PRS (if any):

None

PRS STATUS

9. Action/Status to Date (check all that apply)

☐ **None**

Date Completed or Anticipated

☐ **Field Investigation** ☐ **Phase I** ☐ **Phase II**

☐ **Interim Measures** ☐ **IM** ☐ **BMP** **IM:** **BMPs:**

☐ **VCA** ☐ **VCM**

☐ **Other** ☐ **Monitoring** ☐ **CMS**

☐ **Report Status** ☒ **SAP** ☐ **RFI Report** **SAP:** 09/30/98 **RFI RPTs:**

SAP INFO:

☐ **NFA/DOU** If checked, supply HH NFA criteria number and date:

SAMPLE INFORMATION

○ Yes ◉ No **10. Have surface/sediment (depth less than 12 inches) samples been collected tha reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, sample ID, SAL, depth, and media (soil, tuff, etc.)
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **11. Have surface water samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, filtered/non-filtered, & flow data, if available.
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **12. Are data pending?**

If yes: 1) List date data are anticipated: _____
2) Provide list of COPCs identified in RFI Work Plan as an attachment.

13. Signature of ER Representative

Los Alamos National Laboratory

Environment, Safety and Health Division
ESH-18 Water Quality and Hydrology Group

AP 4.5 Surface Water Assessment
Erosion Matrix for PRS 73-005

CRITERIA EVALUATED	Value	Erosion/Sediment Transport Potential Low 0.1	Medium 0.5	High 1.0	Calculated Score
Site Setting (43)					
On mesa top	1	Defined based on topographic setting			1.0
Within bench of canyon	4				
Within the canyon floodplain but not watercourse	13				
Within bottom of canyon channel in watercourse	17				
Estimated % ground and canopy cover	13	>75%	25-75%	<25%	1.3
Slope	13	0-10%	10-30%	>30%	1.3
Surface Water Factors-Run-off (46)					
Visible evidence of runoff discharging? (Yes/No)	5	If no, score of 0 for runoff section.			5.0
		If yes, score 5 and proceed with section.			
Where does runoff terminate?	19	Other	Bench Setting	Drainage/Wetland	19.0
Has runoff caused visible erosion? (Yes/No)	22	Sheet	Rill	Gully	0.0
		If no, score as 0. If yes, calculate as appropriate.			
Surface Water Factors-Run-on (11)					
Structures adversely affecting run-on (Yes/No)	7*	If yes, score as 7. If no, score as 0.			0.0
Current operations adversely impacting (Yes/No)	4	If yes, score as 4. If no, score as 0.			0.0
Natural drainages onto site (Yes/No)	7*	If yes, score as 7. If no, score as 0.			0.0
**Select either structures or natural drainages.*					
MAX. POSSIBLE EROSION MATRIX SCORE:	**100**			**Total Score**	27.6**

** Indicates BMPs in place. Erosion potential without BMPs may be greater.

Report Printed 7/14/98 4:20:04 PM.

Los Alamos National Laboratory
SURFACE WATER
SITE ASSESSMENT

SITE INFORMATION

1a) PRS Number 73-005 **1b) Structure Number** **1c) FMU Number** 80

2. Date/Time (M/D/Y H:M am/pm) 7/2/98 8:30:00 AM

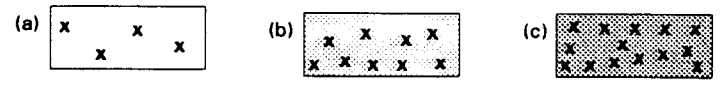
SITE SETTING (check all that apply)

3. ◉ **On mesa top (a).** ○ **In the canyon floor, but not in an established channel (c).**
   ○ **Within a bench of a canyon (b).** ○ **Within established channel in the canyon floor (d).**

Explanation: Sites are in the former contractor row south of State Road 502 and south of the airport. Sites drain into DP Canyon.

4. Estimated ground and/or canopy cover at site: (deciduous leaves, pine needles, rocks, vegetation, trees, structures, asphalt, etc.)

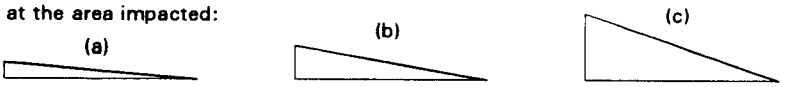
(illustration)



Estimated % of ground/canopy cover: ○ 0% to 25% ○ 25% to 75 ◉ 75% to 100

Explanation: Area is covered with native grasses, oak and pine.

5. Steepest slope at the area impacted:



◉ Less than 10% ○ 10% to 30% ○ 30% and greater

Explanation: Area is on the mesa top.

RUNOFF FACTORS

Y / N

☑ ☐ **6. Is there visible evidence of runoff discharging from site? If yes, answer a) - c) below:**

☐ ☑ **6a) Is runoff channelized? If yes, describe** ○ Man-made channel. ◉ Natural channel.

Explanation: Two natural channels drain area. Larger channel also drains area along State Road 502 and the airport.

RUNOFF FACTORS, CONT'D

6b) Where does evidence of runoff terminate?

- (●) **Drainage or wetland (name)** DP Canyon
- ( ) **Within bench of canyon setting (name)**
- ( ) **Other (i.e., retention pond, meadow, mesa top)**

Explanation: Run-off goes over mesa edge into DP Canyon.

Y / N

☐ ☑ 6c) Has runoff caused visible erosion at the site? If yes, explain below ( ) Sheet ( ) Rill ( ) Gully

Explanation: Two natural drainage channels.

RUN-ON FACTORS

Please rate the potential for storm water to run on to this site: (Check EITHER #7 or #9)

☐ ☑ 7. Are structures (i.e., buildings, roof drains, parking lots, storm drains) creating run-on to the site?

Explanation: Run-on from State Road 502 is channelized through the site.

☐ ☑ 8. Are current operations (i.e., fire hydrants, NPDES outfalls) adversely impacting run-on to the site?

Explanation: One very old hydrant in area.

☐ ☑ 9. Are natural drainage patterns directing stormwater onto site?

Explanation: Sheet flow across into small channels within the site.

ASSESSMENT FINDING:

☐ ☑ **10. Based on the above criteria and the assessment of this site, does soil erosion potential exist? (REFER TO EROSION POTENTIAL MATRIX.)**

Jeff Walterscheid

11. Signature of Water Quality/Hydrology Representative

JV Initials of independent reviewer.

Check here when information is entered in database: ☑

This page is for ESH-18 notes, recommendations, and photos.

	Y	N	
12 a)	◉	○	Is there visible trash/debris on the site?
b)	○	◉	Is there visible trash/debris in a watercourse?

Description of existing BMPs:

None.

○	○	Are BMPs being properly maintained? If no, describe in "Other Internal Notes."
○	○	Are BMPs effectively keeping sediment in place and reducing erosion potential?

OTHER INTERNAL NOTES:

Minimal soil erosion.

Los Alamos National Laboratory
Environmental Restoration Program
CONSTITUENT ASSESSMENT

LANL-ER-AP-4.5
Part A

SITE INFORMATION

1. PRS Number: 73-006
2. Date (M/D/Y): 11/21/97 Time (am/pm) 9:10:00 AM
3. ER Point of Contact: Carl Newton
4. FMU/Responsible Party Contact: Ed Hoth
5. HSWA: Yes
6. Site Ranking System (SRS): #38
7. Description of the historical operations of this PRS:

Per the approved OU 1071 RFI work plan, the incinerator building (PRS 73-002) contained two drainlines that discharged through separate outfalls to Pueblo Canyon. These two outfalls are defined as PRS 73-006. The incinerator drains are presumed to have handled wash water. The period of operation of these drainlines was probably concurrent with that of the incinerator (1947 to 1973).

8. Description of the current operations of this PRS (if any):

No current operations. The western outfall was removed as part of a VCA. Based upon existing information, the eastern outfall appears to have been subsequently removed during installation of airport utilities.

PRS STATUS

9. Action/Status to Date (check all that apply)

	Date Completed or Anticipated
☐ None	
☒ Field Investigation ☒ Phase I ☐ Phase II	07/23/97
☐ Interim Measures ☐ IM ☐ BMP	IM:
	BMPs:
☐ VCA ☐ VCM	
☐ Other ☐ Monitoring ☐ CMS	
☐ Report Status ☐ SAP ☐ RFI Report SAP:	RFI RPTs:
SAP INFO:	
☐ NFA/DOU If checked, supply HH NFA criteria number and date:	

SAMPLE INFORMATION

○ Yes ◉ No **10. Have surface/sediment (depth less than 12 inches) samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, sample ID, SAL, depth, and media (soil, tuff, etc.)
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **11. Have surface water samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, filtered/non-filtered, & flow data, if available.
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **12. Are data pending?**

If yes: 1) List date data are anticipated: _____
2) Provide list of COPCs identified in RFI Work Plan as an attachment.

Gary McMaster for
13. Signature of ER Representative
BRAD MARTIN

Los Alamos National Laboratory

Environment, Safety and Health Division
ESH-18 Water Quality and Hydrology Group

AP 4.5 Surface Water Assessment
Erosion Matrix for PRS 73-006

CRITERIA EVALUATED	Value	Erosion/Sediment Transport Potential Low 0.1	Medium 0.5	High 1.0	Calculated Score
Site Setting (43)					
On mesa top	1	Defined based on topographic setting			
Within bench of canyon	4				4.0
Within the canyon floodplain but not watercourse	13				
Within bottom of canyon channel in watercourse	17				
Estimated % ground and canopy cover	13	>75%	25-75%	<25%	6.5
Slope	13	0-10%	10-30%	>30%	13.0
Surface Water Factors-Run-off (46)					
Visible evidence of runoff discharging? (Yes/No)	5	If no, score of 0 for runoff section.			5.0
		If yes, score 5 and proceed with section.			
Where does runoff terminate?	19	Other	Bench Setting	Drainage/Wetland	9.5
Has runoff caused visible erosion? (Yes/No)	22	Sheet	Rill	Gully	11.0
		If no, score as 0. If yes, calculate as appropriate.			
Surface Water Factors-Run-on (11)					
Structures adversely affecting run-on (Yes/No)	7*	If yes, score as 7. If no, score as 0.			7.0
Current operations adversely impacting (Yes/No)	4	If yes, score as 4. If no, score as 0.			0.0
Natural drainages onto site (Yes/No)	7*	If yes, score as 7. If no, score as 0.			*
**Select either structures or natural drainages.*					
MAX. POSSIBLE EROSION MATRIX SCORE:	**100**			**Total Score**	56**

** Indicates BMPs in place. Erosion potential without BMPs would be greater.

Los Alamos National Laboratory
SURFACE WATER
SITE ASSESSMENT

SITE INFORMATION

1a) PRS Number 73-006 **1b) Structure Number** 73-2 **1c) FMU Number** 80

2. Date/Time (M/D/Y H:M am/pm) 10/15/97 2:10:00 PM

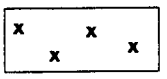
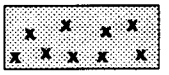
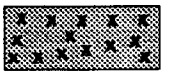
SITE SETTING (check all that apply)

3. ◉ **On mesa top (a).** ○ **In the canyon floor, but not in an established channel (c).**

◉ **Within a bench of a canyon (b).** ○ **Within established channel in the canyon floor (d).**

Explanation: South side of Pueblo Canyon behind old incerator building TA-73-2. PRS extends from edge of mesa top to small bench within canyon. Incinerator surface disposal.

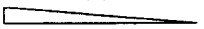
4. Estimated ground and/or canopy cover at site: (deciduous leaves, pine needles, rocks, vegetation, trees, structures, asphalt, etc.)

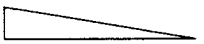
(illustration) (a)  (b)  (c) 

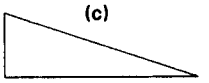
Estimated % of ground/canopy cover: ○ 0% to 25% ◉ 25% to 75 ○ 75% to 100

Explanation: Sparse vegetation. Primarily rock and debris from former incinerator activity.

5. Steepest slope at the area impacted:

(a)  ○ Less than 10%

(b)  ○ 10% to 30%

(c)  ◉ 30% and greater

Explanation: Steep slope along side of canyon.

RUNOFF FACTORS

Y / N

☒ ☐ **6. Is there visible evidence of runoff discharging from site? If yes, answer a) - c) below:**

☐ ☒ 6a) Is runoff channelized? If yes, describe ○ Man-made channel. ○ Natural channel.

Explanation:

RUNOFF FACTORS, CONT'D

6b) Where does evidence of runoff terminate?

- ○ **Drainage or wetland (name)**
- ◉ **Within bench of canyon setting (name)** Bench within Pueblo Canyon
- ○ **Other (i.e., retention pond, meadow, mesa top)**

Explanation:

Y / N

☒ ☐ 6c) Has runoff caused visible erosion at the site? If yes, explain below ○ Sheet ◉ Rill ○ Gully

Explanation: Rill from edge of mesa top extending half way to bench.

RUN-ON FACTORS

Please rate the potential for storm water to run on to this site: (Check EITHER #7 or #9)

☒ ☐ 7. Are structures (i.e., buildings, roof drains, parking lots, storm drains) creating run-on to the site?

Explanation: Run-off from concrete pad behind Building TA-73-2.

☐ ☒ 8. Are current operations (i.e., fire hydrants, NPDES outfalls) adversely impacting run-on to the site?

Explanation:

☒ ☐ 9. Are natural drainage patterns directing stormwater onto site?

Explanation: Sheet flow down surrounding slope.

ASSESSMENT FINDING:

☐ ☒ **10. Based on the above criteria and the assessment of this site, does soil erosion potential exist? (REFER TO EROSION POTENTIAL MATRIX.)**

T. Lemke

11. Signature of Water Quality/Hydrology Representative

Initials of independent reviewer.

Check here when information is entered in database: ☒

This page is for ESH-18 notes, recommendations, and photos.

	Y	N	
12 a)	●	○	Is there visible trash/debris on the site?
b)	○	●	Is there visible trash/debris in a watercourse?

Description of existing BMPs:

Strasw bales in place along edge of mesa top.

● ○ Are BMPs being properly maintained? If no, describe in "Other Internal Notes."

● ○ Are BMPs effectively keeping sediment in place and reducing erosion potential?

OTHER INTERNAL NOTES:

Steep slope with bare soil at edge of mesa top. Evidence of erosion exists.
Site is covered with ash and rusted cans deposited into canyon from incinerator activity.

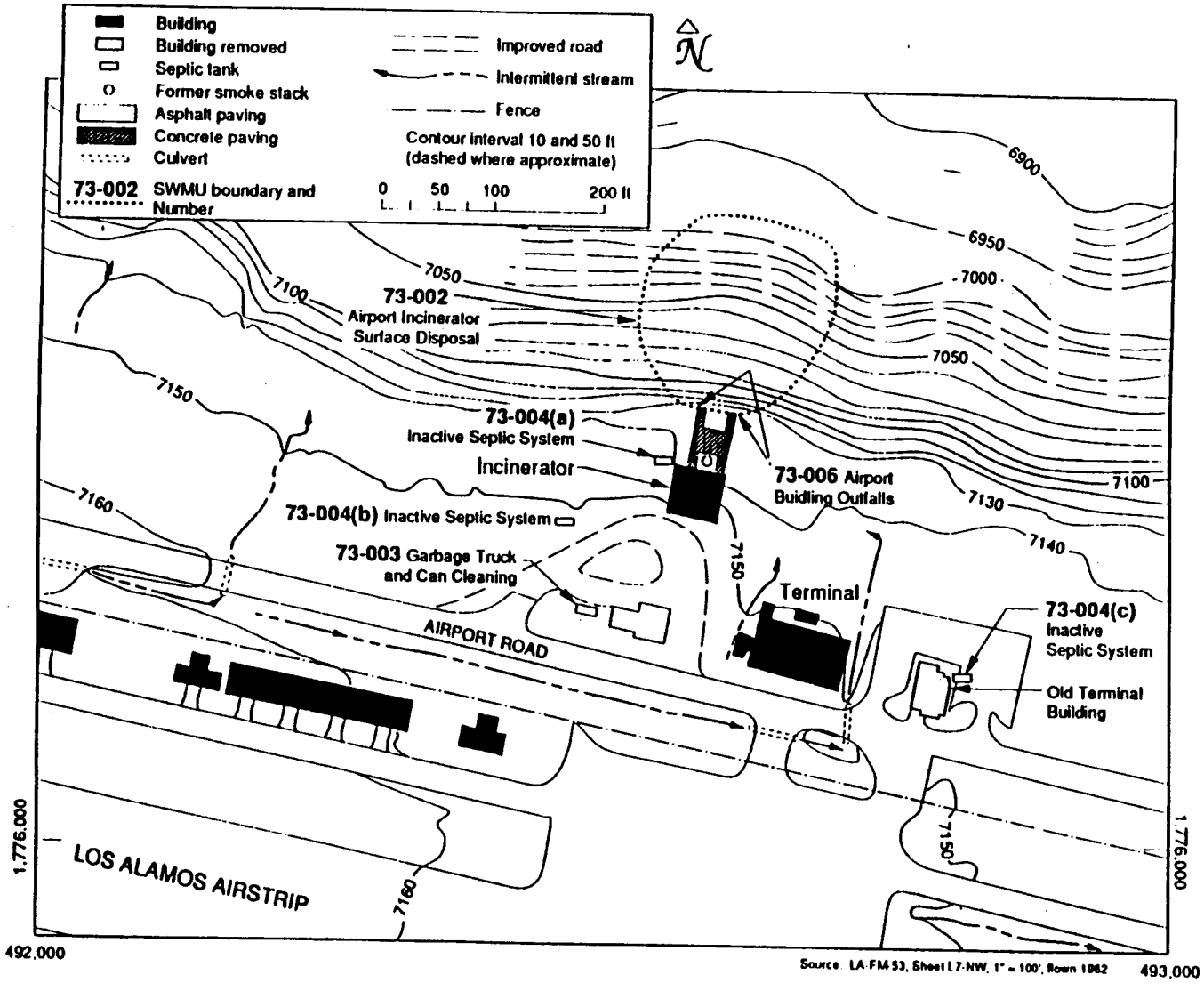


Figure 5-86. SWMU Aggregate 73-B, Los Alamos Airport (West).

Los Alamos National Laboratory
Environmental Restoration Program
CONSTITUENT ASSESSMENT

LANL-ER-AP-4.5
Part A

SITE INFORMATION

1. PRS Number: 73-007 **2. Date (M/D/Y):** 09/24/98 **Time (am/pm):** 4:48:00 PM

3. ER Point of Contact Gabriela Lopez **4. FMU/Responsible Party Contact** _____

5. HSWA No **6. Site Ranking System (SRS) #** None

7. Description of the historical operations of this PRS:

PRS 73-007 consisted of a septic tank and inlet/outlet lines in the Contractor's Row area. Construction contractors occupied the area from 1947 to early 1950. There are no records discussing historical operations of PRS 73-007.

8. Description of the current operations of this PRS (if any):

None.

PRS STATUS

9. Action/Status to Date (check all that apply)

		Date Completed or Anticipated	
☐ None			
☐ Field Investigation ☐ Phase I ☒ Phase II			
☐ Interim Measures ☐ IM ☐ BMP	IM:		
	BMPs:		
☒ VCA ☐ VCM			09/30/96
☐ Other ☐ Monitoring ☐ CMS			
☐ Report Status ☐ SAP ☐ RFI Report	SAP: 09/30/98	RFI RPTs:	
SAP INFO:			

☐ **NFA/DOU** If checked, supply HH NFA criteria number and date: 5 09/30/96

SAMPLE INFORMATION

◉ Yes ○ No **10. Have surface/sediment (depth less than 12 inches) samples been collected tha reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, sample ID, SAL, depth, and media (soil, tuff, etc.)
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **11. Have surface water samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, filtered/non-filtered, & flow data, if available.
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **12. Are data pending?**

If yes: 1) List date data are anticipated: _____
2) Provide list of COPCs identified in RFI Work Plan as an attachment.

Gabriela Lopez

13. Signature of ER Representative

Los Alamos National Laboratory

Environment, Safety and Health Division
ESH-18 Water Quality and Hydrology Group

AP 4.5 Surface Water Assessment
Erosion Matrix for PRS 73-007

CRITERIA EVALUATED	Value	Erosion/Sediment Transport Potential Low 0.1	Medium 0.5	High 1.0	Calculated Score
Site Setting (43)					
On mesa top	1	Defined based on topographic setting			1.0
Within bench of canyon	4				
Within the canyon floodplain but not watercourse	13				
Within bottom of canyon channel in watercourse	17				
Estimated % ground and canopy cover	13	>75%	25-75%	<25%	1.3
Slope	13	0-10%	10-30%	>30%	1.3
Surface Water Factors-Run-off (46)					
Visible evidence of runoff discharging? (Yes/No)	5	If no, score of 0 for runoff section.			5.0
		If yes, score 5 and proceed with section.			
Where does runoff terminate?	19	Other	Bench Setting	Drainage/Wetland	19.0
Has runoff caused visible erosion? (Yes/No)	22	Sheet	Rill	Gully	0.0
		If no, score as 0. If yes, calculate as appropriate.			
Surface Water Factors-Run-on (11)					
Structures adversely affecting run-on (Yes/No)	7*	If yes, score as 7. If no, score as 0.			0.0
Current operations adversely impacting (Yes/No)	4	If yes, score as 4. If no, score as 0.			0.0
Natural drainages onto site (Yes/No)	7*	If yes, score as 7. If no, score as 0.			0.0
**Select either structures or natural drainages.*					
MAX. POSSIBLE EROSION MATRIX SCORE:	**100**			**Total Score**	27.6

Report Printed 7/14/98 4:22:05 PM.

Los Alamos National Laboratory
SURFACE WATER
SITE ASSESSMENT

SITE INFORMATION

1a) PRS Number 73-007 **1b) Structure Number** **1c) FMU Number**

2. Date/Time (M/D/Y H:M am/pm) 7/2/98 8:30:00 AM

SITE SETTING (check all that apply)

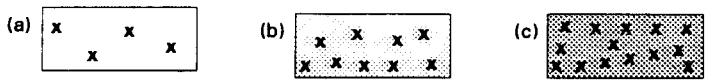
3. ◉ **On mesa top (a).** ○ **In the canyon floor, but not in an established channel (c).**

○ **Within a bench of a canyon (b).** ○ **Within established channel in the canyon floor (d).**

Explanation: Sites are in the former contractor row south of State Road 502 and south of the airport. Sites drain into DP Canyon.

4. Estimated ground and/or canopy cover at site: (deciduous leaves, pine needles, rocks, vegetation, trees, structures, asphalt, etc.)

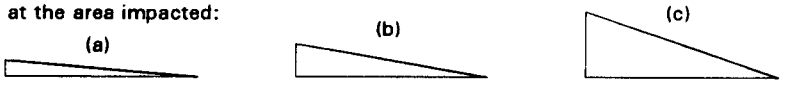
(illustration)



Estimated % of ground/canopy cover: ○ 0% to 25% ○ 25% to 75 ◉ 75% to 100

Explanation: Area is covered with native grasses, oak and pine.

5. Steepest slope at the area impacted:



◉ Less than 10% ○ 10% to 30% ○ 30% and greater

Explanation: Area is on the mesa top.

RUNOFF FACTORS

Y / N

☑ ☐ **6. Is there visible evidence of runoff discharging from site? If yes, answer a) - c) below:**

☐ ☑ 6a) Is runoff channelized? If yes, describe ○ Man-made channel. ◉ Natural channel.

Explanation: Two natural channels drain area. Larger channel also drains area along State Road 502 and the airport.

RUNOFF FACTORS, CONT'D

6b) Where does evidence of runoff terminate?

- (●) **Drainage or wetland (name)** Pueblo Canyon
- ( ) **Within bench of canyon setting (name)**
- ( ) **Other (i.e., retention pond, meadow, mesa top)**

Explanation: Run-off goes over mesa edge into DP Canyon.

Y / N

☐ ☑ 6c) Has runoff caused visible erosion at the site? If yes, explain below ( ) Sheet ( ) Rill ( ) Gully

Explanation: Two natural drainage channels.

RUN-ON FACTORS

Please rate the potential for storm water to run on to this site: (Check EITHER #7 or #9)

☐ ☑ 7. Are structures (i.e., buildings, roof drains, parking lots, storm drains) creating run-on to the site?

Explanation: Run-on from State Road 502 is channelized through the site.

☐ ☑ 8. Are current operations (i.e., fire hydrants, NPDES outfalls) adversely impacting run-on to the site?

Explanation: One very old hydrant in area.

☐ ☑ 9. Are natural drainage patterns directing stormwater onto site?

Explanation: Sheet flow across into small channels within the site.

ASSESSMENT FINDING:

☐ ☑ **10. Based on the above criteria and the assessment of this site, does soil erosion potential exist? (REFER TO EROSION POTENTIAL MATRIX.)**

Jeff Walterscheid

11. Signature of Water Quality/Hydrology Representative

SW Initials of independent reviewer.

Check here when information is entered in database: ☑

This page is for ESH-18 notes, recommendations, and photos.

	Y	N	
12 a)	◉	○	Is there visible trash/debris on the site?
b)	○	◉	Is there visible trash/debris in a watercourse?

Description of existing BMPs:

○	○	Are BMPs being properly maintained? If no, describe in "Other Internal Notes."
○	○	Are BMPs effectively keeping sediment in place and reducing erosion potential?

OTHER INTERNAL NOTES:

Minimal soil erosion.

FIGURE 1

INORGANICS WITH CONCENTRATIONS EXCEEDING BACKGROUND SCREENING VALUES AT PRS 73-007

Location Description	Location ID	Sample ID	Lead	Silver	Thallium	Zinc
Outfall sample	73-02203	0173-96-0251	**50**	**2.2**	**1.4**	**120**

FIGURE 2

DETECTED ORGANICS AT PRS 73-007

Location Description	Location ID	Sample ID	Di-n-butylphthalate (mg/kg)
Outfall sample	73-02203	0173-96-0251	**0.96**

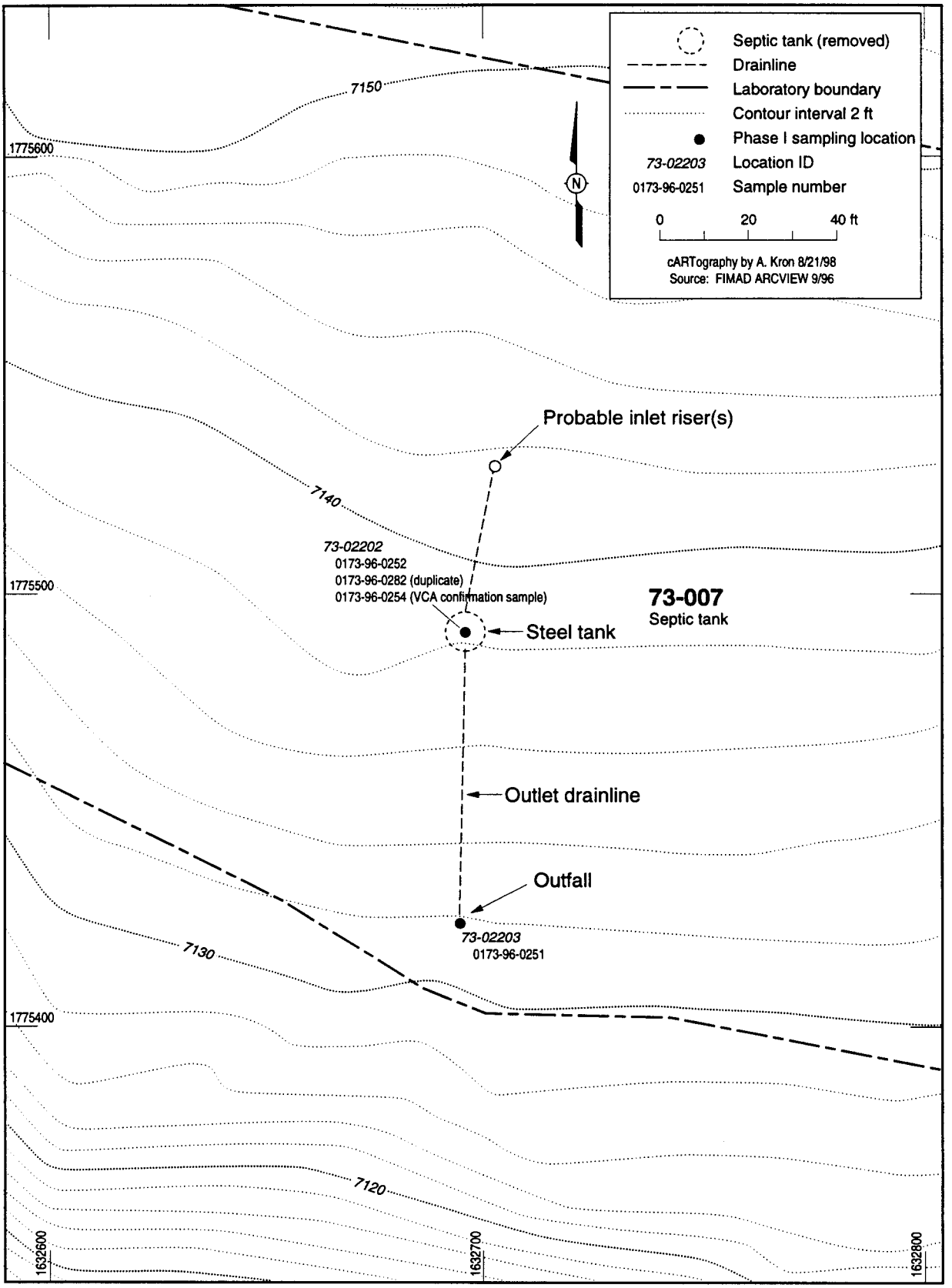
TABLE 4.2.1.2-1

PRS 73-007
SUMMARY OF SAMPLES COLLECTED

Location ID	Sample ID	Location Description and Depth	Matrix	VOCs	SVOCs	PCBs/ Pest.	TAL Metals	RAD[a]
73-02202	0173-96-0252	Inside septic tank	Sediment	2286	2286	2286	2287	2288
73-02202	0173-96-0282	Duplicate of 0173-96-0252	Sediment	2286	2286	2286	2287	2288
73-02203	0173-96-0251	End of outlet pipe at 1.8–2.1 ft	Soil	2286	2286	2286	2287	2288
73-02202	0173-96-0254	Confirmatory sample below tank at 5–5.3 ft	Tuff	2496	2496	2496	2497	NA[b]

a. RAD = radiological analyses: gross alpha/beta/gamma and tritium

b. NA = not analyzed



F4.2.1.2-1 / TA-73 SAP / 092598

Figure 4.2.1.2-1. PRS 73-007 Phase I and VCA sampling locations

Los Alamos National Laboratory
Environmental Restoration Program
CONSTITUENT ASSESSMENT

LANL-ER-AP-4.5
Part A

SITE INFORMATION

1. PRS Number: C-73-005(a) **2. Date (M/D/Y):** 09/24/98 **Time (am/pm):** 4:52:00 PM

3. ER Point of Contact Gabriela Lopez **4. FMU/Responsible Party Contact** _____

5. HSWA No **6. Site Ranking System (SRS) #** None

7. Description of the historical operations of this PRS:

PRS C-73-005(a-f) consists of 6 unlined pits of various dimensions ranging from 3 feet to 6 feet wide, 5 feet to 12 feet long and 2.5 feet to 6 feet deep in the Contractor's Row Area. Construction Contractors occupied the area from 1947 to early 1950. There are no records discussing historical operations of PRS 73-005(a-f)

8. Description of the current operations of this PRS (if any):

None

PRS STATUS

9. Action/Status to Date (check all that apply)

		Date Completed or Anticipated	
☐ **None**			
☐ **Field Investigation** ☐ **Phase I** ☒ **Phase II**			
☐ **Interim Measures** ☐ **IM** ☐ **BMP**	**IM:**		
	BMPs:		
☑ **VCA** ☐ **VCM**			09/30/96
☐ **Other** ☐ **Monitoring** ☐ **CMS**			
☐ **Report Status** ☐ **SAP** ☐ **RFI Report**	**SAP:** 09/30/98	**RFI RPTs:**	
SAP INFO:			

☐ **NFA/DOU** If checked, supply HH NFA criteria number and date: 5 09/30/97

SAMPLE INFORMATION

◉ Yes ○ No **10. Have surface/sediment (depth less than 12 inches) samples been collected tha reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, sample ID, SAL, depth, and media (soil, tuff, etc.)
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **11. Have surface water samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, filtered/non-filtered, & flow data, if available.
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **12. Are data pending?**

If yes: 1) List date data are anticipated: _____
2) Provide list of COPCs identified in RFI Work Plan as an attachment.

