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

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

Date: April 14, 1998
Refer to: EM/ER:98-109

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

SUBJECT: SAP FOR DP CANYON (FORMER FU 1, OU 1106)

Dear Mr. Garcia:

Enclosed please find the Sampling and Analysis Plan (SAP) for DP Canyon. This SAP is being submitted for your review under the Canyons Focus Area and is an addendum to the Task/Site Work Plan for Los Alamos Canyon and Pueblo Canyon submitted to the Environmental Protection Agency in November 1995. The format of the SAP has been agreed to by your staff, as documented in your March 27, 1998, letter, "Approval of Sampling and Analysis Plans, Canyons Investigations, Los Alamos National Laboratory."

If you have any questions, please call David Broxton at (505) 667-2492 or Joe Mose at (505) 667-5808.

Sincerely,

Julie A. Canepa, Program Manager
LANL/ER Project

Sincerely,

Theodore J. Taylor, Program Manager
DOE/LAAO

JC/TT/ss

Enclosure: SAP for DP Canyon (Former FU 1, OU 1106)

6998

Cy (w/ enc.):
D. Broxton, EES-1, MS D462
D. Griswold, AL-ERD, MS A906
J. Harry, EES-5, MS M992
J. Mose, LAAO, MS A316
N. Naraine, DOE-HQ, EM-453
A. Pratt, EES-13, MS J521
C. Rodriguez, CIO/ER, MS M992
T. Taylor, LAAO, MS A316
J. White, ESH-19, MS K490
S. Yanicak, NMED-AIP, MS J993
RPF, MS M707

Cy (w/o enc.):
A. Dorries, TSA-11, MS M992
T. George, EM/ER, MS M992
D. Katzman, ERM Golder, MS M327
T. Longo, DOE-HQ, EM-453
D. McInroy, EM/ER, MS M992
J. Plum, LAAO, MS A316
G. Rael, AL-ERD, MS A906
J. Vozella, LAAO, MS A316
EM/ER File, MS M992

Reneau

59373

Sampling Plan for DP Canyon

Potential Release Site C-0-021

Environmental Restoration Project

April 1998

A Department of Energy Environmental Cleanup Program

Los Alamos NATIONAL LABORATORY

LA-UR-97-3071

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1.0 INTRODUCTION

This site work/sampling plan describes the investigation planned for DP Canyon, potential release site (PRS) C-0-021, as part of Los Alamos National Laboratory's (LANL's) Environmental Restoration (ER) Project. This investigation will assess the inventory of contaminants present in sediments and alluvial ground water in DP Canyon, the current risk posed by these contaminants to people using the site for recreational activities, and the potential for future transport of these contaminants within DP and Los Alamos Canyons. This investigation may lead to specific recommendations for remedial actions in DP Canyon. At a minimum, it will integrate with the ongoing assessments of Los Alamos and Pueblo Canyons by the LANL ER Project Canyons Investigation Team (LANL 1995, 01-0049).

Included in this site work/sampling plan are the site description, problem definition, historical data, sampling approach, and sampling implementation plan for DP Canyon. Guidance on the LANL ER Project's overall approach to site investigation, as well as the general history of the Laboratory, is available in the LANL ER Project Installation Work Plan (IWP) (LANL 1996, 1379). The IWP also includes the LANL ER Project Quality Assurance Project Plan (QAPP), which describes the requirements for personnel training, sample handling and custody, as well as data management, review, validation, and verification. When appropriate, this site work/sampling plan will reference the administrative procedures, quality procedures, and standard operating procedures (SOPs) included in the QAPP.

1.1 Site Description

DP Canyon begins in the Los Alamos town site and extends for 1.5 miles to its confluence with Los Alamos Canyon (Fig. 1.1-1). DP Mesa, which is the location of Technical Area (TA) 21, is the southern boundary of DP Canyon. A portion of the Los Alamos town site that includes housing and the Los Alamos airport composes the northern boundary. Between these two mesas, the area of land that drains to the canyon is approximately 0.6 square miles. As estimated in the early 1970s, approximately 0.2 square miles of this drainage area is developed with roads, buildings, parking areas, and airport facilities (Purtymun 1974, 0193).

The upper mile of DP Canyon is cut into Unit 3 of the Tshirege Member (QBT) of the Bandelier Tuff, which is a moderately welded unit (LANL 1996, 01-0048; Broxton and Eller 1995, 1162). The stream channel gradient in this upper portion is approximately 100 ft per mile. Grass and small shrubs grow along the channel banks, and the channel contains sand, gravel, and occasional exposed tuff (Purtymun 1974, 0193).

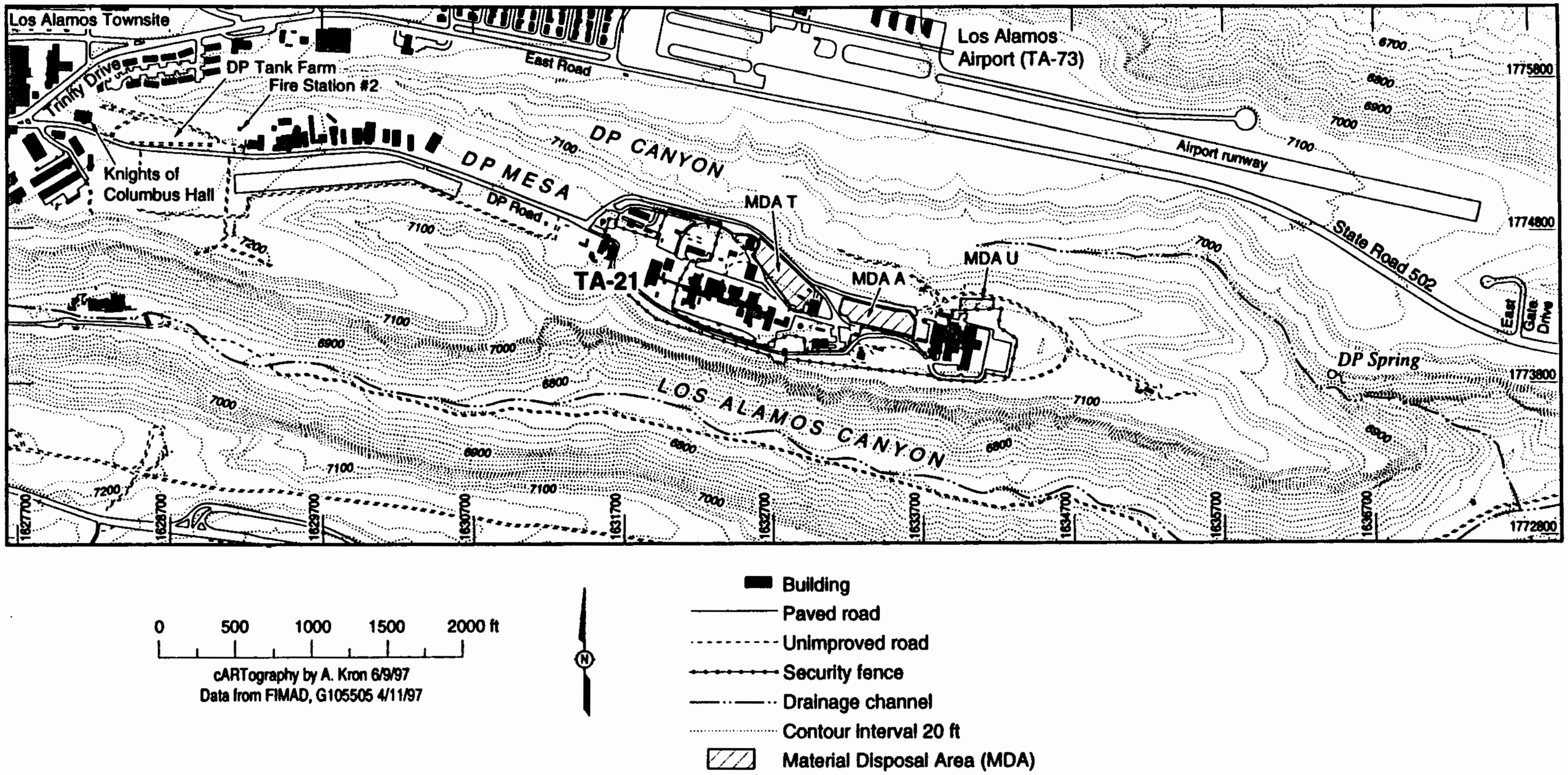

Fig. 1.1-1 DP Canyon and its surrounding area.

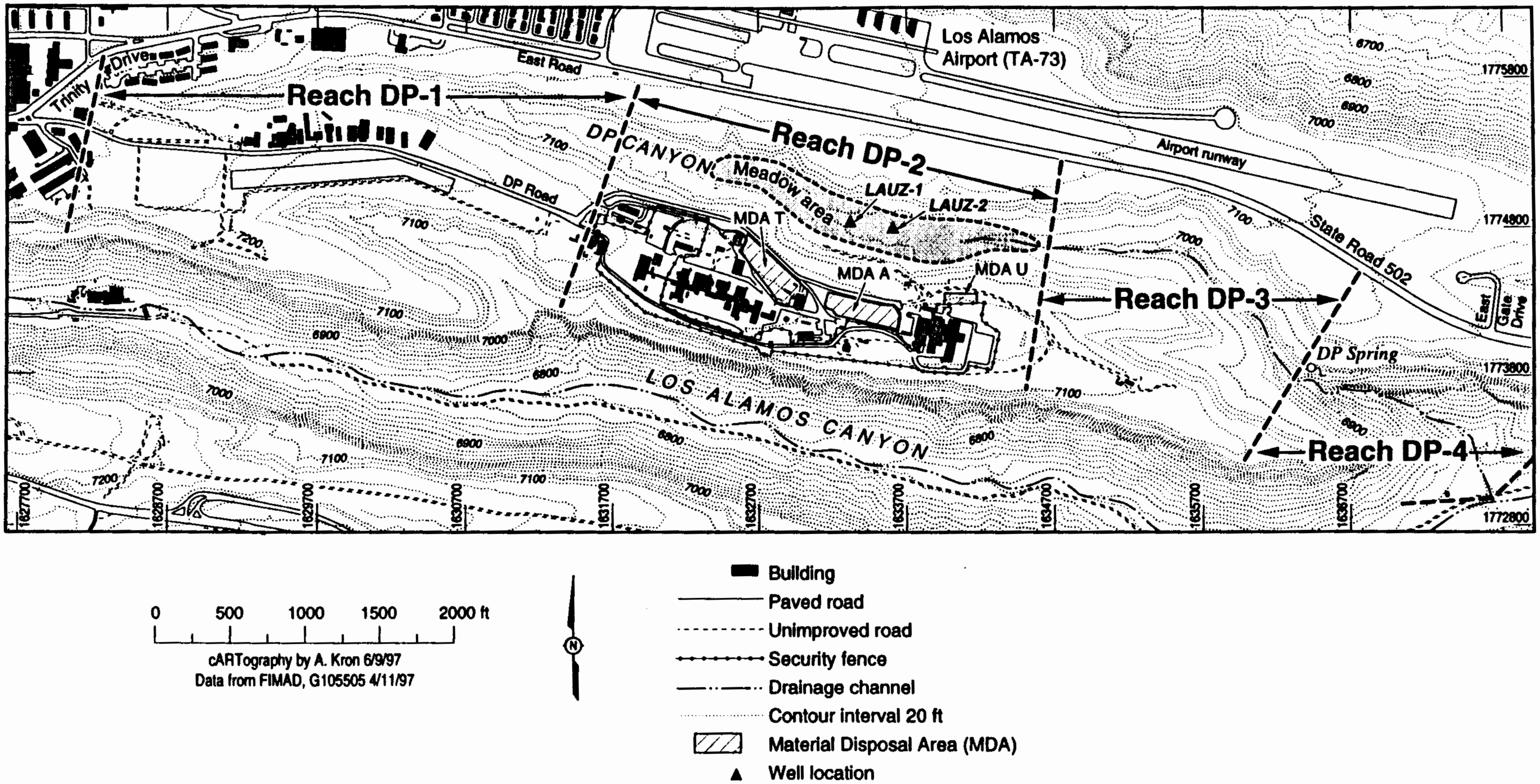

Fig. 1.1-2 DP Canyon reaches.

The lower 0.5 mile of DP Canyon cuts through in descending order: (1) Qbt 2, Qbt 1v, and Qbt 1g, (2) Tepuras and volcaniclastic sediments of the Cerro Toledo interval, and (3) the upper part of the Otowi member. This portion of the canyon is deep and narrow, and the stream channel fills the canyon floor. The stream channel gradient in this lower portion is approximately 760 ft per mile. The channel is composed of sand, boulders, and occasional exposed tuff, and it is strewn with large boulders and blocks of tuff that have dislodged from the canyon walls (Purtymun 1974, 0193).

In the lower portion of DP Canyon near the east end of DP Mesa, DP Spring flows from the north canyon wall (Fig. 1.1-1). As discussed in Reneau, "Geomorphic Studies at DP Mesa and Vicinity," the spring originates approximately 20 ft above the canyon floor at the contact between the Tshirege member of the Bandelier Tuff and overlying valley fill sediments (Broxton and Eller 1995, 1162). The valley fill includes both alluvium and colluvium, and it buries a paleochannel cut into the tuff. DP Spring flows from 0 to 20 L/min, depending on the season. In 1991, vegetation growing around DP Spring was used to determine that the spring had been flowing for at least 10 years (LANL 1991, 0689).

Aside from the contribution from DP Spring, stream flow in DP Canyon is intermittent. The stream flow consists of industrial effluent from permitted outfalls and storm water and snowmelt runoff from DP Mesa and the Los Alamos town site. Stream flow from DP Canyon reaches Los Alamos Canyon during storm water runoff events (LANL 1991, 0689).

