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Date: December 21, 1998
Refer to: EM/ER:98-483

Mr. Benito Garcia
NMED-HRMB
P.O. Box 26110
Santa Fe, NM 87502

SUBJECT: REACH REPORT FOR UPPER LOS ALAMOS CANYON

Dear Mr. Garcia:

Enclosed are three copies of an interim reach report that describes investigations of sediment contamination in Upper Los Alamos Canyon. A companion report on investigations in Lower Los Alamos Canyon should be ready for distribution in the near future. As with the Pueblo Canyon reach report, this report was prepared for Department of Energy-Los Alamos Area Office to meet FY98 Performance Measures, and include preliminary evaluations of 1) potential present-day human health risk associated with contaminated sediments; 2) potential ecological risk; and 3) relevant transport processes that redistribute sediments and associated contaminants. One goal of these reports is to identify data gaps that may require additional data collection before completion of Environmental Restoration Project investigations in these canyons. We welcome comments from New Mexico Environment Department (NMED) on our approach, our preliminary conclusions, and our recommendations for additional data collection. Such input would help assure that we are addressing significant concerns of NMED as we continue investigations in Los Alamos Canyon and Pueblo Canyon and as we proceed with characterization activities in other canyons.

Sincerely,

Julie A. Canepa, Program Manager
LANL/ER Project

Sincerely,

Theodore J. Taylor, Program Manager
DOE/LAAO

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Enclosure: Reach Report for Upper LA Canyon

7233

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LA-UR-98-3974
September 1998

Evaluation of Sediment Contamination in Upper Los Alamos Canyon

Reaches LA-1, LA-2, and LA-3

Environmental Restoration Project
A Department of Energy Environmental Cleanup Program

Los Alamos
NATIONAL LABORATORY
Los Alamos, NM 87545

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EXECUTIVE SUMMARY

This interim report presents the results of investigations on contaminated sediments in upper Los Alamos Canyon and recommendations concerning potential additional assessments, sampling and analysis, and remedial actions. The objectives of this work include defining the nature and extent of contaminants within the sediments of upper Los Alamos Canyon, evaluating potential human health and ecological risk related to these contaminants, and evaluating the processes that redistribute these contaminants and the consequences of this redistribution. The risk assessments presented in this report are preliminary and are intended to identify whether there is a need for immediate action to mitigate risk or additional data collection. More comprehensive risk assessments will be presented in future reports on Los Alamos Canyon that will incorporate the results of ongoing groundwater investigations and additional sediment investigations.

Upper Los Alamos Canyon has received contaminants from multiple potential release sites (PRSs) within the watershed since the Laboratory was established in 1943. The most significant contaminant source was the 21-011(k) outfall at former Technical Area (TA) -21, where radioactive effluent was discharged between 1956 and 1985 into DP Canyon, a small tributary to Los Alamos Canyon. The second most important source for contaminants present in sediments along the stream channel was apparently an outfall that discharged onto Hillside 137 at former TA-1 between the mid 1940s and the mid 1950s. Additional sources exist at TA-1, TA-2, TA-21, and TA-53. Contaminants may also have reached the main channel from other technical areas and from residential and commercial areas in the Los Alamos townsite.

The technical approach followed in this investigation focused on detailed evaluations of contamination within three sections of upper Los Alamos Canyon, called "reaches." These reaches were selected (1) to encompass the range of potential risk related to contaminated sediments along the full length of the canyon downstream from the PRSs and (2) to allow testing and refinement of a conceptual model describing the distribution and transport of contaminants. Phased field investigations included detailed geomorphic mapping and characterization of post-1942 sediments, those sediments potentially containing contaminants resulting from Laboratory operations. An evaluation of data collected during each phase was used to revise the conceptual model, identify key uncertainties, and focus subsequent data collection.

The most significant chemical of potential concern (COPC) in the sediments of upper Los Alamos Canyon with regard to potential human health risk is cesium-137, which was released from TA-21 and is present downstream from DP Canyon. Plutonium-239,240, released primarily from former TA-1, is the most pervasive COPC upstream from DP Canyon. These radionuclides and other COPCs have been distributed by floods along the full length of upper Los Alamos Canyon downstream from former TA-1, a distance of more than 10 km, and have been dispersed laterally away from the stream channel for distances varying from less than 5 m to at least 25 m. Concentrations of cesium-137 in sediments transported by floods were highest during the early period of effluent releases from the 21-011(k) outfall, between 1956 and 1968, and concentrations dropped rapidly after 1968 following reductions in the discharge of cesium-137. Available data indicate that cesium-137 concentrations have been stable or have declined since 1978 and that concentrations will not increase in the future. Radionuclide concentrations are higher in relatively fine-grained sediment deposits of a given age than in associated coarse-grained sediment deposits; therefore, potential risk is higher in those areas where fine-grained sediments have been deposited. Because of these particle-size effects and time-dependent changes in contamination, cesium-137 concentrations are highest in fine-grained sediments that were deposited between 1956 and 1968. The highest concentrations of americium-241, cesium-137, plutonium-238,

strontium-90, and tritium were found close to DP Canyon, with much lower concentrations downstream near the Laboratory boundary. The highest concentrations of plutonium-239,240 have been found farther upstream, below former TA-1.

Inventories of the key radionuclides in upper Los Alamos Canyon sediments show geographic variations that are very similar to variations in radionuclide concentrations. Because risk is a function of contaminant concentrations, potential remedial actions that are designed to reduce either the total radionuclide inventory or the part of the radionuclide inventory most susceptible to remobilization in floods would therefore target the same areas as potential remedial actions designed to reduce risk at a site. Pockets of relatively fine-grained sediment that were deposited downstream from DP Canyon between 1956 and 1968 would be the primary target for remediation under either circumstance, and these areas could be easily identified using field measurements of gamma radiation.

Two of the most important radionuclide COPCs in upper Los Alamos Canyon, cesium-137 and strontium-90, have relatively short half-lives of 29 to 30 years, and significant decreases in concentration due to radioactive decay will occur over time frames relevant for evaluating risk and sediment remobilization. Implementing institutional controls that limit possible land uses until significant radioactive decay has occurred could therefore be an effective risk mitigation technique if measures to reduce risk are necessary.

Other COPCs identified in the sediments of upper Los Alamos Canyon include 9 radionuclides, 10 inorganic chemicals, and 23 organic chemicals. All these COPCs are found at low levels relative to the key radionuclides. In general, the concentrations of most of the other radionuclide and inorganic COPCs are positively correlated with either cesium-137 or plutonium-239,240 concentrations, indicating collocation of these COPCs and similar histories of release and transport. The concentrations of the organic COPCs are not correlated with the key radionuclides, and their sources and distributions are more poorly defined because of large gaps in data coverage. Collection of additional data on organic COPCs is needed to complete future human health and ecological risk assessments.

The preliminary assessments of potential human health and ecological risk presented in this report indicate that levels of contamination in the sediments of upper Los Alamos Canyon do not require immediate remedial actions with regard to present-day risk. In addition, because concentrations of contaminants in sediments carried by floods are not increasing over time and present levels of contamination have not been shown to either cause an unacceptable risk in downstream areas or exceed regulatory standards, no immediate remedial action is required in the context of future remobilization of contaminated sediments. Thus, possible decisions to implement any remedial action in upper Los Alamos Canyon should be made in the context of future assessments and/or future policy directives.

1.0 INTRODUCTION

1.1 Purpose

This interim report describes sediment investigations conducted in upper Los Alamos Canyon (Figure 1.1-1) in 1996, 1997, and 1998 by personnel from the Canyons Focus Area (formerly Field Unit 4) as part of the Los Alamos National Laboratory ("the Laboratory") Environmental Restoration (ER) Project. Investigations were focused on three reaches of the canyon following the technical strategy described in the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* ("the work plan") (LANL 1995, 50290; LANL 1997, 56421) and modified by the *Core Document for Canyons Investigations* ("the core document") (LANL 1997, 55622; LANL 1998, 57666). Data collected from the three reaches in upper Los Alamos Canyon are used to define the nature and extent of contamination within young alluvial sediments (post-1942 sediments), to revise a conceptual model for contaminant distribution and transport, to perform preliminary assessments for potential human and ecological risk, and to determine if there is a need for immediate remedial action or additional data collection. In a future report these data will be combined with additional data on sediment, groundwater, and surface water in Los Alamos Canyon and Pueblo Canyon to support a canyons-wide assessment, which will involve a more comprehensive assessment of human and ecological risk related to present-day levels of contamination and the effects of future transport of contaminants.

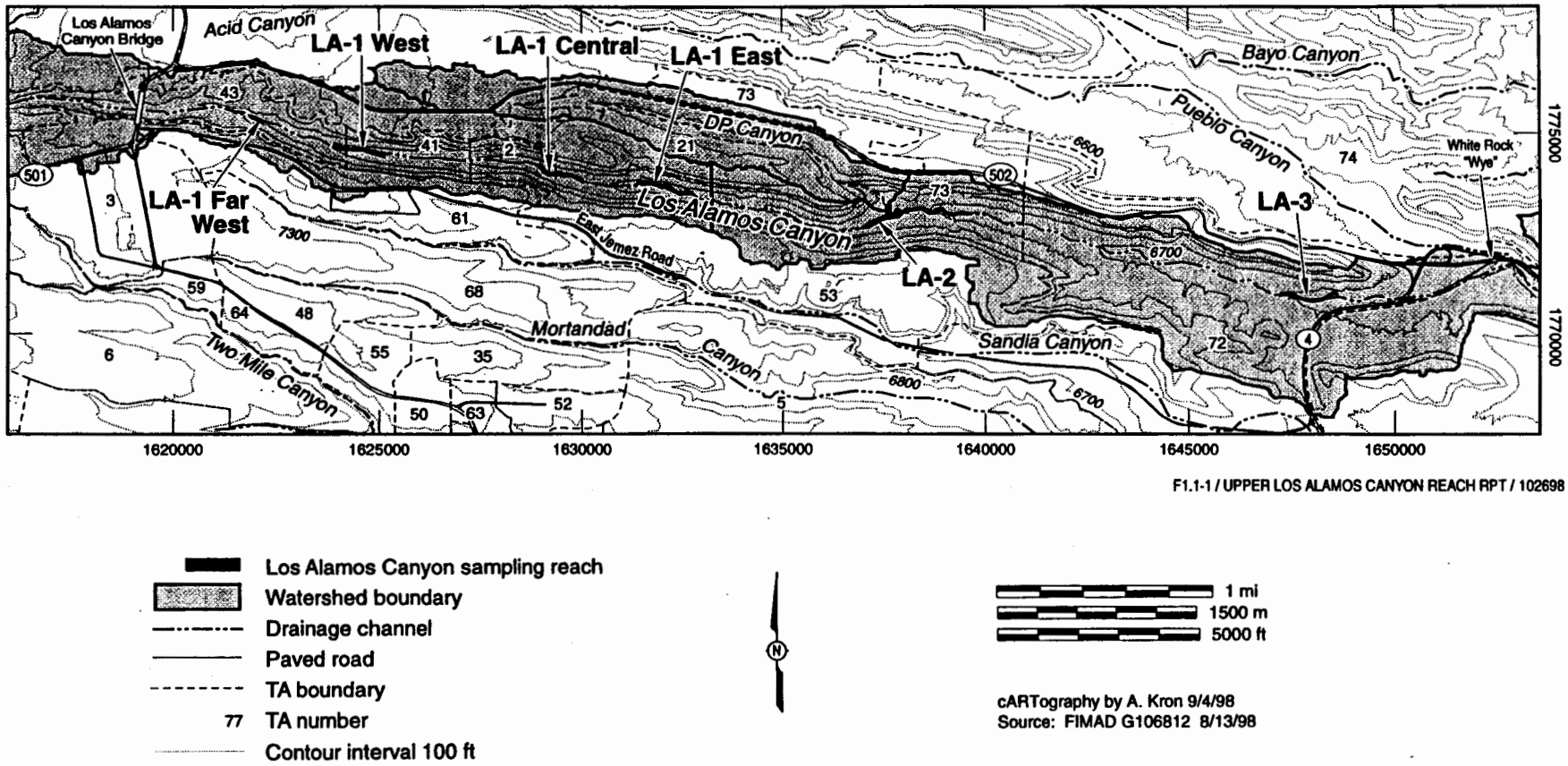
1.2 Regulatory Context

Regulatory requirements governing the ER Project canyons investigations are discussed in Section 1.4 of the core document (LANL 1997, 55622). In particular these investigations address requirements of Module VIII of the Laboratory's Hazardous Waste Facility Permit ("the HSWA Module") (EPA 1990, 1585) under the Resource Conservation and Recovery Act (RCRA), including addressing "the existence of contamination and the potential for movement or transport to or within Canyon watersheds." In addition to federal and state regulations, Department of Energy (DOE) Order 5400.5, "Radiation Protection of the Public and the Environment," provides guidance on residual radioactivity at DOE facilities.

1.3 Background

1.3.1 Geography, Geology, and Hydrology

Los Alamos Canyon heads in the Sierra de los Valles on Santa Fe National Forest land below the north side of Pajarito Mountain and extends eastward across the Pajarito Plateau within the Laboratory boundary. Upper Los Alamos Canyon, as referred to in this report, is the area upstream from the confluence of Los Alamos Canyon and Pueblo Canyon. Upper Los Alamos Canyon has a drainage area of 27.8 km^2 and a basin length of approximately 20 km. Geologic units exposed within the upper Los Alamos Canyon watershed include Pliocene and Miocene dacites of the Tschicoma Formation, Quaternary ignimbrites of the Otowi and Tshirege Members of the Bandelier Tuff, and Quaternary pumice beds and volcaniclastic sediments of the Cerro Toledo interval (Griggs 1964, 8795; Smith et al. 1970, 9752). The part of the canyon within the Laboratory boundary is underlain by the Bandelier Tuff and the Cerro Toledo interval, except for the far eastern end where Pliocene basaltic rocks of the Cerros del Rio volcanic field are exposed.



F1.1-1 / UPPER LOS ALAMOS CANYON REACH RPT / 102698

Figure 1.1-1. Map of the part of the upper Los Alamos Canyon watershed that includes Los Alamos National Laboratory, showing Laboratory technical areas and sampling reaches.

Stream flow in upper Los Alamos Canyon includes snowmelt runoff originating in the Sierra de los Valles and runoff from rain storms, which may often have local sources on the plateau. In some years snowmelt runoff extends completely across the plateau and crosses the eastern Laboratory boundary. In many years storm runoff also crosses the eastern Laboratory boundary and can reach the Rio Grande. DP Canyon is a source for many summer floods in upper Los Alamos Canyon, and the magnitude and frequency of these floods is enhanced by runoff from paved areas in the Los Alamos townsite at the head of DP Canyon.

1.3.2 Laboratory History and Operations

Several active and former Laboratory sites within the upper Los Alamos Canyon watershed have or may have contributed contaminants to the main channel of Los Alamos Canyon, including some of the original Manhattan Project laboratories within the current Los Alamos townsite that date back to 1943. Technical areas (TAs) that were or that might have been sources for contaminants include TA-1, TA-2, TA-3, TA-21, TA-41, TA-43, TA-53, and TA-61 (Figure 1.1-1). Brief summaries of pertinent information on key sites in the upper Los Alamos Canyon watershed are presented below.

1.3.2.1 Technical Area 1

Outfalls located in former TA-1 along the north rim of Los Alamos Canyon, within the current Los Alamos townsite, constitute significant sources of contamination for upper Los Alamos Canyon. TA-1 was established in 1943 during the Manhattan Project, and initial contaminant releases could date to this period. The contaminated areas are commonly referred to as Hillsides 137, 138, and 140 and are each the hillside component of a TA-1 aggregate of potential release sites (PRSs). Hillside 137 is within Aggregate G; Hillside 138 is within Aggregate F; and Hillside 140 is within Aggregate C (LANL 1992, 43454) (Figure 1.3-1).

Hillside 137 initially received direct discharges from a laundry for radioactively contaminated clothing, gloves, glassware, and other materials located in former Building D-2. The laundry was eventually moved to another building, and Septic Tank 137 (PRS 1-001[c]) was installed and connected by a drain line to an electronics shop in D-2. The buildings in Aggregate G were vacated in the mid 1950s (LANL 1992, 43454). Previous ER Project sample data for Hillside 137 indicated radionuclide concentrations above background values for plutonium-238; plutonium-239,240; uranium-234; uranium-235; and uranium-238. Inorganic chemicals reported as detected above background values include arsenic, barium, beryllium, chromium, lead, mercury, nickel, selenium, silver, thallium, and total uranium (LANL 1996, 54465).

Hillside 138 received discharges from Septic Tank 138 (PRS 1-001[d]). The septic tank was connected to former Buildings K, V, and Y, which were operational from the early 1940s through the late 1950s (Ahlquist et al. 1977, 5710; LANL 1995, 49703). Building K was used as a chemical stock room and contained a still for repurifying mercury (Mitchell 1944, 4984; Kershaw 1945, 4827). Uranium and beryllium machining and dry boron grinding was conducted in Building V (H-Division 1952, 32426). Building Y contained a cryogenics and physics laboratory that handled tritium, deuterium, uranium-238, and polonium-210 (Ahlquist et al. 1977, 5710). Previous ER Project sample data indicated radionuclide concentrations above background values for cesium-137; plutonium-238; plutonium-239,240; uranium-234; uranium-235; and uranium-238. Inorganic chemicals reported as detected above background values include arsenic, beryllium, chromium, lead, mercury, nickel, and silver (LANL 1995, 49703).

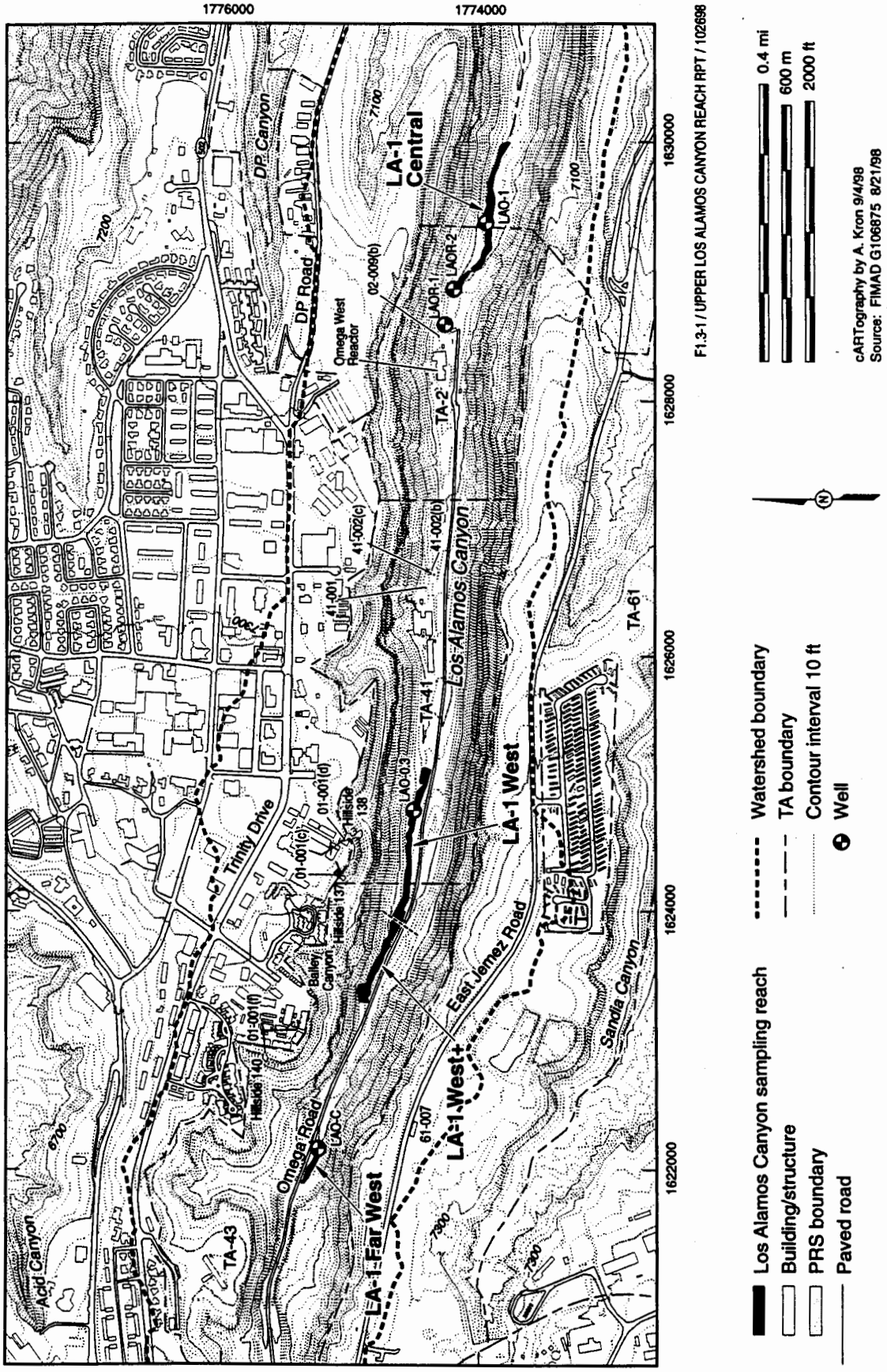


Figure 1.3-1. Map of upper Los Alamos Canyon showing reaches LA-1 West and LA-1 Central and the location of selected PRSs.

Hillside 140 received discharges from Septic Tank 140 (PRS 1-001[f]). The septic tank served the former HT Building, which was used for machining natural and enriched uranium for only six or seven months in 1945 (Ahlquist et al. 1997, 5710). Previous ER Project sample data indicate radionuclide concentrations above background values for plutonium-238; plutonium-239,240; uranium-234; uranium-235; and uranium-238. Inorganic chemicals detected above UTLs include antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, silver, and total uranium (LANL 1996, 54467).

1.3.2.2 Technical Area 2 and Technical Area 41

TA-2 and TA-41 are located within Los Alamos Canyon between reaches LA-1 West and LA-1 Central (Figure 1.3-1), and both sites have been used continuously since 1943 (LANL 1993, 21404). TA-2 has housed a series of research nuclear reactors, and TA-41 is used for weapons development and long-term studies of weapon subsystems.

Contaminants reported within soils and sediments at TA-2 include cesium-137; strontium-90; plutonium-239,240; chromium; mercury; silver; and uranium. The Omega West Reactor, which operated from 1956 to 1993, was a source of tritium releases into alluvial groundwater. Leach fields located east of Building 2-1 (PRS 02-009) were associated with water boiler reactors and have cesium-137 and strontium-90 above background values (LANL 1993, 21404).

The most important potential contaminant sources at TA-41 are a septic system (PRS 41-001) and a sewage treatment plant that operated from 1951 until 1987 (PRS 41-002). These PRSs may have plutonium, tritium, uranium, and perhaps other radionuclides above background values (LANL 1993, 21404).

Because ER Project investigations have not been completed at TA-2 and TA-41, the nature of contamination at these PRSs is only partially defined. In addition, results of both previous investigations and this investigation are inconclusive as to whether any of the TA-2 or TA-41 PRSs have been significant sources of contaminants for surface sediments along the active channel.

1.3.2.3 Technical Area 21

TA-21 was established in 1945 on DP Mesa and was the site of a plutonium processing plant and polonium and tritium research laboratories (LANL 1991, 7528). TA-21 includes the most significant source for contaminants in the upper Los Alamos Canyon watershed, outfall 21-011(k), which discharged northward into DP Canyon (Figure 1.3-2). Several other outfalls that discharged into DP Canyon or southward into Los Alamos Canyon may have also contributed contaminants to the main stream channels in these canyons. Information on the most significant PRSs that have been identified by ER Project investigations at TA-21 that may relate to contaminants in Los Alamos Canyon sediments are summarized below.

PRS 21-011(k), located on the north rim of DP Canyon, is an outfall that received radioactive liquid waste effluent from an industrial waste treatment plant located at Building 21-35 between 1956 and 1968, and effluent from a more recent industrial waste treatment plant between 1968 and 1985 (LANL 1991, 7529). This outfall has not been used since 1985. Radionuclides found above screening action levels (SALs) on the slope below the outfall include americium-241; cesium-137; plutonium-238; plutonium-239,240; and strontium-90. No other contaminants were identified above background values. Four hundred cubic yards of the most contaminated soil below the outfall were removed in an interim action in 1996, and the site is currently awaiting risk assessment for radioactivity before determining what future actions may be required (LANL 1995, 52350; LANL 1997, 55648).

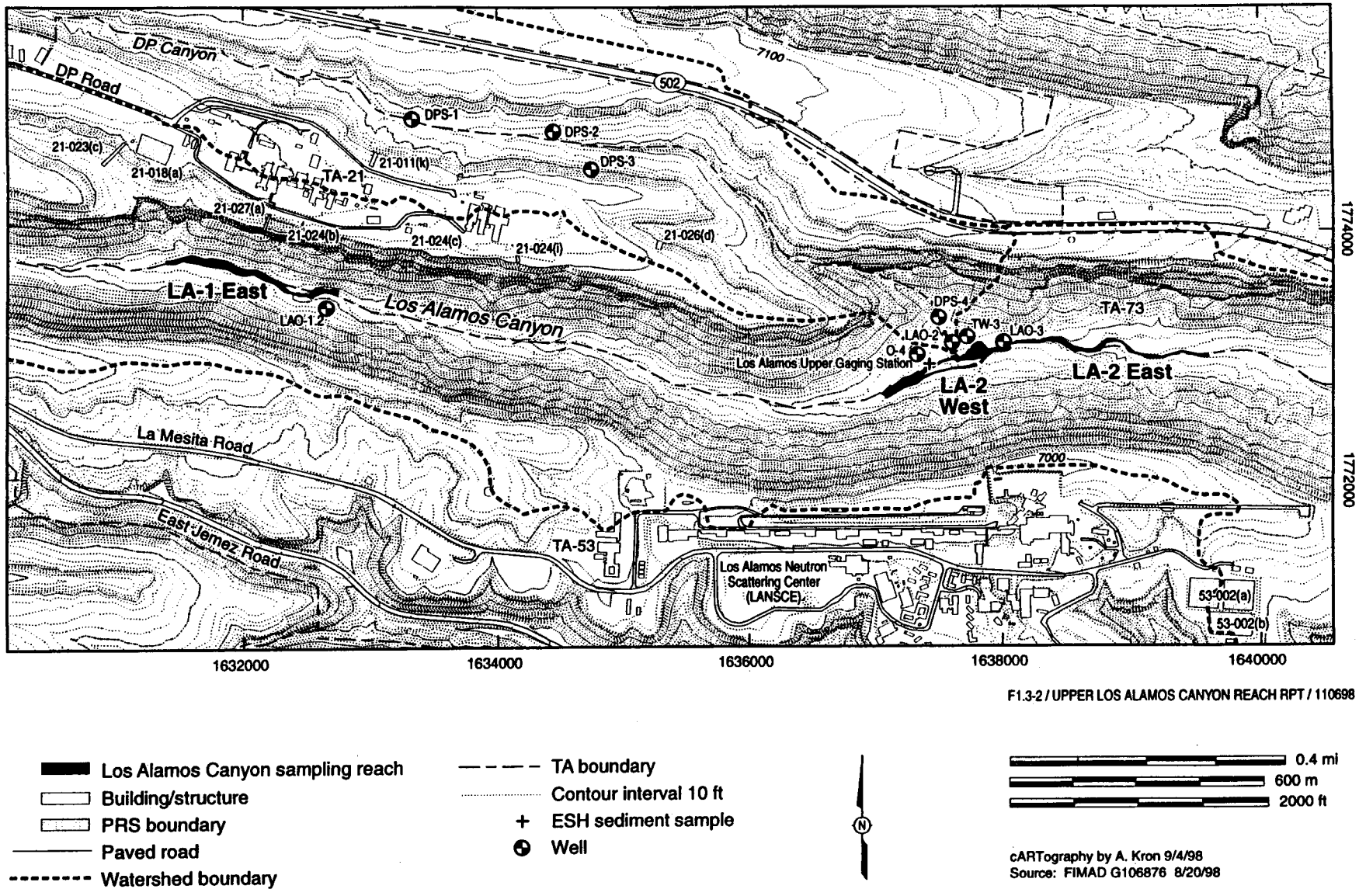


Figure 1.3-2. Map of upper Los Alamos Canyon showing reaches LA-1 East and LA-2 and the location of select PRSs.

PRS 21-018(a) consists of Material Disposal Area (MDA) V, which received liquid waste effluent from laundry operations in Building 21-20. MDA V includes three absorption beds on the south side of DP Mesa that sometimes overflowed into Los Alamos Canyon (LANL 1991, 7529). Sediment sampling in 1946 documented that plutonium from this source was entering the main stream channel in Los Alamos Canyon at that time (Kingsley 1947, 4186). Analytes identified above SALs include the metals antimony, cadmium, copper, lead, mercury, and uranium and the radionuclides americium-241; cesium-137; plutonium-238; plutonium-239,240; strontium-90; tritium; uranium-234; uranium-235; and uranium-238 (LANL 1996, 54969).

PRS 21-023(c) was a septic system that routed sewage from Building 21-33 through Septic Tank 21-62 to the south rim of DP Mesa (LANL 1991, 7529). Building 21-33 housed a waste treatment laboratory where research into the recovery of plutonium from liquid process wastes was performed. The septic system was installed in 1948 and removed in 1965. Radionuclides identified at concentrations above a local TA-21 baseline were americium-241; plutonium-238; plutonium-239,240; strontium-90; and uranium; americium-241 and plutonium-239 were detected above SALs. Metals identified above baseline concentrations but below SALs were arsenic, cadmium, chromium, copper, lead, nickel, and zinc (LANL 1995, 52350).

PRS 21-024(b) is a septic system that routed sewage from Building 21-17 through Septic Tank 21-55 to the south rim of DP Mesa. The outfall presently consists of a short cast iron pipe inside the security fence (LANL 1991, 7529). Analytes identified above the TA-21 baseline include the radionuclides americium-241; plutonium-239,240; tritium; and total uranium and the metals arsenic, chromium, nickel, selenium, and zinc. Only plutonium-239,240 concentrations were above SALs (LANL 1995, 52350).

PRS 21-024(c) is a septic system that routed sewage from Building 21-54 (removed in 1969) through Septic Tank 21-56 (abandoned in place in 1966) to the south rim of DP Mesa (LANL 1991, 7529). Analytes identified above the TA-21 baseline include the radionuclides americium-241; plutonium-239,240; strontium-90; tritium; and total uranium and the metals cadmium, chromium, copper, lead, nickel, silver, and vanadium. Chromium and lead exceeded SALs in the surface soil. Low concentrations of polychlorinated biphenyls (PCBs) and other unidentified organic chemicals were also detected (LANL 1995, 52350).

PRS 21-024(i) is a septic system that routed sewage from Building 21-152 through Septic Tank 21-181 (abandoned in place in 1965) to the south rim of DP Mesa (LANL 1991, 7529). Current ER Project investigations indicate the radionuclides actinium-227, tritium, and uranium isotopes and the metals arsenic, barium, chromium, copper, lead, mercury, selenium, vanadium, and zinc are present above background values. Arsenic, chromium, and lead were also detected in previous investigations with arsenic exceeding SALs. Low concentrations of PCBs and other unidentified organic chemicals have also been reported (LANL 1995, 52350).

PRS 21-026(d) is a National Pollutant Discharge Elimination System (NPDES) -permitted outfall from a sewage treatment plant on the eastern part of DP Mesa, which flows into a tributary drainage of DP Canyon (LANL 1991, 7529). Reconnaissance sampling in 1988 identified elevated levels of gross alpha, beta, and gamma activity and elevated tritium concentrations in the effluent. Subsequent ER Project investigations found concentrations of the radionuclides americium-241, tritium, and plutonium-239,240 and the inorganic chemicals cadmium, chromium, copper, nickel, silver, and zinc above the TA-21 baseline. Numerous semivolatile organic compounds (SVOCs) that are characteristic of paving materials were detected, including benz(a)anthracene, benzo(a)fluoranthene, and indeno[1,2,3-cd]pyrene at

maximum concentrations at least four times their SALs. Chrysene was detected at a maximum concentration approximately 50% of its SAL (LANL 1994, 31591).

PRS 21-027(a) is a complex drainage system that routed liquid wastes from Building 21-3 to the south rim of DP Mesa. The system originates at the southwest corner of Building 21-3 with floor drains from equipment rooms, connects to a storm drain, and then empties into a ponding area. This area also receives NPDES-permitted discharges of treated cooling water effluent. The combined effluents from the pond flow eastward along the south side of the mesa to a culvert that carries them to the mesa edge (LANL 1991, 7529). The radionuclides americium-241; plutonium-238; plutonium-239,240; and total uranium have been found above background values with plutonium-238; plutonium-239,240; and americium-241 exceeding SALs. Arsenic was also detected above background value, and chromium was detected above SAL (LANL 1995, 52350).

1.3.2.4 Technical Area 53

TA-53 includes a proton accelerator and associated experimental and support buildings used for research with subatomic particles; it is the current site of the Los Alamos Neutron Science Center (LANL 1994, 34756). Construction began in 1967, and the accelerator became fully operational in 1974. Water from surface impoundments at the east end of TA-53, collectively known as PRSs 53-002(a and b), may have contributed contaminants to an unnamed tributary drainage to Los Alamos Canyon between reaches LA-2 and LA-3 (Figures 1.3-2 and 1.3-3). The surface impoundments received sanitary, radioactive, and industrial wastewater from various TA-53 buildings as well as septic tank sludge from other Laboratory buildings. The northern impoundments were active from the early 1970s until 1993. The southern impoundment came online in 1985 and is currently active and receiving radioactive liquid waste. The operating group tentatively plans to remove the southern impoundment in late 1998. Contaminants detected in impoundment sludge during previous investigations at 0.1 times SALs for noncarcinogenic chemicals or greater than SALs for radionuclides and carcinogenic organic chemicals include chromium, copper, lead, mercury, thallium, Aroclor-1254, Aroclor-1260, bis(2-ethylhexyl)phthalate, α-BHC, cobalt-60, neptunium-237, sodium-22, and tritium. Additionally, thallium, dieldrin, cesium-134, and manganese-54 were detected in the clay liner (LANL 1998, 58841).

1.3.2.5 Other Technical Areas

Laboratory sites at several other technical areas are located within the upper Los Alamos Canyon watershed and could potentially have contributed contaminants to the canyon floor, including TA-3, TA-43, and TA-61, although no PRSs in these technical areas have yet been identified as being actual contaminant sources for Los Alamos Canyon (LANL 1993, 51977). TA-3 is located south of the bridge across Los Alamos Canyon on Diamond Drive (Omega Bridge) and is a heavily developed technical area that includes the Laboratory administration building; only a small part of TA-3 drains into Los Alamos Canyon. TA-43 is a small technical area immediately north of the bridge that has housed the Health Research Laboratory since 1953 (LANL 1990, 7511). TA-61 is located along East Jemez Road near the Los Alamos County municipal landfill and has a few small support buildings. Significant PCB releases occurred at one TA-61 PRS (61-007) located within the topographic extent of the Los Alamos Canyon watershed (LANL 1993, 51977), although the PRS is immediately south of East Jemez Road; surface runoff from this mesa-top site may have been directed southward into Sandia Canyon instead of into Los Alamos Canyon. This site was remediated before the ER Project began.

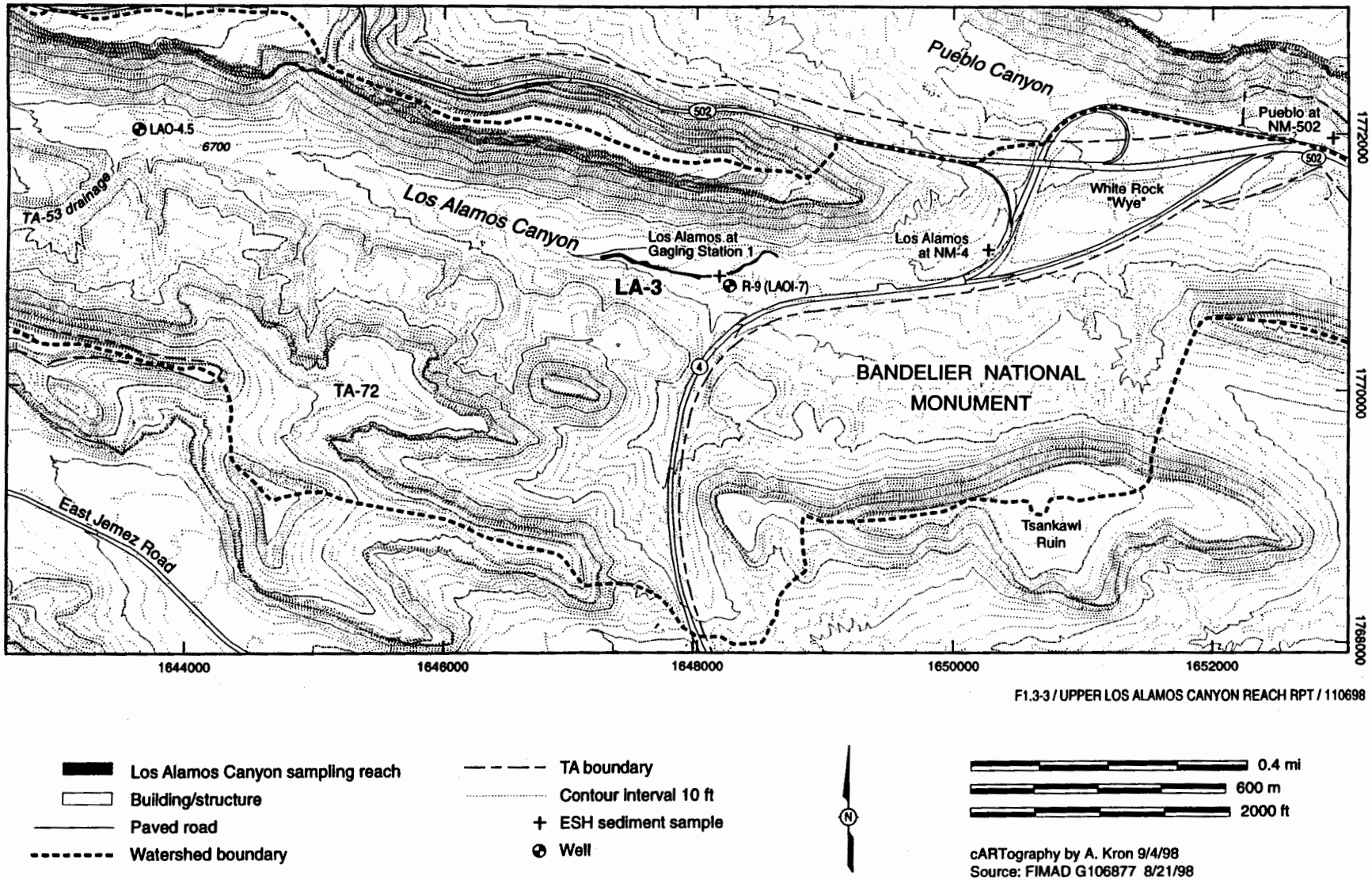


Figure 1.3-3. Map of upper Los Alamos Canyon including reach LA-3.

1.4 Current Land Use

Upper Los Alamos Canyon downstream from the bridge is entirely owned by DOE. Two Laboratory technical areas, TA-2 and TA-41, are located on the canyon floor, and these areas are closed to the public. TA-2 includes the Omega West nuclear reactor, which was closed in 1993 and is awaiting decontamination and decommissioning (D&D). TA-41 is an active technical area that has been used for weapons research. West of TA-41 is a paved road (Omega Road) that is open to the public. East of the TA-2 security fence is a dirt road that extends to state road NM 4; it is also open to the public. This part of the canyon is often used for recreational activities such as hiking (Kron 1993, 58665). The eastern part of upper Los Alamos Canyon near state road NM 4, including sampling reach LA-3 and extending downstream to the confluence with Pueblo Canyon (Figure 1.3-3), is presently being considered for potential land transfer to either Los Alamos County or San Ildefonso Pueblo (DOE 1998, 58671).

1.5 Previous Sediment Investigations

Contaminants associated with sediments in upper Los Alamos Canyon have been investigated in many studies since the Laboratory was established in 1943. The first sediment sampling, in 1946, indicated the presence of plutonium at several sites within the canyon, with the highest concentrations reported below the outfall from the TA-21 laundry (PRS 21-018[a]) (Kingsley 1947, 4186). Subsequent work has included repeated sediment sampling at a series of stations as part of the Laboratory Environmental Surveillance Program since 1970 (e.g., Environmental Surveillance and Compliance Programs 1997, 56684) and more detailed topical studies. Additional studies that included sediment sampling have been conducted associated with the Laboratory Environmental Surveillance Program (e.g., Purtymun 1971, 4795; Purtymun et al. 1990, 6992); the Laboratory Environmental Sciences Group (e.g., Hakonson and Bostick 1975, 29678; Nyhan et al. 1976, 11747; Nyhan et al. 1982, 7164); the ER Project (LANL 1995, 52974); and the New Mexico Environment Department (Dale 1996, 58930). An additional study was recently conducted by Arizona State University, combining existing data on plutonium in sediments with geomorphic mapping of Los Alamos Canyon downstream from DP Canyon to provide an improved estimate of the inventory of plutonium in the canyon (Graf 1995, 48851; Graf 1996, 55537). Some of this earlier work is summarized in the work plan (LANL 1995, 50290) and formed the basis for a preliminary conceptual model of contaminant distribution and transport and for design of a technical approach for the present investigations, as summarized in the next section.

1.6 Preliminary Conceptual Model and Technical Approach

Available data on contaminants in upper Los Alamos Canyon sediments before this investigation indicated that cesium-137; plutonium-239,240; and other radionuclides discharged into DP Canyon from TA-21 were the primary contaminants of concern, although releases of inorganic and organic chemicals also occurred. Because of their geochemical characteristics, nearly all the cesium and plutonium was expected to be adsorbed onto sediment particles, and subsequent transport of these radionuclides would have been largely controlled by sediment transport processes. Strontium-90 released from TA-2 and TA-21 was recognized as a major contaminant in alluvial groundwater and was also expected to occur within the sediments, although strontium-90 is more soluble and transport processes would be different than for cesium and plutonium. Contaminants associated with sediments have been dispersed by floods from the original release sites downstream within upper Los Alamos Canyon and also into lower Los Alamos Canyon and the Rio Grande. Contaminant concentrations in post-1942 sediments vary greatly, related to factors such as the distance from the source, sediment particle size, and the age of the deposit. Radionuclide concentrations are expected to be generally higher in sediment deposits closer to the source and in finer-grained sediments than in downstream deposits or in coarser-grained sediments. In

addition, radionuclide concentrations are expected to be highest in sediment deposits that are relatively close to the age of the peak contaminant releases and lower in younger sediments (LANL 1995, 50290). Available data indicated that the plutonium inventory in upper Los Alamos Canyon was much less than in Pueblo Canyon, associated with both lower plutonium concentrations and smaller sediment volumes (Graf 1996, 55537), and that less investigation would thus be required in upper Los Alamos Canyon downstream from DP Canyon than in Pueblo Canyon.

The technical approach adopted in this investigation includes detailed geomorphic mapping and sediment sampling in a series of reaches selected at key locations in the canyon, following the "representative reach" concept presented by Graf (1994, 55536). This work was focused on determining the nature and extent of contamination, evaluating risk, and testing components of the preliminary conceptual model in a phased approach. Geomorphic mapping and sediment sampling concentrated on identifying and characterizing post-1942 sediments, those sediments younger than the initial contaminant releases. An evaluation of data collected in each phase was used to revise the conceptual model, identify key uncertainties, and focus subsequent data collection. Investigation goals include evaluating present and future potential risk, evaluating sediment transport processes and future contaminant redistribution, and providing data necessary to make decisions about possible remedial action alternatives.

1.7 Deviations from the Work Plan

While conducting the sediment investigations in upper Los Alamos Canyon, the Canyons Focus Area technical team made some modifications to the proposed work described in Section 7.2 of the work plan (LANL 1995, 50290). These deviations are briefly discussed below.

During implementation of the work plan the technical team realized that several potential source areas for contaminants upstream from DP Canyon might be more significant than originally thought, and that the single reach planned for investigation would be insufficient to determine the relative importance of different PRSs as source areas. Therefore, geomorphic mapping and sediment sampling were conducted in several additional areas not specified in the work plan, which increased the total area of investigation. Reach LA-1 was redefined from the area originally specified downstream from TA-2 to include several additional subreaches, and the original reach LA-1 was designated as LA-1 Central. LA-1 East extends downstream from the outfall channel draining the former TA-21 laundry (PRS 21-018[a]) (Figure 1.3-2), a site which had been identified as having the highest levels of plutonium in either Los Alamos Canyon or Pueblo Canyon in 1946 (Kingsley 1947, 4186). LA-1 West extends downstream from the Hillside 137 drainage channel and includes the Hillside 138 drainage channel (Figure 1.3-1), both of which were below outfalls from the original Manhattan Project plutonium building and related buildings; ER investigations completed after the work plan was written identified both of these sites as potentially significant contaminant sources (LANL 1995, 49703; LANL 1996, 54465). LA-1 West+ extends upstream from the Hillside 137 drainage channel and is downstream from both Bailey Canyon (which receives drainage from several TA-1 PRSs) and Hillside 140 and was used to evaluate possible contaminant contributions from additional TA-1 PRSs. Finally, LA-1 Far West is located upstream from the Hillside 140 drainage channel and all other former TA-1 PRSs and was used to evaluate if contaminants were present from other upstream sources.

Radiological field surveys conducted in upper Los Alamos Canyon in 1996 revealed that the concentrations of radionuclide contaminants upstream from DP Canyon were too low to allow definition of the extent of contaminated sediments using field instruments. Therefore, no radiological surveys were conducted in reach LA-1 during the 1997 investigations, and sample site selection in LA-1 was based entirely on geomorphic criteria instead of relying on field radiological data as was proposed in the work

plan. The 1996 surveys also indicated that alpha radiation was too low to distinguish from background and that beta radiation was correlated with gamma radiation downstream from DP Canyon and therefore provided no additional information on contaminant distribution. Thus, investigations downstream from DP Canyon in 1997 used only field measurements of gamma radiation.

Sample preparation deviated from that specified in the work plan by the decision to sieve each sample to remove all gravel and organic matter larger than 2 mm before analysis. The work plan had specified removal by hand of large stones and organic and other debris, but the technical team decided later that this process would not provide enough consistency in sample preparation.

1.8 Unit Conventions

This report uses primarily metric units of measure, although English units are used for contours on topographic maps, in reference to elevations derived from topographic maps, and for New Mexico State Plane coordinates as shown on some maps. English units are also used for radioactivity (curies [Ci] instead of becquerels [Bq]). Scales with both metric and English units of distance are shown on maps. Conversions from metric to English units are presented in Appendix A-2.0.

1.9 Report Organization

Section 2 of this report presents results of the field investigations of sediments in the upper Los Alamos Canyon reaches. Section 2.1 introduces each reach and its major geographic characteristics. Section 2.2 describes the methods of investigation in the reaches, including geomorphic mapping, physical characterization of young sediments, radiological field measurements, and sediment sampling activities. Section 2.3 presents results of these field investigations in each reach, including physical and radiological characteristics of the geomorphic units and key aspects of the post-1942 geomorphic history.

Section 3 of this report presents analytical results from sediment samples collected in the upper Los Alamos Canyon reaches. Section 3.1 is a data review that evaluates which radionuclides and organic and inorganic chemicals should be retained as chemicals of potential concern (COPCs). Section 3.2 evaluates each COPC in the context of likely sources within the upper Los Alamos Canyon watershed and possible collocation with other COPCs. Section 3.3 presents a detailed evaluation of radionuclide data from sediment samples collected in each reach, focused on cesium-137 and plutonium-239,240, which were selected as key contaminants in this investigation. Included in Section 3.3 are discussions of variations in radionuclide concentration among the different geomorphic units in each reach, the relations of radionuclide concentration to the age and particle size characteristics of the sediment deposits, the amount (inventory) of different radionuclides contained within the different units, and the potential for remobilization of contaminants contained within the different units.

Section 4 of this report presents a conceptual model describing contamination in the sediments of upper Los Alamos Canyon, which has been revised and refined from the preliminary conceptual model presented in the work plan based on the results of this investigation. Section 4.1 discusses the present nature and extent of contamination in upper Los Alamos Canyon sediments. Section 4.2 discusses controls on contaminant distribution, including the effects of particle size variations on radionuclide concentration and temporal and spatial trends in contaminant concentration. Section 4.3 discusses the fate and transport of contaminants in the sediments of upper Los Alamos Canyon, including processes that have redistributed contaminants since the initial releases and future remobilization and transport of these contaminants.

Section 5 of this report presents preliminary assessments of potential human and ecological risk related to contaminants contained within the sediments of upper Los Alamos Canyon. Section 5.1 presents the human health risk assessment. Section 5.2 presents the ecological screening assessment.

Section 6 of this report summarizes key conclusions of this investigation, highlights key remaining uncertainties, and provides recommendations concerning possible additional assessments, data collection, and/or remedial action.

Section 7 presents references cited in this report.

Appendix A presents a list of acronyms used in this report, metric to English conversions, and metric prefixes.

Appendix B presents supplemental information on the characterization of geomorphic units in the upper Los Alamos Canyon reaches. Appendix B-1.0 presents dendrochronological analyses (tree-ring dating). Appendix B-2.0 presents data on the thickness of post-1942 fine-grained overbank facies sediment in the different geomorphic units. Appendix B-3.0 presents data on particle size characteristics and organic matter content in the sediment samples. Appendix B-4.0 presents radiological field measurements and a discussion of instrument calibration and use. Appendix B-5.0 presents the chronology of sediment sampling events in the upper Los Alamos Canyon reaches and the primary goals of each sampling event.