13. Signature of ER Representative

Los Alamos National Laboratory

Environment, Safety and Health Division
ESH-18 Water Quality and Hydrology Group

AP 4.5 Surface Water Assessment Erosion Matrix for PRS C-73-005(a)

CRITERIA EVALUATED	Value	Erosion/Sediment Transport Potential Low 0.1	Medium 0.5	High 1.0	Calculated Score
Site Setting (43)					
On mesa top	1	Defined based on topographic setting			1.0
Within bench of canyon	4				
Within the canyon floodplain but not watercourse	13				
Within bottom of canyon channel in watercourse	17				
Estimated % ground and canopy cover	13	>75%	25-75%	<25%	1.3
Slope	13	0-10%	10-30%	>30%	1.3
Surface Water Factors-Run-off (46)					
Visible evidence of runoff discharging? (Yes/No)	5	If no, score of 0 for runoff section. If yes, score 5 and proceed with section.			5.0
Where does runoff terminate?	19	Other	Bench Setting	Drainage/Wetland	19.0
Has runoff caused visible erosion? (Yes/No)	22	Sheet	Rill	Gully	0.0
		If no, score as 0. If yes, calculate as appropriate.			
Surface Water Factors-Run-on (11)					
Structures adversely affecting run-on (Yes/No)	7*	If yes, score as 7. If no, score as 0.			0.0
Current operations adversely impacting (Yes/No)	4	If yes, score as 4. If no, score as 0.			0.0
Natural drainages onto site (Yes/No)	7*	If yes, score as 7. If no, score as 0.			0.0
**Select either structures or natural drainages.*					
MAX. POSSIBLE EROSION MATRIX SCORE:	**100**			**Total Score**	27.6

Report Printed 7/14/98 4:22:26 PM.

SITE INFORMATION

1a) PRS Number C-73-005(a) **1b) Structure Number** **1c) FMU Number**

2. Date/Time (M/D/Y H:M am/pm) 7/2/98 8:30:00 AM

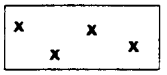
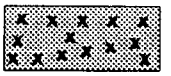
SITE SETTING (check all that apply)

3. ◉ **On mesa top (a).** ○ **In the canyon floor, but not in an established channel (c).**

○ **Within a bench of a canyon (b).** ○ **Within established channel in the canyon floor (d).**

Explanation: Sites are in the former contractor row south of State Road 502 and south of the airport. Sites drain into DP Canyon.

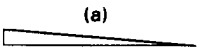
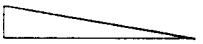
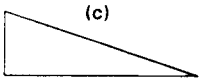
4. Estimated ground and/or canopy cover at site: (deciduous leaves, pine needles, rocks, vegetation, trees, structures, asphalt, etc.)

(illustration) (a)  (b) (c) 

Estimated % of ground/canopy cover: ○ 0% to 25% ○ 25% to 75 ◉ 75% to 100

Explanation: Area is covered with native grasses, oak and pine.

5. Steepest slope at the area impacted:

(a)  (b)  (c) 

◉ Less than 10% ○ 10% to 30% ○ 30% and greater

Explanation: Area is on the mesa top.

RUNOFF FACTORS

Y / N

☑ ☐ **6. Is there visible evidence of runoff discharging from site? If yes, answer a) - c) below:**

☐ ☑ **6a) Is runoff channelized? If yes, describe** ○ Man-made channel. ◉ Natural channel.

Explanation: Two natural channels drain area. Larger channel also drains area along State Road 502 and the airport.

RUNOFF FACTORS, CONT'D

6b) Where does evidence of runoff terminate?

- (●) **Drainage or wetland (name)** Pueblo Canyon
- ( ) **Within bench of canyon setting (name)**
- ( ) **Other (i.e., retention pond, meadow, mesa top)**

Explanation: Run-off goes over mesa edge into DP Canyon.

Y / N

☐ ☑ 6c) Has runoff caused visible erosion at the site? If yes, explain below ( ) Sheet ( ) Rill ( ) Gully

Explanation: Two natural drainage channels.

RUN-ON FACTORS

Please rate the potential for storm water to run on to this site: (Check EITHER #7 or #9)

☐ ☑ 7. Are structures (i.e., buildings, roof drains, parking lots, storm drains) creating run-on to the site?

Explanation: Run-on from State Road 502 is channelized through the site.

☐ ☑ 8. Are current operations (i.e., fire hydrants, NPDES outfalls) adversely impacting run-on to the site?

Explanation: One very old hydrant in area.

☐ ☑ 9. Are natural drainage patterns directing stormwater onto site?

Explanation: Sheet flow across into small channels within the site.

ASSESSMENT FINDING:

☐ ☑ **10. Based on the above criteria and the assessment of this site, does soil erosion potential exist? (REFER TO EROSION POTENTIAL MATRIX.)**

Jeff Walterscheid

11. Signature of Water Quality/Hydrology Representative

SV Initials of independent reviewer.

Check here when information is entered in database: ☑

This page is for ESH-18 notes, recommendations, and photos.

	Y	N	
12 a)	◉	○	Is there visible trash/debris on the site?
b)	○	◉	Is there visible trash/debris in a watercourse?

Description of existing BMPs:

○	○	Are BMPs being properly maintained? If no, describe in "Other Internal Notes."
○	○	Are BMPs effectively keeping sediment in place and reducing erosion potential?

OTHER INTERNAL NOTES:

Minimal soil erosion.

Los Alamos National Laboratory
Environmental Restoration Program
CONSTITUENT ASSESSMENT

LANL-ER-AP-4.5
Part A

SITE INFORMATION

1. PRS Number: C-73-005(b) **2. Date (M/D/Y):** 09/24/98 **Time (am/pm):** 5:01:00 AM

3. ER Point of Contact Gabriela Lopez **4. FMU/Responsible Party Contact** _____

5. HSWA No **6. Site Ranking System (SRS) #** None

7. Description of the historical operations of this PRS:

PRS C-73-005(a-f) consists of 6 unlined pits of various dimensions ranging from 3 feet to 6 feet wide, 5 feet to 12 feet long and 2.5 feet to 6 feet deep in the Contractor's Row Area. Construction Contractors occupied the area from 1947 to early 1950. There are no records discussing historical operations of PRS 73-005(a-f)

8. Description of the current operations of this PRS (if any):

None

PRS STATUS

9. Action/Status to Date (check all that apply)

		Date Completed or Anticipated	
☐ **None**			
☐ **Field Investigation** ☐ **Phase I** ☐ **Phase II**			
☐ **Interim Measures** ☐ **IM** ☐ **BMP**	**IM:**		
	BMPs:		
☑ **VCA** ☐ **VCM**			09/30/96
☐ **Other** ☐ **Monitoring** ☐ **CMS**			
☐ **Report Status** ☐ **SAP** ☐ **RFI Report**	**SAP:** 09/30/98	**RFI RPTs:**	
SAP INFO:			

☐ **NFA/DOU** If checked, supply HH NFA criteria number and date: 5 09/30/97

SAMPLE INFORMATION

◉ Yes ○ No **10. Have surface/sediment (depth less than 12 inches) samples been collected tha reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, sample ID, SAL, depth, and media (soil, tuff, etc.)
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **11. Have surface water samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, filtered/non-filtered, & flow data, if available.
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **12. Are data pending?**

If yes: 1) List date data are anticipated: _____
2) Provide list of COPCs identified in RFI Work Plan as an attachment.

13. Signature of ER Representative

Los Alamos National Laboratory
Environmental Restoration Program
CONSTITUENT ASSESSMENT

LANL-ER-AP-4.5
Part A

SITE INFORMATION

1. PRS Number: C-73-005(c) **2. Date (M/D/Y):** 09/24/98 **Time (am/pm):** 5:03:00 PM

3. ER Point of Contact Gabriela Lopez **4. FMU/Responsible Party Contact** _____

5. HSWA No **6. Site Ranking System (SRS) #** None

7. Description of the historical operations of this PRS:

PRS C-73-005(a-f) consists of 6 unlined pits of various dimensions ranging from 3 feet to 6 feet wide, 5 feet to 12 feet long and 2.5 feet to 6 feet deep in the Contractor's Row Area. Construction Contractors occupied the area from 1947 to early 1950. There are no records discussing historical operations of PRS 73-005(a-f)

8. Description of the current operations of this PRS (if any):

None

PRS STATUS

9. Action/Status to Date (check all that apply)

		Date Completed or Anticipated
☐ **None**		
☐ **Field Investigation** ☐ **Phase I** ☐ **Phase II**		
☐ **Interim Measures** ☐ **IM** ☐ **BMP**	**IM:**	
	BMPs:	
☑ **VCA** ☐ **VCM**		09/30/96
☐ **Other** ☐ **Monitoring** ☐ **CMS**		
☐ **Report Status** ☐ **SAP** ☐ **RFI Report**	**SAP:** 09/30/98	**RFI RPTs:**
SAP INFO:		

☐ **NFA/DOU** If checked, supply HH NFA criteria number and date: 5 09/30/97

SAMPLE INFORMATION

◉ Yes ○ No **10. Have surface/sediment (depth less than 12 inches) samples been collected tha reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, sample ID, SAL, depth, and media (soil, tuff, etc.)
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **11. Have surface water samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, filtered/non-filtered, & flow data, if available.
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **12. Are data pending?**

If yes: 1) List date data are anticipated: _____
2) Provide list of COPCs identified in RFI Work Plan as an attachment.

13. Signature of ER Representative

Los Alamos National Laboratory
Environmental Restoration Program
CONSTITUENT ASSESSMENT

LANL-ER-AP-4.5
Part A

SITE INFORMATION

1. PRS Number: C-73-005(d) **2. Date (M/D/Y):** 09/24/98 **Time (am/pm):** 5:04:00 PM

3. ER Point of Contact Gabriela Lopez **4. FMU/Responsible Party Contact** _____

5. HSWA No **6. Site Ranking System (SRS) #** None

7. Description of the historical operations of this PRS:

PRS C-73-005(a-f) consists of 6 unlined pits of various dimensions ranging from 3 feet to 6 feet wide, 5 feet to 12 feet long and 2.5 feet to 6 feet deep in the Contractor's Row Area. Construction Contractors occupied the area from 1947 to early 1950. There are no records discussing historical operations of PRS 73-005(a-f)

8. Description of the current operations of this PRS (if any):

None

PRS STATUS

9. Action/Status to Date (check all that apply)

	Date Completed or Anticipated	
☐ **None**		
☐ **Field Investigation** ☐ **Phase I** ☐ **Phase II**		
☐ **Interim Measures** ☐ **IM** ☐ **BMP**	**IM:**	
	BMPs:	
☑ **VCA** ☐ **VCM**		09/30/96
☐ **Other** ☐ **Monitoring** ☐ **CMS**		
☐ **Report Status** ☐ **SAP** ☐ **RFI Report**	**SAP:** 09/30/98	**RFI RPTs:**
SAP INFO:		

☐ **NFA/DOU** If checked, supply HH NFA criteria number and date: 5 09/30/97

SAMPLE INFORMATION

◉ Yes ○ No **10. Have surface/sediment (depth less than 12 inches) samples been collected tha reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, sample ID, SAL, depth, and media (soil, tuff, etc.)
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **11. Have surface water samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, filtered/non-filtered, & flow data, if available.
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **12. Are data pending?**

If yes: 1) List date data are anticipated: _____
2) Provide list of COPCs identified in RFI Work Plan as an attachment.

13. Signature of ER Representative

Los Alamos National Laboratory

Environment, Safety and Health Division
ESH-18 Water Quality and Hydrology Group

AP 4.5 Surface Water Assessment Erosion Matrix for PRS C-73-005(d)

CRITERIA EVALUATED	Value	Erosion/Sediment Transport Potential Low 0.1	Medium 0.5	High 1.0	Calculated Score
Site Setting (43)					
On mesa top	1	Defined based on topographic setting			1.0
Within bench of canyon	4				
Within the canyon floodplain but not watercourse	13				
Within bottom of canyon channel in watercourse	17				
Estimated % ground and canopy cover	13	>75%	25-75%	<25%	1.3
Slope	13	0-10%	10-30%	>30%	1.3
Surface Water Factors-Run-off (46)					
Visible evidence of runoff discharging? (Yes/No)	5	If no, score of 0 for runoff section.			5.0
		If yes, score 5 and proceed with section.			
Where does runoff terminate?	19	Other	Bench Setting	Drainage/Wetland	19.0
Has runoff caused visible erosion? (Yes/No)	22	Sheet	Rill	Gully	0.0
		If no, score as 0. If yes, calculate as appropriate.			
Surface Water Factors-Run-on (11)					
Structures adversely affecting run-on (Yes/No)	7*	If yes, score as 7. If no, score as 0.			0.0
Current operations adversely impacting (Yes/No)	4	If yes, score as 4. If no, score as 0.			0.0
Natural drainages onto site (Yes/No)	7*	If yes, score as 7. If no, score as 0.			0.0
**Select either structures or natural drainages.*					
MAX. POSSIBLE EROSION MATRIX SCORE:	**100**			**Total Score**	27.6

Report Printed 7/14/98 4:26:23 PM.

Los Alamos National Laboratory
SURFACE WATER
SITE ASSESSMENT

SITE INFORMATION

1a) PRS Number C-73-005(d) **1b) Structure Number** **1c) FMU Number**

2. Date/Time (M/D/Y H:M am/pm) 7/2/98 8:30:00 AM

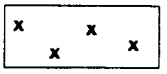
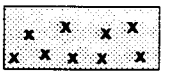
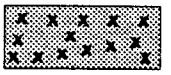
SITE SETTING (check all that apply)

3. (●) **On mesa top (a).** ( ) **In the canyon floor, but not in an established channel (c).**

( ) **Within a bench of a canyon (b).** ( ) **Within established channel in the canyon floor (d).**

Explanation: Sites are in the former contractor row south of State Road 502 and south of the airport. Sites drain into DP Canyon.

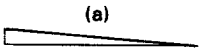
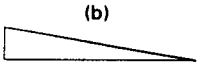
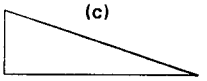
4. Estimated ground and/or canopy cover at site: (deciduous leaves, pine needles, rocks, vegetation, trees, structures, asphalt, etc.)

(illustration) (a)  (b)  (c) 

Estimated % of ground/canopy cover: ( ) 0% to 25% ( ) 25% to 75 (●) 75% to 100

Explanation: Area is covered with native grasses, oak and pine.

5. Steepest slope at the area impacted:

(a)  (b)  (c) 

(●) Less than 10% ( ) 10% to 30% ( ) 30% and greater

Explanation: Area is on the mesa top.

RUNOFF FACTORS

Y / N

☑ ☐ **6. Is there visible evidence of runoff discharging from site? If yes, answer a) - c) below:**

☐ ☑ **6a) Is runoff channelized? If yes, describe** ( ) Man-made channel. (●) Natural channel.

Explanation: Two natural channels drain area. Larger channel also drains area along State Road 502 and the airport.

RUNOFF FACTORS, CONT'D

6b) Where does evidence of runoff terminate?

- (●) **Drainage or wetland (name)** Pueblo Canyon
- ( ) **Within bench of canyon setting (name)**
- ( ) **Other (i.e., retention pond, meadow, mesa top)**

Explanation: Run-off goes over mesa edge into DP Canyon.

Y / N

☐ ☑ 6c) Has runoff caused visible erosion at the site? If yes, explain below ( ) Sheet ( ) Rill ( ) Gully

Explanation: Two natural drainage channels.

RUN-ON FACTORS

Please rate the potential for storm water to run on to this site: (Check EITHER #7 or #9)

☐ ☑ 7. Are structures (i.e., buildings, roof drains, parking lots, storm drains) creating run-on to the site?

Explanation: Run-on from State Road 502 is channelized through the site.

☐ ☑ 8. Are current operations (i.e., fire hydrants, NPDES outfalls) adversely impacting run-on to the site?

Explanation: One very old hydrant in area.

☐ ☑ 9. Are natural drainage patterns directing stormwater onto site?

Explanation: Sheet flow across into small channels within the site.

ASSESSMENT FINDING:

☐ ☑ **10. Based on the above criteria and the assessment of this site, does soil erosion potential exist? (REFER TO EROSION POTENTIAL MATRIX.)**

Jeff Walterscheid

11. Signature of Water Quality/Hydrology Representative

SJV Initials of independent reviewer.

Check here when information is entered in database: ☑

This page is for ESH-18 notes, recommendations, and photos.

	Y	N	
12 a)	◉	○	Is there visible trash/debris on the site?
b)	○	◉	Is there visible trash/debris in a watercourse?

Description of existing BMPs:

○	○	Are BMPs being properly maintained? If no, describe in "Other Internal Notes."
○	○	Are BMPs effectively keeping sediment in place and reducing erosion potential?

OTHER INTERNAL NOTES:

Minimal soil erosion.

Los Alamos National Laboratory
Environmental Restoration Program
CONSTITUENT ASSESSMENT

LANL-ER-AP-4.5
Part A

SITE INFORMATION

1. PRS Number: C-73-005(e) **2. Date (M/D/Y):** 09/24/98 **Time (am/pm):** 5:06:00 PM

3. ER Point of Contact Gabriela Lopez **4. FMU/Responsible Party Contact** _____

5. HSWA No **6. Site Ranking System (SRS) #** None

7. Description of the historical operations of this PRS:

PRS C-73-005(a-f) consists of 6 unlined pits of various dimensions ranging from 3 feet to 6 feet wide, 5 feet to 12 feet long and 2.5 feet to 6 feet deep in the Contractor's Row Area. Construction Contractors occupied the area from 1947 to early 1950. There are no records discussing historical operations of PRS 73-005(a-f)

8. Description of the current operations of this PRS (if any):

None

PRS STATUS

9. Action/Status to Date (check all that apply)

		Date Completed or Anticipated
☐ **None**		
☐ **Field Investigation** ☐ **Phase I** ☐ **Phase II**		
☐ **Interim Measures** ☐ **IM** ☐ **BMP**	**IM:**	
	BMPs:	
☑ **VCA** ☐ **VCM**		09/30/96
☐ **Other** ☐ **Monitoring** ☐ **CMS**		
☐ **Report Status** ☐ **SAP** ☐ **RFI Report**	**SAP:** 09/30/98 **RFI RPTs:**	
SAP INFO:		
☐ **NFA/DOU** If checked, supply HH NFA criteria number and date:	5	09/30/97

SAMPLE INFORMATION

◉ Yes ○ No **10. Have surface/sediment (depth less than 12 inches) samples been collected tha reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, sample ID, SAL, depth, and media (soil, tuff, etc.)
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **11. Have surface water samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, filtered/non-filtered, & flow data, if available.
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **12. Are data pending?**

If yes: 1) List date data are anticipated: _____
2) Provide list of COPCs identified in RFI Work Plan as an attachment.

13. Signature of ER Representative

Los Alamos National Laboratory
Environmental Restoration Program
CONSTITUENT ASSESSMENT

LANL-ER-AP-4.5
Part A

SITE INFORMATION

1. PRS Number: C-73-005(f)
2. Date (M/D/Y): 09/24/98 Time (am/pm): 5:06:00 PM
3. ER Point of Contact: Gabriela Lopez
4. FMU/Responsible Party Contact:
5. HSWA: No
6. Site Ranking System (SRS) #: None
7. Description of the historical operations of this PRS:

PRS C-73-005(a-f) consists of 6 unlined pits of various dimensions ranging from 3 feet to 6 feet wide, 5 feet to 12 feet long and 2.5 feet to 6 feet deep in the Contractor's Row Area. Construction Contractors occupied the area from 1947 to early 1950. There are no records discussing historical operations of PRS 73-005(a-f)

8. Description of the current operations of this PRS (if any):

None

PRS STATUS

9. Action/Status to Date (check all that apply)

	Date Completed or Anticipated	
☐ None		
☐ Field Investigation ☐ Phase I ☐ Phase II		
☐ Interim Measures ☐ IM ☐ BMP	IM:	
	BMPs:	
☑ VCA ☐ VCM		09/30/96
☐ Other ☐ Monitoring ☐ CMS		
☐ Report Status ☐ SAP ☐ RFI Report	SAP: 09/24/98	RFI RPTs:
SAP INFO:		
☐ NFA/DOU If checked, supply HH NFA criteria number and date:	5	09/30/97

SAMPLE INFORMATION

◉ Yes ○ No **10. Have surface/sediment (depth less than 12 inches) samples been collected tha reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, sample ID, SAL, depth, and media (soil, tuff, etc.)
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **11. Have surface water samples been collected that reflect current site conditions?**

If yes: 1) Attach data
2) Include analyte name, value, units, location ID, filtered/non-filtered, & flow data, if available.
3) Please attach existing map, showing where samples were taken, if available.

○ Yes ◉ No **12. Are data pending?**

If yes: 1) List date data are anticipated:
2) Provide list of COPCs identified in RFI Work Plan as an attachment.

13. Signature of ER Representative

AOCs C-73-005(a through f)
SUMMARY OF CHARACTERIZATION SAMPLES COLLECTED[a]

Location ID	Sample ID	Location Description and Depth	Matrix	VOCS	SVOCS	PCBS/ Pest.	TAL Metals	RAD[b]
73-02204	0173-96-0259	C-73-005(a) - Inside Septic Pit at 2.6–3.7 ft	Soil	2286	2286	2286	2287	2288
73-02205	0173-96-0258	C-73-005(a) - Inside Septic Pit at 2.7–3.8 ft	Soil	2286	2286	2286	2287	2288
73-02206	0173-96-0260	C-73-005(a) - Outlet Trench at 0.0–0.7 ft	Soil	2286	2286	2286	2287	2288
73-02199	0173-96-0263	C-73-005(b) - Inside Septic Pit at 1.3–2.1 ft	Soil	2286	2286	2286	2287	2288
73-02200	0173-96-0262	C-73-005(b) - Inside Septic Pit at 1.0–2.0 ft	Soil	2286	2286	2286	2287	2288
73-02201	0173-96-0264	C-73-005(b) - End of Outlet Pipe at 0.0–0.2 ft	Soil	2286	2286	2286	2287	2288
73-02197	0173-96-0268	C-73-005(c) - Inside Septic Pit at 0.0–0.8 ft	Soil	2271	2271	2271	2272	2273
73-02198	0173-96-0269	C-73-005(c) - Inside Septic Pit at 0.4–1.2 ft	Soil	2271	2271	2271	2272	2273
73-02195	0173-96-0271	C-73-005(d) - Inside Septic Pit at 1.9–2.9 ft	Soil	2271	2271	2271	2272	2273
73-02196	0173-96-0272	C-73-005(d) - Inside Septic Pit at 1.5–2.5 ft	Soil	2271	2271	2271	2272	2273
73-02193	0173-96-0274	C-73-005(e) - Inside Septic Pit at 1.0–1.9 ft	Soil	2271	2271	2271	2272	2273
73-02194	0173-96-0275	C-73-005(e) - Inside Septic Pit at 1.0–2.0 ft	Soil	2271	2271	2271	2272	2273
73-02191	0173-96-0280	C-73-005(f) - Inside Septic Pit at 1.5–2.5 ft	Soil	2271	2271	2271	2272	2273
73-02192	0173-96-0281	C-73-005(f) - Inside Septic Pit at 1.5–2.5 ft	Soil	2271	2271	2271	2272	2273

a. Numbers in the cells for each analytical suite are request numbers.

b. RAD = Radiological analyses: gross alpha/beta/gamma and tritium

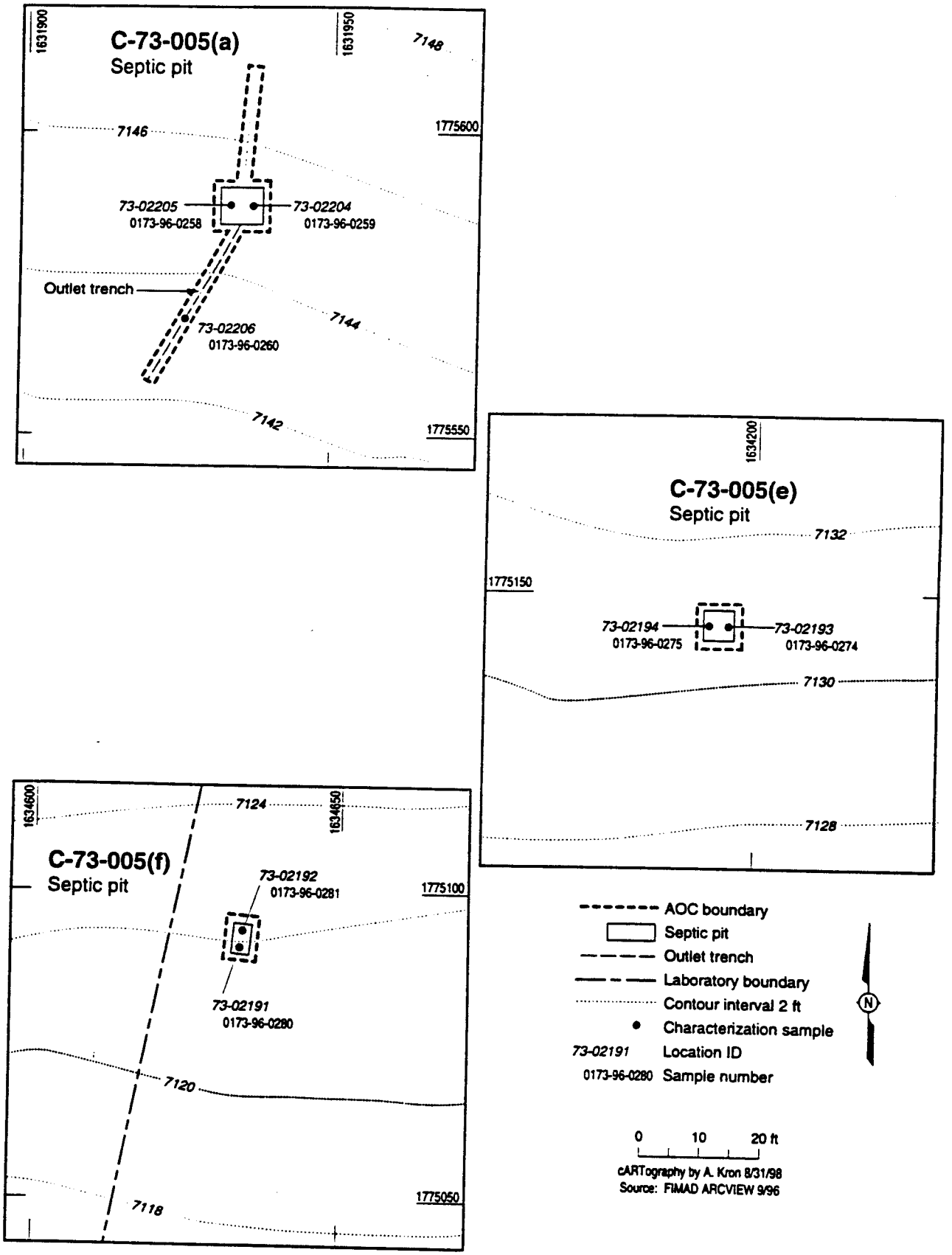


Figure 5.2.1.2-1. Phase I sample locations at AOCs C-73-005(a, e, and f).

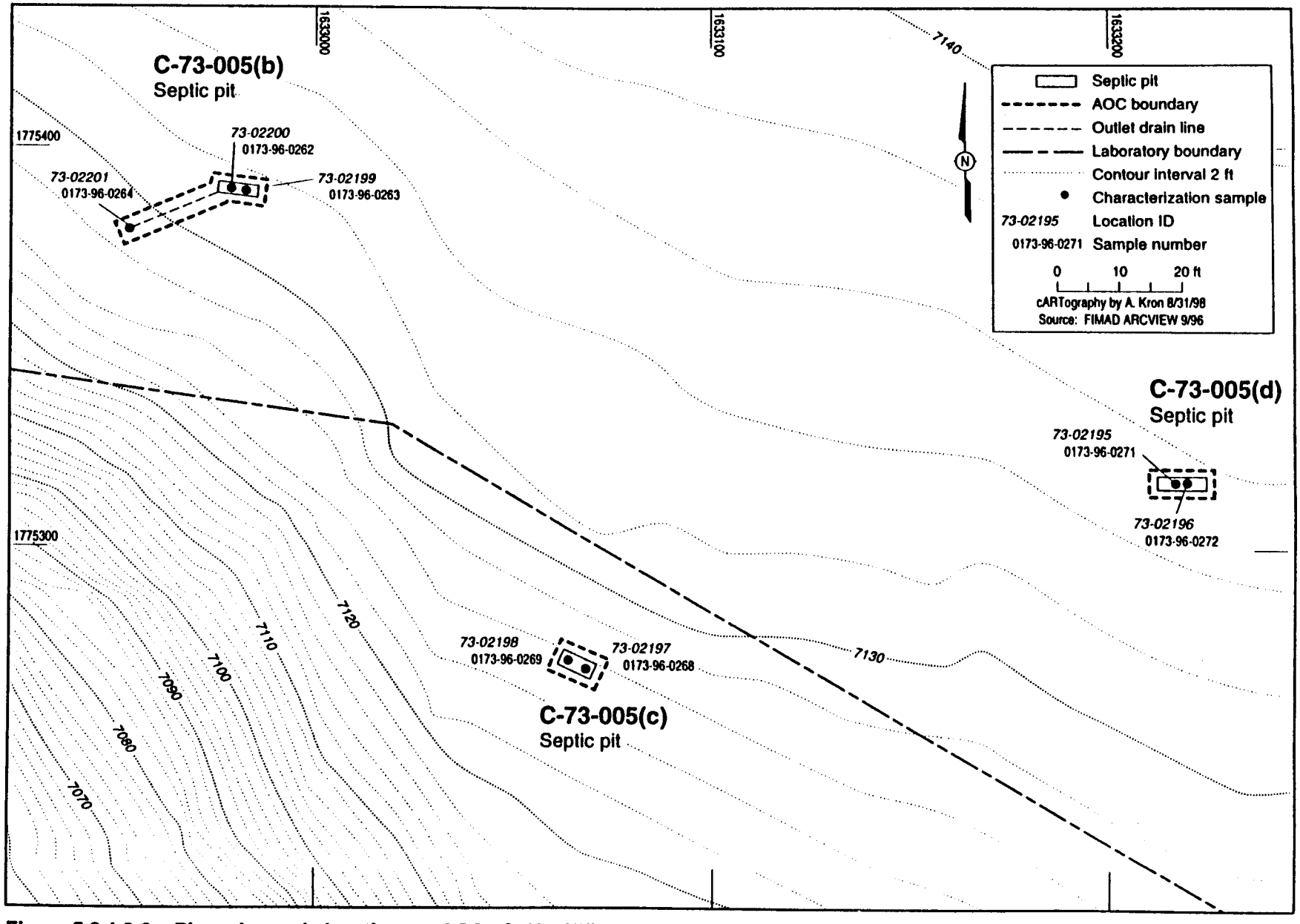


Figure 5.2.1.2-2. Phase I sample locations at AOCs C-73-005(b, c, and d).