For the purposes of this investigation, DP Canyon will be considered as four sections, which will be referred to as Reaches DP-1 through DP-4 (Fig. 1.1-2). Reaches DP-2 and DP-4 are further subdivided into eastern and western portions. Each reach will be treated as a single unit for sampling and analysis, but the canyon will be treated as a single unit for risk assessment. The reaches are described in detail in Section 2.2.

1.2 Problem Definition

The data collected during this investigation will determine the contamination in DP Canyon. As stated above, the overall objective of this investigation will be to assess (1) the inventory of contaminants present in sediments and alluvial water in DP Canyon, (2) the current risk posed by these contaminants to people using the site for recreational activities, and (3) the potential for future transport of these contaminants within DP and to Los Alamos Canyon. This assessment may lead to specific recommendations for remedial actions within DP Canyon and the contributing PRSs.

Historical data, environmental surveillance data, and data from Resource Conservation and Recovery Act (RCRA) facility investigations (RFIs) suggest that DP Canyon is a significant source area for contamination in Los Alamos Canyon. The RFI data include data recently collected by the LANL ER Canyons Investigation Team that suggest that DP Canyon is a primary contributor to the elevated radionuclide activities in Los Alamos Canyon. Los Alamos Canyon will be addressed in a separate investigation being conducted by the Canyons Investigation Team.

The investigation being conducted by the Canyons Investigation Team fulfills part of the Hazardous and Solid Waste Amendments (HSWA) requirements described in Section 1.5 of the HSWA Module (EPA 1990, 0306). This site work/sampling plan for DP Canyon supports the work plans required in Section 1.5 of the HSWA Module. It will address the presence of contamination in DP Canyon, and the potential for contamination to migrate from DP Canyon to Los Alamos Canyon. The investigation described in this site work/sampling plan will integrate with the Canyons Investigation Team's ongoing assessments of Los Alamos and Pueblo Canyons (LANL 1995, 01-0049).

While DP Canyon will be considered by the Canyons Investigation Team for its contribution to contamination in Los Alamos Canyon, DP Canyon warrants a separate assessment because of the number of PRSs (approximately 25) that are known, and possible sources of contamination in the canyon. The contributing PRSs are associated with TA-21 and TA-73, and the release histories and types of contaminants at these PRSs vary widely. As a result, a canyon-wide or watershed-scale assessment strategy will be required to address contaminants in DP Canyon. Contaminated sediments will be investigated. In addition, alluvial ground water and storm water in DP Canyon will be investigated to determine their roles in contaminant migration.

The potential for exposure to contaminants in DP Canyon will be evaluated according to the expected land use for the site. DP Canyon is currently under institutional control and no one resides or farms in the canyon. The most realistic exposure scenario for current and near-future use of DP Canyon is recreational. Because two of the major contaminants in the canyon are cesium-137 (which has a half-life of 30.2 years) and strontium-90 (which has a half-life of 29.1 years), the potential for exposure will decrease as these radionuclides decay.

The conceptual model for exposure to contaminants under a recreational scenario in DP Canyon is presented in Fig. 1.2-1. This model shows the nature of releases, the fate and transport of these releases in environmental media, and the exposure pathways used in the human health risk assessment. This investigation will test the key assumptions of the conceptual model, and will use the pathways presented in the model in estimating the risk associated with the site and the potential for future transport of contaminants.

1.3 Historical Data

A variety of data are currently available for DP Canyon. These include data from previous RFIs conducted at several locations in and near DP Canyon (see Fig. 1.3-1), as well as data from environmental surveillance and other Laboratory activities. Table 1.3-1 presents a summary of the historical data available for DP Canyon, showing contaminants exceeding screening action levels (SALs). Note that SALs change over time. The SALs cited in Table 1.3-1 are those that were submitted in historical documents.

The following sections present the DP Canyon data from surface water investigations (Section 1.3.1), subsurface investigations (Section 1.3.2), soil and sediment investigations (Section 1.3.3), and geomorphology investigations (Section 1.3.4). Sections 1.3.1 through 1.3.3 focus on areas associated with DP Canyon where sampling results exceeded current SALs. SALs are listed in the Facility for Information Management, Analysis, and Display (FIMAD) database. SALs are based on residential land use, and they conservatively overestimate the risk under the recreational scenario, which is the most realistic scenario for DP Canyon. SALs are an appropriate comparison for data collected in the 0–12 ft interval, which describes most of the historical data collected from DP Canyon.

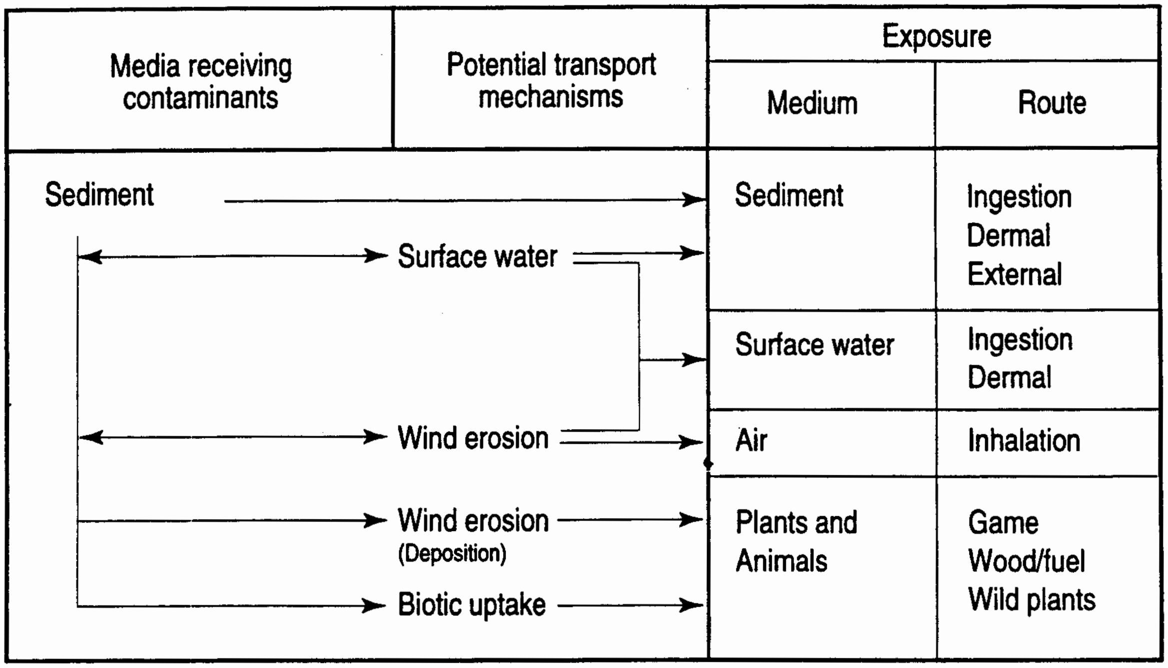

Fig. 1.2-1 DP Canyon conceptual model for human exposure pathways.

TABLE 1.3-1

SUMMARY OF HISTORICAL DATA FOR DP CANYON

SITE INVESTIGATED	DATE	CONTAMINANTS EXCEEDING SALs[a]
Surface Water Investigations		
DP Spring	1991–1995	Strontium-90[b], radium-226[b], radium-228[b]
PRS 21-029, DP Tank Farm	1995	TPH[c,d]
Subsurface Investigations		
Alluvial Well LAUZ-1 (water)	1994	Strontium-90[b]
Deep Well LADP-4 (water)	1993	None
PRS 21-029, DP Tank Farm (soil)	1995	TPH[c,d]
	1996	TPH[c,d]
Soil and Sediment Investigations		
Sediment sampling stations DPS-1 and DPS-4	1976–1995	Cesium-137[e], strontium-90[e]
TA-21 grid	1992	VOCs[f], SVOCs[g], PAHs[i], antimony, beryllium[i], thallium
	1993	None
PRS 21-029, DP Tank Farm	1995	TPH[c,d]
PRS 21-011(k)	1982	Cesium-137
	1989	Cesium-137, plutonium-238, plutonium-239, strontium-90, thorium-230, thorium-232, uranium-238
	1992	Beryllium[i], cadmium, americium-241, plutonium-238, plutonium-239, strontium-90[j]
	1993	Americium-241, cesium-137, plutonium-238, plutonium-239, strontium-90, thorium-228
	1996	Americium-241, cesium-137, plutonium-238, plutonium-239, strontium-90
PRS 21-024(f), septic tank effluent pit	1988	None
	1992	None
	1993	None
PRS 21-024(g), septic tank and outfall	1988	Tetrachloroethylene, arsenic[i]
	1992	None
	1993	None

TABLE 1.3-1 (CONTINUED)

SUMMARY OF HISTORICAL DATA FOR DP CANYON

SITE INVESTIGATED	DATE	CONTAMINANTS EXCEEDING SALs[a]
PRS 21-024(h), septic tank and outfall	1988	None
	1992	Plutonium-239[k], thorium-228[i,k]
	1993	None
	1995	Not determined
PRS 21-024(l), outfall	1988	PAHs
	1992	None
PRS 21-024(n), outfall	1988	None
	1992	None
PRSs 21-004(a,b,c), aboveground tanks	1994	Radium-224[c,l]
PRS 21-004(d), outfall	1988	None
	1992	Thorium-228[i,k,l]
PRS 21-026(d), surface disposal area	1992	PAHs
PRS 21-013(a)	1994	Arsenic[i,l]
PRS 21-013(c,d,e)	1995	Nitrophenol, pentachlorophenol, PAHs, arsenic[i,l], radium-224[c,l], thorium-228[g,i]
PRSs 21-014 and 21-017, MDAs A and U and associated sediment accumulation areas	1993, 1994	PAHs, arsenic[i,l], beryllium[i], naturally occurring radionuclides[l]
PRS 21-016, MDA T and associated sediment accumulation areas	1993, 1994	PAHs, arsenic[i,l], beryllium[i], naturally occurring radionuclides, americium-241, cesium-137, plutonium-239, strontium-90
PRSs C-73-005(a–f), septic pit areas	1996	None
PRS 73-007, septic tank and outfall	1996	None
The confluence of DP and Los Alamos Canyons	1996	Cesium-137, strontium-90

[a] SALs are listed in Facility for Information Management, Analysis, and Display (FIMAD).
[b] Value exceeds Environmental Protection Agency (EPA) drinking water standards.
[c] There is currently no SAL.
[d] TPH = Total petroleum hydrocarbons.
[e] VOCs = Volatile organic compounds.
[f] SVOCs = Semivolatile organic compounds.
[g] The calculated SAL is less than background. Therefore, results for this analyte were compared to background.
[h] Analyte was detected at depths greater than six inches.
[i] Analyte was detected at levels slightly above background.

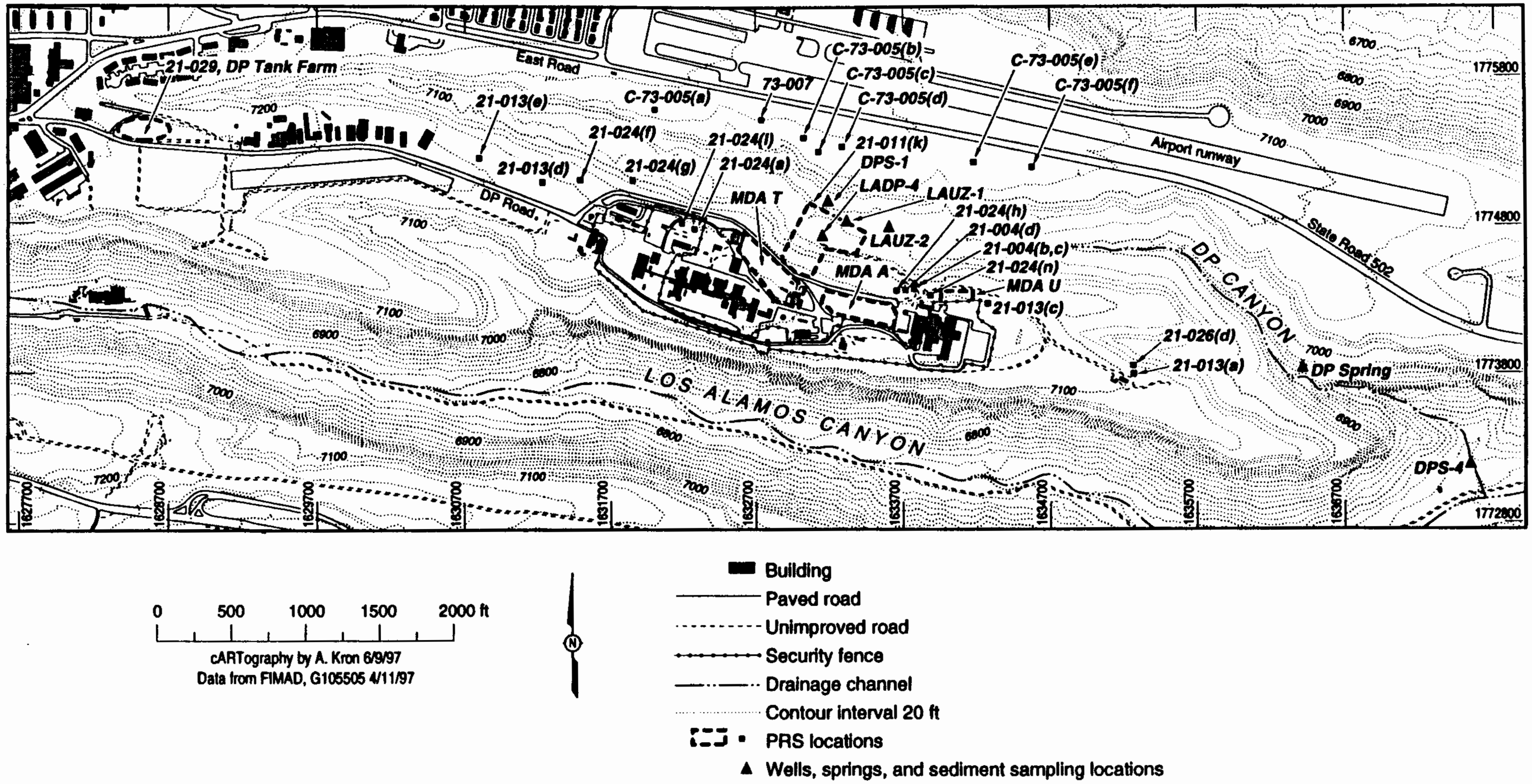

Fig. 1.3-1 PRSs contributing contaminants to DP Canyon.