Appendix C presents the results of quality assurance (QA) and quality control (QC) activities pertaining to the upper Los Alamos Canyon sediment samples. Appendix C-1.0 summarizes the QA/QC activities. Appendix C-2.0 addresses inorganic chemical analyses. Appendix C-3.0 addresses radiochemical analyses. Appendix C-4.0 addresses organic chemical analyses. Appendix C-5.0 presents data qualifiers for the samples.

Appendix D presents analytical suites and results of sediment analyses in this investigation. Appendix D-1.0 presents target analytes and detection limits. Appendix D-2.0 presents sample request numbers and analytical suites for each sample. Appendix D-3.0 presents summaries of analytical results. Appendix D-4.0 presents analytical results for COPCs.

Appendix E presents supplemental statistical analyses of the analytical results of this investigation. Appendix E-1.0 presents statistical evaluations of the inorganic chemical data. Appendix E-2.0 presents statistical evaluations of the radionuclide data. Appendix E-3.0 evaluates the possible collocation of COPCs. Appendix E-4.0 presents an analysis of radionuclide concentrations in field QA samples and resampled layers.

Appendix F-1.0 presents the ecological scoping checklist for the upper Los Alamos Canyon reaches.

1.10 Acknowledgments

The authors of this report had the following responsibilities. Reneau was responsible for documenting the field investigations and interpreting the analytical results in the context of the field setting and was also the principal investigator for sediment characterization during the field work. Ryti was responsible for data review, statistical analyses, and ecological screening and was also the lead for statistical analysis during all phases of the field investigation. Tardiff was responsible for the human health risk assessment included in this report. Linn was responsible for the data validation activities included in this report.

In addition to the authors of this report, numerous individuals contributed to this investigation.

Paul Drakos, Danny Katzman, Eric McDonald, and Brad Wilcox contributed to the geomorphic characterization activities. Wilcox contributed to development of the original technical strategy in the work plan and to initial phases of the field investigation. McDonald contributed to initial phases of the field investigations; helped develop field criteria for recognizing buried soils and the thickness of post-1942 sediment deposits; performed bulk density measurements; and was the lead for particle size analysis and development of a sediment background data set. Drakos and Katzman contributed to the second year of the field investigations, and Drakos was the lead for dendrochronological analyses.

Linnea Wahl lead the radiological field screening activities and provided summaries of these activities. Gross gamma radiation walkover surveys were performed by the Environmental Restoration Group (ERG) (Dave Hunter, Darrio Rocha, and John Taylor) and CHEMRAD (Mike Blair, Chuck Flynn, and Brett Lawrence), and fixed-point radiological measurements were performed by ERG and by ERM under the direction of Wahl. Florie Caporuscio lead initial planning for the radiological screening activities.

Johnnye Lewis was the lead for risk assessment during the field investigations. Ralph Perona contributed to risk assessment activities during both the field investigations and report preparation. Alison Dorries was the lead for initial development of the risk assessment approach in the work plan.

Jeff Blossom, Marcia Jones, and Matt Rice provided geographic information system (GIS) support. Jenny Harris was the lead for sediment sampling. Deba Daymon was the field team manager. Data management support was provided by Felicia Aguilar, Candi Chroninger, Chelsea Leeches, and Robert Trujillo. Ken Mullen provided environmental surveillance data. Maureen Oakes served as editor for this report; Christy Fläming was the graphic artist, and Pam Maestas was the compositor. Assistance in this investigation was also provided by the following individuals, including help with field work, data analysis, and report preparation: Larry Baker, Andy Crowder, Clint Daymon, Dave Frank, Rose Gallaway, John Hayes, Lorrie Houston, Andi Kron, Jared Lyman, Greg McDermott, Mary Mullen, Trung Nguyen, Marty Peifer, Bill Phillips, Stephanie Pratt, Carmella Romero, Celina Salazar, Jim Santo, Cathy Smith, Darrill Stafford, Jeff Walterscheid, and Ray Wright.

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Finally, Will Graf provided early technical inspiration for part of the approach to geomorphic characterization used in this investigation; Dave Broxton provided guidance as the technical team leader throughout work plan preparation, field work, and report preparation; and Allyn Pratt supported all phases of this investigation as leader of Field Unit 4 and the Canyons Focus Area.

2.0 FIELD INVESTIGATIONS

2.1 Introduction to Reaches

The initial locations of the upper Los Alamos Canyon reaches were selected to address a variety of goals, including identifying variations in contaminant concentration, contaminant inventory, and risk along the length of upper Los Alamos Canyon and improving the understanding of transport processes (LANL 1995, 50290). Each reach was intended to be long enough to capture local variations in contaminant concentrations related to variations in the age, thickness, and particle size of young (post-1942) sediment deposits but short enough that the effects of downstream dilution of contaminants were minimized. During field work, the geographic boundaries of the reaches were finalized, including the addition of subreaches to better define geographic variations in contamination and to better identify contaminant sources. The locations of the reaches within the upper Los Alamos Canyon watershed are shown in Figure 1.1-1; larger scale topographic maps showing the relation of the sampling reaches to key Laboratory sites are included in Figures 1.3-1 through 1.3-3. The general nomenclature for the geomorphic units used in this report is discussed in Section 2.2.1.1, and the specific units in each reach are discussed in Section 2.3. Geographic characteristics of these reaches are briefly summarized below.

Reach LA-1 is located downstream from the Los Alamos Canyon bridge and includes several subreaches that may have received contaminants from a series of potential releases sites (PRSs) in Technical Area (TA) -1, TA-2, TA-3, TA-21, TA-41, and TA-43. The canyon floor is relatively narrow through LA-1, and the stream is incised into the Tshirege Member and the Otowi Member of the Bandelier Tuff. LA-1 Far West is a short subreach upstream of Hillside 140. LA-1 West+ is a short subreach between Bailey Canyon and Hillside 137. LA-1 West is located between the drainage channel from Hillside 137 and TA-41 and includes the channel draining Hillside 138. LA-1 Far West, LA-1 West+, and LA-1 West are the wettest of the upper Los Alamos Canyon reaches, usually having surface water. LA-1 Central is located downstream from TA-2 and is drier than LA-1 West, often lacking surface water. LA-1 East is located downstream from the channel draining the former laundry at TA-21 and is also usually dry.

Reach LA-2 includes the confluence of DP Canyon and Los Alamos Canyon. LA-2 West is a relatively short subreach located upstream from the confluence, and LA-2 East is a relatively long subreach located downstream from the confluence. LA-2 East includes the part of Los Alamos Canyon where contamination derived from TA-21 and discharged into DP Canyon is expected to be highest. The canyon floor is relatively narrow in LA-2, and the stream is incised into the Otowi Member of the Bandelier Tuff. The stream gradient is slightly less in LA-2 than upstream in LA-1, and the channel is usually dry.

Reach LA-3 is located a short distance upstream from state road NM 4. The canyon is wider here than in LA-2, but the part of the canyon floor containing the active floodplain is narrower. The stream flows less frequently here than in LA-2. Alluvium locally pinches out on basalt in the stream bed immediately downstream of LA-3.

2.2 Methods of Investigation

2.2.1 Geomorphic Mapping

Field investigations in each reach began by preparing a preliminary geomorphic map that focused on identifying young (post-1942), potentially contaminated sediment deposits and subdividing these deposits into geomorphic units with different age, sedimentological characteristics, and/or radiological characteristics. These geomorphic units delineate the horizontal extent of contamination in each reach and also provide grouping of areas with similar physical and/or radiological characteristics. Where uncertainties existed in identifying the limits of potentially contaminated sediments, boundaries were

drawn conservatively such that the area potentially impacted by post-1942 floods was overestimated rather than underestimated.

Mapping in each reach was at a scale of 1:200 and involved taping distances along the channel from known reference points and frequently measuring unit width. Aerial photographs were not useful in mapping any of the upper Los Alamos Canyon reaches because of the narrowness of the active canyon floor and the density of vegetation. Boundaries between geomorphic units were typically defined on the basis of topographic breaks, vegetation changes, and/or changes in surface sediments, although in some areas boundaries are more approximate. In reaches LA-2 East and LA-3 field radiological measurements were used to distinguish some geomorphic units on the basis of variations in gross gamma radiation.

Geomorphic mapping was iterative, and the maps were revised after each phase of investigation in each reach. For example, in LA-2 East field radiological measurements were used to define a relatively small area with elevated cesium concentrations, which was broken out as a separate geomorphic unit (unit c3). In addition, geodetic surveying of sample locations that followed each sampling event often led to map revisions so that the surveyed sample locations were within the appropriate geomorphic unit (for example, the surveyed location of a sample site on a stream bank could plot within the active channel as depicted on a preliminary geomorphic map because of small inaccuracies in unit boundaries). Refining of the conceptual model during the investigations also resulted in reexamination of previous map assignments and additional revisions to the maps.

2.2.1.1 Geomorphic Unit Nomenclature

The nomenclature used for geomorphic units is consistent among reaches and subreaches whenever possible, although complete consistency was not possible. The following general convention was used for naming units.

The designation "c" refers to post-1942 channel units, which are areas occupied by the main stream channel or experiencing significant deposition of coarse-grained channel sediments sometime in the post-1942 period; "c1 " is the presently active channel, "c2" is the youngest recognized abandoned channel unit in each reach, and "c3" includes older abandoned channel units. The designation "c2b" is used in LA-2 East to define part of the c2 unit where gross gamma radiation is relatively high. Available data did not allow each named unit to be the same age in every reach, and a direct correlation of units between reaches is not possible. For example, isotopic ratios in sediment samples from the c3 unit in LA-3 indicates that it contains sediment of similar age to the c2 unit in LA-2 East and is younger than the c3 unit in LA-2 East.

The designation "f" refers to floodplain areas that were or may have been inundated by overbank floodwaters since 1942 but that were not occupied by the main stream channel; "f1 " indicates areas that were probably inundated by floods during this period, as shown by geomorphic evidence and/or analytical data; "f2" indicates areas that were possibly subjected to minor inundation but where the evidence is generally inconclusive. If f2 surfaces were inundated, the thickness of post-1942 sediment would be small.

Other designations on the geomorphic maps delineate various areas that have not been directly impacted by post-1942 floods downstream of potential contaminant sources. Following standard geologic nomenclature, "Q" indicates deposits from the Quaternary period. "Qal" refers to active channel alluvium in tributary drainages. "Qc" refers to colluvium. "Qt" refers to pre-1943 stream terraces that have not been inundated by post-1942 floods. "Qf" refers to fans from tributary drainages.

2.2.2 Physical Characterization of Young Sediments

Physical characterization of the geomorphic units included measurements of the thickness of post-1942 sediments, general field descriptions of particle size, and laboratory particle size analysis for samples submitted for standard chemical and/or radiological analyses. Bulk density was also measured on a subset of sample intervals for use in calculating contaminant inventories; these measurements are presented along with density measurements for Pueblo Canyon reaches in Reneau et al. (1998, 59159). The determination of unit thicknesses used a variety of approaches, including identifying the depth that the bases of trees are buried by sediment; recognizing buried soil horizons; and searching for the presence of "exotic" material that indicates a post-1942 age (e.g., quartzite clasts imported from quarries closer to the Rio Grande, coal, or various man-made materials). Cesium and plutonium analyses were also used at some sites to directly determine the thickness (i.e., vertical extent) of contaminated sediment and provide supporting evidence for the inferred thickness of post-1942 sediment, although in some areas these radionuclides may extend into pre-1943 sediment because of vertical translocation. Selected trees were cored for dendrochronologic analysis (tree-ring dating) to help confirm the thickness of post-1942 sediment and to provide improved age estimates for specific sediment deposits (see Stokes and Smiley 1968, 57644, for a discussion of tree-ring dating methods). Additional details of the methods and results of the physical characterization of post-1942 sediment in the upper Los Alamos Canyon reaches are presented in Appendix B.

An important distinction within the post-1942 sediments involves general particle size variations because contaminant concentrations tend to be higher in finer-grained sediments of a given age. Field measurements focused on differentiating "overbank facies" and "channel facies" sediments, which are similar to the "top stratum" and "bottom stratum" of Brakenridge (1988, 57640). As used in this report, "overbank facies" refers to sediment generally transported as suspended load during floods, which are commonly deposited on floodplains from water that overtops stream banks, and "channel facies" refers to sediment generally transported as bed load and deposited along the main stream channel. Overbank facies sediment has typical median particle size of silt to fine sand, and channel facies sediment has typical median particle size of coarse or very coarse sand; medium sands could be assigned to either facies, depending on the stratigraphic context. These facies are not restricted to specific geomorphic units; overbank facies sediment typically forms upper layers on floodplains and abandoned channel units and can also be found as thin layers along active channels, and channel facies sediment can be deposited on floodplains during large floods and associated with channel aggradation. It should also be stressed that these distinctions are somewhat arbitrary, with gradations commonly occurring. Nevertheless, they form an important basis for differentiating sediment deposits of similar age that may have much different levels of contamination.

2.2.3 Radiological Field Measurements

The initial geomorphic mapping in reach LA-2 was followed by use of a series of field instruments to define differences in alpha, beta, and gamma radiation among the geomorphic units and to focus subsequent sampling. Gross gamma radiation walkover surveys were conducted first, providing excellent spatial coverage of variations in gamma radiation although the individual measurements have relatively low precision. The walkover surveys were followed by higher precision "fixed-point" alpha, beta, and gamma radiation measurements at selected field locations. A subset of the fixed-point locations was selected for *in situ* gamma spectroscopy measurements. Most of these field measurements were made during a pilot study phase of investigation when the utility of different field methods was being evaluated. During this pilot study phase, gross gamma radiation walkover surveys were also conducted in reaches LA-1 Central and LA-3, and a gross beta radiation walkover survey was conducted in LA-1 Central. Levels of gamma radiation, largely related to cesium-137, were found to be high enough downstream from DP Canyon that field gamma radiation measurements provided excellent definition of horizontal and

vertical variations in cesium concentration. Therefore, investigations in LA-2 East and LA-3 relied heavily on the gross gamma radiation walkover survey data and fixed-point gamma radiation measurements. Beta radiation was also elevated above background values in LA-2 East, but the fixed-point measurements indicated that beta and gamma radiation were strongly correlated such that the beta radiation data provided no additional information on contaminant distribution (Figure B4-6). The fixed-point alpha radiation measurements and the *in situ* gamma spectroscopy measurements were not found to be helpful in the field investigation. Because of this, only the gross gamma radiation measurements in reaches LA-2 and LA-3 are discussed in the body of this report, although methods and results for all the field instruments are presented in Appendix B-4.0.

2.2.4 Sediment Sampling and Preliminary Data Evaluation

Sediment sampling in this investigation followed a phased approach that included a combination of sampling for "full-suite," "limited-suite," and "key contaminant" analyses. Preliminary evaluation of data after each sampling phase was performed to help identify uncertainties and to focus subsequent sample collection and analysis. The primary goals and other information about each sampling event are summarized in Appendix B-5.0.

Full-suite analyses were obtained on samples from LA-2 and LA-3 after the field radiological surveys, with the goal of identifying all analytes that were present above background values and determining the primary risk drivers. The specific sample sites and sample depths included intervals with the highest field radiological measurements in each reach as well as intervals with relatively low radiation. The sample sites also included representative fine-grained and coarse-grained sediment deposits from the range of geomorphic units. The full-suite analyses included a series of inorganic chemicals, organic chemicals, and radionuclides and are listed in Section 3.1 and Appendix C.

Subsequent sampling phases in all reaches were primarily focused on key contaminants that were used to define the horizontal and vertical variations in contaminant levels. Cesium-137 was selected as a key contaminant for LA-2 East and LA-3 because preliminary risk assessments using the full-suite analyses indicated that cesium-137 is the main risk driver downstream from DP Canyon. Plutonium-239,240 (unresolved isotopes) was selected as a key contaminant in LA-1 and LA-2 West because it is the only analyte that is consistently present above background values in sediment samples upstream from DP Canyon. Specific sample sites in each sampling event were selected to reduce uncertainties in the horizontal and vertical extent of contamination, the average and range of contaminant concentrations in each unit, the inventory of the key contaminants, and controls on their distribution (e.g., effects of sediment age and sediment particle size).

To most effectively reduce the uncertainty in total plutonium inventory in each reach, a stratified random sample allocation process was applied (using calculations based on equation 5.10 in Gilbert 1987, 56179). To evaluate uncertainty in this sample allocation process, Monte Carlo calculations were performed using the Crystal Ball version 4 add-in to Microsoft Excel software. These calculations used available data on the area, thickness, and radionuclide concentration in each geomorphic unit and sediment facies to help determine the number of samples to be collected from each unit and each facies. For example, a unit with a relatively large volume of post-1942 sediment, high radionuclide concentrations, and/or high variability in radionuclide concentration would be assigned more samples than a similar unit with small volume, low concentrations, and/or low variability in radionuclide concentration.

In all reaches a series of samples were also collected for limited-suite analyses, including analytes measured above background values in the full-suite analyses in LA-2. The limited suite included metals, polychlorinated biphenyls (PCBs) and pesticides, and select radionuclides and is discussed in Section 3.0.

A primary goal of these limited-suite analyses was to evaluate to what degree concentrations of cesium and plutonium were correlated with concentrations of the other analytes and hence to what degree they are collocated within the same sediment deposits. Analytical results from the first sampling phases in LA-2 East indicated that the ratios of some of the radionuclides had varied over time (e.g., ratio of plutonium-239,240 to plutonium-238), and some of the limited-suite sampling was used to evaluate differences in sediment age. Sample collection for limited-suite analyses included sample intervals that had yielded the highest cesium or plutonium concentration within each reach as well as intervals with more representative concentration and including the range of geomorphic units and sediment facies that had been identified.

2.3 Results

2.3.1 Reach LA-1

2.3.1.1 Physical Characteristics

Reach LA-1 is in a part of upper Los Alamos Canyon with a narrow canyon floor. The area that has been impacted by post-1942 floods averages approximately 13 to 15 m wide in LA-1 West, LA-1 Central, and LA-1 East. The areal distribution of the geomorphic units is shown on Figures 1.3-1 and 1.3-2 and Figures 2.3-1 to 2.3-4, and topographic relations are illustrated in the cross sections of Figures 2.3-5 to 2.3-7. Physical characteristics of the geomorphic units in LA-1 are summarized in Table 2.3-1. Data on particle size and unit thickness are presented in Tables B3-1 and Table B3-4 and Figures B2-1 to B2-3.

The active channel, c1, averages 1.5 to 2 m wide in the different LA-1 subreaches and has a bed composed of coarse sand and gravel. The active channel is usually bordered by abandoned post-1942 channel units (c2, c3) that average approximately 4 to 5 m in combined width and have average heights of 0.4 to 1.0 m above the channel. The c2 and c3 units are usually capped by an average of approximately 0.2 to 0.4 m of relatively fine-grained overbank sediments dominated by fine to very fine sand. In parts of LA-1 Central and LA-1 East, the upper parts of the c3 units are composed of gravel and coarse sand that represent gravel bars deposited on older floodplains. In each subreach unit c3 has surfaces that are higher above the channel than c2, although the c2 and c3 units may have ages that overlap within and between subreaches.

Active floodplains (f1) in LA-1 are typically 4 to 5 m wide in LA-1 Far West and LA-1 West+ and broaden to an average width of 7 to 8 m in LA-1 West, LA-1 Central, and LA-1 East. The f1 unit averages 0.9 to 1.1 m above the active channel and is capped by an average of 0.1 to 0.25 m of overbank sediments dominated by very fine sand and coarse silt. Potentially active floodplains (f2) in the different subreaches are slightly higher than f1 and average from 0 to 4 m wide. These areas either have not been inundated by post-1942 floods or were only briefly inundated, experiencing little post-1942 sediment deposition.

2.3.1.2 Radiological Characteristics

Gross beta and gross gamma radiation walkover surveys in reach LA-1 Central in 1996 indicated that levels of beta- and gamma-emitting radionuclides were not high enough to allow contaminated areas to be distinguished from background radiation in LA-1. This conclusion was supported by field radiological data from reach LA-2 West and by analytical data on sediment samples collected from TA-2 and TA-41 (in former Operable Unit 1098). Therefore, field radiation measurements were not used in the geomorphic mapping in LA-1 in 1997 or to help select sample sites. A summary of the field radiation measurements in LA-1 Central and maps showing measurement locations are presented in Appendix B-4.0.

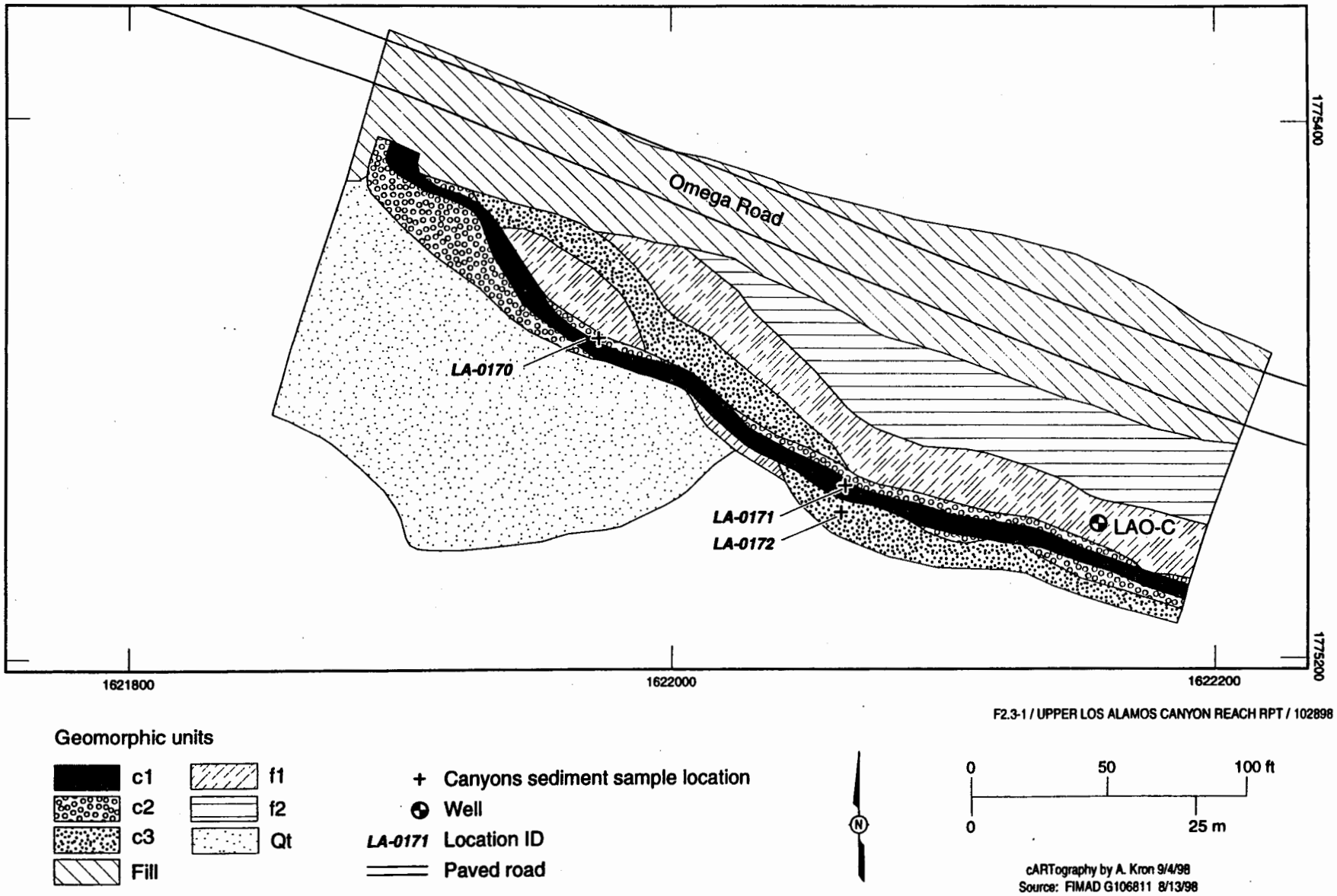


Figure 2.3-1. Geomorphic map of reach LA-1 Far West showing sample locations.

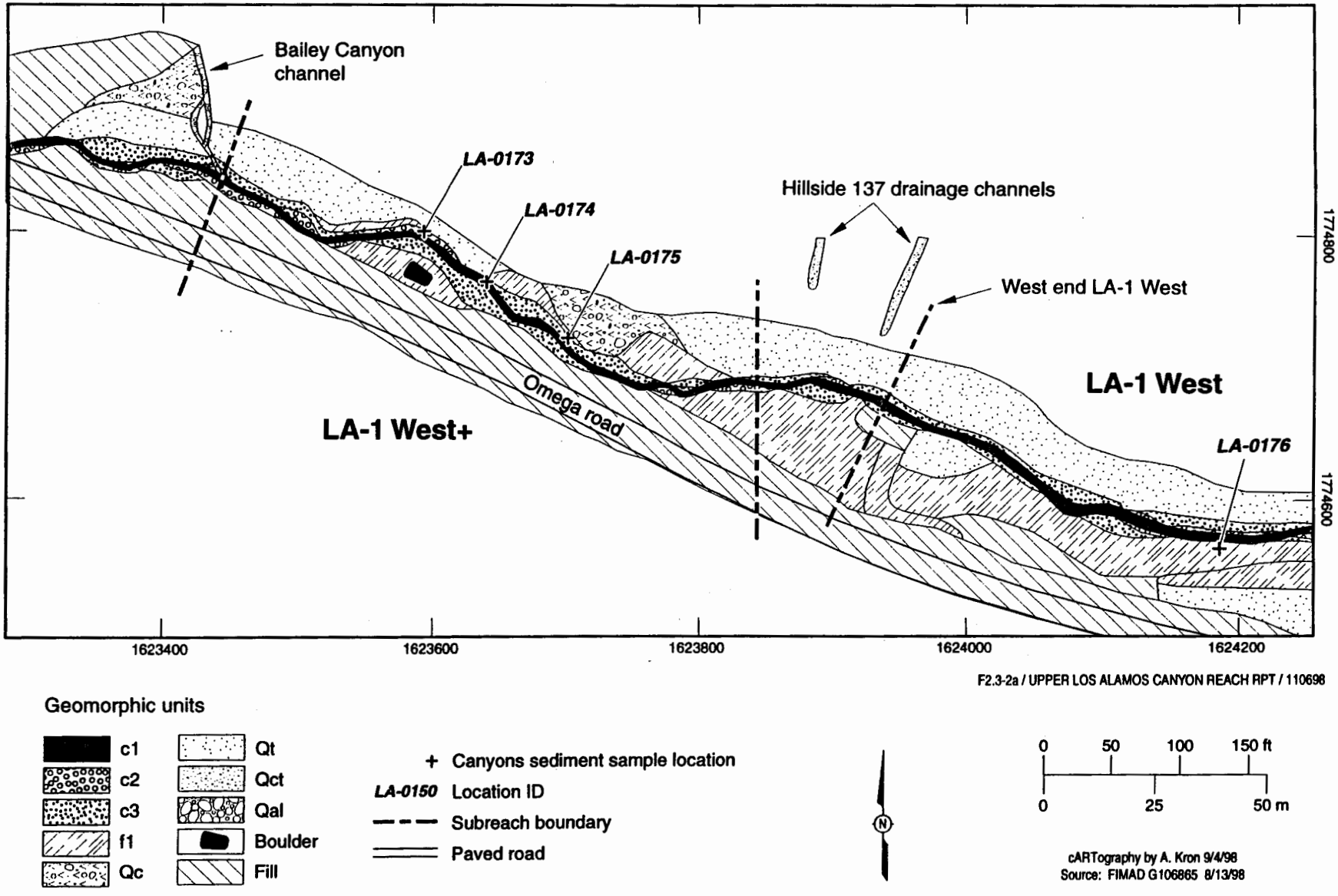


Figure 2.3-2a. Geomorphic map of reach LA-1 West+ showing sample locations.

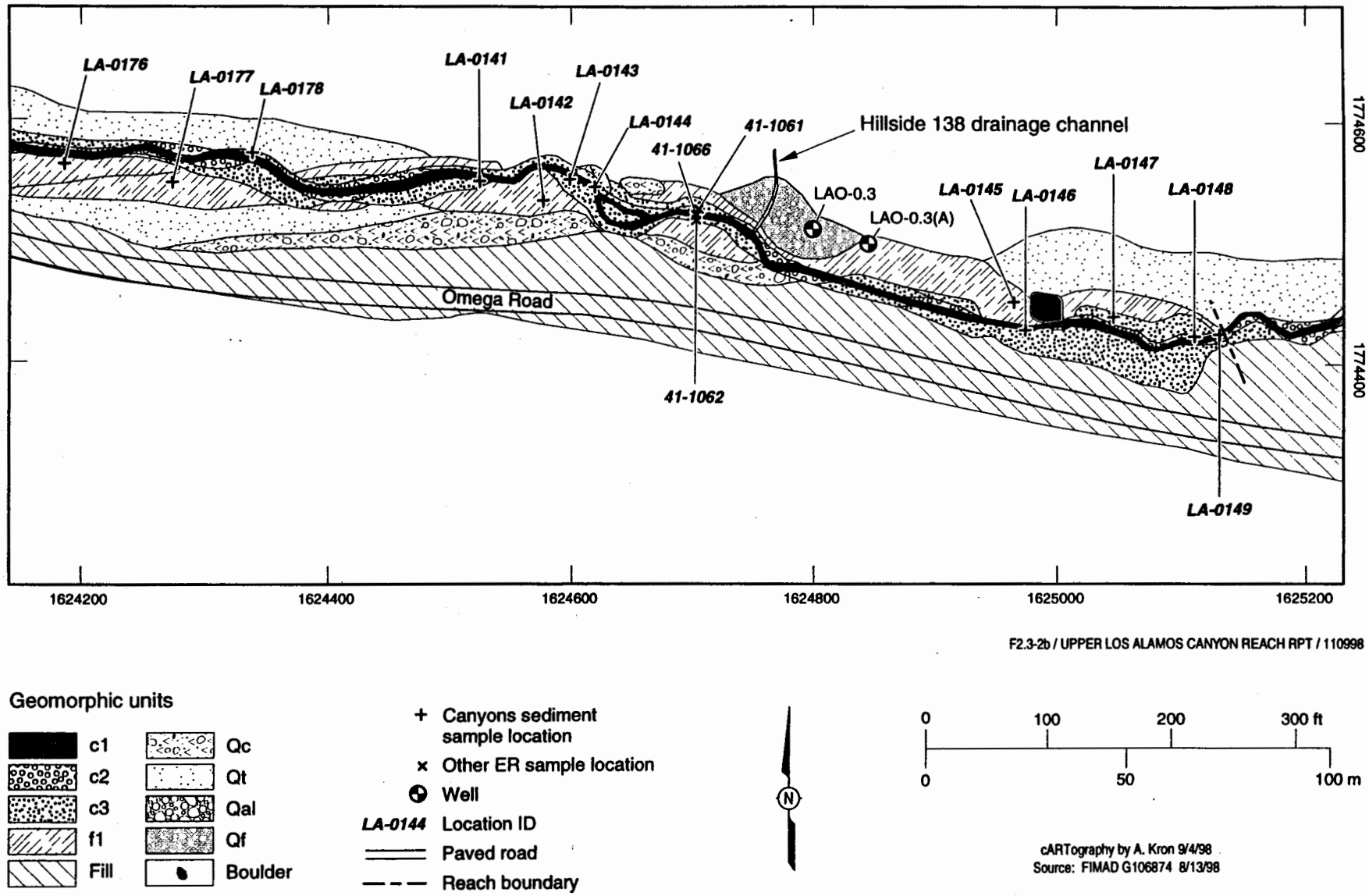


Figure 2.3-2b. Geomorphic map of reach LA-1 West showing sample locations.

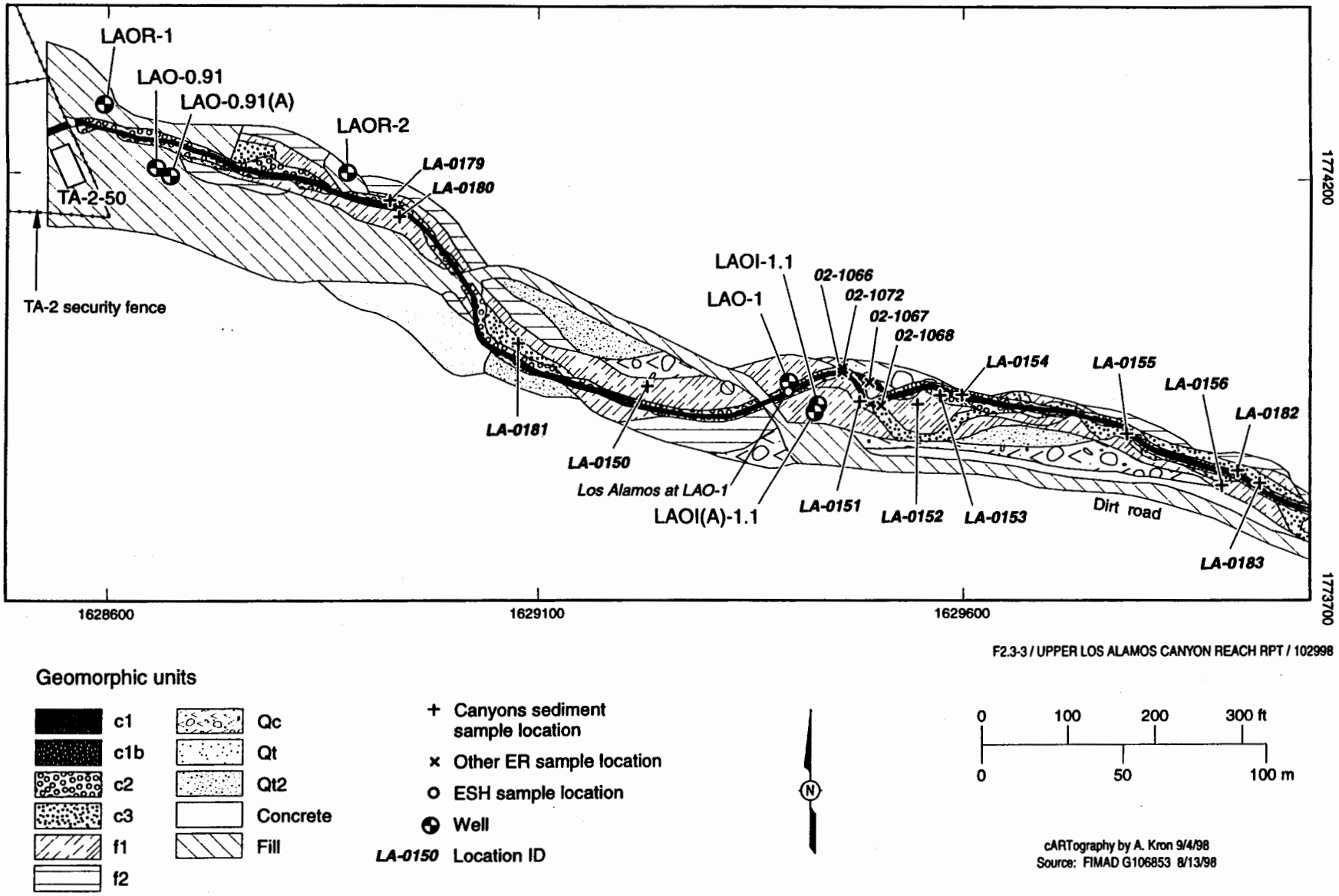


Figure 2.3-3. Geomorphic map of reach LA-1 Central showing sample locations.

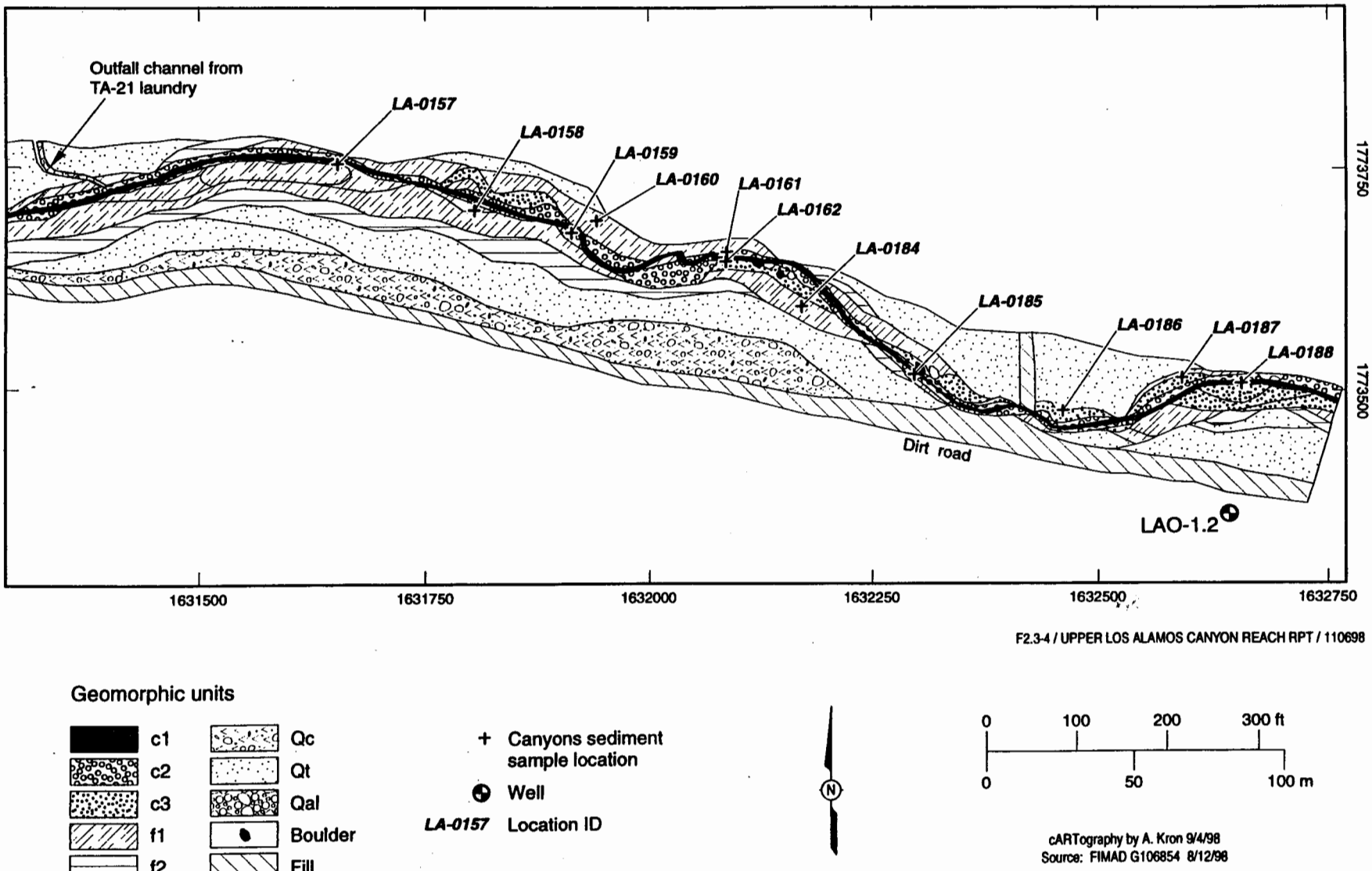


Figure 2.3-4. Geomorphic map of reach LA-1 East showing sample locations.

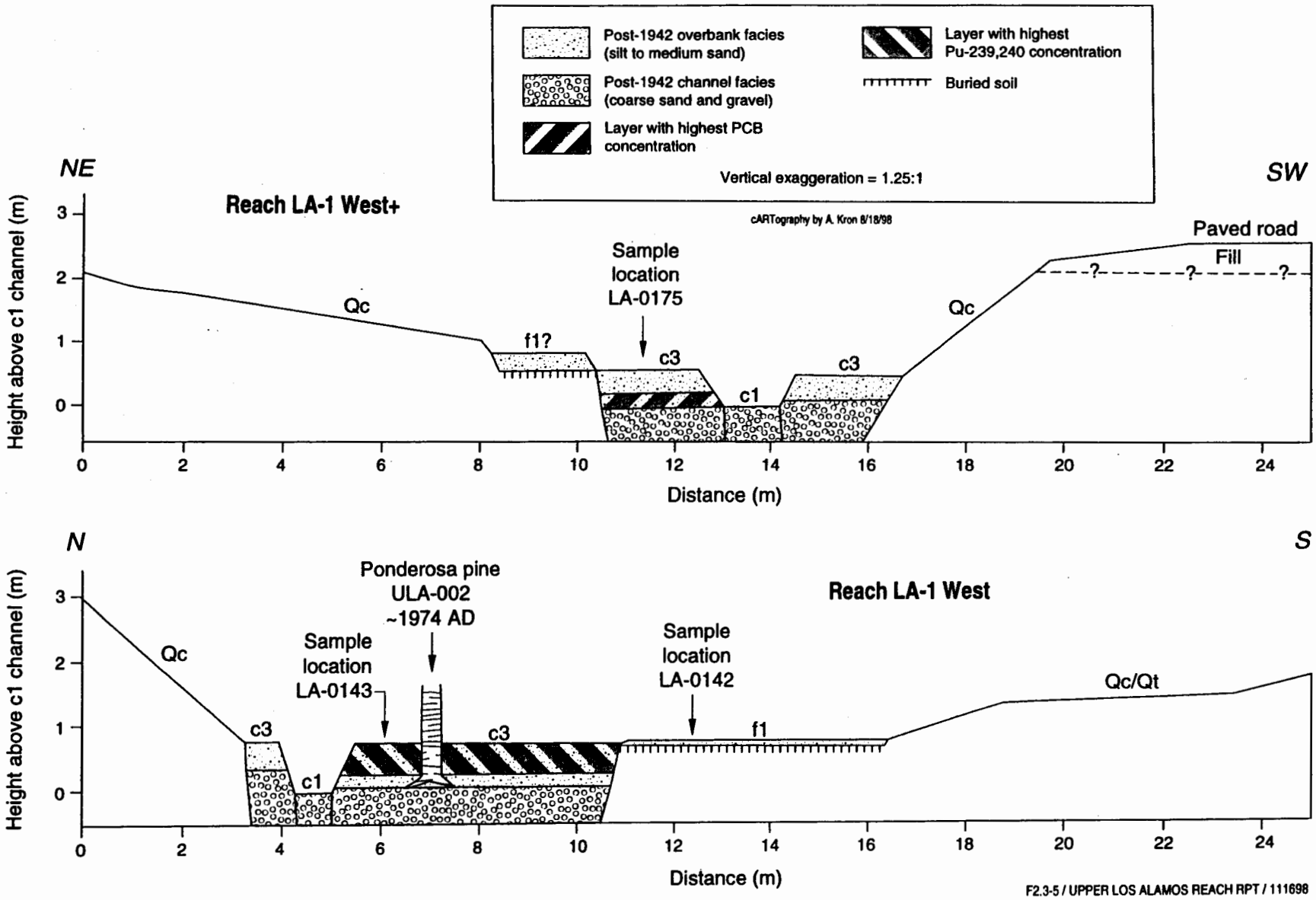


Figure 2.3-5. Schematic cross sections showing relationship between geomorphic units in reaches LA-1 West+ and LA-1 West.

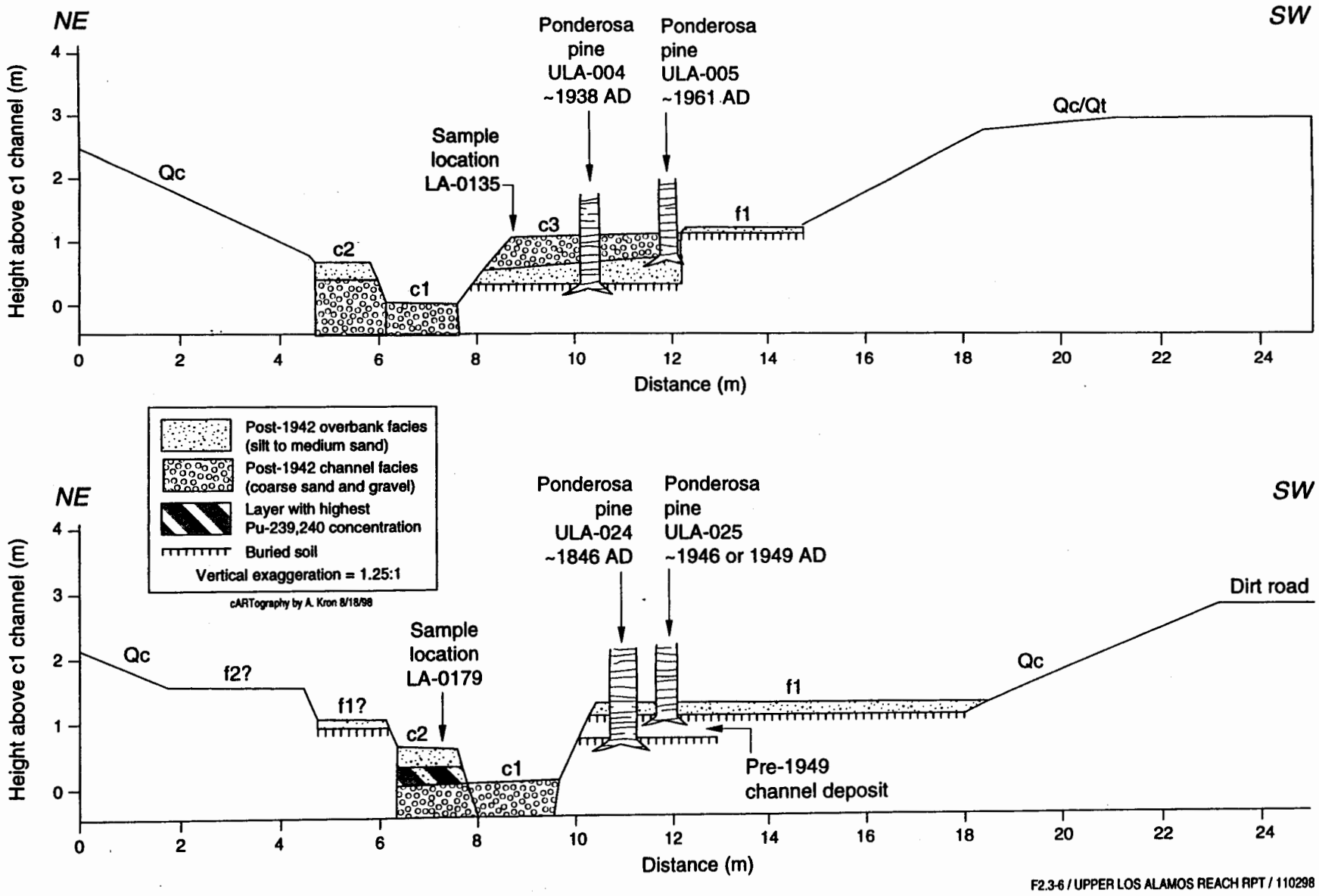


Figure 2.3-6. Schematic cross sections showing relationship between geomorphic units in reach LA-1 Central.

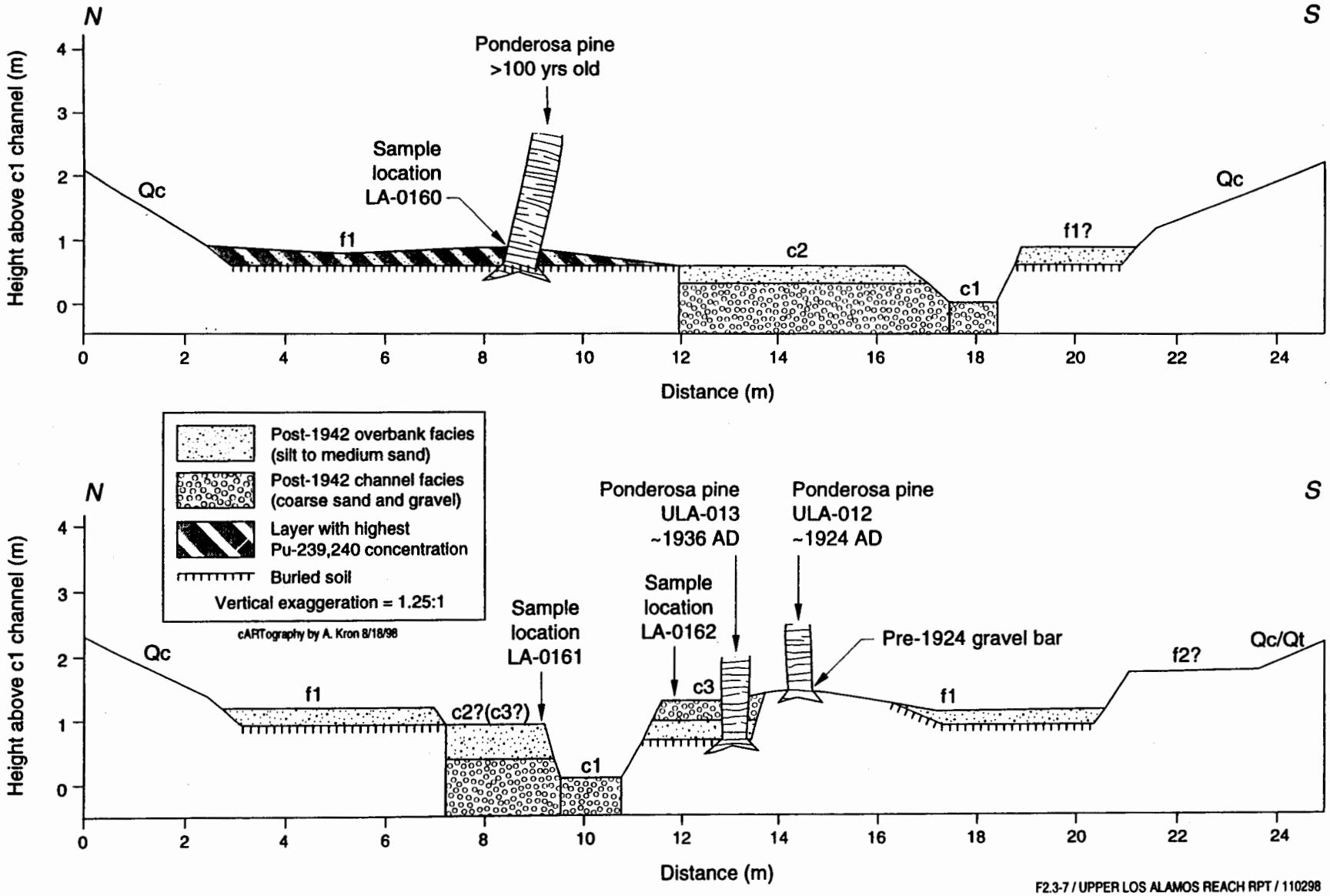


Figure 2.3-7. Schematic cross sections showing relationship between geomorphic units in reach LA-1 East.