INORGANICS WITH CONCENTRATIONS EXCEEDING BACKGROUND VALUES (BVs) AT PRS C73-005(a-f)

Location ID	Sample ID	Copper (mg/kg)	Lead (mg/kg)	Manganese (mg/kg)	Mercury (mg/kg)	Silver (mg/kg)	Thallium (mg/kg)	Zinc (mg/kg)
	BV	14.7	22.3	671	0.1	1.0	0.73	48.8
73-02205	0173-96-0258	**20**	**41**	**1100**	**0.42**	**2.2**	**1.4**	**110**
73-02204	0173-96-0259	**16**	**41**	95	**0.26**	**2.2**	**1.4**	**110**
73-02206	0173-96-0260	6.8	**29**	340	0.11(U)	**2.1**	**1.3**	44
73-02200	0173-96-0262	6.6	9.9	190	0.1(U)	2(U)	**1.3**	23
73-02199	0173-96-0263	6.9	18	200	0.1(U)	**2.1**	1.3(U)	31
73-02201	0173-96-0264	12	**31**	210	0.1(U)	2(U)	**1.3**	43
73-02197	0173-96-0268	6.9	**24**	390	0.11	2.1(U)	1.3(U)	**110**
73-02198	0173-96-0269	7.7	16	400	0.11(U)	2.1(U)	1.3(U)	39
73-02195	0173-96-0271	14	**200**	380	0.11(U)	2.2(U)	1.3(U)	**290**
73-02196	0173-96-0272	9.7	**90**	400	0.11	2.1(U)	1.3(U)	**150**
73-02193	0173-96-0274	7.1	**26**	240	0.11	2.1(U)	1.3(U)	**70**
73-02194	0173-96-0275	6.5	18	250	0.11	2.2(U)	1.4(U)	36
73-02191	0173-96-0280	9.5	**30**	320	0.11	2.2(U)	1.3(U)	**61**
73-02192	0173-96-0281	6.4	19	330	0.11	2.1(U)	1.3(U)	37

ORGANICS WITH DETECTED CONCENTRATIONS AT PRS C73-005(a-f)

Location ID	Sample ID	4,4'-DDT	4-Isopropyltoluene	Acetone	Benzo(a) anthracene	Benzo(a) pyrene	Benzo(b) fluoranthene
	EQL	0.0033	0.005	0.02	0.33	0.35	0.33
73-02205	0173-96-0258	0.0036(U)	0.0055(U)	0.022(U)	0.18(U)	0.18(U)	0.18(U)
73-02204	0173-96-0259	0.0036(U)	0.0054(U)	0.022(U)	0.18(U)	0.18(U)	0.18(U)
73-02206	0173-96-0260	0.0035(U)	0.0054(U)	0.022(U)	**0.29**	**0.23**	**0.3**
73-02200	0173-96-0262	0.0034(U)	0.0051(U)	0.02(U)	0.17(U)	0.17(U)	0.17(U)
73-02199	0173-96-0263	**0.01**	0.0052(U)	**0.024**	0.17(U)	0.17(U)	0.17(U)
73-02201	0173-96-0264	0.0034(U)	**0.012**	**0.08**	0.17(U)	0.17(U)	0.17(U)
73-02197	0173-96-0268	0.0035(U)	0.0053(U)	0.021(U)	0.18(U)	0.18(U)	0.18(U)
73-02198	0173-96-0269	0.0033(U)	0.0051(U)	0.02(U)	0.17(U)	0.17(U)	0.17(U)
73-02195	0173-96-0271	**0.01**	0.0053(U)	0.021(U)	0.18(U)	0.18(U)	0.18(U)
73-02196	0173-96-0272	**0.01**	0.0053(U)	0.021(U)	1.1(U)	1.1(U)	1.1(U)
73-02193	0173-96-0274	0.0035(U)	0.0053(U)	**0.054**	0.17(U)	0.17(U)	0.17(U)
73-02194	0173-96-0275	0.0035(U)	**0.0086**	**0.041**	0.18(U)	0.18(U)	0.18(U)
73-02191	0173-96-0280	**0.0059**	0.0053(U)	0.021(U)	0.18(U)	0.18(U)	0.18(U)
73-02192	0173-96-0281	0.0035(U)	0.0053(U)	0.021(U)	0.17(U)	0.17(U)	0.17(U)

Location ID	Sample ID	Benzo(K) fluoranthene	Chrysene	Fluoranthene	Methylene Chloride	Phenanthrene	Pyrene	Toluene
	PQL	0.33	0.33	0.33	0.005	0.33	0.33	0.005
73-02205	0173-96-0258	0.18(U)	0.18(U)	0.18(U)	0.0055(U)	0.18(U)	**0.2**	0.0055(U)
73-02204	0173-96-0259	0.18(U)	0.18(U)	**0.2**	0.0054(U)	0.18(U)	**0.21**	0.0054(U)
73-02206	0173-96-0260	**0.23**	**0.35**	**0.63**	0.0054(U)	**0.26**	**0.42**	0.0054(U)
73-02200	0173-96-0262	0.17(U)	0.17(U)	0.17(U)	0.0051(U)	0.17(U)	0.17(U)	0.0051(U)
73-02199	0173-96-0263	0.17(U)	0.17(U)	0.17(U)	0.0052(U)	0.17(U)	0.17(U)	0.0052(U)
73-02201	0173-96-0264	0.17(U)	0.17(U)	0.17(U)	**0.01(J+)**	0.17(U)	0.17(U)	**0.0061(J+)**
73-02197	0173-96-0268	0.18(U)	0.18(U)	0.18(U)	0.0053(U)	0.18(U)	0.18(U)	0.0053(U)
73-02198	0173-96-0269	0.17(U)	0.17(U)	0.17(U)	0.0051(U)	0.17(U)	0.17(U)	0.0051(U)
73-02195	0173-96-0271	0.18(U)	0.18(U)	0.18(U)	0.0053(U)	0.18(U)	0.18(U)	0.0053(U)
73-02196	0173-96-0272	1.1(U)	1.1(U)	1.1(U)	0.0053(U)	1.1(U)	1.1(U)	0.0053(U)
73-02193	0173-96-0274	0.17(U)	0.17(U)	0.17(U)	0.0053(U)	0.17(U)	0.17(U)	0.0053(U)
73-02194	0173-96-0275	0.18(U)	0.18(U)	0.18(U)	0.0054(U)	0.18(U)	0.18(U)	**0.0065**
73-02191	0173-96-0280	0.18(U)	0.18(U)	0.18(U)	0.0053(U)	0.18(U)	0.18(U)	0.0053(U)
73-02192	0173-96-0281	0.17(U)	0.17(U)	0.17(U)	0.0053(U)	0.17(U)	0.17(U)	0.0053(U)

Appendix D

Chemical Properties

APPENDIX D CHEMICAL PROPERTIES

This appendix presents specific chemical properties that effect the fate and transfer of chemicals identified in the Phase I sampling of PRSs 73-004(a), 73-004(b), 73-006, etc.

Inorganic Chemicals

Information on the fate and transport of inorganic chemicals in the soil presented here is from *Casarett and Doull's Toxicology, The Basic Science of Poisons, 3rd Edition,* by Casarett et al. (Casarett et al. 1986, ER ID 59093, pp. 827–843), *The Nature and Properties of Soils, 8th Edition,* by N. C. Brady (Brady 1974, ER ID 58203, pp. 563–566), Soil Survey of Los Alamos County, New Mexico by J. W. Nyhan, (Nyhan 1978, ER ID 5702, pp. 24, 25),*The Merck Index,12th Edition,* edited by S. Budavari et al., (Merck 1996, ER ID 58033) and the toxicological profiles from the Agency for Toxic Substances and Disease Registry for each of the inorganic chemicals (ATDSR 1990, ER ID 56531).

Arsenic

Prediction of chemical valence states. Arsenic occurs in the +3 and +5 oxidation states. Inorganic compounds in the +3 oxidation state are generally more toxic, however, conversion to arsenic (V) is normally favored in the environment. (*Toxicological Chemistry, A Guide to Toxic Substances in Chemistry,* by Stanley E. Manahan, Manahan 1989, ER ID 59377, p. 110).

Affinity of arsenic for soil, water and air. Arsenic is stable in dry air and insoluble in water, Therefore, volatilization of arsenic into the air and transport of arsenic as a dissolved component of water is not expected to be a concern at PRS 73-003 and 73-004(b) (Merck 1996, ER ID 58033, ¶ 832). However, transport and partitioning of arsenic in water depends upon the chemical form (oxidation state and counter ion) of the arsenic and on interactions with other materials present. Arsenic may be transported by leaching into rainfall or snowmelt. However, because many arsenic compounds tend to adsorb to soils or sediments, leaching usually results in transportation over only short distances in soil. Sediment-bound arsenic may be released back into the water by chemical or biological interconversions of arsenic species (ATSDR 1993, ER ID 56531).

Potential for uptake. Bioconcentration of arsenic occurs in aquatic organisms, primarily in algae and lower invertebrates. Bioconcentration factors (BCFs) measured in freshwater invertebrates and fish for several arsenic compounds ranged from 0 to 17. Biomagnification in aquatic food chains does not appear to be significant, although some fish and invertebrates contain high levels of arsenic compounds. Terrestrial plants may accumulate arsenic by root uptake from the soil (ATSDR 1993, ER ID 56531).

Chromium

Prediction of chemical valence states. In the chemically combined form, chromium exists in all oxidation states from +2 through +6 (Manahan 1989, ER ID 59377, p. 99). Chromium in soil is present mainly as insoluble oxide Cr 2O 3•nH 2O (ATSDR 1993, ER ID 56531). Therefore, it is not very mobile in soil (ATSDR 1993, ER ID 56531).

The reduction of chromium(VI) and the oxidation of chromium(III) in water has been investigated. The reduction of chromium(VI) by S-2 or Fe+2 ions under anaerobic conditions was fast, and the reduction half-life ranged from instantaneous to a few days. However, the reduction of chromium(VI) by organic sediments and soils was much slower and depended on the type and amount of organic material and on the redox condition of the water. The reaction was generally faster under anaerobic than aerobic conditions. The reduction half-life of chromium(VI) in water with soil and sediment ranged from 4 to 140 days (ATSDR 1993, ER ID 56531).

Affinity of chromium for soil, water and air. Since chromium compounds cannot volatilize from water, transport of chromium from water to the atmosphere is not likely. Most of the chromium released into water will ultimately be deposited in the sediment. A very small percentage of chromium can be present in water in both soluble and insoluble forms. Soluble chromium generally accounts for a very small percentage of the total chromium. Most of the soluble chromium is present as chromium(VI) and soluble chromium(III) complexes. Soluble forms and suspended chromium can undergo intramedia transport. Chromium(VI) in water will eventually be reduced to chromium(III) by organic matter in the water. The sorption of chromium to soil depends primarily on the clay content of the soil and, to a lesser extent, on Fe 2O 3 and the organic content of soil. Chromium that is irreversibly sorbed onto soil, for example, in the interstitial lattice of geothite, FeOOH, will not be bioavailable to plants and animals under any condition. Organic matter in soil is expected to convert soluble chromate, chromium(VI), to insoluble chromium(III) oxide, Cr 2O 3. Chromium in soil may be transported to the atmosphere as an aerosol. Surface runoff from soil can transport both soluble and bulk precipitate of chromium to surface water (ATSDR 1993, ER ID 56531).

The fate of chromium in soil is partly dependent on the redox potential and the pH of the soil. In most soils, chromium will be present predominantly in the chromium(III) state. In deeper soil where anaerobic conditions exist, chromium(VI) will be reduced to chromium(III) by S-2 and Fe+2 present in soil. The reduction of chromium(VI) to chromium(III) is possible in aerobic soils that contain appropriate organic energy sources to carry out the redox reaction. The reduction of chromium(VI) to chromium(III) is facilitated by low pH. From thermodynamic considerations, chromium(VI) may exist in the aerobic zone of some natural soil. The oxidation of chromium(III) to chromium(VI) in soil is facilitated by the presence of low oxidizable organic substances, oxygen, manganese dioxide, and moisture. Oxidation is also enhanced at elevated temperatures in surface soil that result from brush fires. Organic forms of chromium(III) (e.g., humic acid complexes) are more easily oxidized than insoluble oxides. However, oxidation of chromium(III) to chromium(VI) was not observed in soil under conditions of maximum aeration and a maximum pH of 7.3. It was later reported that soluble chromium(III) in soil can be partly oxidized to chromium(VI) by manganese dioxide in soil, and the process is enhanced by pH higher than 6. Because most chromium(III) in soil is immobilized due to adsorption and complexation with soil materials, the barrier to this oxidation process is the lack of availability of mobile chromium(III) to immobile manganese dioxide in soil surfaces. Due to this lack of availability of mobile chromium(III) to manganese dioxide surfaces, a large portion of chromium in soil will not be oxidized to chromium(VI), even in the presence of manganese dioxide and favorable pH conditions (ATSDR 1993, ER ID 56531).

Potential for uptake. Chromium is not expected to biomagnify in the aquatic food chain. Bioaccumulation of chromium from soil to above-ground parts of plants is unlikely. There is no indication of biomagnification of chromium along the terrestrial food chain (soil-plant- animal) (ATSDR 1993, ER ID 56531).

Copper

Prediction of chemical valence states. Copper occurs in the +1 and +2 oxidation states.

Affinity of copper for soil, water and air. Most copper deposited in soil will be strongly adsorbed and remain in the upper few centimeters of soil. Copper's movement in soil is determined by a host of physical and chemical interactions of copper with the soil components. In general, the copper will adsorb to organic matter, carbonate minerals, clay minerals, or hydrous iron and manganese oxides. Sandy soils with low pH have the greatest potential for leaching. However, the soil in the area of the 73-004(b) outfall is alkaline to neutral, so leaching of copper would not be a great concern at this site. In most temperate soil, the pH, organic matter, and ionic strength of the soil solutions are the key factors affecting

adsorption. The ionic strength and pH of the soil solution affect the surface charge of soils and thereby influence ionic interaction. When the amount of organic matter is low, the mineral content or Fe, Mn and Al oxides become important in determining the adsorption of copper (ATSDR 1990, ER ID 56531).

Copper binds to soil much more strongly than other divalent cations, and the distribution of copper in the soil solution is less affected by pH than other metals. In a study of competitive adsorption and leaching of metals in soil columns of widely different characteristics, copper eluted much more slowly and in much lower quantities than Zn, Cd, and Ni from two mineral soils and not at all from peat soil, which contained the greatest amount of organic matter. A study looked at pH-dependent adsorption of the bivalent transition metal cations (Cd, Cu, Pb, and Zn) in two mineral soils and two soils containing considerable organic matter. Adsorption increased with pH, and Cu and Pb were much more strongly retained than Cd and Zn. Reduction in absorptivity after removal of the organic matter demonstrated the importance of organic matter in binding copper (ATSDR 1990, ER ID 56531).

Copper shows a pronounced solubility in soil only in the oxidizing environment; in the reducing environment, solubility is low. Above pH 6, precipitation becomes the more dominant process for removing copper from water. Copper binding in soil may be correlated with pH, cation exchange capacity, and the organic content of the soil, the presence of iron oxides, and even the presence of inorganic carbon such as carbonates. Copper may also be incorporated in mineral lattices where it is unlikely to have ecological significance. Broad generalizations are not possible since the situation will differ among different soils. In soils with a high organic carbon content, however, copper will be tightly bound to organic matter. In sediment, copper is generally associated with mineral matter or tightly bound to organic material. As is common when a metal is associated with organic matter, copper is generally associated with fine, as opposed to coarse, sediment. (ATSDR 1990, ER ID 56531).

Potential for uptake. There is abundant evidence that there is no biomagnification of copper in the food chain (ATSDR 1990, ER ID 56531).

Lead

Prediction of chemical valence states. Lead occurs in the +2 and +4 oxidation states. Lead in the +2 oxidation state has some chemical similarities to calcium (Manahan 1989, ER ID 59377, p. 105).

Affinity of lead for soil, water and air. The fate of lead in soil is affected by the specific or exchange adsorption at mineral interfaces, the precipitation of sparingly soluble solid forms of the compound, and the formation of relatively stable organic-metal complexes or chelates with soil organic matter. These processes are dependent on such factors as soil pH, and organic matter content of soil, the presence of inorganic colloids and iron oxides, ion-exchange characteristics, and the amount of lead in soil. The accumulation of lead in most soils is primarily a function of the rate of deposition from the atmosphere. Most lead is retained strongly in soil, and very little is transported into surface water or groundwater. Lead is strongly sorbed to organic matter in soil, and although not subject to leaching, it may enter surface waters as a result of erosion of lead-containing soil particulates. Lead may be converted to lead sulfate at the soil surface which is relatively soluble when compared with lead carbonate or phosphate. Inorganic lead may be bound into crystalline matrices of rocks and remain essentially immobile. Lead complexes and precipitates in soil and their transformation depend on the soil type. In soil with a high organic matter content and a pH of 6-8, (which is approximately the pH of the soil on East Mesa) lead may form insoluble organic lead complexes; if the soil has less organic matter at the same pH, hydrous lead oxide complexes may form or lead may precipitate out with carbonate or phosphate ions. Entrainment of soil particles is another route of lead transport. The downward movement of lead from soil to groundwater by leaching is very slow under most natural conditions (ATSDR 1993, ER ID 56531).

Potential for uptake. Plants and animals may bioconcentrate lead but biomagnification has not been detected. Although the bioavailability of lead in soil to plants is limited because of the strong absorption of lead to soil organic matter, the bioavailability increases as the pH and the organic matter content of the soil are reduced. Lead is not biomagnified in aquatic or terrestrial food chains (ATSDR 1993, ER ID 56531).

Mercury

Prediction of chemical valence states. Mercury occurs in the +1 and +2 oxidation states. In soils and surface waters, mercury can exist in the mercuric (Hg+2) and mercurous (Hg+1) states as a number of complex ions with varying water solubilities (ATSDR 1993, ER ID 56531).

Affinity of mercury for soil, water and air. Mercury is transported to aquatic ecosystems via surface runoff. It is tightly bound to both organic and inorganic particles. Sediments with high sulfur content will strongly bind mercury. Mercuric mercury, present as complexes and chelates with ligands, is probably the predominant form of mercury present in surface waters. The transport and partitioning of mercury in surface waters and soils is influenced by the particular form of the compound. More than 97% of the dissolved gaseous mercury found in water consists of elemental mercury. Volatile forms (e.g., metallic mercury and dimethylmercury) are expected to evaporate to the atmosphere, whereas solid forms partition to particulates in the soil or water column and are transported downward to the sediments in the water column (ATSDR 1993, ER ID 56531).

The sorption process is related to the organic matter content of the soil or sediment. Mercury is sorbed to soil with high iron and aluminum content up to a maximum loading capacity of 15 g/kg. Inorganic mercury sorbed to particulate material is not readily desorbed. Thus, freshwater and marine sediments are important repositories for inorganic forms of the compound, and leaching is a relatively insignificant transport process in soils. However, surface runoff is an important mechanism for moving mercury from soil to water, particularly for soils with high humic content. Mobilization of sorbed mercury from particulates can occur through chemical or biological reduction to elemental mercury and bioconversion to volatile organic forms. Adsorption of mercury in soil is decreased with increasing pH and/or chloride ion concentrations. Metallic mercury may move through the top 3-4 cm of dry soil at atmospheric pressure; however, it is unlikely that further penetration would occur (ATSDR 1993, ER ID 56531).

The volatilization and leaching of various forms of mercury (elemental, mercuric sulfide, mercuric oxide, and mercurous oxide) from soils or wastes was examined using the headspace method for volatilization and the RCRA leaching protocols for leaching through soil to determine if the leachates exceeded the RCRA limit of 200 mg/L. With the exception of mercuric sulfide, the other forms of mercury increased in concentrations in the headspace vapor and in the leachate as the soil concentrations increased, although the elemental mercury concentrations never exceeded the RCRA limit, indicating that it was relatively unleachable. Mercuric sulfide also did not exceed the background level for the leachate and was consistently less than 0.001 mg/m3 for the vapor concentrations, indicating that it too was unleachable and did not volatilize. This study also showed that concentrations of mercury in leachate could not be correlated with the concentration of mercury in the soil or in the headspace vapors. Mercuric sulfide has been found to strongly adsorb to soil, and even with weathering, any mercury released from the mercuric sulfide is readsorbed by the soil (ATSDR 1993, ER ID 56531).

The most common organic form of mercury, methylmercury, is soluble, mobile, and quickly enters the aquatic food chain (ATSDR 1993, ER ID 56531).

Potential for uptake. Inorganic mercury compounds added to soils react quickly with the organic mater and clay minerals to form insoluble compounds. In this form the mercury is quite unavailable to growing plants. (Brady). The methylation of mercury by microorganisms is a detoxication response that allows the organism to dispose of heavy metal ions as small organometallic complexes. Conditions for methylation by sediment microorganisms are strict and occur only within a narrow pH range. The rate of synthesis of methyl mercury also depends on redox potential, composition of the microbial population, availability of Hg2+, and temperature. The best conversion rate for inorganic mercury to methyl mercury under ideal conditions is less than 1.5 percent per month (Casarett et al. 1986, ER ID 59093, p. 842).

The potential for bioaccumulation in terrestrial food chains is demonstrated by the uptake of mercury by the edible mushroom Pleurotus ostreatus, grown on compost containing mercury at concentrations of up to 0.2 mg/kg. The bioaccumulation factor was 65-140, indicating that there are risks to human health if these mushrooms are eaten. However, other data indicate that virtually no mercury is taken up from the soil into the shoots of plants such as peas, although mercury concentrations in the roots may be significantly elevated and reflect the mercury concentrations of the surrounding soil (ATSDR 1993, ER ID 56531).

Vanadium

Prediction of chemical valence states. Vanadium occurs in the +2 through +5 oxidation states (ATSDR 1992, ER ID 56531).

Affinity of vanadium for soil, water and air. The mobility of vanadium in soils is affected by the pH of the soil. Relative to other metals, vanadium is fairly mobile in neutral or alkaline soils, such as at 73-004(b). Similarly, under oxidizing unsaturated conditions some mobility is observed, but under reducing, saturated conditions vanadium is immobile (ATSDR 1992, ER ID 56531).

Potential for uptake. In the terrestrial environment bioconcentration is more commonly observed among the lower plant phyla than in the higher, seed-producing phyla. The vanadium levels in terrestrial plants are dependent upon the amount of water-soluble vanadium available in the soil, pH, and growing conditions. It has been found that the uptake of vanadium into the above-ground parts of many plants is low, although root concentrations have shown some correlation with levels in the soil. Certain legumes, such as Astralagus preussi, have been shown to be vanadium accumulators. Vanadium is believed to replace molybdenum as a specific catalyst in nitrogen fixation, and the root nodules of these plants may contain vanadium levels three times greater than those of the surrounding soil. Of the few plants known to actively accumulate vanadium, Amanita muscaria, a poisonous mushroom, has been demonstrated to contain levels up to 112 ppm (dry weight). Vanadium appears to be present in all terrestrial animals, but, in vertebrates, tissue concentrations are often so low that detection is difficult. The highest levels of vanadium in terrestrial mammals are generally found in the liver and skeletal tissues. No data are available regarding biomagnification of vanadium within the food chain, but human studies suggest that it is unlikely; most of the 1%-2% vanadium that appears to be absorbed by humans following ingestion is rapidly excreted in the urine with no evidence of long-term accumulation (ATSDR 1992, ER ID 56531).

Zinc

Prediction of chemical valence states. Zinc occurs in the environment primarily in the +2 oxidation state. It dissolves in acids to form hydrated Zn+2 cations and in strong bases to form zincate anions (probably Zn[OH] 4-2) (ATSDR 1994, ER ID 56531).

Affinity of zinc for soil, water and air. Zinc sorbs strongly onto soil particulates. Zinc can occur in both suspended and dissolved forms in surface water. Dissolved zinc may occur as the free (hydrated) zinc ion

or as dissolved complexes and compounds with varying degrees of stability. Suspended (undissolved) zinc may be dissolved following minor changes in water chemistry or may be sorbed to suspended matter (ATSDR 1994, ER ID 56531).

The mobility of zinc in soil depends on the solubility of the speciated forms of the element and on soil properties such as cation exchange capacity, pH, redox potential, and chemical species present in soil; under anaerobic conditions, zinc sulfide is the controlling species. Since zinc sulfide is insoluble, the mobility of zinc in anaerobic soil is low. In a study of the effect of pH on zinc solubility, it was showed that when the pH is <7, an inverse relationship exists between the pH and the amount of zinc in solution. As negative charges on soil surfaces increase with increasing pH, additional sites for zinc adsorption are activated and the amount of zinc in solution decreases. The active zinc species in the adsorbed state is the singly charged zinc hydroxide species (i.e., Zn[OH]+). The amount of zinc in solution generally increases when the pH is >7 in soils high in organic matter. This is probably a result of either the release of organically complexed zinc, reduced zinc adsorption at higher pH, or an increase in the concentration of chelating agents in soil. Consequently, movement towards groundwater is expected to be slow (ATSDR 1994, ER ID 56531).

Bioavailability. With respect to bioconcentration from soil by terrestrial plants, invertebrates, and mammals, BCFs of 0.4, 8, and 0.6, respectively, have been reported. The concentration of zinc in plants depends on the plant species, soil pH, and the composition of the soil. Plant species do not concentrate zinc above the levels present in soil (ATSDR 1994, ER ID 56531).

Organic Chemicals

Organic chemicals detected in the Phase I sampling at 73-004(b) are bis(2-ethylhexyl)phthalate, pesticides 4,4'- DDD, DDE, DDT, alpha and gamma chlordane, PAHs benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene.

Information on the fate and transport of organic chemicals in the soil presented here is from *Fate and Transport of Organic Chemicals in the Environment, A Practical Guide,* Second Edition, by Ronald E. Ney, Ph.D., Government Institutes, 1995, pp. 9-13, 18, and 19 (Ney 1995, ER ID 58210).

Chemical properties of organic chemicals, such as water solubility, adsorption coefficient, and vapor pressure, help determine the fate and transport of such chemicals. Water solubility is perhaps the most important chemical characteristic used to assess chemical mobility, stability or breakdown, accumulation, bioaccumulation and sorption. Soil sorption, chemical sorption, or bound chemicals in soil may be expressed as the extent that an organic chemical partitions between a solid phase and a liquid phase. This value is known as the adsorption coefficient (Koc). Volatilization of a chemical into the air is an important migration pathway. The vapor pressure of a chemical provides an indication of whether a chemical will volatilize into the air.

The higher the water solubility of a chemical, the more likely it is to be mobile and less likely it is to be accumulative, bioaccumulative, volatile, and persistent. A highly soluble chemical (greater than 1,000 ppm or mg/L), is prone to biodegradation and metabolism that may detoxify the parent chemical. The lower the water solubility of a chemical, (less than 10 ppm or mg/L), the more likely it is that it will be immobilized via adsorption, and thus less mobile, more accumulative or bioaccumulative, persistent in the environment, and slightly prone to biodegradation and may be metabolized in plants and animals. A chemical with a low vapor pressure, (less than 0.000001 torr) is less likely to volatilize into the air. A chemical with high vapor pressure (greater than 0.01 torr) is more likely to volatilize into the air.

Chemicals with a high Koc of greater than 10,000 will adsorb to soil organic carbon. Chemicals with a low Koc of 1,000 will not adsorb to soil organic carbon. A chemical with a low BCF, such as zero, indicates that no bioaccumulation and possible metabolism in animals. A chemical with a high BCF, such as 63,000, indicates that the chemical should bioaccumulate, cause food-chain contamination and should not be metabolized to any extent in animals (Ney 1995, ER ID 58210, p. 77). The table below presents readily available information on the COPCs. This information is based on research that has been done on the COPCs. Because there are different concerns for different chemicals, such as bioconcentration for DDT, research will tend to focus in those areas of concern. Therefore, not all information is available for each COPC, resulting in "NRA", not readily available, in parts of the table.

Chemical	Water Solubility[a] (mg/L)	Bioconcentration Factor	Vapor Pressure[a] (torr)	Koc
Benzoic Acid	2,900 (MT)[b]	NRA[c]	1 at 96°C (MT)	182 (MT)
Bis(2-ethylhexyl)phthalate[d]	0.6 (Ney)[e]	130 (Ney)[e]	2 x 10-7 (MT)	100,000(MT)
alpha & gamma Chlordane[f]	0.056 (Ney)[e]	3,140 (Ney)[e]	1.5 x 10-7 (MT)	1,000,000 (MT)
Diethylphthalate	1,000 (Ney)[e]	NRA	0.05 (Ney)[e]	69 (MT)
Di-n-butylphthalate	13 (MT)	NRA	1.4x10-5 (MT)	1,380 (MT)
4,4'- DDD	0.005 (Ney)[e]	63,830 (Ney)[e]	1.02 x 10-6 (MT)	977,000 (MT)
4,4'- DDE	0.01 (Ney)[e]	27,400 (Ney)[e]	6.49 x 10-6 (MT)	1,000,000 (MT)
4,4'- DDT	0.0017 (Ney)[e]	84,500 (Ney)[e]	1.9 x 10-7 (MT)	238,000 (Ney)[e]
HpCDD (heptachlorinated dibenzo-p-dioxins)	2.4×10^{-6} (ATSDR)	NRA	5.6×10^{-12} to 7.4x10-8 (ATSDR)	NRA
OCDD (octa-chlorinated dibenzo-p-dioxins)	0.4×10^{-9} (ATSDR)	NRA	8.25×10^{-13} (ATSDR)	NRA
Phenol	82,000-93,000 (Ney)[e]	NRA	0.02 (Ney)[e]	27 (Ney)[e]
Trichlorofluoromethane	1,100 (Ney)[e]	NRA	667.4 (Ney)[e]	NRA
Trichlorotrifluoroethane	136 (MT)	NRA	270 (MT)	400 (MT)
Toxaphene	0.4 (Ney)[e]	26,400 flowing water, 4,250 static water (Ney)[e]	1 x 10-6 (MT)	1500 (MT)
Polycyclic Aromatic Hydrocarbons				
Benz(a)anthracene	0.014 (Ney)[e]	NRA	5×10^{-9} (Ney)[e]	1,380,000 (MT)
Benzo(a)pyrene	0.0038 (Ney)[e]	NRA	5×10^{-9} (Ney)[e]	1,400,000 – 1,900,000 (MT)
Benzo(b)fluoranthene	0.012 (Ney)[e]	NRA	5×10^{-7} (Ney)[e]	550,000 (MT)
Benzo(k)fluoranthene	0.00055 (MT)	NRA	9.59 x 10-11 (MT)	4,370,000 (MT)
Benzo(g,h,i)perylene	0.00026	NRA	1.01 x 10-10	7,760,000 (MT)
Chrysene	0.002 (Ney)[e]	NRA	6.3×10^{-7} (Ney)[e]	245,000 (MT)
Fluoranthene	0.26 (Ney)[e]	NRA	6×10^{-6} (Ney)[e]	41,700 (MT)
Indeno(1,2,3-cd)pyrene	0.062 (MT)	NRA	1 x 10-10 (MT)	30,900,000 (MT)
2-Methylnaphthlene	25.4 (Ney)[e]	NRA	NRA	8,500 (Ney)[e]
Naphthalene	866 (Ney)[e]	NRA	NRA	1,300 (Ney)[e]
Phenanthrene	1.29 (Ney)[e]	NRA	6.8×10^{-4} (Ney)[e]	23,000 (Ney)[e]
Pyrene	0.135 (Ney)[e]	NRA	6.85×10^{-7} (Ney)[e]	63,400 (Ney)[e]

a. Temperature of 20°C

b. *Groundwater Chemicals Desk Reference* by John Montgomery and Linda Welkom, Lewis Publishers, Michigan, 1990.

c. NRA = not readily available

d. Di-2-ethylhexylphthalate was used as a surrogate for bis(2-ethylhexyl)phthalate.

e. *Fate and Transport of Organic Chemicals in the Environment, A Practical Guide,* Second Edition, by Ronald E. Ney, Ph.D., Government Institutes, 1995, pp. 46, 47, 59, 72, 77–79, 92, 93, 110, 129, 134, 143, 144, 151, 162, 164.

f. Information provided is for technical grade chlordane

Radionuclides

Certain radionuclides behave similarly in the environment due to their chemical properties. Radionuclides that may be present at the PRSs in the 73-2 SWMU group, cesium, americium, plutonium and uranium, can be grouped as light metals and actinides. The following information is summarized from *Radioecology: Nuclear Energy and the Environment*, Volume 1, F. Ward Whicker and Vincent Schultz, CRC Press, 1982, pp. 150–151 and 158–162 (Whicker and Schultz 1982, ER ID 58209).

Cesium-137 is a light metal. Cesium-137 has a half-life of about 30 years and is a beta and gamma emitter. Soils and sediments of high clay content can effectively immobilize cesium by chemical binding, thus acting like a sink for cesium-137. Sandy soils with a low cation exchange capacity allow for the cycling of cesium through the system for long periods of time. The physiological and ecological behavior of cesium-137 is similar to that of potassium, an essential nutrient. A scarcity of potassium in the environment will usually lead to an increase in cesium-137 accumulation in the biota.

Americium-241, plutonium-238, -239, and uranium-234, -235, -238 are all actinides. Americium-241 has a half-life of 432.7 years. Plutonium-238 and -239 have half-lives of 87.7 and 2.41×10^4 years, respectively. Uranium-234, -235, and -238 have half-lives of 2.46×10^5, 7.04×10^8, and 4.47×10^9 years, respectively. The main energy emission of these radionuclides is alpha radiation. In general, the actinide nuclides form comparatively insoluble compounds in the environment and are not considered biologically mobile. The actinides are transported in ecosystems mainly by physical and sometimes chemical processes. Uptake of actinides by plants from soil is generally considered to be low, based on plutonium. Plutonium in the environment undergoes hydrolysis and oxidation with PuO2 as a common form. Under most environmental conditions, plutonium occurs in forms that are comparatively insoluble and are poorly transferred across biological membranes. Movement of plutonium from soil and sediments to plants and animals is greatly inhibited by its insolubility and poor absorption at biological membranes.

Appendix E

Relevant Documents

APPENDIX E RELEVANT DOCUMENTS

All reference documents specific to this SAP can be found in this appendix. All other documents referenced in this SAP can be found in the ER Project Reference Library.

This appendix includes the following archival and technical documents referred to in this SAP.

56531 ATSDR (Agency for Toxic Substances and Disease Registry), 1990, 1992, 1993, 1994. ATSDR's Toxicological Profiles on CD-ROM. **(ATSDR 1990, 1992, 1993, and 1994, ER ID 56531)**

58033 The Merck Index, 1996. *The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals,* Twelfth Edition, Merck & Co., Whitehouse Station, New Jersey. **(Merck 1996, ER ID 58033)**

58203 Brady, N. C., 1974. *The Nature and Properties of Poison,* Eighth Edition, Macmillan Publishing Co., New York, New York. **(Brady 1974, ER ID 58203)**

58209 Whicker, F. W., and V. Schultz, 1982. *Radioecology: Nuclear Energy and the Environment,* Vol. 1., CRC Press, Boca Raton, Florida. **(Whicker and Schultz 1982, ER ID 58209)**

58210 Ney, R. E., 1995. *Fate and Transport of Organic Chemicals in the Environment,* Second Edition, Government Institutes, Rockville, Maryland. **(Ney 1995, ER ID 58210)**

58982 Shanley, P., January 21, 1988. ER Project Teleconference Notes. Memo to Kim Hill. **(Shanley 1998, ER ID 58982)**

59093 Casarett, L. J., J. Doulls, C.D. Klaassen, and M. O. Amdur, 1986. *Casarett and Doulls Toxicology, The Basic Science of Poisons,* Third Edition, Macmillan Publishing Company, New York, New York. **(Casarett et al. 1986, ER ID 59093)**

59377 Manahan, S. E., 1989. *Toxicological Chemistry, A Guide to Toxic Substances in Chemistry.* Lewis Publishers, Inc., Chelsea, Michigan. **(Manahan 1989, ER ID 59377)**

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ATSDR [Year], FR ID 56531

AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY
U.S. Public Health Service

ATSDR's

Toxicological Profiles on CD-ROM

User's Guide

CRC
LEWIS PUBLISHERS
Boca Raton New York London Tokyo

Library of Congress Cataloging-in-Publication Data
Cataloging-in-Publication data is available at the Library of Congress

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CRC Press, Inc.
2000 Corporate Blvd., N.W.
Boca Raton, FL 33431

If there are questions or problems regarding the operation of
ATSDR's Toxicological Profiles, call CRC Press, Inc. at
561-994-0555 extension 2375
e-mail address: jbrody@crcpress.com

ISBN 1-56670-154-6
© 1997 by CRC Press, Inc.
Printed in the United States of America 1 2 3 4 5 6 7 8 9 0
Printed on acid-free paper

ARSENIC

Prepared by:

Life Systems, Inc.