1.3.1 Surface Water Investigations

DP Spring. DP Spring flows from the north canyon wall in the lower portion of DP Canyon near the east end of DP Mesa. In a 1991 study by Adams et al., "Fluorescein Dye Experiment at DP Spring and Sewage Outfall," water from DP Spring was analyzed and found to contain low levels of tritium, ranging from 381 to 2 704 pCi/L (Broxton and Eller 1995, 1162). These levels are well below the US Environmental Protection Agency's (EPA's) drinking water standard of 20 000 pCi/L provided in EPA proposed rule 40 CFR Parts 141 and 142, "National Primary Drinking Water Regulations" (July 18, 1991). Sampling of DP Spring continued until 1995. Tritium levels in DP Spring, while still exceeding the current background precipitation level of approximately 32 pCi/L, decreased between 1991 and 1995. (Goff 1996, 01-0058)

Other radionuclides detected in DP Spring include cesium-137, plutonium-238, plutonium-239, radium-226, radium-228, strontium-90, thorium-230, thorium-232, uranium-234, uranium-235, and uranium-238. Of these radionuclides, radium-226, radium-228, and strontium-90 have EPA drinking water standards. For radium-226 and radium-228, only one sample (collected in 1994) exceeded the EPA drinking water standard; for strontium-90, five samples (collected from 1993 to 1995) exceeded the standard. Concentrations of radium-226 and radium-228 decreased with time during the sampling period from 1991 to 1995; strontium-90 concentrations showed no trend over time (LANL 1996, 01-0048).

The presence of chlorate, which is specifically related to weapons research, shows a dramatic decrease from 1991 to 1994. DP Spring has elevated levels of boron, phosphate, lead, chlorine, and chlorate compared to values for regional background waters published by Blake et al. (Blake et al. 1995, 1355; LANL 1996, 01-0048).

In 1992, a fluorescein dye experiment determined that DP Spring is not hydrologically connected to the TA-21 sewage treatment outfall at the east end of DP Mesa (PRS 21-026[d]). As reported in Adams et al., DP Spring may be hydrologically connected to the alluvial ground water in DP Canyon (Broxton and Eller 1995, 1162).

PRS 21-029, DP Tank Farm. PRS 21-029, the former location of DP Tank Farm, is on the south edge of DP Canyon near the canyon head. The site was used from 1946 to 1985 as a fuel distribution station with both aboveground and underground fuel tanks. In 1995, a hydrocarbon seep in DP Canyon was sampled as part of the DP Tank Farm investigation. Four surface water samples were collected from the seep and surrounding areas and analyzed at a mobile laboratory for volatile organic compounds (VOCs) and total petroleum hydrocarbons (TPH). The results of these analyses show that although a petroleum sheen was visible on these samples, petroleum-related products were not present at levels greater than 1 ppm. However, as noted in the RFI Report for PRS 21-029, the mobile laboratory's detection limits were high, and a great deal of uncertainty surrounds the estimate of TPH at 1 ppm (LANL 1996, 01-0035). Other results from the DP Tank Farm investigation are discussed in Sections 1.3.2 and 1.3.3.

1.3.2 Subsurface Investigations

Alluvial Wells LAUZ-1 and LAUZ-2. In 1994 two wells, LAUZ-1 and LAUZ-2, were drilled to determine whether shallow alluvial water or perched ground water was present in DP Canyon. These wells are located in Reach DP-2 East, with LAUZ-1 located farther upstream than LAUZ-2 (Fig. 1.1-2). The total depth of each well is 15 ft. Both wells are completed with 4-in.-diameter PVC pipe, and a 5-ft-long slotted PVC screen is located between 5 and 10 ft below the surface.

Figure 1.3-2 shows the geologic log for these wells. Alluvial water was encountered in both wells at approximately 4.5 ft below the surface. The saturated zone at that time was approximately 3.5 ft thick. An initial water sample from LAUZ-1 had a strontium-90 concentration of 526 pCi/L (the EPA drinking water standard is 8 pCi/L). The alluvial water is thought to be a source for DP Spring. This site work/sampling plan includes a tracer test that will use these wells to test the hypothesis of connection between the alluvial water in DP Canyon and DP Spring. The tracer test will also provide hydrologic information on the transport time between the proposed alluvial water source and DP Spring if a concentration is found.

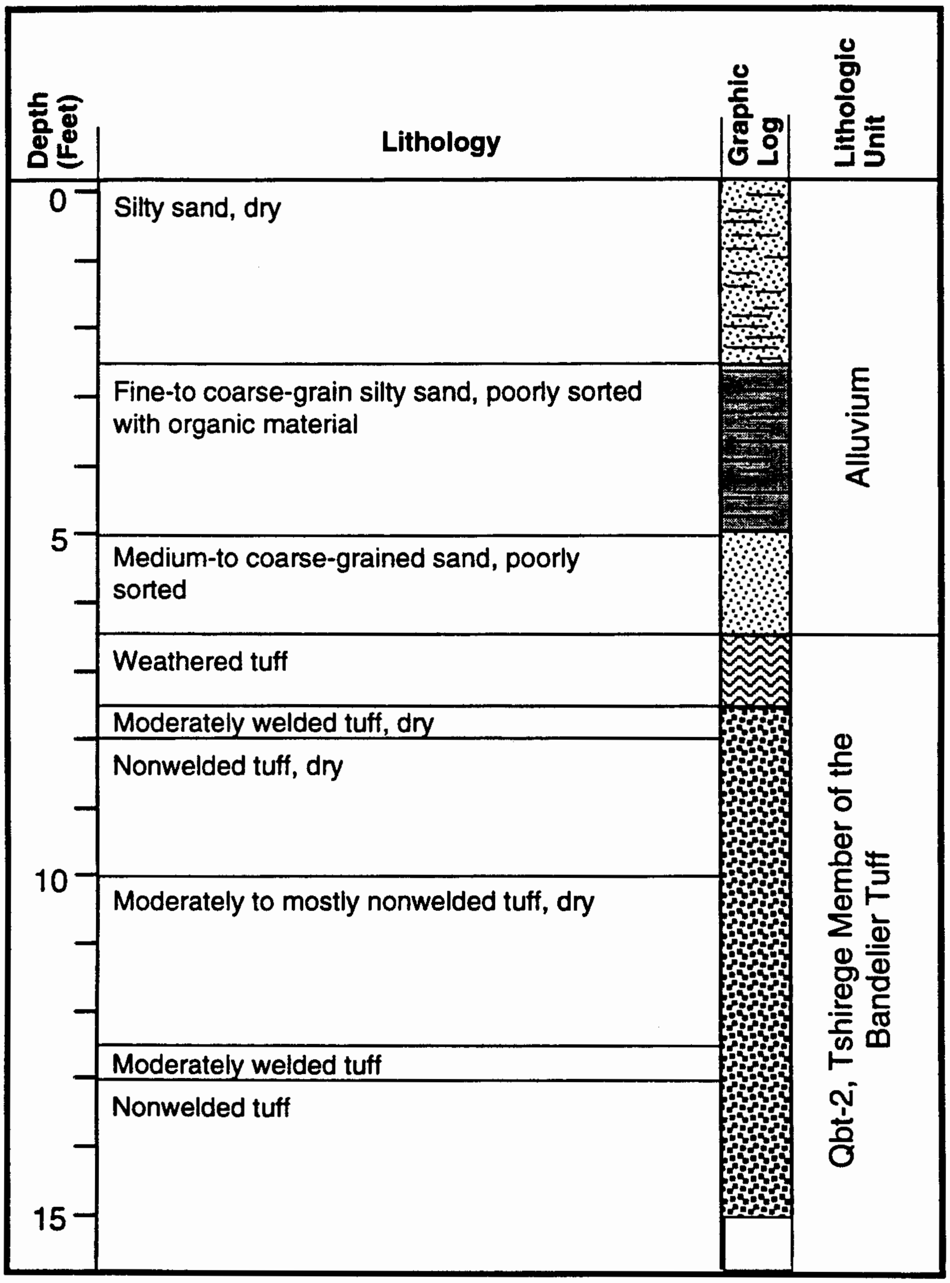

Fig. 1.3-2 Generalized geologic log for well LAUZ-2.

Deep Well LADP-4. In 1993, an 800-ft borehole (LADP-4) was drilled in DP Canyon to determine whether there is perched ground water beneath DP Canyon. This borehole was also used to investigate the lateral extent of subsurface contaminant migration associated with TA-21. No perched ground water was found beneath DP Canyon, and results from borehole samples indicated that tritium is not present at levels exceeding the SAL (Broxton and Eller 1995, 1162).

PRS 21-029, DP Tank Farm. In 1995, a hydrocarbon seep in DP Canyon was sampled as part of the DP Tank Farm (PRS 21-029) investigation. Three boreholes were drilled in the stream channel to a depth of 9 ft, and samples were collected and analyzed at a mobile laboratory for VOCs, methyl ethyl ketone (MEK), acetone, and TPH. The results of these analyses indicate that petroleum products were present in the two boreholes on the north bank of the stream channel opposite DP Tank Farm, but not in the borehole on the south bank of the channel downgradient from DP Tank Farm (LANL 1996, 01-0035). Other results of this investigation are discussed in Sections 1.3.1 and 1.3.3.

Remedial activities were conducted at DP Tank Farm in 1996. Approximately 1 720 cu yd of petroleum-contaminated soil were excavated from the east side of the site; the highest TPH concentration was as great as 8 900 mg/kg. Confirmation samples were collected from the sidewalls and bottom (to 32 ft) of the excavation and analyzed for TPH and benzene, toluene, ethylbenzene, and xylenes (known collectively as BTEX). The results of these analyses indicate that TPH is present at levels as great as 670 mg/kg, and that BTEX is present at levels less than the regulatory threshold (LANL 1996, 01-0035; LANL 1996, 55347; NMED 1996, 56512; LANL 1997, 56512).

1.3.3 Soil and Sediment Investigations

Sediment Sampling Stations DPS-1 and DPS-4. Since the late 1970s, the LANL Environmental Surveillance Program has been collecting sediment samples from two sediment sampling stations, DPS-1 and DPS-4, in the active channel of DP Canyon (see Fig. 1.3-1). These samples were analyzed for metals and radionuclides. Evaluation of cesium-137, strontium-90, and plutonium-239 results shows that cesium-137 and strontium-90 were present at levels exceeding SALs. Decreasing concentrations have been found since the mid-1980s, and for the past five years the values have been well below SALs (LANL 1996, 01-0055).

TA-21 Sampling Grid. In 1992, samples were collected from depths of 0 to 1 in. and 0 to 6 in. on a 40-m by 40-m grid over all of TA-21, including the south slope of DP Canyon. The purpose of this investigation was to identify contaminants deposited in the surficial soil layer by airborne emissions, primarily from TA-21. Samples were analyzed for semivolatile organic compounds (SVOCs), metals, and radionuclides (LANL 1994, 1259). Elevated antimony, VOCs, and SVOCs [(mostly polycyclic aromatic hydrocarbons (PAHs)] were detected at one location each (not the same location) at levels exceeding SALs, and thallium was detected at six locations at levels exceeding the SAL. Beryllium was elevated at many locations; however, beryllium data from the TA-21 grid sampling are unreliable, as discussed in the TA-21 RFI report (LANL 1994, 1259). Comparison of results from the two depths demonstrates that contamination generally is most concentrated in the 0- to 1-in. depth, and downward transport is strongly retarded (LANL 1994, 1259).

In 1993, the grid established in 1992 was extended by adding 15 sample locations on the western side of the grid in DP Canyon. The grid was extended to identify a possible source farther up DP Canyon that could explain why 1992 samples contained plutonium-239 and americium-241 at levels exceeding background. Samples were collected from 0- to 1-in. and 0- to 6-in. depths and analyzed for SVOCs, metals, and radionuclides (LANL 1995, 1261). The results from this investigation indicate that no contaminants are present at levels exceeding SALs. No upstream source of plutonium-239 or americium-241 was identified.

PRS 21-029, DP Tank Farm. In 1995, a hydrocarbon seep in DP Canyon was sampled as part of the DP Tank Farm (PRS 21-029) investigation. Sediment and tuff samples were collected along the stream channel and analyzed at a mobile laboratory for VOCs, MEK, acetone, and TPH (LANL 1996, 01-0035). The results of these analyses indicate that TPH and diesel were present in the tuff collected near the seep. Other results of this investigation are discussed in Sections 1.3.1 and 1.3.2.

PRS 21-011(k), Outfall. PRS 21-011(k) is an outfall on the south slope of DP Canyon that received discharges from TA-21 plutonium processing operations. Investigations were conducted at PRS 21-011(k) in 1982, 1989, 1992, and 1993.

In 1982, an aerial radiation survey was conducted over DP Canyon (Fritzsche 1982, 01-0051). Beginning at the approximate location of PRS 21-011(k) and extending downstream, gamma radiation from cesium-137 was observed. The data obtained from this survey were used to estimate that the inventory of cesium-137 in DP Canyon in 1982 ranged from 120 to 730 mCi.

In 1989, during LANL Environmental Surveillance Program monitoring, samples were collected from sediment accumulated in the main drainage channel at PRS 21-011(k) and analyzed for metals and radionuclides (LANL 1991, 0689). The results of these analyses show radionuclides (cesium-137, plutonium-238, plutonium-239, strontium-90, thorium-230, thorium-232, and uranium-238) at levels exceeding SALs.