TABLE 2.3-1

GEOMORPHIC MAPPING UNITS IN REACH LA-1

Subreach	Unit	Estimated Average Unit Height Above Channel (m)	Unit Area (m^2)	Average Unit Width[a] (m)	Sediment Facies	Estimated Average Thickness (m)	Typical Median Particle Size Class (<2 mm fraction)	Typical Soil Texture	Notes
LA-1 Far West[b]	c1	b	198	1.8	Channel	b	b	b	Active channel
	c2	b	223	2.0	Overbank	b	b	b	Younger abandoned post-1942 channel
					Channel	b	b	b	
	c3	b	318	2.9	Overbank	b	b	b	Older abandoned post-1942 channel
					Channel	b	b	b	
	f1	b	514	4.7	Overbank	b	b	b	Active floodplain
	f2	b	514	4.7	Overbank	b	b	b	Potentially active floodplain
						b	b	b	
LA-1 West+[b]	c1	b	198	1.4	Channel	b	b	b	Active channel
	c2	b	108	0.8	Overbank	b	b	b	Younger abandoned post-1942 channel
					Channel	b	b	b	
	c3	b	334	2.4	Overbank	b	b	b	Older abandoned post-1942 channel
					Channel	b	b	b	
	f1	b	563	4.0	Overbank	b	b	b	Active floodplain
	f2	b	514	3.7	Overbank	b	b	b	Active floodplain
LA-1 West	c1	0	715	1.9	Channel	<1.0	Coarse sand	Gravelly sand	Active channel
	c2	0.4	294	0.8	Overbank	0.25 ± 0.14	Fine sand	Sandy loam	Younger abandoned post-1942 channel
					Channel	<1.0	Coarse sand	Gravelly sand	
	c3	0.6	1610	4.4	Overbank	0.42 ± 0.22	Fine sand	Sandy loam	Older abandoned post-1942 channel
					Channel	<1.0	Coarse sand	Gravelly loamy sand	
	f1	0.9	2781	7.5	Overbank	0.24 ± 0.16	Very fine sand	Sandy loam	Active floodplain

a. Average unit width uses lengths of 110 m for LA-1 Far West, 140 m for LA-1 West+, 370 m for LA-1 West, 390 m for LA-1 Central, and 430 m for LA-1 East.

b. Characteristics assumed to be the same as in LA-1 West.

TABLE 2.3-1 (continued)

GEOMORPHIC MAPPING UNITS IN REACH LA-1

Subreach	Unit	Estimated Average Unit Height Above Channel (m)	Unit Area (m^2)	Average Unit Width* (m)	Sediment Facies	Estimated Average Thickness (m)	Typical Median Particle Size Class (<2 mm fraction)	Typical Soil Texture	Notes
LA-1 Central	c1	0	681	1.7	Channel	<1.0	Coarse sand	Gravelly sand	Active channel
	c1b	0.2	29	0.1	Channel	<1.0	?	?	Part of active channel during large floods
	c2	0.5	806	2.1	Overbank	0.31 ± 0.14	Very fine sand	Sandy loam	Younger abandoned post-1942 channel
					Channel	<1.0	Coarse sand	Gravelly loamy sand	
	c3	1.0	740	1.9	Overbank	0.22 ± 0.21	Very fine sand	Sandy loam	Older abandoned post-1942 channel
					Channel	<1.0	Coarse sand		Gravelly sand
	f1	1.1	2953	7.6	Overbank	0.11 ± 0.09	Very fine sand	Sandy loam	Active floodplain
	f2	1.2	1269	3.3	Overbank	<0.05	Very fine sand?	Sandy loam?	Potentially active floodplain
LA-1 East	c1	0	596	1.4	Channel	<1.0	Coarse sand	Gravelly sand	Active channel
	c2	0.4	1202	2.8	Overbank	0.30 ± 0.14	Fine sand	Sandy loam	Younger abandoned post-1942 channel
					Channel	<1.0	Coarse sand	Gravelly sand	
	c3	0.8	967	2.2	Overbank	0.25 ± 0.18	Very fine sand	Sandy loam	Older abandoned post-1942 channel
					Channel	<1.0	Coarse sand	Gravelly loamy sand	
	f1	0.9	3373	7.8	Overbank	0.21 ± 0.14	Coarse silt	Loam	Active floodplain
	f2	1.1	1456	3.4	Overbank	<0.05	Very fine sand?	Sandy loam?	Potentially active floodplain

*Average unit width uses lengths of 110 m for LA-1 Far West, 140 m for LA-1 West+, 370 m for LA-1 West, 390 m for LA-1 Central, and 430 m for LA-1 East.

2.3.1.3 Geomorphic History

Geomorphic processes within reach LA-1 since 1942 have included the lateral migration of the active channel within an area that averages 5 to 7 m wide, represented by the width of the c1, c2, and c3 units, and the occasional overtopping of higher pre-1943 surfaces during floods. Some vertical changes in the elevation of the stream bed have occurred in LA-1, resulting in young (post-1942) overbank facies sediments in some places occurring below the elevation of the present channel and channel gravels occurring up to 1.0 m above the present channel. The largest vertical changes in channel elevation are recorded by c3 gravel bars in LA-1 Central and LA-1 East that probably record local aggradation during one or more floods (e.g., Figures 2.3-6 and 2.3-7). These gravel bars commonly contain rounded concrete, indicating that they postdate initial development of TA-2 and TA-41, and tree-ring dating at a c3 gravel bar in LA-1 Central indicates deposition sometime after 1961 (Figure 2.3-6).

The post-1942 overbank facies sediment and associated contaminants present within LA-1 are stored within both the c2 and c3 units relatively close to the active channel and the f1 units farther away from the channel. The sediments contained within the c2 and c3 units are particularly susceptible to remobilization by lateral bank erosion during floods, and the average residence time for sediment at these sites is probably less than 50 years and may be less than 30 years. This conclusion is based in part on the similarity in unit characteristics between LA-1 and LA-2 and evidence for sediment residence times in LA-2 provided by isotopic ratios (Section 2.3.2.2). Approximately 40 to 60% of the overbank sediments in the different subreaches are stored on floodplain surfaces that have average residence times of greater than 50 years and are less susceptible to remobilization by bank erosion during floods. Trees older than 100 years are common on the floodplains, and average sediment residence times in these areas similarly exceed 100 years. The floodplain areas are most likely to be subjected to occasional overtopping during large floods, resulting in the deposition of additional fine-grained sediment.

2.3.2 Reach LA-2

2.3.2.1 Physical Characteristics

Reach LA-2 is in a part of upper Los Alamos Canyon where the canyon is somewhat wider than in LA-1, but where the canyon floor is still relatively narrow. LA-2 West and LA-2 East are contiguous subreaches that are divided by the confluence with DP Canyon. The area that has been impacted by post-1942 floods averages approximately 15 m wide in LA-2 West and 10 m wide in LA-2 East. The areal distribution of the geomorphic units is shown on Figures 1.3-2, 2.3-8, and 2.3-9, and topographic relations are illustrated in the cross sections of Figures 2.3-10 and 2.3-11. Physical characteristics of the geomorphic units in LA-2 are summarized in Table 2.3-2. Data on particle size and unit thickness are presented in Table B3-2, Table B3-5, and Figure B2-4.

The active channel, c1, averages 1.5 to 2 m wide in both LA-2 West and LA-2 East and has a bed composed of coarse sand and gravel. The active channel is usually bordered by abandoned post-1942 channel units (c2, c3) that average approximately 5.5 to 7.5 m in combined width and have average heights of 0.6 to 1.2 m above the channel. The characteristics of the abandoned channel units vary between LA-2 West and LA-2 East (Table 2.3-2), in part related to inputs of sediment from DP Canyon. In both subreaches c2 is a relatively low abandoned channel unit that almost continuously borders the channel, but the width of this unit doubles between LA-2 West and LA-2 East, from approximately 2.5 m to 5 m. In addition, the thickness of relatively fine-grained overbank sediments that cap these units also doubles from approximately 0.25 m to 0.5 m, and the typical particle size increases from very fine sand to fine sand at the confluence with DP Canyon. Unit c2b is a subdivision of the c2 unit in LA-2 East that is distinguished by the relatively higher levels of gamma radiation than typical c2 units, as discussed in Section 2.2.2.2.

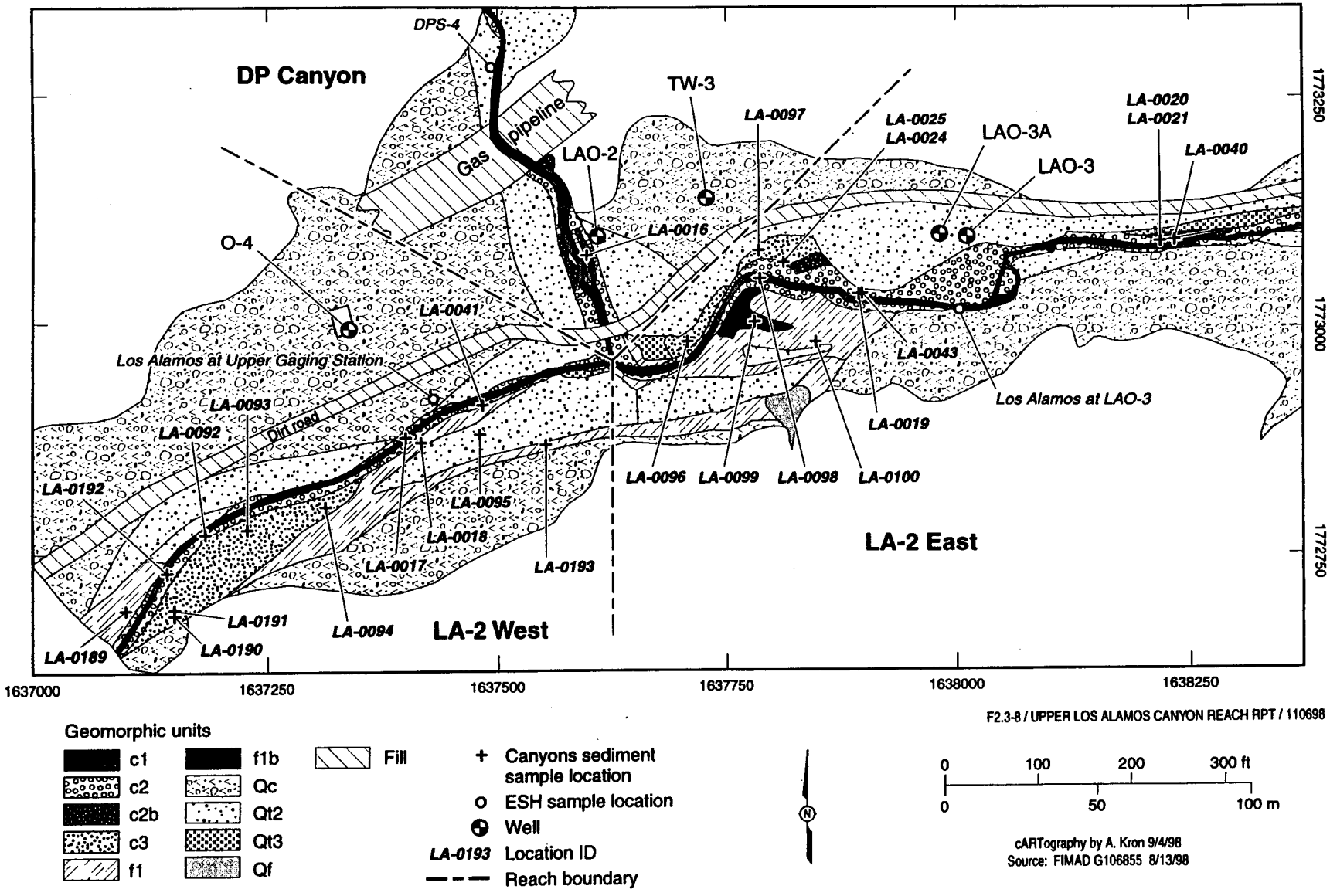


Figure 2.3-8. Geomorphic map showing sample locations in the west half of reach LA-2, including reach LA-2 West, lower DP Canyon, and part of LA-2 East.

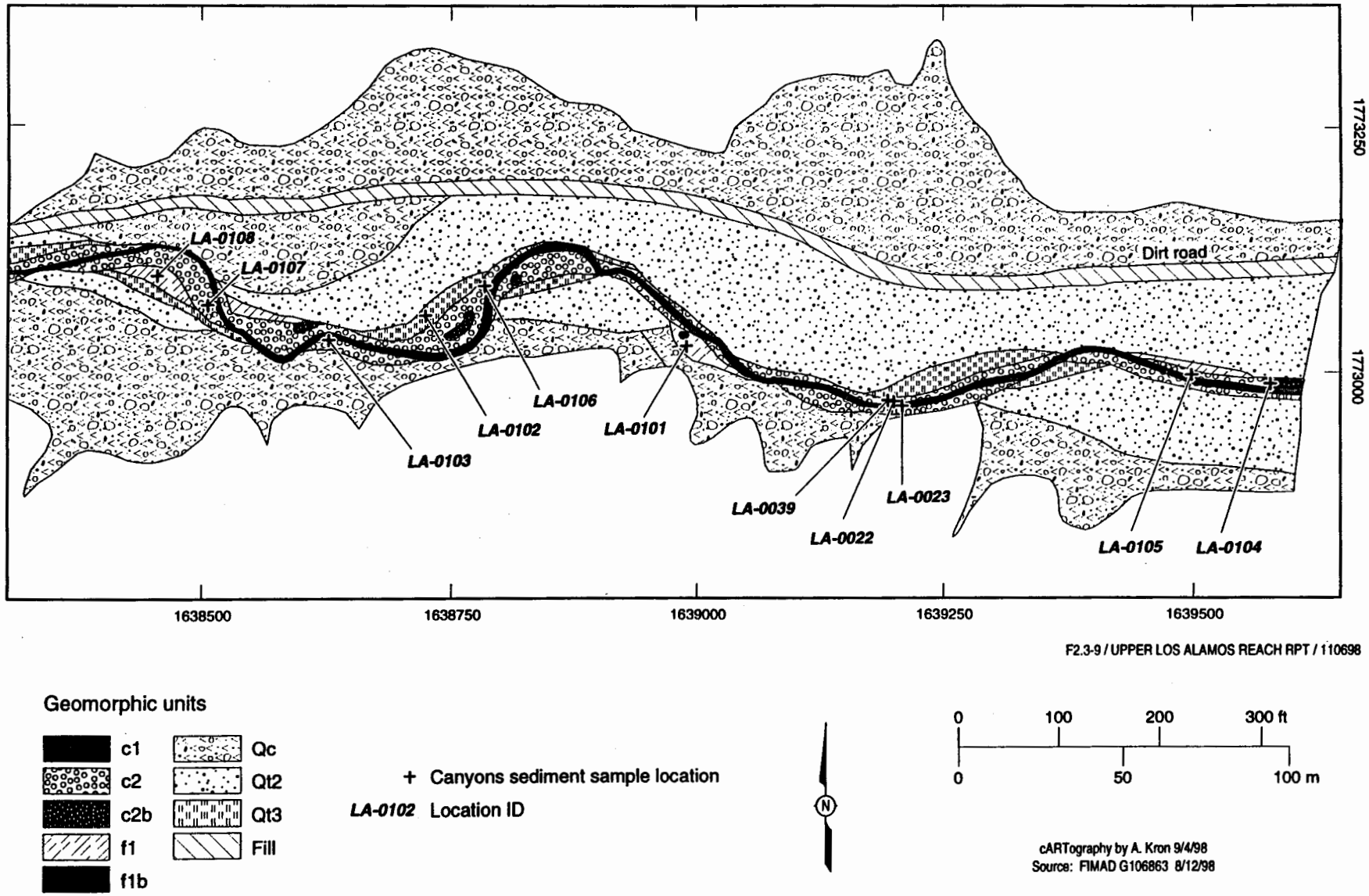


Figure 2.3-9. Geomorphic map showing sample locations in east half of reach LA-2, within LA-2 East.

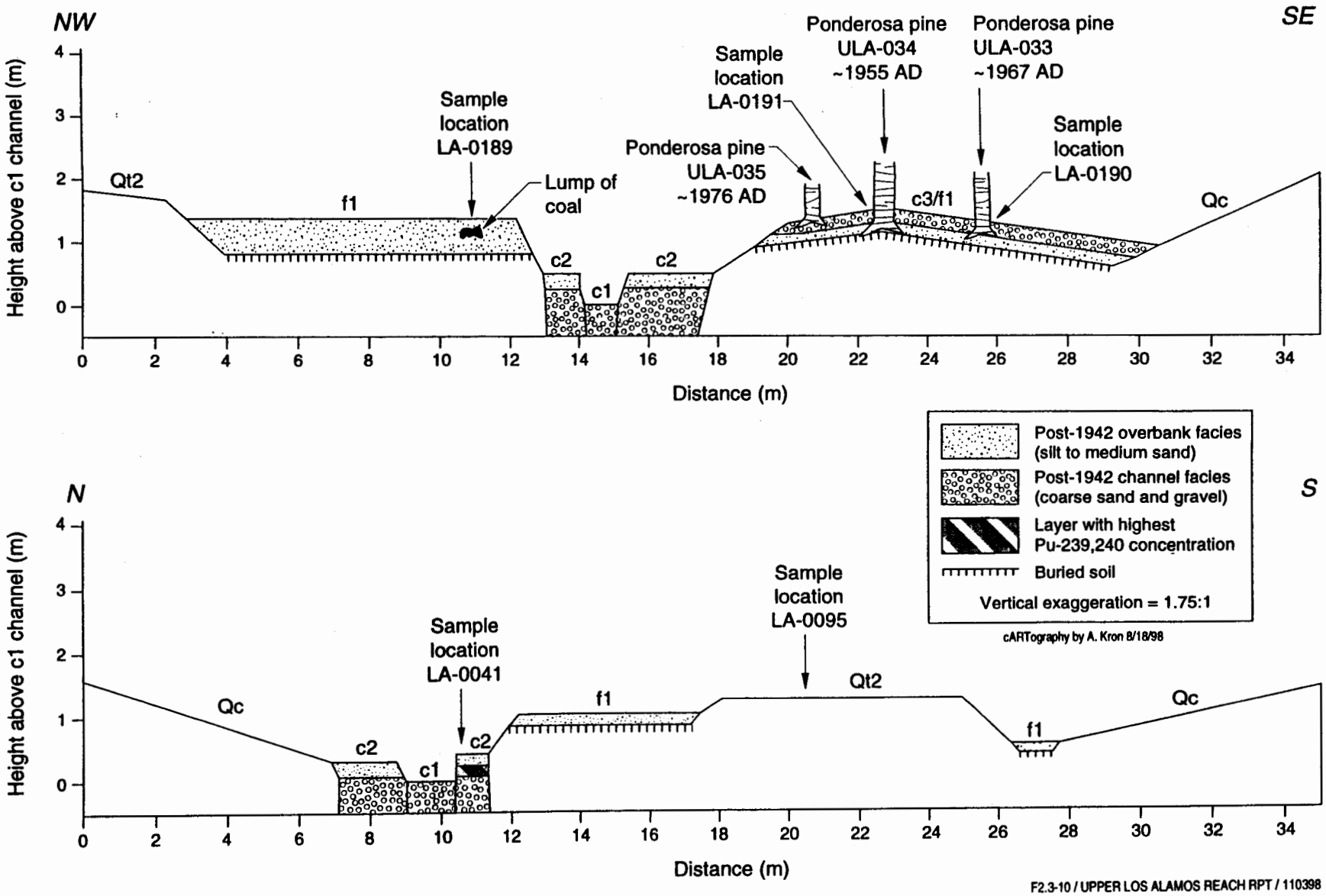


Figure 2.3-10. Schematic cross sections showing relationship between geomorphic units in reach LA-2 West.

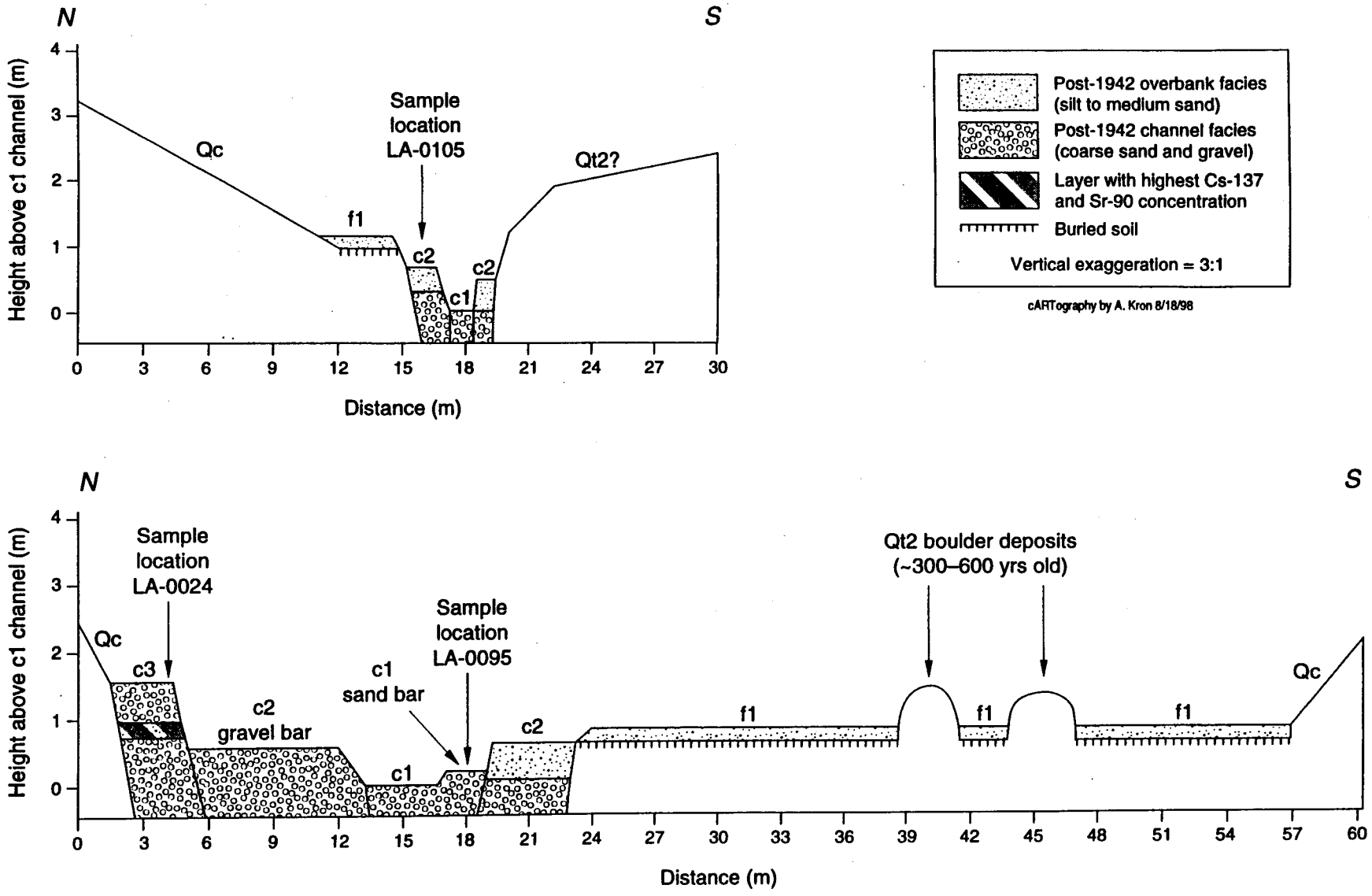


Figure 2.3-11. Schematic cross sections showing relationship between geomorphic units in reach LA-2 East.

TABLE 2.3-2

GEOMORPHIC MAPPING UNITS IN REACH LA-2

Subreach	Unit	Estimated Average Unit Height Above Channel (m)	Unit Area (m^2)	Average Unit Width* (m)	Sediment Facies	Estimated Average Thickness (m)	Typical Median Particle Size Class (<2 mm fraction)	Typical Soil Texture	Notes
LA-2 West	c1	0	349	1.7	Channel	<1.0	Coarse sand	Gravelly sand	Active channel
	c2	0.6	510	2.4	Overbank	0.24 ± 0.10	Very fine sand	Sandy loam	Younger abandoned post-1942 channel
					Channel	<1.0	Coarse sand	Gravelly loamy sand	
	c3	1.1	1008	4.8	Overbank	0.05 ± 0.05	Very fine sand	Sandy loam	Older abandoned post-1942 channel
					Channel	<1.0	Medium sand	Gravelly sandy loam	
	f1	1.0	1296	6.2	Overbank	0.15 ± 0.11	Very fine sand	Sandy loam	Active floodplain
LA-2 East	c1	0	1321	1.9	Channel	<1.0	Coarse sand	Gravelly sand	Active channel
	c2	0.7	3290	4.8	Overbank	0.49 ± 0.21	Fine sand	Sandy loam	Typical abandoned post-1942 channel
					Channel	<1.0	Coarse sand	Gravelly loamy sand	
	c2b	0.7	223	0.3	Overbank	0.55	Fine sand	Sandy loam	Abandoned post-1942 channel with intermediate concentrations of cesium
					Channel	<1.0	Coarse sand	Gravelly loamy sand	
	c3 NE	1.2	173	0.3	Channel	0.65	Coarse sand	Sand	Abandoned post-1942 channel with highest concentrations of cesium
					Overbank	0.15	Very fine sand	Gravelly sandy loam	
					Channel	<1.0	Coarse sand	Gravelly sand	
	c3 SW	1.2	126	0.2	Overbank?	0.15	Medium sand	Gravelly loamy sand	Area closely related to c3 ne but with thinner sediments (related to f1b?)
					Overbank	0.15	Fine sand	Sandy loam	
	f1	1.2	1784	2.6	Overbank	0.15 ± 0.11	Very fine sand	Sandy loam	Active floodplain
	f1b	1.2	174	0.3	Overbank	0.15	Coarse silt	Sandy loam	Active floodplain with highest concentrations of cesium; related to c3

*Average unit width uses lengths of 210 m for LA-2 West and 680 m for LA-1 East.

The c3 units also differ between LA-2 West and LA-2 East. The c3 unit in LA-2 West consists of a relatively wide post-1942 gravel deposit that buried a large area of floodplain and which is capped by a thin layer of relatively fine-grained overbank sediment (Figure 2.3-10). In contrast, the c3 unit in LA-2 East is relatively narrow and is restricted to the west part of the subreach, within 90 m of DP Canyon (Figure 2.3-11). The c3 unit in LA-2 East is defined by areas with the highest field gamma radiation measurements in Los Alamos Canyon and consists of two discrete areas with different sediment characteristics but with similar levels of gamma radiation at the surface. The larger northeast area (c3 NE) consists of thick coarse-grained channel facies sediment deposits with a thin (0.2 m) buried overbank sediment layer where the highest concentrations of cesium-137 and strontium-90 were measured (Figure 2.3-11); this area was chosen for a study in 1996 on the uptake of contaminants by garden vegetables (Fresquez et al. 1997, 58929; Fresquez et al. 1998, 58972). The smaller southwest area (c3 SW) has a thin (0.15 m) surface layer with radionuclide concentrations similar to those found in the buried layer in the northeast c3 unit and particle size characteristics intermediate between typical channel facies and overbank facies sediment (medium sand); below this is a fine-grained overbank facies sediment layer with radionuclide levels that are much lower, although still elevated. The southwest c3 unit represents a flood levee that could be defined as a floodplain unit but is considered to represent an abandoned channel unit here for convenience because of its radiological characteristics. Both parts of the c3 unit in LA-2 East are probably dominated by sediment derived from floods from DP Canyon.

Active floodplains (f1) in LA-2 average approximately 6 m wide in LA-2 West and 3 m wide in LA-2 East (Table 2.3-2). The larger widths in LA-2 West are associated with the large c3 gravel deposits. The f1 unit averages 1.0 to 1.2 m above the active channel and is capped by an average of 0.05 m of overbank sediments dominated by very fine sand in LA-2 West and an average of 0.15 m of very fine sand in LA-2 East. An f1b subunit is distinguished in LA-2 East based on relatively high field gamma radiation measurements; the f1b unit is located close to the c3 units and probably represents sediments deposited from the same floods that deposited the c3 sediments. The area of the f1b unit in LA-2 East and the f1 unit in LA-2 West includes large boulder deposits that are designated unit Qt2 and that represent deposits from an exceptionally large flood that occurred approximately 300 to 600 years ago, as shown by radiocarbon dating (Reneau and McDonald 1996, 55538).

2.3.2.2 Radiological Characteristics

The gross gamma radiation walkover survey and fixed-point radiation measurements in reach LA-2 West indicated that levels of alpha-, beta-, and gamma-emitting radionuclides were not high enough to allow contaminated areas to be distinguished from background radiation in LA-2 West. Therefore, field radiation measurements were not used in the geomorphic mapping in LA-2 West or to help select sample sites. The gross gamma radiation walkover measurements are presented in Figure 2.3-12, and a summary of the field radiation measurements in LA-2 West are presented in Appendix B-4.0.

The gross gamma radiation walkover surveys in reach LA-2 East indicated that levels of gamma-emitting radionuclides downstream from DP Canyon were high enough to allow precise mapping of the horizontal extent of these radionuclides (Figures 2.3-12 and 2.3-13). Therefore, these measurements were used both to refine the preliminary geomorphic map and to subdivide areas in LA-2 East on the basis of variations in gross gamma radiation. In addition, fixed-point gamma radiation measurements were used to examine vertical variations in gamma-emitting radionuclides within the geomorphic units and to select specific sample layers. The fixed-point gamma radiation data are presented in Appendix B-4.0, including depth profiles of gamma radiation in a series of stratigraphic sections through the c2, c2b, and c3 units (Figure B4-5). The fixed-point beta radiation measurements also showed levels above background values, but beta radiation was strongly correlated with gamma radiation (Figure B4-4) and these measurements provided no additional useful information. The fixed-point alpha radiation measurements did not reveal alpha radiation above background values. The fixed-point alpha and beta radiation measurements are presented in Appendix B-4.0.

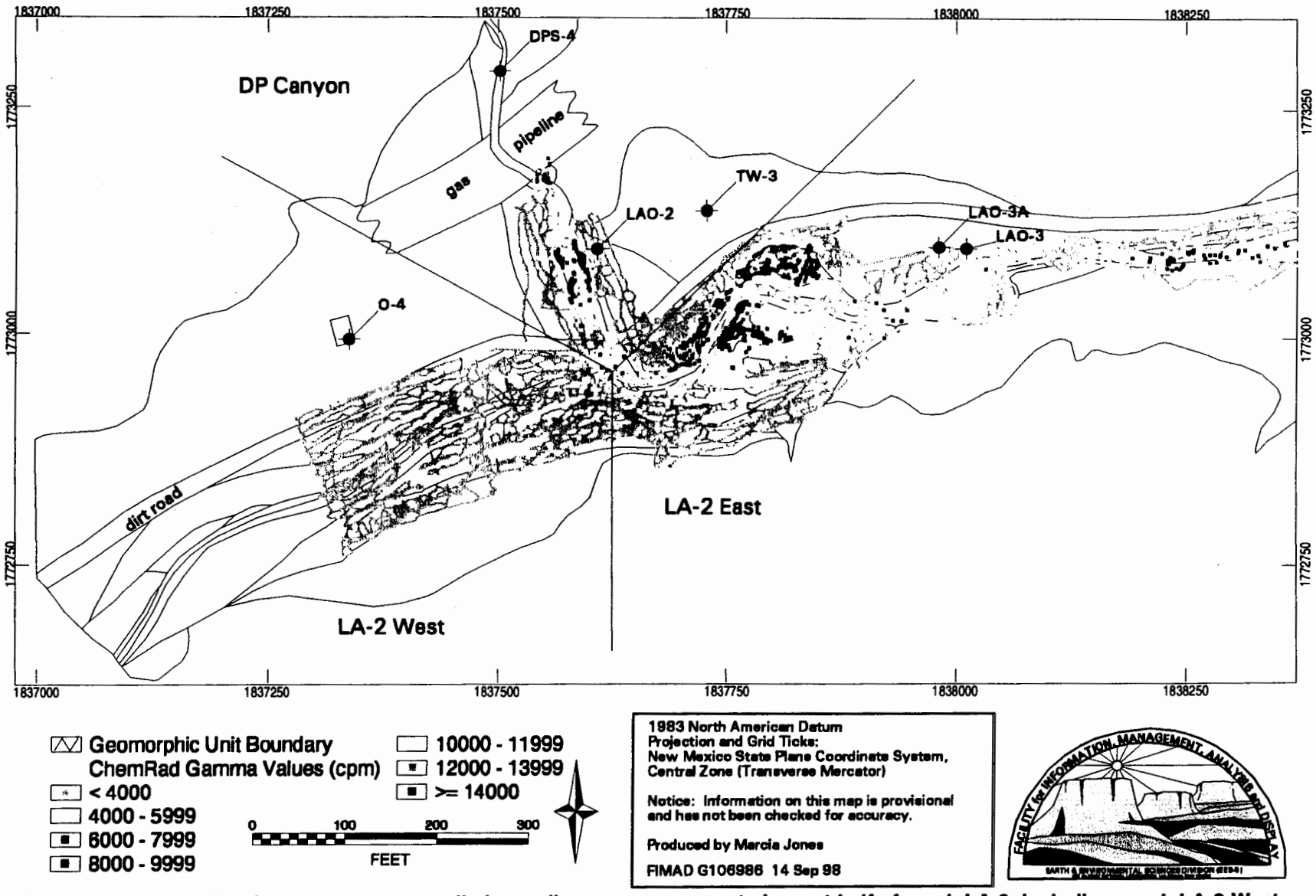


Figure 2.3-12. Map showing gross gamma radiation walkover measurements in west half of reach LA-2, including reach LA-2 West, lower DP Canyon, and part of LA-2 East.

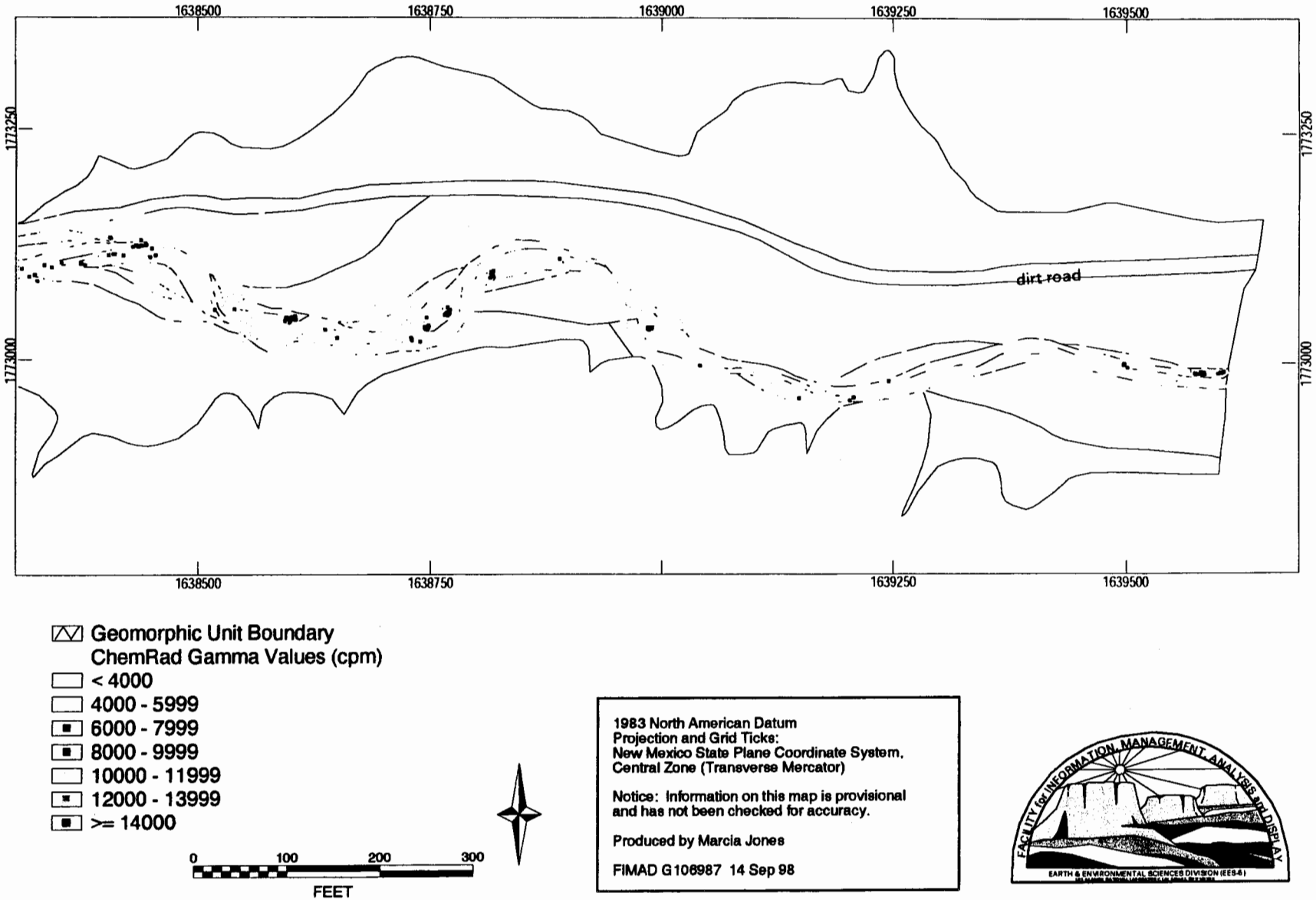
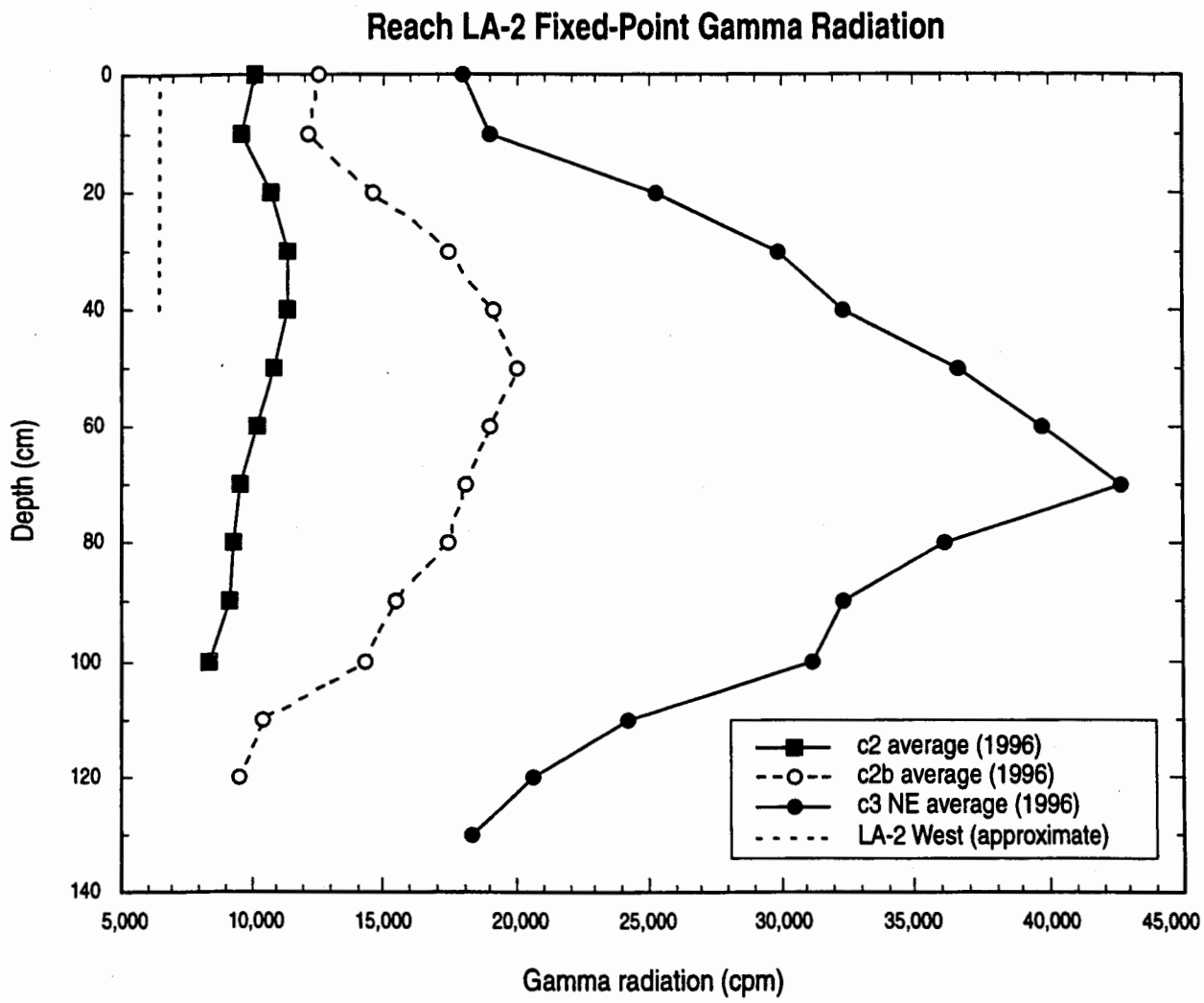


Figure 2.3-13. Map showing gross gamma radiation walkover measurements in east half of reachÊLA-2, within LA-2 East.

The gross gamma radiation walkover measurements in LA-2 East indicated that the highest levels of gamma radiation occur in two nearby areas 20 to 90 m downstream from the confluence with DP Canyon (Figure 2.3-12), which were designated c3 SW and c3 NE. Gross gamma measurements by CHEMRAD (from Oak Ridge, Tennessee) with 1-second count times and an unshielded probe were typically 8000 to 15,000 counts per minute (cpm) in the c3 units, with a maximum measurement of 16,700 cpm. In comparison, typical gamma radiation values upstream from DP Canyon in LA-2 West were 2000 to 4000 cpm, which represents local background radiation; typical values in the widespread c2 unit downstream from DP Canyon are 4000 to 6000 cpm. The gross gamma walkover measurements also indicated small areas with intermediate levels of gamma radiation, which were designated c2b and f1 b. The c2b unit includes areas that have the same physical characteristics as the typical c2 unit but where gamma radiation was typically 5000 to 8000 cpm. The f1b unit is a floodplain that is located across the channel from the c3 unit and where gamma radiation was typically 6000 to 8000 cpm.

The fixed-point gamma radiation measurements in LA-2 East were mostly from vertical exposures in the stream banks and were used to define vertical variations in gross gamma radiation. These measurements used 1-minute count times and a shielded probe. The shielded probe focuses the measurements on the specific sediment layer of interest better than the unshielded probe used for the walkover survey, although the measurements are still affected by gamma radiation derived from nearby layers. Measurements with the shielded probe are also made near the soil surface instead of at a height of approximately 0.3 m. Therefore, these measurements cannot be directly compared, although they show the same relative differences in gamma radiation.

The fixed-point gamma radiation measurements show that in most units the highest levels of radiation occur in the subsurface, and these subsurface layers generally correspond to the finest-grained sediment within individual stratigraphic sections. The relations of variations in radionuclide concentration and sediment particle size is discussed further in Section 3.3.3. Figure 2.3-14 shows average variations in gamma radiation through the c2, c2b, and c3 units, combining measurements from all vertical sections in each unit (the individual depth profiles are shown in Figure B4-5, and the complete set of fixed-point measurements is presented in Table B4-1). In the c3 unit, average gamma radiation increases with depth from approximately 18,000 cpm at the surface to an average of approximately 42,500 cpm at a depth of 0.7 m; the maximum value obtained in this unit was 46,701 cpm from a depth of 0.7 m at section LA2-S4 (sample location LA-0024). In the c2b unit, average gamma radiation increases with depth from approximately 12,500 cpm at the surface to an average of approximately 20,000 cpm at a depth of 0.5 m; the maximum value obtained in this unit was 24,480 cpm from a depth of 0.7 m at section LA2-S11 (sample location LA-0020). In the c2 unit, average gamma radiation increases with depth from approximately 10,000 cpm at the surface to an average of approximately 11,500 cpm at a depth of 0.3 m; the maximum value obtained in this unit was 12,897 cpm from a depth of 0.5 m at section LA2-S13 (sample location LA-0107). In contrast, the highest measurement obtained with this instrument in LA-2 West, upstream from DP Canyon, was 6955 cpm from the c2 unit (fixed-point site LA2-81). Measurements in LA-2 West provide an approximate upper limit of local background gamma radiation because of the general absence of gamma-emitting radionuclides above background values (Section 3,3,3) . Gamma radiation in the c1 unit in LA-2 East overlaps with the background range, with a maximum of 7693 cpm at fixed- point site LA2-61 (sample location LA-0023) and a minimum of 6155 cpm at fixed-point site LA2-33.



F2.3-14 / UPPER LOS ALAMOS REACH RPT / 110698

Figure 2.3-14. Plots of average gross gamma radiation against depth for sections from the c2, c2b, and c3 units in reach LA-2 East.

2.3.2.3 Geomorphic History

Geomorphic processes within reach LA-2 since 1942 have included the lateral migration of the active channel within an area that averages approximately 4 m wide in LA-2 West and 7 m wide in LA-2 East and the occasional overtopping of higher pre-1943 surfaces during floods. The c3 units in both LA-2 West and LA-2 East represent distinct aggradational periods, periods when the stream bed rose because of the deposition of significant amounts of channel facies sediment, although the nature and timing of these depositional periods was apparently different between the subreaches. In LA-2 West, the c3 aggradation is represented by wide gravel bars that were deposited over the former floodplain surface, and tree-ring dating indicates gravel deposition between 1967 and 1976 (trees ULA-033 and ULA-035, Table B1-1 and Figure 2.3-10). Similar gravel bars also occur in the c3 units of LA-1 Central and LA-1 East (Section 2.3.1.3). In contrast, the c3 unit in LA-2 East is dominated by channel sands and apparently records deposition from one or more large floods that emanated from DP Canyon between 1956 and 1968. The c3 unit in LA-2 East has the highest concentrations of radionuclides derived from the 21-011(k) outfall and released into DP Canyon (with recorded releases beginning in 1956), and the isotopic ratios in these sediments indicates that the sediment predates 1968 (as discussed in Section 3.3.3.2). The c3 unit in LA-2 West is presently isolated from the active channel and is relatively stable, but the c3 unit in LA-2 East is mostly located on the outside of a sharp bend in the channel and is very susceptible to bank erosion during large floods.

The c2 unit in LA-2 East provides a record of the dominant processes of erosion and deposition that have occurred in this part of upper Los Alamos Canyon since 1968 when there was a major increase in the use of plutonium-238 at the Laboratory (Nyhan et al. 1975, 11746; Nyhan et al. 1976, 11747). The history of the c2 unit in LA-2 West is probably similar to that in LA-2 East, although age control is poor in LA-2 West. The elevation of the stream bed has been relatively stable during this period, located within 0.5 m of its current elevation as indicated by the height of buried channel gravels relative to the present channel. In contrast to this apparent vertical stability, available data indicate that lateral erosion is common. Specifically, isotopic ratios in the c2 overbank sediments show that most of these sediments were deposited after 1978 when discharge of americium-241 increased at the 21-011(k) outfall (Section 3.3.1.5). Age control provided by isotopic ratios suggest that the c2 unit contains only small volumes of overbank sediment deposited between 1968 and 1978, dominantly in the areas mapped as c2b, and contains even smaller volumes of sediment deposited before 1968. Hence, the average residence time of overbank sediment in these locations is apparently less than 20 years, and remobilization of most of this sediment by lateral bank erosion could occur in similar time frames. Only small volumes of the fine-grained overbank facies sediment is located on the more stable floodplain surfaces.