Under Subcontract to:

Clement International Corporation

Under Contract No. 205-88-0608

Prepared for:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service

Agency for Toxic Substances and Disease Registry

April 1993

CHROMIUM

Prepared by:

Syracuse Research Corporation

Under Subcontract to:

Clement International Corporation

Under Contract No. 205-88-0608

Prepared for:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service

Agency for Toxic Substances and Disease Registry

April 1993

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Prepared by:

Syracuse Research Corporation

Under Subcontract No. ATSDR-88-0608-02

Prepared for:

Agency for Toxic Substances and Disease Registry

U.S. Public Health Service

December 1990

LEAD

Prepared by:

Clement International Corporation

Under Contract No. 205-88-0608

Prepared by:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service

Agency for Toxic Substances and Disease Registry

April 1993

MERCURY

Prepared by:

Clement International Corporation

Under Contract No. 205-88-0608

Prepared for:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service

Agency for Toxic Substances and Disease Registry

April 1993

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Prepared by:

Clement International Corporation

Under Contract No. 205-88-0608

Prepared for:

Agency for Toxic Substances and Disease Registry

U.S. Public Health Service

July 1992

ZINC

(Update)

Prepared by:

Clement International Corporation

and

Syracuse Research Corporation

Under Contract No. 205-88-0608

Prepared for:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service

Agency for Toxic Substances and Disease Registry

May 1994

MERCK 1996
ER ID 58033

THE MERCK INDEX

AN ENCYCLOPEDIA OF
CHEMICALS, DRUGS, AND BIOLOGICALS

TWELFTH EDITION

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Published by
Merck Research Laboratories
Division of
MERCK & CO., INC.
Whitehouse Station, NJ

1996

MERCK & CO., INC.
Whitehouse Station, N.J.
U.S.A.

1st Edition—1889
2nd Edition—1896
3rd Edition—1907
4th Edition—1930
5th Edition—1940
6th Edition—1952
7th Edition—1960
8th Edition—1968
9th Edition—1976
10th Edition—1983
11th Edition—1989

Library of Congress Catalog
Card Number 89-60001
ISBN Number 0911910-12-3

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Printed in the U.S.A.

832. Arsenic. Grey arsenic; metallic arsenic; arsen (German). As; at. wt 74.9216; at. no. 33; valences 3, 5. Group VA(15) element, classified as a metalloid. Naturally occurring isotope (mass number): 75 (100%); known artificial, radioactive isotopes: 66-74; 76-87. Arsenic compds were described and used in antiquity, especially as poisons; their reduction to the element was known to medieval alchemists. Albertus Magnus credited with isolation of the element from the mineral orpiment in ~1250 A.D. First precise directions for the prepn of As found in Paracelsus' writings (*ca.* 1520). Arsenic probably occurs throughout the universe. Meteorites reported to contain from 0.0005 to 0.1% As. Occurrence in the earth's crust: 1.8 ppm. Found in nature to a small extent as the element; occurs mostly in minerals such as realgar (As_4S_4), orpiment (A_2S_3), arsenolite (As_2O_3). Commercial sources: as by-product in flue dusts from smelting copper, lead, cobalt and gold ores; by melting $FeAs_2$ or FeAsS ores. Prepn of pure As by reduction with carbon (sugar charcoal) and sublimation in N_2: Krepelka, *Coll. Czech. Chem. Commun.* **2**, 255 (1930); E. H. Archibald, *The Preparation of Pure Inorganic Substances* (Wiley, New York, 1932) p 269. Other methods: Schenk in *Handbook of Preparative Inorganic Chemistry* vol. 1, G. Brauer, Ed. (Academic Press, New York, 2nd ed., 1963) pp 591-593. *Reviews: Gmelin's, Arsenic* (8th ed.) **17**, 475 pp (1952); Smith, "Arsenic, Antimony and Bismuth" in *Comprehensive Inorganic Chemistry* vol. 2, J. C. Bailar, Jr. *et al.*, Eds. (Pergamon Press, Oxford, 1973) pp 547-683; *Chemistry of the Elements*, N. N. Greenwood, A. Earnshaw, Eds. (Pergamon Press, New York, 1984) pp 637-697; S. C. Carapella, Jr. in Kirk Othmer *Encyclopedia of Chemical Technology* vol. 3 (John Wiley & Sons, 4th ed., 1992) pp 624-633; G. O. Doak *et al.*, *ibid.* pp 633-659. Review of carcinogenicity studies: *IARC Monographs* **23**, 39-141 (1980); of toxicology and human exposure: *Toxicological Profile for Arsenic* (PB93-182376, 1993) 198 pp. Book: "The Chemistry of Organic Arsenic, Antimony and Bismuth Compounds," S. Patai, Ed. (John Wiley & Sons, New York, 1994) 962 pp.

Allotropic forms: α-form, metallic, steel-gray, shiny, brittle, rhombohedral crystal structure; β-form, dark gray, amorphous sold, d 4.700, transforms to metallic form at 280°. Can be heated to burn in air with bluish flame, giving off an odor of garlic and dense white fumes of As_2O_3. Stable in dry air; loses its luster on exposure to humid air as surface oxidizes, forming a black modification + As_2O_3. Brinell hardness: 147; Mohs' scale: 3.5. d_4^{25} 5.778. Sublimes$_{760}$ 615° without melting. mp 818° at 36 atm. Heat of vaporization 11.2 kcal/g-atom. Heat of sublimation 30.5 kcal/g-atom. Heat of fusion: 22.4 kcal/g-atom (*Gmelin's, loc. cit.* pp 135-136). Also reported as: heat of fusion: 6.620 kcal/g-atom; heat of sublimation 7.63 kcal/g-atom: D. R. Stull, G. C. Sinke, *Thermodynamic Properties of the Elements*, Advances in Chemistry Series **18** (A.C.S., Washington, 1956) pp 11, 44. Latent heat of fusion: 27,740 J/mol K. Latent heat of sublimation: 31,974 J/mol K (Carapella). Specific heat (25°) 24.6 J/mol K. Dielectric constant = 10.23 at 20° and 60 cycles. Electrical and magnetic properties of crystalline As: Taylor *et al.*, *J. Phys. Chem. Solids* **26**, 69 (1965). Insol in water. Not attacked by cold H_2SO_4 or HCl; converted by HNO_3 or hot H_2SO_4 into arsenous or arsenic acid.

A yellow modification which has no metallic properties has been reported from sudden cooling of As-vapor. This yellow arsenic is converted back to the gray modification upon very short exposure to ultraviolet light.

Note: In German and other languages *Arsenik* means arsenic trioxide.

Caution: Overexposure to arsenic and arsenic compounds has been associated with acute and chronic toxicity due to inhalation or ingestion. Organic forms are usually less harmful than inorganic forms. Direct contact can cause local irritation and dermatitis. Overexposure has been associated with an increased risk of skin, liver, bladder, kidney and lung cancer. *See Toxicological Profile, loc. cit.* This substance and certain arsenic compounds have been listed as known carcinogens: *Seventh Annual Report on Carcinogens* (PB95-109781, 1994) p 21.

USE: In metallurgy for hardening copper, lead, nonferrous alloys; automotive body solder. In semiconductor materials. In the manufacture of low-melting glass. As wood preservative, herbicide, pesticide.

~~BRA-74-001~~
BRADY 1974
ER ID
58203

THE NATURE AND PROPERTIES OF SOILS *8th Edition*

NYLE C. BRADY

Professor of Soil Science
New York State College of Agriculture and Life Science
Cornell University
and Director, International Rice Research Institute,
Philippines

MACMILLAN PUBLISHING CO., INC.
New York

COLLIER MACMILLAN PUBLISHERS
London

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PRINTED IN THE UNITED STATES OF AMERICA

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MACMILLAN PUBLISHING CO., INC.
866 Third Avenue, New York, New York 10022

COLLIER-MACMILLAN CANADA, LTD.

Library of Congress Cataloging in Publication Data

Brady, Nyle C
The nature and properties of soils.

Sixth-7th ed. by H. O. Buckman and N. C. Brady.
1. Soil science. I. Buckman, Harry Oliver, (date) The nature and properties of soils. II. Title.
S591.B79 1974 631.4 73-1046
ISBN 0-02-313350-3

Printing: 8 Year: 8

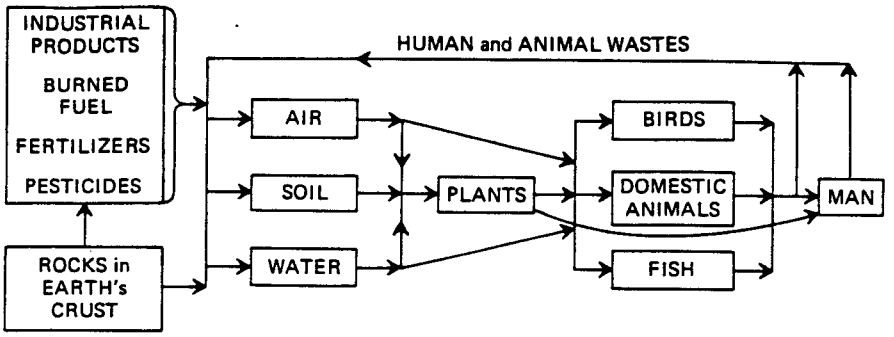

FIGURE 21:3. Sources of heavy metals and their cycling in the soil–water–air–organism ecosystem. It should be noted that the content of metals in tissue generally builds up as movement is made from left to right, indicating the vulnerability of man to heavy metal toxicity.

It is obvious that soils are only a part of the biological cycle relative to heavy metals and other inorganic toxin contamination. At the same time, soils are the ultimate depositories of large quantities of these compounds. Furthermore, the variety of chemical reactions which these elements undergo in soils controls to a considerable extent their rate of cycling if not their removal from the cycle altogether. A brief summary of these reactions follows.

21:6. Behavior of Inorganic Contaminants in Soils

There is considerable variation in the level of these elements present in soils and plants. This is borne out by the data in Table 21:6, which give the ranges commonly found. These relative concentrations are of particular significance as the behavior of each of these elements is considered.

Four of the heavy metals, zinc, copper, manganese, and nickel, have similar chemical characteristics and undergo similar reactions in soils, and so will be discussed as a group. Each of the other elements is sufficiently different in its properties to be given specific consideration.

ZINC, COPPER, MANGANESE, AND NICKEL. The reaction of these elements in soils is definitely affected by the pH, organic matter content, and the oxidation–reduction status of the soil. Ordinarily at pH values of 6.5 and above they tend to be only slowly available to plants, especially if they are present in their high-valent or oxidized forms. Consequently, most soils will tie up relatively large quantities of these elements if the soil pH is high and the drainage good.

The tendency of the cations of these elements to "chelate" in the presence of organic matter decidedly influences their behavior (see p. 493). The relative strength of chelation is generally copper > nickel > zinc > manganese.

TABLE 21:6. *Range of Concentration in Soils and Plants of Inorganic Elements which Sometimes Occur as Environmental Contaminants*[a]

Element	Common Range in Concentration (ppm)	
	Soils	Plants
Arsenic	0.1–40	0.1–5
Boron	2–100	30–75
Cadmium	0.1–7	0.2–0.8
Copper	2–100	4–15
Fluorine	30–300	2–20
Lead	2–200	0.1–10
Manganese	100–4,000	15–100
Nickel	10–1,000	1
Zinc	10–300	15–200

[a] From Allaway (2).

Since iron is more tightly adsorbed than any of them, its presence in a soluble form reduces the chelation tendency of all these elements. However, high pH and good drainage reduce the probability that soluble iron will be present in appreciable quantities.

CADMIUM. Only in recent years has this element been suspected of being toxic to human populations. About ten years ago it was reported that hypertension of laboratory animals was associated with prolonged low-level feeding of this element. There has been too little research accomplished since then to determine the soil and other factors influencing the content of cadmium in food. Likewise, there is little information available on cadmium reactions in soils. Because of its chemical similarity to zinc, however, it would be expected to behave in soils much the same as does zinc. Further research will be needed to determine how cadmium behaves in soils and how its concentration in plants might be controlled.

MERCURY. Research in Sweden and Japan as well as the United States has called attention to toxic levels of this element in certain species of fish. This situation stems from soil reactions whereby mercury is changed from insoluble inorganic forms not available to living organisms to organic forms that can be assimilated easily. Metallic mercury is first oxidized by the following chemical reaction in the sediment layer of lakes and streams:

$$Hg^0 \xrightarrow{[O]} Hg^{++}$$

The divalent mercury is then converted by microorganisms to methylmercury, which is water soluble and can be absorbed through the food chain by fish. The methylmercury can be changed to dimethylmercury through

biochemical reactions such as the following:

$$Hg^{++} \rightarrow \underset{\text{Methylmercury}}{CH_3Hg^+}$$

$$CH_3Hg^+ \rightarrow \underset{\text{Dimethylmercury}}{CH_3HgCH_3}$$

Apparently the reactions will take place in either aerobic or anaerobic conditions. The methylmercury concentrates as it moves up the food chain, accumulating in some fish to levels which may be toxic to man.

Inorganic mercury compounds added to soils react quickly with the organic matter and clay minerals to form insoluble compounds. In this form the mercury is quite unavailable to growing plants. However, it can be reduced to metallic mercury, which is subject to volatilization and movement elsewhere in the environment. Mercury is not readily absorbed from soil by plants unless it is in the methylmercury form.

LEAD. Interest in the soil as a source of lead for crop plants is heightened by the concern over airborne lead from automobile exhausts. The importance of this airborne source is verified by the concentrations of lead in plants and soils along heavily traversed highways (see Fig. 21:4). The airborne particles are moved far from the point of exhaust and are an important factor in determining the lead content of foods. Just how much lead is deposited directly on the leaf surface and how much is deposited on the soil and later taken up by the plants is not known. However, behavior of this element in soil would suggest that much of the lead in food crops comes from atmospheric contamination.

Soil lead is largely unavailable to plants, as evidenced by the small increases in lead content of plants following soil applications of the element. As with the other toxic metallic cations, lead is quite insoluble in soil, especially if the soil is not too acid. Most lead is found in the surface soil, indicating little if any downward movement. As might be expected, liming reduces the availability of the element and its uptake by plants.

ARSENIC. Reasonably heavy applications of arsenical pesticides over a period of years, especially to orchard soils, have resulted in the accumulation of soil arsenic, in a few cases to toxic levels. These toxicities have in turn led to both soil and plant studies of the reaction and uptake of arsenic. Such studies suggest that arsenic behaves in soils very much like phosphate. For this reason most of the applied arsenate is relatively unavailable for plant growth and uptake. Being present in an anionic form (for example, AsO_4^{3-}), arsenic is adsorbed by hydrous iron and aluminum oxides. This adsorbed arsenate is replaceable from these oxides by phosphate through the process of anion exchange. The similarity in properties between phosphates and arsenates is important to remember.

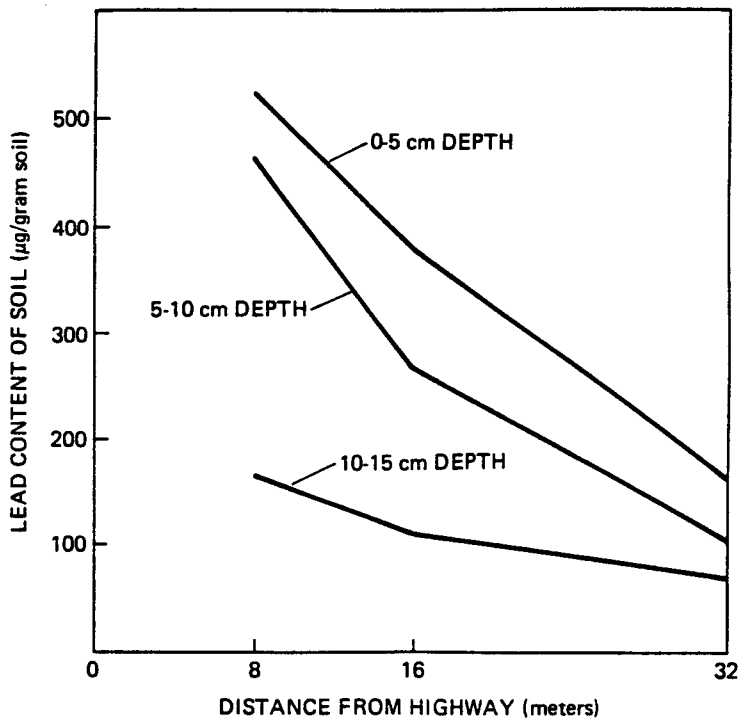

FIGURE 21:4. Lead content of soils at increasing distance from a heavily traveled highway near Beltsville, Maryland. Note that the lead is highest near the automobile traffic (source of lead) and tends to be concentrated in the upper depths. [*Adapted from Lagerwerff and Specht* (9).]

In spite of the capacity of most soils to tie up arsenates, long-term additions of arsenical sprays have in a few instances resulted in decided toxicities to some sensitive plants (see Fig. 21:5). Even though the arsenic level in the plant tissue grown on such soils generally is not toxic to animals, normal plant growth is limited by excess arsenic in the soils. The arsenic toxicity can be reduced by applying to the soil sulfates of zinc, iron, or aluminum. These probably form insoluble arsenate compounds similar to those that form with phosphates.

BORON. Soil contamination by boron can occur from irrigation water high in this element or by excess fertilizer application. The boron can be adsorbed by organic matter and clays but is still available to plants except at high soil pH. Boron is relatively soluble in soils, toxic quantities being leachable especially from acid sandy soils. Boron toxicity is usually considered a localized problem and is probably much less important than a deficiency of the element.

WHICKER + SCHULTZ
1982
ER ID 58209

Radioecology: Nuclear Energy and the Environment

Volume I

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ER ID
58209.1

CRC Press, Inc.
Boca Raton, Florida

Library of Congress Cataloging in Publication Data

Whicker, F. Ward.
Radioecology: nuclear energy and the environment.

Includes bibliographies and index.
1. Radioecology. I. Schultz, Vincent, joint author. II. Title.
QH543.5.W48 574.5'222 80-26184
ISBN 0-8493-5353-X (v.1)
ISBN 0-8493-5354-8 (v.2)

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Direct all inquiries to CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, Florida, 33431.

© 1982 by CRC Press, Inc.

International Standard Book Number 0-8493-5353-X (Volume I)
International Standard Book Number 0-8493-5354-8 (Volume II)

Library of Congress Card Number 80-26184
Printed in the United States

physiological behavior of K, Rb, and Cs is remarkably similar. In general, the physiological behavior of Rb and Cs can be inferred reasonably well from that of K, an essential nutrient. The potassium radioisotope of greatest general interest is ^{40}K. This primordial nuclide occurs naturally and has a half-life of 1.3×10^9 years. It is homogenously mixed with stable potassium and its isotopic abundance is about 0.0119% by mass. Owing to its ubiquitous distribution, abundance, and penetrating gamma rays, ^{40}K accounts for a significant fraction of the natural background radiation exposure. The isotopic difference between ^{40}K and stable K is so slight that behavior is essentially identical and the isotopic abundance is preserved in biotic and abiotic materials.

Rubidium has some 16 possible radioisotopes, most of which are short-lived and not particularly important. Rubidium-87, however, is a primordial, naturally occurring radionuclide with a half-life of about 4.8×10^{10} years. Also of some interest is 18.6 day ^{86}Rb, which is a potential fission and neutron activation product. This nuclide exhibits concentration factors averaging 1500 in freshwater plants, 250 in freshwater animals, and 15 in marine animals.[13] These values are quite similar to comparative data for ^{137}Cs as well as stable Cs and K.

Cesium-137 is one of the best-studied of all the radionuclides. It is a very abundant fission product, with a half-life of about 30 years. Its production in nuclear weapons detonations has resulted in wide distribution throughout the biosphere and its mobility and physiological properties have led to detectable concentrations in essentially all organisms. The fact that ^{137}Cs emits energetic photons makes it simple to measure and, also, a potentially significant contributor to genetic dose in humans and other species. Because of its abundance, half-life and biological mobility, ^{137}Cs is a critical component of nuclear fission wastes.

As with most other radionuclides, cesium can enter plants by aerial deposition or surface adsorption and root uptake, and animals by inhalation, ingestion, and surface absorption or adsorption. As already stated, Cs is a chemical analog of K and behaves similarly. However, it does not behave identically. In fact, in specific food chains, Cs concentrations tend to increase with trophic level and its ratio to K can increase likewise.[14,28] In numerous studies the observed ratio (Cs/K) consumer ÷ (Cs/K) food varies from one to four and averages about three. The apparent explanation for this phenomenon is that while Cs and K are both assimilated to approximately the same extent, Cs is retained in the body longer. In fact, the biological half-time of Cs exceeds that of K by a factor of two to five in humans,[28] and this trend probably also holds for most other animals as well. We are not certain to what extent the trophic level effect is unique to Cs. This phenomenon has not been generally observed with other radionuclides. On the other hand, the trophic level effect has been observed for the pesticide DDT[29] and continuing research may well uncover other substances which concentrate with trophic level.

An important concept with regard to radionuclides such as ^{137}Cs, which are chemically analogous to major nutrient elements, is that the tendency for the radionuclide to accumulate in the biota is reduced if there is an abundance of the analogous element in the environment. Conversely, a scarcity of the analogous element usually leads to increased accumulation of the radionuclide in the biota. This pattern was illustrated for Sr and Ca (Figure 7) and a similar effect has also been shown for ^{137}Cs concentrations in fish from lakes in Finland which have a range of K concentrations in water.[15] This concept also applies to terrestrial ecosystems. For instance, increases in K intake in animals has been shown to reduce retention of Cs, which could effectively reduce the Cs body burden.[30,31] A comprehensive review of cesium and its relationships to potassium in ecosystems was prepared by Davis.[32]

As pointed out earlier in this chapter, the long-term availability of cesium and many other radionuclides depends heavily upon ecosystem characteristics, and in particular,

soil properties. Soils and sediments of high clay content can effectively immobilize Cs by chemical binding. In such systems, the soil acts like a sink for Cs and in time very little of the nuclide is available for biological incorporation. Other systems have sandy soils with a low cation exchange capacity and larger quantities of Cs can be recycled through the biota of such systems for long periods of time.

2. Group IIA (Ca, Sr, Ba, Ra)

This group, termed the "alkaline earth metals", contains elements which have two valence electrons and an oxidation state of plus 2. These elements are chemically reactive and seldom occur in the free state. They commonly form salts such as carbonates, sulfates, and chlorides. Calcium is by far the most abundant of the alkaline earths in the biosphere and is an essential biological nutrient. The ecological and physiological behavior of Sr, Ba, and Ra can be inferred approximately from the behavior of calcium. Our principal interest in calcium, from the standpoint of radioecology, is the fact that its flow through ecological systems markedly affects important radionuclides such as ^{90}Sr, ^{140}Ba, and ^{226}Ra. The most important radioisotope of calcium, ^{45}Ca, is seldom produced by man or nature in sufficient quantities to be considered a biological hazard; rather, it is of greater interest as a tracer to study the behavior of Ca. A specific review of some of the radioecological aspects of calcium is available.[33]

The strontium radioisotopes ^{89}Sr and ^{90}Sr received great notoriety and study during the era of atmospheric nuclear testing in the 1950s and early 1960s. Strontium-90, like ^{137}Cs, is produced in high yields from nuclear fission and is persistent in the biosphere because of its 28-year half-life. Strontium has a tendency to form compounds that are comparatively soluble. Because of this and its chemical similarity to calcium, Sr isotopes are comparatively mobile in ecosystems and deposit in calcium-bearing tissues such as bone and shells, where they can remain for years. The beta particles of ^{90}Sr, and its radioactive daughter ^{90}Y, irradiate portions of the bone marrow, the site of blood cell formation, and thus are considered potential internal hazards.

Owing to its metabolic control by calcium, Sr uptake by organisms has often been expressed as an "observed ratio",[34] which is defined as the Sr/Ca ratio in an organism divided by the Sr/Ca ratio in the diet (or soil in the case of plant uptake). Observed ratios for soil to plants are usually close to unity, suggesting little discrimination between Sr and Ca by plants.[35] On the other hand, observed ratios describing food to animal tissue transfers are usually less than unity, indicating discrimination against Sr in favor of Ca.[35] Many studies have demonstrated that factors such as soil composition, diet, and age can substantially modify observed ratios. Therefore, the observed ratio is not a predictive panacea. Observed ratios describing Sr/Ca transport from water to fish muscle and bone also suggest discrimination against Sr.[36] Nevertheless, concentration factors for Sr in aquatic organisms can be very high.[13] In summary, strontium isotopes in the environment readily enter food chains, but tissue concentrations do not appear to increase with trophic level. High available calcium budgets in ecosystems tend to reduce the bioaccumulation of strontium.

The general behavior of isotopes of barium is not unlike that of strontium. Of several barium radioisotopes, ^{140}Ba is the most important.[37] A high-yield fission product, ^{140}Ba has a half-life of 12.8 days and emits both beta and gamma radiation. Because of the comparatively short life of ^{140}Ba, it will enter food chains primarily by the more direct pathways, such as foliar deposition and inhalation. Also because of its short half-life, ^{140}Ba generally does not build up in the calcium-bearing tissues to the same extent as, say, ^{90}Sr. If deposited in bone, ^{140}Ba will likely be removed mainly by radioactive decay rather than by excretion. In summary, ^{140}Ba is biologically mobile, but important for only a limited time following its entry into the environment.

Isotopes of radium constitute the most important naturally occurring radionuclides

^{144}Pr pair emits a mixture of beta particles and gamma rays, but the 3 MeV beta of ^{144}Pr is the dominant contributor to dose from internally deposited ^{144}Ce. Despite the generally low solubility and mobility of ^{144}Ce, the nuclide has been found in fish tissues following U.S. nuclear testing in the Pacific,[64] and in mule deer livers from worldwide fallout.[44] In the latter case, 71% of the estimated dose to deer liver resulting from several fallout radionuclides, was contributed by ^{144}Ce-^{144}Pr. In view of the very low assimilation expected for ^{144}Ce, the only reasonable explanation for significant liver burdens would be chronic ingestion for a long period, coupled with tenaceous retention by the organ. In aquatic ecosystems, ^{144}Ce concentration factors range from 1 to 10^4, with somewhat higher values for plants than animals and generally higher values for freshwater than marine biota.[13]

Promethium has 10 radioisotopes, but no stable isotopes. The isotope ^{147}Pm is a comparatively high-yield fission product which contributes a significant fraction of the total beta activity 2 to 10 years post-fission. Its peak relative abundance occurs 5 years after fission. Since ^{147}Pm is essentially a pure beta emitter, it does not contribute significantly to external exposure from fallout fields and is mainly of interest as an internal emitter. Its detection and measurement normally requires chemical separation, therefore it has not received as much study as some of the other rare earths. Like most of the other rare earths, the fraction of ingested ^{147}Pm assimilated is $<10^{-4}$, and 80% of the body burden is likely to be found in bone, with about 6% in the liver and 2% in the kidney.[6] Mean concentration factors of roughly 4000 and 700 have been reported for freshwater plants and animals, respectively.[13]

F. Actinides (Th, U, Pu)

The actinide elements include number 89 (actinium) and higher numbered elements. Included are the naturally occurring elements Ac, Th, Pa, and U, as well as the transuranium elements, which are largely produced by artificial neutron bombardment of natural uranium. All actinide elements can exist in the (III) oxidation state, but this state is most stable only for Ac, Am, and higher-numbered elements.[66] The (IV) oxidation state is most stable for Th, Np, and Pu, while the (VI) state is most stable for U. Elements 91 through 95 can exist in several oxidation states, complicating their chemistry. The actinides are chemically similar to the rare earths in a number of ways which can make their separation difficult. Like the rare earths, electrons can be added to a subshell of actinides, in this case the 5f subshell.

A very important feature of the actinides is that they are all radioactive, yet half-lives of the actinide nuclides vary widely. It is noteworthy that isotopes of all actinides can arise from the decay or neutron capture of primordial uranium. Certain isotopes of Ac, Th, Pa, and U arise in the decay chains of long-lived, primordial ^{235}U, ^{238}U, and ^{232}Th. Although some of the less massive transuranium nuclides, such as ^{239}Np and ^{239}Pu, are formed naturally in small quantities through neutron capture of ^{238}U, the overwhelming production of transuranics is the result of man's activities. Elements heavier than uranium arise principally through neutron capture and through beta decay, which effectively adds a proton to the nucleus. The high neutron fluxes associated with nuclear reactors and nuclear detonations can lead to successive neutron captures by heavy nuclei, leading to yet heavier, neutron-rich nuclides. Greater stability of such neutron-rich nuclides is frequently achieved through beta decay and the formation of a new element of higher atomic number. Prior to 1940, the transuranium elements were unknown. Early investigations were conducted with microgram quantities of these elements, and nowadays very large quantities are produced by the nuclear industry.

Many of the actinide nuclides emit alpha particles, which increases their potential hazard as internal emitters. In addition to presenting potential radiation hazards, sev-

eral of the longer-lived actinides such as ^{232}Th, ^{238}U, and ^{237}Np can occur in sufficient mass quantities to be chemically toxic. Beta particle and photon emissions are also common among the actinides and a few nuclides, such as ^{242}Cm and ^{244}Cm, undergo spontaneous fission, which leads to emission of neutrons.

In general, the actinide nuclides form comparatively insoluble compounds in the environment and are therefore not considered biologically mobile. Furthermore, their interaction with biological systems is largely passive, and the heavier actinides, at least, have no known essential biological function. The actinides are transported in ecosystems mainly by physical and sometimes chemical processes. They tend to attach, sometimes strongly, to surfaces; and they tend to accumulate in soils and sediments which ultimately serve as storage reservoirs. Subsequent movement is largely associated with geological processes such as erosion and sometimes leaching. Organisms can effect actinide movement to a minor extent, usually through their own movements which cause rearrangement of abiotic materials.

Organisms are exposed to the actinides largely through surface contact, inhalation, and ingestion. Ordinarily, very little of these substances passes biological membranes to lodge internally, unless inhalation is the route of exposure. Uptake of the actinides by terrestrial plants from soil is generally considered to be low, especially if one considers plutonium, the element for which most data exist. Plant/soil concentration ratios for true uptake of Pu generally run of the order of 10^{-4} or less, especially for the oxide and hydroxide forms which usually occur in the environment.[67] There is scattered evidence, however, that a somewhat higher plant/soil concentration ratios exist for U and Am.[67,68] There is considerable variation in plant uptake of actinides, according to the specific element, soil characteristics, and plant species. Uranium is apparently taken up to a greater extent than thorium and some plant species accumulate uranium to the extent that they may serve as bioindicators of uranium ore deposits.[40] In field situations, actinides associated with vegetation are frequently attached to the surfaces to a much greater extent than they are biologically incorporated.

In the case of terrestrial animals, the actinides are taken in mainly through ingestion and inhalation, the latter pathway generally being regarded as the more important of the two. This is generally true for recent environmental deposits which can be readily resuspended in the airstream. As deposits age and weather into the soil, however, the ingestion pathway may become relatively more significant. For submicron particles, the fraction of inhaled actinides which enters the blood exceeds the fraction of ingested material which enters the blood. Furthermore, submicron, insoluble radioactive particles may reside in the deep lung for considerable periods of time. Larger particles are usually swallowed following inhalation and thus enter the gastrointestinal tract where they encounter the same physiological environment as ingested material. Assimilation of all actinide elements from the gastrointestinal tract is assumed to be less than 0.01%.[6] In addition, the actinides deposit within the body in similar fashion and based on animal experiments, some 80% or more of the total body burden is expected to be found in bone, with 1 to 10% in both the kidney and liver.[6] Retention of all the actinides except uranium is normally long, with whole body biological half-times of 10^4 days or greater assumed for predictive purposes. Uranium is excreted somewhat more rapidly from the body, as indicated by a biological half-time of the order of 10^2 days. Under conditions of continuous ingestion of most actinides, bone or the gastrointestinal tract are usually considered critical organs for dosimetry purposes. For inhalation of small, insoluble particles, the lung is usually the critical organ.