In 1992, samples were collected from sediments accumulated in the main drainage channel at PRS 21-011(k) and analyzed for VOCs, SVOCs, metals, and radionuclides (except cesium-137) (LANL 1994, 1260). The results of these analyses show metals (beryllium and cadmium) and radionuclides (americium-241, plutonium-238, plutonium-239, and strontium-90) at levels exceeding SALs.

In 1993, samples were collected from sediment accumulated in drainage channels at locations where the radiation survey indicated elevated radioactivity. Samples were analyzed for radionuclides (LANL 1995, 1261). The results of these analyses show americium-241, cesium-137, plutonium-238, plutonium-239, strontium-90, and thorium-228 at levels exceeding SALs.

In 1996, remedial activities were conducted at PRS 21-011(k). Approximately 390 cu yd of radioactively contaminated sediment (colluvium) having greater than approximately 400 pCi/g of cesium-137 were excavated from the site. Samples were collected after excavation to assist in planning a final remedy for the site. Samples were analyzed for gamma-emitting radionuclides by gamma spectroscopy, isotopic plutonium, and strontium-90 (LANL 1996, 01-0044). As expected, preliminary results show that americium-241, plutonium-239, plutonium-238, cesium-137, and strontium-90 are still present at levels exceeding SALs.

PRS 21-024(f), Septic Tank and Effluent Pit. PRS 21-024(f) is a septic tank and effluent pit on the south rim of DP Canyon that received sewage from Building TA-21-45. Investigations were conducted at PRS 21-024(f) in 1988, 1992, and 1993.

In 1988, a sample was collected from the center of the effluent pit and analyzed for VOCs, SVOCs, polychlorinated biphenyls (PCBs)/pesticides, metals, and radionuclides (LANL 1991, 0689). The results of these analyses show no contaminants at levels exceeding SALs.

In 1992, samples were collected from around the rim of the effluent pit at depths of 0 to 6 in., 6 to 12 in., and 12 to 18 in. Samples were analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1994, 1260). The results of these analyses show no contaminants at levels exceeding SALs.

In 1993, one borehole was drilled through the effluent pit to a depth of 10 ft and a second borehole was drilled near the septic tank to a depth of 20 ft. Samples were analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1995, 1261). The results of these analyses show no contaminants at levels exceeding SALs.

PRS 21-024(g), Septic Tank and Outfall. PRS 21-024(g) is a septic tank and outfall on the south rim of DP Canyon that received sewage from a TA-21 warehouse and electronics shop. Investigations were conducted at PRS 21-024(g) in 1988, 1992, and 1993.

In 1988, samples were collected up-slope from the septic tank and analyzed for VOCs, SVOCs, PCBs/pesticides, metals, and radionuclides (LANL 1991, 0689). The results of these analyses show only tetrachloroethylene and arsenic at levels exceeding SALs.

In 1992, samples were collected up-slope and downslope of the septic tank at depths of 0 to 6 in., 6 to 12 in., and 12 to 18 in. Samples were analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1994, 1260). The results of these analyses show no contaminants at levels exceeding SALs.

In 1993, a borehole was drilled near the septic tank outlet pipe to a depth of 20 ft. Samples were analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1995, 1261). The results of these analyses show no contaminants at levels exceeding SALs.

PRS 21-024(h), Septic Tank and Outfall. PRS 21-024(h) is a septic tank and outfall on the south rim of DP Canyon that received sewage from Building TA-21-151. Investigations were conducted at PRS 21-024(h) in 1988, 1992, and 1993.

In 1988, a sample was collected from the outfall area and analyzed for VOCs, SVOCs, PCBs/pesticides, metals, and radionuclides (LANL 1991, 0689). The results of these analyses show no contaminants at levels exceeding SALs.

In 1992, samples were collected from the outfall area at depths of 0 to 6 in., 6 to 12 in., and 12 to 18 in. Samples were analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1994, 1260). The results of these analyses show plutonium-239 and thorium-228 at levels exceeding SALs; however, these samples were collected at depths greater than 6 in. Thus, the contaminants are not available for surface transport into DP Canyon.

In 1993, a borehole was drilled near the septic tank to a depth of 20 ft. Samples were analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1995, 1261). The results of these analyses show no contaminants at levels exceeding SALs.

In 1995, remedial activities were conducted at PRS 21-024(h) so that the septic tank could be abandoned according to current New Mexico Environment Department (NMED) guidance. Approximately 18 cu yd of waste were removed from the septic tank and replaced with gravel. In preparation for the remediation, samples were collected from the septic tank and analyzed for VOCs, SVOCs, metals, and isotopic plutonium (LANL 1996, 01-0045). The results of these analyses show that before the septic tank was emptied, several VOCs were present at levels exceeding SALs. The outfall downgradient from the septic tank was assessed for plutonium-239 using field instruments; the results of this assessment indicate that plutonium-239 levels are less than the cleanup level of 75 pCi/g (LANL 1995, 01-0061).

PRS 21-024(l), Outfall. PRS 21-024(l) is an outfall on the south rim of DP Canyon that received liquid waste from a floor drain in a TA-21 vault used to store plutonium and uranium metal. Investigations were conducted at this PRS in 1988 and 1992.

In 1988, a sample was collected northeast of the outfall area and analyzed for VOCs, SVOCs, PCBs/pesticides, metals, and radionuclides (LANL 1991, 0689). The results of these analyses show only SVOCs (PAHs detected in asphalt) at levels exceeding SALs.

In 1992, samples were collected from the outfall area at a depth of 0 to 6 in. and analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1994, 1260). The results of these analyses show no contaminants at levels exceeding SALs.

PRS 21-024(n), Outfall. PRS 21-024(n) is an outfall on the south rim of DP Canyon that received liquid waste from a drain in Building TA-21-155, which has been a warehouse, laboratory, and furnace building. This PRS was investigated in 1988 and 1992.

In 1988, a sample was collected at the discharge point and analyzed for VOCs, SVOCs, PCBs/pesticides, metals, and radionuclides (LANL 1991, 0689). The results of these analyses show no contaminants at levels exceeding SALs.

In 1992, samples were collected from the outfall area at depths of 0 to 6 in., 6 to 12 in., and 12 to 18 in. and analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1994, 1260). The results of these analyses show no contaminants at levels exceeding SALs.

PRSs 21-004(a,b,c), Aboveground Tanks. PRSs 21-004(a,b,c) are three aboveground tanks near the south rim of DP Canyon. PRS 21-004(a) does not appear to have ever received waste and PRSs 21-004(b,c) received radioactive liquid waste. These PRSs were investigated in 1994.

At PRS 21-004(a), swipe samples were collected from the drain valve and inside surface of the tank, screened for alpha radiation, and found to be free of removable alpha contamination (LANL 1996, 01-0046).

At PRSs 21-004(b,c), boreholes were drilled to 5 ft. Samples were analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1994, 1260). The results of these analyses show no contaminants at levels exceeding SALs. Radium-224, which has no SAL, was detected at values slightly greater than background.

PRS 21-004(d), Outfall. PRS 21-004(d) is an outfall upgradient from the aboveground tanks [PRSs 21-004(b,c)] on the south rim of DP Canyon that received liquid laboratory wastes, liquid wastes from chilled water systems, and overflow from a radioactive liquid waste pumping station. This PRS was investigated in 1988 and 1992.

In 1988, a sample was collected downgradient from the discharge point and analyzed for VOCs, SVOCs, PCBs/pesticides, metals, and radionuclides (LANL 1991, 0689). The results of these analyses show no contaminants at levels exceeding SALs.

In 1992, samples were collected from the outfall area at depths of 0 to 6 in., 6 to 12 in., and 12 to 18 in. and analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1994, 1260). The results of these analyses show thorium-228 at levels exceeding the SAL (which is less than background). The thorium-228 contamination, found in the 12- to 18-in. interval at levels only slightly greater than background, is not available for transport into DP Canyon.

PRS 21-026(d), Outfall. PRS 21-026(d) is an outfall on the south rim of DP Canyon that received liquid wastes from the TA-21 sewage treatment plant (PRSs 21-026[a,b,c]). This PRS was investigated in 1992. Samples were collected from the outfall area at depths of 0 to 6 in., 6 to 12 in., and 12 to 18 in. and analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1994, 1260). The results of these analyses show only SVOCs (PAHs found in asphalt) at levels exceeding SALs.

PRS 21-013(a), Surface Disposal Area. PRS 21-013(a) is a surface disposal area on the south rim of DP Canyon that received sand from TA-21 sewage treatment plant filter beds. Investigations were conducted at this site in 1994. Samples were collected at depths of 0 to 6 in., 6 to 12 in., and 12 to 18 in. and analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1996, 01-0047). The results of these analyses show only arsenic at levels slightly exceeding regional background.

PRSs 21-013(c,d,e), Surface Disposal Areas. In 1995, remedial activities were conducted at PRSs 21-013(c,d,e), three surface disposal areas near the south rim of DP Canyon that received building debris and other nonradioactive materials. These sites were remediated to remove construction debris and not for chemical or radiological contamination. Approximately 50 cu yd of debris were removed from PRS 21-013(c), 35 cu yd were removed from PRS 21-013(d), and 100 cu yd were removed from PRS 21-013(e). Samples were collected to verify site cleanup. These samples were analyzed for VOCs, SVOCs, metals, PCBs, and radionuclides (ICF Kaiser Engineers, Inc. 1995, 01-0050). The results of these analyses show SVOCs (nitrophenol, pentachlorophenol, and PAHs found in asphalt) and radionuclides (radium-224 and thorium-228) at levels exceeding SALs, and metals (arsenic) at levels exceeding background. All contaminant values (except PAHs) are only slightly greater than background.

Surface Areas at MDAs A, T, and U and Associated Sediment Accumulation Areas. Material Disposal Area (MDA) A is a disposal area for radioactive solid wastes, MDA T is a disposal area for cement paste contaminated with americium-241 and liquid wastes from plutonium processing at TA-21, and MDA U is a disposal area for radioactive liquid wastes. These sites and the associated sediment accumulation areas in channels on the south slope of DP Canyon were investigated in 1993 and 1994. Samples from the MDA surfaces were collected on the mesa top from a depth of 0 to 6 in. Samples from the sediment accumulation areas were collected from depths of 0 to 3 in., 3 to 6 in., and 6 to 12 in. Samples were analyzed for SVOCs, metals, and radionuclides (LANL 1996, 01-0053).

The results of these analyses show several SVOCs (PAHs found in asphalt) and radionuclides at levels exceeding SALs. Metals (arsenic and beryllium, which have no SALs) were found at levels exceeding background. Arsenic values are only slightly greater than background; beryllium was found at levels nearly 10 times background at one location in the MDA T surface. At MDAs A and U and the associated sediment accumulation areas, naturally occurring radionuclides were found at levels exceeding SALs, but only slightly greater than background. Anthropogenic radionuclides were not found at levels exceeding SALs. At MDA T and the associated sediment accumulation areas, both naturally occurring radionuclides and anthropogenic radionuclides (americium-241, cesium-137, plutonium-239, and strontium-90) were found at levels exceeding background and SALs. Because the contaminants identified at MDA T and the associated sediment accumulation areas are similar to those identified at PRS 21-011(k), and the MDA T drainage areas are so close to PRS 21-011(k), it is difficult to define the boundary between these two PRSs.

PRSs C-73-005 (a–f), Septic Pits. PRSs C-73-005(a–f) are six pits excavated into the tuff on the north rim of DP Canyon that received sewage from office buildings in the late 1940s. These PRSs were remediated in 1996. Before the pits were backfilled, samples were collected from the bottoms of the pits and from beneath outlet drain lines (where they existed). Samples were analyzed for VOCs, SVOCs, metals, and radionuclides (LANL 1996, 01-0052). The results of these analyses show no contaminants at levels exceeding SALs.

PRS 73-007, Septic Tank and Outfall. PRS 73-007 is a septic tank and outfall on the north rim of DP Canyon that received sewage from office buildings in the late 1940s. Remedial activities were conducted at this PRS in 1996. The septic tank was removed, and the outlet drain line was left in place. Samples were collected from beneath the septic tank at a depth of approximately 5 ft and from beneath the end of the outlet drain line at a depth of approximately 2 ft. Samples were analyzed for VOCs, SVOCs, PCBs/pesticides, and metals; the sample from beneath the end of the outlet drain line was also analyzed for radionuclides (LANL 1996, 01-0052). The results of these analyses show no contaminants at levels exceeding SALs.

DP Canyon and the Confluence with Los Alamos Canyon. In 1996, investigations were conducted near the confluence of DP Canyon and Los Alamos Canyon by the LANL ER Canyons Investigation Team. Sediment samples were collected from the active stream channel and adjacent sediment deposits in DP Canyon and Los Alamos Canyon above and below the confluence. Samples were analyzed for SVOCs, metals, and radionuclides. In DP Canyon, preliminary results (unpublished) show SVOCs (Aroclor-1260™, pesticides, and PAHs), metals (lead, mercury, selenium, uranium, and zinc), and radionuclides (americium-241, cesium-137, plutonium-238, plutonium-239, radium-226, strontium-90, tritium, uranium-235, and uranium-238) at levels exceeding background [sediment upper tolerance limits (UTLs) or reporting limits]. Of these contaminants, cesium-137 and strontium-90 were found at levels greater than SALs. In Los Alamos Canyon downstream from the confluence with DP Canyon, most of these radionuclides (except plutonium-239, uranium-235, and uranium-238) were found at levels much greater than the levels found in Los Alamos Canyon upstream from the confluence with DP Canyon. These results demonstrate that radionuclides have moved from DP Canyon and have been deposited in Los Alamos Canyon.