Significant changes in the character of the c2 unit in LA-2 occurs at the confluence of DP and Los Alamos Canyons, which indicates that DP Canyon is a major sediment source for Los Alamos Canyon and that floods derived from this tributary also influence erosion rates in Los Alamos Canyon. The average thickness of overbank sediment on the c2 unit roughly doubles at this location, averaging 24 cm upstream and 49 cm downstream (Table 2.3-2), and this increased thickness probably records deposition of sediment derived from DP Canyon. The decrease in channel gradient and the decrease in confinement that occur when floods exit the steep and narrow lower part of DP Canyon would both contribute to deposition of sediment downstream from the confluence. The width of the c2 unit also increases downstream from DP Canyon, which may indicate greater rates of lateral bank erosion downstream from the confluence caused by floods that emanate from DP Canyon. Field observations indicate that floods commonly occur in DP Canyon when Los Alamos Canyon upstream from the confluence is not flooding, and runoff from paved areas in the Los Alamos townsite in the headwaters of DP Canyon is believed to contribute to this high flood frequency in DP Canyon.

2.3.3 Reach LA-3

2.3.3.1 Physical Characteristics

Reach LA-3 is in a part of upper Los Alamos Canyon close to state road NM 4 and the Laboratory boundary where the canyon floor is much wider than in upstream reaches but where the active part of the canyon floor is narrower. The area that has been impacted by post-1942 floods averages approximately 6.5 to 9 m wide. The areal distribution of the geomorphic units is shown on Figures 1.3-3, 2.3-15, and 2.3-16, and topographic relations are illustrated in the cross sections of Figure 2.3-17. Physical characteristics of the geomorphic units in LA-3 are summarized in Table 2.3-3. Data on particle size and unit thickness are presented in Table B3-3, Table B3-6, and Figure B2-5.

The active channel, c1, averages 2 m wide in LA-3 and has a bed composed of coarse sand and gravel. The active channel is usually bordered by abandoned post-1942 channel units (c2 and c3) that average approximately 3.5 m in combined width and have average heights of 0.4 to 0.7 m above the channel. The c2 and c3 units are usually capped by an average of approximately 0.4 to 0.55 m of relatively fine-grained overbank sediments dominated by very fine sand.

Active floodplains (f1 and f2) are relatively narrow in LA-3 and only discontinuously border the abandoned channel units. The f1 unit has an average width of only 1 m, has an average height of approximately 0.8 m, and is capped by an average of approximately 0.4 m of overbank sediment dominated by very fine sand. The f1 unit is commonly closely associated with the c3 unit and is distinguished by the pre-1943 age of the underlying channel facies sediment deposits. The f2 unit is wider, averaging approximately 2.4 m wide but is probably overlain by thin and discontinuous post-1942 overbank sediment layers. Field gamma radiation measurements are within background ranges on the f2 unit, and f2 is considered to represent a post-1942 floodplain solely on the basis of analytical data that indicate the presence of radionuclides at relatively low concentrations but above background values.

2.3.3.2 Radiological Characteristics

Based on the results of the radiological field measurements in reach LA-2 East, only gross gamma radiation walkover measurements and fixed-point measurements were made in reach LA-3. The gross gamma radiation walkover measurements in LA-3 are presented in Figures 2.3-18 and 2.3-19, all the fixed-point measurements are presented in Table B4-3, and gamma radiation depth profiles are presented in Figure B4-8.

The gross gamma radiation walkover survey indicated that levels of gamma-emitting radionuclides in reach LA-3 were much closer to background than in LA-2 East and that these measurements were less useful than in LA-2 East for defining geomorphic unit boundaries based on variations in gamma radiation. In addition, vegetation cover in the post-1942 geomorphic units in LA-3 is much denser than LA-2, often consisting of thick brush that prevented walkover measurements, and the post-1942 geomorphic units are generally narrower in LA-3 than in LA-2, which also limited the utility of this procedure. However, sites with gamma radiation above background values were clearly identified during the walkover survey, and the walkover survey helped guide the fixed-point measurements. Maximum gamma radiation measured during the walkover survey was 6840 cpm in the c3 unit, and values of 4000 to 5000 cpm were common in the c3 unit. In comparison, typical values in the c1 and c2 units were 3000 to 4500 cpm, which overlap with data from nearby colluvial slopes where measurements reached 4500 cpm.

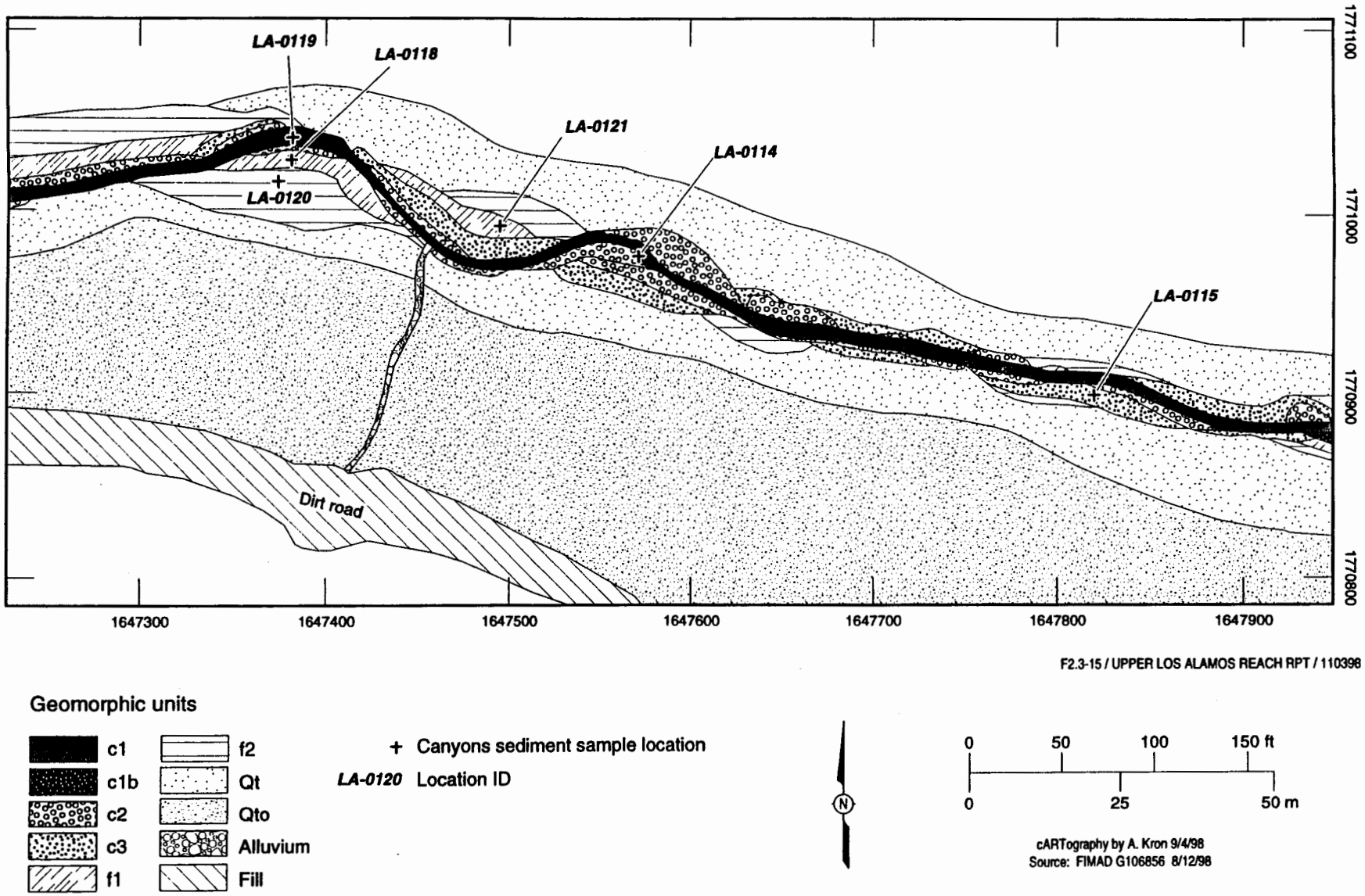


Figure 2.3-15. Geomorphic map of west half of reach LA-3 showing sample locations.

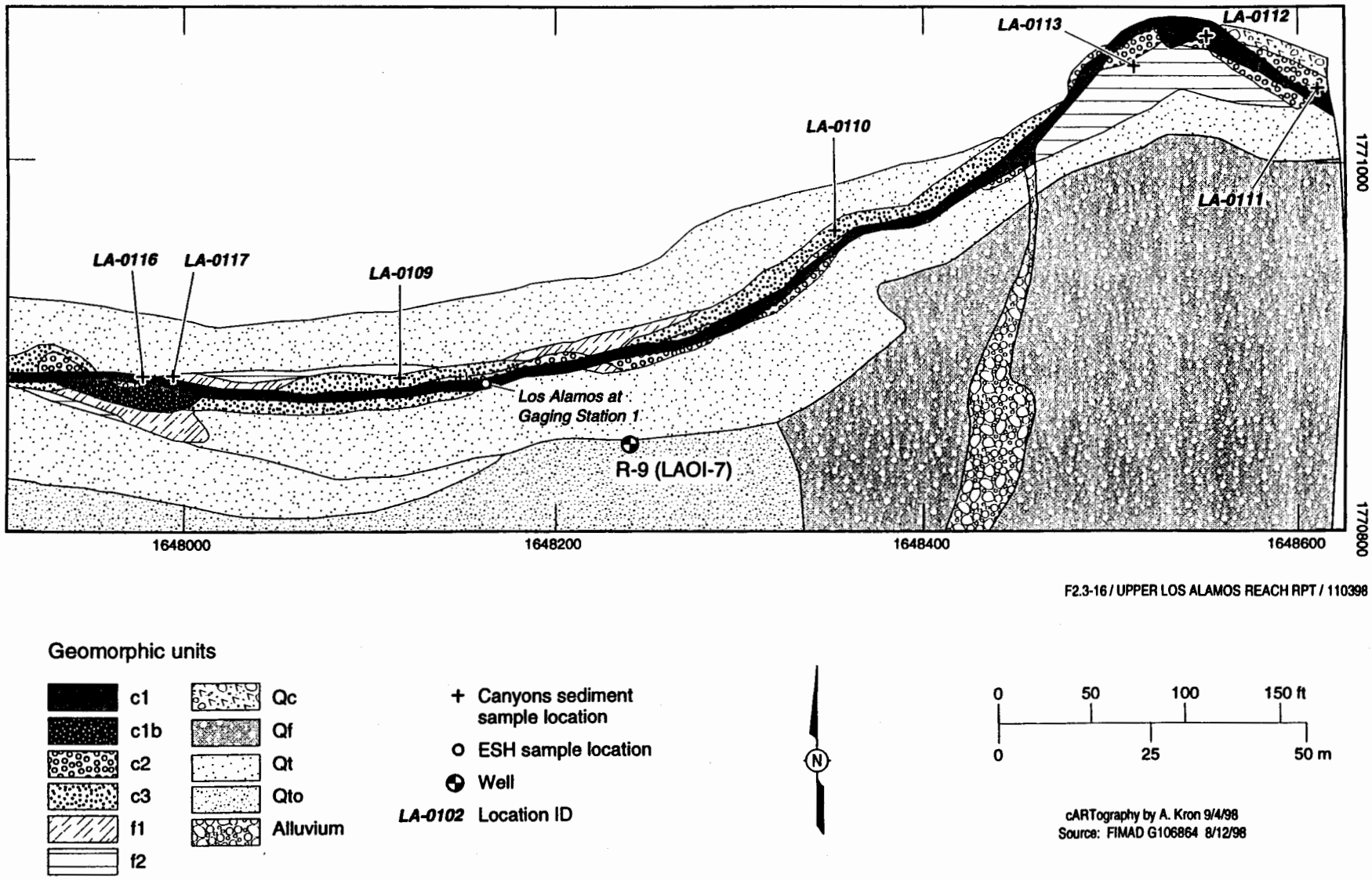


Figure 2.3-16. Geomorphic map of east half of reach LA-3 showing sample locations.

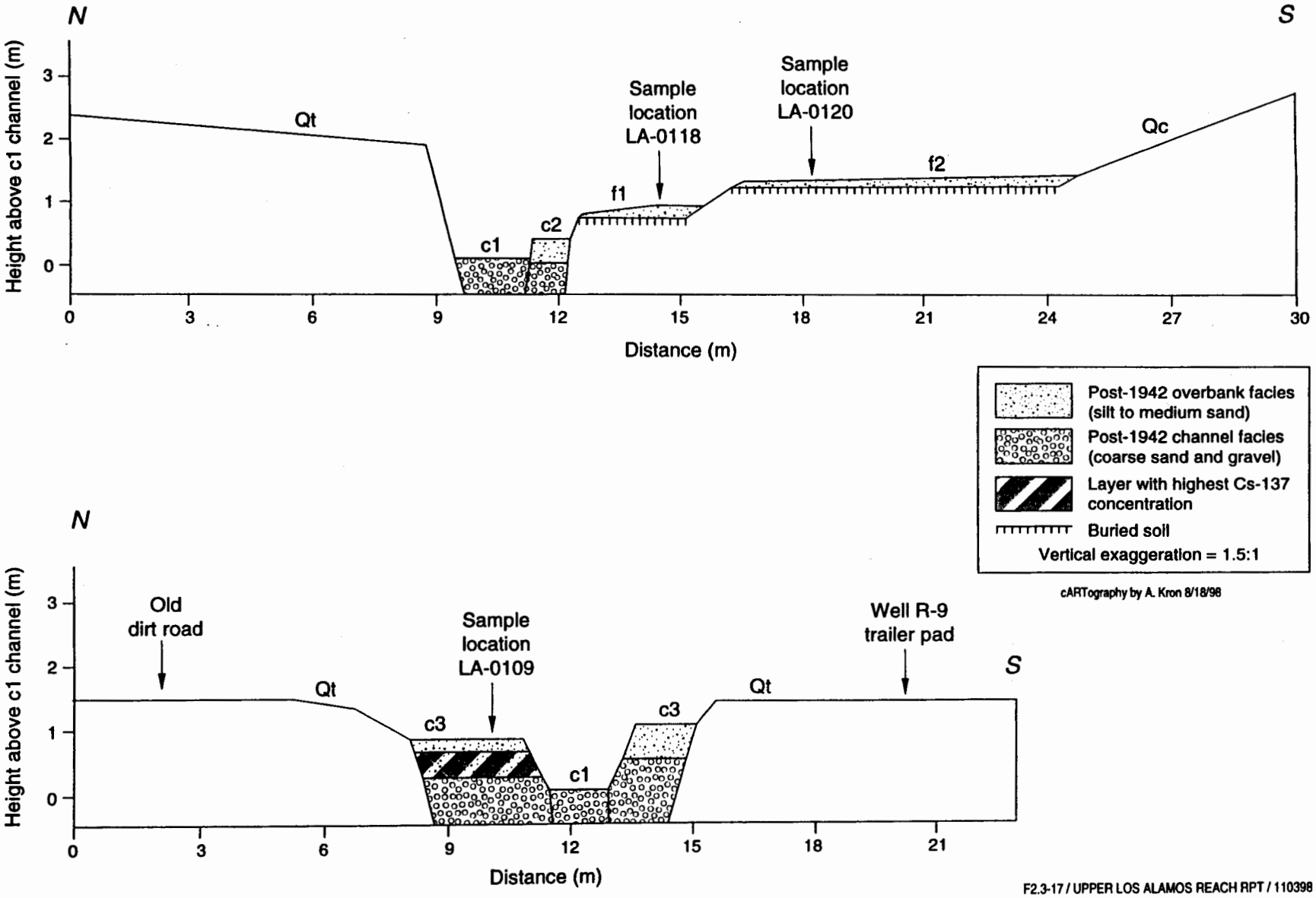


Figure 2.3-17. Schematic cross sections showing relationship between geomorphic units in reach LA-3.

TABLE 2.3-3

GEOMORPHIC MAPPING UNITS IN REACH LA-3

Unit	Estimated Average Unit Height Above Channel (m)	Unit Area (m^2)	Average Unit Width (m)	Sediment Facies	Estimated Average Thickness (m)	Typical Median Particle Size Class (<2 mm fraction)	Typical Soil Texture	Notes
c1	0	897	2.0	Channel	<1.0	Coarse sand	Gravelly sand	Active channel
c1b	0.2	62	0.1	Channel	<1.0	Coarse sand	Gravelly sand	Sand and gravel bars adjacent to active channel
c2	0.4	651	1.5	Overbank	0.41 ± 0.12	Very fine sand	Sandy loam	Younger abandoned post-1942 channel
				Channel	<1.0	Coarse sand	Gravelly sand	
c3	0.7	834	1.9	Overbank	0.55 ± 0.09	Very fine sand	Sandy loam	Older abandoned post-1942 channel
				Channel	<1.0	Coarse sand	Gravelly sand	
f1	0.8	433	1.0	Overbank	0.42 ± 0.22	Very fine sand	Sandy loam	Active floodplain
f2	1.1	1034	2.4	Overbank	<0.05	Fine sand	Sandy loam	Potentially active floodplain

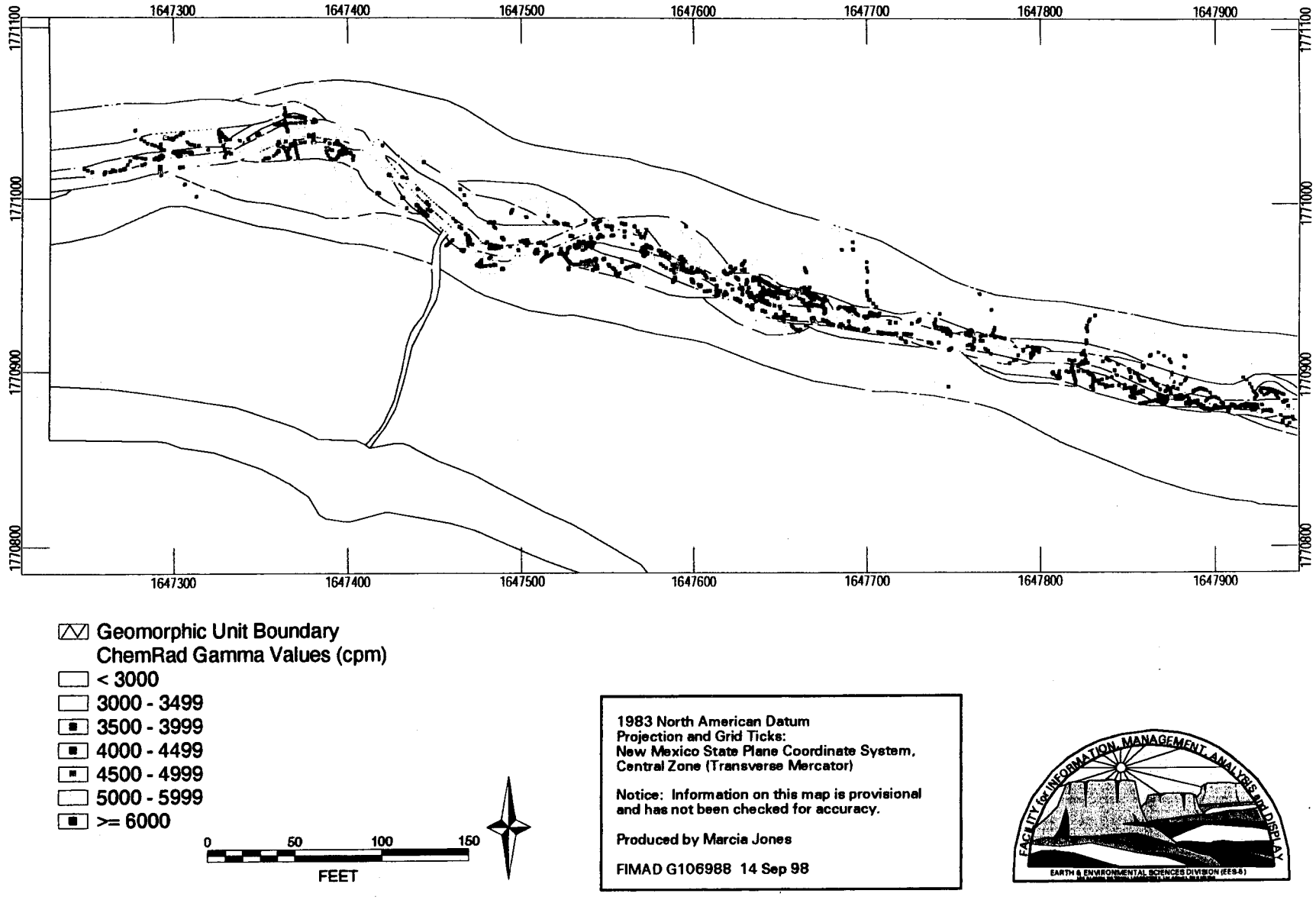


Figure 2.3-18. Map showing gross gamma radiation walkover measurements in west half of reachÊLA-3.

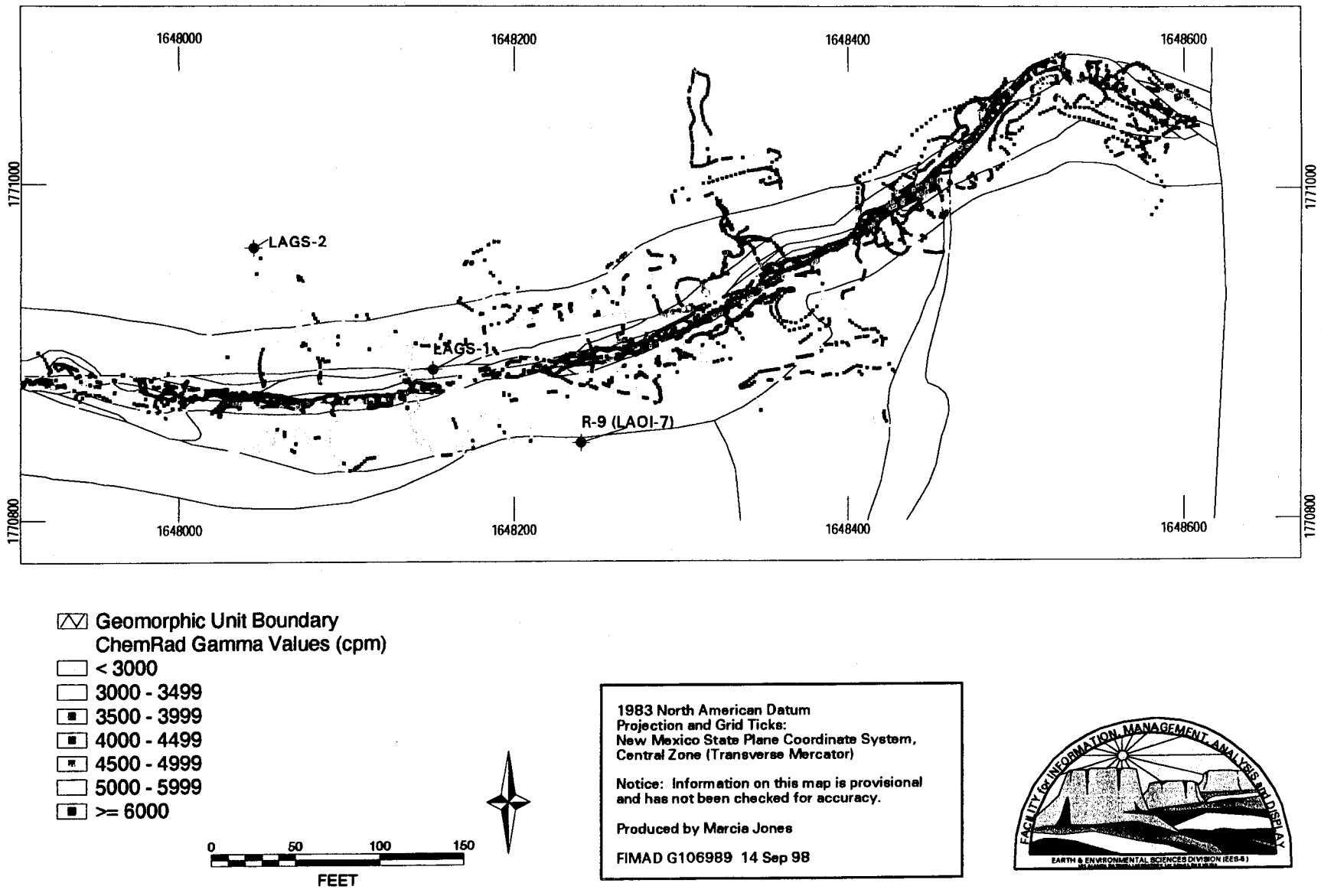


Figure 2.3-19. Map showing gross gamma radiation walkover measurements in east half of reachÊLA-3.

The fixed-point gamma radiation measurements in LA-3 were mostly from vertical exposures in the stream banks and were used to subdivide the post-1942 abandoned channel units, to define vertical variations in gross gamma radiation, and to select sample sites. Plots showing gamma radiation in each vertical section (Figure B4-8) were overlaid, and profiles that had similar radiation were grouped into one of six "bins." The four bins with the highest radiation levels were assigned to the c3 unit, and the two bins with the lowest radiation levels were assigned to the c2 unit. The assigned bins for each section are indicated in Table B4-3. Sediment sampling was conducted in representative sections within three of the four c3 bins and both of the c2 bins, and the sediment layer with the highest gamma radiation in each of these five sections was chosen for full-suite analyses.

As in LA-2 East, the fixed-point gamma radiation measurements in LA-3 show that in most units the highest levels of radiation occur in the subsurface, and these subsurface layers generally correspond to the finest-grained sediment within individual stratigraphic sections. The relations of variations in radionuclide concentration and sediment particle size is discussed further in Section 3.3.4.2. Figure 2.3-20 shows average variations in gamma radiation through the c2 and c3 units, combining measurements from all vertical sections in each unit (the individual depth profiles are shown in Figure B4-8, and the complete set of fixed-point measurements is presented in Table B4-3). Average values through pre-1942 stream terraces (Qt unit) are also shown for comparison. Note that some sections were measured twice: first in late May 1997 when the stream was flowing and the sediment was relatively moist and again in late June 1997 when the stream was no longer flowing and the sediment was drier. Radiation measurements were consistently high in June (Table B4-3, Figure B4-8), consistent with less attenuation of gamma radiation occurring in the drier sediment, although the relative difference between different sections and different layers within individual sections did not change significantly. Binning was performed using the May 1997 data set for consistency, and the average values in Figure 2.3-20 also use only the May 1997 data.

In the c3 unit, average gamma radiation increases with depth from approximately 8000 cpm at the surface to an average of approximately 9300 cpm at a depth of 0.3 to 0.4 m. The maximum values obtained in c3 in May and June 1997 were both from section LA3-S5 (sample location LA-0109): 10,695 cpm from a depth of 0.4 m in May and 11,038 cpm from a depth of 0.45 m in June. In the c2 unit, average gamma radiation increases with depth from approximately 7600 cpm at the surface to an average of approximately 8000 cpm at a depth of 0.4 m. The maximum values obtained in c2 in May and June 1997 were both from section LA3-S17 (sample location LA-0111): 8546 cpm from a depth of 0.3 m in May and 9481 cpm from the same depth in June. The f1 unit has levels of gamma radiation intermediate between c2 and c3 and probably includes sediment correlative with both units. In contrast, the highest measurement obtained with this instrument in pre-1942 geomorphic units is 8131 cpm from the Qt unit (fixed-point site LA3-19, May 1997), and surface measurements averaged approximately 6900 cpm. The highest measurement obtained from the c1 unit is 7049 cpm (fixed-point site LA3-66, sample location LA-0112, June 1997), which is indistinguishable from background radiation.

2.3.3.3 Geomorphic History

Geomorphic processes within reach LA-3 since 1942 have included the lateral migration of the active channel within a narrow area that averages 5.5 m wide, represented by the width of the c1, c2, and c3 units, and the occasional overtopping of higher pre-1943 surfaces during floods. The channel location has apparently been stable, and at one site a tree that germinated circa 1924 AD is growing on a stream bank near the active channel and below a Qt stream terrace (tree ULA-001, Table B1-1; near sample site LA-0110), indicating little change in channel geometry for more than 70 years. Isotopic ratios within LA-3 overbank sediment (discussed in Section 3.3.4.2) indicate that only small volumes of sediment occur in LA-3 that were deposited between 1942 and 1968, and lateral bank erosion rates are apparently high enough that the average residence time of overbank sediment close to the active channel is less than 30 years.

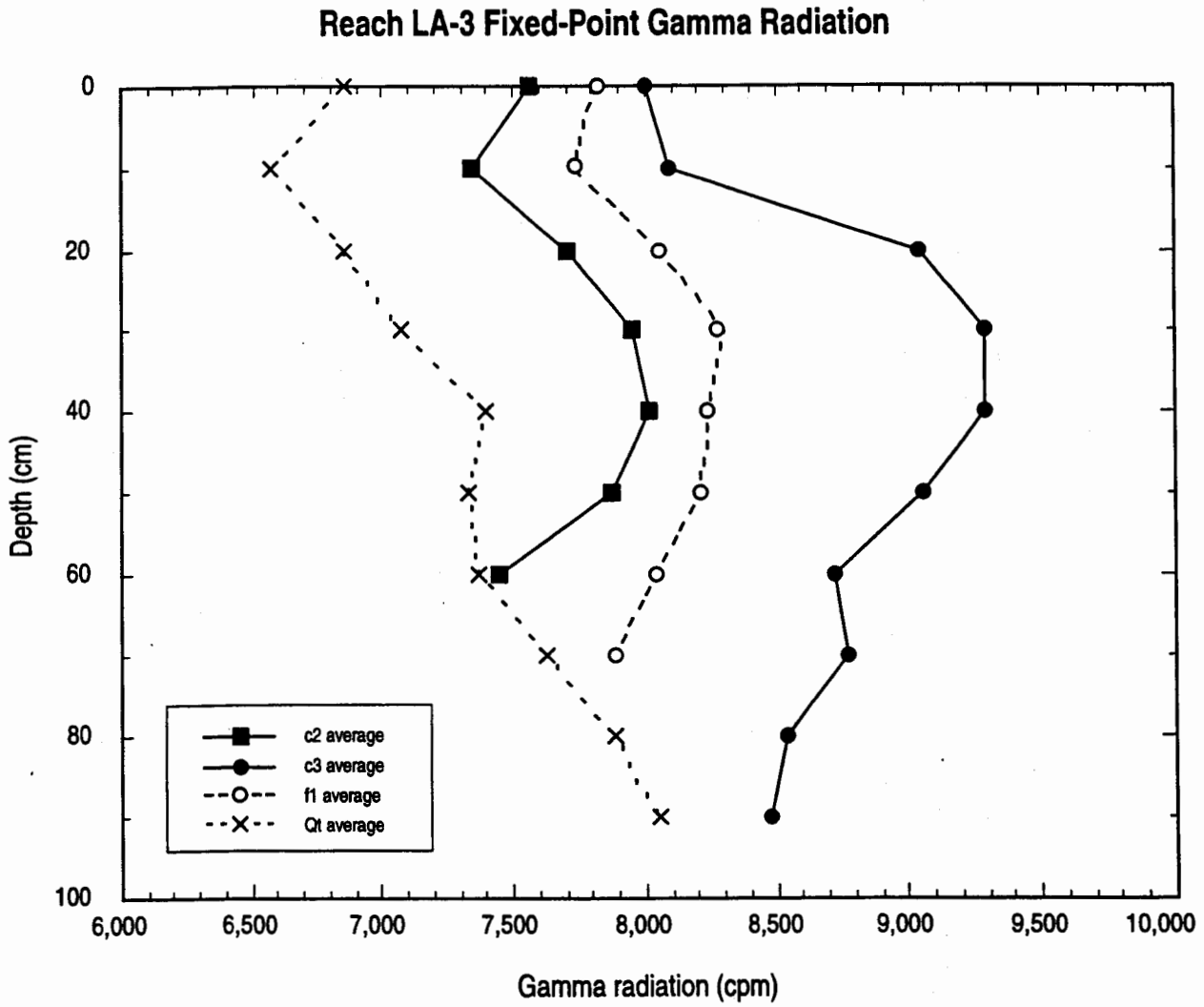


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Figure 2.3-20. Plots of average gross gamma radiation against depth from the c2, c3, f1, and Qt units in reach LA-3.

This conclusion is consistent with the evidence in LA-2 East (discussed in Section 2.3.2.3), in turn suggesting that similar conditions exist between LA-2 and LA-3. Stratigraphic evidence indicates that the stream bed in LA-3 has remained within approximately 0.5 m of its present elevation during this period, which is also consistent with evidence in LA-2. The vertical stability of the stream bed in LA-3 may be aided by the occurrence of basalt in the channel bed a short distance downstream, which prevents significant channel incision over these time scales.

Floods in LA-3 since 1942 have been largely confined to the area close to the active channel, and the combined width of abandoned channel units and post-1942 floodplains in LA-3 is less than in any of the upstream reaches. This observation may indicate that floods produced in the upper parts of the watershed have attenuated by the time they reach LA-3, having lower peak discharges than upstream. The largest flood since 1942 in LA-3 may have occurred before the initial releases of cesium-137 from the 21-011(k) outfall, as indicated by a sample from the f2 unit at the east end of LA-3 (sample location LA-0113, Figure 2.3-16) that has plutonium-239,240 above the background value but cesium-137 below the background value.

2.3.4 Supplemental Characterization between Reaches

After it was recognized that gross gamma radiation walkover measurements provided a fast and efficient means to identify variations in gamma radiation within parts of upper Los Alamos Canyon, supplemental characterization between reaches was conducted in May 1996. This characterization involved the collection of gamma radiation measurements from a series of short (10 to 45 m long) sections of the active stream channel and adjacent post-1942 geomorphic units extending from the TA-2 security fence downstream to state road NM 4. The methods used in this survey are discussed further in Appendix B-4.1.1.

Gamma radiation data were collected from approximately 30% of the 7 km of Los Alamos Canyon between TA-2 and state road NM 4. Figure 2.3-21 summarizes these data, showing average values from each measurement interval for both the active channel and the adjacent surfaces where fine-grained overbank facies sediment has been deposited. Gamma radiation is relatively low between TA-2 and DP Canyon and probably records background radiation levels because of the general absence of gamma-emitting radionuclides above background values in these areas (Section 3). Gamma radiation increases dramatically at DP Canyon and then progressively decreases to state road NM 4, although radiation at the eastern end of the survey is still elevated relative to radiation upstream from DP Canyon. Gamma radiation both upstream and downstream from DP Canyon is higher on surfaces underlain by fine-grained sediment than along the active channel, and the difference is most pronounced downstream from DP Canyon. The differences between gamma radiation in coarse-grained and fine-grained sediment upstream from DP Canyon probably reflect variations in naturally occurring gamma-emitting radionuclides between these sediments, whereas the differences downstream from DP Canyon reflect fluvial segregation of cesium-137 derived from the 21-011(k) outfall superimposed on the background variations.

The gross gamma walkover radiation data reveal that although there is a general decreasing trend in radiation level from DP Canyon to state road NM 4, considerable variability can exist in any area (Figure 2.3-21). For example, data obtained approximately 1.1 to 1.5 km downstream from DP Canyon show that some areas have gamma radiation at higher levels than that measured in the typical c2 unit in LA-2 East (which extends 0.6 km downstream from DP Canyon), although radiation at other sites is lower. These data are consistent with the variability that exists in LA-2 East associated with sediment deposits of different ages and suggest that the areas of highest radiation measured farther downstream correspond to areas containing sediment equivalent in age to the c2b or c3 units in LA-2 East. Irregular variability in gamma radiation has also been identified in aerial radiological surveys of this area (Fritzsche 1990, 58971).

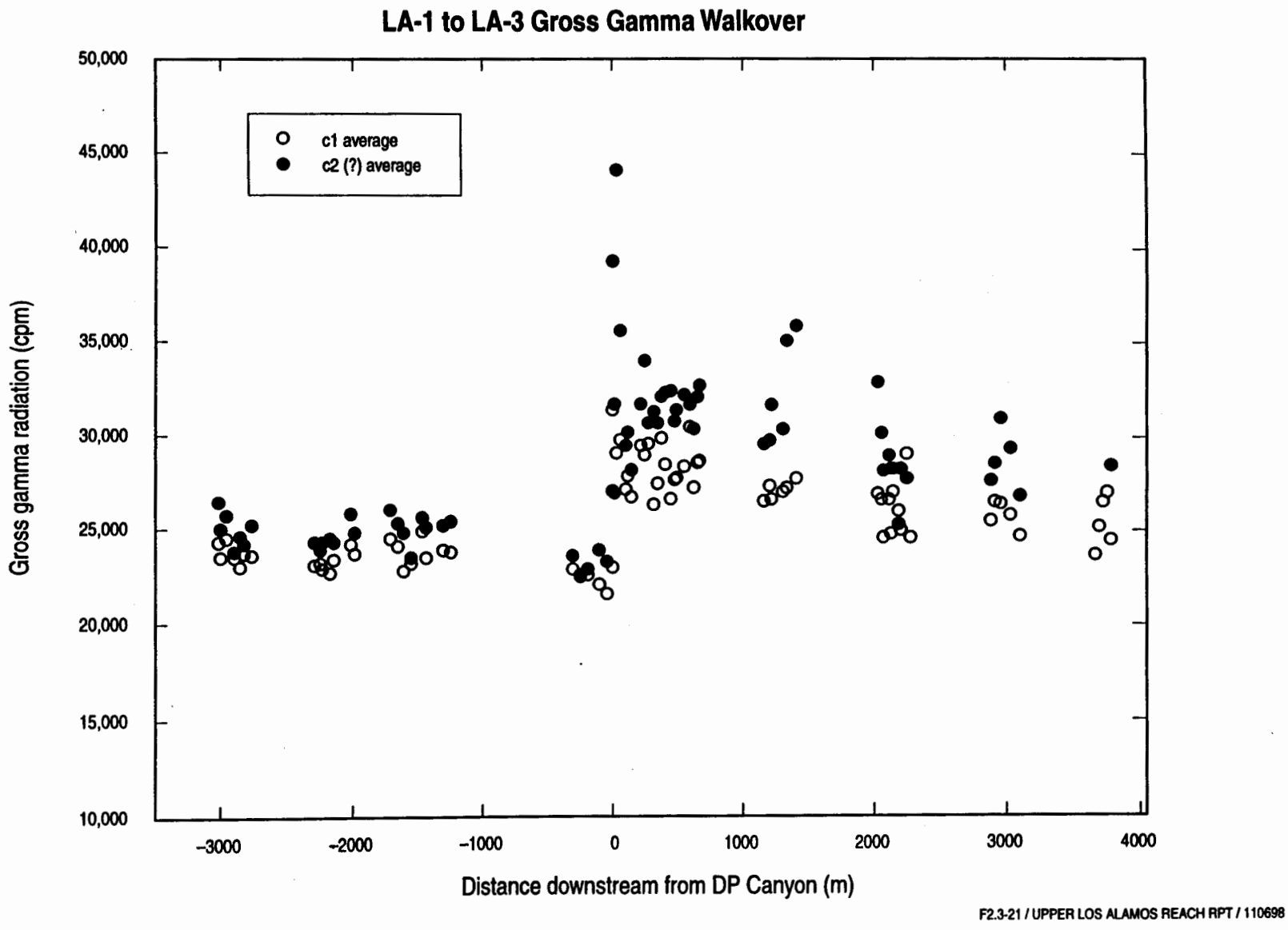


Figure 2.3-21. Average values of gross gamma radiation measured in short walkover surveys between TA-2 and state road NM 4 plotted against distance from DP Canyon.

3.0 ANALYTICAL RESULTS AND DATA REVIEW

3.1 Data Review

Sediment samples collected in the upper Los Alamos Canyon reaches included samples for full-suite, limited-suite, and key contaminant analyses. The samples were collected following the technical approach presented in Chapter 5 of the work plan (LANL 1995, 50290). Samples were collected to represent specific geomorphic units and sediment facies within each reach. The variability within and among these geomorphic units and sediment facies is a key variable to assess and will be considered in Sections 3.2 and 3.3. The number of samples varies among classes of analytes. The number of samples analyzed for organic chemicals; inorganic chemicals (target analyte list [TAL] metals with a subset of samples analyzed for total cyanide, boron, titanium, uranium, and total uranium); and radionuclides is presented in Table 3.1-1. Full-suite analyses were obtained for 18 samples in reaches LA-2 and LA-3. The full-suite analytes included inorganic chemicals that are on the TAL; polychlorinated biphenyls (PCBs) and pesticides; semivolatile organic compounds (SVOCs); americium-241 by alpha spectroscopy; tritium; isotopic uranium; isotopic thorium; strontium-90; isotopic plutonium; americium-241, cesium-137, and other radionuclides in the gamma spectroscopy suite; tritium; radium-226; gross alpha/beta radiation; and gross gamma radiation. The specific analytes chosen for either limited-suite analyses or key contaminant analyses varied among the different reaches, and no single analyte suite was obtained for every sampled sediment layer in upper Los Alamos Canyon. In addition to the full-suite analyses, the following analytes were included in either limited-suite or key contaminant analyses: isotopic plutonium (161 total analyses); americium-241, cesium-137, and other radionuclides in the gamma spectroscopy suite (116 analyses); strontium-90 (73 analyses); inorganic chemicals that are on the TAL (49 analyses); PCBs (36 analyses); pesticides (25 analyses); isotopic uranium (42 analyses); americium-241 by alpha spectroscopy (31 analyses); tritium (20 analyses); and radium-226 (2 analyses).

TABLE 3.1-1

NUMBER OF SAMPLES ANALYZED BY SUITE

Analytical Suite	Reach			
	LA-1	LA-2	LA-3	Total
PCBs	9	2	0	11
Pesticides and PCBs	16	12	8*	36
SVOCs	0	12	8*	20
Inorganic chemicals (TAL)	27	14	8	49
Boron, uranium, titanium	0	10	0	18
Total cyanide, total uranium	0	10	8	18
Americium-241 (by alpha spectroscopy)	11	12	8	31
Gross alpha/beta radiation	0	10	8	18
Gross gamma radiation	0	10	8	18
Gamma-spectroscopy radionuclides	11	59	46	116
Tritium	0	12	8	20
Isotopic plutonium	85	55	21	161
Isotopic thorium	0	10	8	18
Isotopic uranium	20	14	8	42
Radium-226	0	2	0	2
Strontium-90	3	51	19	73

*These sample results were rejected.

The objective of this data review is to determine which analytes should be retained for further assessment and which analytes should be eliminated before human health and ecological risk calculations. Considerations in these assessments include the magnitude of contaminant concentrations relative to background values (or detection limits for organic chemicals), the correlation between contaminant concentrations between reaches and within reaches, and potential quality control (QC) problems with the laboratory analyses.

3.1.1 Inorganic Chemical Comparison with Background

Inorganic chemicals on the TAL were analyzed in 49 sediment samples collected from all three upper Los Alamos Canyon reaches. Four other inorganic chemicals were also requested from a subset of samples. Total uranium and total cyanide were requested for 18 samples collected in reaches LA-2 and LA-3. Boron, titanium, and uranium were requested for 10 samples from reach LA-2. Inorganic chemical sample results were compared with the sediment background values that are presented in "Inorganic and Radionuclide Background Data for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory" (Ryti et al. 1998, 58093).

As detailed in Appendix C, QC problems associated with this data set were caused by the detection of inorganic chemicals in method blanks, recoveries outside of the control range for the laboratory control samples, differences between laboratory duplicates greater than ±15%, values out of the control windows for the inductively coupled plasma (ICP) serial dilutions, and high or low recoveries in the matrix spike samples. Blank contamination is a QC indicator of possible positive bias in sample results. Thus, reported concentrations for samples with blank contamination could be overestimates of the actual environmental concentrations. Laboratory control samples can be used to indicate possible high or low bias associated with the entire analytical measurement process. Matrix spike samples are used to assess the quality of the sample digestion, extraction, and analysis procedures. A low recovery suggests that there was either incomplete recovery of an analyte in these procedures or sample heterogeneity. A high recovery indicates either sample heterogeneity or a matrix interference. One of the reasons for the repeated difficulties in the recoveries is the heterogeneous nature of many sediment samples. Also, for several of the analytes there are interferences in the ICP technique, which can also cause problems with the reported recoveries.

Data qualifications due to blank contamination were noted for seven inorganic chemicals in a subset of the samples: arsenic (5 samples), boron (10 samples), chromium (1 sample), nickel (4 samples), selenium (26 samples), sodium (2 samples), and thallium (4 samples). A high recovery on the copper laboratory control sample was noted for one sample request (18 samples), which is an indicator of high bias. High matrix spike duplicate recovery problems were noted for titanium (10 samples), which is also an indicator of possible high bias. Low matrix spike recoveries were noted for antimony (10 samples), mercury (2 samples), manganese (8 samples), and selenium (8 samples); these results were qualified as nondetected sample results. Another 10 antimony results from sample request number (RN) 2104 had unacceptably low recovery on the matrix spike duplicate, which led to rejecting these data. These rejected antimony results are from samples collected in reach LA-2 and will not be used in this report. Appendix C also shows that some laboratory duplicate measurements are out of the ±35% control window for aluminum (11 samples), iron (11 samples), and lead (18 samples). These problems are not considered to be serious and most likely reflect the heterogeneous nature of the sediment samples. In summary, some of the QC problems associated these data would lead to overstating environmental concentrations and thus could lead to incorrectly identifying some of these inorganic chemicals as chemicals of potential concern (COPCs) because of high laboratory bias. Other QC problems were associated with possibly underestimating environmental concentrations and warrant additional discussion before eliminating any affected inorganic chemicals as COPCs.

The analytical methods for the inorganic chemicals are comparable to those used to generate the Laboratory background data, with the exception of antimony. Some of the upper Los Alamos Canyon antimony data were generated by inductively coupled plasma emission spectroscopy (ICPES), which results in a detection limit above what is typically found in background soils. Because the upper Los Alamos Canyon antimony data were generated by ICPES, the antimony detection limits for these samples are elevated above the background value.

Because the Laboratory background data contain values for both "uranium" and "total uranium," the uranium sample preparation and analysis methods must be reviewed to identify the appropriate uranium background data. Total uranium results for upper Los Alamos Canyon samples were analyzed by the inductively coupled plasma mass spectroscopy (ICPMS) analytical method with total sample dissolution preparation, which is the analytical/preparation method used to determine the total uranium background value. Uranium sample results were also analyzed by ICPMS but were prepared by Environmental Protection Agency (EPA) Method 3050A, which is comparable to the preparation method used to derive the uranium background value.

Of 27 inorganic chemicals, 25 were detected in at least one upper Los Alamos Canyon sediment sample. Antimony and boron were not detected in any sample. The detection limit for most antimony sample results exceeded the background value. The detection limit for one boron sample result was greater than the background value. Detection limits for some of the cadmium, mercury, selenium, and silver analyses were also greater than the background value. Tables 3.1-2, 3.1-3, and 3.1-4 present the concentration range and frequency of results above the background value for the 25 detected inorganic chemicals and the 2 nondetected inorganic chemicals for reaches LA-1, LA-2, and LA-3, respectively.

One inorganic chemical, antimony, was not detected in any sample, but several samples had detection limits above the background value. Antimony is retained as a COPC solely because of the elevated detection limits for some samples.

Eleven inorganic chemicals (aluminum, cobalt, total cyanide, iron, magnesium, manganese, nickel, potassium, sodium, thallium, and titanium) were measured above the detection limit and below the background value. The only QC problem of note for these chemicals was the possible low bias for manganese in eight LA-3 samples (see Appendix C). The maximum manganese sample result in reach LA-3 was 40% less than the background value, which suggests that any correction for possible low bias would not change the conclusion of the manganese background comparisons. Thus, these eleven inorganic chemicals will not be retained for further assessment in this report. Additional discussion and graphical data presentations for these chemicals can be found in Appendix E.

Statistical and graphical data evaluation approaches led to the elimination of six inorganic chemicals that did not differ from background data. These inorganic chemicals, which have at least one result greater than the background value, included arsenic, barium, beryllium, boron, calcium, and vanadium. These six chemicals will not be retained for further assessment in this report. Additional discussion and graphical data presentations for these chemicals can be found in Appendix E.

Nine other inorganic chemicals were shown to be elevated above background values by a statistical and graphical background comparison and are retained as COPCs. The statistical analyses and graphs that support this evaluation are provided in Appendix E. These inorganic chemicals include cadmium, total chromium, copper, lead, mercury, selenium, silver, uranium (whether reported as uranium or total uranium), and zinc. It is worth noting that copper, total chromium, and selenium had QC indicators of positive bias, which could suggest that these chemicals have been erroneously identified as COPCs.

However, all sample results are used as reported without any adjustment for possible analytical bias; therefore, copper, total chromium, and selenium will be retained for further assessment.