In aquatic systems, the actinides are readily adsorbed on the surfaces of plants and small animals such as zooplankton, and thus they enter the food chain. However, concentration factors generally decline substantially with trophic level and in the internal as compared to external tissues by virtue of membrane discrimination. Concentra-

tion factors for Th, U, Pu, Am, and Cm have been reported, but most data are for ^{239}Pu. Noshkin[69] summarized published ^{239}Pu concentration factors for marine environments, and most values for invertebrates and algae were in the range of 10^2 to 10^4. Concentration factors for vertebrate tissues ranged from 1 to 10^3. Concentration factors for other actinides can generally be expected to fall into these ranges.

Because of their high natural abundance in certain localities and ubiquitous presence in the biosphere, Th and U deserve some additional discussion. So does plutonium, because it has been studied to a far greater extent than the other transuranics. In terms of total quantities of transuranic radioactivity generated by the nuclear industry, several radionuclides, including ^{239}Np, ^{241}Pu, ^{241}Am, and ^{242}Cm are considerably more abundant than the well-studied fissile nuclide ^{239}Pu.[70] However, the environmental behavior of these nuclides is not well studied, but some general inferences to them can be made, with caution, from data on ^{239}Pu.

Thorium occurs ubiquitously throughout the lithosphere and is found at an average concentration of about 10 ppm in crustal material.[66] Its geographic distribution, however, shows many "hot spots", the more notable of which occur in Brazil and India.[41] Such hot spots are usually characterized by monazite-bearing sands, or certain types of volcanic intrusives. Thorium has a potential role in the nuclear fuel cycle because neutron capture by primordial ^{232}Th produces ^{233}Th, which decays through ^{233}Pa to form fissile ^{233}U. In addition, thorium has certain industrial uses, such as in the manufacture of incandescent gas mantles and welding rods. Of the 13 isotopes of Th, three are very long-lived with half-lives >>1000 years. The isotopes of predominant importance are ^{232}Th and ^{228}Th of the natural thorium series, and ^{234}Th and ^{230}Th, which are decay products in the natural uranium series (see Table 2 Chapter 4).

Mobility of Th in biological systems is extremely low. Plant uptake of the element is essentially negligible,[40,68] as is its absorption by animals, and there is apparently no evidence for measurable quantities of ^{232}Th in foods or in marine biota.[71,72] However, there is evidence for small quantities of ^{228}Th in plant and animal tissues.[72,73] This nuclide probably is generated within biological tissues by the decay of ^{228}Ra, which is taken up by plants and animals to a far greater extent than thorium. This may be of some significance because Th is retained tenaceously by bone and the carcinogenic effects of ^{228}Th at higher levels appear to be substantially greater than ^{226}Ra, and perhaps even greater than ^{239}Pu.[74]

Uranium is undoubtedly the most significant element of the nuclear era. It is the raw material from which is generated, either through fission or neutron activation, the majority of radionuclides discussed in this book. Natural uranium is present in the earth's crust at an average concentration of roughly 4 ppm and high grade ores in the Belgian Congo and Canada contain up to 1 to 4% U_3O_8.[66] Medium grade ores, ranging from 0.05 to 1% U_3O_8 occur more frequently in the U.S. and elsewhere. Natural uranium is 99.27% ^{238}U, which is fertile and 0.72% ^{235}U, which is fissile and therefore a primary fuel for nuclear reactors. Because of the long (4.5×10^9 year) half-life of ^{238}U, it is of low specific activity. Because of this, and its generally low biological mobility in ecological systems, it has received less attention from a radioecological point of view than it probably deserves.

Although of generally "low" biological mobility, uranium is taken up by plants to a considerably higher degree than thorium. In particular, certain perennial plants concentrate U in excess of 100 ppm, with plant/soil concentration ratios ranging from 10^{-4} to values in excess of 10^{-1}, and considerable effort has been spent investigating the use of certain species in prospecting for uranium.[75-77] The availability of U in soil apparently varies over a wide range according to soil chemistry and this undoubtedly contributes to high variability in plant uptake. There is some evidence that uranium stimulates plant growth at low concentrations, that it becomes toxic at slightly higher

levels, and that certain species appear to be associated with soils containing uranium, selenium, and sulfur.[75] Through a comprehensive series of studies in both aquatic and terrestrial ecosystems, Kovalsky and co-workers found that uranium occurs in detectable concentrations in a variety of biota, but concentrations generally diminish with trophic level.[78] Uranium is present in the human diet to the extent that some 1 to 2 μg/day may be ingested per person.[39] In some localities, where spring waters contain elevated levels of U, 10 to 300 μg/day can be ingested by people.[39] Concentration factors ranging from 10 to 400 have been reported for U in marine biota.[13] Natural uranium is chemically toxic because of its low specific activity, and it is frequently difficult to distinguish radiation and chemical effects from the element.

Some 14 isotopes of plutonium have been documented, but most interest has centered around fissile ^{239}Pu, with secondary attention focused upon ^{238}Pu and ^{241}Pu. Because ^{239}Pu is a long-lived, bone-seeking alpha emitter of comparatively high radiotoxicity, and because of its potential importance as a nuclear fuel for reactors as well as a component of nuclear weapons, it has generated much respect, and from the public, much fear. It has been labeled as "one of the most toxic substances known to man". This has led to widespread adoption of the phrase, "the most toxic substance known to man", and frequent hysteria in connection with the politics of nuclear power and national defense. In actuality, while ^{239}Pu is comparatively hazardous under certain circumstances, it is no more toxic than naturally occurring ^{228}Th,[74] and probably far less toxic than arsenic, or certain biological toxins.[79] Despite much general misunderstanding of plutonium, "perhaps no single element has ever been so intensively studied,"[80] and consequently, a great deal is known about its physics, chemistry,[81] and biology.[82] The ecology of plutonium has also been investigated rather intensively, particularly within the last decade,[67] and a number of recent reviews on the subject are available.[69,83-87]

A fundamental reason for the attractiveness of ^{239}Pu as a nuclear fuel is that it can be chemically separated from its precursor, ^{238}U, in rather pure form. In contrast, the other fissile isotopes, ^{233}U and ^{235}U, require much more effort to separate from ^{238}U and to obtain in sufficent purity to serve as a reactor fuel or weapon component. Although plutonium can be chemically isolated from other elements, its chemistry is extremely complex. This complexity is due in large measure to the ability of Pu to exist in four oxidation states (III, IV, V, and VI), frequently simultaneously, in appreciable concentrations in aqueous systems.[81] It also occurs in six allotropic forms as a metal. In general, plutonium in the environment can be expected to undergo hydrolysis and oxidation, with PuO_2 a more common form. However, Pu can form complexes with a variety of organic and inorganic compounds.[88,89] When complexed with chelating agents, such as with DTPA for example, plutonium solubility in soil, uptake by plants, and general biological mobility is significantly increased.[88,90] Under most environmental conditions,however, plutonium occurs in forms which are comparatively insoluble and which are poorly transferred across biological membranes.

As a result of nuclear weapons testing, some 0.3 to 0.5 million curies of plutonium have been introduced into the biosphere.[82] This has resulted in very low levels of Pu, ubiquitously distributed in the environment. Additionally, accidents, inadvertent releases, and experiments have caused higher level Pu contamination in local areas. Examples include U.S. Air Force bomber accidents in Spain and Greenland, atmospheric reentry of a ^{238}Pu-powered satellite, releases at Rocky Flats, Oak Ridge, Hanford, and Mound Laboratory, and experiments at the Nevada Test Site.[91] Cleanup operations were instituted at several sites having the higher levels of Pu contamination. Residual contamination in undisturbed sites has provided opportunity to study the ecological behavior of plutonium in several kinds of environments.

In terrestrial ecosystems, well over 90%, and usually over 99% of the plutonium is found in the soil.[92] The remainder is distributed among the litter and biotic components of the ecosystem. An exception to this trend may be noted immediately following a contamination event, when a large fraction may be associated with vegetation. Distribution of Pu in aquatic systems is normally comparable, with sediments rapidly becoming the dominant reservoir of the material. Movement of Pu from soil and sediments to plants and animals is greatly inhibited by its insolubility and strong discrimination at biological membranes. As a rule of thumb, 10^{-4} is a reasonable discrimination factor for Pu to be applied at each step in the soil-plant-animal mineral chain. Concentrations of Pu in plants are normally of the order of 10^{-6} to 10^{-3} the concentrations in the soil in which they grow, when aerial deposition does not contribute to the plant activity.[90] Resuspension of soil particles and subsequent deposition on foliage surfaces can result in much higher plant/soil concentration ratios, up to 10^{-1} in some cases. Normally, less than 10^{-4} of the plutonium ingested by consumers is absorbed from the intestinal tract.[82] If inhaled, however, a somewhat larger fraction of the Pu can enter the body. For instance, some 5% of a pulmonary deposit can be absorbed into the blood stream and 15% can enter the lymphatic system.[93]

Plutonium deposits in the body are retained tenaceously.[93] For instance, pulmonary and lymph node deposits are cleared with half-times of the order of 500 and 1000 days, respectively. Skeletal deposit retention half-times increase with body weight, and range from roughly 1 year in small mammals to over 100 years in humans. The distribution of plutonium in biological tissues tends to be nonuniform, and "hot spots" are commonly observed. This complicates the dosimetry and has led to considerable controversy regarding the biological consequences of internal deposits.[94]

It is important to be aware of the fact that a tremendous amount of research has been conducted on the biological effects of internally deposited plutonium, and more is known about the biomedical aspects of this element than most other hazardous materials. An excellent review on this is available.[82] From an ecological viewpoint, the isotopes of plutonium do not appear to be as hazardous as some of the more biologically mobile radionuclides such as ^{137}Cs or ^{90}Sr. Based upon substantial research efforts, no specific physical injury to plants, animals, or man has been shown to be caused by plutonium, even though such exposures have occurred.

G. Summary: General Properties of Selected Radionuclides

A general idea of the ecological behavior of specific radionuclides can be obtained through tabulation of various attributes. Such attributes include general chemistry, half-life, distribution in ecosystems and organisms, modes of exposure to organisms, and absorption and retention by organisms. Table 2 represents an attempt at such a tabulation. Because of the wide variations in the quantification of such attributes, qualitative or semiquantitative descriptions are used, with the intent of giving generalized expectations for selected radionuclides. The literature should be consulted for more specific data which are to be applied to specific cases.

Much lumping and oversimplification are necessary for any generalized discussion of radionuclide behavior. For example, ecological transport is usually difficult to describe in terms that apply to all steps in a food chain, which apply to aquatic as well as terrestrial ecosystems, or which cover all chemical forms of the radionuclide in question. With such caveats in mind, we can proceed. In Table 2, important exposure modes or processes are described for animals and plants, both terrestrial and aquatic, with the kinds of organisms being implied by the name of the process. The categories describing degree of food chain transport and successive trophic level concentration are particularly subject to variations between specific trophic levels and between

NEY 1995
ER ID 58210

FATE *and* TRANSPORT *of* ORGANIC CHEMICALS *in the* ENVIRONMENT

A Practical Guide

Second Edition

(Formerly *Where Did That Chemical Go?*)

ERID 58210.1

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99 98 97 96 95 5 4 3 2 1

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Chapters 1–5 of this book were originally published as *Where Did That Chemical Go?* (New York: Van Nostrand Reinhold, 1990)

Printed in the United States of America

Library of Congress Cataloging-in-Publication Data

Fate and transport of organic chemicals in the environment: a practical guide/ Ronald E. Ney. – 2nd ed.
p. cm.
Rev. ed. of: Where did that chemical go? c1990.
Includes index.
1. Organic compounds--Environmental aspects. 2. Pollution--Risk assessment. I. Ney, Ronald E. 1936- Where did that chemical go? II. Title
TD196.073N49 1995
628.5' 2--dc20 95-31004
CIP

ISBN: 0-86587-470-0

Chapter 2
Physical and Chemical Processes

WATER SOLUBILITY

Water solubility is perhaps the most important chemical characteristic, used to assess (1) chemical mobility, (2) chemical stability or breakdown, (3) chemical accumulation, (4) chemical bioaccumulation, and (5) chemical sorption in any environmental compartment. Water solubility should be one of the easiest chemical test methods; however, if you were to look up the solubility of DDT, you would find a long list of solubilities. Luckily those values are presented in a range that enables one to make some kind of assessment or prediction; and that is the purpose of our discussions.

What can water solubility be used for? Remember these key points:

1. The higher the water solubility of a chemical, the more likely it is to be mobile, and the less likely it is to be accumulative, bioaccumulative, volatile, and persistent; and a highly soluble chemical is prone to biodegradation and metabolism that may detoxify the parent chemical.
2. The lower the water solubility of a chemical, the more likely it is that it will be immobilized via adsorption, and thus it is less mobile, more accumulative or bioaccumulative, persistent in environmental compartments, and slightly prone to biodegradation, and it may be metabolized in plants and animals.
3. The in-between range of high and low water solubilities indicates chemicals whose behavior could go either way, as discussed in 1 and 2 above.

The above generalities are meaningless unless we have values or ranges on which to base predictions. Thus, to discern the fate of chemi-

cals by water solubilities, let us assign the following numerical values, presented by Ney [3]:

1. Low solubility: less than 10 ppm (<10 ppm).
2. Medium solubility: between 10 and 1 ,000 ppm.
3. High solubility: greater than 1,000 ppm (>1,000 ppm).

Table 2-1 may be used to link the environmental fate of chemicals to their water solubility (WS).

The relationships are not clear-cut, as the water solubility of a chemical can also affect other degradative or transformation process, such as hydrolysis, photolysis, and/or biodegradation. Water solubility can be used to predict sorption or desorption with soil organic matter/organic carbon, mobility/leaching, and bioaccumulation in animals by means of lipo-solubility prediction. These aspects of its use will be discussed in other chapters.

Proven, validated test methods should be used to measure the water solubility of a chemical. If at all possible, a radiolabeled parent chemical should be used. The use of a radiolabeled chemical will enable the researcher to discern whether sorption to equipment, phototransformation (easily prevented), or dissociation has occurred, and, most important, to validate chemical stability, solubility, and analytical methodology. A radiolabeled chemical should be used to validate most studies.

In the environment there would be many effects on chemical solubility, such as the effects of temperature, the concentration of chemicals, sorption, and so on.

Table 2-1. Water Solubility (WS)

ENVIRONMENTAL COMPARTMENTS	LOW < 10PPM	MEDIUM 10-1,000PPM	HIGH > 1,000PPM
Mobility	n *	either way	yes
Adsorption	yes	either way	n
Biodegradation	maybe	either way	yes
Metabolism	maybe	either way	yes
Accumulation	yes	either way	n
Bioaccumulation	yes	either way	n
Persistence	yes	either way	n
Dissipation	n to slowly	either way	yes
Food-chain contamination	yes	either way	n

* n denotes negligible.

If no data on solubility exist, then one could predict solubility by using chemical structure methodology, an advanced predictive technique for chemists. I have found the best illustrations in the *Handbook of Chemical Property Estimation Methods* by Warren J. Lyman, William F. Reehl, and David H. Rosenblatt, published by the McGraw-Hill Book Company, a source that will be cited frequently in this book [2]. Kenaga [1] also has reported on mathematical equations used to calculate solubility.

Lyman et al. [2] reported dichloro diphenyl trichloroethane (DDT) to have a measured solubility of 1.2 μg/L or 1.7 μg/L, indicating a large range for error (200%). Lyman et al. [2] also reported a water solubility, using the chemical structure of DDT, of 3.89 μg/L. Other sources report that DDT is almost insoluble. For the purpose of this discussion, let us use the solubilities of 1.2 μg/L and 3.89 μg/L to predict what may happen in the environment. To do this, we will convert μg/L to ppm, for use with Table 2-1. The following example will help you to understand how to convert μg/L (ppb) to mg/L (ppm) (in this case, 1.2 μg/L):

ppm = mg/L (parts per million = milligrams per liter)
ppb = μg/L (parts per billion = micrograms per liter)
μg/L = one millionth of a gram per liter
mg/L = one thousandth of a gram per liter

$$\frac{1{,}000 \text{ mg/L}}{1{,}000{,}000 \ \mu\text{g/L}} \times 1.2 \ \mu\text{g/L} =$$

$$\frac{0.001 \text{ mg/L} \times 1.2 \ \mu\text{g/L}}{\mu\text{g/L}} = 0.0012 \text{ mg/L (ppm)}$$

DDT has a water solubility in the range of 0.0012 ppm to 0.00389 ppm; thus, it falls at the level of <10 ppm (see Table 2-1).

With this one piece of data, we can say that DDT will persist in any environmental compartment, accumulate in soil, bioaccumulate in plants and animals, and bioconcentrate in the food-chain. The same data can be used in other predictive methods, which will be discussed in following chapters.

If the solubility of a chemical were 1,000 ppm, then predictions about its fate could be based on Table 2-1. If it were in the range of 10 to 1,000 ppm, problems could arise, and additional data might be needed to predict its fate in environmental compartments. The use of other predictive methods will be discussed in following chapters.

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OCTANOL WATER

The octanol water partition coefficient (Kow), or partition coefficient (P), is an indicator of the bioaccumulation or bioconcentration potential of a chemical in the fatty tissue of living organisms. The Kow or P value (which has no units) is an indicator of water solubility, mobility, sorption, and bioaccumulation. The symbols Kow and P are used interchangeably, but this book will use only Kow.

The Kow represents a mathematical equation expressing the ratio of the equilibrium concentrations of a chemical in octanol and water phases; that is, it is the ratio of the concentration of a chemical in octanol to the concentration of that chemical in water at equilibrium. Simply put, it is the ratio of an organic chemical's distribution between octanol and water phases:

$$\text{Kow} = \frac{\text{concentration of organic chemical in octanol phase}}{\text{concentration of organic chemical in water phase}}$$

The use of the Kow depends on its size:

1. The higher the Kow is, the greater the affinity of the chemical to bioaccumulate/bioconcentrate in the food chain, the greater its potential for sorption in soil, and the lower its mobility. This also means lower solubility in water. Do not confuse water solubility with Kow, as the ratio does not express water solubility, and there are no units of measure, just a number.

2. The lower the Kow is the less the chemical's affinity to bioaccumulate, the greater its potential for mobility, the greater its solubility, and the greater its potential to biodegrade and to be metabolized by plants and animals.

Here also we need numbers for assessment of chemical fate; thus, I have made the following numerical assignments [3]:

1. A Kow of less than 500 (<500) would be indicative of high water solubility, mobility, little to no bioaccumulation or accumulation, and degradability by microbes, plants, and animals.
2. A high Kow, greater than 1,000 (>1,000), is indicative of low water solubility, immobility, nonbiodegradability, and a chemical that is bioaccumulative, accumulative, persistent, and sorbed in soil.
3. A midrange Kow, 500 to 1,000, indicates that the chemical can go the way of either low or high Kow.

Table 2-2 show how to predict the environmental fate of chemicals by using the Kow.

There are many ways to obtain a Kow, by either laboratory test or mathematical equations. Proven and validated test methods should be chosen. If at all possible, a radiolabeled parent chemical should be used; the reasons for doing so were discussed in the section on water solubility.

If no data exist, chemical structure can be used to predict the Kow, [2]. Lyman et al. [2] and Kenaga [1] have reported on the use of mathematical equations for Kow prediction.

Table 2-2. Octanol Water Partition Coefficient and Fate of Chemicals

ENVIRONMENTAL COMPARTMENTS	LOW KOW <500	MEDIUM KOW 500–1,000	HIGH KOW >1,000
Persistent	n *	either way	yes
Adsorbed	n	either way	yes
Absorbed	yes	either way	n
Biodegraded	yes	either way	n to slowly
Metabolized	yes	either way	n to slowly
Accumulated	n	either way	yes
Bioaccumulated	n	either way	yes
Dissipated	yes	either way	n

* n denotes negligible.

REFERENCE

[1] Lyman, Warren J., William F. Reehl, and David H. Rosenblatt, *Handbook of Chemical Property Estimation Methods*, McGraw Hill Book Company, Chapter 8, 1982.

VOLATILIZATION

A chemical on or in soil, on or in water, or on plants or animals may volatilize and get into the air. Vapor pressure is one of the most important factors governing volatilization, and provides an indication of whether a chemical will volatilize into the air under environmental conditions.

Some of the factors that effect volatilization in the environment are climate, sorption, hydrolysis, and phototransformation [l]. Here are guidelines:

1. A chemical with a low vapor pressure (VP), high adsorptive capacity, or high water solubility is less likely to volatilize into the air.
2. A chemical with a high VP, low sorptive capacity, or very low water solubility is more likely to volatilize into the air.
3. Chemicals that are gases at ambient temperatures will get into the air. (Gases at ambient temperature are not considered herein.)

Rapid volatilization into the air could result in immediate hazards for chemicals released indoors or outdoors if workers are in the area (e.g., agricultural workers). Vapor pressure is reported in terms of mm Hg (millimeter or mercury) or torr (which is equivalent to mm Hg). Table 2-5 will help you to visualize the possibilities.

REFERENCE

[1] Ney, Ronald E., Jr., "Fate, Transport and Prediction Model Application to Environmental Pollutants," Spring Research Symposium, James Madison University, UP, April 16, 1981.

SOIL SORPTION

The physical-chemical process by which a soil(s) ties up chemicals so that they are not released or are very slowly released in the environment is called adsorption, or bound residues. A chemical that is held by soil but is easily released is absorbed (in the way that a sponge holds water). The release mechanism considered herein is water, which is available in nature.

Plant root systems, as reported by Ney [4], have been shown to release adsorbed chemicals from soil for uptake into plant parts. Animals ingesting soil have also released the adsorbed chemical(s) for uptake. The mobility of adsorbed chemicals is prevented in soils. Here, the use of the word soil means only those soils that can adsorb chemicals, because soils do not all adsorb chemicals (e.g., sand, low-organic soils, etc., do not).

The movement of soil or soil particles containing an adsorbed chemical can contaminate other environments (e.g., as soil runoff or airborne particulates).

Sorption to soil, in almost all cases, can prevent phototransformation, hydrolysis, volatilization, mobility by water solubility, and microbial biodegradation.

Prior to the 1970s, many scientists would report that soils studied contained no chemical residues when, in fact, the scientists did not consider adsorbed residues or breakdown products. As previously discussed, the only way to discern what really occurs is to use a radiolabeled parent chemical. If the chemical cannot be extracted from soil with water

Table 2-5. Vapor Pressure (mm Hg or torr) and Fate of Chemicals.

ENVIRONMENTAL SURFACES	LOW < 0.000001	MEDIUM 0.000001 TO 0.01	HIGH > 0.01
Volatility	low	medium	high
Accumulation	yes	maybe	n *
Bioaccumulation	yes	maybe	n
Food-chain contamination	yes	maybe	n
Persistence	yes	maybe	n
Adsorption	high	maybe	low
Dissipation	yes	maybe	n
Problem if acutely hazardous	n	maybe	yes
Problem only if hazardous via long term	yes	maybe	n
Solubility	high	medium	low

* n denotes negligible.

Benzo [*a*] anthracene

Data

WS at 25°C	0.014 mg/L	[4]
Kow	407,380	[4]
VP at 20°C	5×10^{-9} torr	[4]

Discussion

- WS indicates that this chemical could adsorb to soil, run off with soil, and be bioaccumulated, and it should not leach and should not be biodegraded.
- Kow indicates bioaccumulation and potential for food-chain contamination. Residues could be expected in the food chain.
- VP indicates that this chemical should not be volatile.

Exposure

Routes of exposure could be by ingestion of contaminated food and water if this chemical were released in the environment.

Benzo [*b*] fluoranthene

Data

WS at 25°C	0.012 mg/L	[4]
Kow	3,715,352	[4]
VP at 20°C	5×10^{-7} torr	[4]

Discussion

- WS indicates that this chemical could absorb to soil, run off with soil, and be bioaccumulated, and it should not leach and should not be biodegraded.
- Kow indicates bioaccumulation and potential for food-chain contamination. Residues could be expected in food and water.
- VP indicates that this chemical should not be volatile.

Exposure

Routes of exposure could be by ingestion of contaminated food and water if this chemical were released into the environment.

Benzo [a] pyrene

Data

WS at 25°	0.0038 mg/L	[4]
Kow	1,096,478	[4]
VP at 20°	5×10^{-9} torr	[4]

Discussion

- WS indicates that the chemical could adsorb in soil, run off with soil, and be bioaccumulated, and it should not leach and should not be biodegraded.
- Kow indicates bioaccumulation and potential food-chain contamination. Residues could be expected in food and water.
- VP indicates that volatility is of no concern.

Exposure

Routes of exposure could be by ingestion of contaminated food and water.

Bifenox (Methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate) (also Modown)

Data

WS	0.35 ppm	[6]
BCF—static water	200	[6]

Discussion

- WS indicates that this chemical should adsorb to soil, run off with soil, and be bioaccumulated, and it should not leach and should not be biodegraded.
- BCF indicates that this chemical could bioaccumulate and could cause food-chain contamination. Residues could be expected in the food chain if the chemical were released in the environment.

Chlorbromuron (3-(4-bromo-3-chlorophenyl)-1-methoxy-1-methylurea)

Data

Pesticide		
WS	50 ppm	[6]
Koc	460	[6]
Soil TLC-Rf	0.14	[1]

Discussion

- WS indicates that this chemical could leach, run off, and be biodegraded, and it should not adsorb to soil and should not be bioaccumulated.
- Koc indicates that adsorption to soil should not occur; however, some adsorption is possible.
- Soil TLC-Rf indicates that leaching is unlikely, which contradicts the WS; however, perhaps biodegradation had occurred in this case, or maybe adsorption had taken place. Remember that the WS is in the "either way" range.
- Bioaccumulation of residues in the food chain may be possible, based on Koc and soil TLC values.

Exposure

Routes of exposure could be by (1) drinking contaminated water, (2) ingestion of contaminated food, and (3) inhalation if the chemical were volatile; however, no data are presented herein to indicate volatility.

Chlordane, Technical (60% Octachloro-4,7-methanotetrahydroindane and 40% related compounds)

Data

Pesticide—termite control		
WS	0.056 ppm	[6]
BCF—flowing water	11,400	[6]
BCF—static water	3,140	[6]
Hydrolysis—loses Cl in presence of alkaline reagents		[8]

Discussion

- WS indicates that chlordane should not be biodegraded in soils, should adsorb to soil, should accumulate in soil, and should be persistent in the soil environment.
- BCF indicates that it should bioaccumulate and cause food-chain contamination.
- Hydrolysis is likely in alkaline soils.
- Chlordane is persistent and can bioaccumulate in the environment and be taken up by plants and animals. It could persist in water, and if it gets into the aquatic environment, food-chain contamination is likely.

Exposure

Exposure could be by (1) drinking contaminated water or (2) eating contaminated plants and animals. If this chemical were volatile, than fallout to noncontaminated areas would be of concern, as well as phototransformation. Inhalation of volatile residues could then be a problem. Bioaccumulation and food-chain contamination are likely if this chemical is released to the environment.

Chlorine

Data

Used in water purification and many other uses	[8]
Gas	[8]

Discussion

- If released, chlorine could cause an inhalation problem. It also can combine with other chemicals in the air to form acids, which may present environmental problems.

Exposure

Routes of exposure could be by (1) inhalation of volatile residues and (2) inhalation of acids that might be formed in air.

Exposure

Routes of exposure cannot be predicted with the data presented above. Additional data will be needed for predictions.

Chrysene (also 1,2-Benzphenanthrene)

Data

WS at 25°C	0.002 mg/L	[4]
Kow	407,380	[4]
VP at 20°C	6.3×10^{-7} torr	[4]

Discussion

- WS indicates that this chemical could adsorb in soil, run off with soil, and be bioaccumulated, and it should not leach and should not be biodegraded.
- Kow indicates bioaccumulation, which could cause food-chain contamination. Residues could be expected in the food chain.
- VP indicates that volatility is of no concern.

Exposure

Routes of exposure could be by ingestion of contaminated food and water if such contamination should occur.

Crufomate (4-*tert*-Butyl-2-chlorophenyl methyl methylphosphoramidate) (also Ruelene)

Data

Pesticide		
WS	200 ppm	[6]
Kow	2,780	[6]

Discussion

- WS indicates that this chemical could go either way in relation to adsorption, leaching, runoff, biodegradation, and bioaccumulation.

- Koc indicates that this chemical should not be adsorbed and should not be bioaccumulated, and it should leach, run off, and be biodegraded.
- VP indicates that this chemical is volatile; thus inhalation could be a problem. Volatile residues and—if the chemical were phototransformed—both parent and phototransformation products could fall out and contaminate water and the food chain.
- This chemical, if not biodegraded rapidly, could cause contamination of water and food. Inhalation would be a problem, based on its volatility.

Exposure

Routes of exposure could be by (1) inhalation of volatile residues, as well as, perhaps, phototransformation products, and (2) consumption of contaminated water and food if such occurred; however, biodegradation may be rapid enough to prevent exposure, but no data are presented on biodegradation herein.

DDD (Dichloro diphenyl dichloroethane)

Data

Pesticide		
WS	0.005 ppm	[6]
Kow	1,047,000	[6]
BCF—static water	63,830	[6]

Discussion

- WS indicates that this chemical should adsorb to soil, run off with soil, and bioaccumulate, and it should not be leached and should not be biodegraded.
- Kow indicates that the chemical should bioaccumulate and could cause contamination to the food chain. This prediction is supported by the value given for BCF and WS.
- BCF indicates that this chemical should bioaccumulate and should cause food-chain contamination. It should not be metabolized to any extent in animals.
- The chemical should contaminate the food-chain if released into the environment. Residues should be expected in the food chain, and very little metabolism is expected in animals.

Exposure

Routes of exposure (1) should be by consumption of contaminated water and food if the chemical were released into the environment, and (2) could be by inhalation if it were volatile; however, no data are presented herein on volatility.

DDE

Data

Pesticide		
WS	0.01 ppm	[6]
Kow	583,000	[6]
BCF—static water	27,400	[6]

Discussion

- WS indicates that this chemical should adsorb to soil, run off with soil, and be bioaccumulated, and it should not be leached and should not be biodegraded.
- Kow indicates that the chemical should bioaccumulate and could cause contamination to the food chain.
- BCF indicates that the chemical should bioaccumulate in the food chain, and little metabolism is expected in animals.
- This chemical should bioaccumuate and should cause contamination to the food chain. Very little metabolism is expected in animals. Residues should be expected in the food chain.

Exposure

Routes of exposure (1) should be by consumption of contaminated water and food if such occurred, and (2) could be by inhalation if the chemical were volatile; however, no data are presented herein on volatility.

DDT (Dichloro diphenyl trichloroethane)

Data

Pesticide		
WS	0.0017 ppm	[6]
Koc	238,000	[6]
Kow	960,00	[6]
BCF—flowing water	61,600	[6]
BCF—static water	84,500	[6]

Discussion

- WS indicates that this chemical should adsorb to soil, run off with soil, and bioaccumulate, and it should not be leached and should not be biodegraded.
- Koc indicates that this chemical should adsorb to soil.
- Kow indicates that this chemical should bioaccumulate and could cause food-chain contamination, and this is supported by the BCF data.
- BCF indicates that this chemical should bioaccumulate in the food chain; thus residues could be expected.
- This chemical should be persistent in all environmental compartments, and residues could be expected throughout the food chain.

Exposure

Routes of exposure could be by (1) consumption of contaminated food and water if the chemical were released into the environment, and (2) inhalation if such occurred; however, no data are presented herein on volatility.

Dialifor (O,O-Diethyl S-(2-chloro-1-phthalimidoethyl) phosphorodithioate) (also dialifos and Torak)

Data

Pesticide		
WS	0.18 ppm	[6]
Kow	49,300	[6]

Exposure

Routes of exposure could be by (1) consumption of contaminated water and food if such occurred, and (2) inhalation if the chemical were volatile; however, no data are presented herein on volatility.

Di-2-ethylhexyl phthalate (also DEHP)

Data

Pesticide		
WS	0.6 ppm	[6]
Kow	9,500	[6]
BCF—flowing water	380	[6]
BCF—static water	130	[6]

Discussion

- WS indicates that this chemical should be adsorbed in soil and be bioaccumulated and could run off with soil particles, and that it should not leach and should not be biodegraded.
- Kow indicates that this chemical could bioaccumulate.
- BCF indicates that the chemical may not bioaccumulate, perhaps because it is metabolized. The data do indicate that a chemical residue could be expected in the food chain. There is a contradiction between WS and Kow values and the BCF; however, that is acceptable because residues of the chemical can be expected in the food chain although bioaccumulation may not occur. Residues could occur in the food chain if the chemical contaminated water.

Exposure

Routes of exposure could be by (1) ingestion of contaminated food, (2) drinking contaminated water, and (3) inhalation if the chemical were volatile; however, no data on volatility are presented herein.

Diethyl phthalate (also DEP)

Data

WS	1,000 mg/L	[4]
VP	0.05 torr	[4]
Kow	26,303	[4]

Discussion

- WS indicates that the chemical could leach, run off, and be biodegraded, and that it should not bioaccumulate and should not be adsorbed in soil.
- VP indicates that the chemical could be volatile, and could fall out and contaminate food and water. If it were phototransformed, the transformation products also could fall out and contaminate food and water. Inhalation of the parent chemical and its photoproducts could be a problem.
- Kow indicates that bioaccumulation and food-chain contamination are likely. This prediction contradicts WS; however, it appears to be a valid prediction with no reason to alter it unless additional data are presented to justify a change.