1.3.4 Geomorphic Investigations

A geomorphic investigation was conducted in DP Canyon during 1992 and 1993 in conjunction with several other earth science investigations at TA-21. The objectives of the geomorphic investigation were to provide information on the surficial processes of sedimentation and erosion in DP Canyon and to define the geomorphic and stratigraphic setting of DP Spring. A geologic map showing rock units and sedimentary deposits in DP Canyon was produced (Broxton and Eller 1995, 1162).

1.4 Regulatory Context

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

The Laboratory's operating permit under RCRA and the New Mexico Hazardous Waste Act (HWA) sets forth requirements that are implemented by the ER Project. The RCRA/HWA Part B Operating Permit Modules I though VII, issued by NMED, and its HSWA Module VIII (hereafter referred to as the HSWA Module), issued by EPA, give specific requirements affecting the conduct of the LANL ER Project (EPA 1990, 0306). The HSWA Module became effective May 23, 1990, and has been updated to reflect changes related to ER Project activities. The most recent update became effective May 19, 1994.

This DP Canyon site work/sampling plan feeds into the requirements of the HSWA Module, Section I.5, "Task/Site Work Plan, Canyon Systems" (EPA 1990, 0306). Although DP Canyon has historically been considered part of the TA-21 RFI rather than the Canyons RFI, DP Canyon flows into Los Alamos Canyon and the investigation of DP Canyon should logically follow the objectives and methods of the Canyons RFI. The investigation of Los Alamos Canyon and Pueblo Canyon is required by the HSWA Module to ensure that the transport of contaminants released into the canyons will not adversely affect human health or the environment either on or off Laboratory property.

2.0 SAMPLING AND ANALYSIS PLAN DESIGN

2.1 Project Overview

To meet the objectives identified in Section 1.2, data will be collected from DP Canyon sediments, as well as storm water and ground water. Sediment samples will be collected from the four reaches, which are described in Section 2.2. Sampling locations will be determined by geomorphic and radiation surveys. Sediment from the head of the canyon will be sampled to help establish a baseline for contaminant concentrations. The water investigation will include storm water sampling for baseline determination, and a tracer study to identify the sources and confirm pathways of contamination in DP Spring. Analytical suites for sediment and water samples will include organic compounds, inorganic compounds, and radionuclides.

There are several key assumptions that underlie the design of the sampling and analysis plan for the DP Canyon investigation. These assumptions include the following:

- Sampling geomorphic features will be an efficient way to characterize and estimate contaminant inventory.
- Certain contaminants can be used as indicators for assessing contaminant distribution.
- Higher contaminant levels are associated with fine-grained sediment and sediment containing large amounts of total organic carbon. Thus, sediment particle size and the amount of total organic carbon in the sediment are fate and transport parameters.
- A recreational scenario is applicable throughout the canyon because DP Canyon is under institutional control and will remain available for recreational use.

2.2 DP Canyon Reach Descriptions

DP Canyon will be considered as four reaches that will be treated as units for sampling, analysis, and risk assessment. Reaches DP-2 and DP-4 are further subdivided into eastern and western portions. Each reach has a distinct physiographic and geomorphic setting. This setting consists of an active channel and buried channel deposits, as well as active and abandoned floodplain surfaces and deposits. These physiographic and geomorphic features provide evidence of processes that result in storage and/or transport of contaminants. The DP Canyon investigation will focus on sediments that were deposited after the Laboratory was established, which are referred to in this document as post-1942 sediments. The four DP Canyon reaches are described individually below.

Reach DP-1. Reach DP-1 comprises the section of DP Canyon from the head of DP Canyon at Trinity Drive to the upper portion of the meadow area (Fig. 2.2-1). Reach DP-1 is characterized by a narrow canyon with post-1942 sediment storage limited to a narrow zone along the active channel. PRSs located along Reach DP-1 include PRS 21-029 (DP Tank Farm), PRSs 21-013(d,e), and PRS 21-024(f) (see Fig. 1.3-1). Contaminant concentrations in Reach DP-1 are not expected to be significant relative to other reaches because there are fewer sources. However, this reach contains commerical areas on the north and south edges of DP Canyon.

Reach DP-2. Reach DP-2 is divided into western and eastern portions (Fig. 2.2-2). The boundary between Reach DP-2 East and Reach DP-2 West is the location where discharges from PRS 21-011(k) and runoff from MDA T enter the canyon. Reach DP-2 West is up-canyon

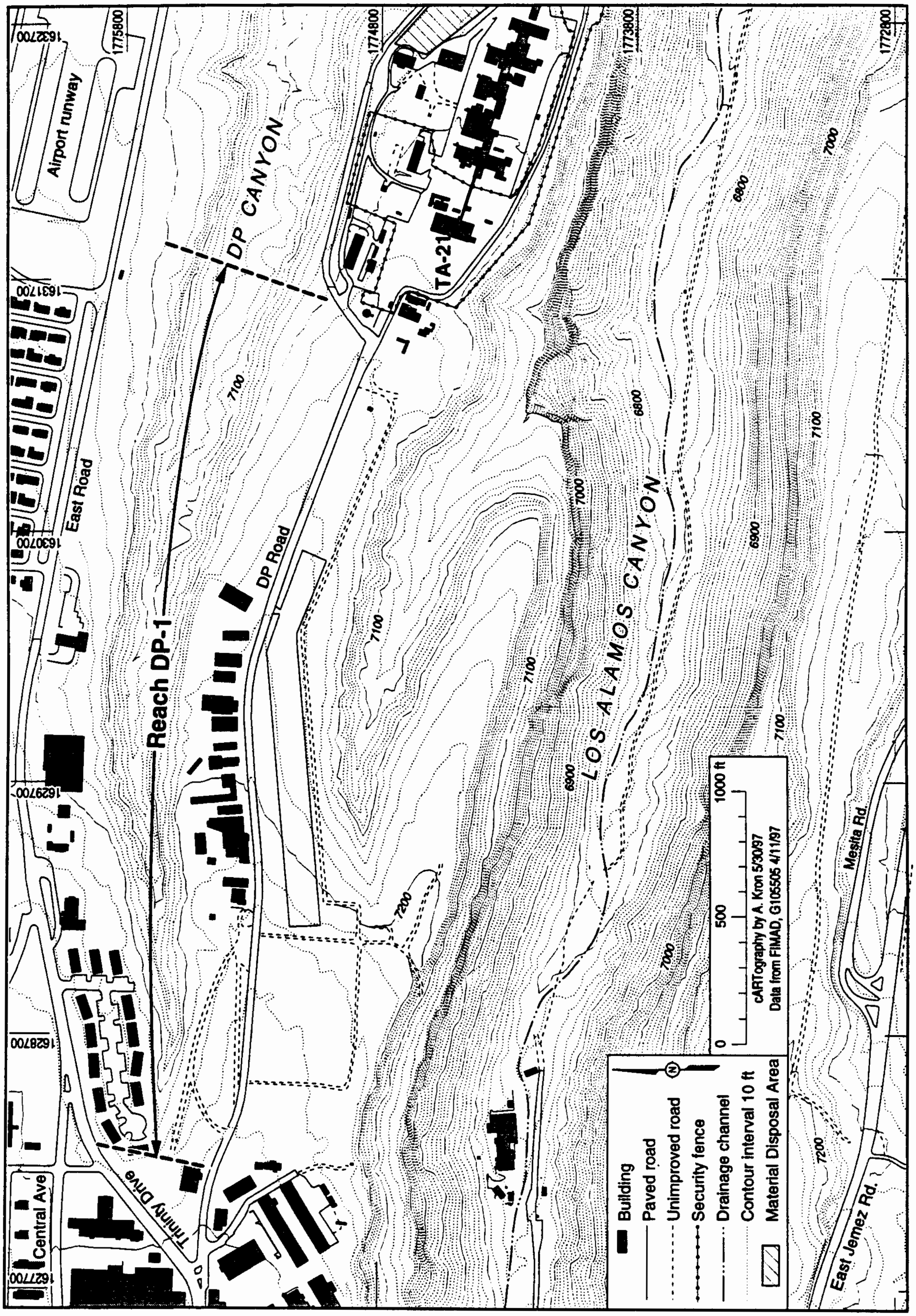

Fig. 2.2-1 Reach DP-1.

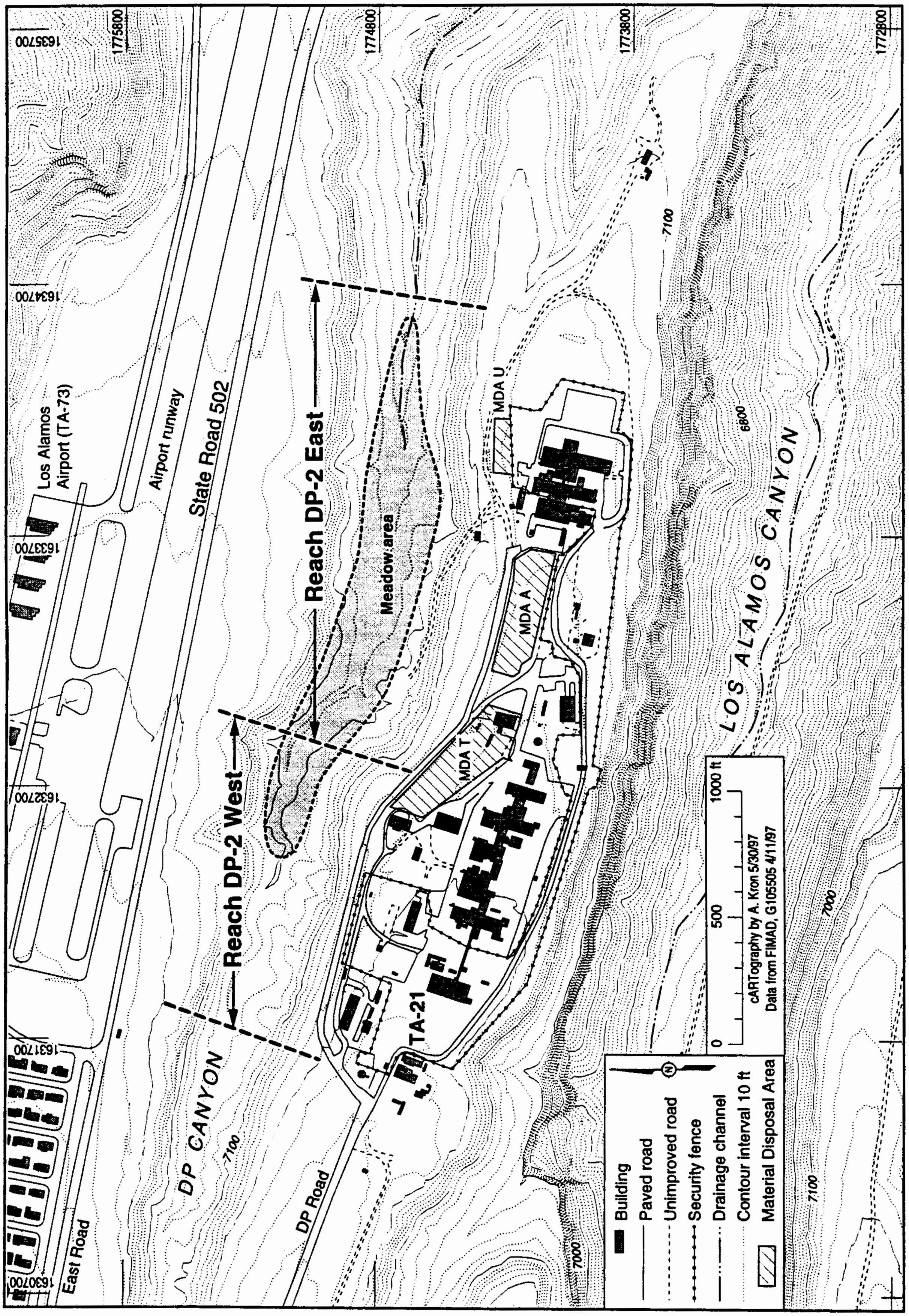

Fig. 2.2-2 Reach DP-2.

from the boundary and is located in the western portion of the meadow area. The valley floor in Reach DP-2 West is wider than that of Reach DP-1, and it has a slightly greater storage of post-1942 sediment. PRSs located along Reach DP-2 West include PRSs 21-024(a,g,l), PRS 73-007, and PRS C-73-005(a) (Fig. 1.3-1).

Reach DP-2 East is situated at the east end of the meadow area, and the valley floor in this reach is the widest in the canyon. Reach DP-2 East contains the largest volume of post-1942 sediment accumulation in the canyon, which makes it potentially the most significant reach with respect to the total DP Canyon contaminant inventory. PRSs located along Reach DP-2 East include PRS 21-011(k), MDA A, MDA T, MDA U, drainage areas associated with these MDAs, PRSs 21-024(h,n), PRSs 21-004(b,c,d), PRS 21-013(c), and PRSs C-73-005(b,c,d,e,f) (Fig. 1.3-1).

Reach DP-3. Reach DP-3 comprises the section of DP Canyon from the east end of the meadow area to the location in the canyon just above DP Spring (Fig. 2.2-3). The valley floor in this reach is within bedrock composed of Qbt 2 of the Tshirege Member. The channel and valley gradient increases in this reach relative to Reach DP-2. Storage of post-1942 sediment is minimal in this reach, suggesting that it will contribute little to the total contaminant inventory for DP Canyon. PRSs located along Reach DP-3 include PRS 21-013(a) and PRS 21-026(d) (Fig. 1.3-1).

Reach DP-4. Reach DP-4 comprises the section of DP Canyon from DP Spring to the confluence with Los Alamos Canyon (Fig. 2.2-3). The entire reach is characterized by a deeply incised canyon with large boulders and recently deposited sediment in the active channel. Reach DP-4 is divided into western and eastern portions. The boundary between Reach DP-4 West and Reach DP-4 East is the location above the confluence with Los Alamos Canyon where the channel gradient decreases significantly. There are no PRSs situated along Reach DP-4.