TABLE 3.1-2

FREQUENCY OF DETECTED INORGANIC CHEMICALS IN REACH LA-1

Analyte	Number of Samples Analyzed	Number of Detects	Concentration Range (mg/kg)[a]	Maximum Detect (mg/kg)	Background Value (mg/kg)	Frequency of Detects above Background Value[b]
Aluminum	27	27	744 to 4810	4810	15400	0/27
Antimony	27	0	[0.37] to [9.2]	ND[c]	0.83	11/27 DL[d]>BV[e]
Arsenic	27	27	0.53 to 2.4	2.4	3.98	0/27
Barium	27	27	10.4 to 128	128	127	1/27
Beryllium	27	27	0.04 to 1.4	1.4	1.31	1/27
Cadmium	27	1	[0.02] to [0.8]	0.05	0.4	0/1, 11/26 DL>BV
Calcium	27	27	361 to 2730	2730	4420	0/27
Chromium, total	27	26	[1.3] to 10.6	10.6	10.5	1/26
Cobalt	27	27	0.81 to 4	4	4.73	0/27
Copper	27	27	5 to 23.8	23.8	11.2	9/27
Iron	27	27	2090 to 7430	7430	13800	0/27
Lead	27	27	7.4 to 43.7	43.7	19.7	17/27
Magnesium	27	27	236 to 994	994	2370	0/27
Manganese	27	27	103 to 300	300	543	0/27
Mercury	27	15	0.01 to 0.16	0.16	0.1	2/15, 0/12 DL>BV
Nickel	27	25	1.2 to 5.4	5.4	9.38	0/25
Potassium	27	27	182 to 978	978	2690	0/27
Selenium	27	1	[0.3] to [1.1]	0.63	0.3	1/1, 25,26 DL>BV
Silver	27	12	[0.08] to 1.7	1.7	1	3/12
Sodium	27	27	28.3 to 431	431	1470	0/27
Thallium	27	0	[0.19] to [0.38]	ND	0.73	0/27
Vanadium	27	27	3 to 11.1	11.1	19.7	0/27
Zinc	27	27	14.1 to 54.5	54.5	60.2	0/27

a. Values in square brackets indicate nondetected results.

b Value is the ratio of the number of detected values exceeding the background value to the number of analyses.

c. ND = not detected

d. DL = detection limit

e. BV = background value

TABLE 3.1-3

FREQUENCY OF DETECTED INORGANIC CHEMICALS IN REACH LA-2

Analyte	Number of Samples Analyzed	Number of Detects	Concentration Range (mg/kg)[a]	Maximum Detect (mg/kg)	Background Value (mg/kg)	Frequency of Detects above Background Value[b]
Aluminum	14	14	2440 to 14300	14300	15400	0/14
Antimony	4	0	[0.43] to [14]	ND[c]	0.83	2/4 DL[d]>BV[e]
Arsenic	14	9	[1.3] to 4.7	4.7	3.98	1/9, 0/5 DL>BV
Barium	14	14	28.2 to 132	132	127	1/14
Beryllium	14	12	0.27 to 1.1	1.1	1.31	0/12, 0/2 DL>BV
Boron	10	0	[1.2] to [5.9]	ND	3.9	1/10 DL>BV
Cadmium	14	3	0.03 to 0.89	0.89	0.4	1/3, 1/11DL>BV
Calcium	14	14	611 to 5740	5740	4420	1/14
Chromium, total	14	14	4.4 to 38.4	38.4	10.5	4/14
Cobalt	14	14	1 to 4.1	4.1	4.73	0/14
Copper	14	14	2.8 to 13.9	13.9	11.2	2/14
Cyanide, total	10	8	0.15 to 0.36	0.36	0.82	0/8, 0/2 DL>BV
Iron	14	14	5480 to 13600	13600	13800	0/14
Lead	14	14	12.2 to 61.9	61.9	19.7	10/14
Magnesium	14	14	333 to 1950	1950	2370	0/14
Manganese	14	14	214 to 457	457	543	0/14
Mercury	14	6	[0.02] to 0.31	0.31	0.1	3/6, 2/8 DL>BV
Nickel	14	10	[1.9] to 9	9	9.38	0/10, 0/4 DL>BV
Potassium	14	14	679 to 2250	2250	2690	0/14
Selenium	14	5	[0.2] to [1.4]	0.65	0.3	2/5, 4/9 DL>BV
Silver	14	1	[0.09] to 15.8	15.8	1	1/1, 2/13 DL>BV
Sodium	14	12	88.2 to 893	893	1470	0/12, 0/2 DL>BV
Thallium	14	2	[0.3] to 0.48	0.48	0.73	0/2, 0/12 DL>BV
Titanium	10	10	88.8 to 409	409	439	0/10
Uranium	10	10	0.21 to 2.9	2.9	2.22	2/10
Uranium, total	10	10	2.7 to 7.2	7.2	6.99	1/10
Vanadium	14	14	6.7 to 21.9	21.9	19.7	1/14
Zinc	14	14	38.3 to 90.5	90.5	60.2	5/14

a. Values in square brackets indicate nondetected results.

b Value is the ratio of the number of detected values exceeding the background value to the number of analyses.

c. ND = not detected

d. DL = detection limit

e. BV = background value

TABLE 3.1-4

FREQUENCY OF DETECTED INORGANIC CHEMICALS IN REACH LA-3

Analyte	Number of Samples Analyzed	Number of Detects	Concentration Range (mg/kg)[a]	Maximum Detect (mg/kg)	Background Value (mg/kg)	Frequency of Detects above Background Value[b]
Aluminum	8	8	1200 to 9180	9180	15400	0/8
Antimony	8	0	[5] to [6.5]	ND[c]	0.83	8/8 DL[d]>BV[e]
Arsenic	8	8	0.49 to 1.8	1.8	3.98	0/8
Barium	8	8	14.3 to 84	84	127	0/8
Beryllium	8	8	0.16 to 0.85	0.85	1.31	0/8
Cadmium	8	0	[0.41] to [0.54]	ND	0.4	8/8 DL>BV
Calcium	8	8	673 to 2780	2780	4420	0/8
Chromium, total	8	8	2.2 to 12.2	12.2	11.2	2/8
Cobalt	8	8	1.6 to 3.6	3.6	4.73	0/8
Copper	8	8	3.2 to 15.4	15.4	10.5	2/8
Cyanide, total	8	0	[0.25] to [0.27]	ND	0.82	8/8 DL>BV
Iron	8	8	5410 to 8270	8270	13800	0/8
Lead	8	8	6 to 44.2	44.2	19.7	6/8
Magnesium	8	8	461 to 1410	1410	2370	0/8
Manganese	8	8	181 to 302	302	543	0/8
Mercury	8	1	[0.05] to 0.14	0.14	0.1	1/1, 7/7 DL>BV
Nickel	8	8	3.2 to 6.4	6.4	9.38	0/8
Potassium	8	8	197 to 1330	1330	2690	0/8
Selenium	8	0	[0.24] to [0.3]	ND	0.3	0/8 DL>BV
Silver	8	0	[1.5] to [1.9]	ND	1	8/8 DL>BV
Sodium	8	8	77.4 to 273	273	1470	0/8
Thallium	8	0	[0.15] to [0.19]	ND	0.73	0/8 DL>BV
Uranium, total	8	8	1.31 to 6.48	6.48	6.99	0/8
Vanadium	8	8	5 to 12.9	12.9	19.7	0/8
Zinc	8	8	33.3 to 51.6	51.6	60.2	0/8

a. Values in square brackets indicate nondetected results.

b Value is the ratio of the number of detected values exceeding the background value to the number of analyses.

c. ND = not detected

d. DL = detection limit

e. BV = background value

In summary, the inorganic chemical data review yielded 10 analytes to be carried forward as COPCs (see Table 3.1-5). A complete presentation of the data for the inorganic chemicals identified as COPCs is provided in Appendix D. These analytes are inferred to potentially record releases from one or more sites in the upper Los Alamos Canyon watershed. The concentrations of the chemicals eliminated as COPCs were well within the background concentration range, except for the one boron detection limit greater than the background value for a LA-2 sample, and the chemicals are justifiably excluded from further assessment.

TABLE 3.1-5

RESULTS OF INORGANIC CHEMICAL DATA REVIEW

Analyte	Result	Rationale
Aluminum	Eliminated as a COPC	No values exceeded the background value.
Antimony	Retained as a COPC	Detection limits in reaches LA-1, LA-2, and LA-3 exceeded the background value.
Arsenic	Eliminated as a COPC	Statistical and graphical methods as presented in Appendix E.
Barium	Eliminated as a COPC	Statistical and graphical methods as presented in Appendix E.
Beryllium	Eliminated as a COPC	Statistical and graphical methods as presented in Appendix E.
Boron	Eliminated as a COPC	Statistical and graphical methods as presented in Appendix E.
Cadmium	Retained as a COPC	Detected values above the background value in reach LA-2 and detection limits above the background value in reaches LA-1 and LA-2.
Calcium	Eliminated as a COPC	Statistical and graphical methods as presented in Appendix E.
Chromium, total	Retained as a COPC	Detected values above the background value in reaches LA-1, LA-2, and LA-3.
Cobalt	Eliminated as a COPC	No values exceeded the background value.
Copper	Retained as a COPC	Detected values above the background value in reaches LA-1, LA-2, and LA-3.
Cyanide, total	Eliminated as a COPC	No values exceeded the background value.
Iron	Eliminated as a COPC	No values exceeded the background value.
Lead	Retained as a COPC	Detected values above the background value in reaches LA-1, LA-2, and LA-3.
Magnesium	Eliminated as a COPC	No values exceeded the background value.
Manganese	Eliminated as a COPC	No values exceeded the background value.
Mercury	Retained as a COPC	Detected values above the background value in reaches LA-1, LA-2, and LA-3 and detection limits above the background value in reach LA-2.
Nickel	Eliminated as a COPC	No values exceeded the background value.
Potassium	Eliminated as a COPC	No values exceeded the background value.
Selenium	Retained as a COPC	Detected values above the background value in reaches LA-1 and LA-2 and detection limits above the background value in reaches LA-1 and LA-2.
Silver	Retained as a COPC	Detected values above the background value in reaches LA-1 and LA-2, and detection limits above the background value in reaches LA-2 and LA-3.
Sodium	Eliminated as a COPC	No values exceeded the background value.
Thallium	Eliminated as a COPC	No values exceeded the background value.
Titanium	Eliminated as a COPC	No values exceeded the background value.
Uranium	Retained as a COPC	Detected values above the background value in reach LA-2 and statistical results presented in Appendix E.
Uranium, total	Retained as a COPC	Detected value above the background value in reach LA-2 and statistical results presented in Appendix E.
Vanadium	Eliminated as a COPC	Statistical and graphical methods as presented in Appendix E.
Zinc	Retained as a COPC	Detected values above the background value in reach LA-2.

3.1.2 Radionuclide Comparison with Background/Fallout Radionuclide Concentrations

A total of 212 samples were analyzed for radionuclides in the three upper Los Alamos Canyon reaches, and the analytical suites for these samples are presented in Table 3.1-1. These analyses were compared with the sediment background values that are presented in "Inorganic and Radionuclide Background Data for Soils, Canyon Sediments, and Bandelier Tuff at Los Alamos National Laboratory" (Ryti et al. 1998, 58093). The analytical methods used for the upper Los Alamos Canyon radionuclide analyses are comparable to those used for the Laboratory background data.

The detected radionuclides include isotopes associated with worldwide fallout. For these radionuclides (tritium; strontium-90; cesium-137; plutonium-238; plutonium-239,240; and americium-241) only sample results collected from the 0 to 15-cm (0 to 6-in.) depth interval are typically compared with regional levels for worldwide fallout in soil samples. However, post-1942 sediment deposits containing fallout-derived radionuclides can be much thicker than 15 cm, and all sediment sample results in this investigation, regardless of collection depth, are compared with the sediment background value.

As described in Appendix C, detection status was determined by either quantitation limits agreed upon in contracts with the analytical laboratories, minimum detectable activities determined by the analytical laboratories, or the 3-sigma total propagated uncertainty (TPU). Detection status was used as the preliminary data evaluation step for isotopic uranium by alpha spectroscopy, isotopic thorium by alpha spectroscopy, americium-241 by alpha spectroscopy, and strontium-90 by beta scintillation. Gamma spectroscopy measures concentrations of 43 radionuclides with varying certainty and applicability to Laboratory releases. Additional evaluation of the detected radionuclides is required to determine which gamma spectroscopy results should be carried forward for background comparisons.

The initial list of detected radionuclides from gamma spectroscopy include actinium-228, americium-241, bismuth-211, bismuth-212, bismuth-214, cesium-134, cesium-137, cobalt-57, cobalt-60, europium-152, lead-212, lead-214, mercury-203, potassium-40, protactinium-231, protactinium-233, protactinium-234M, radium-224, radium-226, thallium-208, uranium-235, and zinc-65 (see Appendix D for a summary of the number of samples and range of detected and nondetected concentrations for all radionuclides). These detected gamma-spectroscopy radionuclides are divided into five categories.

- The first category includes those radionuclides that are daughters of naturally-occurring thorium and uranium isotopes (actinium-228 [half-life = 6.2 hours], bismuth-211 [half-life = 2.1 minutes], bismuth-212 [half-life = 7 minutes], bismuth-214 [half-life = 20 minutes], lead-212 [half-life = 11 hours], lead-214 [half-life = 27 minutes], protactinium-231 [half-life = 33,000 years], protactinium-234M [half-life = 6.7 hours], radium-224 [half-life = 3.7 days], radium-226 [half-life = 1,600 years], and thallium-208 [half-life = 3.1 minutes]). These thorium and uranium daughters are typically short-lived radiological decay products, and their abundance can be predicted from the general condition known as secular equilibrium (Ryti et al. 1998, 58093). Most of the radiological dose conversion factors used in risk assessments for the parent radionuclides account for the expected activity of the daughter radionuclides. Thus, these detected thorium and uranium daughters are of no further interest for this report.

- The second category consists of potassium-40 (half-life = 1,300,000,000 years), which is a naturally-occurring isotope that is abundant in the Earth's crust and is not known to be associated with Laboratory releases. Thus, potassium-40 will not receive any further evaluation in this report.

- The third category consists of cobalt-57 (half-life = 270 days), protactinium-233 (half-life = 27 days), and zinc-65 (half-life = 240 days), which are nuclear reactor activation or fission products with half-lives of less than 1 year. Because of the short half-life and low detected concentrations of these radionuclides (see Appendix D for concentration range), these radionuclides are excluded from further evaluation.

- The fourth category consists of mercury-203 (half-life = 47 days), which is used as an analytical laboratory control standard and does not warrant further evaluation in this report.

- The last category consists of plutonium chemistry or nuclear reactor activation or fission products with a half-life of greater than 1 year, which includes americium-241 (half-life = 430 years), cesium-134 (half-life = 2.1 years), cesium-137 (half-life = 30 years), cobalt-60 (half-life = 5.3 years), europium-152 (half-life = 14 years), and uranium-235 (half-life = 700,000,000 years). Because of possible contaminant sources for these radionuclides in the upper Los Alamos Canyon watershed, all will be carried forward to the background comparison. Americium-241 and uranium-235 were also measured by alpha spectroscopy; because alpha spectroscopy is more accurate for these radionuclides, it will be used in preference to gamma spectroscopy in cases where data from both methods are available for a sample.

In summary, americium-241, cesium-134, cesium-137, cobalt-60, europium-152, and uranium-235 are the only gamma-spectroscopy radionuclides carried forward to the background comparison. Sixteen other detected gamma spectroscopy-radionuclides were eliminated for the reasons presented above.

As discussed in Appendix C, most of the QC problems associated with the radionuclide analyses are considered to be minor and do not affect the identification of COPCs. For example, some measures of laboratory measurement bias were suggested to be out of control limits for a small number of samples. Radionuclide interference was suggested as a possible source of positive bias for 14 strontium-90 sample results. Laboratory precision for the radionuclide analyses was within control standards except for the laboratory duplicate analysis for 48 plutonium-239,240 sample results. The overall quality and comparability of the radionuclide data are also evident through the detailed statistical analyses in Appendix E. For example, Appendix E shows the strong correlation of the results for radionuclides in the uranium and thorium decay chains, which is consistent with the hypothesis of secular equilibrium (Ryti et al. 1998, 58093).

Fifteen radionuclides were detected in the sediment samples. Tables 3.1-6, 3.1-7, and 3.1-8 present the concentration range and frequency of results above the background value for these radionuclides for reaches LA-1, LA-2, and LA-3, respectively. A summary presentation of the data for these radionuclides is provided in Appendix D.

Three detected radionuclides, cesium-134, cobalt-60, and europium-152, have no background data. The radionuclide evaluation method is to retain such analytes for further evaluation. Thus, cesium-134, cobalt-60, and europium-152 are retained as COPCs. The other 12 radionuclides were retained as COPCs because these analytes were determined to be greater than background values by using the graphical and statistical approaches provided in Appendix E. These radionuclides included americium-241; cesium-137; plutonium-238; plutonium-239,240; strontium-90; thorium-228; thorium-230; thorium-232; tritium; uranium-234; uranium-235; and uranium-238.

TABLE 3.1-6

FREQUENCY OF DETECTED RADIONUCLIDES IN REACH LA-1

Analyte	Number of Analyses	Number of Detects	Concentration Range (pCi/g)[a]	Maximum Detect (pCi/g)	Background Value/Fallout Value (pCi/g)	Frequency of Detects above Background Value/Fallout Value[b]
Americium-241	11	9	0.0283 to 0.571	0.571	0.04	7/9
Cesium-137	11	8	[-0.0054] to 2.8993	2.8993	0.9	2/8
Plutonium-238	85	25	[-0.011] to 0.083	0.083	0.006	24/25
Plutonium-239,240	85	81	[0.0006] to 19.3	19.3	0.068	77/81
Uranium-234	20	20	0.336 to 2.28	2.28	2.59	0/20
Uranium-235	20	18	[0.018] to 0.146	0.146	0.2	0/18
Uranium-235[c]	11	2	[-0.0273] to 0.2899	0.2899	0.2 or DL[c]	1/2
Uranium-238	20	20	0.304 to 2.31	2.31	2.29	1/20

a. Values in square brackets indicate nondetected results.

b Value is the ratio of the number of detected values exceeding the background value to the number of analyses.

c. By gamma spectroscopy

d. DL = detection limit

TABLE 3.1-7

FREQUENCY OF DETECTED RADIONUCLIDES IN REACH LA-2

Analyte	Number of Analyses	Number of Detects	Concentration Range (pCi/g)[a]	Maximum Detect (pCi/g)	Background Value/Fallout Value (pCi/g)	Frequency of Detects above Background Value/Fallout Value[b]
Americium-241	12	10	[0.034] to 3.954	3.954	0.04	9/10
Americium-241[c]	59	37	[-0.223] to 28	28	0.04 or DL[d]	37/37
Cesium-134	28	1	[0] to 0.18	0.18	0.2 or DL	1/1
Cesium-137	59	57	[0.12] to 230	230	0.9	49/57
Cobalt-60	59	1	[-0.041] to [0.16]	0.116	DL	1/1
Europium-152	59	1	[-0.084] to [0.59]	0.474	0.2 or DL	1/1
Tritium	12	10	0.007 to [0.454]	0.143	0.093	4/10
Plutonium-238	55	30	[-0.008] to 2.01	2.01	0.006	30/30
Plutonium-239,240	55	53	[0.017] to 10.62	10.62	0.068	52/53
Thorium-228	10	10	1.01 to 2.104	2.104	2.28	0/10
Thorium-230	10	10	1.1 to 2.442	2.442	2.29	1/10
Thorium-232	10	10	1.04 to 2.11	2.11	2.33	0/10
Uranium-234	14	14	0.87 to 2.8	2.8	2.59	2/14
Uranium-235	14	14	0.052 to 0.186	0.186	0.2	0/14
Uranium-238	14	14	0.776 to 2.52	2.52	2.29	4/14
Strontium-90	51	37	[-0.06] to 39.56	39.56	1.04	34/37

a. Values in square brackets indicate nondetected results.

b Value is the ratio of the number of detected values exceeding the background value to the number of analyses.

c. By gamma spectroscopy

d. DL = detection limit

TABLE 3.1-8

FREQUENCY OF DETECTED RADIONUCLIDES IN REACH LA-3

Analyte	Number of Analyses	Number of Detects	Concentration Range (pCi/g)[a]	Maximum Detect (pCi/g)	Background Value/Fallout Value (pCi/g)	Frequency of Detects above Background Value/Fallout Value[b]
Americium-241	8	8	0.125 to 2.59	2.59	0.04	8/8
Americium-241[c]	46	26	[-0.23] to 11.8	11.8	0.04 or DL[d]	26/26
Cesium-137	46	44	[0.051] to 13.8	13.8	0.9	37/44
Cobalt-60	46	4	[-0.047] to 0.206	0.206	DL	4/4
Europium-152	46	2	[-0.145] to [0.525]	0.492	0.2 or DL	2/2
Plutonium-238	21	16	[-0.003] to 0.769	0.769	0.006	16/16
Plutonium-239,240	21	21	0.067 to 3.18	3.18	0.068	20/21
Thorium-228	8	8	0.728 to 2.9	2.9	2.28	1/8
Thorium-230	8	8	0.574 to 2.61	2.61	2.29	1/8
Thorium-232	8	8	0.703 to 2.64	2.64	2.33	1/8
Uranium-234	8	8	0.386 to 1.94	1.94	2.59	0/8
Uranium-235	8	6	[0.025] to 0.143	0.143	0.2	0/6
Uranium-235[c]	8	1	[0.026] to 0.211	0.211	0.2 or DL	1/1
Uranium-238	8	8	0.37 to 1.83	1.83	2.29	0/8
Strontium-90	19	8	[-0.24] to 7.03	7.03	1.04	7/8

a. Values in square brackets indicate nondetected results.

b Value is the ratio of the number of detected values exceeding the background value to the number of analyses.

c. By gamma spectroscopy

d. DL = detection limit

In summary, the radionuclide data review yielded 15 analytes to be carried forward as COPCs (see Table 3.1-9) based on comparison of sample results with background values and the statistical and graphical data evaluations presented in Appendix E. A complete presentation of sample results for radionuclide COPCs is provided in Section 3.3 and Appendix D-3.0.

3.1.3 Evaluation of Organic Chemicals

Thirty-six sediment samples were analyzed for PCBs and pesticides, and eleven additional sediment samples were analyzed for PCBs but not pesticides. Twenty sediment samples were analyzed for SVOCs. Twenty-three organic chemicals were detected in these samples.

As presented in Appendix C, serious QC deficiencies were associated with RN 3312R, which was eight samples submitted for PCB/pesticide and SVOC analyses. These sample results were rejected and will not be used in this report. These data represented the complete organic data set for reach LA-3. Other QC problems were not as serious and were associated with a select number of analytes and samples. One SVOC that is commonly found as a laboratory contaminant (bis[2-ethylhexyl]phthalate) was classified as a nondetect in nine samples because of contamination of that chemical in the blank. Indicators of possible low bias were noted by low surrogate recoveries for two SVOC samples. A possible indicator of high bias was noted for one Aroclor-1260 sample result. In summary, only minor QC problems were noted that should not impact the identification of detected organic chemicals.

TABLE 3.1-9

RESULTS OF RADIONUCLIDE DATA REVIEW

Analyte	Result	Rationale
Americium-241	Retained as a COPC	Detected sample results were greater than the background value in reaches LA-1, LA-2, and LA-3.
Cesium-134	Retained as a COPC	Detected in reach LA-2, and it has no background value.
Cesium-137	Retained as a COPC	Detected sample results were greater than the background value in reaches LA-1, LA-2, and LA-3.
Cobalt-60	Retained as a COPC	Detected in reaches LA-2 and LA-3, and there were documented cobalt-60 releases from TA-53.
Europium-152	Retained as a COPC	Detected in reaches LA-1, LA-2, and LA-3, and it has no background value.
Plutonium-238	Retained as a COPC	Detected sample results were greater than the background value in reaches LA-1, LA-2, and LA-3.
Plutonium-239,240	Retained as a COPC	Detected sample results were greater than the background value in reaches LA-1, LA-2, and LA-3.
Thorium-228	Retained as a COPC	Detected sample results were greater than the background value in reach LA-3, and statistical testing presented in Appendix E showed LA-3 results were greater than the background value.
Thorium-230	Retained as a COPC	Detected sample results were greater than the background value in reaches LA-2 and LA-3, and statistical testing presented in Appendix E showed LA-3 results were greater than the background value.
Thorium-232	Retained as a COPC	Detected sample results were greater than the background value in reaches LA-3, and statistical testing presented in Appendix E showed LA-3 results were greater than the background value.
Uranium-234	Retained as a COPC	Detected sample results were greater than the background value in reaches LA-2, and statistical testing presented in Appendix E showed LA-2 results were greater than the background value.
Uranium-235	Retained as a COPC	Statistical testing presented in Appendix E showed LA-2 results were greater than the background value.
Uranium-238	Retained as a COPC	Detected sample results were greater than the background value in reach LA-2, and statistical testing presented in Appendix E showed LA-2 results were greater than the background value.
Strontium-90	Retained as a COPC	Detected sample results were greater than the background value in reaches LA-1, LA-2, and LA-3.
Tritium	Retained as a COPC	Detected sample results were greater than the background value in reaches LA-2 and LA-3.

As noted in Appendix C, many of the reported detected SVOCs are less than the estimated quantitation limit (EQL). The greater sensitivity of the analytical method (lower detection limit) for some samples reflects differences in potential interferences from the matrix or absence of other organic chemicals. All organic chemicals that were detected in at least one sample are retained for further assessment, regardless of whether such reported detections are less than the EQL.

Tables 3.1-10 and 3.1-11 present the concentration range and frequency of detects for these analytes in reaches LA-1 and LA-2, respectively. A complete presentation of the data for these detected organic chemicals is in Appendix D.

TABLE 3.1-10

FREQUENCY OF DETECTED ORGANIC CHEMICALS IN REACH LA-1

Analyte	Number of Analyses	Number of Detects	EQL (mg/kg)	Range of Concentrations (mg/kg)*	Maximum Detect (mg/kg)	Frequency of Detects
Aroclor-1254	25	7	0.033	[0.037] to 1.5	1.5	7/25
Aroclor-1260	25	13	0.033	[0.037] to 1	1	13/25
α-Chlordane	16	1	0.00165	[0.0018] to 0.0072	0.0072	1/16
γ-Chlordane	16	1	0.00165	[0.0018] to 0.0068	0.0068	1/16
4,4'-DDE	16	4	0.0033	[0.0036] to 0.0085	0.0085	4/16
4,4'-DDT	16	10	0.0033	[0.0036] to 0.048	0.048	10/16

*Values in square brackets indicate nondetected results.

TABLE 3.1-11

FREQUENCY OF DETECTED ORGANIC CHEMICALS IN REACH LA-2

Analyte	Number of Analyses	Number of Detects	EQL (mg/kg)	Range of Concentrations (mg/kg)*	Maximum Detect (mg/kg)	Frequency of Detects
Aroclor-1260	13	13	0.033	0.016 to 0.59	0.59	13/13
4,4'-DDE	11	1	0.0033	[0.003] to 0.033	0.033	1/11
4,4'-DDT	11	2	0.0033	[0.003] to 0.02	0.02	2/11
Acenaphthene	11	3	0.33	0.067 to [0.355]	0.26	3/11
Anthracene	11	9	0.33	0.026 to [0.324]	0.096	9/11
Benz(a)anthracene	11	9	0.33	0.026 to 0.368	0.368	9/11
Benzo(a)pyrene	11	9	0.33	0.059 to 0.655	0.655	9/11
Benzo(b)fluoranthene	11	9	0.33	0.065 to 0.66	0.66	9/11
Benzo(g,h,i)perylene	11	5	0.33	0.146 to [0.47]	0.298	5/11
Benzo(k)fluoranthene	11	2	0.33	0.017 to [0.355]	0.019	2/11
Chrysene	11	9	0.33	0.073 to 0.41	0.41	9/11
Dibenz(a,h)anthracene	11	1	0.33	0.029 to [0.38]	0.029	1/11
Dibenzofuran	9	1	0.33	0.036 to [0.355]	0.036	1/9
Di-n-butylphthalate	9	6	0.33	0.037 to [0.329]	0.055	6/9
Fluoranthene	11	10	0.33	0.053 to 0.725	0.725	10/11
Fluorene	11	3	0.33	0.01 to [0.355]	0.066	3/11
Indeno(1,2,3-cd)pyrene	11	7	0.33	0.13 to 0.341	0.341	7/11
Naphthalene	11	3	0.33	0.083 to [0.355]	0.2	3/11
Phenanthrene	11	10	0.33	0.036 to 0.432	0.432	10/11
Pyrene	11	10	0.33	0.05 to 0.589	0.589	10/11

*Values in square brackets indicate nondetected results.

In summary, 23 organic chemicals were retained as COPCs because they were positively detected in at least one sample, as presented in Table 3.1-12.

TABLE 3.1-12

RESULTS OF ORGANIC CHEMICAL DATA REVIEW

Analyte	Result	Rationale
Aroclor-1254	Retained as a COPC	Detected in reach LA-1.
Aroclor-1260	Retained as a COPC	Detected in reaches LA-1 and LA-2.
α-Chlordane	Retained as a COPC	Detected in reach LA-1.
γ-Chlordane	Retained as a COPC	Detected in reach LA-1.
4,4'-DDE	Retained as a COPC	Detected in reaches LA-1 and LA-2.
4,4'-DDT	Retained as a COPC	Detected in reaches LA-1 and LA-2.
Acenaphthene	Retained as a COPC	Detected in reach LA-2, and no data are available for other reaches.
Anthracene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Benz(a)anthracene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Benzo(a)pyrene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Benzo(b)fluoranthene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Benzo(g,h,i)perylene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Benzo(k)fluoranthene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Chrysene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Dibenz(a,h)anthracene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Dibenzofuran	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Di-n-butylphthalate	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Fluoranthene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Fluorene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Indeno(1,2,3-cd)pyrene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Naphthalene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Phenanthrene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.
Pyrene	Retained as a COPC	Detected in reach LA-2, and no data are available for the other reaches.

3.2 Nature and Sources of Contamination

Contamination in upper Los Alamos Canyon sediments was investigated using a combination of full-suite, limited-suite, and key contaminant analyses; statistical analyses of the analytical data; and detailed geomorphic mapping and physical characterization of post-1942 sediments. The nature, characteristics, and probable sources of contaminants are discussed for COPCs identified in Section 3.1, including evidence for the possible collocation of contaminants. These COPCs include 15 radionuclides, 10 inorganic chemicals, and 23 organic chemicals. Identifying the sources of contaminants is an important part of the conceptual model that describes their distribution, and evidence pertaining to the sources of each COPC is discussed in this section. Available data indicate that the primary sources for most of these COPCs are discharges from the 21-011(k) outfall at Technical Area (TA) -21 into DP Canyon and one or more outfalls from former TA-1. Other TA-21 sources, including the former laundry, contributed americium-241; plutonium-239,240; and other radionuclides to Los Alamos Canyon upstream from DP Canyon. Plutonium-239,240 derived from TA-1 is viewed as the key contaminant for Los Alamos Canyon upstream from DP Canyon. Americium-241, cesium-137, and strontium-90 are viewed as key radionuclides for upper Los Alamos Canyon downstream from DP Canyon. Additional details on all

COPCs are presented in Appendix E, and detailed discussions of americium-241; cesium-137; plutonium-239,240; and strontium-90 are presented in Section 3.3.

Several graphical methods are used in this section to visually present variations in the COPCs within reaches and between reaches. For all COPCs, summary figures are presented that show the normalized maximum value of COPCs relative to background values (or, in the case of organic chemicals, the EQL); values below 1.0 on these figures indicate results below the background values. To highlight the pattern of COPCs between reaches, the chemicals are ordered within each group (organic chemicals, inorganic chemicals, and radionuclides) from highest to lowest for reach LA-2. Thus, the normalized values for LA-2 follow a decreasing trend by chemical. Where values for other reaches also follow a decreasing trend, a positive correlation in maximum values between reaches is suggested. Note that the "maximum" results for some COPCs are actually for samples with concentrations reported as below detection limits, but they are considered here to provide conservative estimates of potential levels of contamination. Other summary figures show only values reported as above detection limits because these results may more accurately portray the actual levels of contamination.

Other graphical methods used to present data on COPCs in the upper Los Alamos Canyon sediment samples include plots of analyte concentration versus distance downstream from the Los Alamos Canyon bridge for representative COPCs. For some inorganic and organic COPCs, these plots distinguish results reported as above and below detection limits to allow better interpretation of the data and uncertainties associated with high detection limits for some analytes. Finally, a scatter plot matrix is shown for the radionuclide COPCs, which indicates strong correlations between concentrations of some radionuclides, in turn indicating collocation of these COPCs within the sediments.

3.2.1 Inorganic COPCs

Ten inorganic chemicals were identified as COPCs in Section 3.1: antimony, cadmium, total chromium, copper, lead, mercury, selenium, silver, total uranium (and leachable uranium), and zinc. Because leachable uranium sample results were obtained only from reach LA-2, discussion of the nature and sources of contamination in this section will address only total uranium sample results (note that isotopic uranium results are discussed in Section 3.2.2). The nature, distribution, and possible sources for each inorganic COPC were evaluated using statistical analyses, which are presented in more detail in Appendix E, in combination with examination of the specific geographic and geomorphic setting of the samples in which these analytes were detected above background values.

Figure 3.2-1 shows maximum results for the inorganic COPCs normalized by background values. Figure 3.2-1a is based on the maximum value (whether it is a detected sample result or a detection limit) for an analyte. Figure 3.2-1b uses only the maximum detected sample results. Three inorganic COPCs (antimony, cadmium, and selenium) were not detected with sufficient frequency to draw conclusions about potential contaminant sources, if any, in the upper Los Alamos Canyon watershed. Antimony was not detected in any sample, and some (or all) detection limits were greater than the background value in all reaches. All nondetect sample results for LA-2 East and LA-3 were greater than the background value, preventing any conclusions concerning the presence or absence of antimony as a contaminant downstream from DP Canyon. However, some samples collected from each of the LA-1 subreaches and from LA-2 West were reported as nondetects with detection limits less than the background value, suggesting that antimony is not an important contaminant in sediments upstream from DP Canyon. Both cadmium and selenium have detected results above the background value, but these include only one sample for cadmium and three samples for selenium. Most nondetect sample results for cadmium and selenium are with a factor of two to four times the background value, providing an upper limit for any possible cadmium or selenium contamination in upper Los Alamos Canyon sediments.

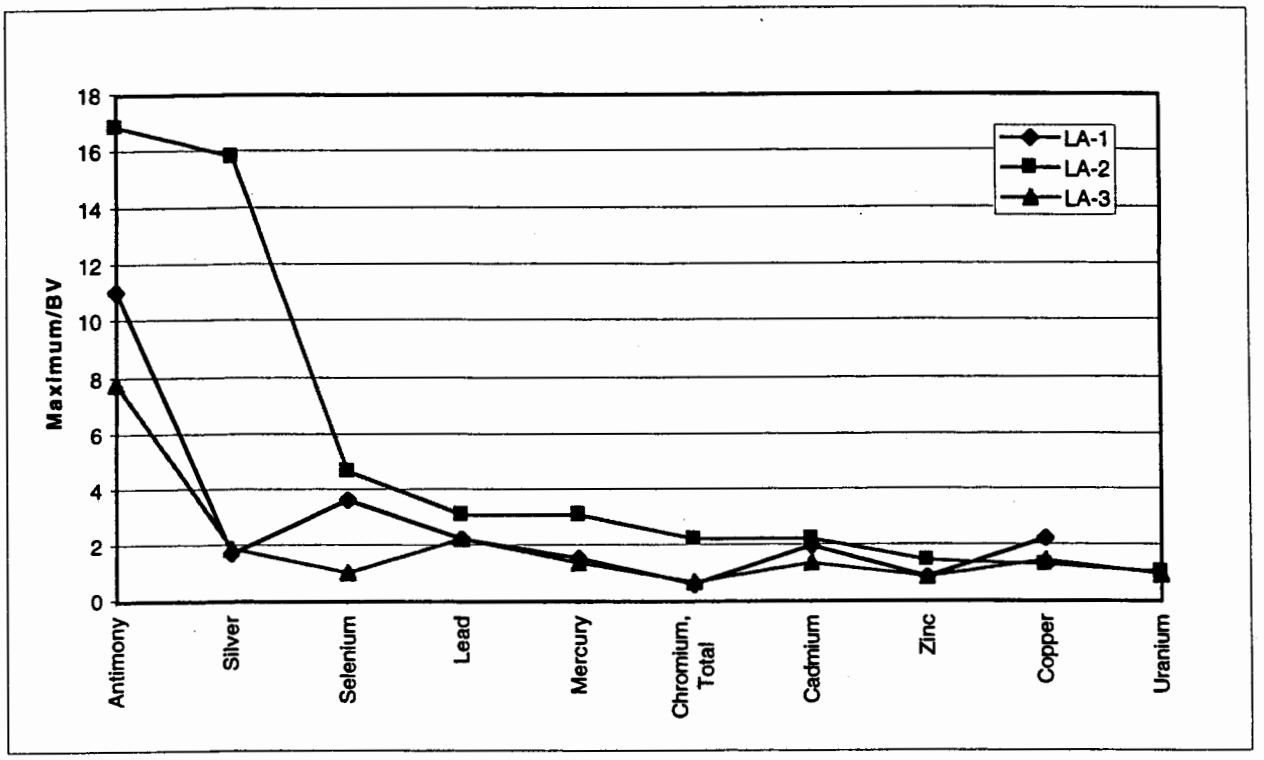


Figure 3.2-1a. Maximum inorganic chemical results, using either detected or nondetected values, normalized by background values.

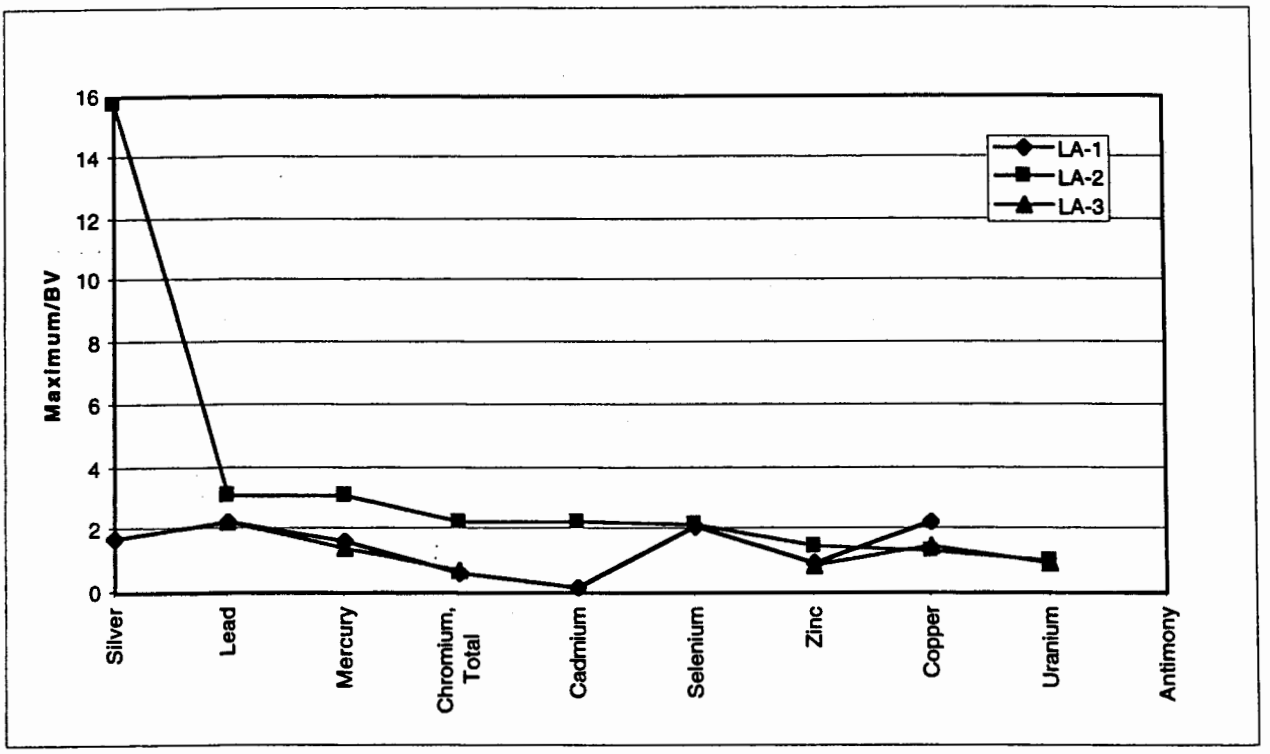


Figure 3.2-1b. Maximum detected inorganic chemical results normalized by background values.

All of the more frequently detected inorganic COPCs, with the exception of copper, have the highest value in reach LA-2. The maximum copper result was from a fine-grained sediment layer in the f1 unit in reach LA-1 East. This layer yielded the highest plutonium-239,240 result in upper Los Alamos Canyon (sample 04LA-97-0275) and was resampled for limited-suite analyses (sample 04LA-97-0572). The sample location is downstream from Potential Release Site (PRS) 21-018(a) (in Material Disposal Area [MDA] V) where both copper and plutonium-239,240 have been reported above screening action levels (SALs) (LANL 1996, 54969), suggesting that this PRS may be a source for the copper found in upper Los Alamos Canyon sediments (note that sampling in 1946 documented that this PRS was a source for plutonium reaching the Los Alamos Canyon stream channel at that time [Kingsley 1947, 4186]).

The maximum upper Los Alamos Canyon sample result for four inorganic COPCs (chromium, lead, total uranium, and zinc) was from sample 04LA-96-0149 collected from a fine-grained sediment layer in the c3 unit in reach LA-2 East downstream from DP Canyon. This sample also had the highest cesium-137 and strontium-90 results for upper Los Alamos Canyon, and sediment at this site was apparently derived largely from DP Canyon and deposited between 1956 and 1968 (Sections 2.3.2 and 3.3.3). The maximum mercury and silver results were from sample 04LA-97-0570, which was collected from a fine-grained sediment layer in the c2 unit in reach LA-2 West upstream from DP Canyon. This sample also had the highest plutonium-239,240 result in LA-2.

Available evidence indicates multiple contaminant sources for some of the metals, including sources upstream of the former TA-1 PRSs. For example, both copper and lead were measured above the background value in sample 04LA-97-0568, which is from a fine-grained sediment layer in LA-1 Far West upstream of all PRSs in former TA-1.

The detected inorganic COPCs exhibit positive and statistically significant correlations in concentration with both cesium-137 and plutonium-239,240. The statistical correlations are not notably different for the two main indicator radionuclides, but review of the scatter plots presented in Appendix E suggests a possible division of inorganic COPCs by the strength of correlation with cesium-137 (associated with releases from TA-21 into DP Canyon) and plutonium-239,240 (associated primarily with releases from TA-1 or TA-21 directly into Los Alamos Canyon). Total chromium and total uranium appear to have a stronger correlation to cesium-137, which suggests a source at the 21-011(k) outfall and also suggests that relatively high concentrations of these metals may occur in DP Canyon sediments. Copper, lead, mercury, silver, and zinc have a stronger relationship to plutonium-239,240, which may suggest that the main anthropogenic source of these metals is discharges from either TA-1 or TA-21 directly into Los Alamos Canyon.

The geographic context of the sample data also suggests that there are multiple contaminant sources for most metals, as shown on Figure 3.2-2. For copper, the highest concentrations and the highest percentage of sample results above the background values occur in reach LA-1. For lead, mercury, and zinc the concentrations are greatest in reach LA-2, with similar concentrations observed in LA-2 West and LA-2 East. This suggests that sediment supplied from DP Canyon adds some additional metals contamination, but there are also sources for these metals in the Los Alamos Canyon watershed upstream of DP Canyon.

3.2.2 Radionuclide COPCs

Fifteen radionuclides were identified as COPCs in Section 3.1: americium-241; cesium-134; cesium-137; cobalt-60; europium-152; plutonium-238; plutonium-239,240; strontium-90; thorium-228; thorium-230; thorium-232; tritium; uranium-234; uranium-235; and uranium-238. Most of these radionuclides have been reported above background values by prior investigations at one or more PRSs in the watershed, including the 21-011(k) outfall and other outfalls at TA-21, the TA-1 hillsides, and surface impoundments at TA-53, as summarized in Section 1.3.2.

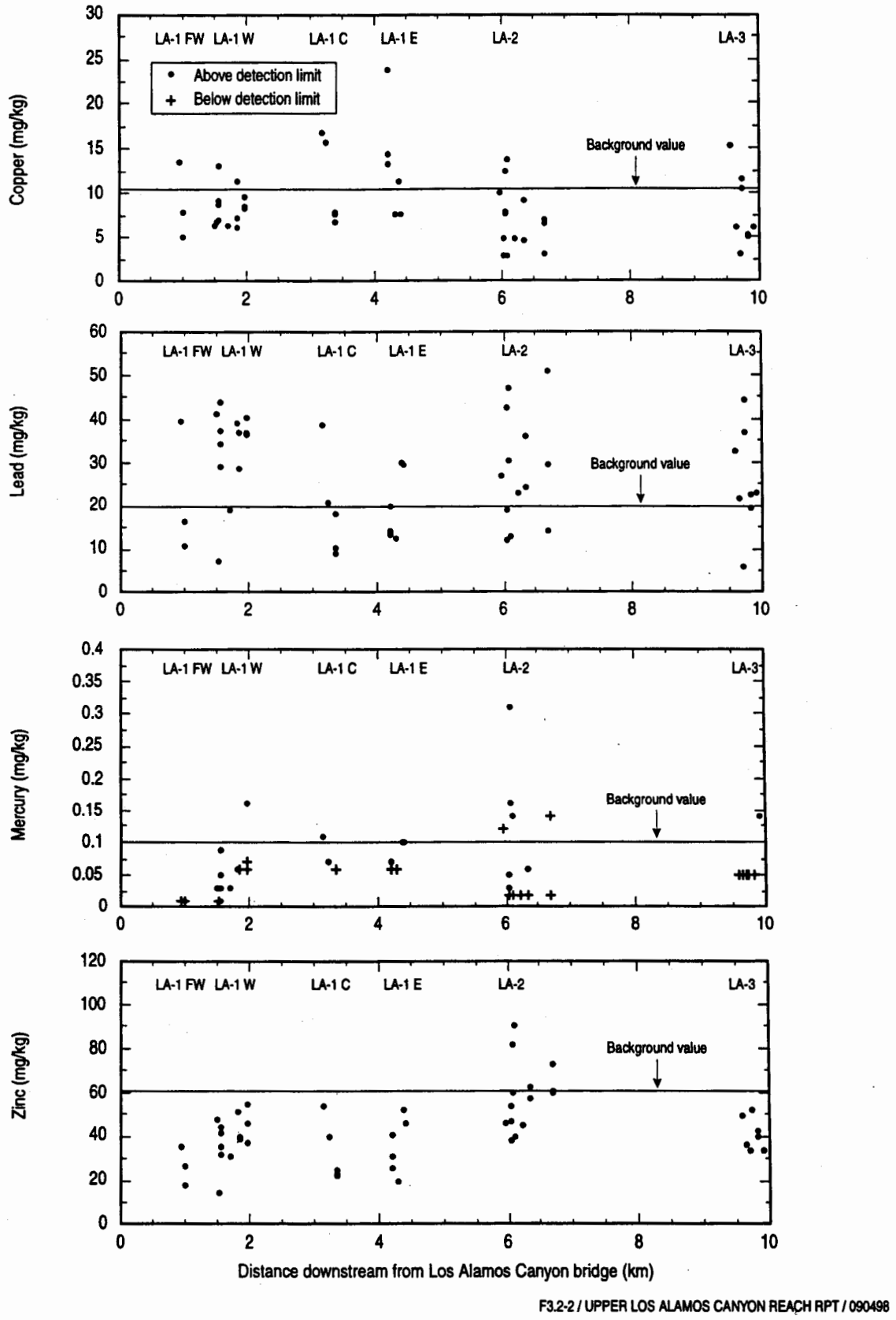


Figure 3.2-2. Plots of the concentration of mercury, lead, copper, and zinc versus distance downstream from the Los Alamos Canyon bridge.

The normalized plot for the radionuclides, Figure 3.2-3, is based on the reported values for each radionuclide (results were not censored by the minimum detectable activity value where both a sample result and the minimum detectable activity were reported). For americium-241, the gamma spectroscopy results were used in this plot instead of the more precise alpha-spectroscopy results to obtain a larger and more representative sample set. The uranium-235 normalized plot is based on the alpha spectroscopy data because they allow more accurate determination of this isotope at or near background values. The normalized plot shows that five radionuclides were detected at activities far above the background value (more than 10 times the background value). These key radionuclides are americium-241; cesium-137; plutonium-238; plutonium-239,240; and strontium-90. The remaining radionuclides were measured at maximum activities less than two times the background value.