Exposure

Routes of exposure could be by (1) inhalation of volatile residues and (2) ingestion of contaminated food and water.

Dimethoate (*O,O*-Dimethyl *S*-[(methylcarbanoyl) methyl]phosphorodithioate) (also Cygon)

Data

Pesticide		
WS	25,000 ppm	[6]
Kow	0.51	[6]

Discussion

- WS indicates that this chemical could leach, run off, and be biodegraded, and it should not bioaccumulate and should not be adsorbed in soil.

Fluoranthene

Data

WS at 25°C	0.26 mg/L	[4]
Kow	213,796	[4]
VP at 20°C	6×10^{-6} torr	[4]

Discussion

- WS indicates that this chemical could adsorb in soil, run off with soil, and be bioaccumulated, and it should not leach and should not be biodegraded.
- Kow indicates that bioaccumulation and food-chain contamination could occur. Residues could be expected in the food chain.
- VP indicates that volatility should be of no concern.

Exposure

Routes of exposure could be by ingestion of contaminated food and water if such occurred.

Fluorene

Data

WS at 25°C	1.98 mg/L	[4]
Kow	15,136	[4]
VP at 20°C	1.3×10^{-2} torr	[4]

Discussion

- WS indicates that this chemical could adsorb in soil, run off with soil, and be bioaccumulated, and it should not leach and should not be biodegraded.
- Kow indicates that bioaccumulation and food-chain contamination could occur. Residues could be expected in the food chain.
- VP indicates volatility; fallout could contaminate food and water. If the chemical were phototransformed, transformation products also could contaminate food and water. Inhalation of the parent chemical and its potential photoproducts could be a problem.

Exposure

Routes of exposure could be by (1) ingestion of contaminated food and water if such occurred, and (2) inhalation if the chemical were volatile; however, no data are presented herein on volatility.

2-Methylnaphthalene

Data

WS	25.4 ppm	[6]
Koc	8,500	[6]
Kow	13,000	[6]

Discussion

- WS indicates that this chemical could go either way in regard to leaching, runoff, adsorption, biodegradation, and bioaccumulation.
- Koc indicates the chemical could adsorb to soil, and this is supported by the Kow value.
- Kow indicates that this chemical should bioaccumulate, and this could cause food-chain contamination.
- If this chemical were released into the environment, it could contaminate the food chain.

Exposure

Routes of exposure could be by (1) consumption of contaminated water and food if such occurred, and (2) inhalation if the chemical were volatile; however, no data are presented herein on volatility.

Methylparathion (*O,O*-Dimethyl-*O*-*p*-nitrophenyl phosphorothioate)

Data

Pesticide		
WS	57 ppm	[6]
Koc	9,800	[6]
Kow	82	[6]
BCF—static water	95	[6]
VP	9.5 mm Hg $\times 10^6$ at 20°C	[3]
Degrades in soil		[3]

Monuron (3-(*p*-Chlorophenyl-1-dimethylurea (also Telvar)

Data

Pesticide	230 ppm	[6]
Koc	100	[6]
Kow	29	[6]

Discussion

- WS indicates that this chemical could go either way in regard to leaching, runoff, adsorption, biodegradation, and bioaccumulation.
- Koc indicates that the chemical should not adsorb.
- Kow indicates that the chemical should not bioaccumulate.
- The data are contradictory, and no two pieces agree. No prediction can be made.

Exposure

Routes of exposure cannot be predicted without additional data. However, to be on the safe side, if a prediction must be given, then it could be that consumption of contaminated water and food, as well as inhalation, could be a problem.

Naphthalene

Data

WS	31.7 ppm	[6]
Koc	1,300	[6]
Kow	2,040	[6]

Discussion

- WS indicates that this chemical is in the range of nonmobile to mobile.
- Koc indicates that adsorption to soil should occur, and solubility should not be conducive to leaching.
- Kow indicates bioaccumulation and food-chain contamination potential, and a water solubility that should not be conducive to mobility (leaching).

- Based on the data, the chemical should not leach, but it could run off With soil particles to contaminate aquatic environments. If any water is contaminated, or if food crops are grown in soils containing this chemical, then bioaccumulation and food-chain contamination are likely.

Exposure

Exposure would be by consumption of contaminated water or food if such occurred. Volatility data are not given; but this chemical could be a problem if volatile, if it were inhaled.

1-Naphthol

Data

WS	866 ± 31 μg/ml	[3]
Kow	700 ± 62	[3]
Koc	522	[3]
Soil TLC-Rf	0	[3]

Discussion

- WS indicates that leaching should not occur, but adsorption to soil should occur, runoff with soil particles could occur, and bioaccumulation is possible.
- Kow indicates that bioaccumulation could occur.
- Koc indicates adsorption to soil.
- Soil TLC-Rf indicated no leaching and showed potential for soil adsorption, bioaccumulation, and low solubility.
- Based on the data, the chemical should not leach, should not biodegrade, and should bioaccumulate.

Exposure

Exposure could be by consumption of contaminated water or food if such contamination occurred. Another route could be by inhalation if the chemical were volatile, but no data are given herein on volatility.

Pentachlorophenol

Data

Pesticide		
WS	14 ppm	[6]
Koc	900	[6]
Kow	102,000	[6]
VP	0.00011 torr (calculated)	[4]
Adsorbs light	245 nm and 318 nm	[4]

Discussion

- WS is in the "either way" range.
- Koc indicates that sorption can occur.
- Kow indicates that bioaccumulation should occur; thus food-chain contamination is likely.
- VP indicates that volatility is not a problem.
- This chemical adsorbs light; therefore, phototransformation can occur in water and on surfaces.

Exposure

Exposure could be by consumption of contaminated water or food if such occurred. Inhalation could be a problem if the chemical were volatile; however, volatility is unlikely.

Phenanthrene

Data

WS	1.29 ppm	[6]
Koc	23,000	[6]
Kow	32,900	[6]
Kow	28,840	[4]
VP at 20°C	6.8×10^{-4} mmHg	[4]

Discussion

- WS indicates that this chemical should be adsorbed to soil, run off with soil, and be bioaccumulated, and it should not be biodegraded and should not be leached.

- Koc indicates that the chemical should be adsorbed to soil and could run off with soil.
- Kow indicates that the chemical should bioaccumulate and could cause food-chain contamination.
- VP indicates potential for volatility and thus inhalation problems. If the chemical were volatile, phototransformation products, if formed, along with the parent chemical, could fall out and contaminate water and the food chain.
- The four pieces of data complement each other. This chemical, if released in the environment, could bioaccumulate and cause food-chain contamination. Residues could be expected in the food chain. Volatile residues of the parent chemical and its possible photoproducts also could present an inhalation problem and a contamination problem, were they to fall out onto water and the food chain.

Exposure

Routes of exposure could be by (1) consumption of contaminated water and food if such occurred, and (2) inhalation; however, additional data are needed for a complete exposure picture.

Phenol (also Carbolic acid)

Data

WS	82,000 ppm	[6]
WS	93,000 ppm	[4]
Koc	27	[6]
VP	0.02 mm Hg	[7]
VP (supercooled liquid)	0.5293 torr	[4]
Kow	1.46	[4]

Discussion

- The WS of 82,000 to 93,000 ppm is an indication that phenol is water-soluble, and should leach into groundwater, run off into surface water, and be biodegraded.
- Koc indicates that adsorption in soil is likely.
- Based on its volatility, the chemical should volatilize from H_2O and soil surfaces.

- Kow indicates that bioaccumulation is unlikely.
- Based on its solubility, the chemical should not adsorb to soil, should be degraded by microbes, and should not bioaccumulate. This is supported by a low Koc of 27 and a low Kow of 1.46. Volatility could be a problem if the chemical were inhaled.

Exposure

Two routes of exposure are possible: (1) inhalation, because of the chemical's volatility, and (2) consumption of contaminated drinking water.

Phosalone (S-[6-Chloro-3-mercaptomethyl)-2-benzoxazolinone] O,O-diethyl phosphorodithioate) (also Zolone)

Data

Pesticide		
WS	10 ppm	[6]
Kow	20,100	[6]

Discussion

- WS indicates that this chemical should be adsorbed to soil, be bioaccumulated, and run off with soil, and it should not be biodegraded and should not be leached.
- Kow indicates that the chemical should be bioaccumulated and could cause food-chain contamination.
- The data support a prediction that the chemical should bioaccumulate and could contaminate the food chain. If this occurred, residues could be expected in the food chain.

Exposure

Routes of exposure could be by (1) consumption of contaminated water and food, and (2) inhalation if the chemical were volatile; however, no data are presented herein on volatility.

Pyrazon (5-Amino-4-chloro-2-phenyl-3(2*H*)-pyridazinone) (also Pyramin (*e*))

Data

Pesticide		
WS	400 ppm	[6]
Koc	120	[6]
Soil TLC-Rf	0.44	[1]

Discussion

- WS indicates that this chemical could go either way in regard to leaching, runoff, adsorption, biodegradation, and bioaccumulation.
- Koc indicates that the chemical should not be adsorbed and could be mobile.
- Soil TLC indicates that the chemical could go either way with respect to adsorption and leaching.
- The data for this chemical are inclusive; however, the prediction is that the chemical could leach, run off, and be biodegraded. Some adsorption to soil could occur. Contamination of the food chain is possible; however, bioaccumulation should not occur. If the chemical were released into the environment, residues could be expected in the food chain, but not bioaccumulation.

Exposure

Routes of exposure could be by (1) consumption of contaminated water and food if such occurred, and (2) inhalation if the chemical were volatile; however, no data are presented herein on volatility.

Pyrene

Data

WS	0.135 ± 0.013 μg/ml	[4]
Kow	124,000 ± 11,000	[4]
Koc	63,400	[4]
VP	6.85×10^{-7} torr	[4]
Photolysis absorbs solar radiation		[4]

Discussion

- WS indicates that leaching and biodegradation are unlikely; however, soil adsorption is likely.
- Koc indicates that runoff is unlikely unless with soil particles, and Kow further supports the prediction that leaching is unlikely. Koc indicates soil adsorption.
- Kow indicates that bioaccumulation and food-chain contamination may occur, and that prediction is supported by WS and Koc.
- Volatility should not be a problem.
- The chemical should not be mobile, could bioaccumulate, and could cause food-chain contamination.

Exposure

Routes of exposure could be by (l) drinking contaminated water and (2) eating contaminated plants and animals. These routes of exposure could occur if the chemical were spilled on cropland or in the aquatic environment.

Pyroxychlor (2-Chloro-6-methoxy-4-(trichloromethyl) pyridine)

Data

Pesticide		
WS	11.3 ppm	[6]
Koc	3,000	[6]
BCF—static water	239	[6]

Discussion

- WS, supported by Koc and BCF, indicates that this chemical could adsorb to soil, run off with soil, and be bioaccumulated, and it should not leach and should not be biodegraded. This could not have been predicted on WS alone because it could gone either way. However, with the use of Koc and BCF, such prediction is possible.
- Koc indicates that adsorption to soil could occur.
- BCF indicates that residues could be expedited in the food chain, as well as bioaccumulation potential.

to residues; however, no data are presented herein to indicate this. It is predicted that residues may occur in the food chain if they are not dissipated rapidly.

Exposure

Routes of exposure could be by (l) consumption of contaminated water and food if such occurred, and (2) inhalation if the chemical were volatile; however, no data are presented herein on volatility.

Toluene (also Toluol)

Data

WS at 25°C	534.8 mg/L	[4]
Kow	490	[4]
VP at 25°C	28.7 torr	[4]

Discussion

- WS, supported by Kow, indicates that this chemical could leach, run off, and be biodegraded, and it should not adsorb in soil and should not be bioaccumulated.
- Kow indicates that bioaccumulation should not occur; however, residues could be expected in the food chain.
- VP indicates volatility; fallout could contaminate food and water. If the chemical were phototransformed, transformation products also could fall out and contaminate food and water. Inhalation of the parent chemical and potential photoproducts could be a problem.

Exposure

Routes of exposure could be by (1) ingestion of contaminated food and water if such occurred, and (2) inhalation of volatile residues.

Toxaphene (Technical chlorinated camphene (67–69% chlorine))

Data

Pesticide		
WS	0.4 ppm	[6]
BCF—flowing water	26,400	[6]
BCF—static water	4,250	[6]

Discussion

- WS indicates that this chemical could adsorb in soil, run off with soil, and be bioaccumulated, and it should not leach and should not be biodegraded.
- BCF indicates that bioaccumulation and food-chain contamination could occur. Residues could be expected in the food chain.

Exposure

Routes of exposure could be by (1) ingestion of contaminated food and water if such occurred, and (2) inhalation if the chemical were volatile; however, no data are presented herein to indicate volatility.

Triallate

Data

WS	4 ppm	[6]
Koc	2,220	[6]

Discussion

- WS indicates that this chemical should adsorb to soil, runoff with soil, and be bioaccumulated, and it should not be biodegraded and should not be leached.
- Koc indicates that the chemical should adsorb to soil, and this prediction is in agreement with the value for WS.
- This chemical could bioaccumulate and cause contamination of the food-chain; however, additional data are needed for a conclusive prediction. If such contamination occurred, then residues could be expected in the food chain.

Exposure

Routes of exposure could be by (1) consumption of contaminated water and food if such contamination occurred, but additional data are needed; and (2) inhalation if the chemical were volatile, but no data are presented herein on volatility.

1,2,4-Trichlorobenzene

Data

WS	30 ppm	[6]
Kow	15,000	[6]
Kow	18,197	[4]
BCF—flowing water	491	[6]
VP at 20°C	0.42 torr	[4]

Discussion

- WS indicates that this chemical could go either way in regard to leaching, runoff, adsorption, biodegradation, and bioaccumulation.
- Kow indicates that the chemical should bioaccumulate.
- BCF indicates that the chemical should have residues in the food chain but not bioaccumulate.
- VP indicates volatility; there is the potential for an inhalation problem. If the chemical were phototransformed, the phototransformates and the parent chemical could fall out onto water and food and thus contaminate the food chain.
- The data indicate that this chemical should have residues in the food chain if the chemical were released into the environment. Bioaccumulation may be prevented by metabolism in animals; however, no data are presented so that one can discern this. Volatility could be an inhalation problem, and fallout of residues could cause food-chain contamination.

Exposure

Routes of exposure could be by (1) consumption of contaminated water and food and (2) inhalation; however, additional data are needed to permit assessment of the potential problems associated with volatility.

Trichlorofluoromethane (also Freon-11 and Fluorocarhon-11)

Data

WS	1,100 mg/L	[4]
Kow	338.84	[4]
VP at 20°C	667.4 torr	[4]

Discussion

- WS indicates that this chemical should leach, run off, and be biodegraded, and it should not be bioaccumulated and should not be adsorbed in soil.
- Kow indicates that this chemical should not bioaccumulate.
- VP indicates volatility, and this could cause inhalation problems. If it were phototransformed, fallout of photoproducts and the parent chemical could contaminate water and food.
- This chemical is volatile, and the parent chemical and potential photoproducts could cause inhalation problems. The major problem should be degradation of the ozone layer in the atmosphere. Residues that fall out onto water and food should volatilize; however, it may take longer for volatilization to occur in water than it would take on food.

Exposure

Route of exposure should be by inhalation of volatile residues. The major concern should be degradation of the ozone layer.

Trichlorofon (also Dimethyl (2,2,2-Trichloro-1-hydroxyethyl) phosphonate, Dylox, Chlorphos, and Anthon)

Data

WS	154,000 ppm	[6]
Kow	3	[6]

Discussion

- WS indicates that this chemical should leach, run off, and be biodegraded, and it should not bioaccumulate and should not be adsorbed to soil.
- Kow indicates that the chemical should not bioaccumulate, and this prediction is supported by the WS value.
- This chemical could contaminate the environment if released into it. Biodegradation, if rapid, should prevent residues from being found in the food chain; however, no data are presented herein to support this prediction.

ER ID 58982
Shanley 1998

ER PROJECT
TELECONFERENCE NOTES

TO: Kim Hill
ORGANIZATION: NMED/EPA
PHONE: 827-1561

FROM: Pat Shanley
ORGANIZATION: ESH-19
PHONE: 667-0663

DATE: 1/21/98

TIME: 9:30 a.m.

OTHER PARTIES: None

DISCUSSION: I contacted Kim Hill to reply to a voice mail from her that indicated that HRMB had a recommendation for sampling at 73-004(a). Kim indicated that HRMB would be uncomfortable proceeding with no additional sampling. It is HRMB's recommendation to collect the samples proposed by LANL (Randy Ryti) during the LANL ER/HRMB meeting on January 15, 1998. In addition, HRMB recommended that sampling be conducted at the location halfway between the cast iron pipe/VCP connection and the previously sampled location "upgradient" of the septic tank. Kim indicated that the contents of the drainline should be sampled as well as the soil or tuff beneath the drainline. Kim acknowledged that there may not be any material in the drainline, and if that is the case, no sample could be collected.

HRMB also had the following two comments:

1. Make sure the mercury is analyzed for in the proposed outfall sampling.

2. Detection limits for some of the existing data are too high.

ACTION ITEMS: Pat will relay information to the January 15 SAP meeting attendees.

DISTRIBUTION:
K. Hill, NMED (email)
T. Taylor, LAAO, MS A316
J. Mose, LAAO, MS A316
D. McInroy, EM/ER, MS M992
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CASARETT et al. 1986
ER ID 59093

Casarett and Doull's TOXICOLOGY

The Basic Science of Poisons

THIRD EDITION

Macmillan Publishing Company
New York

Collier Macmillan Canada, Inc.
Toronto

Collier Macmillan Publishers
London

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Earlier editions: *Toxicology: The Basic Science of Poisons*, edited by Louis J. Casarett and John Doull, copyright © 1975 by Macmillan Publishing Company. *Casarett and Doull's Toxicology: The Basic Science of Poisons*, edited by John Doull, Curtis D. Klaassen, and Mary O. Amdur, copyright © 1980 by Macmillan Publishing Company.

MACMILLAN PUBLISHING COMPANY
866 Third Avenue, New York, New York 10022

Collier Macmillan Canada, Inc.
Collier Macmillan Publishers • London

Library of Congress Cataloging-in-Publication Data
Toxicology (Macmillan Publishing Company)
Casarett and Doull's toxicology.
Includes bibliographies and index.
1. Toxicology. I. Casarett, Louis J. II. Doull, John, 1923– . III. Klaassen, Curtis D. IV. Amdur, Mary O. V. Title. [DNLM: 1. Poisoning. 2. Poisons. QV 600 T757]
RA1211.T6338 1986 615.9 86-8683
ISBN 0-02-364650-0

Printing: 1 2 3 4 5 6 7 8 Year: 6 7 8 9 0 1 2 3 4

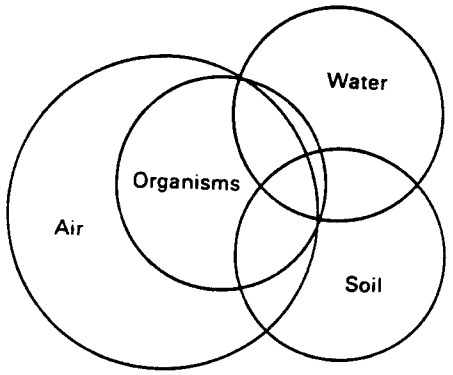

Figure 26–1. Overlapping relationships of environmental compartments.

contamination of the environment may be either from point sources or from nonpoint sources. The results of point source pollution are generally easy to identify and the remedies are frequently more attainable. Nonpoint source pollution, on the other hand, is generally less dramatic in its initial effects, but is more difficult to contain or correct.

The production, use, and disposal of industrial chemicals all lead to contamination of soil and water. Production activities lead to soil and water contamination when by-product chemicals are not properly conserved during manufacturing processes. For example, in various smelting operations toxic chemicals present in ores may not be properly controlled. Naturally occurring arsenic in copper ores, for example, frequently finds its way into soil and water. Accidental spillage of industrial chemicals may also result in contamination, sometimes dramatically, of soil and water. Careless manufacturing practices in a small chemical firm in Hopewell, Virginia, led to serious contamination of the James River and Chesapeake Bay by the pesticide Kepone. Even though these practices have now ceased, the contamination of the estuarine system will be present for many decades. Another example is the contamination of the Ohio River with carbon tetrachloride resulting from an accidental dumping of the material from a chemical plant. Such incidents of point source contamination of water can generally be prevented or controlled by the appropriate use of technology. The result, however, of not controlling such point source pollution is frequently a very high cost for decontamination, where that is even possible, and frequently both acute and chronic detrimental effects on organisms.

The use of chemicals for their intended purpose often leads to contamination, sometimes undesirably, of soil and water. Lead contamination of soils and occasionally water near highways results from the use of tetraethyl lead as an antiknock component of gasoline for automobiles. Although a commitment was made to reduce the use of this compound in gasoline, the many years during which it was used and the nonpoint source nature of the contamination have resulted in concentrations of lead that will remain for many years in soils and water. A chemical that is intentionally added to water for therapeutic purposes is fluorine. The use of water fluoridation to prevent tooth decay is well known and has been practised in the United States for many years. Excessive concentrations of fluorine, however, can result in undesirable effects in teeth, manifested primarily by their mottling and discoloration. Careful attention must be paid to the use of fluorine to prevent overfluoridation with its undesirable side effects.

The disposal of industrial chemicals following their use presents a major problem in several industries. Detergents used in clothes laundering are discharged into sewage systems and ultimately into rivers, lakes, and streams. Phosphate detergents then serve as nutrients for algae and other organisms that can cause major difficulties in these bodies of water. The green scum resulting from algal blooms is a familiar sight in some areas. The contamination of rivers resulting from discharge of water containing organic mercurials used in paper manufacturing presents a problem in some local situations. Other chemicals resulting from paper making can also present serious water pollution problems. Asbestos tailings resulting from mining operations have also contaminated water systems in some parts of the United States, and this has resulted in concern over the potential health effects of the material that then finds its way into drinking-water systems.

The use of chemicals in agriculture results in contamination of soil and water, including groundwater, through the direct use of pesticides and fertilizers. Pesticides are, of course, applied directly to the soil in some cases to control insects, weeds, and plant diseases. Some of these chemicals can persist for many years and thereby cause concern about their potential movement from soil into water systems and from both soil and water into organisms that live in and on water and soil. The effects of pesticides in the food chain are now generally familiar. Likewise, fertilizers applied to the soil to promote plant growth and productivity can leach or run off from soil and find their way into natural water systems, causing an upset in the ecologic balance to the degree that organisms living in those systems can be either enhanced or otherwise affected.

The domestic and urban use and disposal of chemicals also result in the contamination of soil and water. Domestic wastes are concentrated in sewage systems and landfill operations. Frequently, large buildups of heavy metals occur as a result. Pesticides and fertilizers used in suburban and some urban situations for lawn and home garden purposes or pest control in other situations also are serious problems when improperly used. Detergents may also cause difficulties as referred to above. The discovery that the process of purifying water can result in the chlorination of certain organic chemicals to produce chlorinated hydrocarbons that are potential carcinogens has generated concern. In some parts of the country concentrations of such chemicals above levels considered to be safe have been found in drinking-water systems.

Finally, metals, minerals, and plant or animal toxins are found in the environment as natural components of water and soil systems. Although they have always been there and always will be, human activities frequently result in excessive production or movement of such chemicals found naturally occurring in the environment and can result in concentrations detrimental to human or other organisms. Furthermore, the possibility of interaction of synthetic chemicals and pollutants with naturally occurring metals, minerals, and toxins must be considered.

Transport, Mobility, and Disposition

The fate and distribution of chemicals in the environment are determined by several variables that can interact in numerous ways. An analogy between pharmacodynamics and chemodynamics can be drawn to illustrate some basic similarities in each approach. First, one must appreciate the physicochemical properties of a chemical, such as water solubility, lipid solubility, partitioning behavior, vapor pressure, pKa for ionic species, chemical stability, etc., if one is to predict the behavior of a chemical in a system—be it human or an ecosystem. Second, the processes that act within the system must be considered. Transport, via serum proteins versus suspended sediments; circulation, via the circulatory system versus the hydrologic cycle; degradation, in liver versus soil microorganisms; and excretion, via urine, feces, and expired air versus dilution in water and air to nondetectable levels or deposition in ultimate sinks such as deep ocean sediments, are all processes that act on chemicals to determine the mobility and final disposition of a chemical in a system. The analogy can be carried one step further to include target organs or tissues affected by the chemical in comparison with the susceptible species of an ecosystem. The fundamental difference in this consideration is one of scale, in both time and dimension, which then requires models of varying scale. Several mathematical models have become available in recent years to predict the transport and fate of organic chemicals and metals in both aquatic and soil systems (Dickson *et al.*, 1982). The soil models are divided into unsaturated and saturated systems while other models deal with runoff and the transport of toxicants in surface waters. The value of such models is in understanding the properties that are most important in determining the environmental fate of a chemical under given conditions. A second objective is to predict exposure of various organisms through time to various toxicants and thus aid regulatory agencies in decision making.

Water Solubility. The water solubility and latent heat of solution are critical properties of a chemical that affect its environmental fate. Many environmental toxicants are hydrophobic, having solubilities in the parts-per-million (ppm, mg/l) to parts-per-billion (ppb, μg/l) range. Reported solubility values vary with the method used for determination (Gunther *et al.*, 1968). Water solubilities are affected by pH (for ionizable chemicals), presence of dissolved salts and organics, and temperature.

Soil Adsorption. Adsorption to particulate matter is a major mechanism by which chemicals are removed from solution. Adsorbent materials in soils and sediments can be divided into clay minerals and soil organic matter. Clay minerals include various hydrous silicates, oxides, and layer silicates. The clay minerals have been extensively studied and are characterized by physical structure or layering type, either 1:1 or 2:1, swelling ability, cation exchange capacity, and specific surface (m^2/g) (Weber, 1972). These parameters are important considerations in the behavior of organic cations, polar organic molecules, and metal ions in soils. High specific surface is associated with small particle size; therefore, the colloidal fraction of the soil is a dominant factor in chemical-soil interactions. Cation exchange capacity of the inorganic fraction is a function of the magnitude and distribution of the structural charge. Exchangeability is dependent on the adsorbed cations, usually sodium, potassium, or calcium, and the nature of the replacing cations.

The water associated with clay plays an important role in defining its characteristics. Adsorbed water on clay surfaces is more ordered than free water. Water on the clay surface may also be more ionized than otherwise. Thus, the hydrogen ion concentration of the clay surface is high. The effect of pH on the adsorption of

classes of chemicals has been summarized by Hamaker and Thompson (1972) (Table 26–1).

Adsorption data for chemicals in soils is usually expressed by the Freundlich isotherm, $x/m = KC^n$; x/m is the amount of chemical sorbed per weight of the adsorbent, C is the equilibrium concentration of the chemical, and K and n are constants. The constant K represents the extent of adsorption while the value n sheds light on the nature of the adsorption mechanism and the role of the solvent, water.

Soil organic matter usually ranges from 0.1 to 7.0 percent and serves as the most important sorptive surface for nonionic chemicals. Above a few percent organic matter, all the soil mineral surfaces are effectively blocked and thus no longer function as adsorbents. Soil organic matter can be divided into two main groups: (1) nonhumic substances, which are fresh or incompletely decomposed plant and animal material, and (2) humic substances, which are more or less completely altered or resynthesized materials. The former serve as a source for the latter. Nonhumic materials include well-known organic chemical groups with definite characteristics: proteins, carbohydrates, organic acids, sugars, fats, waxes, resins, lignins, pigments, and low-molecular-weight compounds. These materials comprise 10 to 15 percent of the soil organic matter. Their composition and residence times are quite variable. Humic substances account for 85 to 90 percent of soil organic matter and their nature is not well understood. Humic substances are fractionated to give fulvic acid, which is soluble in both alkali and acid; humic acid, which is soluble in alkali but not in acid; and the humin fraction, which cannot be readily extracted with cold alkali. Humic acid and fulvic acid are aromatic polymers with molecular weights that range from 5000 to 100,000 and from 2000 to 9000, respectively. Functional groups that have been identified on humic substances are carboxyl, phenolic hydroxyl, alcoholic hydroxyl, carbonyl, and methoxy. Heterocyclic rings with oxygen and nitrogen atoms are also present. A hypothetic structure for humic acid has been proposed by Kononova (1966) as shown below.

Vaporization. Vaporization from soil, water, or plant surfaces is a major transport process for many chemicals. The volatility of a chemical is a function of its vapor pressure, but the rate of vaporization also depends on environmental conditions such as temperature, degree of adsorption, soil properties, and soil water content. Airflow over the evaporating surface affects

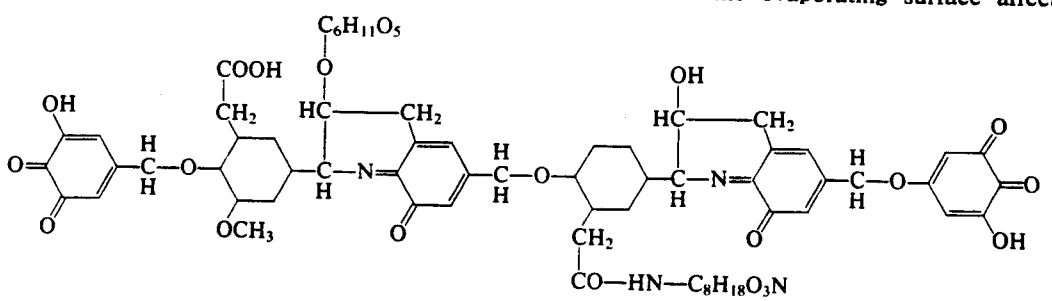

Table 26–1. CLASSES OF MATERIALS RELATED TO THE EFFECT OF pH ON ADSORPTION*

CLASS	EXAMPLE	pK_a	MOLECULAR FORM *Low* pH	MOLECULAR FORM *High* pH	pH *Effect*
Strong acid	Linear alkylsulfonates		Anion	Anion	Small
Weak acid	Picloram	3.7	Free acid	Anion	Large adsorption; pH approx. pK_a
Strong base	Diquat		Cation	Cation	Decrease at very low pH (18 N H_2SO_4)
Weak base	Ametryne		Cation	Free base	Increasing adsorption to pH approx. pK_a and then decrease
Polar molecules	Diuron		Nonionized	Un-ionized	Small
Neutral molecules	DDT	Nil	Nonionized	Un-ionized	Probably none

* From Hamaker, J. W., and Thompson, J. M.: Adsorption. In Goring, C. A. I., and Hamaker, J. W. (eds.): *Organic Chemicals in the Soil Environment*, Vol. 1. Marcel Dekker, Inc., New York, 1972. Reprinted by courtesy of Marcel Dekker, Inc.

vaporization rate since air movement continuously replaces and mixes air around the evaporating surface. Many chemicals evaporate simultaneously with water, which leads some researchers to believe that chemicals such as DDT "codistill" with water. This phenomenon can be demonstrated in laboratory distillations at 100°C, but does not occur at normal environmental temperatures. Instead, water evaporation and DDT volatilization occur independently. Higher vapor loss from most soil surfaces correlates with pesticide volatilization, but is due to desorption of chemicals from soil adsorption sites by water molecules and the mass flow of chemical to the soil surface by the "wick effect." This phenomenon has been noted with chemicals such as 2,4-D esters, thiolcarbamates, triazines, organochlorine insecticides, and *N*-methyl-carbamates. Volatility of organic chemicals from water increases with decreasing water solubility. As a result, a chemical with both low vapor pressure in the solid phase and very low water solubility would be much more volatile from aqueous solution than might be expected. DDT is again the example.

Partitioning. The distribution relationships for a chemical between the environmental compartments of air, soil, water, and biota can be expressed by a series of partition coefficients (McCall *et al.*, 1983). The soil sorption constant (K_d) relates the amount of chemical sorbed to soil to the concentration in water (Table 26–2). Since organic matter is a key to the sorption process in many soils, as discussed above, the sorption characteristics of a chemical can be normalized by use of K_{oc}, which relates sorption properties to soil organic matter. Air-water distribution, expressed as K_w from Henry's law, is valid only for dilute solutions, which is the case for most environmental chemicals. The bioconcentration factor (BCF) is actually a measure of the partitioning of a chemical between water and fish but is a suitable indicator for biota in general. This information provides relative rankings of chemicals, although variations will occur among different organisms with respect to bioconcentration. A laboratory measure of the partitioning of a chemical between *n*-octanol and water provides K_{ow}, which is related to water solubility. K_{ow} values have been correlated with bioconcentration factors and soil sorption constants for a number of organic chemicals. Recently, retention times for chemicals on reversed-phase high-performance liquid chromatography (RP-HPLC) have been used to predict partitioning between the organic and aqueous phases of the environment (Swann *et al.*, 1983). Thus, with just a few measurements of the properties of a chemical (water solubility, vapor pressure, melting point, partitioning parameters, or RP-HPLC retention times) it is possible to guess a chemical's expected environmental distribution.