Reach DP-4 West is the upstream portion of the reach where the channel gradient is greatest. Small, localized pockets of post-1942 sediment accumulation occur around large boulders and along the margins of the valley floor. Reach DP-4 West has minimal sediment storage and is expected to contribute little to the total contaminant inventory of DP Canyon.

Reach DP-4 East is the portion of the reach that extends from the east/west division point to the confluence with Los Alamos Canyon. Reach DP-4 East has a lesser gradient than Reach DP-4 West, and has significant post-1942 sediment storage, suggesting that it could be important to the overall contaminant inventory in the canyon.

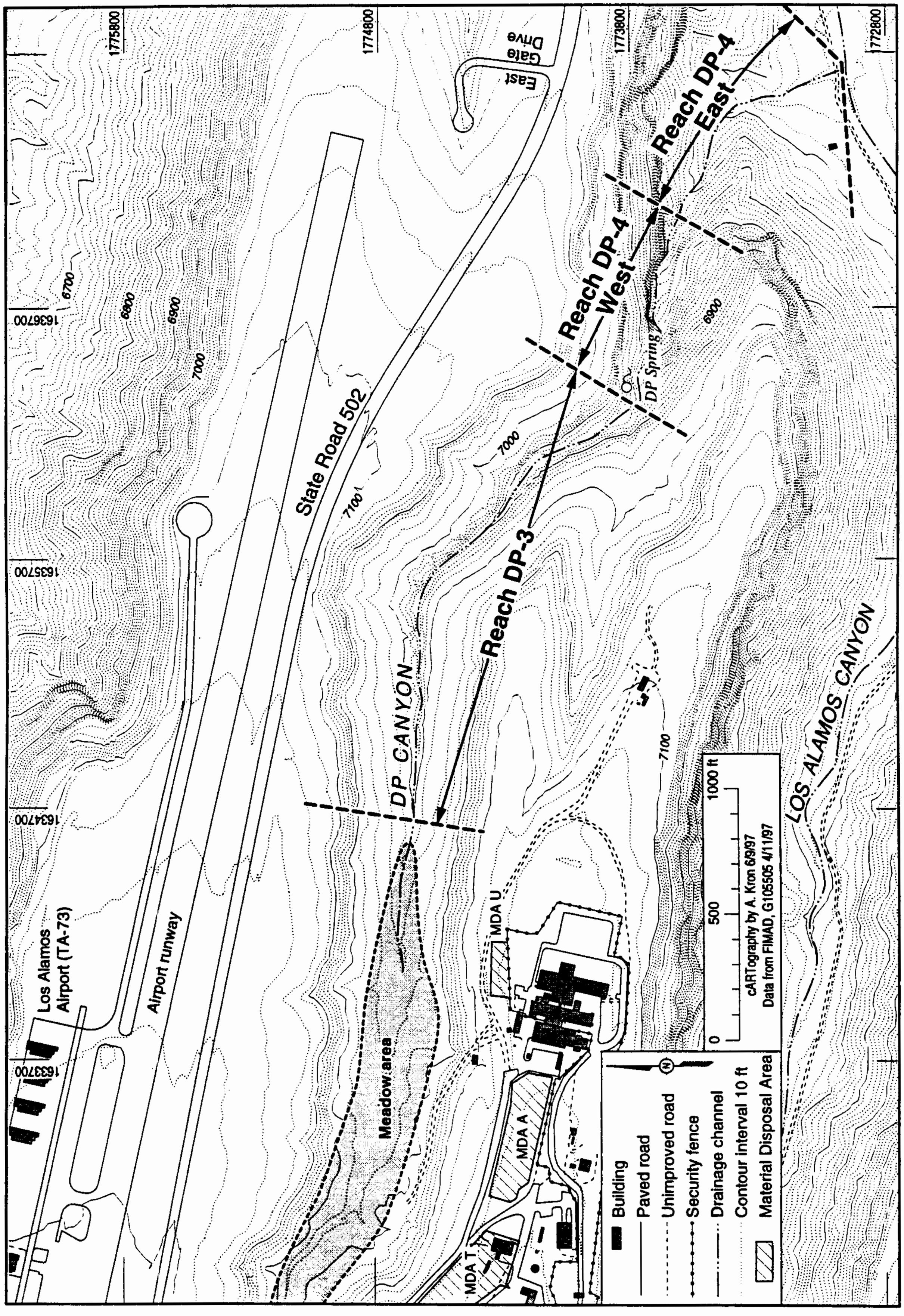

Fig. 2.2-3 Reaches DP-3 and DP-4.

2.3 Significant Geomorphic Units in DP Canyon

The following is a description of the major geomorphic units and sedimentary deposits that are expected to contain contaminants in DP Canyon.

Active Channel Deposits. An active channel is one in which water flows either intermittently or continuously during most runoff events. Channel sediment is dominated by coarse sand and gravel. Because heavy metals and most radionuclides discharged from the Laboratory preferentially adsorb to finer-sized sediment particles, and because the active channel sediments are young relative to the period of contaminated discharges, it is expected that active channel sediments may contain the lowest concentrations of contaminants. The sediments in the active channels are the most likely to be transported downstream, both by the relatively frequent storm water discharges and by occasional large floods in the canyons.

Buried Channel Deposits. Buried channel deposits contain coarse channel sediment (deposited when the channels were active), and often fine sediment (deposited by flooding after the channel was abandoned or by deposition of fines during waning storm water flow). Contaminant concentrations are expected to vary, depending both on the grain size and the age of the deposit, as contaminant releases will have varied over time. Available data suggest that buried channel deposits may contain significant concentrations and inventories of contaminants that are available for transport farther downstream either by large floods or by lateral erosion of the stream bank.

Active and Buried Floodplain and Slackwater Deposits. Floodplains are usually located adjacent to stream channels and are often characterized by buried, coarse-grained channel deposits overlain by fine-grained sediment deposited from the suspended load of over-bank floodwater. Slackwater deposits can also occur during waning flow within a channel or in areas protected from higher velocity flows. Because heavy metals and most radionuclides preferentially adsorb onto the fine-grained sediment, the contaminant concentrations may be highest in sediments within the floodplain and slackwater deposits. The contaminant concentrations may vary with the age of the deposit depending on contaminant release history. The sediment in the floodplains may have the longest residence times in the canyons because it probably moves little until mobilized by lateral erosion of the stream bank.

Identifying the floodplains will serve to focus more detailed geomorphic and radiation surveys within each reach. Boundaries of geomorphic units are commonly marked by distinct topographic breaks, although in places such boundaries may be gradual and more difficult to delineate. Direct visual observation of partially buried objects (e.g., young, live ponderosa pine trees) and debris, especially debris that can be linked to Laboratory activities (e.g., road aggregate containing quartzite cobbles), provide conclusive evidence of post-1942 sediment deposition events and, therefore, the age of some geomorphic units. Further evidence of the age of geomorphic units can be obtained by observing the nature and age of vegetation in different areas of the reach. Flood debris, such as driftwood, may provide additional evidence of the extent of historic flooding and the distribution of over-bank sediment deposition.

2.4 Sediment Investigation

This section discusses the design of the sediment investigation of DP Canyon. The four DP Canyon reaches will be characterized by air photo analysis and mapping, field surveys (geodetic, radiation, and geomorphic), and analysis of sediment samples collected both from potentially contaminated deposits within geomorphic units and from unimpacted areas.

2.4.1 Field Surveys and Mapping of DP Canyon Reaches

Each of the four canyon reaches will be surveyed and mapped, relying primarily on nonintrusive techniques. The objective of the surveys is to refine existing maps of each reach to indicate the location, extent, and nature of key geomorphic features and gross radiological contamination. In particular, the correlation between geomorphic features and radiological contamination will be examined by comparing the results of the geomorphic and radiation surveys.

2.4.1.1 Geodetic Survey

The objectives of the geodetic survey are to establish the boundaries of the reach and allow for accurate mapping of the field radiation data and the sample locations. Licensed surveyors will provide data in the New Mexico state plane coordinate system.

2.4.1.2 Radiation Survey

The objectives of the radiation survey are to (1) provide information about the distribution of radionuclides across and within geomorphic units (such as active channels, buried channel deposits, and floodplains), (2) identify areas where radioactivity exceeds background levels by a statistically significant amount (such areas may be candidates for sampling), and (3) define sampling locations.

The radiation survey will consist of two parts: (1) a walkover survey of gamma radiation, and (2) fixed-point measurements of alpha, beta, and gamma radiation. The walkover survey will collect gross gamma radiation measurements at multiple points. These measurements will provide information about gamma-emitting radionuclides on the surface and in the subsurface sediment. During the walkover survey, many short count-time (less than one minute) measurements will be collected. These measurements will provide low-resolution, qualitative data over a large area and will allow rapid identification of specific areas of elevated radioactivity. The results of the walkover survey will be used to select locations for the fixed-point measurements of alpha, beta, and gamma radiation. The walkover survey will be conducted using instruments appropriate for the possible radionuclides in each reach.

Fixed-point measurements of gross alpha, beta, and gamma radiation for long count times (one minute or greater) will be collected from ground surfaces and from stream bank surfaces. Vertical faces of bank cuts along the active channel will be surveyed to determine whether contaminants are present in the subsurface and to evaluate possible variations in contaminant concentrations between sediment layers. The gross alpha and beta radiation measurements will provide information about radionuclides on or near the surface of the sediment layer; gross gamma radiation measurements will provide information about radionuclides on and beneath the surface. The number of measurement points will depend on the walkover survey data and the size of the area of interest.

2.4.1.3 Geomorphic Survey

The objective of the geomorphic survey is to identify, describe, and map surface deposits and landforms that provide evidence for processes that can result in storage and/or transport of contaminants. In particular, the survey will focus on identifying potentially contaminated post-1942 sediment deposits.

The geomorphic survey of each canyon reach will be guided by the conceptual model of the significant geomorphic features and sedimentary deposits illustrated in Fig. 2.4-1. Five primary geomorphic units/sedimentary deposits may be present within each reach: (1) active channel sediments, (2) buried channel deposits, (3) active post-1942 floodplain and floodplain deposits, (4) pre-1942 alluvial deposits including buried floodplain or slackwater deposits, and (5) pre- and post-1942 colluvium. Laboratory-related contaminants could occur in any of these units, but the greatest concentrations are expected in the active and buried floodplain and slackwater (fine-grained) deposits.

The results of the radiation survey will be used to refine the boundaries of geomorphic features identified by aerial photographs and field mapping. To be most efficient, the two surveys (radiation and geomorphic) will be carried out concurrently.

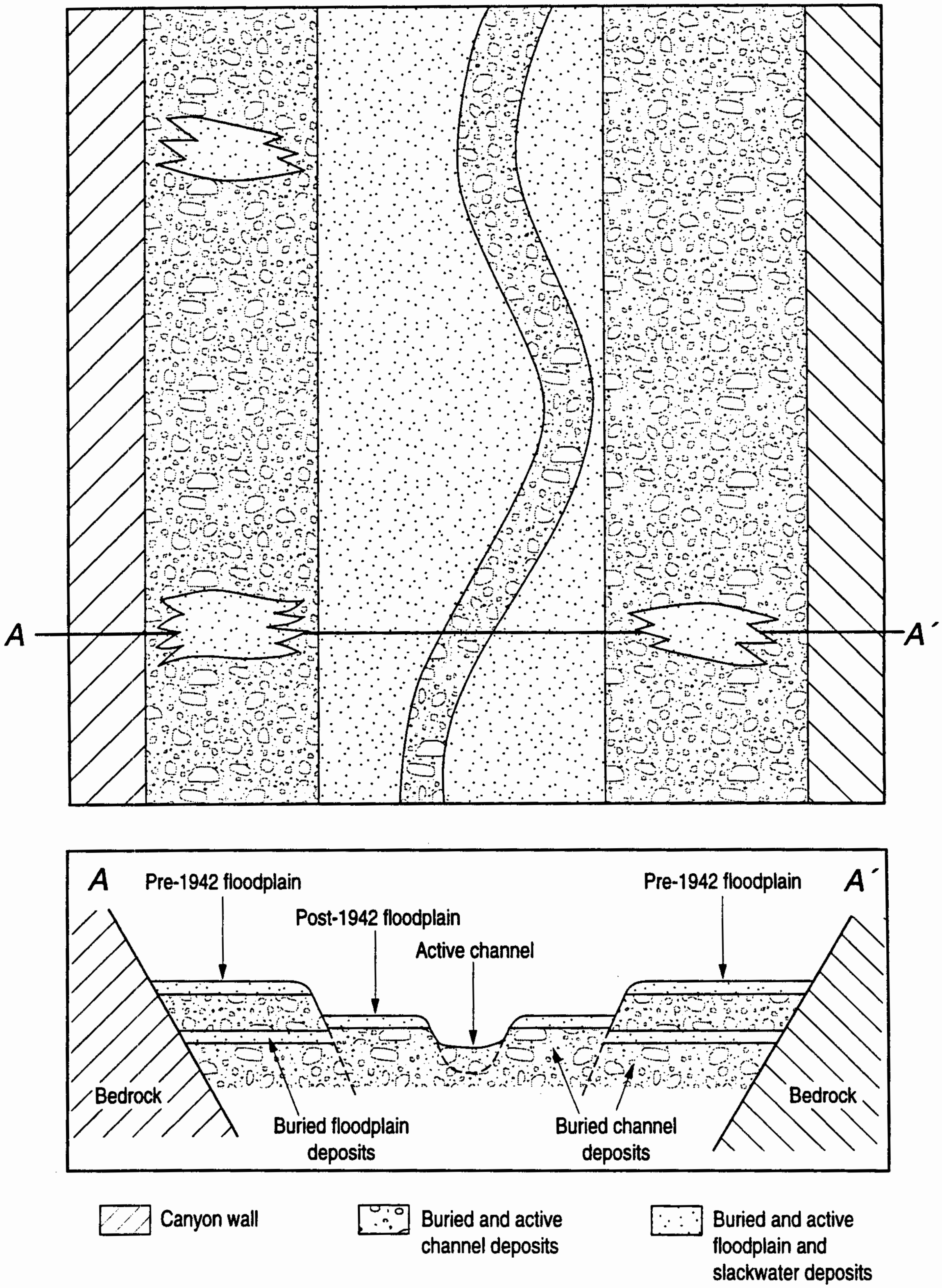

Fig. 2.4-1 Conceptual model of the significant geomorphic features and sedimentary deposits in DP Canyon.