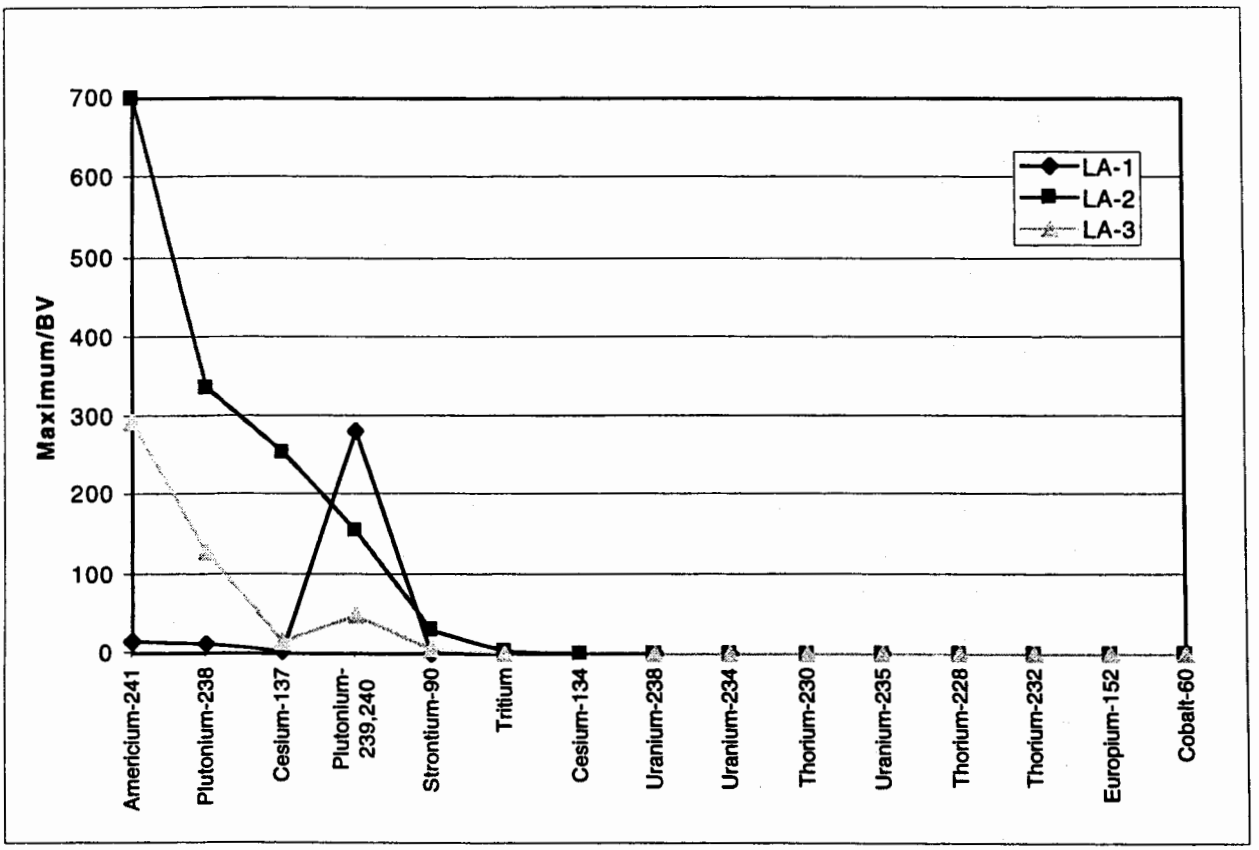
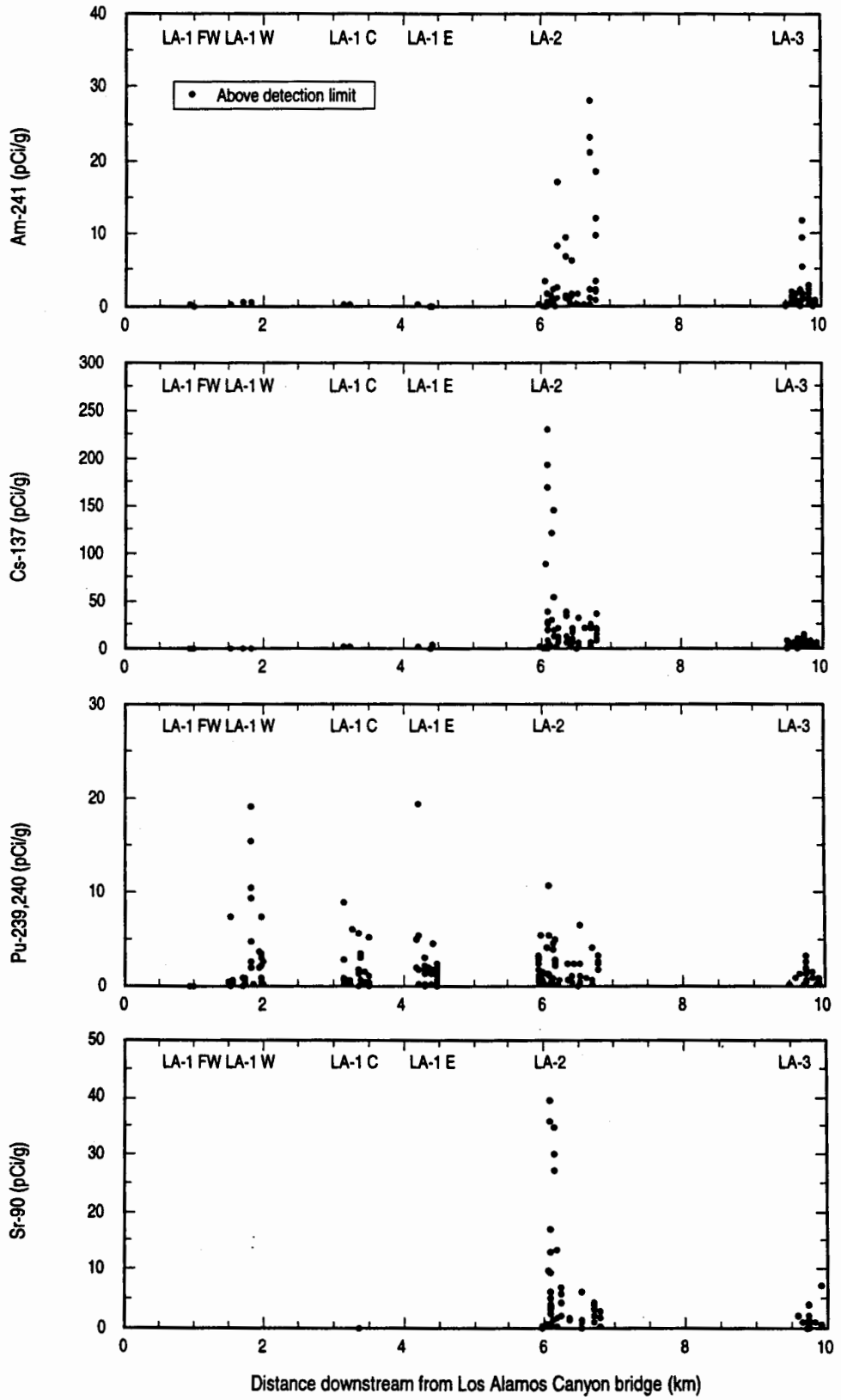


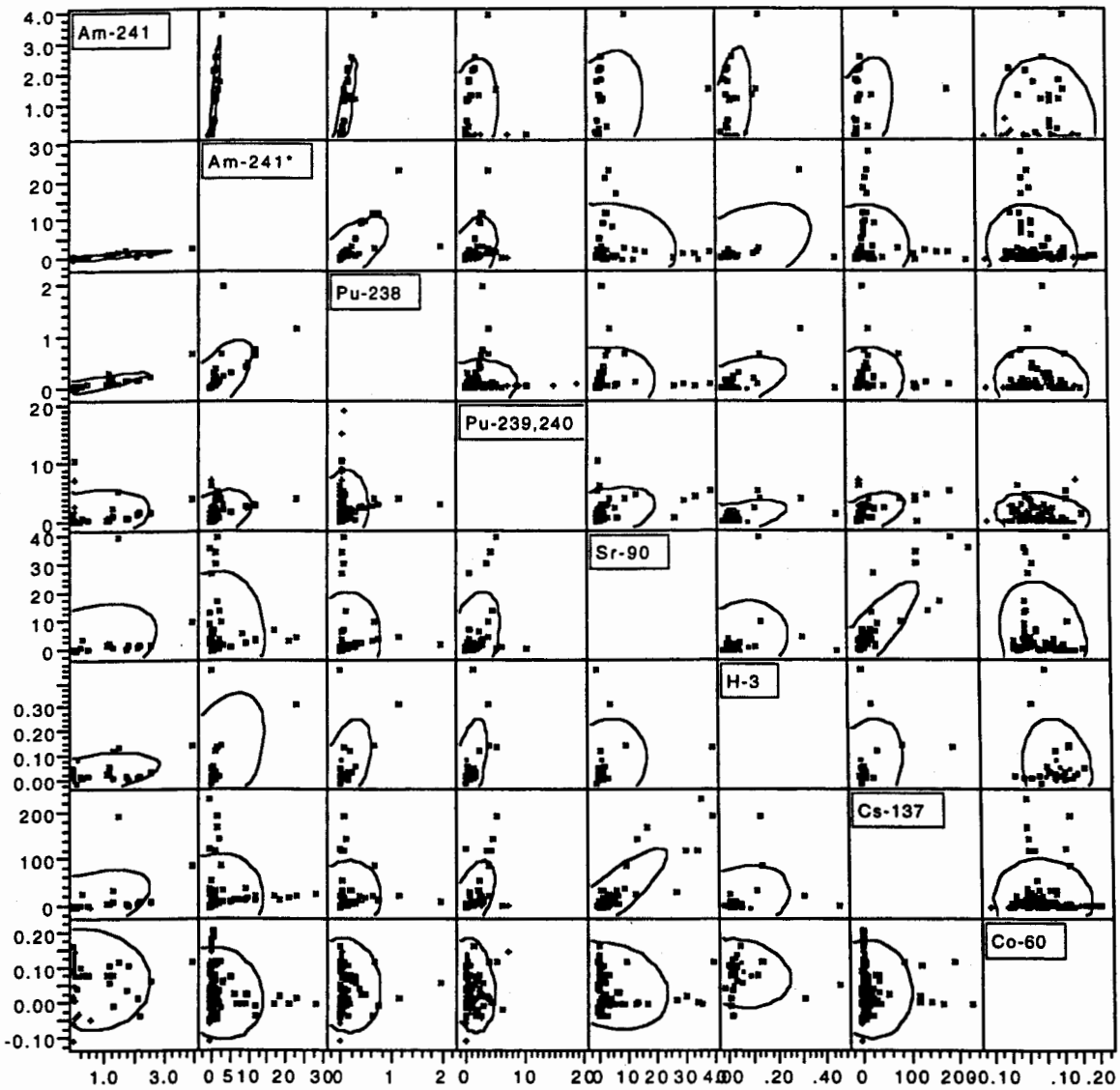
Figure 3.2-3. Plot of the maximum radionuclide results normalized by the background value.

Evidence of the general source areas for the key radionuclides and variations between reaches are seen in plots showing radionuclide concentration as a function of distance along the channel (Figure 3.2-4). Concentrations of americium-241, cesium-137, and strontium-90 clearly increase greatly in reach LA-2 relative to upstream, reflecting their source at the 21-011(k) outfall in the DP Canyon watershed, and decrease downstream in reach LA-3. The occurrence of the highest americium-241 values in slightly different locations than the highest cesium-137 and strontium-90 values is also seen in this plot. A general decrease in plutonium-239,240 concentration between reaches LA-1 West and LA-3 is also well displayed in Figure 3.2-5. The variations in these key radionuclides are discussed further in Section 3.3.



F3.2-4 / UPPER LOS ALAMOS CANYON REACH RPT / 110998

Figure 3.2-4. Plots of americium-241; cesium-137; plutonium-239,240; and strontium-90 activity versus distance downstream from the Los Alamos Canyon bridge.



* = by gamma spectroscopy

Figure 3.2-5a. Scatter plot matrix of selected radionuclide COPCs.

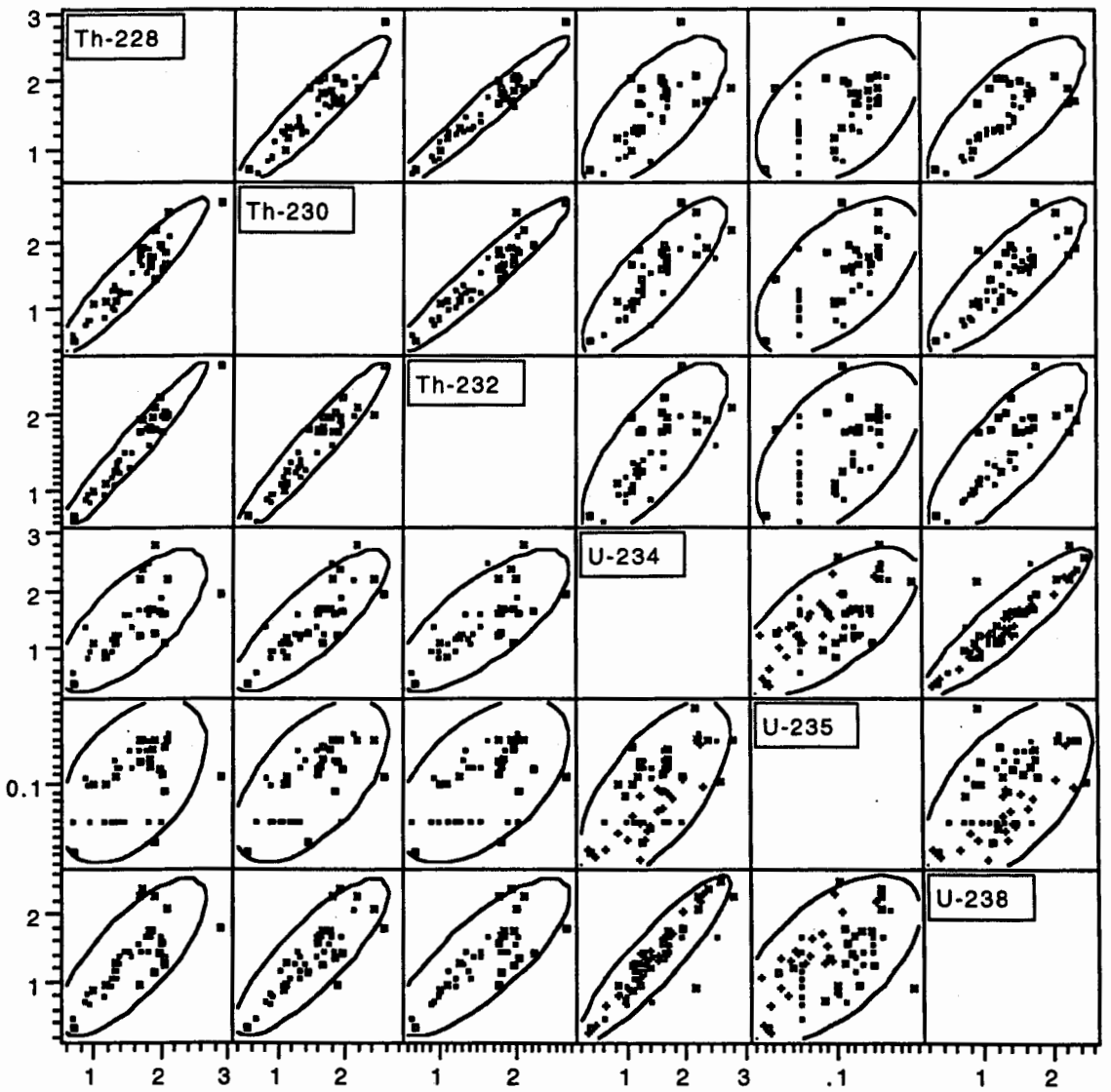


Figure 3.2-5b. Scatter plot matrix of thorium and uranium isotope COPCs.

The possible collocation of key radionuclide COPCs with each other and with tritium and cobalt-60 is graphically evaluated using a scatter plot matrix (Figure 3.2-5a). To facilitate interpretation of the correlation between radionuclides, the scatter plot matrix shows the paired sample results, and the ellipse shown on each scatter plot encloses 95% of the data. Cases where the ellipse approaches a line suggest a highly significant statistical correlation. Appendix E provides additional information on the statistical correlation of radionuclide COPCs.

The strongest correlations among the key radionuclides are between cesium-137 and strontium-90 and between americium-241 and plutonium-238. These correlations apparently relate to variations in the release history from the 21-011(k) outfall, as discussed in Section 3.3. The positive correlations between these pairs of radionuclides also allow concentrations of unsampled radionuclides to be estimated where data on other radionuclides are available (e.g., the strontium-90 concentration in sediment downstream from DP Canyon averages approximately one-fifth the cesium-137 concentration). Plutonium-239,240 is not correlated with any of the other key radionuclides, which is consistent with this radionuclide having primary sources upstream from DP Canyon.

Tritium was detected at low levels above the background value in reach LA-2; it is apparently correlated with cesium-137 and strontium-90 and associated with releases into DP Canyon. The maximum detected tritium result was from sample 04LA-96-0149, collected from a fine-grained sediment layer in the c3 unit of LA-2 East, which is also the sample that had the highest cesium-137 and strontium-90 results. Tritium was also detected at a similar value in the single DP Canyon sample (04LA-96-0140). No tritium results above the background value were noted in reaches LA-2 West or LA-3, which is why tritium analyses were not obtained from reach LA-1. Note that the two highest tritium results shown on Figure 3.2-5a are nondetected results, as discussed in Appendix E, which partially obscures the correlation between tritium and cesium-137.

Cobalt-60 is not correlated with any of the key radionuclides, as shown on Figure 3.2-5a. Cobalt-60 was detected in five samples, with the four highest collected from reach LA-3 and the fifth from reach LA-2 East. The higher frequency of detects and the higher values from LA-3 are consistent with known releases from TA-53 (LANL 1998, 57666). It is possible that higher concentrations of cobalt-60 could occur in locations between LA-2 and LA-3 where the unnamed side canyon draining that part of TA-53 enters Los Alamos Canyon (Figure 1.3-3). It is also possible that detectable quantities of other radionuclides could be found in samples collected upstream of LA-3 derived from TA-53 sources, although their concentrations upstream would likely be low because such radionuclides were not detected in LA-3. One notable analyte is sodium-22, which was also released in large quantities from TA-53 but was not detected in any upper Los Alamos Canyon samples.

The radionuclides present at relatively low levels above the background value include isotopes that may be associated with plutonium chemistry and nuclear reactor fission or activation products. Cesium-134, with a radiological half-life of 2.1 years, was identified as a COPC because of a single detection out of 47 sample results in sample 04LA-96-0147, collected from the c1 unit in reach LA-2 East. The detected cesium-134 result was approximately 40% greater than the maximum nondetect cesium-134 sample result. Because of the approximately two-year half-life of cesium-134, cesium-134 in this sediment layer would have decayed to a nondetectable quantity between the date that the sample was collected (September 24, 1996) and the present (September 1998). Thus, cesium-134 warrants no further discussion of potential sources given its infrequent detection at low activities and its relatively short radiological half-life. Europium-152 was detected in 6 of 116 samples, providing a detection frequency of approximately 5%. The "detected" europium-152 sample results fall within the range of nondetect sample results, and no available data from PRSs or from Laboratory sites suggest releases of europium-152 into the upper Los Alamos Canyon watershed. Because of its infrequent detection at low activities, europium-152 also warrants no further discussion of possible contaminant sources and distribution.

The radionuclides present at relatively low levels above the background value also include naturally-occurring uranium and thorium isotopes. To properly evaluate these radionuclides, they will be discussed in the context of the radiological decay chains in which they occur. The actinium decay chain is represented by uranium-235, which is also the parent radionuclide for this chain. There are known sources of uranium-235 from activities at TA-21 as well as high levels of uranium-235 from uranium metal used at TA-1. The maximum value for uranium-235 is from a fine-grained sediment layer in the c2 unit of LA-2 East (sample 04LA-97-0053), and most of the uranium-235 in upper Los Alamos Canyon seems to be collocated with cesium-137; thus, it is apparently associated with contaminated sediments derived from DP Canyon. However quantities of uranium-235 entering Los Alamos Canyon from DP Canyon are relatively small because the maximum result is below the background value, and uranium-235 was only identified as a COPC because of a statistical distributional shift (Appendix E-2.2). Uranium-235 shows positive correlations with other uranium isotopes (Figure 3.2-5b), which suggests that most of the uranium-235 represents natural uranium isotopic ratios.

Three other radionuclide COPCs detected at low levels are in the uranium decay chain: thorium-230, uranium-234, and uranium-238. Maximum results for all of these isotopes are within 15% of background values. Apparent anomalies are indicated by the geographic locations of the maximum values for these radionuclides. The maximum uranium-234 value is from the single DP Canyon sample (04LA-96-0140), the maximum uranium-238 value is from reach LA-2 West (sample 04LA-97-0570), and the maximum thorium-230 value is from reach LA-3 (sample 04LA-97-0147). This observation is counter to the equal activity expected of these radionuclides from the principle of secular equilibrium, which is expected for releases of natural uranium. However, these anomalies are of little practical importance because the values for isotopes in the uranium decay chain show good positive correlations with each other (Figure 3.2-4a), which confirms secular equilibrium for most sample results. Uranium decay chain isotopes appear to be correlated with cesium-137, which suggests that they may be primarily associated with contaminant sources in the DP Canyon watershed. However, the apparent correlation of isotopic uranium with cesium-137 is biased by the lack of cesium-137 data for the sample with the highest uranium-238 result and the second highest uranium-234 result (sample 04LA-97-0570 in LA-2 West), which is same sample that yielded the highest plutonium-239,240 result in LA-2. This collocation of the maximum values for plutonium-239,240 and uranium-238 in LA-2 suggests partial collocation of these radionuclides, and hence sources for uranium both within the DP Canyon watershed and upstream from DP Canyon.

Two other radionuclide COPCs detected at low levels are in the thorium decay chain: thorium-228 and thorium-232. The maximum values for these isotopes, and the only results above background values, occur in reach LA-3 (sample 04LA-97-0147); results from this sample are only 10 to 30% above background values. There are no known thorium-228 or thorium-232 releases to account for these modestly elevated values in LA-3. One possible explanation is that the small apparent difference between the LA-3 samples and background data (or between results from reaches LA-3 and LA-2) is that the LA-3 isotopic thorium data were from a different laboratory than the background data (which is the same laboratory that produced the reach LA-2 data). Thus, the high LA-3 isotopic thorium results could be related to an analytical bias between laboratories. Thorium decay chain isotopes do not appear to be correlated with either cesium-137 or plutonium-239,240; thus, the elevated activity of the thorium decay chain isotopes has no apparent source at upper Los Alamos Canyon PRSs.

3.2.3 Organic COPCs

Twenty-three organic chemicals were detected at low levels in the upper Los Alamos Canyon sediment samples and therefore identified as COPCs, as discussed in Section 3.1.3. All results for organic chemicals from reach LA-3 were rejected and will not be used in this report. Analyses for six of these organic COPCs, including PCBs and pesticides, were obtained in reaches LA-1 and LA-2, and analyses

for the remaining 17 organic COPCs, in the semivolatile organic compound (SVOC) suite, were obtained only in the full-suite analyses in reach LA-2. The SVOCs are mostly within two chemical groups: either polycyclic aromatic hydrocarbons (PAHs) or plasticizers. Low levels of all specific chemical groups (PCBs, pesticides, PAHs, and plasticizers) are commonly found to be associated with areas receiving runoff from light industrial settings at the Laboratory and urban settings in the Los Alamos townsite, whereas significant releases of such chemicals from the Laboratory should be recognizable by large exceedances of the detection limit in sample results. Therefore, the mainly low levels detected in the upper Los Alamos Canyon sediment samples may represent only small releases and/or dispersed sources.

In the normalized plots for organic chemicals in Figure 3.2-6, the maximum detected sample result is used. Figure 3.2-6a presents the normalized plot for PCBs and pesticides, and Figure 3.2-6b presents the normalized plot for SVOCs. Aroclor-1254, Aroclor-1260, and 4,4'-DDT were measured at greater than 10 times the EQL in reach LA-1, and 4,4'-DDE was detected at 10 times the EQL in reach LA-2. None of the other organic COPCs were detected at greater than 5 times the EQL, and all of the SVOCs were less than 2.5 times the EQL for any sample.

Of the six organic COPCs in the PCB-pesticide suite, all except one, the PCB Aroclor-1254, were detected in both reaches LA-1 and LA-2. Aroclor-1254 was detected only in LA-1, and the highest result was in a sample from a fine-grained sediment layer in reach LA-1 West+ upstream of Hillside 137 (sample 04LA-97-0577). The highest detected concentrations for the remaining PCBs and pesticides, except 4,4'-DDE, were also in LA-1, which suggests that the major source for these chemicals is in the upper part of the Los Alamos Canyon watershed. However, there is considerable variation in the concentrations of the different organic COPCs among the subreaches, as illustrated in Figure 3.2-7. Aroclor-1260 was detected in both reaches LA-1 and LA-2, with the maximum result occurring in a sample from reach LA-1 East. It is notable that Aroclor-1260 was detected in one sample in reach LA-1 Far West (sample 04LA-97-0624), indicating at least a partial source farther upstream. The source of these PCBs is unknown. PCB releases have been reported from at least one PRS in the Los Alamos Canyon watershed upstream from Hillside 137, PRS 61-007 near the Los Alamos County landfill (Section 1.3.2.5), although this is a mesa-top site on the south side of east Jemez Road, and drainage from the PRS may have been directed southward toward Sandia Canyon. It is also possible that undocumented releases of PCBs occurred from other upstream technical areas (i.e., TA-3 and TA-43) or from areas outside the Laboratory in the Los Alamos townsite.

For the 17 organic COPCs that were analyzed only in samples from reach LA-2 (all PAHs or plasticizers in the SVOC category), no inference on spatial trends within the upper Los Alamos Canyon watershed can be made. For these LA-2 samples, the concentrations of the SVOCs are low, less than 2.5 times the EQL; thus, no major contaminant release is indicated by the data. Possible nonpoint sources for PAHs and plasticizers are the numerous roadways and parking areas in commercial and residential areas in the Los Alamos townsite and Laboratory technical areas. Various materials such as charcoal and coal that have been observed within upper Los Alamos Canyon sediments might also contribute to some of the low-level SVOC detects. PCBs and pesticides were detected in all subreaches in LA-1 and LA-2, and available data do not show any consistent geographic variations in these COPCs; instead they suggest multiple sources. Because the sources of the organic COPCs have not been identified, it is not possible to predict where concentrations would be highest. Additional sample collection from reaches LA-1 and LA-3 is needed to adequately evaluate the concentrations of the organic COPCs. SVOC data should be collected from reaches LA-1 and LA-3, and data on PCBs and pesticides should be collected from reach LA-3. In addition, obtaining data on organic chemicals upstream from all PRSs would help evaluate the possible importance of non-Laboratory sources for these chemicals.

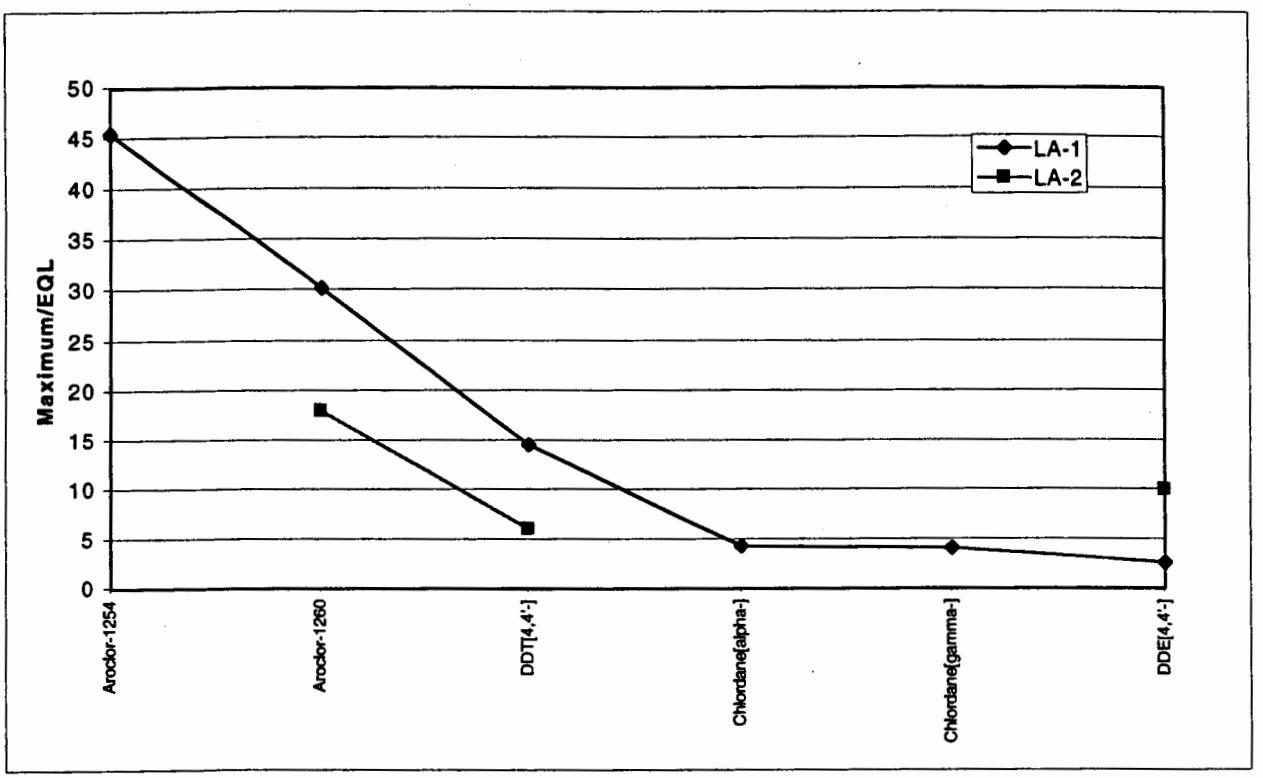


Figure 3.2-6a. Maximum detected PCB and pesticide results normalized by EQLs.

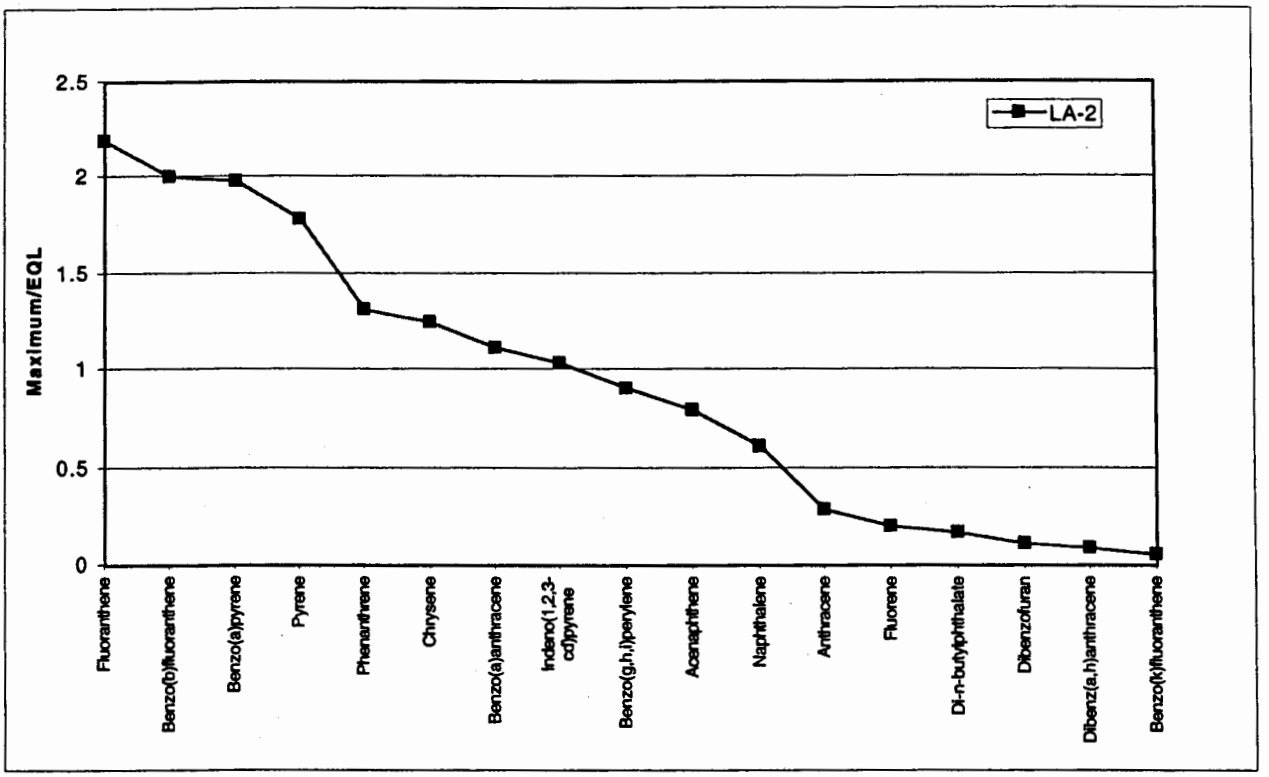
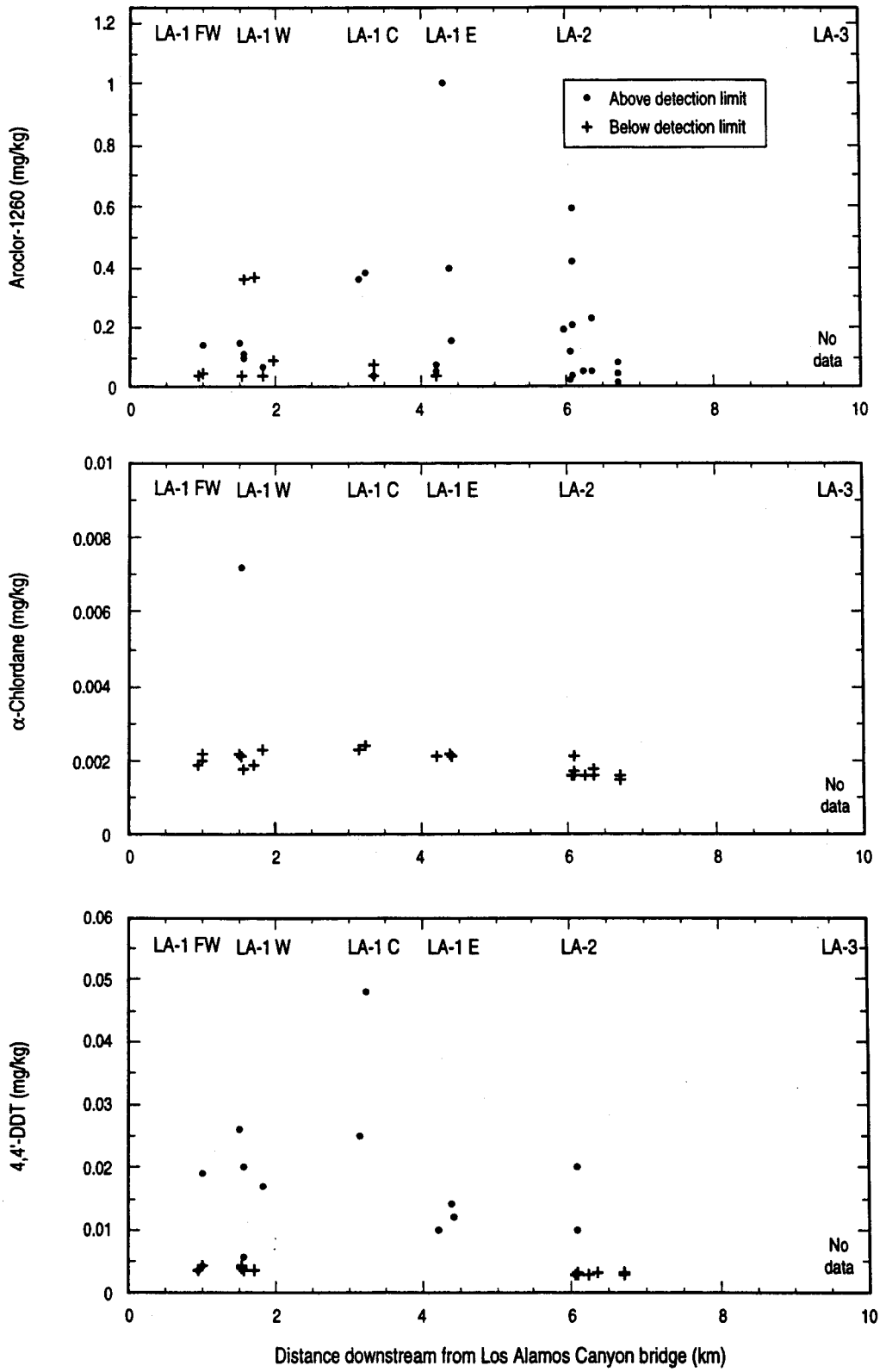


Figure 3.2-6b. Maximum detected SVOC results normalized by EQLs.



F3.2-7 / UPPER LOS ALAMOS CANYON REACH RPT / 111698

Figure 3.2-7. Plots of Aroclor-1260; 4,4'-DDT; and α-chlordane concentrations versus distance downstream from the Los Alamos Canyon bridge.

3.3 Key Contaminant Analyses

The radionuclides cesium-137 and plutonium-239,240 were selected as key contaminants for different reaches in upper Los Alamos Canyon based on the results of the full-suite analyses of this investigation and prior sediment sampling. Preliminary human health screening assessments that used the full-suite analyses in reach LA-2 identified cesium-137 as being the most significant COPC in upper Los Alamos Canyon downstream from DP Canyon; therefore, all samples in reaches LA-2 East and LA-3 were analyzed for cesium-137. Data on an additional COPC, americium-241, were obtained during the gamma spectroscopy analyses for cesium-137 and are available for all samples from reaches LA-2 East and LA-3. Preliminary screening assessments using the full-suite analyses identified strontium-90 as being the second most important contributor to potential human health risk associated with contaminants in sediments, and strontium-90 is also a significant COPC in alluvial groundwater in upper Los Alamos Canyon (LANL 1995, 50290; Longmire et al. 1996, 54168). Therefore, analyses for strontium-90 were obtained from many samples in LA-2 and LA-3 to evaluate its concentration and distribution.

Data from the full-suite analyses in reach LA-2 West did not identify any COPC as being present at high enough concentrations to pose a significant potential for risk upstream from DP Canyon; therefore, selection of a key contaminant in these areas was made based on an examination of results from other investigations. Specifically, analyses of sediment samples collected from both routine environmental surveillance sampling stations upstream from DP Canyon (e.g., Environmental Surveillance and Compliance Programs 1997, 56684) and from ER Project investigations at former Operable Unit (OU) 1098 (TA-2 and TA-41) indicated that plutonium-239,240 was the only analyte consistently above background values. Thus, plutonium-239,240 was selected as a key contaminant for LA-1 and LA-2 West for defining the horizontal and vertical extent of contamination and variations in contaminant concentration between different sediment layers, and plutonium analyses were obtained for all samples from these reaches. Plutonium analyses were also obtained from many samples in LA-2 East and LA-3 because of the possibility that some sediment deposits could postdate initial plutonium releases but predate major releases of cesium-137 from TA-21. In addition, examination of data from reach LA-2 East indicated that the ratio of plutonium-239,240 to plutonium-238 (plutonium 239/238 ratios) provided valuable information on the ages of different sediment deposits, and plutonium analyses were also obtained in LA-2 East and LA-3 to evaluate sediment age.

In this section the data on americium-241; cesium-137; plutonium-238; plutonium-239,240; and strontium-90 for each reach are presented. The discussion is focused on examining variations in the concentrations of these key radionuclides between geomorphic units and sedimentary facies in each reach and the effects of particle size variations and sediment age on contaminant concentrations. In addition, these data are combined with data on the areas, thicknesses, and density of post-1942 sediments in the geomorphic units to calculate approximate inventories of the key radionuclides by unit and by reach. In Section 4 these data are used to refine the conceptual model for contaminant transport and distribution in upper Los Alamos Canyon, and in Section 5 these data and data on the other COPCs are used to prepare preliminary assessments of human health risk and ecological risk.

3.3.1 Geomorphic and Statistical Evaluation of Radionuclide Data

Concentrations of each radionuclide vary by several orders of magnitude within the sediments of upper Los Alamos Canyon, and this variability is affected by the age of the sediment relative to the time of contaminant releases, the physical processes of sediment transport, the mixing of sediment from a variety of sources, and other factors. The geomorphic and statistical evaluation of this complex data set is a critical part of this investigation that is essential for evaluating variations in risk within a reach and

between reaches, constraining the effects of future transport, and developing remediation strategies, if required. Aspects of the geomorphic and statistical evaluation of the radionuclide data that pertain to subsequent discussions of each reach are presented below.

3.3.1.1 Binning of Radionuclide Data

The cesium-137 and plutonium-239,240 data collected in this investigation were examined to determine what grouping of samples in each reach was optimal for the combined purposes of defining geomorphic variations in contaminant concentration and statistically describing the variability in contaminant concentration. These grouped or "binned" data are used in the geomorphic assessments and human health risk assessments in this report; therefore, the specific binning process is an important part of the data evaluation. The variability in contaminant concentrations within these bins were also used in the sample allocation process discussed in Section 2.2.4, and can be used in future uncertainty analyses as proposed in the core document (LANL 1997, 55622; LANL 1998, 57666). The binning process is discussed here to document the specific rationale used in this investigation.

The radionuclide data in each subreach were first examined after being binned by individual geomorphic units and sediment facies, and where appropriate these subsets of data were combined into larger bins to increase sample size and allow better statistical evaluation. In some cases additional subdivisions within a geomorphic unit were defined, particularly where contaminant concentrations were highest (e.g., subdividing a buried stratigraphic interval with higher cesium-137 concentrations from near surface sediments with lower concentrations). Channel facies and overbank facies samples were kept in separate bins in all reaches because maximum and average radionuclide concentrations were always higher in the finer-grained overbank sediments than in related coarser-grained channel sediments. Samples within the same sediment facies in different units were kept in separate bins if the variations in radionuclide concentration provided information on time-dependent trends in a reach (e.g., where c1 sediment in active channels has less cesium-137 than texturally similar c2 sediment in older, abandoned channel units), but these subsets were combined where no such trends were apparent in the data. Plutonium-239,240 data were used to bin the samples in LA-1 and LA-2 West, and cesium-137 data were used to bin the samples in LA-2 East and LA-3.

3.3.1.2 Evaluation of Effects of Sediment Age and Particle Size

Possible temporal trends in radionuclide concentration in a reach were evaluated by examining the radionuclide data in terms of different ages of associated geomorphic units. Constraints on absolute or relative sediment age were provided by examination of historical aerial photographs, isotopic ratios in sediments, spatial relations between geomorphic units, and/or vertical stratigraphic relations (deeper sediments being older). Because all radionuclide COPCs tend to occur in higher concentrations in finer-grained sediments of a given age, it is necessary to compare samples with similar particle size characteristics to determine if differences or similarities in radionuclide concentration between samples allow insight into time-dependent trends. For each reach, all samples were compared on scatter plots showing the relation of concentrations of different radionuclides to various particle size parameters (e.g., percent silt and clay and median particle size), helping to identify sediment packages that share similar relations between radionuclide concentration and particle size. Scatter plots comparing radionuclide data and organic matter content were also examined because many contaminants can be preferentially associated with organic colloids (Langmuir 1997, 56037), and positive correlations have been reported between radionuclide concentration and organic matter content in sediments at the Laboratory (Nyhan et al. 1976, 11747). Although positive correlations between radionuclide concentrations and organic matter

content are suggested in parts of the upper Los Alamos Canyon data set, these relations are not as well developed as with particle size parameters.

3.3.1.3 Radionuclide Inventory

The approximate inventories of the key radionuclides within each geomorphic unit and each stratigraphic subdivision of geomorphic units were calculated using the data on average radionuclide concentrations (pCi/g), the estimated area (m^2) and average thickness (m) of each sediment package, sediment density (g/cm^3), and average gravel content (weight %). Area and thickness data are summarized in Section 2.3, and gravel data are presented in Appendix B-3.0. Sediment density measurements are presented in Appendix B-4.0 of Reneau et al. (1998, 59159). In these calculations it is assumed that the volume of each unit occupied by gravel contains no radionuclide COPCs because of the relations seen between particle size and radionuclide concentration in upper Los Alamos Canyon sediment samples (Sections 3.3.2.2, 3.3.3.2, and 3.3.4.2). The total radionuclide inventory in each reach is normalized by reach length, as measured along the stream channel on topographic maps prepared by the Facility for Information Management, Analysis, and Display (FIMAD), to facilitate comparison of the amount of each radionuclide in reaches of varying lengths and extrapolation between reaches (units of mCi/km).

3.3.1.4 Potential Remobilization

Estimates of the percentage of the total radionuclide inventory most susceptible to remobilization in each reach are made based on proximity to the active channel and the geomorphic history of channel changes as discussed in Section 2.3. These estimates assume a time scale of approximately 50 years and geomorphic processes similar to those documented during the past 55 years (post-1942) and involve judgments as to the average residence time of sediment in the different units. Where the average sediment residence time in a particular geomorphic setting is judged to be greater than 50 years, most of the sediment is assumed to be not susceptible to remobilization; instead, additional sediment deposition may be the most important geomorphic process (e.g., most of the f1 units). All active channel sediment is assumed to be susceptible to remobilization during the next 50 years. Abandoned channel units that occur adjacent to the active channel and that record gradual channel migration, such as the c2 unit in all reaches, are also assumed to be susceptible to remobilization. However, some areas of abandoned post-1942 channels that occur away from the active channel, such as much of the c3 unit in LA-2 West, are not considered to be as susceptible to remobilization during the next 50 years. Most floodplain areas are assumed to be stable for the next 50 years, based partly on the common presence of trees greater than 100 years old, although channel migration may result in relatively small amounts of remobilization of sediment on the floodplains.

3.3.1.5 Isotopic Ratios

The ratios of different radionuclide COPCs released into the upper Los Alamos Canyon watershed have varied among different PRSs and have also varied over time at some individual PRSs, and isotopic ratios can provide insight into sediment sources and sediment age. For example, variations in the ratio of plutonium-239,240 to plutonium-238 (plutonium 239/238 ratios) indicate variations in the use of plutonium in Laboratory operations. Early Laboratory operations primarily used bomb-grade plutonium, which is dominated by plutonium-239,240, and high plutonium-239/238 ratios are found in sediments whose plutonium is largely derived from early Laboratory operations (such as Pueblo Canyon downstream from TA-45 where plutonium 239/238 ratios are typically 100 to 300 [Reneau et al. 1998, 59159]). In contrast, research using plutonium-238 became common at the Laboratory beginning in 1968 (Nyhan et al. 1975, 11746; Nyhan et al 1976, 11747), resulting in lower plutonium 239/238 ratios. Monitoring data from the

21-011(k) outfall from TA-21 into DP Canyon indicate average plutonium 239/238 ratios of approximately 1.7 from 1968 until the releases stopped in 1985 (data from SAIC 1998, 58719). An additional change in radionuclide releases documented by the 21-011(k) outfall data is the increased discharge of americium-241 beginning in 1978. Average ratios of cesium-137 to americium-241 at 21-011(k) from 1973 to 1977 are approximately 8.9, whereas average ratios from 1978 to 1985 are 0.6. The ratio of americium-241 to plutonium-239,240 is highest after 1978, averaging approximately 4.9 from 1978 to 1985 and only 0.8 from 1973 to 1977.

Note that the cesium/americium ratios in sediment deposits will change over time because of radioactive decay of cesium-137 (half-life of 30.2 years), although the major differences between units will still be apparent. Sediment deposited in 1975 with an original cesium/americium ratio of 8.9 will now have a cesium/americium ratio of 5.3, and sediment deposited in 1982 with an original ratio of 0.6 will now have a ratio of 0.4. The sediments in upper Los Alamos Canyon with the highest cesium-137 content are believed to have been deposited between 1956 and 1968, and cesium/americium ratios in these sediments average 40 to 85 (c3 unit of LA-2 East, Section 3.3.3). If these sediments were deposited in 1962, they would have originally had cesium/americium ratios of 90 to 195.

In this report the ratios of various radionuclides were calculated from the analytical data for each sample and for averages in each bin. Averages for each bin are presented in tables for each reach, and the actual ratios of individual samples are sometimes used to constrain the age of specific sediment layers. Note that all these ratios are approximate, in part because of the relatively poor precision of many of the analyses associated with reported results close to the detection limit in many samples or the use of relatively low-precision analytical methods (i.e., the predominant use of gamma spectroscopy measurements for americium-241 instead of the more precise alpha spectrometry method). However, the calculation of isotopic ratios using average concentrations within many samples should be more reliable than ratios calculated from individual samples because measurement uncertainties will be reduced by averaging a large data set. In addition, sediment with the highest radionuclide concentrations probably provides the most accurate estimate of isotopic ratios in the initial releases because sediment with low concentrations may include relatively high percentages of fallout-derived radionuclides.

3.3.1.6 Evaluation of Radionuclide Variability in Collocated Samples

Another important consideration in the assessment of these data is the comparability of collocated sample results. There are two types of collocated samples in the upper Los Alamos Canyon data set. First are field splits of the same sample material, which are called quality assurance (QA) duplicate analyses and were collected in a random manner from a variety of geomorphic settings. Second are stratigraphic sections that were resampled because of high values after the initial sampling round or other reasons, which are called resamples. The collection of resamples tests the repeatability of specific sample results. This evaluation of collocated samples uses data on americium-241; cesium-137; plutonium-238; plutonium-239,240; and strontium-90 because of the importance of these radionuclides in upper Los Alamos Canyon. Figure E4-1 in Appendix E shows the relationship between 35 pairs of QA duplicate results and 7 pairs of resample results for these key radionuclides. The QA duplicates show less variability than the resamples, and the most significant variability in resamples is in two pairs of strontium-90 results from reach LA-2 West. Both of these strontium-90 resamples may record initial sample results that were biased high because of a laboratory measurement interference. The initial strontium-90 results for the resamples are from RN 2833, which may have a high analytical laboratory bias (Appendix C-3.0). The remainder of the collocated sample results generally show good agreement between the initial result and the second result, including resampling of the layer in LA-2 East that has the highest cesium-137 and strontium-90 values in upper Los Alamos Canyon. Therefore, this evaluation of

the collocated sample results suggests that local spatial variability and analytical measurement error represents a small part of the variability in concentration of the key radionuclides, with the exception of strontium-90.

3.3.2 Reach LA-1

3.3.2.1 Contaminant Concentrations

Most sediment samples from the c1, c2, c3, and f1 units in reach LA-1 downstream from Bailey Canyon contain plutonium-239,240 concentrations above the background value of 0.068 pCi/g (Table 3.3-1), indicating rapid mixing of sediment derived from TA-1 PRSs with sediment carried by floods from upstream parts of Los Alamos Canyon. Plutonium-239,240 concentrations are relatively low in LA-1 West+ between Bailey Canyon and Hillside 137, averaging 0.38 pCi/g in overbank facies sediment samples, and increase immediately downstream of Hillside 137 (Table 3.3-2). Available data from this investigation and prior investigations indicate that strontium-90 is below the background value of 1.04 pCi/g upstream from DP Canyon and that americium-241, cesium-137, and plutonium-238 are elevated above background values, although occurring at much lower levels than downstream from DP Canyon. Only the plutonium-239,240 data for LA-1 will be discussed here.