Bioaccumulation. Bioaccumulation is different from other environmental processes because it concentrates rather than diffuses the chemical in question. This concentration effect is expressed as the ratio of the concentration of a chemical in the organism to that in the medium (usually water). Bioaccumulation refers to both uptake of dissolved chemicals from water (bioconcentration) and uptake from ingested food and sediment residues. The two properties of a chemical that are responsible for high bioaccumulation ratio values are: (1) high partition coefficient, i.e., lipophilic, and (2) recalcitrance

Table 26–2. KEY PHYSICAL AND ENVIRONMENTAL PROPERTIES IN FATE ASSESSMENT*

PROPERTY	DEFINITION
Soil sorption coefficient (K_d)	$\frac{\mu g \text{ Chemical soil/g of soil}}{\mu g \text{ Chemical water/g of water}}$
Soil sorption constant (K_{oc})	$\frac{K_d}{\% \text{ Organic carbon}} \times 100$
Water-air ratio (K_w)	$\frac{\mu g \text{ Chemical/cm}^3 \text{ of water}}{\mu g \text{ Chemical/cm}^3 \text{ of air}}$
n-Octanol-water coefficient (K_{ow})	$\frac{\mu g \text{ Chemical/ml } n\text{-octanol}}{\mu g \text{ Chemical/ml of water}}$
Bioconcentration factor (BCF)	$\frac{\mu g \text{ of Chemical/g of fish}}{\mu g \text{ of Chemical/g of water}}$

* From Swann, R. L., *et al*: A rapid method for the estimation of the environmental parameters octanol/water partition coefficient, soil sorption constant, water to air ratio, and water solubility. *Residue Rev.*, **85**:17–28, 1983.

toward all types of degradation. The length of the food chain also determines final concentrations in the top organisms. Bioaccumulation ratios have been determined for a variety of environmental chemicals in laboratory model ecosystems and correlate well with the *n*-octanol/water partition coefficients.

Degradation. Transformations of chemicals in soil and water occur by chemical, photochemical, and biochemical reactions. Degradation results in the true "disappearance" of a chemical's molecular form, as opposed to transport processes, which merely move chemicals from one environmental compartment to another. However, it must be recognized that transport processes that move chemicals to ultimate sinks, such as deep ocean sediments, for all practical purposes do remove chemicals from the environment.

Chemical transformations are classified as hydrolyses, oxidations, reductions, nucleophilic substitutions involving water, and free radical reactions. These reactions may be catalyzed by the presence of metal ions, metal oxides, clay surfaces, organic compounds, and organic surfaces. The pH of solutions and the effective pH of clay surfaces, which may be quite different from the surrounding aqueous environment, can significantly influence rates of degradation. Other obvious conditions that affect degradation rates are temperature, moisture content in soils, and other environmental processes that alter chemical concentrations. The kinetics of degradation rates are dependent on the mechanism of degradation. Some degradative processes follow first-order kinetics, while others are best described by a "hyperbolic rate model" (Hamaker, 1972).

Photochemical reactions of chemicals occur in air and water but are probably of little or no significance in soils. For a chemical to undergo a photochemical reaction, it must absorb light energy from an appropriate portion of the spectrum or have the light energy transferred through an intermediate substance known as a sensitizer. Ultraviolet light (4- to 400-nm wavelengths) has sufficient energy to break existing chemical bonds, but light above 450 nm, which represents an energy of 65 kcal/mole, is usually not sufficient to initiate reactions. Light of wavelengths shorter than 295 nm does not reach the earth's surface in appreciable amounts. The principal reactions are photo-oxidations and photoreductions which proceed through light-formed free radicals and which then react with molecular oxygen or abstract hydrogen from organic compounds, respectively.

Biologic reactions of chemicals in soil and water are mediated primarily by microorganisms. Microorganisms are quite versatile when confronted with foreign chemicals. The major reactions involved are dehalogenation, hydrolysis, oxidations, reductions, conjugations, and methylations. They are also very important in the natural cycles of many elements, such as mercury and arsenic. These natural cycles can be disturbed by introduction of various forms of metals and can increase formation of toxic species, e.g., methyl mercury. The types and rates of microbiologic reactions are determined by the microbial ecology of any given system. Thus, pH, temperature, redox potential, nutrient availability and microbial interactions will affect the microbial degradation of a chemical.

Chemodynamics. As we have seen above, there are numerous routes by which chemicals enter the environment and many factors to consider in understanding their behavior once they are there. Much of what is known about chemodynamics is derived from studies of pesticides and, to a lesser extent, industrial chemicals and heavy metals. Certainly, pesticide applications, sewage sludge disposal, and industrial waste effluents each present different starting points for a consideration of chemodynamics. We shall deal with environmental processes in the following sections and attempt to relate the (1) physicochemical properties of a chemical and (2) the environmental conditions that serve as modifiers of the processes. Each process has a rate that describes the transport from one component to the next and a rate that describes the degradation of the chemical in question. A complete analysis of all of the rates for entry, transport, and degradation of a chemical will describe its ultimate fate in the water and soil. More detailed discussion of these processes will be found in the monograph by Thibodeaux (1979).

PESTICIDES

The major classes of pesticides have been grouped as "nonpersistent" or "slightly residual," "moderately persistent" or "moderately residual," or "persistent" or "highly residual" (Harris, 1969; Kearney *et al.*, 1969). Persistence times reflect the time required for 75 to 100 percent disappearance of pesticide residues from the site of application. Nonpersistent pesticides have persistence values of 1 to 12 weeks; moderately persistent pesticides, 1 to 18 months; and persistent pesticides, two to five years. Persistence times vary with environmental conditions and the generalizations about the classes are subject to several exceptions by individual pesticides within the class (Figure 26–2).

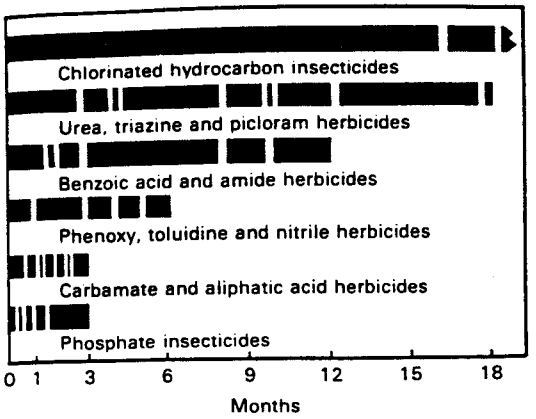

Figure 26–2. Persistence in soils of several classes of insecticides and herbicides. (From Kearney, P. C.; Nash, R. G.; and Isensee, A. R.: Persistence of pesticide residues in soils. In Miller, M. W., and Berg, G. G. [eds.]: *Chemical Fallout*. Charles C Thomas Pub., Springfield, Ill., 1969.)

Persistent Pesticides

Chlorinated Hydrocarbon Insecticides. This group of chemicals includes DDT, TDE (a major metabolite of DDT), methoxychlor, and related chemicals; the cyclodiene insecticides, aldrin, dieldrin, endrin, heptachlor, chlordane, mirex, and Kepone; the hexachlorocyclohexanes (commonly referred to as BHC) and the purified gamma isomer, lindane; and toxaphene. The technology, application, and biologic and environmental aspects of this class of insecticides have been authoritatively reviewed in a two-volume treatise by Brooks (1974). The persistence of pesticides in the environment has been the subject of numerous books and reviews.

DDT, its major metabolites, DDD (TDE) and DDE (which are collectively referred to as DDT-R), and dieldrin, which is both an insecticide and the major metabolite of the insecticide aldrin, are ubiquitous residues and the prime examples of persistent pesticides. Studies with DDT and dieldrin have elucidated several important concepts in environmental toxicology. First, persistence is not a desirable attribute as originally believed. Second, the transport and disposition of persistent pesticides is affected by physical and biologic processes, which occur from the micro to the global scale. Third, high lipid solubility combined with chemical and biologic stability can lead to biologic magnification of pesticide residues.

Persistence is primarily a function of physicochemical properties of substances. In addition, the sorption/desorption process is one of the important factors controlling the fate of pesticides in soils. Sorption of pesticides in soils has been reviewed by numerous authors (Goring, 1967; Bailey and White, 1970; Weber, 1972). Chlorinated hydrocarbon insecticides are highly soluble in lipids and most organic solvents, but have low water solubilities and relatively low vapor pressures. Studies of the adsorption of chlorinated hydrocarbons on various soils are difficult because of their low water solubility. However, studies with PCBs, which have many similar physicochemical properties to the chlorinated hydrocarbons, show that adsorption of the hydrophobic chlorinated hydrocarbons depends strongly on the presence of soil organic matter. Once adsorbed, these chemicals do not readily desorb. Two implications are readily apparent: (1) such compounds will not leach or diffuse in soils and (2) transport into the hydrosphere from contaminated soils will be through erosion of soil particles or sediment, not by desorption and dissolution. When chlorinated hydrocarbons are poorly adsorbed, as in sandy soils, the vaporization loss will be significant as compared to that in soils with higher organic matter.

Volatilization of pesticides into the atmosphere from water and soils is also a transport route. The volatility of a chemical from soil or water is a function of its vapor pressure, but the actual vaporization rate depends on several environmental parameters. Temperature, soil properties, soil water content, and other physicochemical properties such as water solubility and degree of adsorption affect the vaporization rate of pesticides from soil. Soil properties such as high organic matter that cause the pesticide to be strongly adsorbed reduce volatility greatly. The importance of soil moisture in volatilization of chlorinated hydrocarbons led to the use of the term "codistillation." DDT codistills with water in the laboratory (Acree *et al.*, 1963). However, the effect observed in soils is more adequately described as displacement of the sorbed pesticide by water molecules, plus a carrier action by water to the soil-air interface. The distribution of a pesticide between water and air is dependent on both water solubility and vapor pressure. As a result, compounds like DDT with very low water solubilities are quite volatile from water.

Degradation of the chlorinated hydrocarbons is quite slow as compared to the other classes of insecticides, and in soil and water is due mainly to the action of microorganisms. To a lesser extent, chemical reactions and photochemical reactions degrade the chlorinated hydrocarbons under certain conditions. A summary of the pathways for DDT emphasizes the importance of dechlorination and dehydrochlorination reactions. Oxidative reactions are only moderately important in this scheme. The formation of DDCN in sewage sludge and lake sediment is an

example of the unique reactions carried out by microorganisms. Epoxidations and rearrangement reactions are common among the cyclodiene insecticides. The most thoroughly studied of these reactions is the epoxidation of aldrin to dieldrin and heptachlor to heptachlor epoxide (Lichtenstein and Schulz, 1960). The rearrangement products are mainly complicated "caged" structures that are still toxic. The caged compounds mirex and Kepone undergo very little detectable degradation. Toxaphene and BHC are degraded initially by dechlorinations and dehydrochlorinations.

The bioaccumulation of the chlorinated hydrocarbons DDT and dieldrin is well documented by environmental residue data (Edwards, 1970). Bioaccumulation ratios relate organism residues to environmental residue levels and are higher in aquatic ecosystems as opposed to terrestial ecosystems (Table 26–3). The processes involved in bioaccumulation are quite complex owing to population fluctuations, food web relationships, metabolic capabilities of various species, and numerous other ecologic considerations. However, the physicochemical parameters of lipid solubility, low water solubility, and chemical stability, which characterize the chlorinated hydrocarbons, appear to be most important in bioaccumulation of organic pesticides.

It may be observed that the effects of bioaccumulation of DDT-R and dieldrin are manifest primarily at the tops of food chains. Predatory fish and birds suffer from acute toxicity, chronic toxicity, and reproductive failures. However, significant declines in organochlorine residues in eggs from brown pelicans have been associated with increases in eggshell thickness and reproductive success in a breeding population in South Carolina (Blus, 1982). Behavioral changes in DDT-treated fish have been demonstrated. Thus, the effects can range from obvious toxicity to subtle behavioral changes, but there is evidence that the population effects of these persistent pesticides are reversible with time.

Cationic Herbicides. The two chemicals of importance in this group are diquat and paraquat, which are used in conservation tillage farming. These compounds readily dissolve and dissociate in aqueous solution. As cations, they are strongly adsorbed to soil particles by cation exchange reactions (Weber, 1972):

Table 26–3. BIOCONCENTRATION OF DDT-R RESIDUES IN PLANTS OR ANIMALS FROM ITS ENVIRONMENT*

		(DDT-R RESIDUE IN ORGANISM DIVIDED BY RESIDUE IN ENVIRONMENT)	
ENVIRONMENT	PLANT OR ANIMAL ORGANISM	*Maximum Value Observed*	*Minimum Value Observed*
Soil	Earthworm	73	0.67
	Beetles	2.81	0.31
	Slugs	3.70	2.33
	Crop roots	0.13	0.04
	Crop foliage	0.08	—
Water	Sea squirt	1,000,000†	200†
	Sea hare	178,000†	—
	Eastern oyster, clam	70,000†	60
	Shrimp	2,800†	280
	Crabs	144	—
	Crayfish	97	17
	Snails	1,480†	—
	Plankton	16,666†	250
	Fish	829,300†	5–(1,450)†
	Fish (DDD)	9,214†	417
	Algae	33	0.34
	Aquatic plants	100,000†	0.45
Diet	Pheasant	2.91	—
	Woodcock	4.5	2.6
	Bald eagle		
	Brain	0.1	—
	Liver	1.9	—
	Fat	35.7	—

* Modified from Edwards, C. A.: *Persistent Pesticides in the Environment*. CRC Press, Cleveland, 1970.
† DDT may be present in excess of solubility in water.

$$\text{Paraquat}^{2+} + 2\text{Na-clay} \rightleftharpoons \text{Paraquat-clay} + 2\,\text{Na}^{+}$$

X-ray studies show that these planar molecules interlayer between the parallel silicate sheets of various clays. The adsorption behavior is also related to surface charge densities on various clays. Adsorption isotherms for these cationic compounds indicate a high affinity of the solute for the adsorbent until the cation exchange capacity is reached.

Paraquat and diquat as soil-bound residues are resistant to microbial degradation and photodecomposition. Tightly adsorbed residues are not biologically available and therefore persist indefinitely. In a field test begun in 1967 nearly all of the paraquat applied was still in the soil in 1973. Annual rate of loss was only 10 percent, which results in an estimated half-life in the field of 6.6 years (Hance *et al.*, 1980). Both diquat and paraquat are nonvolatile and are not transported in the vapor phase. Environmental transport is thus tied to sediment transport processes.

Moderately Persistent Pesticides

Triazine Herbicides. The triazines behave as weak bases in aqueous solution with pK_a values that range from 1.1 to 4.3. Water solubilities are therefore determined by the pH level, with the triazines being more soluble at low pH levels. The behavior and fate of triazines in soils has been extensively studied and reviewed (Gunther, 1970). Adsorption of triazines through an exchange process to organic matter and clay minerals is dependent on the pH of the solution and the acidity of the adsorbent surface. Hydrogen bonding and hydrophobic bonding are other mechanisms by which soil organic matter adsorbs triazine herbicides, especially at higher pH levels.

Hydrolysis and oxidation are the general routes of soil metabolism for triazine herbicides. Photodecomposition appears to be minimal on soils. Vapor transport losses of triazines are dependent on vapor pressure and pH of the evaporating surface, since ionized compounds are less volatile. Transport from soil to water occurs in solution and in sediments.

Considerable attention has been focused on the possibility that the observed decline in submersed aquatic vegetation in the Chesapeake Bay was caused by herbicide runoff from agricultural use. The compound of greatest concern was atrazine, one of the triazine herbicides extensively used in Maryland. Laboratory studies (Forney and Davis, 1981) and field measurements and observations (Forney and Davis, 1981; Wu, 1981), however, do not support the conclusion of a relationship between atrazine and the observed decline of the aquatic vegetation.

Phenylurea Herbicides. Between 20 and 25 different substituted phenylurea compounds are presently commercially available as herbicides for the control of annual and perennial grasses in a variety of crops. The phenylureas can be divided into three categories based on their water solubilities, which in turn seem to be related to a number of other properties that the groups have in common (Weber, 1972). Fenuron, the most water soluble of the phenylureas at approximately 2900 to 3850 ppm, is in a category by itself. This compound is also the most mobile in soil systems of all the phenylureas. Fenuron has been shown to move substantially in a lateral direction over the soil surface and in a vertical direction into the subsoil. Its movement is also related to soil texture and organic matter content. Movement was greater in coarse-textured soils and was decreased at higher organic contents.

The middle group of phenylureas in terms of water solubility includes monuron, diuron, linuron, monolinuron, fluometuron, metobromuron, norea, and siduron, in which water solubilities range from 18 to 580 ppm. Compounds in this category are moderately mobile in the soil; their relative movement decreases as the water solubilities decrease. Movement of the compounds also decreases as organic matter content of the soil increases, and in turn, the herbicidal activity of the phenylureas decreases as the compounds are bound to the soil organic matter.

The least soluble of the phenylureas are neburon and chloroxuron, where water solubilities range from 2.0 to 4.8 ppm. These compounds are rather immobile in the soil.

Most of the phenylurea compounds have relatively low vapor pressures and are not very volatile from the soil. Soil pH does not appear to significantly affect adsorption, mobility, or herbicidal activity of the phenylureas. The field persistence of these compounds is moderate, with residues remaining following application for several months at the longest.

The phenylurea herbicides are readily biotransformed by most biologic systems. The combination of their low mammalian toxicity and biodegradability leads to the conclusion that these compounds are not significant factors in the contamination of soil and water systems, and their significance as environmental pollutants seems to be minimal.

Substituted Dinitroanilines. The substituted dinitroanilines are an important group of herbicides, which include trifluralin, oryzalin, pen-

dimethalin, and related materials. These compounds are only slightly soluble in water, have generally low vapor pressures, and are relatively immobile in soil systems, remaining essentially where they are applied. They have been classed among the least mobile of the herbicides. Like many of the herbicides they appear to be readily adsorbed by soil organic matter. Compounds that were the most highly adsorbed were also the least available to growing plants and hence the least effective as herbicides. The dinitroanilines are considered to be moderately persistent herbicides in the soil. They are generally considered to have a very low degree of toxicity to mammals and are degraded in the environment to products without significant adverse effects on organisms.

Nonpersistent Pesticides

Phenoxy and Related Acidic Herbicides. A large group of compounds may be designated as acidic herbicides, since they are chemicals that possess carboxyl or phenolic functional groups and which ionize in aqueous systems yielding pK_a's of <4. The behavior of these chemicals is closely correlated with their acid character. The most significant factor with respect to mobility of these compounds is the organic matter content of the soil. Various adsorption studies have shown that the compounds are readily adsorbed by soil organic matter. Furthermore, in acidic systems these compounds are also adsorbed by clay particles. A number of these compounds are commercially available in either the acid form or as esters. The behavior of the esters might be expected to be considerably different from that of the acid forms.

Included within this group of herbicides are several important herbicide classes. The phenoxyacetic acids, including 2,4-D and its esters, were introduced following World War II for their high activity against many broad-leaved weeds. The chlorinated aliphatic acids include dalapon and trichloroacetic acid, compounds used against perennial weeds. The benzoic acid herbicides include chloramben, dicamba, diclobenil, and several other compounds. This is a very heterogeneous group of herbicides used for a variety of purposes. The dinitrophenols are a group of broad-spectrum herbicides, the most common of which is dinitro-*o*-cresol (DNOC).

Phenylcarbamate and Carbanilate Herbicides. The phenylcarbamate herbicides are much more water soluble than the substituted anilines. In spite of this, however, they are very immobile in soil systems. Again, these compounds have been shown to be inactivated by adsorption to soil organic matter. Compounds in this group include propham, chlorpropham, barban, terbutol, and dichlormate. The mechanism of adsorption to soil organic matter is thought to involve hydrogen bonding between the carboxyl groups of the organic matter and the nitrogen and carbonyl oxygen of the carbamate.

Ethylenebisdithiocarbamate Fungicides. The metal derivatives of the ethylene*bis*dithiocarbamates are one of the most important groups of fungicides currently used in agriculture. The principal compounds in this group are the manganese and zinc derivatives, maneb and zineb, and the disodium derivative, nabam (see Chapter 18). A closely related group is dithiocarbamates, represented by ferbam, ferric dimethyldithiocarbamate, and ziram, zinc dimethyldithiocarbamate. From a toxicologic standpoint these compounds have caused concern because of the common contaminant, degradation product, and metabolite, ethylenethiourea, a known carcinogen. This group is thoroughly considered in a two-volume treatise on antifungal compounds (Siegel and Sisler, 1977).

These compounds may be used as seed protectants and foliar fungicides. Only small quantities find their way into the soil, and once there, are rapidly degraded. In soil ethylenethiourea, ethylenethiuram monosulfide, CS_2, and H_2S result from treatment with nabam, zineb, and maneb. Ethylenethiourea is further degraded to ethyleneurea. Plants growing on treated soil will take up residues of ethylenethiourea, which are translocated and further biotransformed. The ethylene*bis*-dithiocarbamates decompose rather rapidly in water.

Because of the carcinogenic activity of ethylenethiourea, its residues found in soils, plants, and food are of concern. Although the residues of ethylenethiourea itself may be small, it has been shown that cooking vegetables containing residues of ethylene*bis*dithiocarbamates release ethylenethiourea. Hence, the toxicologic significance of residues of these chemicals in soil, once thought to be of little consequence, is now a matter of considerable attention.

Synthetic Pyrethroids. The synthetic pyrethroid insecticides are examples of optimized insecticidal activity, selectivity, and tailored environmental persistence. These compounds are modeled after natural pyrethrins, which possess the first two properties but are insufficiently stable under agricultural use conditions to be commercially viable. Through modifications of both the acid and alcohol portions of these esters (Figure 26–3) compounds of desired residual activity have been synthesized while maintaining the biodegradable ester linkage. Thus, this group of insecticides, which has been actively

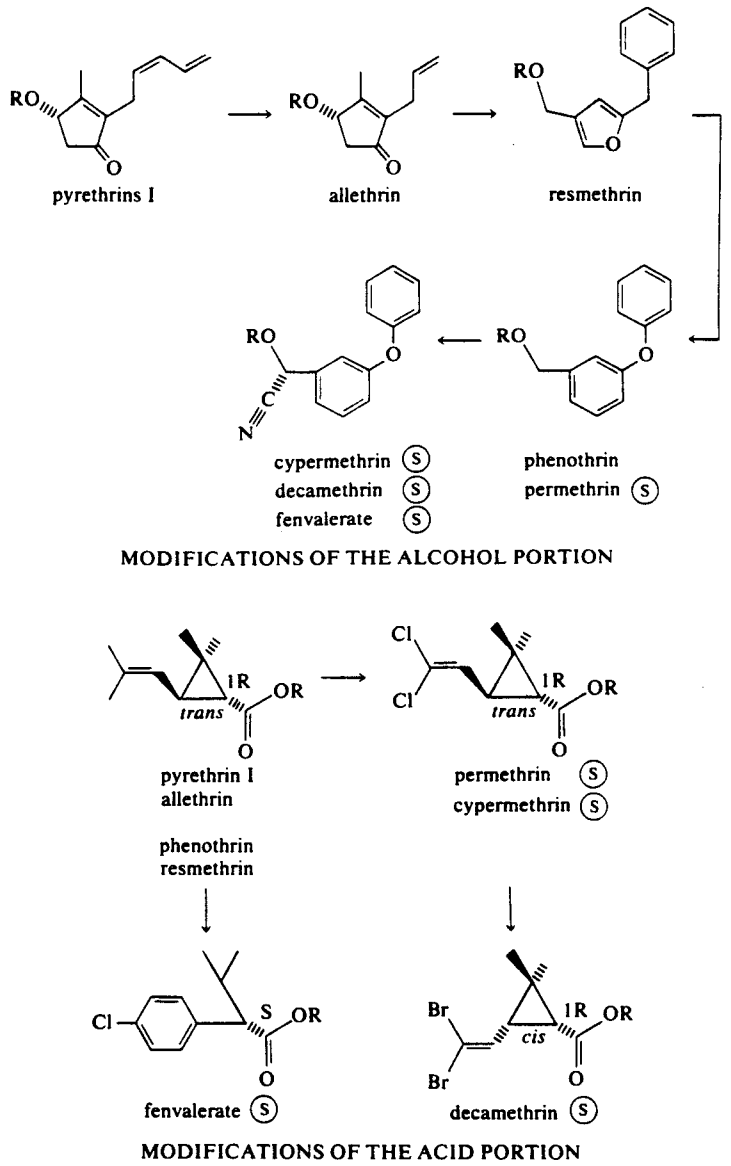

Figure 26–3. Development of synthetic pyrethroid insecticide structures leading to stable compounds ((S)) that can be used on field crops. (Modified from Elliot, 1977; Casida, 1980.)

researched since the mid-1970s, represents an enlightened approach to the tradeoff between environmental persistence versus residual activity. These compounds are generally very toxic to fish in laboratory aquarium bioassays. However, under field conditions the residues are tightly bound to sediment, and the toxicity is greatly reduced.

Organophosphorus and Carbamate Insecticides. In contrast to the persistent insecticides, particularly the chlorinated hydrocarbons, the organophosphorus and carbamate insecticides are relatively nonpersistent in the environment. They are typically applied to crops, sometimes directly to the soil as systemic insecticides, for the control of phytophagous pests. These chemicals generally persist from only a few hours through several weeks to months. Only in rare instances are organophosphorus or carbamate residues found in crops beyond the growing season during which they were applied. These chemicals have generally replaced the chlorinated hydrocarbon insecticides as the principal weapons in the arsenal of American agriculture against the invasion of the pests that compete with humans for food and fiber. More than half

(57 percent in 1971) of the total volume of insecticides applied in the United States is made up of members of this group of chemicals. These compounds have been comprehensively reviewed by Eto (1974) and Kuhr and Dorough (1976).

The organophosphates and carbamates used as insecticides are neutral esters of phosphoric and carbamic acids. A large number of these compounds representing a variety of chemical, physical, and biologic properties are presently in commercial use, allowing their specific application to be tailored to particular needs. They act as anticholinesterase agents by phosphorylating or carbamylating acetylcholinesterase freeing in the process a leaving group, which is generally easily further degraded (see Chapter 18). This reaction may take place as well in the environment by chemical or photochemical mechanisms. Thus, these compounds do not generally represent a serious problem as contaminants of soil and water. Their breakdown products are usually nontoxic, being composed of low-molecular-weight, volatile molecules that are easily degraded and utilized by organisms.

The rate of chemical and biochemical transformation of the organophosphorus and carbamate insecticides depends on the specific properties of the individual compounds. Some of these compounds are relatively soluble in water. Being esters, they are also susceptible to hydrolysis. The half-lives of a number of common organophosphorus insecticides at various temperatures and pH values are given in Table 26–4. Most organophosphorus and carbamate compounds are stable at acid pH values. However, under alkaline conditions hydrolysis is rapid, the breakdown rate increasing approximately tenfold for each pH unit above 7. An increase of 10° of temperature will increase the hydrolysis rate approximately fourfold (Mühlmann and Schrader, 1957).

Organophosphorus and carbamate insecticides may contaminate soils by either direct application or through runoff from applications to crops. When these compounds are present in the soil, their disappearance is influenced by their interaction with the physical characteristics of the soil, the water content of the soil, and the microflora present. They may be tightly bound in certain types of soils, even to the point where they are unavailable for biologic decomposition. Under such conditions very little movement takes place even though water may be running through the soil or over its surface. The combination of interaction with soil components and rapid chemical and biochemical degradation in the soil results in minimal contamination of water supplies and soil to which compounds have not been applied.

A notable exception to this generalization was the discovery that the carbamate insecticide aldicarb has leached into the ground water aquifers that constitute the major source of drinking water on Long Island, New York. This acutely

Table 26–4. EFFECT OF TEMPERATURE AND pH ON THE HYDROLYSIS IN WATER OF SOME ORGANOPHOSPHORUS INSECTICIDES*

TEMP. (°C)†	HALF-LIFE						
	Parathion	*Paraoxon*	*Methyl Parathion*	*Disulfoton*	*Trichlorofon*	*Dichlorvos*	*Azinphos-methyl*
Days							
10	3,000	1,200	760	4,830	2,400	240	1,070
20	690	320	175	1,110	526	61.5	240
30	180	93	45	290	140	17.3	61.5
40	50	29	12.5	78	41	5.8	18
50	15	9.6	4.0	24	10.7	1.66	5.46
60	4.75	3.2	1.34	7.8	3.2	0.58	1.9
70	1.65	1.2	0.47	2.7	1.13	0.164	0.61
Hours							
70							
pH 1	34	18.5	15.4	62	32	2.3	24
3	21	23	11.2	62	33	3.4	9
5	19.5	24.4	10.7	60	15.3	2.8	8.9
7	7.8	11.5	6.9	27.6	0.7	0.45	4.8
9	2.7	2.1	1.5		0.1		

* Data from Mühlmann, R., and Schrader, G.: Hydrolyse der insektiziden Phosphorsäureester. *Z. Naturforsch.*, **12b**:196–208, 1957.

† At pH 1 to 5.

toxic compound provided effective control of potato insects, but the particularly sandy, porous soil and the climactic conditions on eastern Long Island resulted in its unexpected movement through the soil into ground water. Estimates of the length of time during which aldicarb would be present in the ground water above the New York State advisory guideline of 7 ppb range up to 20 years (Cornell University, 1983), although the estimates are based on models whose reliability has not been thoroughly tested and on monitoring data that are incomplete. Subsequently, aldicarb has been found in ground water in other locations.

The detection of organophosphorus and carbamate insecticides in soil can be difficult. Their interaction with soil components renders them unavailable to exert their toxic action on organisms and makes them difficult to remove by conventional solvent extraction techniques. Hence, methods that depend on removal of residues from soil particles often underestimate the presence of these compounds. The analysis of organophosphorus and carbamate residues in water, on the other hand, is relatively uncomplicated and easily done. Extraction of large quantities of water with organic solvents and subsequent analysis provides a very sensitive assay for small quantities of organophosphorus and carbamate insecticides in water, although other water pollutants may complicate the analyses when they are coextracted with the insecticide.

When organophosphates or carbamates reach the soil, their subsequent disposition is influenced by interaction with the mineral components of the soil, soil organic matter, soil pH, and soil moisture. In addition, the flora and fauna present in the soil are responsible for the degradation of these insecticides into innocuous breakdown products. After treatment of soil with organophosphorus compounds in laboratory or controlled field studies, extraction of the material from the soil is increasingly difficult as time progresses (Duff and Menzer, 1973; Menzer *et al.*, 1971).

The persistence of these compounds is, at least in part, a function of interactions with the mineral components of soil. Metallic ions in soils interact with organophosphorus insecticides. Malathion, for example, is quickly incorporated into the montmorillonite clay interlayer region, where it is adsorbed as a double layer. The mechanism was shown to be hydrogen binding between carbonyl oxygen atoms and the hydration water shells of cations. In this case adsorption was so strong that no degradation of the malathion was observed (Bowman *et al.*, 1970). Similarly, Saltzman and Yaron (1972) have shown a strong affinity of parathion for sodium montmorillonite. On the other hand, diazinon and chlorpyrifos were decomposed rapidly on contact with copper(II)-montmorillonite (Mortland and Raman, 1967).

Binding of organophosphorus and carbamate insecticides correlates well with the organic matter content of soils (Edwards, 1966). It has been shown, for example, that the amount of mevinphos bound by soils increased with increasing organic matter content. Furthermore, the absorption of phorate from the soil by plants appeared to be in competition with the binding of the compound with the organic matter content of the soil.

In a kinetic study of the adsorption of carbaryl to soil organic matter surfaces, Leenheer and Ahlrichs (1971) found that carbaryl was more readily adsorbed to acid soils than to neutral or alkaline soils. This may be due to decreased displacement of the carbamate from the active sites by water at lower pH values.

Soil moisture has a major influence on the availability and extractability of residues of organophosphorus and carbamate insecticides, apparently because of competition between the insecticides and water for the adsorption sites on the soil particles. Harris (1964) has shown, for example, that diazinon, parathion, trichlorfon, and mevinphos are 135-fold, 28-fold, 20-fold, and 1.4-fold, respectively, more active in moist soils than in dry soils. Analytic procedures for the recovery of residues from soils generally recommend the addition of water for the desorption of the residues from soil particles before extraction with an organic solvent. However, even though there is a major interaction between these insecticides and water, they do not appear to move freely in soils with water, and loss by leaching does not appear to be a major factor in the disappearance of these compounds from soils, with some notable exceptions.

The fact that microorganisms exert a major influence on the behavior of pesticide residues in soil has been demonstrated by observing the effect of soil sterilization on the breakdown of a number of compounds. Getzin (1968) showed that zinophos degraded faster in nonautoclaved soil, although the decomposition of diazinon was unaffected by autoclaving. Getzin and Rosefield (1968) showed that malathion, Ciodrin, dichlorvos, mevinphos, parathion, methyl parathion, Supracide, dimethoate, and chlorpyrifos were all degraded faster in nonsterile soils. Lichtenstein *et al.* (1968) showed that both sodium azide treatment and autoclaving reduced soil bacteria and resulted in an increased persistence of parathion. Bro-Rasmussen *et al.* (1968) reported that sterilization extensively affected diazinon degradation in loam and sandy loam

soils. The effect of sterilization of soil on pesticide degradation may appear to be somewhat ambiguous because of changes other than the destruction of soil microorganisms that would have an effect on the degradation of compounds applied. In general, however, there is at least strong evidence that microorganisms exert a major influence on the degradation of pesticides in soils.