2.4.2 Sediment Sample Collection and Analysis

2.4.2.1 Full-Suite Analysis

To distinguish Laboratory-related contaminants from contaminants related to the Los Alamos town site, samples will be collected up-canyon from PRSs along the canyon rim and analyzed for a full suite of chemicals of potential concern (COPCs) (see Section 3.2.6). Data assessment will be conducted to determine whether additional samples are needed to develop a representative statistic for baseline constituent distribution.

Samples will also be collected from the canyon slopes in areas downgradient from PRSs where the radiation survey indicates that contamination is present, and from canyon bottom sediments at various depths, depending on the sediment stratum thickness. Subsurface samples will be collected in exposed stream cuts, where possible, to minimize excavation. Some samples will also be collected in areas with normal or background radiation levels to identify metals or other contaminants that may be collocated with radionuclides.

To supplement historical data, selected sediment samples from each reach will be analyzed for the full suite of COPCs defined in Section 3.2.6. Constituent concentrations will be compared to the LANL-wide background data set, the TA-21 baseline data set, and the baseline data collected as part of this investigation. The sampling strategy for any sampling tasks subsequent to the collection of samples for full-suite analyses will be based on the full-suite data and field surveys. Requirements for additional data will be developed as needed.

2.4.2.2 Limited-Suite Analysis

It is assumed that the results of full-suite analyses, in conjunction with the results of the assessment of Los Alamos Canyon contaminant inventory and risk calculations, will eliminate several COPCs, and that analysis for a limited suite of COPCs will be conducted during additional phases of the sediment investigation. The full-suite results will also be used to determine whether it is valid to assume that certain contaminants can be used as indicators for assessing contaminant distribution. In this way concentrations of certain COPCs can be used to estimate concentrations of other COPCs, thereby further narrowing the COPCs included in the limited analytical suite.

Samples will be allocated for a limited suite of analyses based on a statistical sampling design, which is described in detail in Appendix A. The locations of samples collected and analyzed for a limited suite of COPCs will be selected based on the results of the geomorphic and radiation surveys. Because the objective of the investigation is to estimate the contaminant inventory within each reach and within each geomorphic unit in each reach, an effort will be made to collect and analyze samples for a limited suite of COPCs that represent a range of field radiation measurements. Thus, these samples will be collected from locations where high, medium, and low radiation levels are identified. If the predetermined number of sample locations is not adequate to represent the range of contamination in the sediments, additional samples may be collected.

2.4.2.3 Sample Collection for Particle Size Distribution and Total Organic Carbon Analysis

Sediment samples will be sieved and each particle size fraction (e.g., silt/clay size fraction, sand size fraction) will be analyzed to provide information on the association between contaminant concentration and particle size. Sediment samples will also be analyzed for total organic carbon to determine the relationship between the amount of organic material in the sediment and contaminant concentration. This information will be useful for understanding contaminant migration potential, mitigating sediment (and contaminant) transport, understanding variations in release history, and designing remedial and waste volume reduction alternatives.

2.5 Storm Water and Alluvial Ground Water Investigation

This section discusses the design of the storm water and alluvial ground water investigation in DP Canyon. The objective of the storm water investigation is to assess the contribution of potential town site related contaminants to DP Canyon. Numerous potential contaminants that are being analyzed for a part of the full-suite analyses (e.g., PAHs and metals) could be entering the canyon as a result of town site activities. The objective of the alluvial ground water investigation is to assess the potential for contaminant transport in ground water and address requirements for characterizing the hydrology of the canyons to determine the Laboratory's impact on ground water. The ground water investigation, in conjunction with the tracer study, will also provide information on ground water transport pathways, risk assessment, and support evaluation of potential future remedial actions addressing ground water contamination. Evaluation of ground water transport pathways includes alluvial system connections to surface water, DP Spring, and possible deeper zones of saturation.

2.5.1 Storm Water Sample Collection and Analysis

To determine baseline contaminant concentrations in storm water entering DP Canyon from the town site, storm water samples will be collected at the following locations: near the storm water culvert at the head of DP Canyon, and at a point immediately down-canyon from commercial areas on the north and south edges of DP Canyon. These are effluent sampling locations for assessing contaminants entering DP Canyon from the town site.

2.5.2 Alluvial Ground Water Sample Collection and Analysis

Water samples collected in alluvial wells LAUZ-1 and LAUZ-2 and at DP Spring will be analyzed to assess temporal trends and spatial patterns in contaminant concentrations.

Additionally, a tracer test using Alluvial Wells LAUZ-1 and LAUZ-2 is proposed to confirm the hypothesis of coupling between DP Canyon alluvial water and DP Spring and to determine travel time and water storage along this pathway. The tracer test will use bromide, which is found in very low concentrations in ground water at Los Alamos. The bromide will be placed in LAUZ-1 to provide information about transport in the alluvial ground water between LAUZ-1, LAUZ-2, and DP Spring.

3.0 SAMPLING AND ANALYSIS PLAN IMPLEMENTATION

3.1 Field Survey Implementation

3.1.1 Geodetic Survey

Licensed surveyors will mark appropriate intervals down the stream channel from the head of DP Canyon to the point where it joins Los Alamos Canyon. These markings will be used as reference points for the walkover survey of gamma radiation. After samples have been collected, state planar coordinates will be identified for sample locations and the boundaries of geomorphic features. All survey data will be submitted to FIMAD. Surveys will be conducted in accordance with LANL-ER-SOP-03.01, Land Surveying Procedures (LANL, 0875).

3.1.2 Radiation Survey

The instruments to be used in the radiation survey are shown in Table 3.1-1.

TABLE 3.1-1

INSTRUMENTS TO BE USED IN THE RADIATION SURVEY FOR DP CANYON

DETECTOR	RADIATION DETECTED	APPLICATION
Zinc sulfide scintillator	Alpha	Fixed-point survey
Plastic scintillator	Beta	Fixed-point survey
Geiger-Mueller™ pancake	Beta and gamma	Fixed-point survey
Sodium iodide scintillator	Gamma	Fixed-point survey, walkover survey
FIDLER[a]	Low-energy gamma, x-ray	Walkover survey (Reaches DP-1 and DP-2 West)

[a]FIDLER = Field instrument for detection of low-energy gamma radiation, which is only suitable for low levels.

3.1.2.1 Walkover Radiation Survey

Using a field instrument for the detection of low-energy radiation (FIDLER) (in Reaches DP 1 and DP-2 West only), a sodium iodide scintillation detector, and a data logger, 0.1-minute measurements will be collected at each approximate 5-ft interval as measured from the nearest geodetic survey stake. If the walkover survey identifies areas where gamma radiation is elevated beyond the decision level (see Section 2.4.1.2), additional measurements will be made to pinpoint the contamination. In addition, the count time may be increased to one minute or longer to obtain a more accurate measurement. Results will be plotted on a map and used to determine locations where fixed-point measurements will be collected.

3.1.2.2 Fixed-Point Radiation Measurements

Using alpha, beta, and gamma (shielded) detectors, 5-minute measurements will be collected at locations where gamma radiation is elevated as indicated by the results of the walkover survey, and where geomorphic units that may contain contaminants are exposed. Results will be plotted on a map and used to determine locations where sediment samples will be collected.

Gross alpha radiation will be measured using a zinc sulfide scintillation detector placed on a prepared surface. Beta radiation will be measured using a plastic scintillation or Geiger-Mueller™ (GM) detector. Gamma radiation will be measured using a sodium iodide scintillation or GM pancake detector. Lead shields will be used on gamma radiation detectors for fixed-point measurements to shield extraneous radiation.

3.1.3 Geomorphic Survey

Each canyon reach will be investigated according to LANL-ER-SOP-03.08, Geomorphic Characterization (LANL, 0875). Field activities will be documented according to LANL-ER-SOP-03.12, Field and Laboratory Notebook Documentation for ER Earth Sciences Studies (LANL, 0875).

Where the geomorphic survey identifies units that are likely to contain contaminants, those units will be considered candidates for fixed-point measurements of alpha, beta, and gamma radiation and for sampling.

3.2 Sediment Sampling and Analysis Implementation

Three sampling tasks have been defined for the sediment investigation: sample collection to evaluate baseline conditions, full-suite analysis, and limited-suite analysis. Particle size distribution and total organic carbon content analyses will be performed on samples.

Each sample location will be marked, surveyed, photographed, and assigned a unique ER Project sample location identification number. All samples will be field screened for gross radioactivity at the point of collection using hand-held instruments. Before shipment from the Sample Management Office to the analytical laboratory, gross-alpha, gross-beta, and gross-gamma radiation measurements will be taken on each sample for Department of Transportation shipping purposes.

Field quality assessment and quality control samples, such as field blanks and collocated samples, will be collected according to the most recent ER Project guidance (LANL 1995, 1164). Quality control samples are not included in the predetermined number of samples.

3.2.1 Baseline Sample Collection

To complete the data set of baseline constituent concentrations, samples will be collected from areas upstream of the known Laboratory contaminant source areas. At least one area at the head of DP Canyon, unaffected by TA-21 and TA-73 discharges, will be selected to assess baseline conditions in DP Canyon. Baseline samples will be analyzed for the suite of analytes defined in Section 3.2.6.

3.2.2 Sample Collection for Full-Suite Analysis

A minimum of one sediment sample will be collected from each reach for a full suite of analyses. A minimum of eight samples will be collected in reaches Reach DP-2 East and Reach DP-4 East for full suite analysis (see Table 3.2-1). These reaches are selected to provide information on possible contaminant collocation near and far from potential source areas. Samples will be collected at locations representing high, medium, and low radioactivity (alpha, beta, or gamma) as measured in the radiation survey.

TABLE 3.2-1

PROPOSED NUMBER OF SOIL SAMPLES TO BE SUBMITTED FOR A FULL SUITE OF ANALYSES

REACH	NUMBER TO ASSESS BASELINE CONDITIONS	NUMBER OF FULL SUITE ANALYSES
DP-1	2	1
DP-2	0	8
DP-3	0	1
DP-4	0	8

3.2.3 Sample Collection for Limited-Suite or Key Contaminant Analysis

Samples will be allocated for a limited suite of analyses based on the statistical sampling design described in Appendix A. The statistical design requires information on the expected volume of potentially contaminated sediments in each reach and the possible concentration of contaminants in each volume. Samples will be submitted for a limited suite of analyses to supplement full-suite data in estimating contaminant inventory, as well as to address current risk from recreational activities and test the assumptions of the geomorphic model. Table 3.2-2 presents the proposed number of samples that will be submitted to provide this information.

TABLE 3.2-2

PROPOSED NUMBER OF SOIL SAMPLES TO BE SUBMITTED FOR A LIMITED SUITE OF ANALYSES

REACH	TOTAL NUMBER OF LIMITED SUITE SEDIMENT SAMPLES PLANNED
DP-1	4
DP-2W	7
DP-2E	33
DP-3	3
DP-4W	3
DP-4E	16

3.2.4 Sample Collection for Particle Size Distribution and Total Organic Carbon Analysis

All sediment samples submitted for laboratory analyses will be sieved in the field to remove the greater than 2mm fraction. Additional sediment samples will be sieved and each particle size fraction (e.g., silt/clay size fraction, sand size fraction) will be analyzed to provide information on the association between contaminant concentration and particle size. Sediment samples will also be analyzed for total organic carbon.

3.2.5 Sediment Sampling Methods

Surface sediment samples will be collected in accordance with LANL-ER-SOP-06.09, Spade and Scoop Method for Collection of Soil Samples; and LANL-ER-SOP-06.10, Hand Auger and Thin-Wall Tube Sampler (LANL, 0875). Most samples collected in the initial sampling tasks will be grab or vertical composite samples. The tools used to collect the sediment samples will depend on the cohesion of the sediment material, the collection depth, and the presence of flowing or standing surface water.

All samples will be collected using the applicable ER Project SOPs for the collection, preservation, identification, storage, transport, and documentation of environmental samples, as described in Section 4.4 in Chapter 4 of the IWP (LANL 1996, 1379). Decontamination of sampling equipment will be performed in accordance with LANL-ER-SOP-01.08, Field Decontamination of Drilling and Sampling Equipment (LANL, 0875). Wash water and other wastes generated during the sampling operation will be managed and disposed of in accordance with LANL-ER-AP-05.3, Management of ER Program Wastes (LANL, 0875).

3.2.6 Analytical Methods for Sediment Samples

Sediment samples will be sent for a full suite of analyses including VOCs, SVOCs (including PAHs), PCBs, metals, and radionuclides (gamma-emitting radionuclides by gamma spectroscopy, plutonium isotopes, uranium isotopes, strontium-90, and tritium); the limited analytical suite analyses will include a subset of these constituent groups. The analytical suites and methods are listed in Table 3.2-3. All analyses will be performed at a fixed laboratory approved by the LANL ER Project, and will be conducted in accordance with EPA SW-846 protocols (EPA, 1222). The detailed analyte lists, estimated quantitation limits (EQLs), required quality control (QC) procedures, and the acceptance criteria are found in the ER Project analytical services statement of work (LANL 1995, 1278).

Sediment samples will be collected to represent specific sediment strata, and it is important that the laboratory sample be representative of the sediment stratum that is collected in the field. Sediment samples submitted for inorganic and radiochemical analyses will be homogenized and sieved in the field to remove the greater than 2mm fraction. The laboratory will be instructed to take representative aliquots from the homogenized sample for each analysis.