Plutonium-239,240 concentrations within reach LA-1 are highest in fine-grained overbank facies sediment deposits in LA-1 West and LA-1 East. Similar maximum values of 19.1 and 19.3 pCi/g were obtained from the c3 unit of LA-1 West and the f1 unit of LA-1 East. Concentrations are apparently less in LA-1 Central, where a maximum of 8.78 pCi/g was obtained from the c2 unit. No consistent relation is seen among plutonium concentrations in the different units in these subreaches, as discussed in the following paragraphs.

In LA-1 West, plutonium-239,240 concentrations are generally similar in the overbank facies samples from the c2 and c3 units, and samples from these units were combined for estimating average concentrations. Average and median concentrations here are the highest of any of the LA-1 subreaches, with an average of 6.9 pCi/g and a median of 4.8 pCi/g (Table 3.3-2). Concentrations are less in overbank sediments in the f1 unit, with an average of 2.0 pCi/g and a median of 1.8 pCi/g. The relatively high concentrations in LA-1 West are consistent with the proximity to the Hillside 137 contaminant source and possible contributions from Hillside 138.

In LA-1 Central, plutonium-239,240 concentrations are apparently highest in overbank sediments of the c2 unit, with an average of 4.1 pCi/g and a median of 2.8 pCi/g (Table 3.3-2). Concentrations in the c3 and f1 overbank sediment samples are similar and are combined for estimating average concentrations, providing an average of 2.3 pCi/g and a median of 1.4 pCi/g.

In LA-1 East, plutonium-239,240 concentrations are highest in overbank sediment samples from the f1 unit, with an average of 5.8 pCi/g and a median of 3.3 pCi/g (Table 3.3-2). Concentrations in the c2 and c3 overbank sediment samples are similar and are combined for estimating average concentrations, providing an average of 1.9 pCi/g and a median of 1.7 pCi/g. The higher plutonium concentrations obtained in the f1 unit in LA-1 East relative to all geomorphic units in LA-1 Central may indicate the addition of contaminants derived from the former laundry at TA-21, although samples from the c2 and c3 units in LA-1 East have similar concentrations of plutonium to LA-1 Central samples. Also note that the higher average concentration calculated for the f1 unit in LA-1 East is biased by a single high result of 19.3 pCi/g that is more than three times greater than the next highest value, and it is possible that the average plutonium-239,240 concentration in the f1 unit has been overestimated.

TABLE 3.3-1

RADIONUCLIDE ANALYSES FROM REACH LA-1

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
LA-1 Far West (upstream of Hillside 140, downstream of bridge)															
c1	LA-0171	0–2	0–5	Channel	2	04LA-97-0579	0.035	-0.036 (U)[c]	-0.0054 (U)	-0.0085 (U)	0.00006 (U)	NA[d]	ms	s	Limited-suite sample
c2	LA-0170	0–12	0–30	Overbank	2	04LA-97-0568	0.034 (U)	0.302 (U)	0.0883 (U)	0.0129 (U)	0.0204 (J)[e]	NA	fs	sl	Limited-suite sample
c3	LA-0172	1.5–15.5	4–39	Overbank	2	04LA-97-0624	0.0283	-0.148 (U)	0.1172 (U)	0.0147 (U)	0.03 (J)	NA	csi	l	Limited-suite sample
LA-1 West+ (upstream of Hillside 137, downstream of Bailey Canyon)															
c1	LA-0174	0–2	0–5	Channel	2	04LA-97-0574	NA	NA	NA	0.003 (U)	0.0158 (U)	NA	cs	gs	Limited-suite sample
c2	LA-0173	0–9.5	0–24	Overbank	2	04LA-97-0573	NA	NA	NA	0.0157 (U)	0.373 (J)	NA	vfs	sl	Limited-suite sample
c3	LA-0175	0–7	0–18	Overbank	2	04LA-97-0575	NA	NA	NA	0.0053 (U)	0.249 (J)	NA	fs	sl	Limited-suite sample
		7–15.5	18–40	Overbank	2	04LA-97-0576	NA	NA	NA	0.0066 (U)	0.269 (J)	NA	ms	sl	Limited-suite sample
		15.5–20.5	40–52	Overbank	2	04LA-97-0577	NA	NA	NA	0.0111 (U)	0.623 (J)	NA	fs	sl	Limited-suite sample
LA-1 West (downstream of Hillside 137) (u = upstream of Hillside 138; d = downstream of Hillside 138)															
c1 (u)	LA-0144	0–2	0–5	Channel	1	04LA-97-0241	NA	NA	NA	-0.0016 (U)	0.081	NA	vcs	gs	
c1 (d)	LA-0149	0–2	0–5	Channel	1	04LA-97-0253	NA	NA	NA	-0.011 (U)	0.164	NA	cs	gs	
c2 (d)	LA-0148	3–10	8–25	Overbank	1	04LA-97-0252	NA	NA	NA	0.027 (U)	2.44	NA	fs	sl	
c2 (u)	LA-0178	0–7.5	0–19	Overbank	2	04LA-97-0625	0.124	0.23 (U)	0.3227	0.038	7.24 (J)	NA	vfs	gsl	Limited-suite sample
c3 (u)	LA-0143	2.5–13	6–33	Overbank	1	04LA-97-0239	NA	NA	NA	0.043	15.36	NA	vfs	sl	
		13–21	33–53	Overbank	1	04LA-97-0240	NA	NA	NA	0.083	19.1	NA	csi	l	
		13-21	33-53	Overbank	2	04LA-97-0571	0.571	0.555 (U)	0.2897	NA	NA	NA	NA	NA	Layer resampled for limited suite
		21–27.5	53–70	Overbank	2	04LA-97-0585	NA	NA	NA	0.033	2.63 (J)	NA	fs	sl	

a. vcs = very coarse sand, cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csi = coarse silt

b. l = loam, sl = sandy loam, s = sand, g = ≥20% gravel

c. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

d. NA = not analyzed

e. 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.

TABLE 3.3-1 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-1

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
LA-1 West (downstream of Hillside 137) (u = upstream of Hillside 138; d = downstream of Hillside 138)															
c3 (d)	LA-0146	0–11	0–28	Overbank	1	04LA-97-0243	NA[c]	NA	NA	0.036	7.32	NA	vfs	sl	Limited-suite sample
		11–19.5	28–49	Overbank	1	04LA-97-0244	NA	NA	NA	0.0075 (U)[d]	2.22	NA	vfs	sl	Limited-suite sample
		19.5–28	49–71	Overbank	1	04LA-97-0245	NA	NA	NA	0.0189 (U)	3.42	NA	csi	gsl	Limited-suite sample
c3 (d)	LA-0147	0–6.5	0–17	Overbank	1	04LA-97-0246	NA	NA	NA	0.0145 (U)	2.03	NA	csi	gl	
		6.5–15.5	17–39	Channel	1	04LA-97-0247	NA	NA	NA	0.0165 (U)	0.728	NA	cs	gls	
		6.5–15.5	17–39	Channel	1	04LA-97-0248	NA	NA	NA	0.0098 (U)	0.693	NA	NA	NA	QA duplicate
		18.5–23	47–59	Overbank	1	04LA-97-0249	NA	NA	NA	0.0158 (U)	3.07	NA	csi	l	
		23–30.5	59–78	Channel?	1	04LA-97-0250	NA	NA	NA	0.0171 (U)	0.465	NA	ms	gsl	
		30.5–36	78–92	Channel	1	04LA-97-0251	NA	NA	NA	0.001 (U)	0.273	NA	cs	gls	
c3? (f1?) (u)	LA-0141	0–4	0–10	Overbank	1	04LA-97-0236	NA	NA	NA	0.049	4.77	NA	vfs	sl	Limited-suite sample
		4–14	10–36	Overbank	1	04LA-97-0237	NA	NA	NA	0.044	10.49	NA	vfs	gsl	Limited-suite sample
		14–19.5	36–50	Overbank	2	04LA-97-0583	NA	NA	NA	0.0302	9.36 (J)[e]	NA	csi	l	
f1 (u)	LA-0177	0–5.5	0–14	Overbank	2	04LA-97-0580	NA	NA	NA	0.0083 (U)	0.356	NA	fs	sl	
		9.5–17	24–43	Overbank	2	04LA-97-0581	NA	NA	NA	0.034	0.819	NA	csi	l	
		21-5–27.5	55–70	Overbank	2	04LA-97-0582	NA	NA	NA	0.008 (U)	0.058 (J)	NA	csi	sil	
f1 (u)	LA-0142	0–3.5	0–9	Overbank	1	04LA-97-0238	NA	NA	NA	-0.0095 (U)	1.99	NA	vfs	sl	
		3.5–8.5	9–22	Overbank	2	04LA-97-0584	NA	NA	NA	0.023 (U)	4.8 (J)	NA	csi	l	
f1 (d)	LA-0145	0–4	0–10	Overbank	1	04LA-97-0242	NA	NA	NA	0.0208	1.83	NA	vfs	sl	
		4–10	10–26	Overbank	2	04LA-97-0586	NA	NA	NA	0.0138 (U)	3.66 (J)	NA	vfs	l	

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csi = coarse silt

b. l = loam, sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel

c. NA = not analyzed

d. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

e. 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.

TABLE 3.3-1 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-1

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
LA-1 West (downstream of Hillside 137) (u = upstream of Hillside 138; d = downstream of Hillside 138)															
f1 (u)	LA-0176	0–6.5	0–16	Overbank	2	04LA-97-0590	0.063	0.484 (U)[c]	0.2408	0.0169 (U)	0.701 (J)[d]	NA[e]	fs	sl	Limited-suite sample
		6.5–12.5	16–32	Overbank	2	04LA-97-0578	NA	NA	NA	0.0328	0.0169 (U)	NA	ms	ls	
LA-1 Central (downstream of TA-2)															
c1	LA-0154	0–2	0–5	Channel	1	04LA-97-0264	NA	NA	NA	-0.0022 (U)	0.076	NA	cs	gs	
c2	LA-0153	0–6.5	0–17	Overbank	1	04LA-97-0261	NA	NA	NA	-0.0005 (U)	0.627	NA	fs	ls	
		14.5–27	37–68	Channel	2	04LA-97-0594	NA	NA	NA	0.0201 (U)	0.216	NA	cs	gs	
c2	LA-0179	0–9.5	0–24	Overbank	2	04LA-97-0602	0.071	0.174 (U)	0.5489	0.0206 (U)	2.76 (J)	NA	csi	sil	Limited-suite sample
		9.5–17.5	24–45	Overbank	2	04LA-97-0587	NA	NA	NA	0.041	8.78 (J)	NA	csi	sil	
		21–36	53–92	Channel	2	04LA-97-0588	NA	NA	NA	0.0124 (U)	0.512 (J)	NA	cs	gls	
c3	LA-0155	6.5–15.5	16–40	Channel	1	04LA-97-0265	NA	NA	NA	0.0123 (U)	0.316	NA	cs	gs	
		15.5–19.5	40–50	Channel	1	04LA-97-0266	NA	NA	NA	-0.001 (U)	0.142	NA	cs	s	
		23.5–27.5	60–70	Overbank	1	04LA-97-0267	NA	NA	NA	0.0184 (U)	1.54	NA	fs	sl	
c3	LA-0181	0–4	0–10	Overbank	2	04LA-97-0613	0.041	0.147 (U)	0.61	-0.0072 (U)	0.531 (J)	NA	fs	ls	Limited-suite sample
		10–23.5	25–60	Channel	2	04LA-97-0593	NA	NA	NA	0.0105	0.16 (J)	NA	cs	s	
c3? (f1?)	LA-0182	4–17	10–43	Overbank	2	04LA-97-0595	NA	NA	NA	-0.0016 (U)	0.988 (J)	NA	fs	sl	
		23.5–27.5	60–70	Overbank	2	04LA-97-0596	NA	NA	NA	0.0188	0.123 (J)	NA	vfs	sl	
c3? (f1?)	LA-0183	0–14	0–36	Overbank	2	04LA-97-0597	NA	NA	NA	0.04	5.1 (J)	NA	csi	sl	
f1	LA-0150	0–3	0–8	Overbank	1	04LA-97-0254	NA	NA	NA	0.0222 (U)	5.94	NA	fs	sl	
f1	LA-0151	0–7	0–18	Overbank	1	04LA-97-0255	NA	NA	NA	0.024	5.54	-0.07 (U)	vfs	sl	Limited-suite sample
		7–11.5	18–29	Overbank	1	04LA-97-0256	NA	NA	NA	0.0035 (U)	1.71	-0.19 (U)	vfs	sl	Limited-suite sample

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csi = coarse silt

b. sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel

c. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

d. 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.

e. NA = not analyzed

TABLE 3.3-1 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-1

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
LA-1 Central (downstream of TA-2)															
f1	LA-0151	11.5–14.5	29–37	Overbank	1	04LA-97-0257	NA[c]	NA	NA	0.0082 (U)[d]	1.23	-0.08 (U)	vfs	sl	Limited-suite sample
		19.5–31.5	50–80	Channel	1	04LA-97-0258	NA	NA	NA	0.0011 (U)	0.0237	NA	cs	gls	
f1	LA-0152	0–4	0–10	Overbank	1	04LA-97-0259	NA	NA	NA	0.0183 (U)	3.48	NA	csi	sil	
		0–4	0–10	Overbank	1	04LA-97-0260	NA	NA	NA	0.0127 (U)	3.04	NA	NA	NA	QA duplicate
f1	LA-0156	0–6.5	0–17	Overbank	1	04LA-97-0268	NA	NA	NA	-0.0072 (U)	0.308	NA	ms	sl	
		6.5–14	17–35	Overbank	1	04LA-97-0269	NA	NA	NA	-0.0022 (U)	0.0115 (U)	NA	vfs	sl	
f1	LA-0180	0–4.5	0–11	Overbank	2	04LA-97-0589	NA	NA	NA	0.023 (U)	0.767 (J)[e]	NA	fs	sl	
		6.5–18.5	17–47	Channel	2	04LA-97-0592	NA	NA	NA	0.001 (U)	0.08 (J)	NA	cs	gs	
LA-1 East (downstream of TA-21 laundry outfall)															
c1	LA-0159	0–2	0–5	Channel	1	04LA-97-0274	NA	NA	NA	0.0123 (U)	0.09	NA	cs	gs	
c2	LA-0185	0–9	0–23	Overbank	2	04LA-97-0623	0.043 (U)	-0.113 (U)	0.3312	0.0123 (U)	1.252 (J)	NA	fs	sl	Limited-suite sample
		9–15.5	23–39	Overbank	2	04LA-97-0599	NA	NA	NA	0.051	1.378 (J)	NA	vfs	sl	
		15.5–26	39–66	Channel	2	04LA-97-0600	NA	NA	NA	0.0239 (U)	0.131 (J)	NA	cs	gs	
c2? (c3?)	LA-0161	0–13	0–33	Overbank	1	04LA-97-0276	NA	NA	NA	0.02 (U)	2.98	NA	vfs	sl	
		19–27	48–68	Channel	1	04LA-97-0277	NA	NA	NA	0.0073 (U)	0.235	NA	cs	gs	
c2? (c3?)	LA-0187	0–5.5	0–14	Overbank	2	04LA-97-0603	NA	NA	NA	0.0171	0.917 (J)	NA	fs	ls	
		5.5–13	14–33	Overbank	2	04LA-97-0604	NA	NA	NA	0.033	2.27 (J)	NA	fs	sl	
		13–20.5	33–52	Overbank	2	04LA-97-0605	NA	NA	NA	0.078	1.52 (J)	NA	fs	sl	

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csi = coarse silt
b. sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel
c. NA = not analyzed
d. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.
e. 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.

TABLE 3.3-1 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-1

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
LA-1 East (downstream of TA-21 laundry outfall)															
c3	LA-0162	0–12.5	0–32	Channel	1	04LA-97-0278	NA[c]	NA	NA	0.0032 (U)[d]	2.19	NA	cs	gs	
		12.5–18.5	32–47	Overbank	1	04LA-97-0279	NA	NA	NA	0.0098 (U)	1.71	NA	vfs	sl	Limited-suite sample
		18.5–26.5	47–61	Overbank	1	04LA-97-0280	NA	NA	NA	0.008 (U)	1.135	NA	vfs	sl	
c3	LA-0186	0–7	0–18	Overbank	2	04LA-97-0622	0.065	-0.201 (U)	2.8993	0.0182 (U)	1.69 (J)[e]	NA	csi	l	Limited-suite sample
		7–14.5	18–37	Overbank	2	04LA-97-0601	NA	NA	NA	0.0139 (U)	4.49 (J)	NA	csi	sil	
c3	LA-0188	0–6.5	0–16	Overbank	2	04LA-97-0606	NA	NA	NA	0.0151 (U)	0.631 (J)	NA	ms	ls	
		6.5–10.5	16–27	Overbank	2	04LA-97-0607	NA	NA	NA	0.04	1.95 (J)	NA	csi	sl	
		10.5–22	27–56	Overbank	2	04LA-97-0608	NA	NA	NA	0.061	2.32 (J)	NA	vfs	l	
		28.5–41	73–104	Channel	2	04LA-97-0609	NA	NA	NA	0.01 (U)	0.35 (J)	NA	cs	gls	
f1	LA-0157	0–7	0–18	Overbank	1	04LA-97-0270	NA	NA	NA	0.0044 (U)	1.78	NA	vfs	sl	
		7–17.5	18–44	Overbank	1	04LA-97-0271	NA	NA	NA	0.0185 (U)	4.9	NA	vfs	sl	
f1	LA-0158	0–13.5	0–34	Overbank	1	04LA-97-0272	NA	NA	NA	0.022 (U)	1.71	NA	csi	sl	Limited-suite sample
		13.5–19	34–48	Overbank	1	04LA-97-0273	NA	NA	NA	0.0283	5.41	NA	csi	l	Limited-suite sample
f1	LA-0160	0–10.5	0–27	Overbank	1	04LA-97-0275	NA	NA	NA	0.065	19.3	NA	csi	gsil	
		0–10.5	0–27	Overbank	2	04LA-97-0572	0.206	0.175 (U)	1.1012	NA	NA	NA	NA	NA	Layer resampled for limited suite
f1	LA-0184	0–3.5	0–9	Overbank	2	04LA-97-0598	NA	NA	NA	0.0154 (U)	1.79 (J)	NA	csi	l	

a. cs = coarse sand, ms = medium sand, vfs = very fine sand, csi = coarse silt
b. l = loam, sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel
c. NA = not analyzed
d. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.
e. 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.

TABLE 3.3-2

SUMMARY OF BINNED ANALYSES IN REACH LA-1

Geomorphic Unit and Sediment Facies	Summary Statistic	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]	Pu-239/238 Ratio
LA-1 Far West (upstream of Hillside 140, downstream of bridge)							
c1 channel, c2 and c3 overbank	average	0.006	0.017	fs	0.207	sl	3
	std. dev.	0.013	0.015				
	maximum	0.015	0.030				
	minimum	-0.009	0.000				
	median	0.013	0.020				
	n	3	3				
LA-1 West+ (upstream of Hillside 137, downstream of Bailey Canyon)							
c1 channel	average	0.003	0.016	cs	0.681	gs	5
	n	1	1				
c2 & c3 overbank	average	0.010	0.379	fs	0.162	sl	39
	std. dev.	0.005	0.172				
	maximum	0.016	0.623				
	minimum	0.005	0.249				
	median	0.009	0.321				
	n	4	4				
LA-1 West (downstream of Hillside 137, upstream of TA-41)							
c1 channel	average	-0.006	0.123	vcs	1.110	gs	N/A[c]
	std. dev.	0.007	0.059				
	maximum	-0.002	0.164				
	minimum	-0.011	0.081				
	median	-0.006	0.123				
	n	2	2				
c2 & c3 overbank	average	0.034	6.881	vfs	0.075	sl	203
	std. dev.	0.019	5.437				
	maximum	0.083	19.100				
	minimum	0.008	2.030				
	median	0.033	4.770				
	n	13	13				

a. vcs = very coarse sand, cs = coarse sand, fs = fine sand, vfs = very fine sand
b. sl = sandy loam, s = sand, g = ≥20% gravel
c. N/A = not applicable

TABLE 3.3-2 (continued)

SUMMARY OF BINNED ANALYSES IN REACH LA-1

Geomorphic Unit and Sediment Facies	Summary Statistic	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]	Pu-239/238 Ratio
LA-1 West (downstream of Hillside 137, upstream of TA-41)							
c3 channel	average	0.012	0.489	cs	0.500	gls	42
	std. dev.	0.009	0.228				
	maximum	0.017	0.728				
	minimum	0.001	0.273				
	median	0.017	0.465				
	n	3	3				
f1 overbank	average	0.015	2.022	vfs	0.072	sl	132
	std. dev.	0.014	1.654				
	maximum	0.034	4.800				
	minimum	-0.010	0.356				
	median	0.017	1.830				
	n	7	7				
background?[c]	average	0.020	0.037	vfs	0.097	sl	2
	std. dev.	0.018	0.029				
	maximum	0.033	0.058				
	minimum	0.008	0.017				
	median	0.020	0.037				
	n	2	2				
LA-1 Central (downstream of TA-2)							
c1 channel	average	-0.002	0.076	cs	0.964	gs	N/A[d]
	n	1	1				
c2 overbank	average	0.020	4.056	vfs	0.063	sl	199
	std. dev.	0.021	4.228				
	maximum	0.041	8.780				
	minimum	-0.001	0.627				

a. cs = coarse sand, vfs = very fine sand
b. sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel
c. Samples inferred to represent background have ≤0.08 pCi/g Pu-239,240 and are from the f1 unit
d. N/A = not applicable

TABLE 3.3-2 (continued)

SUMMARY OF BINNED ANALYSES IN REACH LA-1

Geomorphic Unit and Sediment Facies	Summary Statistic	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]	Pu-239/238 Ratio
LA-1 Central (downstream of TA-2)							
c2 overbank	median	0.021	2.760				
	n	3	3				
c2 channel	average	0.016	0.364	cs	0.865	gls	22
	std. dev.	0.005	0.209				
	maximum	0.020	0.512				
	minimum	0.012	0.216				
	median	0.016	0.364				
	n	2	2				
c3 & f1 overbank	average	0.013	2.271	vfs	0.110	sl	170
	std. dev.	0.014	2.152				
	maximum	0.040	5.940				
	minimum	-0.007	0.123				
	median	0.018	1.385				
	n	12	12				
c3 channel	average	0.007	0.206	cs	0.741	gs	28
	std. dev.	0.007	0.096				
	maximum	0.012	0.316				
c3 channel	minimum	-0.001	0.142				
	median	0.011	0.160				
	n	3	3				
background?[c]	average	0.000	0.038	ms	0.358	gls	N/A[d]
	std. dev.	0.002	0.037				
	maximum	0.001	0.080				
	minimum	-0.002	0.012				
	median	0.001	0.024				
	n	3	3				

a. cs =coarse sand, ms = medium sand, vfs = very fine sand

b. sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel

c. Samples inferred to represent background have ≤0.08 pCi/g Pu-239,240 and are from the f1 unit

d. N/A = not applicable

TABLE 3.3-2 (continued)

SUMMARY OF BINNED ANALYSES IN REACH LA-1

Geomorphic Unit and Sediment Facies	Summary Statistic	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]	Pu-239/238 Ratio
LA-1 East (downstream of TA-21 laundry outfall)							
c1 channel	average	0.012	0.090	cs	0.784	gs	7
	n	1	1				
c2 & c3 overbank	average	0.029	1.865	vfs	0.091	sl	64
	std. dev.	0.022	1.010				
	maximum	0.078	4.490				
	minimum	0.008	0.631				
	median	0.018	1.690				
	n	13	13				
c2 channel	average	0.016	0.183	cs	0.832	gs	12
	std. dev.	0.012	0.074				
	maximum	0.024	0.235				
	minimum	0.007	0.131				
	median	0.016	0.183				
	n	2	2				
c3 channel	average	0.007	1.270	cs	0.666	gls	192
	std. dev.	0.005	1.301				
	maximum	0.010	2.190				
	minimum	0.003	0.350				
	median	0.007	1.270				
	n	2	2				
f1 overbank	average	0.026	5.815	csi	0.055	l	227
	std. dev.	0.021	6.814				
	maximum	0.065	19.300				
	minimum	0.004	1.710				
	median	0.020	3.345				
	n	6	6				

a. cs = coarse sand, vfs = very fine sand, csi = coarse silt,
b. l = loam, sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel
c. Samples inferred to represent background have ≤0.08 pCi/g Pu-239,240 and are from the f1 unit

Channel facies sediment samples from the c1, c2, and c3 units in LA-1 downstream of Hillside 137 have measured plutonium-239,240 concentrations ranging from 0.08 to 2.2 pCi/g, although only one sample exceeded 0.8 pCi/g (Table 3.3-1). The highest concentration was obtained from a c3 sample in LA-1 East, although the only other channel facies sample from this unit provided a value of 0.35 pCi/g, similar to c2 channel facies samples in LA-1 East and c2 and c3 samples from LA-1 West and LA-1 Central (Table 3.3-2). In all subreaches, active channel sands (c1) have lower concentrations of plutonium than samples from the abandoned channel units (c2 and c3).

3.3.2.2 Age and Particle Size Relations

Age control for sediment deposits is sparse in reach LA-1, limiting confidence in inferences about possible trends in contaminant concentration over time. However, available data suggest that there have been no major decreases in plutonium-239,240 concentrations over time, and relatively high concentrations can occur in sediments that are less than 20 to 25 years old. The sediment sample with the second highest plutonium concentration in LA-1, 19.1 pCi/g in sample 04LA-97-0240 from the c3 unit in LA-1 West (Table 3.3-1), is from a fine-grained silt-rich layer that buries a tree with an estimated germination date of 1974 AD (tree ULA-022, Table B1-1, Figures 2.3-5 and 3.3-1). This sediment layer may also bury a tree that germinated circa 1978 AD (tree ULA-023). Tree ULA-022 is growing on a coarser overbank sediment deposit with only 2.6 pCi/g plutonium-239,240 (sample 04LA-97-0585, a fine sand layer, Figure 3.3-1), which was deposited sometime between 1942 and 1974.

In LA-1 Central and LA-1 East additional data are available on the ages of some overbank sediment deposits that, in combination with the LA-1 West data, show no consistent trend of higher or lower concentrations of plutonium-239,240 in sediment deposited early or late in the period since initial contaminant releases. In LA-1 Central, sediment that postdates 1970 AD (sample 04LA-97-0613 at tree ULA-040) has only 0.5 pCi/g plutonium-239,240, and texturally similar sediment that was deposited between 1942 and 1961 AD (sample 04LA-97-0267 near tree ULA-005, Figure 2.3-6) has 1.5 pCi/g. In LA-1 East, a silt-rich layer that occurs beneath tree ULA-028 and was deposited between 1942 and 1955 AD has 4.5 pCi/g plutonium-239,240 (sample 04LA-97-0601), and a texturally similar layer that buries this tree and postdates 1955 has 1.7 pCi/g (sample 04LA-97-0622).

Examination of variations in plutonium-239,240 concentration with depth within the c2 and c3 units in the different LA-1 subreaches also shows no consistent differences between deeper (older) and shallower (younger) samples that would provide evidence for significant changes in plutonium concentration over time (Figures 3.3-1 to 3.3-3). Samples with the highest plutonium concentration within each unit can be located near the surface, near the middle of an overbank deposit, or near the bottom.

Scatter plots of plutonium-239,240 concentrations versus particle size in LA-1 indicate that plutonium concentration in each subreach generally increases with decreasing particle size, although much variability exists in these relationships (Figures B3-1 to B3-4). For all three subreaches downstream from Hillside 137, plots of plutonium concentration against the percentage of silt and clay in each sample show the best trends, and the highest concentrations in each subreach occur in samples that have at least 55% silt and clay. Variations in plutonium concentration in the channel facies sediment samples also appear to be related to silt and clay content. The higher plutonium-239,240 concentrations that occur in the c2 and c3 channel facies samples in each subreach, in comparison to c1, are consistent with higher percentages of silt and clay in the c2 and c3 samples. In some subreaches there is also an apparent correlation of organic matter content with plutonium concentration, although correlations with silt and clay content appear better.

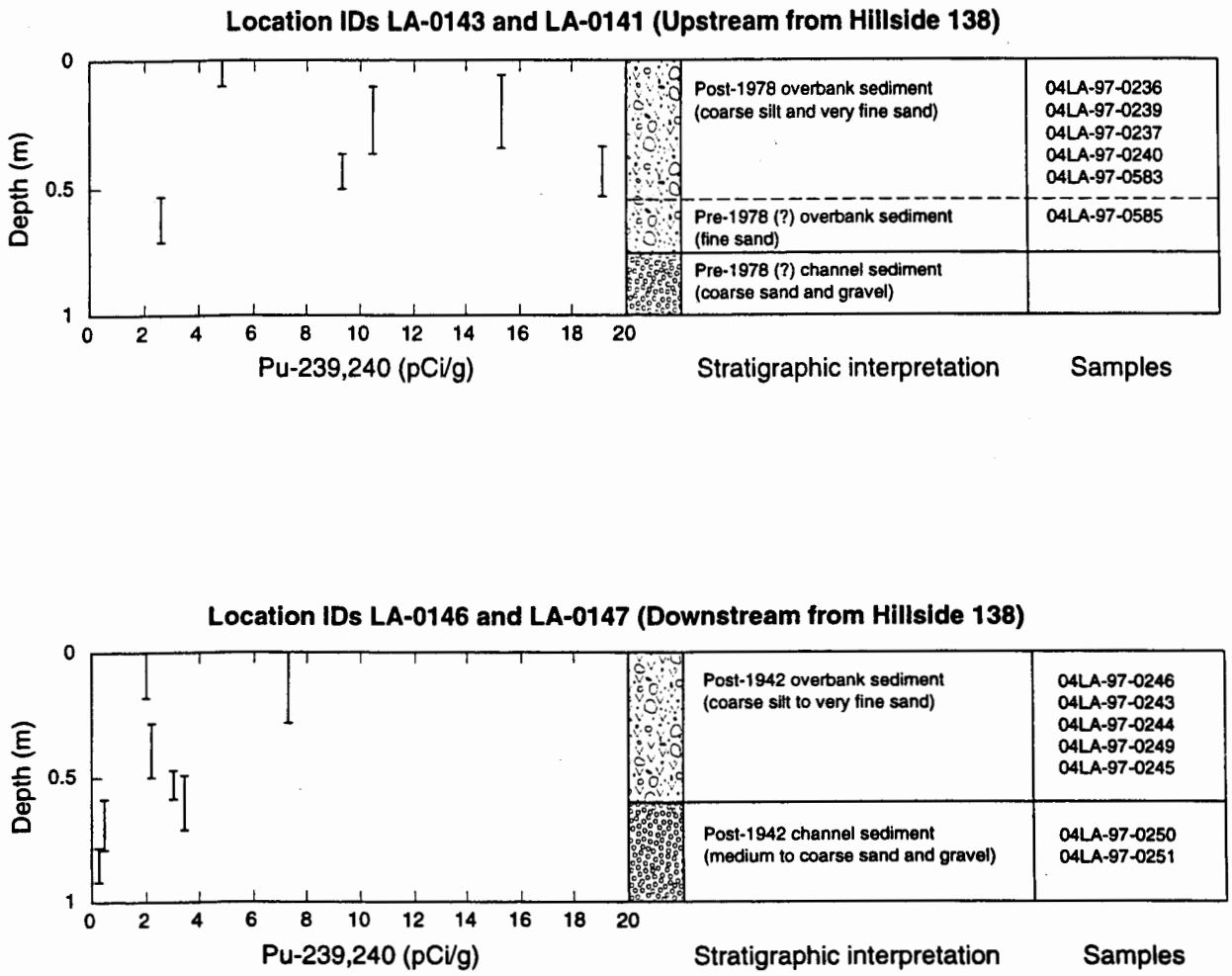
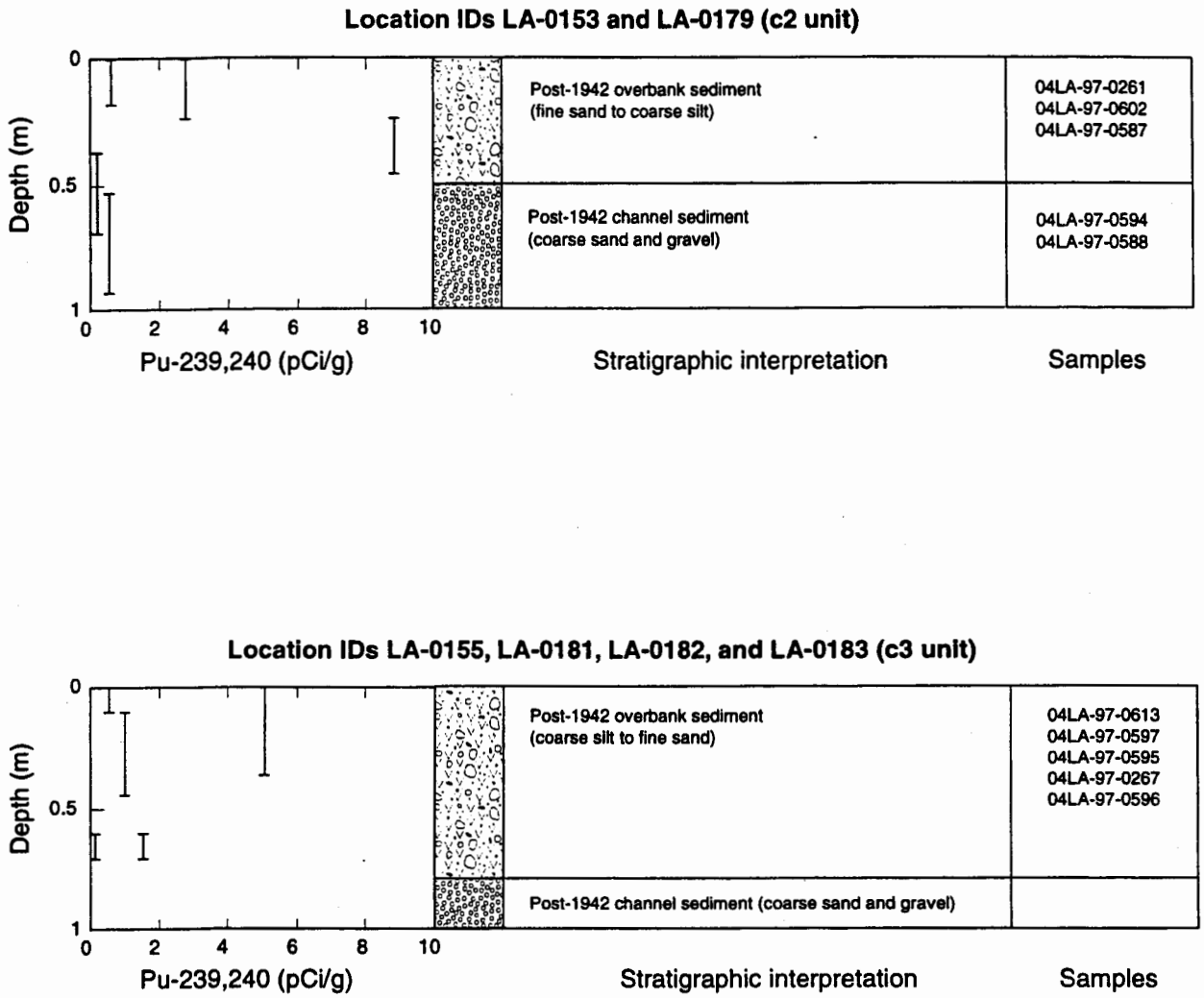
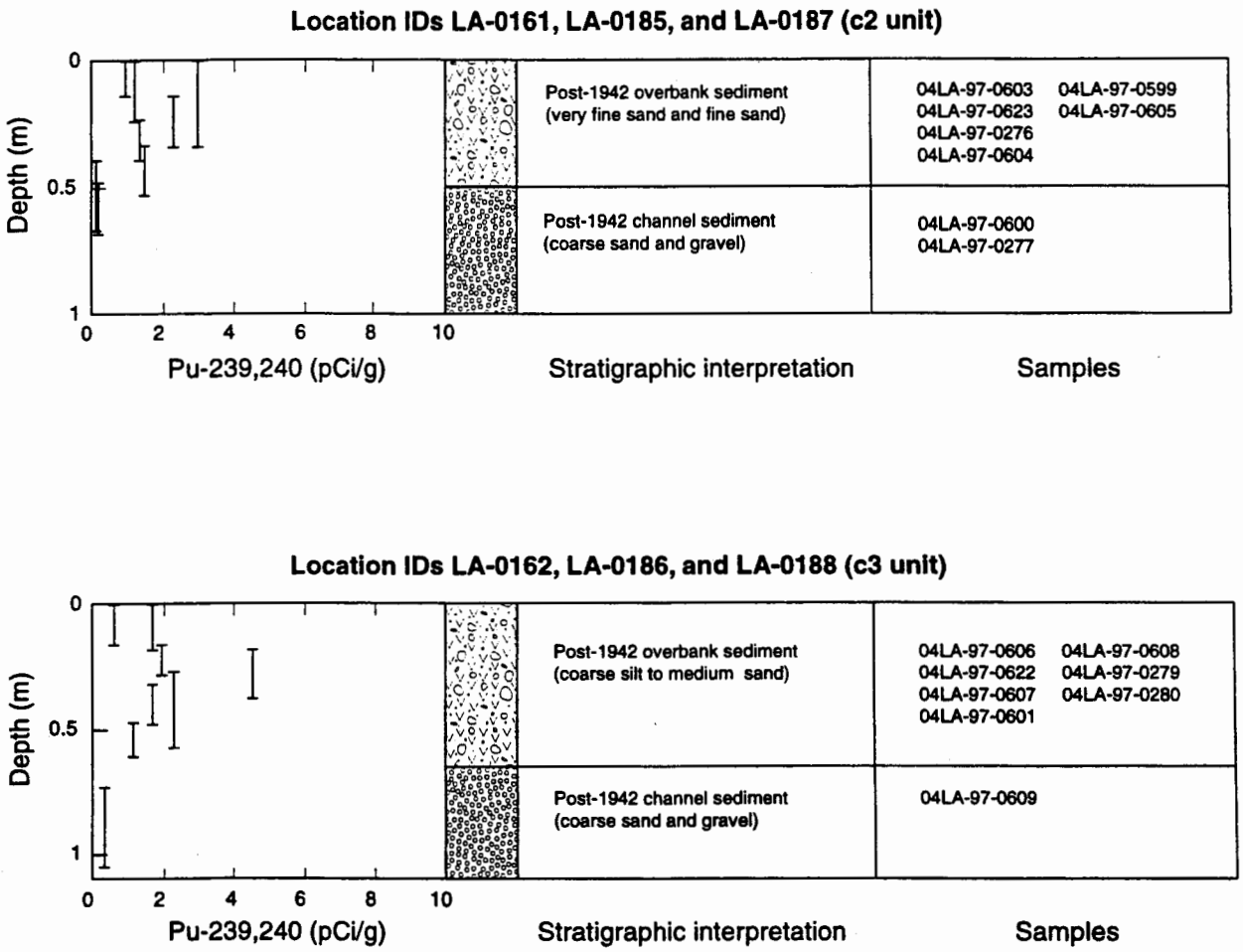


Figure 3.3-1. Depth variations in plutonium-239,240 concentration at sample sites in the c3 unit in reach LA-1 West.



F3.3-2 / UPPER LOS ALAMOS CANYON REACH RPT / 110998

Figure 3.3-2. Depth variations in plutonium-239,240 concentration at sample sites in reach LA-1 Central.



F3.3-3 / UPPER LOS ALAMOS CANYON REACH RPT / 110998

Figure 3.3-3. Depth variations in plutonium-239,240 concentration at sample sites in reach LA-1 East.

Figure 3.3-4 shows relations of plutonium-239,240 concentration to particle size and organic matter content for the combined data set of all samples from LA-1 West, LA-1 Central, and LA-1 East. Visual examination suggests that the strongest correlation is between plutonium concentration and silt and clay content and the weakest is between plutonium concentration and organic matter content, although positive correlations are suggested by all plots in Figure 3.3-4. Figure 3.3-4 also shows the generally low concentrations in samples with median particle sizes of 0.5 mm or greater, or those samples with median particle size classes of coarse sand or very coarse sand, further illustrating the importance of the finer-grained overbank facies sediment.

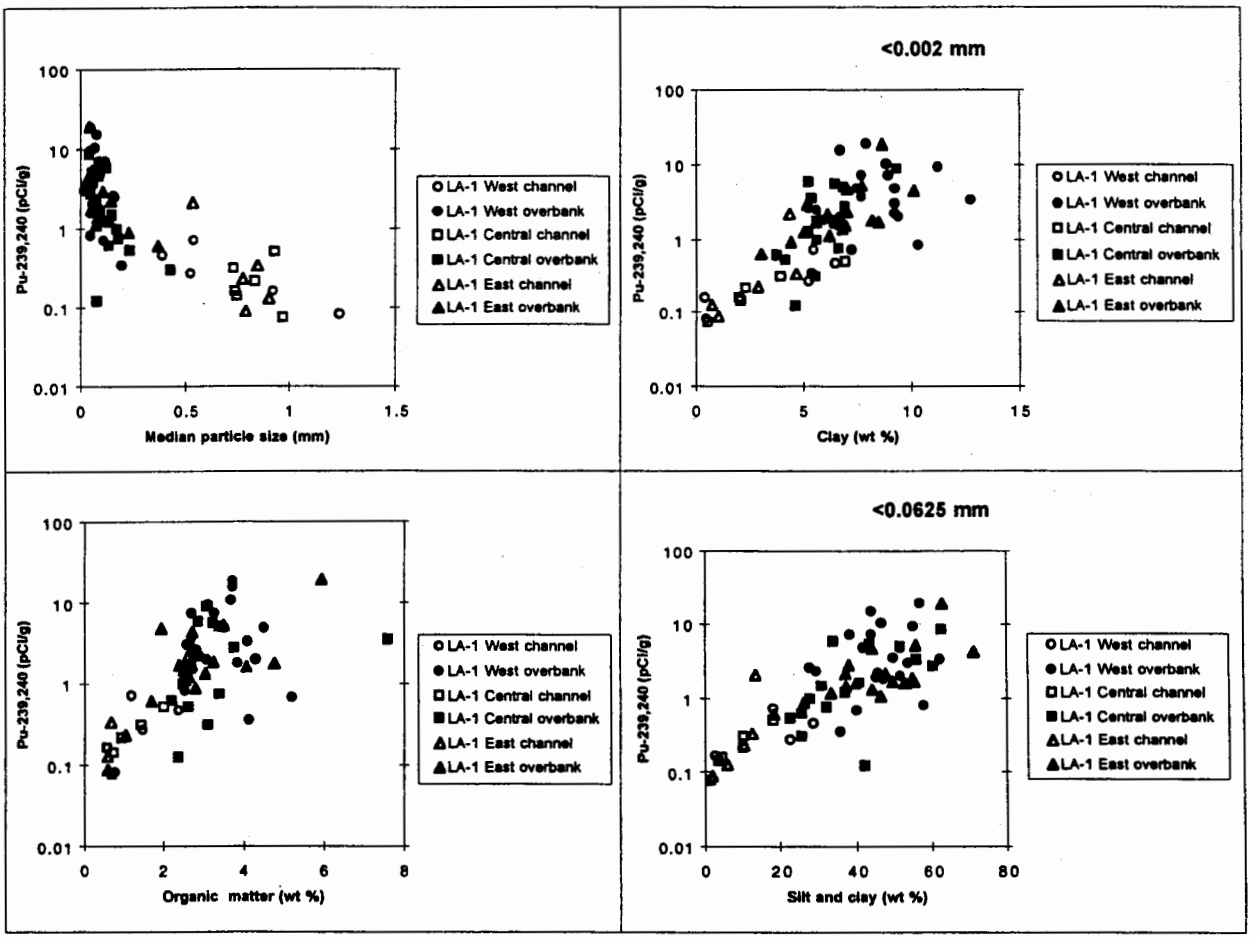
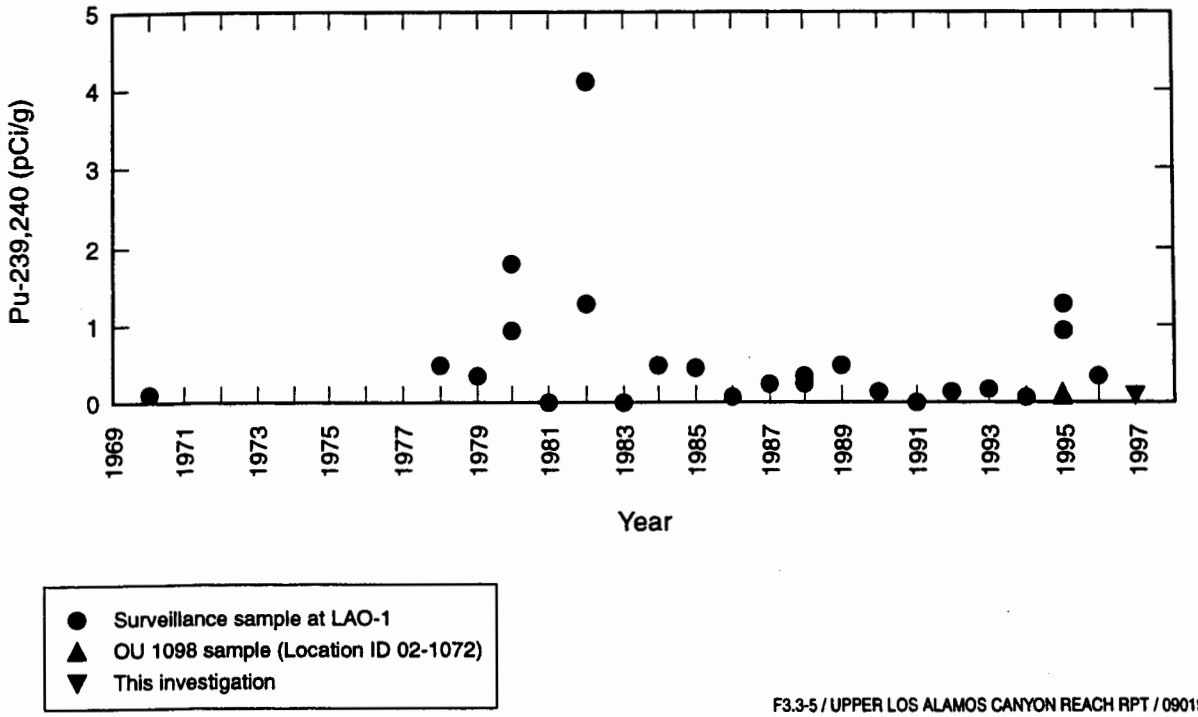


Figure 3.3-4. Scatter plots of plutonium-239,240 against particle size parameters and organic matter content for all samples from reaches LA-1 West, LA-1 Central, and LA-1 East.

Additional data on plutonium-239,240 concentrations in LA-1 sediments are available from samples collected from the environmental surveillance sampling station at LAO-1 within LA-1 Central that date back to 1970 (e.g., Environmental Surveillance and Compliance Programs 1997, 56684) (Figure 3.3-5). These data show a wide range in plutonium-239,240 concentration (0.001 to 4.1 pCi/g) and no systematic variations over time. Most data from this station are higher than the analysis obtained from the c1 unit of LA-1 Central in this investigation (0.076 pCi/g, Table 3.3-1) and are also higher than stream channel samples collected near this station in 1995 as part of OU 1098 investigations (0.078 to 0.12 pCi/g from Location ID 02-1072, Figure 3.3-5). Note that two surveillance samples collected in 1995 had reported

concentrations of 0.917 and 1.277 pCi/g, an order of magnitude higher than OU 1098 samples collected in the same year. It is possible that these large differences in plutonium-239,240 concentration in part result from variations in the percentage of silt and clay between samples, although particle size data are not available from the earlier samples to test this hypothesis. Because of these uncertainties, the plutonium data from the environmental surveillance station is not considered useful for evaluating possible trends in contaminant concentration over time.



F3.3-5 / UPPER LOS ALAMOS CANYON REACH RPT / 090198

Figure 3.3-5. Relation of plutonium-239,240 concentration to age from active channel sediment samples collected from reach LA-1 Central.

3.3.2.3 Contaminant Inventory

The estimated plutonium-239,240 inventory varies among the LA-1 subreaches associated with variations in estimated average plutonium concentrations (Table 3.3-3). The estimated inventory downstream of TA-1 contaminant sources is highest in LA-1 West (17.6 mCi/km) and is lowest immediately upstream in LA-1 West+ (0.9 mCi/km). By comparison, if all the post-1942 sediment in LA-1 West+ had plutonium-239,240 at the background value of 0.068 pCi/g, the total inventory would be 0.3 mCi/km; using the average plutonium-239,240 value from the sediment background data set of 0.025 pCi/g (McDonald et al. 1996, 55532) provides an estimated "background inventory" of 0.1 mCi/km. The estimated inventory is relatively high in LA-1 East (13.4 mCi/km) and relatively low in LA-1 Central (6.0 mCi/km).