There is little data on the effects of organophosphates and carbamates on organisms living in water and soil. In general, only minute amounts of residues of the insecticides and their toxic degradation products are found in natural water systems. Thus, their biologic effect seems to be minimal. In soil, however, there is greater likelihood of the presence and buildup of toxic residues. Several studies have shown that some compounds can cause reduction in bacterial populations. Garretson and San Clemente (1968) showed that parathion inhibited nitrifying chemolithotrophic bacteria, although malathion did not. Sommer (1970) showed that organophosphates had little effect, while carbamates markedly inhibited nitrification. In studies to assess the effect of diazinon on soil microorganisms Gunner and co-workers (Gunner *et al.*, 1966; Gunner, 1970) showed that the compound exerted a selective effect on both soil and rhizosphere microflora expressed as selective enrichment of coccoidal rods. In another instance the microflora that arose in response to diazinon belonged primarily to one species of *Arthrobacter*. Similar results were obtained by Stojanovic *et al.* (1972) with carbaryl as the test insecticide. Various studies show that these insecticides may cause a variety of effects on the soil flora and fauna not always expressed as directly toxic effects.

Glyphosate. This compound is an important nonselective, postemergence herbicide for control of deep-rooted perennial species and some biennial and annual grasses. It is very mobile in soil and water and is readily translocated in plants, even downward (Marquis *et al.*, 1981), as demonstrated in Sago pond weed when the compound applied to the shoots was translocated to the roots. Even at low temperatures, glyphosate is degraded in soil (Mueller *et al.*, 1981) and would not be expected to persist from one growing season to the next.

NONPESTICIDAL ORGANIC CHEMICALS

In a continuing data-gathering program, the U.S. Environmental Protection Agency monitors organic chemicals in the drinking water of the United States. The list was begun in 1973; 253 different organic chemicals were detected through November 1975. In an updated report issued in 1976, the number had increased to 309; in 1978, the number was over 700. Undoubtedly the number will continue to increase as monitoring programs increase in their sophistication and extent of coverage. The list of chemicals detected includes both aliphatic and aromatic hydrocarbons, pesticides, industrial chemicals, plasticizers, and solvents. Many of these materials are halogenated, and some are produced by chlorination of the water during the purification process, including trihalomethanes and halogenated carboxylic acids (Johnson *et al.*, 1982). Others appear through industrial and municipal discharges, urban and rural runoff, natural sources, and sewage purification practices.

The principal objective of the nationwide survey of organic chemicals in drinking water made by the Environmental Protection Agency is to determine the extent and significance of the occurrence of suspected carcinogens in water (Symons *et al.*, 1975). These data were considered in a series of reports on the potential health effects of chemicals in drinking water that have been produced by the National Academy of Sciences (National Research Council, 1977–83) under mandate of the Safe Drinking Water Act of 1974.

Low-Molecular-Weight Halogenated Hydrocarbons

Of particular concern is the production of low-molecular-weight chlorinated hydrocarbons through the use of chlorination for water purification. This concern focuses principally on the four trihalomethanes, chloroform, bromodichloromethane, dibromochloromethane, and bromoform; and carbon tetrachloride and 1,2-dichloroethane. A study was conducted by the Environmental Protection Agency to ascertain the presence of these chemicals in water, and whether they were produced by chlorination. A National Organics Reconnaissance Survey (NORS) was conducted in November 1974 for this purpose (Symons *et al.*, 1975) and was followed by the National Organics Monitoring Survey (NOMS) in 1976 (Brass *et al.*, 1977). The results are summarized in Table 26–5. It was noted that all of these materials were found in drinking water and most were found in the raw water before chlorination. Several conclusions can be drawn from these and subsequent studies (National Research Council, Vol. 3, 1980). Chloroform, bromodichloromethane, dibromochloromethane, and bromoform do result from chlorination of precursors, particularly naturally occurring humic substances, in the raw water. On the other hand, carbon tetrachloride, meth-

Table 26–5. ORGANICS DETECTED IN WATER IN THE EPA NATIONAL ORGANICS RECONNAISSANCE SURVEY*

COMPOUND	RAW WATER ANALYSIS		FINISHED WATER ANALYSIS		
	No. of Locations Where Detected	*Concentration Range (μg/l)*	*No. of Locations Where Detected*	*Concentration*	
				Range (μg/l)	*Median*
Chloroform	49	<0.1–0.9	80	<0.1–311	21
Bromodichloromethane	7	<0.2–0.8	78	0.3–116	6
Dibromochloromethane	1	3	72	<0.4–110	1.2
Bromoform	0	—	26	<0.8–92	5
Carbon tetrachloride	4	<2–4	10	<2–3	—
1,2-Dichloroethane	11	<0.2–3	26	<0.2–6	—

* Data derived from *Preliminary Assessment of Suspected Carcinogens in Drinking Water. Report to Congress.* U.S. Environmental Protection Agency, Washington, D.C., 1975.

ylene chloride, and 1,2-dichloroethane do not appear to be produced chemically during the treatment process. Raw water with low turbidity generally yields finished water low in trihalomethanes. There appears to be a correlation between chloroform, dibromochloromethane, bromodichloromethane, and bromoform concentrations. The ratio between the four chemicals appears to be relatively constant in all waters examined, indicating the probability of a common precursor or group of precursors for these halogenated hydrocarbons.

Studies have been conducted to compare the rate and extent of trihalomethane formation when chlorine was added to raw river water, filtered water, and activated-carbon treated water (National Research Council, Vol. 3, 1980). When sufficient chlorine is added to satisfy the chlorine demand, chlorination of raw river water yields approximately seven times as much chloroform as chlorination of filtered water and approximately 80 times as much as chlorination of activated carbon-treated water. Concentrations of humic materials are probably reduced during coagulation, settling, and filtration, thereby reducing the rate and extent of chloroform formation by chlorination. Thus, it may be possible to reduce the quantity of chlorinated hydrocarbons formed during chlorination by altering the water purification process so that chlorination is performed following the removal of humic materials through filtration and coagulation steps.

As yet, there is no generally accepted substitute for the use of chlorine as a disinfectant in water purification. However, the confirmation that chlorination produces a number of halogenated hydrocarbons has stimulated an extensive investigation of other chemicals that could be used for this purpose, such as chloramines, chlorine dioxide, ozone, bromine, and iodine (National Research Council, Vol. 3, 1980).

Concern about low-molecular-weight halogenated hydrocarbons in drinking water came to public attention in the mid-1970s when it was reported that the drinking water supply of New Orleans, Louisiana, contained more chlorinated hydrocarbons than untreated Mississippi River water (Dowty *et al.*, 1975). In addition, these workers reported the presence of chlorinated hydrocarbons, including carbon tetrachloride, in blood plasma collected from human volunteers in New Orleans. Following that report, Page *et al.* (1976) reported a statistical correlation between the incidence of certain types of cancer among the New Orleans population and the source of the water supply. While later studies (Gottlieb *et al.*, 1982) have not confirmed all of the earlier conclusions with respect to cancer incidence, a case-control cancer mortality study showed a definite association between surface chlorinated water in southern Louisiana and significant risk of rectal cancer. No increased risk of colon cancer and no effect on bladder cancer from water was detected. There was a significant association between chlorine levels in water and breast cancer incidence. A similar case-control study was conducted to determine the possible association of drinking water with cancer incidence in Wisconsin (Kanarek and Young, 1982). It was concluded that colon cancer in Wisconsin was related to the combination of chlorination and organic contamination. Chlorinated ground water was also responsible for elevated colon cancer. Presently, it is generally accepted that it is highly likely that there is a relationship between rectal, colon, and bladder cancer and water quality (Crump and Guess, 1980; Cantor, 1982). However, it appears that the increases in cancer risks lie near the lower limit of what can be reliably detected by epidemiologic methods. Clearly, however, there is cause for concern about the exposure of a very large percentage of the population to these chemicals in drinking water.

In addition to the possibility of a relationship between trihalomethanes and cancer, there is also concern about other chronic effects of these chemicals in drinking water. Studies in mice (Munson *et al.*, 1982) have shown increased liver weights, elevations of SGOT and SGPT, decreased spleen weights, and a decreased number of splenic IgM antibody-forming cells in a 14-day gavage treatment at one-tenth of the LD50 dose. The enzyme changes, however, were not observed in a 90-day study, indicating that there may be the development of tolerance to the chemicals over a longer term of exposure.

Aromatic Halogenated Hydrocarbons

In recent years a number of halogenated aromatic compounds have engendered increasing concern about their effects as environmental pollutants. The polychlorinated biphenyls (PCB) have appeared as ubiquitous contaminants of soil and water. Chlorophenols used for a variety of purposes have been detected in surface waters and drinking water. The extremely toxic 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) has contaminated large areas of both water and soil through industrial accidents, improper waste disposal, wide-scale application of herbicides containing small quantities of the chemical as a contaminant, and as a trace byproduct of combustion.

Polychlorinated Biphenyls. PCBs are very stable materials of low flammability, which contain from 12 to 68 percent chlorine. They are exceptionally persistent in the environment, some even more persistent than the chlorinated hydrocarbon insecticides, with which they often have been confused in analytic studies of environmental samples. They have been used as insulating materials in electrical capacitors and transformers, plasticizers in waxes, in paper manufacturing, and for a variety of other industrial purposes. The diversity of their use patterns, the large quantities used, and their stability has led to widespread occurrence of these compounds in soil and water. Fish from the upper Hudson River and Lake Ontario have been found to contain PCB concentrations from 5 to 20 ppm. Fish from a number of other rivers throughout the United States have also been found to contain comparable quantities of PCBs. Waterfowl have also accumulated high concentrations of PCBs. These examples of PCB pollution have occurred in spite of efforts to restrict and eventually eliminate the release of such compounds into the environment.

The health effects of PCBs are well established. Investigations have shown that PCBs interfere with reproduction in phytoplankters (Masser *et al.*, 1972). Other observed effects in mammals and birds include microsomal enzyme induction, porphyrogenic action, tumor promotion, estrogenic activity, and immunosuppression (Bitman 1972; Vos, 1972). Other adverse effects are possible since the PCBs are lipophilic, a property, along with their stability, that leads to bioaccumulation and the possibility of long-term effects that have not been completely identified.

Chlorophenols. Pentachlorophenol has been used in significant quantities since 1936 as a wood preservative. As a result of this use surface water and treated drinking water have been found to contain as much as 0.70 and 0.06 ppb, respectively, pentachlorophenol (Buhler *et al.*, 1973). Hexachlorophene 2,2′-methylene-*bis*-(3,4,6-trichlorophenol) has been widely used as an antibacterial agent in a number of consumer products, including soaps and deodorants. It has been detected in surface waters as high as 48 ppb and in drinking water at 0.01 ppb (Buhler *et al.*, 1973). Hexachlorophene is resistant to biotransformation and tends to persist in the environment and bioaccumulates in food chains (Sims and Pfaender, 1975).

Pentachlorophenol has a fairly high acute toxicity and has been shown to cause reproductive failures in rats. The acute toxicity of hexachlorophene is also quite high. The compound has exhibited neurotoxicity in dogs, sheep, and rats. One of the concerns about these chemicals is their possible contamination by the very toxic polychlorinated dibenzo-*p*-dioxins and dibenzofurans. The presence of these chemicals and their contaminants in water needs to be closely monitored because of their high toxicity and the possibility of adverse health effects in man.

2,3,7,8-Tetrachlorodibenzo-*p*-dioxin. What was probably the most dramatic and catastrophic occurrence of environmental pollution by a toxic chemical occurred in Seveso, Italy, July 10, 1976. On that date a safety disk in a reaction vessel being used to manufacture 2,4,5-trichlorophenol, an intermediate in the production of hexachlorophene and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), ruptured, releasing a chemical cloud over the region. The cloud contained predominantly 2,4,5-trichlorophenol. However, an estimated 3 to 16 kg of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD, also improperly called simply "dioxin"), a potent teratogen, was also released. The area was thus contaminated with the greatest concentration of TCDD ever found in the environment, up to 51.3 ppm in some samples.

TCDD is extremely toxic to some animal species as indicated by its acute oral LD50 reported between 0.6 and 115 μg/kg (National Research Council, 1977). It causes degenerative changes

in the liver and thymus, chloracne, porphyria, altered serum enzyme concentrations, loss of body weight, induction of microsomal enzymes, and is a potent carcinogen in rats. Thymic atrophy is a very sensitive index of TCDD exposure in many animals while chloracne is the most prominent symptom for human exposures. To date, there have been no known human deaths from TCDD exposure.

The significance of TCDD as an environmental pollutant lies in (1) its extreme biologic potency and potential chronic effects, (2) the ability of analytic methods to detect trace quantities of TCDD in environmental samples, and (3) the inability of toxicologists to agree on the significance of exposure to these trace residues. Confounding the scientific questions are the emotional aspects of unknowing exposure to TCDD through Agent Orange spraying in Vietnam, TCDD-contaminated soils in Times Beach, Missouri, and industrial accident exposure in Seveso, Italy. Indeed, TCDD has become a household word, much like DDT in the 1960s.

Phthalate Ester Plasticizers

The phthalate ester plasticizers are used in virtually every major product category, including construction, automotive, household products, apparel, toys, packaging, and medical products, resulting in the widest possible distribution of these materials. The industry today comprises ten major suppliers who produce approximately 1 billion pounds of over 25 different compounds. The two most abundantly produced phthalate ester plasticizers are di-2-ethylhexylphthalate (DEHP) (400 million pounds in 1977) and di-*n*-butylphthalate (DBP).

The phthalate esters are now known to be ubiquitously distributed in the environment. They have been found complexed with the fulvic acid components of humic substances in soil (Ogner and Schnitzer, 1970) and in both marine and estuarine waters. Fulvic acid apparently functions as a solubilizer for the rather insoluble phthalate esters and thus serves to mediate the mobilization, transport, and immobilization of these materials in soil and water. Hites (1973) reported the presence of phthalate esters in the Charles and Merrimack Rivers in Massachusetts. In the Charles River, concentration of phthalate esters at river mile 7 was approximately 1.9 ppb, while at the mouth of the river concentrations had decreased to 0.97 ppb. In another study (Giam *et al.*, 1978), phthalate ester plasticizers were detected in the open ocean environment of the Gulf of Mexico and the North Atlantic. DEHP and DBP were found in almost all samples analyzed, including a deep-sea jellyfish, *Atolla*, from 1000-m depths in the North Atlantic (Morris, 1970), Atlantic herring, and mackerel (Musial *et al.*, 1981). Concentrations of DEHP in surface water ranged from 4.9 to 130 ng/liter. DBP ranged from a nondetectable level to 95 ng/liter. Lower levels of both compounds were found in sediment. It has become clear that the phthalate ester plasticizers are general contaminants of virtually all soil and water ecosystems; it has become very difficult to analyze any soil or water sample without detecting the presence of phthalate esters.

Because of the widespread occurrence of these compounds, their toxicity is of concern. In general, the phthalate esters have low acute toxicity. The intraperitoneal LD50 dose in mice ranges from 1.5 to 14.2 g/kg (Rubin and Jaeger, 1973). Ninety-day and two-year feeding studies of DEHP in rats and one-year feeding studies in guinea pigs and dogs indicated a low order of chronic toxicity. However, recent studies have demonstrated the carcinogenicity of DEHP in Fischer 344 rats and B6C3F1 mice. At both the maximally tolerated dose and one-half of the maximally tolerated dose, liver tumors were produced in both sexes (Kluwe *et al.*, 1982a, 1982b, 1983). A conference on phthalates, convened in 1981, evaluated these results and concluded that the weight of evidence on the carcinogenicity of DEHP was very strong (Conference on Phthalates, 1982). At the conference it was also noted that the experiments reported prior to the report of Kluwe and co-workers were not properly designed to permit the evaluation of the carcinogenicity of phthalates in mice or rats (Wilbourn and Montesano, 1982). It has also been pointed out that much more testing is desirable on this class of compounds; the report on carcinogenicity did not permit an analysis of the mechanism, which appeared to be nongenetic. There is obviously a need for further testing of other phthalates as well.

Other subtle chronic toxic effects of DEHP have been reported (Rubin and Jaeger, 1973). As little as 4 μg/ml in the culture medium was lethal to 97 to 98 percent of cultured beating chick embryo heart cells. This concentration could be reached in human blood stored in vinyl plastic bags for a period of one to two days. Considerable interest in the chronic toxicity of low levels of phthalate esters has been evident over the last several years. The reader is referred to a series of papers on a number of possible toxic effects published in Volume 45 of *Environmental Health Perspectives* (1982), which were reported at the 1981 Conference on Phthalates.

Data reported by Mayer and Sanders (1973) indicate that DEHP and DBP may also be detrimental to the reproduction of some aquatic organisms at low concentrations. *Daphnia magna*

reproduction was decreased by approximately 80 percent by continuous exposure of 30 $\mu g/l$ DEHP for up to 21 days. Reproduction in zebra fish and guppies was also decreased by low concentrations of DEHP.

Although the concentrations of phthalate esters in soil and water are quite low, the recent report of carcinogenicity and the continuing reports of the ubiquitous presence of residues in the environment led to concern about the potential for human health effects. Because phthalates have been found to occur in drinking water in the United States (Brass *et al.*, 1977) and are present in food, that concern is reinforced.

METALS

The toxicology of metals, including their use, occurrence, and effects, has already been presented in Chapter 19. In this section we will deal only with some aspects of the natural cycles of elements and conditions that alter the process involved. It is necessary to limit this treatment to the best-studied examples of environmentally important elements: mercury, cadmium, lead, arsenic, and selenium. (Note: arsenic and selenium are not metals, but the term will be used to include these metalloids.)

Mercury. Methyl mercury pollution of Minimata Bay and the subsequent human poisoning from consumption of contaminated seafood has stimulated much research on the origin and fate of methyl mercury. An important theme throughout the discussion of metals is the question of chemical species. Mercury, for example, exists in the inorganic form as free mercury, Hg°, mercury ion in salts and complexes, Hg^{2+}; or as organic mercury compounds, such as phenylmercuric salts, which have been used as fungicides and herbicides, and the alkyl-mercury compounds including methyl mercury. In natural systems, a dynamic equilibrium that is determined by the physiochemical and biologic conditions of the soil-water system exists between the various chemical species. Some organic forms of mercury are man-made, such as the phenylmercuric compounds, while methyl mercury is produced by humans, sediment microorganisms, nonbiologically in sediments, and possibly by some fish. As expected, each species of mercury has its own set of physical, chemical, and toxicologic properties.

Mercury is transported to aquatic ecosystems via surface runoff and through the atmosphere. It is complexed or tightly bound to both organic and inorganic particles. Sediments with high sulfur content will strongly bind mercury. Organic acids such as fulvic and humic acid are usually associated with the mercury that is not bound to particles.

Methylation of mercury by microorganisms is a detoxication response that allows the organism to dispose of heavy metal ions as small organometallic complexes. Conditions for methylation by sediment microorganisms are strict and occur only within a narrow pH range. The rate of synthesis of methyl mercury also depends on the redox potential, composition of the microbial population, availability of Hg^{2+}, and temperature. Vitamin B_{12} derivatives are believed to be the methylating agents, since mechanistically they are the only methyl carbanion and methyl radical donating coenzymes known (Ridley *et al.*, 1977). An understanding of the biomethylation reaction mechanisms together with oxidation-reduction chemistry of elements allows predictions of the environmental conditions necessary for the biomethylation of mercury and several other metals. However, the best conversion rate for inorganic mercury to methyl mercury under ideal conditions is less than 1.5 percent per month (Jensen and Jernelov, 1969).

Little or no methyl mercury is found in sediments. Conversion of inorganic mercury to methyl mercury results in its desorption from sediment particles at a relatively fast rate. Demethylation by sediment microorganisms also occurs at a rapid rate when compared to methylation. Methyl mercury released in surface waters can undergo photodecomposition to inorganic mercury. However, methyl mercury can also be bioaccumulated by plankton algae and fish. In fish, the rate of absorption of methyl mercury is faster than that for inorganic mercury, and the clearance rate is slower with a net result of high methyl mercury concentrations in the muscle tissue. Selenium, which is present in seawater and seafood, readily complexes with methyl mercury and is believed to have an important protective action against the toxic effects of methyl mercury. In summary, the danger of methyl mercury poisoning, as occurred in Minimata, arises from direct methyl mercury contamination rather than methylation of environmental sources of inorganic mercury.

Cadmium. Cadmium has long been recognized as a toxic element. Its importance as an environmental contaminant was demonstrated in the outbreak of itai-itai disease caused by smelter wastes that contaminated rice paddies in Japan (see Chapter 19). Cadmium deposits are found as sulfides with zinc, copper, and lead deposits, and cadmium is recovered as a byproduct of smelting processes for those metals. A major environmental source of cadmium is vapor emissions that contaminate surrounding

soil and water through fallout during smelting. Natural soil concentrations of cadmium are less than 1 ppm and average about 0.4 ppm. Sewage sludge is often contaminated with cadmium, which then concentrates in plants grown on contaminated soils. The problem of heavy-metal contamination, especially cadmium, has been one of the most serious concerns impeding the use and disposal of domestic sewage sludge on agricultural lands. Cadmium also enters agricultural soils as a contaminant of phosphate fertilizers. There is some evidence for the leaching of cadmium in soils.

Among the metals, cadmium is one of the most readily absorbed and accumulated in plants grown on contaminated soil. The significance of this phenomenon is readily apparent in the relationship of cadmium concentrations in rice with the incidence of itai-itai disease. Although there is some question about the specific etiology of this disease, there is ample evidence from many studies of a positive correlation between rice cadmium content and the incidence of the disease in Japan (see, for example, Nogawa *et al.*, 1982, 1983).

Cadmium concentrations in fresh waters are usually less than 1 ppb, while concentrations in seawater range from 0.05 to 0.2 ppb and average about 0.15 ppb (Fleischer *et al.*, 1974). Higher concentrations of cadmium in surface water are usually due to metallurgical plants, plating operations, cadmium pigments, batteries, plastics manufacture, or from sewage effluent. Mine drainage and mineralized areas also contribute significantly to cadmium fluxes in the Mississippi River in the Missouri-Tennessee-Kentucky area.

Drinking water in soft-water areas can serve as a source of cadmium through corrosion of plumbing. However, this source is estimated to be small in relation to food intake. As in the association of selenium and mercury, there appears to be a protective effect with zinc and calcium against cadmium toxicity.

Lead. The use of lead, its mining, and its processing date back several centuries. Changing usage patterns rather than increased consumption determine present environmental inputs from man's use of lead. Batteries, gasoline additives, and paint pigments are major uses, but combustion of gasoline additives is the major source of environmental pollution by lead. Thus, lead is primarily an atmospheric pollutant that enters soil and water as fallout, a process determined by physical form and particle size. The net result is a buildup of lead near heavily traveled roads. In a study in Massachusetts, there was a close concordance between the use of leaded gasoline and umbilical cord blood lead levels. This suggests that further reductions in leaded gasoline usage would result in lower human exposure levels (Rabinowitz and Needleham, 1983).

Lead enters aquatic systems from runoff or as fallout of insoluble precipitates and is found in sediments. Typical fresh-water concentrations lie between 1 and 10 μg/l while natural lead concentrations in soil range from 2 to 200 ppm and average 10 to 15 ppm. Deep ocean waters, below 1000 m, contain lead at 0.02 to 0.04 μg/kg concentrations, but surface waters of the Mediterranean Sea and Pacific Ocean contain 0.20 and 0.35 μg/kg levels (National Academy of Sciences, 1972). Drinking water concentrations of lead may be greatly increased in soft-water areas through corrosion of lead-lined piping and connections. However, average drinking-water intake is considerably less than food sources.

The biologic methylation of inorganic lead to tetramethyl lead by lake sediment microorganisms has been demonstrated (Wong *et al.*, 1975), but the significance of this observation remains unknown. It has not been possible to detect tetramethyl lead, trimethyl lead, or dimethyl lead in sediments or water that have high lead levels.

Arsenic. Arsenic is widely distributed in the environment. Man's input of arsenic into the global cycle occurs through smelting, coal burning, and the use of arsenical pesticides. Speciation of arsenic is an important consideration in the fate, movement, and action of this element. The chemical and biochemical transformations of arsenic include oxidation, reduction, and methylation, which affect the volatilization, adsorption, dissolution, and biologic disposition of the arsenic species involved.

Arsenic contamination of soils from point sources such as copper smelters or coal-burning power plants is easier to control than the dispersive use of arsenical pesticides, resulting in nonpoint-source pollution. Various forms of arsenic are used as pesticides. Chromated copper arsenate continues to grow in usage as a wood preservative (Fitzgerald, 1983). Arsenic acid (H_3AsO_4) is a leaf desiccant used in cotton production, lead and calcium arsenates were used as insecticides, and organic arsenicals, which include methanearsonic acid and its sodium salts as well as dimethyl arsenic acid (cacodylic acid), are used as postemergence herbicides. The transport of arsenic in the environment is largely controlled by adsorption/desorption processes in soil and sediments. Therefore, sediment movement is responsible for transfer of arsenic soil residues to their ultimate sinks in deep

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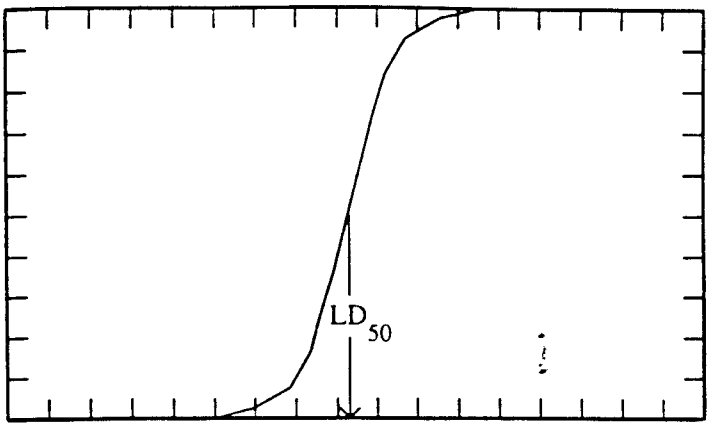

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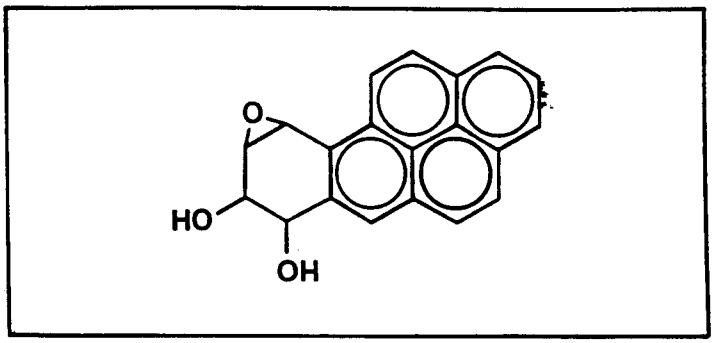

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Manahan 1989
ER ID 59377

Library of Congress Cataloging-in-Publication Data

Manahan, Stanley E.
Toxicological chemistry

Bibliography: p.
Includes index.
1. Toxicological chemistry I. Title.
RA1219.3.M36 1988 615.9'00154 88-25552
ISBN 0-87371-149-1

Third Printing 1990

Second Printing 1989

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LEWIS PUBLISHERS, INC.
121 South Main Street, Chelsea, Michigan 48118

PRINTED IN THE UNITED STATES OF AMERICA

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Professor Manahan has written books on environmental chemistry, applied chemistry and quantitative chemical analysis. He has been the author or co-author of approximately 70 research articles.

Vanadium

Vanadium (V) is a transition metal with an electron configuration of $\{Ar\}4s^2 3d^3$. In the combined form it exists in the +3, +4, and +5 oxidation states, of which the +5 is the most common. Vanadium is of concern as an environmental pollutant because of its high levels in residual fuel oils and subsequent emission as small particulate matter from the combustion of these oils in urban areas. Vanadium occurs as chelates of the porphyrin type in crude oil and it concentrates in the higher boiling fractions during the refining process. A major industrial use of vanadium is in catalysts, particularly those in which sulfur dioxide is oxidized in the production of sulfuric acid. The other major industrial uses of vanadium are for hardening steel, as a pigment ingredient, in photography, and as an ingredient of some insecticides. In addition to environmental exposure from the combustion of vanadium-containing fuels, there is some potential for industrial exposure.

Probably the vanadium compound to which people are most likely to be exposed is vanadium pentoxide, V_2O_5. Exposure normally occurs via the respiratory route, and the pulmonary system is the most likely to suffer from vanadium toxicity. Bronchitis and bronchial pneumonia are the most common pathological effects of exposure; skin and eye irritation may also occur. Severe exposure can also adversely affect the gastrointestinal tract, kidneys, and nervous system.

Chromium

Chromium (Cr) is a transition metal with an electron configuration of $\{Ar\}4s^1 3d^5$. In the chemically combined form it exists in all oxidation states from +2 through +6, of which the +3 and +6 are the more notable.

In strongly acidic aqueous solution, chromium(III) may be present as the hydrated cation $Cr(H_2O)_6^{3+}$. At pH values above approximately 4 this ion has a strong tendency to precipitate from solution as shown by the reaction:

feces. The mechanisms by which excretion occurs are not well understood.

Minimata Bay

The most notorious incident of widespread mercury poisoning in modern times occurred in the Minimata Bay region of Japan during the period 1953-1960. Mercury waste from a chemical plant draining into the bay contaminated seafood consumed regularly by people in the area. Overall, 111 cases of poisoning with 43 deaths and 19 congenital birth defects were documented. The seafood was found to contain 5-20 parts per million of mercury.

Lead

Lead (Pb) ranks fifth behind iron, copper, aluminum, and zinc in industrial production of metals.[8] About half of the lead used in the United States goes for the manufacture of lead storage batteries. Other uses include solders, bearings, cable covers, ammunition, plumbing, pigments, and caulking.

Metals commonly alloyed with lead are antimony (in storage batteries), calcium and tin (in maintenance-free storage batteries), silver (for solder and anodes), strontium and tin (as anodes in electrowinning processes), tellurium (pipe and sheet in chemical installations and nuclear shielding), tin (solders), and antimony and tin (sleeve bearings, printing, high-detail castings).

The electron configuration of lead is $\{Xe\}4f^{14}5d^{10}6s^{2}6p^{2}$ and it has four valence electrons. Lead is one of a small group of "p-block" metals that are representative elements with partially filled *p* orbitals. Inorganic lead exists in chemical compounds in both the +2 and +4 oxidation states. Lead(II) compounds are predominantly ionic (e.g., $Pb^{2+}SO_4^{2-}$), whereas lead(IV) compounds tend to be covalent (e.g., tetraethyllead, $Pb(C_2H_5)_4$). Some lead(IV) compounds, such as PbO_2, are strong oxidants. Lead forms several basic lead salts, such as $Pb(OH)_2{\cdot}2PbCO_3$, which was once the most widely used white paint pigment and the source of considerable chronic lead poisoning to the children who ate peeling white paint. Many compounds of lead in the +2 oxidation state (lead(II)) and a few in the +4 oxidation state

effective against syphilis and they are still used to treat amebic dysentery. Arsobal, or Mel B, an organoarsenical, is the most effective drug for the treatment of the neurological stage of African trypanosomiasis for which the infectious agents are *Trypanosoma gambiense* or *T. rhodesiense*.

Exposure and Absorption of Arsenic

Arsenic can be absorbed through both the gastrointestinal and pulmonary routes. Although the major concern with arsenic is its effect as a systemic poison, arsenic trichloride ($AsCl_3$) and the organic arsenic compound, Lewisite (used as a poison gas in World War I) can penetrate skin; both of these compounds are very damaging at the point of exposure and are strong vesicants (causes of blisters).[11] The common arsenic compound As_2O_3 is absorbed through the lungs and intestines. The degree of coarseness of the solid is a major factor in how well it is absorbed. Coarse particles of this compound tend to pass through the gastrointestinal tract and to be eliminated with the feces.

Arsenic occurs in the +3 and +5 oxidation states, and inorganic compounds in the +3 oxidation state are generally more toxic. The conversion to arsenic(V) is normally favored in the environment, which somewhat reduces the overall hazard of this element.

Arsenic is a natural constituent of most soils. It is found in a number of foods, particularly shellfish. The average adult ingests somewhat less than 1 milligram of arsenic per day through natural sources.

Metabolism, Transport, and Toxic Effects of Arsenic

Biochemically, arsenic acts to coagulate proteins, forms complexes with coenzymes, and inhibits the production of ATP. Like cadmium and mercury, arsenic is a sulfur-seeking element. Arsenic has some chemical similarities to phosphorus,[12] and it substitutes for phosphorus in some biochemical processes, with adverse metabolic effects. Figure 5.7 summarizes one such effect. The top reaction in the figure illustrates the enzyme-catalyzed synthesis of 1,3-diphosphoglycerate from glyceraldehyde 3-phosphate. The product undergoes additional reactions to produce adenosine triphosphate (ATP),