More detailed analysis for particle size will use either LANL or off-site facilities using the American Society for Testing and Materials (ASTM) methods described in LANL-ER-SOP-11.02, Particle Size Distribution of Soil/Rock Samples (LANL, 0875). ASTM Method D 422-63 may be used to determine the 10 μm size fraction (respirable particulate) in sediment samples. Other analyses, such as mineralogy, may be performed. Sediment sieving may be performed in the field if the field method is deemed adequate for the project needs.

TABLE 3.2-3

ANALYTICAL SUITES AND METHODS

ANALYTE SUITE	ANALYTICAL LABORATORY METHOD
Inorganic Constituents	
Metals	Inductively coupled plasma emission spectroscopy, Graphite furnace atomic absorption, Inductively coupled plasma mass spectrometry, Cold vapor atomic absorption
Organic Constituents	
Polychlorinated biphenyl compounds	Gas chromatography/electron capture detection
Semivolatile organic compounds	Gas chromatography/mass spectroscopy
Volatile organic compounds	Gas chromatography/mass spectroscopy
Radionuclides	
Tritium	Liquid scintillation
Plutonium-238, -239	Alpha spectrometry
Uranium-234, -235, -238	Alpha spectrometry
Gamma-emitting radionuclides	Gamma spectroscopy
Strontium-90	Gas proportional counting

3.3 Water Sampling

Three sampling tasks are defined for the storm water/alluvial ground water investigation: storm water sample collection to evaluate potential contaminant contribution from activities related to the Los Alamos town site, alluvial ground water sampling at wells LAUZ-1 and LAUZ-2, and sampling at DP Spring.

3.3.1 Storm Water Sample Collection

Two storm water samples will be collected from the culvert located at the head of DP Canyon, and two storm water samples will be collected at a point in DP Canyon below commercial areas on the north and south edges of DP Canyon. These samples will be collected during two separate storm events, preferably after significant dry spells to evaluate the impact of dirty, oily roads. Filtered and unfiltered samples will be analyzed. The amount of total suspended solids will also be determined for the filtered samples.

3.3.2 Alluvial Ground Water Sample Collection

One water quality sample will be collected each quarter for one year from each well (LAUZ-1, LAUZ-2) and from DP Spring. Specific sample times may be adjusted to capture extreme hydrological conditions such as extreme wet or dry periods and allow for assessment of possible impacts on ground water quality resulting from water level fluctuations.

The tracer study will involve injecting a bromide solution into alluvial aquifer well LAUZ-1 and monitoring the concentration of the tracer solution in two downgradient locations, LAUZ-2 and DP Spring. Initially, samples will be collected and analyzed at the two downgradient locations on a daily basis (utilizing an autosampler at DP Spring). Sampling frequency will be adjusted depending on how quickly the bromide tracer is moving. A bromide ion-specific electrode will be used to screen for bromide in the samples. This method will allow for on-site tracer concentration measurements that will greatly aid in ensuring that the sampling frequency is appropriate to capture the tracer behavior. Because the electrode can only measure down to 1 mg/L under ideal conditions and because of potential chloride interference, the electrode will only be useful for tracking the gross behavior of the tracer. Ion chromatography (IC) will be used to confirm bromide analysis. Only selected samples will be sent for IC analysis and selection will be based on the electrode results. Additional samples may be run later if needed to better define the tracer behavior.

3.3.3 Water Sampling Methods

Storm water from the culvert at the head of DP Canyon will be sampled in accordance with LANL-ER-SOP-06.29, Single-Stage Sampling for Surface Water Run-Off (LANL, 0875). Ground water from monitoring wells LAUZ-1 and LAUZ-2 will be sampled in accordance with LANL-ER-SOP-06.01, Purging of Wells for Representative Sampling of Ground Water; and LANL-ER-SOP-06.03, Sampling for Volatile Organics (LANL, 0875). Samples from DP Spring will be collected in accordance with LANL-ER-SOP-06.13, Surface Water Sampling (LANL, 0875).

3.3.4 Analytical Methods for Surface and Ground Water Samples

Surface and ground water samples will be sent for a full-suite of analyses as listed in Section 3.2.6; samples submitted for a limited-suite of analyses may be analyzed for a subset of these constituent groups. The analytical suites and methods are listed in Table 3.2-3. All analyses will be performed at a fixed laboratory approved by the LANL ER Project, and will be conducted in accordance with EPA SW-846 protocols (EPA, 1222). The detailed analyte lists, EQLs, required QC procedures, and acceptance criteria are found in the ER Project analytical services statement of work (LANL 1995, 1278).

3.4 Schedule

Implementation of this SAP is scheduled to begin in Summer of 1997.

4.0 DATA ASSESSMENT

4.1 Verification and Routine Data Validation

All data to be used for site decision-making will be loaded into the ER Project electronic data system (the Oracle database maintained by FIMAD). These data will include field sample information, field measurements, and the results of laboratory analyses. The analytical data produced by the contract laboratories will use the standard LANL data verification and baseline validation procedures.

4.2 Data Quality Assessment

Data quality assessment (DQA) for the results from this sampling and analysis plan will use the general framework outlined in Section D3 of the LANL ER Project QAPP (LANL 1996, 1379). The DQA for this project will be conducted to meet the needs of the LANL ER Canyons Investigation Team and the needs outlined in this document.

The DQA will focus on determining if adequate data have been collected to estimate the contaminant inventory. The estimated inventory will be expressed as a statistical distribution. Data will be considered adequate if 75% of the statistical distribution is within 20% of the median inventory estimate.

The key data inputs to the inventory calculation include:

- the volume of sediment contained within geomorphic units, to be determined from aerial photos, measurements of area and thickness of geomorphic units, field observations of particle size, and estimates of the age of the geomorphic unit deposit; and
- the concentrations of contaminants within geomorphic units, to be determined from laboratory analysis of contaminants identified at source PRSs, radiation surveys for indicator contaminants, and correlation between indicator contaminants and other contaminants.

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APPENDIX A STATISTICAL APPROACH TO LIMITED-SUITE SAMPLE ANALYSIS FOR DP CANYON

One objective of the DP Canyon investigation is to estimate the inventory of contaminants in sediments. The statistical design requires information on the expected volume of potentially contaminated sediments in each reach and the possible concentration of contaminants in each volume. Based on aerial photographs, existing data, and a visual survey of DP Canyon, the approximate surface area and thickness of post-1942 sediments in each of the four DP Canyon reaches has been estimated as shown in Table A-1. The volume of sediment in each reach was calculated by multiplying the estimated area of post-1942 sediment deposits by the estimated thickness of the deposits. As the table demonstrates, Reach DP-2 East comprises more than 50% of the area and volume of post-1942 sediments in DP Canyon.

TABLE A-1

CURRENT ESTIMATES OF THE AREA, DEPTH, AND VOLUME OF CONTAMINATED MATERIAL IN DP CANYON

REACH	AREA (m^2)	% OF TOTAL AREA	DEPTH (m)	VOLUME (m^3)	% OF TOTAL VOLUME
DP-1	4768	12.9	0.90	4291	10.0
DP-2 West	4926	13.3	1.20	5911	13.8
DP-2 East	18593	50.3	1.20	22312	52.0
DP-3	93	0.3	0.90	84	0.2
DP-4 West	93	0.3	0.90	84	0.2
DP-4 East	8512	23.0	1.20	10214	23.8
Total area	36985		Total volume	42896	

Based on the volume estimates in Table A-1, half of the sampling effort will be directed to the reach that contains half of the volume of sediments. [The statistical term for reaches is strata, and the statistical methodology is known as stratified random sampling (SRS). Gilbert presents the equations used for SRS (Gilbert 1987, 0312). The simplest SRS allocation is based on the proportion of the total represented by each strata. Thus, the percentage of area and volume presented in Table A-1 represents a simple SRS sample allocation.] Another consideration in sample allocation to reaches is the average concentration of contaminants present in each reach.

Historical information on releases at Technical Area (TA) 21 and the existing Resource Conservation and Recovery Act (RCRA) facility investigation (RFI) data for source potential release sites (PRSs) suggests that the majority of the contaminants currently located in DP Canyon originated from releases at PRS 21- 011(k) and the Material Disposal Area (MDA) T drainages. Of these two sources, the liquid effluent released at PRS 21-011(k) represents the larger potential source term. Several radionuclides were released from PRS 21-011(k), including strontium-90, cesium-137, plutonium-238, plutonium-239, and americium-241. Reach DP-2 was divided into two reaches based on the location affected by releases from PRS 21-011(k). Thus, elevated activity of cesium-137 and the other radionuclides is expected in reaches downstream from the outlet pipe: Reaches DP-2 East, DP-3, DP-4 West, and DP-4 East. The optimal statistical allocation requires selection of a radionuclide for estimating variability of concentration within a reach. Cesium-137 was selected because of the amount of this radionuclide released from PRS 21-011(k) and the ease of detecting cesium-137 with field gamma instruments. As an initial estimate, cesium-137 variability was assumed to be low in the reaches upstream of PRS 21-011(k) (1 pCi/g was assumed in Reaches DP-1 and DP-2 West which is roughly equal to cesium-137 background activity), and high in the downstream reaches (10 pCi/g on an order of magnitude higher cesium-137 activity, see Table A-2). These assumptions were made to adjust sample allocation for the likely pattern of contaminant concentration in reach sediments. The optimal allocation suggests that nearly all of the samples should be collected from Reaches DP-2 East and DP-4 East. If estimates of the volume or concentration of contaminated sediments change as new data are collected, samples can be re-allocated based on this new information.

The optimal allocation for stratified random sampling designs is based on equation 5.10 presented in Gilbert (1987, 0312). The equation is:

$$f_h = \frac{\left(\frac{v_h}{v_{total}}\right)\cdot\sigma_h}{\sum_{h=1}^{L}\left(\frac{v_h}{v_{total}}\right)\cdot\sigma_h}$$

where:

f_h = fraction of samples in the h^{th} reach,

v_h = area of the h^{th} reach,

v_{total} = total area, and

σ_h = estimated standard deviation of concentration in the h^{th} reach.

TABLE A-2

ESTIMATED STANDARD DEVIATION OF CESIUM-137 AND VOLUME OF REACHES USED FOR OPTIMAL SAMPLE ALLOCATION IN STRATIFIED RANDOM SAMPLING

REACH	ESTIMATED REACH STANDARD DEVIATION (pCi/g of Cesium-137)	VOLUME (m^3)	SAMPLING WEIGHTING FACTOR	% ALLOCATION TO REACH FOR OPTIMAL NUMBER OF SAMPLES
DP-1	1.0	4291	0.100	1.3
DP-2 West	1.0	5911	0.138	1.8
DP-2 East	10.0	22312	5.201	66.2
DP-3	10.0	84	0.020	0.2
DP-4 West	10.0	84	0.020	0.2
DP-4 East	10.0	10214	2.381	30.3
	Total Volume	42896		

The next consideration in developing the sample allocation is to establish an adequate number of samples. The stratified random sampling formulas provide an estimate of the expected standard error in the mean concentration as a function of the number of samples. This relationship for the assumptions made for DP Canyon is presented in Fig. A-1. At a value of approximately 40 samples, the expected variability in the estimate of mean cesium-137 concentration is approaching a point where additional sampling effort does not significantly reduce inventory uncertainty. Thus, 40 samples are proposed as the minimum number of samples needed to establish the contaminant inventory in DP Canyon.

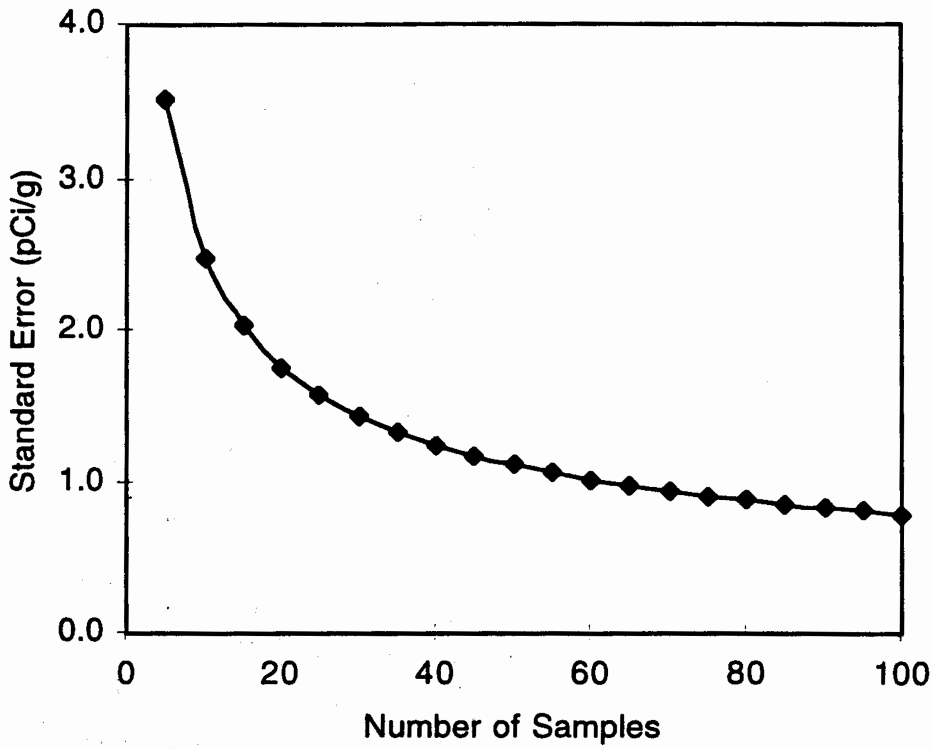

Fig. A-1 Relationship between the standard of the estimate of the mean cesium-137 concentration versus the number of samples collected in DP Canyon.

REFERENCE

Gilbert, R. O., 1987. Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold, New York, New York. **(Gilbert 1987, 0312)**