TABLE 3.3-3

ESTIMATED PLUTONIUM INVENTORY IN REACH LA-1

Sediment Facies	Geomorphic Unit	Section	Area (m^2)	Estimated Average Thickness (m)	Estimated Volume (m^3)	Estimated Fraction <2 mm	Estimated Density (g/cm^3)	Estimated Average Plutonium-239,240 Concentration (pCi/g)	Estimated Plutonium-239,240 Inventory (mCi)	Percent of Total Subreach Inventory	Percent Potentially Susceptible to Remobilization	Estimated Inventory Most Susceptible to Remobilization (mCi)	Percent of Total Subreach Inventory Susceptible to Remobilization
LA-1 West+													
Channel	c1	All	198	0.5	99	0.5	1.23	0.02	0.00	1%	100%	0.00	1%
Channel	c2	Lower	108	0.5	54	0.5	1.23	0.04	0.00	1%	100%	0.00	1%
Channel	c3	Lower	334	0.5	167	0.5	1.23	0.04	0.00	3%	100%	0.00	3%
Subtotal			**640**		**320**				**0.01**	**5%**		**0.01**	**5%**
Overbank	c2	Upper	108	0.25	27	0.87	1.04	0.38	0.01	8%	100%	0.01	8%
Overbank	c3	Upper	334	0.42	140	0.91	1.04	0.38	0.05	42%	100%	0.05	42%
Overbank	f1	All	563	0.24	135	0.96	1.04	0.38	0.05	42%	10%	0.01	4%
Overbank	f2	All	514	0.02	10	0.96	1.04	0.38	0.00	3%	0%	0.00	0%
Subtotal					**313**				**0.11**	**95%**		**0.06**	**53%**
Total									**0.12**	**100%**			**59%**
LA-1 West													
Channel	c1	All	715	0.5	358	0.5	1.23	0.12	0.03	0%	100%	0.03	0%
Channel	c2	Lower	294	0.5	147	0.5	1.23	0.49	0.04	1%	100%	0.04	1%
Channel	c3	Lower	1610	0.5	805	0.5	1.23	0.49	0.24	4%	100%	0.24	4%
Subtotal			**2619**		**1310**				**0.31**	**5%**		**0.31**	**5%**
Overbank	c2	Upper	294	0.25	74	0.87	1.04	6.88	0.46	7%	100%	0.46	7%
Overbank	c3	Upper	1610	0.42	676	0.91	1.04	6.88	4.40	68%	100%	4.40	68%
Overbank	f1	All	2781	0.24	667	0.96	1.04	2.02	1.35	21%	10%	0.13	2%
Subtotal					**1417**				**6.21**	**95%**		**5.00**	**77%**
Total									**6.52**	**100%**			**81%**

TABLE 3.3-3 (continued)

ESTIMATED PLUTONIUM INVENTORY IN REACH LA-1

Sediment Facies	Geomorphic Unit	Section	Area (m^2)	Estimated Average Thickness (m)	Estimated Volume (m^3)	Estimated Fraction <2 mm	Estimated Density (g/cm^3)	Estimated Average Plutonium-239,240 Concentration (pCi/g)	Estimated Plutonium-239,240 Inventory (mCi)	Percent of Total Subreach Inventory	Percent Potentially Susceptible to Remobilization	Estimated Inventory Most Susceptible to Remobilization (mCi)	Percent of Total Subreach Inventory Susceptible to Remobilization
LA-1 Central													
Channel	c1	All	681	0.5	341	0.5	1.23	0.08	0.02	1%	100%	0.02	1%
Channel	c1b	All	29	0.5	15	0.5	1.23	0.08	0.00	0%	100%	0.00	0%
Channel	c2	Lower	806	0.5	403	0.5	1.23	0.36	0.09	4%	100%	0.09	4%
Channel	c3	Lower	740	0.5	370	0.5	1.23	0.21	0.05	2%	100%	0.05	2%
Subtotal			**2256**		**1128**				**0.15**	**7%**		**0.15**	**7%**
Overbank	c2	Upper	806	0.31	250	0.99	1.04	4.06	1.04	44%	100%	1.04	44%
Overbank	c3	Upper	740	0.22	163	0.95	1.04	2.27	0.37	16%	100%	0.37	16%
Overbank	f1	All	2953	0.11	325	0.95	1.04	2.27	0.73	31%	10%	0.07	3%
Overbank	f2	All	1269	0.02	25	0.95	1.04	2.27	0.06	2%	0%	0.00	0%
Subtotal					**763**				**2.20**	**93%**		**1.48**	**63%**
Total									**2.35**	**100%**			**70%**
LA-1 East													
Channel	c1	All	596	0.5	298	0.5	1.23	0.09	0.02	0%	100%	0.02	0%
Channel	c2	Lower	1202	0.5	601	0.5	1.23	0.18	0.07	1%	100%	0.07	1%
Channel	c3	Lower	967	0.5	484	0.5	1.23	1.27	0.38	7%	100%	0.38	7%
Subtotal			**2765**		**1383**				**0.46**	**8%**		**0.46**	**8%**
Overbank	c2	Upper	1202	0.30	361	0.94	1.04	1.87	0.66	11%	100%	0.66	11%
Overbank	c3	Upper	967	0.25	242	0.98	1.04	1.87	0.46	8%	100%	0.46	8%
Overbank	f1	All	3373	0.21	708	0.94	1.04	5.82	4.03	70%	10%	0.40	7%
Overbank	f2	All	1456	0.02	29	0.94	1.04	5.82	0.17	3%	0%	0.00	0%
Subtotal					**1340**				**5.32**	**92%**		**1.52**	**26%**
Total									**5.78**	**100%**			**34%**

Most of the estimated plutonium inventory in each subreach is contained within the relatively fine-grained overbank facies sediment deposits, and only 5 to 8% is contained within the coarse-grained channel facies sediment (Table 3.3-3). In LA-1 West the largest part, 68%, is estimated to be contained within overbank sediments of the c3 unit adjacent to the active channel. In LA-1 Central 44% of the estimated inventory is contained within overbank sediments of the c2 unit, also adjacent to the active channel. In contrast, 70% of the estimated inventory in LA-1 East is contained within overbank sediments in the f1 unit, which is mostly located away from the active channel. Therefore, most of the plutonium located within LA-1 West and LA-1 Central is judged to be susceptible to remobilization during floods over the next 50 years, and most of the plutonium located within LA-1 East is judged to be stable over this time frame.

3.3.3 Reach LA-2

3.3.3.1 Contaminant Concentrations

Concentrations of most radionuclide contaminants change dramatically between LA-2 West and LA-2 East, reflecting significant contributions of contaminants from DP Canyon. Americium-241, cesium-137, and plutonium-238 are each present at relatively low levels above background values in LA-2 West and increase significantly in concentration downstream from DP Canyon. Strontium-90 is apparently not present above the background value in sediments in LA-2 West but is a significant COPC downstream in LA-2 East (note that it was not possible to replicate strontium-90 results above the background value in LA-2 West, as discussed in Section 3.3.1.6, and these results are discounted as probably representing a laboratory bias). In contrast, the concentrations of plutonium-239,240 are similar in LA-2 West and LA-2 East, and the highest value was obtained upstream from DP Canyon (Table 3.3-4). In addition, the maximum plutonium-239,240 value obtained in LA-2 East is less than the maximum in each of the LA-1 subreaches downstream from Hillside 137. These observations suggest that the most significant sources of plutonium-239,240 in upper Los Alamos Canyon are located upstream from DP Canyon, although plutonium 239,240 has also been supplied from DP Canyon.

Concentrations of cesium-137 in most sediment samples downstream from DP Canyon are above the background value of 0.9 pCi/g, and all samples upstream from DP Canyon are below the background value except for one sample from the f1 unit (1.6 pCi/g in sample 04LA-96-0142). The highest levels of cesium in LA-2 occur in a thin subsurface layer of overbank facies sediment in the small c3 unit in LA-2 East, with a maximum of 192 pCi/g and an average of 153 pCi/g (Tables 3.3-4 and 3.3-5; Figures 2.3-11 and 3.3-6). Note that a higher value of 230 pCi/g was obtained upon resampling the same site that provided the analysis of 192 pCi/g (Figure 3.3-6) but that only the initial results are used for calculating averages. In contrast to the high values in the c3 unit, cesium-137 in overbank facies sediment of the widespread c2 unit and related layers within the c2b unit have a maximum of 33 pCi/g, an average of 13.5 pCi/g, and a median of 13 pCi/g. Intermediate concentrations of cesium-137, averaging 36 pCi/g, occur in subsurface layers within the c2b unit.

Concentrations of cesium-137 in coarse-grained channel facies sediment in LA-2 East show patterns similar to the fine-grained overbank facies sediment, and concentrations are highest in the c3 unit. Cesium-137 in channel facies sediment averages 31 and 45 pCi/g for upper and lower layers in the c3 unit, 6.1 pCi/g in the c2 unit, and 2.5 pCi/g in c1.

TABLE 3.3-4

RADIONUCLIDE ANALYSES FROM REACH LA-2

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
LA-2 West (Upstream from DP Canyon)															
c1	LA-0017	0–3	0–8	Channel	1	04LA-96-0141	0.034 (U)[c]	0.15 (U)	0.12 (U)	0.005 (U)	0.211	0.66 (U)	cs	s	Full-suite sample
c2	LA-0041	0–5	0–13	Overbank	2	04LA-96-0215	NA[d]	<0.29 (U)	0.33 (J)[e]	NA	NA	2.4 (J+)[f]	vfs	sl	
		0–5	0–13	Overbank	4	04LA-97-0569	0.035	NA	NA	0.0121 (U)	1.336 (J)	0.28 (U)	NA	NA	Layer resampled for limited suite
		8–11	20–28	Overbank	2	04LA-96-0216	NA	<0.25 (U)	0.38 (J)	NA	NA	3.3 (J+)	fs	sl	
		8–11	20–28	Overbank	4	04LA-97-0570	0.104	NA	NA	0.039	10.62 (J)	0.45 (J+)	NA	NA	Layer resampled for limited suite
		16–20	41–51	Channel	2	04LA-96-0217	NA	<0.24 (U)	0.32 (J)	NA	NA	3.7 (J+)	cs	gls	
		24–28	61–71	Channel	2	04LA-96-0218	NA	<0.25 (U)	0.28 (J)	NA	NA	3.1 (J+)	ms	gls	
		16–28	41–71	Channel	4	04LA-97-0621	NA	NA	NA	-0.0038 (U)	0.943 (J)	NA	NA	NA	Layer resampled for plutonium
c2	LA-0092	0–5.5	0–14	Overbank	3	04LA-97-0096	NA	NA	NA	0.017 (U)	0.982	0.08 (U)	fs	sl	
		0–5.5	0–14	Overbank	3	04LA-97-0097	NA	NA	NA	0.026 (U)	1.36	0.01 (U)	NA	NA	QA duplicate
		5.5–12.5	14–32	Overbank	3	04LA-97-0052	NA	0.058 (U)	0.634	0 (U)	1.3	-0.06 (U)	vfs	sl	Limited-suite sample
		12.5–17	32–44	Overbank	3	04LA-97-0098	NA	NA	NA	0.069	5.4	0.18 (U)	fs	gsl	
		17–24	44–60	Channel	3	04LA-97-0099	NA	NA	NA	-0.004 (U)	0.843 (U)	0.24 (U)	cs	gs	
c2	LA-0192	0–8	0–20	Overbank	4	04LA-97-0615	NA	NA	NA	0.04	2.28 (J)	NA	vfs	sl	
		15.5–20.5	39–52	Overbank	4	04LA-97-0616	NA	NA	NA	0.021 (U)	2.99 (J)	NA	vfs	sl	
		15.5–20.5	39–52	Overbank	4	04LA-97-0617	NA	NA	NA	0.043	2.82 (J)	NA	NA	NA	QA duplicate
		20.5–37.5	52–95	Channel	4	04LA-97-0618	NA	NA	NA	0.0006 (U)	0.378 (J)	NA	ms	gsl	
		20.5–37.5	52–95	Channel	4	04LA-97-0619	NA	NA	NA	0.0163 (U)	0.275 (J)	NA	NA	NA	QA duplicate
c3	LA-0093	0–4	0–10	Overbank	3	04LA-97-0103	NA	NA	NA	0.049	1.49	0.23 (U)	vfs	gsl	
c3	LA-0094	0–8	0–3	Overbank	3	04LA-97-0104	NA	NA	NA	0.007 (U)	0.595	0.15 (U)	vfs	sl	

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand

b. sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel

c. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

d. NA = not analyzed

e. 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.

f. J+ = The analyte was positively identified, and the reported value is an estimate and likely biased high.

TABLE 3.3-4 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-2

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
LA-2 West (Upstream from DP Canyon)															
c3	LA-0190	8.5–12.5	22–32	Overbank	4	04LA-97-0612	NA[c]	NA	NA	0.0282	1.64 (J)[d]	NA	csl	sl	
c3	LA-0191	0–8	0–20	Channel	4	04LA-97-0614	NA	NA	NA	0.0088 (U)[e]	0.731 (J)	NA	ms	gsl	
f1 (c3?)	LA-0018	0–3	0–8	Overbank	1	04LA-96-0142	0.043 (U)	0.15 (U)	1.6	0.01 (U)	1.31	0.77 (U)	fs	ls	Full-suite sample
f1	LA-0189	0–11.5	0–29	Overbank	4	04LA-97-0610	NA	NA	NA	0.0075 (U)	1.033 (J)	NA	fs	sl	
		16.5–22.5	42–57	Overbank	4	04LA-97-0611	NA	NA	NA	0.0352	3.18 (J)	NA	csl	sl	
f1	LA-0193	0–4.5	0–11	Overbank	4	04LA-97-0620	NA	NA	NA	0.0186 (U)	1.216 (J)	NA	csl	sil	
Qt2? (f2?)	LA-0095	0–4.5	0–11	Overbank	3	04LA-97-0100	NA	NA	NA	0.003 (U)	0.085	0.29 (U)	fs	ls	Background?
LA-2 East (downstream of DP Canyon)															
c1	LA-0023	0–4	0–10	Channel	1	04LA-96-0147	0.278	0.15 (U)	2.12	0.027 (U)	0.22	1.04	cs	s	Full-suite sample
c1	LA-0098	0–8	0–20	Channel	3	04LA-97-0060	NA	0.47 (U)	2.88	0.061	0.314	1.22	cs	s	
c2	LA-0019	0—6	0–15	Overbank	1	04LA-96-0143	1.245	1.13	5.77	0.309	0.632	2.21	ms	s	Full-suite sample
c2	LA-0019 (0043)	7–10	18–25	Overbank	2	04LA-96-0225	NA	8.3	13	NA	NA	5.8 (J+)[f]	fs	sl	
		14–17	36–43	Overbank	2	04LA-96-0226	NA	17	21	NA	NA	6.9 (J+)	csl	sil	
		19–22	48–56	Overbank	2	04LA-96-0227	NA	2.5	9.2	NA	NA	4.1 (J+)	vfs	sl	
c2	LA-0022	0–3	0–8	Overbank	1	04LA-96-0146	1.136	0.77	4.76	0.091	0.54	1.91	ms	s	Full-suite sample
c2	LA-0022 (0039)	8–12	20–30	Overbank	2	04LA-96-0205	NA	28	25	NA	NA	NA	vfs	l	
		8–12	20–30	Overbank	3	04LA-97-0053	NA	23.1	22.4	1.17	4	4.38	csl	gsl	Layer resampled for limited suite
		16–19	41–48	Overbank	2	04LA-96-0206	NA	21	20	NA	NA	3.3 (J+)	vfs	sl	
		21–25	53–64	Channel	2	04LA-96-0207	NA	2.3	5.7	NA	NA	4 (J+)	cs	gs	
c2	LA-0103	14–22	35–55	Channel	3	04LA-97-0085	NA	1.21	9.71	NA	NA	NA	cs	gls	

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csl = coarse to medium silt

b. l = loam, sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel

c. NA = not analyzed

d. 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.

e. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

f. J+ = The analyte was positively identified, and the reported value is an estimate and likely biased high.

TABLE 3.3-4 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-2

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
LA-2 East (downstream of DP Canyon)															
c2	LA-0105	0–5	0–13	Overbank	3	04LA-97-0087	NA[c]	2.17	7.26	NA	NA	NA	fs	sl	
		5–7.5	13–19	Overbank	3	04LA-97-0088	NA	18.4	14	NA	NA	NA	vfs	gsl	
		7.5–12	19–30	Overbank	3	04LA-97-0075	NA	9.72	19.3	0.509	2.5	NA	vfs	gsl	
		16–31.5	40–80	Channel	3	04LA-97-0089	NA	2.07	8.2	NA	NA	NA	cs	gls	
c2	LA-0106	0–4.5	0–11	Overbank	3	04LA-97-0065	NA	1.56	5.46	0.183	0.931	1.45	fs	ls	
		8–14	20–35	Overbank	3	04LA-97-0066	NA	0.118 (U)[d]	32.9	0.05	2.39	6.16	fs	sl	
		14–19.5	35–50	Overbank	3	04LA-97-0067	NA	0.236	0.647	0.013 (U)	6.39	0.84	ms	sl	
		21.5–31	55–80	Channel	3	04LA-97-0068	NA	0.092 (U)	0.59	-0.008 (U)	0.45	-0.03 (U)	cs	gls	
c2	LA-0107	0–7	0–18	Overbank	3	04LA-97-0090	NA	1.66	6.04	NA	NA	NA	ms	s	
		7–15	18–39	Overbank	3	04LA-97-0091	NA	6.34	15.8	NA	NA	NA	fs	gsl	
		15–20.5	39–65	Overbank	3	04LA-97-0076	NA	1.46	21.1	0.395	2.35	NA	vfs	gsl	
c2b	LA-0020	0–6	0–15	Overbank	1	04LA-96-0144	1.242	1.06	5.52	0.155	0.653	1.86	ms	s	Full-suite sample
c2b	LA-0020 (0040)	8–12	20–30	Overbank	2	04LA-96-0211	NA	7	13	NA	NA	NA	fs	sl	
		15–19	38–48	Overbank	2	04LA-96-0212	NA	9.4	38	NA	NA	NA	fs	sl	
c2b	LA-0020 (0021)	25–29	64–74	Overbank	1	04LA-96-0145	1.372	1.23	34.53	0.189	2.31	1.27	fs	ls	Full-suite sample
c2b	LA-0104	0–3	0–7	Overbank	3	04LA-97-0061	NA	3.28	8.53 (U)	2.01	3.16	1.52	fs	sl	
		3–10.5	7–27	Overbank	3	04LA-97-0062	NA	12.1	22.1	0.652	2.63	2.82	vfs	sl	
		11–15.5	28–39	Overbank	3	04LA-97-0063	NA	3.46	35.2	0.248	2.24	1.88	vfs	sl	
		16–31.5	40–80	Channel	3	04LA-97-0064	NA	0.787	11.2	0.056	1.59	0.27 (U)	cs	gls	
c3 (NE)	LA-0024 (0025)	0–6	0–15	Channel	1	04LA-96-0148	0.348	0.17 (U)	27.85	0.028 (U)	0.95	3.93	cs	s	Full-suite sample
		6–9	15–23	Channel	2	04LA-96-0220	NA	<1.1 (U)	25	NA	NA	13 (J+)[e]	ms	sl	
		13–18	33–46	Channel	2	04LA-96-0221	NA	<1 (U)	39	NA	NA	9.3 (J+)	cs	s	

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand

b. sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel

c. NA = not analyzed

d. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

e. J+ = The analyte was positively identified, and the reported value is an estimate and likely biased high.

TABLE 3.3-4 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-2

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
LA-2 East (downstream of DP Canyon)															
c3 (NE)	LA-0024 (0025)	26–32	66–81	Overbank	1	04LA-96-0149	1.508	1.68	192.31	0.07	5.41	39.56	ms	sl	Full-suite sample
		29–32	74–81	Overbank	2	04LA-96-0222	NA[c]	<1.6 (U)[d]	230	NA	NA	36 (J+)[e]	csl	gsll	Layer resampled
		35–39	89–99	Channel	2	04LA-96-0223	NA	1.6 U (U)	170	NA	NA	17 (J+)	cs	s	
		45–48	114–122	Channel	2	04LA-96-0224	NA	0.6 (J)[f]	18	NA	NA	6 (J+)	ms	s	
		50–58	127–147	Channel	2	04LA-96-0229	NA	0.48 (U)	8	NA	NA	4.9 (J+)	cs	gs	
c3 (NE)	LA-0097	24–33	60–83	Overbank	3	04LA-97-0057	NA	2.28	146	0.126	4.85	13.5	csl	gsll	
		33–39	83–98	Channel	3	04LA-97-0058	NA	0.655	19.2	0.079	2.74	1.53	cs	s	
		39–46	98–118	Channel	3	04LA-97-0059	NA	0.463	11.3	0.031 (U)	2.17	0.28 (U)	cs	gs	
c3 (SW)	LA-0096	0–6	0–15	Overbank?	3	04LA-97-0054	NA	1.46	121	0.07	3.89	30.2	ms	gls	
		0–6	0–15	Overbank?	3	04LA-97-0055	NA	1.5	122	0.054	4.39	34.6	NA	NA	QA duplicate
		6–12	15–30	Overbank	3	04LA-97-0056	NA	0.266 (U)	29.5	0.035 (U)	0.851	27.1	fs	sl	
f1	LA-0100	0–1	0–3	Overbank	3	04LA-97-0072	NA	-0.223 (U)	0.464	-0.002 (U)	0.043	NA	csl	l	Background?
f1	LA-0101	0–4	0–10	Overbank	3	04LA-97-0073	NA	0.288	21.9	0.006 (U)	0.88	NA	ms	s	
f1	LA-0108	0–3	0–7	Overbank	3	04LA-97-0077	NA	1.2	5.57	0.089	1.08	NA	vfs	sl	
		4.5–8.5	11–22	Overbank	3	04LA-97-0078	NA	0.57 (U)	1.32	0.073	0.426	NA	vfs	gsl	
f1b	LA-0099	0–3.5	0–9	Overbank	3	04LA-97-0071	NA	0.299 (U)	54.5	0.058	2.39	NA	csl	sl	
Qt3	LA-0102	0–5	0–12	Overbank	3	04LA-97-0074	NA	0.102 (U)	0.243	0.001 (U)	0.017 (U)	NA	fs	sl	Background?
DP Canyon															
c2b	LA-0016	0–3	0–8	Overbank	1	04LA-96-0140	3.954	2.74	87.82	0.688	4.15	9.87	fs	gls	Full-suite sample

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csl = coarse to medium silt

b. l = loam, sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel

c. NA = not analyzed

d. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

e. J+ = The analyte was positively identified, and the reported value is an estimate and likely biased high.

f. 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.

TABLE 3.3-5

SUMMARY OF BINNED ANALYSES IN REACH LA-2

Geomorphic Unit and Sediment Facies	Summary Statistic	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]	Pu-239/238 ratio	Am-241/ Pu-239 ratio[c]	Cs-137/ Am-241 ratio
LA-2 West (upstream from DP Canyon)												
c1 channel	average	0.15	0.12	0.005	0.211	0.660	cs	0.815	s	42	0.71	1
	n	1	1	1	1	1						
c2 overbank	average	0.20	0.45	0.03	3.56	1.18	vfs	0.108	sl	126	0.0	2
	std. dev.	0.12	0.16	0.02	3.46	1.56						
	maximum	0.29	0.63	0.07	10.62	3.30						
	minimum	0.06	0.33	0.00	0.98	-0.06						
	median	0.25	0.38	0.02	2.28	0.18						
	n	3	3	7	7	5						
c2 and c3 channel	average	0.25	0.30	0.000	0.72	2.35	cs	0.548	gls	N/A[d]	NA[e]	1
	std. dev.	0.01	0.03	0.006	0.25	1.85						
	maximum	0.25	0.32	0.009	0.94	3.70						
	minimum	0.24	0.28	-0.004	0.38	0.24						
	median	0.25	0.30	-0.002	0.79	3.10						
	n	2	2	4	4	3						
c3 and f1 overbank	average	0.15	1.60	0.022	1.49	0.38	vfs	0.082	sl	67	0.1	11
	std. dev.	N/A	N/A	0.016	0.82	0.34						
	maximum	N/A	N/A	0.049	3.18	0.77						
	minimum	N/A	N/A	0.007	0.60	0.15						
	median	N/A	N/A	0.019	1.31	0.23						
	n	1	1	7	7	3						

a. cs = coarse sand, vfs = very fine sand

b. sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel

c. These ratios calculated only for samples or paired samples from same sediment layer that have both analyses.

d. N/A = not applicable

e. NA = not analyzed

TABLE 3.3-5 (continued)

SUMMARY OF BINNED ANALYSES IN REACH LA-2

Geomorphic Unit and Sediment Facies	Summary Statistic	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]	Pu-239/238 ratio	Am-241/ Pu-239 ratio[c]	Cs-137/ Am-241 ratio
LA-2 West (upstream from DP Canyon)												
Qt2 overbank (background?)	average	N/A[d]	N/A	0.003	0.085	0.29	fs	0.175	ls	28	NA[e]	NA
	n	N/A	N/A	1	1	1						
DP Canyon												
c2b overbank	average	2.74	87.82	0.69	4.15	9.87	fs	0.164	gls	6	0.7	32
	n	1	1	1	1	1						
LA-2 East (downstream from DP Canyon)												
c1 channel	average	0.31	2.50	0.044	0.27	1.13	cs	0.713	s	6	1.2	8
	std. dev.	0.23	0.54	0.024	0.07	0.13						
	maximum	0.47	2.88	0.061	0.31	1.22						
	minimum	0.15	2.12	0.027	0.22	1.04						
	median	0.31	2.50	0.044	0.27	1.13						
	n	2	2	2	2	2						
c2 and c2b (0–0.3 m) overbank	average	7.19	13.52	0.50	2.380	3.33	fs	0.142	sl	5	1.4	2
	std. dev.	8.11	8.42	0.60	1.758	1.98						
	maximum	28.00	32.90	2.01	6.390	6.90						
	minimum	0.12	0.65	0.01	0.540	0.84						
	median	2.89	13.00	0.31	2.390	2.82						
	n	20	20	11	11	13						
c2 channel	average	1.42	6.05	-0.008	0.450	1.99	cs	0.620	gls	N/A	0.2	4
	std. dev.	1.00	4.00	N/A	N/A	2.85						
	maximum	2.30	9.71	N/A	N/A	4.00						

a. cs = coarse sand, fs = fine sand
b. sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel
c. These ratios calculated only for samples or paired samples from same sediment layer that have both analyses.
d. N/A = not applicable
e. NA = not analyzed

TABLE 3.3-5 (continued)

SUMMARY OF BINNED ANALYSES IN REACH LA-2

Geomorphic Unit and Sediment Facies	Summary Statistic	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]	Pu-239/238 ratio	Am-241/ Pu-239 ratio[c]	Cs-137/ Am-241 ratio
LA-2 East (downstream from DP Canyon)												
c2 channel	minimum	0.09	0.59	N/A[d]	N/A	-0.03						
	median	1.64	6.95	N/A	N/A	1.99						
	n	4	4	1	1	2						
c2b (0.3–0.55 m) overbank	average	4.70	35.91	0.22	2.28	1.58	fs	0.147	sl	10	1.0	8
	std. dev.	4.22	1.84	0.04	0.05	0.43						
	maximum	9.40	38.00	0.25	2.31	1.88						
	minimum	1.23	34.53	0.19	2.24	1.27						
	median	3.46	35.20	0.22	2.28	1.58						
	n	3	3	2	2	2						
c2b channel	average	0.79	11.20	0.06	1.59	0.27	cs	0.673	gls	28	0.5	14
	n	1	1	1	1	1						
c3 channel (upper NE)	average	0.89	30.62	0.03	0.95	8.74	cs	0.758	s	34	0.2	40
	std. dev.	0.15	7.40	N/A	N/A	4.56						
	maximum	1.00	39.00	N/A	N/A	13.00						
	minimum	0.79	25.00	N/A	N/A	3.93						
	median	0.89	27.85	N/A	N/A	9.30						
	n	2	3	1	1	3						
c3 overbank (middle NE and upper SW)	average	1.81	153.10	0.089	4.72	27.75	vfs	0.105	gsl	53	0.4	85
	std. dev.	0.42	36.18	0.032	0.77	13.20						
	maximum	2.28	192.31	0.126	5.41	39.56						

a. cs = coarse sand, fs = fine sand, vfs = very fine sand

b. sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel

c. These ratios calculated only for samples or paired samples from same sediment layer that have both analyses.

d. N/A = not applicable

TABLE 3.3-5 (continued)

SUMMARY OF BINNED ANALYSES IN REACH LA-2

Geomorphic Unit and Sediment Facies	Summary Statistic	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]	Pu-239/238 ratio	Am-241/ Pu-239 ratio[c]	Cs-137/ Am-241 ratio
LA-2 East (downstream from DP Canyon)												
c3 overbank (middle NE and upper SW)	minimum	1.46	121.00	0.070	3.89	13.50						
	median	1.68	146.00	0.070	4.85	30.20						
	n	3	3	3	3	3						
c3 channel (lower NE)	average	0.76	45.30	0.055	2.46	5.94	cs	0.699	gs	45	0.2	60
	std. dev.	0.48	69.86	0.034	0.40	6.61						
	maximum	1.60	170.00	0.079	2.74	17.00						
	minimum	0.46	8.00	0.031	2.17	0.28						
	median	0.60	18.00	0.055	2.46	4.90						
	n	5	5	2	2	5						
c3 overbank (lower SW)	average	0.27	29.50	0.035	0.85	27.10	fs	0.140	sl	24	0.3	111
	n	1	1	1	1	1						
f1 overbank	average	0.46	7.31	0.04	0.61	NA[d]	vfs	0.104	sl	15	0.8	16
	std. dev.	0.59	9.98	0.05	0.47	NA						
	max	1.20	21.90	0.09	1.08	NA						
	min	-0.22	0.46	0.00	0.04	NA						
	median	0.43	3.45	0.04	0.65	NA						
	n	4	4	4	4	0						
f1b overbank	average	0.30	54.50	0.058	2.39	NA	csl	0.056	sl	41	0.1	182
	n	1	1	1	1	0						
Qt3 overbank (background?)	average	0.10	0.24	0.001	0.017	NA	fs	0.179	sl	17	6.0	2
	n	1	1	1	1	0						

a. cs = coarse sand, fs = fine sand, vfs = very fine sand, csl = coarse silt

b. sl = sandy loam, s = sand, g = ≥20% gravel

c. These ratios calculated only for samples or paired samples from same sediment layer that have both analyses.

d. NA = not analyzed

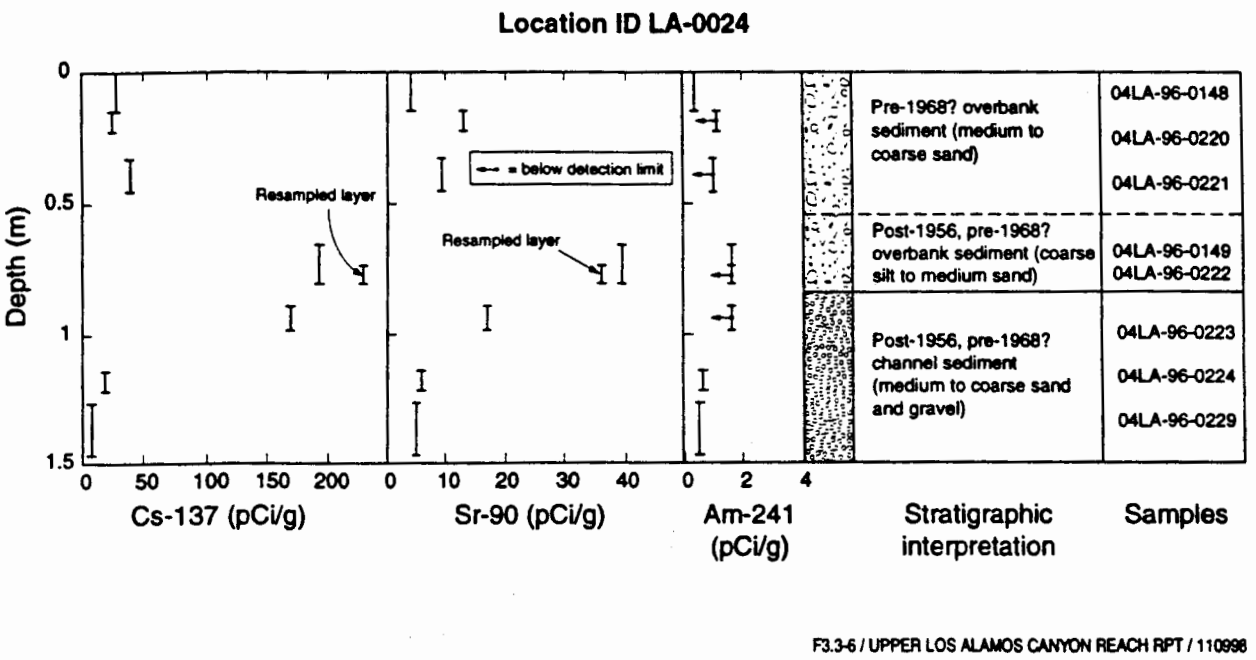


Figure 3.3-6. Depth variations in cesium-137, americium-241, and strontium-90 concentrations at sample sites in the c3 unit in reach LA-2 East.

Concentrations of strontium-90 in LA-2 East show variations similar to those seen with cesium-137. The maximum value for strontium-90 was obtained in thin overbank sediment layers in the c3 unit, with a maximum of 40 pCi/g and an average of 28 pCi/g (Tables 3.3-4 and 3.3-5; Figure 3.3-6). Strontium-90 in the widespread c2 unit has a maximum value of 6.4 pCi/g and an average value of 3.4 pCi/g. Concentrations in coarse-grained channel facies sediment are less than in the overbank facies sediments, averaging 8.7 and 5.9 pCi/g in the upper and lower c3 channel units, 2.0 pCi/g in the c2 unit, and 1.1 pCi/g in c1.

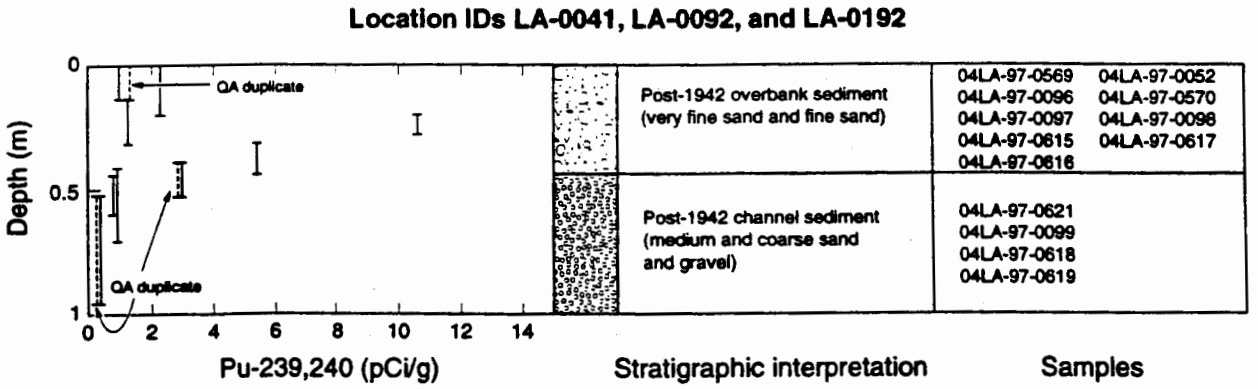
Concentrations of plutonium-239,240 in most sediment samples in LA-2 are above the background value of 0.068 pCi/g (Table 3.3-4). In LA-2 West, the highest concentrations were obtained from overbank sediments in the c2 unit, with a maximum concentration of 10.6 pCi/g, an average of 3.6 pCi/g, and a median of 2.3 pCi/g (Table 3.3-5). Concentrations in overbank sediments of the c3 and f1 units are lower, with an average of 1.5 pCi/g and a median of 1.3 pCi/g. Plutonium-239,240 is lower in channel facies sediment samples, with an average of 0.7 pCi/g and a median of 0.8 pCi/g in samples from the c2 and c3 units.

In LA-2 East, the highest concentration of plutonium-239,240 (6.4 pCi/g) was obtained from an overbank sediment sample from the c2 unit, although averages and medians are higher in the c3 unit (Tables 3.3-4 and 3.3-5). Plutonium-239,240 in overbank sediments averages 4.7 pCi/g in c3 and 2.4 pCi/g in c2. Few plutonium-239,240 analyses were obtained in channel facies sediment in LA-2 East, but values from the c3 unit (0.95 to 2.7 pCi/g) are higher than obtained from c2 (0.45 pCi/g) and c1 (0.27 pCi/g).

Americium-241 and plutonium-238 show much different distributions in the various geomorphic units and sediment facies in LA-2 East than displayed by the other radionuclides. Both show highest concentrations in overbank facies layers within the c2 unit, with maximums of 28 pCi/g for americium-241 and 2.0 pCi/g for plutonium-238; averages in this unit are 7.2 and 0.5 pCi/g, respectively (Tables 3.3-4 and 3.3-5). In contrast, americium-241 in overbank facies sediment averages only 1.8 pCi/g in the c3 unit and 4.7 pCi/g in the c2b unit. These variations between units are related to variations in the release history from the 21-011(k) outfall, as discussed in Section 3.3.3.2. Both americium-241 and plutonium-238 are present at lower concentrations in the coarse-grained channel facies sediment, with americium-241 averaging 1.4 pCi/g in c2 channel facies sediment samples.

3.3.3.2 Age and Particle Size Relations

Age control for sediment samples from LA-2 West are not sufficient to confidently evaluate possible trends in plutonium-239,240 concentration over time although, as discussed for reach LA-1 (Section 3.3.2.2), relatively high concentrations may occur in relatively young deposits. The highest plutonium-239,240 value obtained from LA-2 West is from a subsurface layer in the relatively young c2 unit (10.6 pCi/g in sample 04LA-97-0570, Table 3.3-4); concentrations from samples on the c3 and f1 units that are inferred to be from older post-1942 sediment deposits are lower. Lower concentrations have also been obtained from texturally similar c2 sediments that are younger than sample 04LA-97-0570 (surface samples, Figure 3.3-7).



F3.3-7 / UPPER LOS ALAMOS CANYON REACH RPT / 110998

Figure 3.3-7. Depth variations in plutonium-239,240 concentration at sample sites in the c2 unit in reach LA-2 West.

Time-dependent trends in contaminant concentration are relatively well defined in LA-2 East, with age control largely provided by changes in the ratios of various isotopes that were released from TA-21 into DP Canyon (Section 3.3.1.5). The c3 and f1b units have relatively high plutonium 239/238 ratios, averaging 34 to 53 in the different overbank and channel units (Table 3.3-5) and are inferred to predate the beginning of major use of plutonium-238 at the Laboratory in 1968; these units are also inferred to postdate the first recorded releases from outfall 21-011(k) in 1956, although the possibility of earlier undocumented releases cannot be ruled out. Plutonium 239/238 ratios in the c2 overbank sediments and

the c1 channel sediments are much lower, averaging 5 to 6, and postdate 1968. Ratios of americium-241 to plutonium-239,240 and cesium-137 indicate that most of the c2 overbank sediments postdate an increase in americium-241 releases from 21-011(k) in 1978. Isotopic ratios in the subsurface c2b overbank sediments are intermediate between those in the c3 and c2 units and are inferred to approximately date to the period from 1968 to 1978.

A clear trend of decreases in both cesium-137 and strontium-90 over time are recorded in the sediment data from LA-2 East. Cesium-137 concentrations were highest before 1968 when the c3 and f1b sediments were being deposited, decreased by the time subsurface layers in the c2b unit were deposited (1968 to 1978?), and decreased further by the time the typical c2 overbank sediments were deposited after 1978. Strontium-90 concentrations also decreased between deposition of the c3 and c2 units.

In contrast to the decreases in cesium-137 and strontium-90 over time, americium-241 and plutonium-238 concentrations were highest in LA-2 East during deposition of the c2 overbank sediments after 1978. As discussed earlier, these increases can be attributed to changes in the release history from outfall 21-011(k). Data are not sufficient to determine if concentrations of these radionuclides have been decreasing in the recent past, since effluent releases stopped in 1985. Within the c2 unit, highest americium-241 concentrations are found in subsurface layers (Figure 3.3-8), but these layers are also typically finer grained than surface layers, and the variations in americium-241 content may largely reflect particle size variations.

At some LA-2 East sample sites the changes in contaminant concentrations and contaminant ratios over time are expressed as vertical variations between different flood layers. For example, in both sampled c2b sections, sediments that are inferred to date to the period from 1968 to 1978 (based on relatively high cesium/americium ratios) are buried beneath sediment dating to 1978 or later (Figure 3.3-9). At one c2 sample site (LA-0106, Figure 3.3-8), the deepest overbank sediment layer yielded the highest plutonium-239,240 concentration in LA-2 East but low cesium-137 concentrations, suggesting a flood layer that predated major releases from 21-011(k). Cesium-137 is relatively high in the overlying layer (34 pCi/g), and isotopic ratios suggest a pre-1968 age. This layer is in turn buried by overbank sediments with typical post-1978 isotopic ratios.

Additional data on possible time-dependent trends in radionuclide concentrations in LA-2 sediments are available from samples collected from environmental surveillance sampling stations in lower DP Canyon and in LA-2 East that date back to 1968 (e.g., Environmental Surveillance and Compliance Programs 1997, 56684) (Figures 3.3-10 and 3.3-11). All of these samples are presumed to represent active channel sediments, although the particle size distribution of these samples is unknown. Despite variability in the data, the results from lower DP Canyon (station DPS-4) suggest significant decreases in the concentrations of cesium-137; plutonium-239,240; and strontium-90 over this time period (Figure 3.3-10), in turn suggesting decreases in the concentrations of these radionuclides in sediments supplied to Los Alamos Canyon. The data from stations at LAO-3 or nearby at test well (TW) -3 within LA-2 East are less conclusive, but possible decreases in the concentrations of both cesium-137 and plutonium-239,240 are suggested (Figure 3.3-11). Note that decreases in cesium-137 and strontium-90 concentration will occur naturally during this time period because of radioactive decay, but such decay would account for only a small part of the trends suggested in these surveillance data.

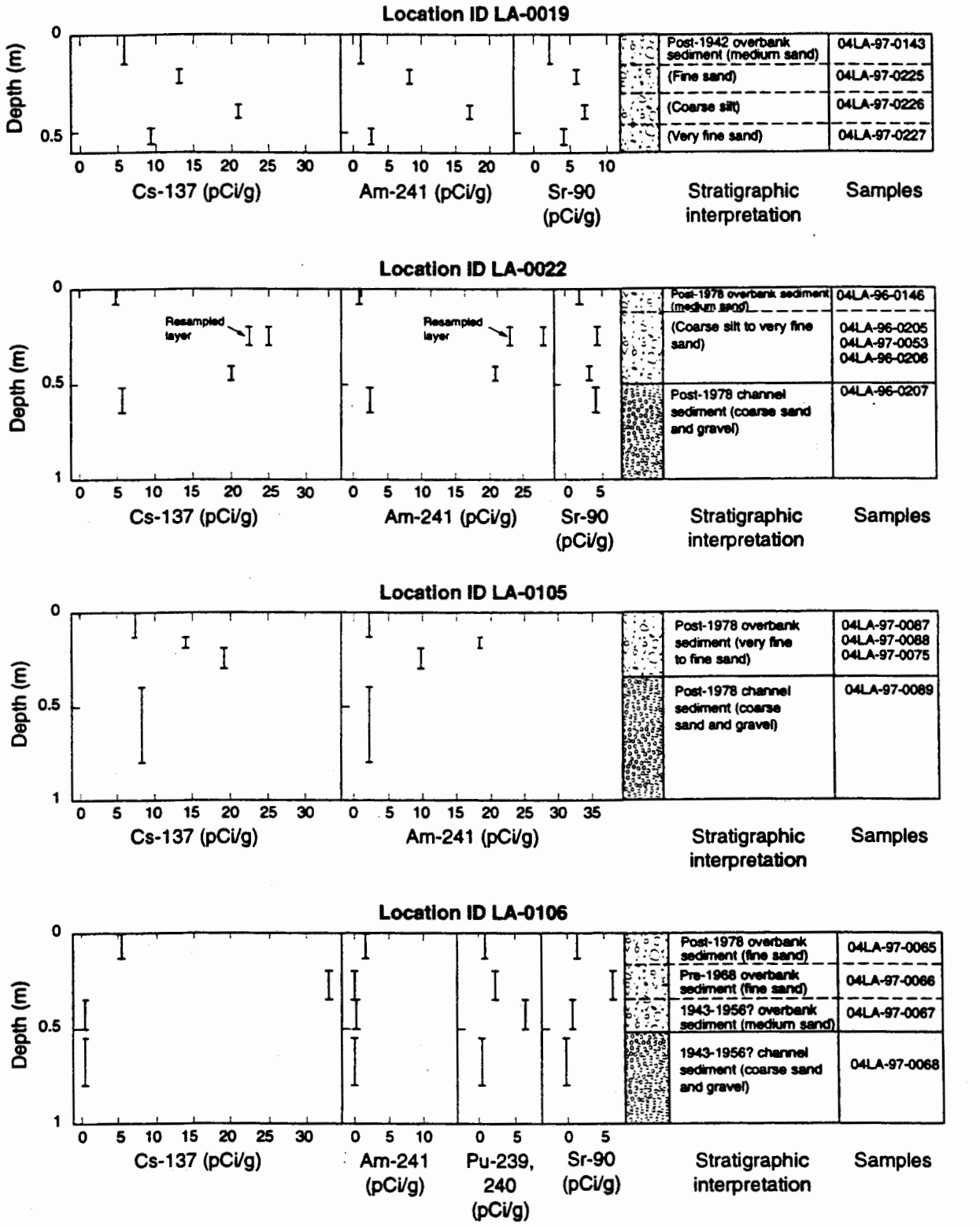
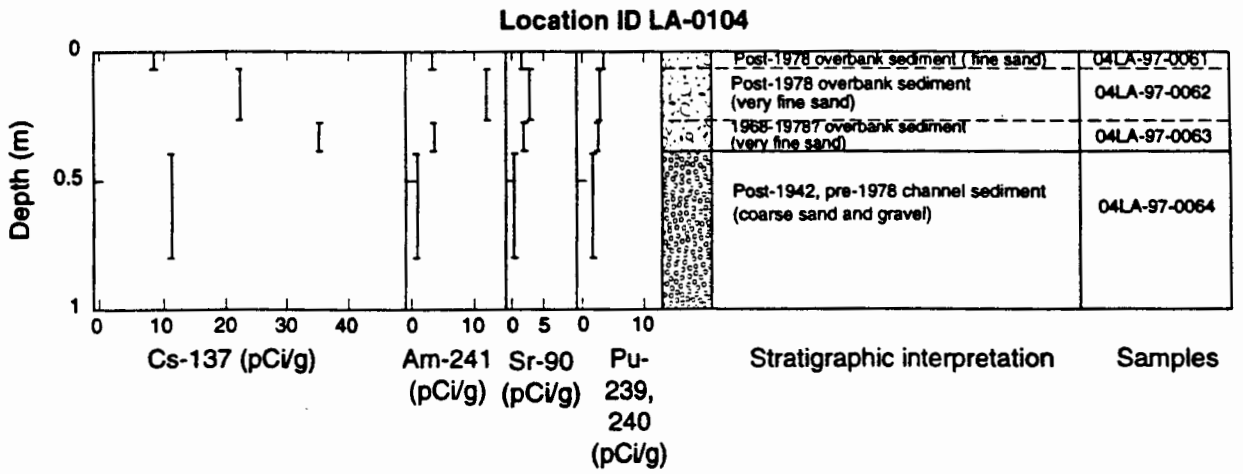
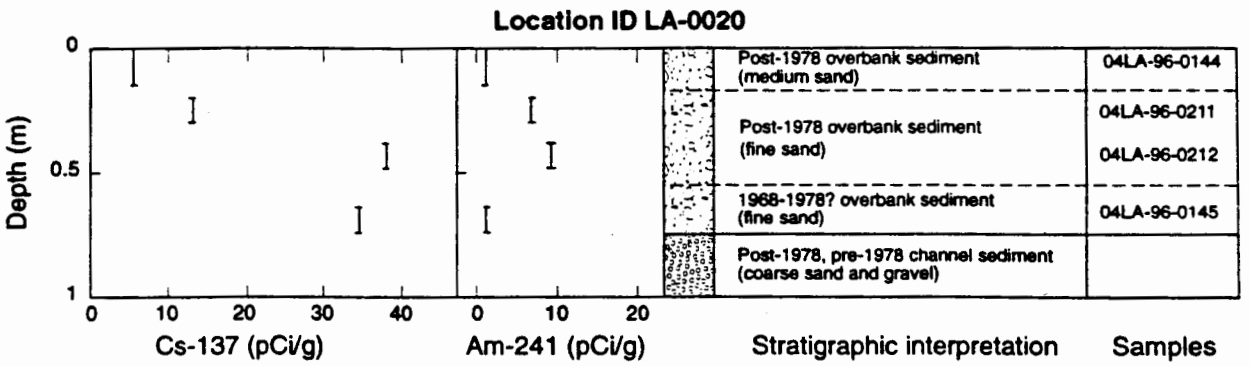


Figure 3.3-8. Depth variations in cesium-137; americium-241; plutonium-239,240; and strontium-90 concentrations at sample sites in the c2 unit in reach LA-2 East.





F3.3-9 / UPPER LOS ALAMOS CANYON REACH RPT / 110998

Figure 3.3-9. Depth variations in cesium-137; americium-241; plutonium-239,240; and strontium-90 concentrations at sample sites in the c2b unit in reach LA-2 East.

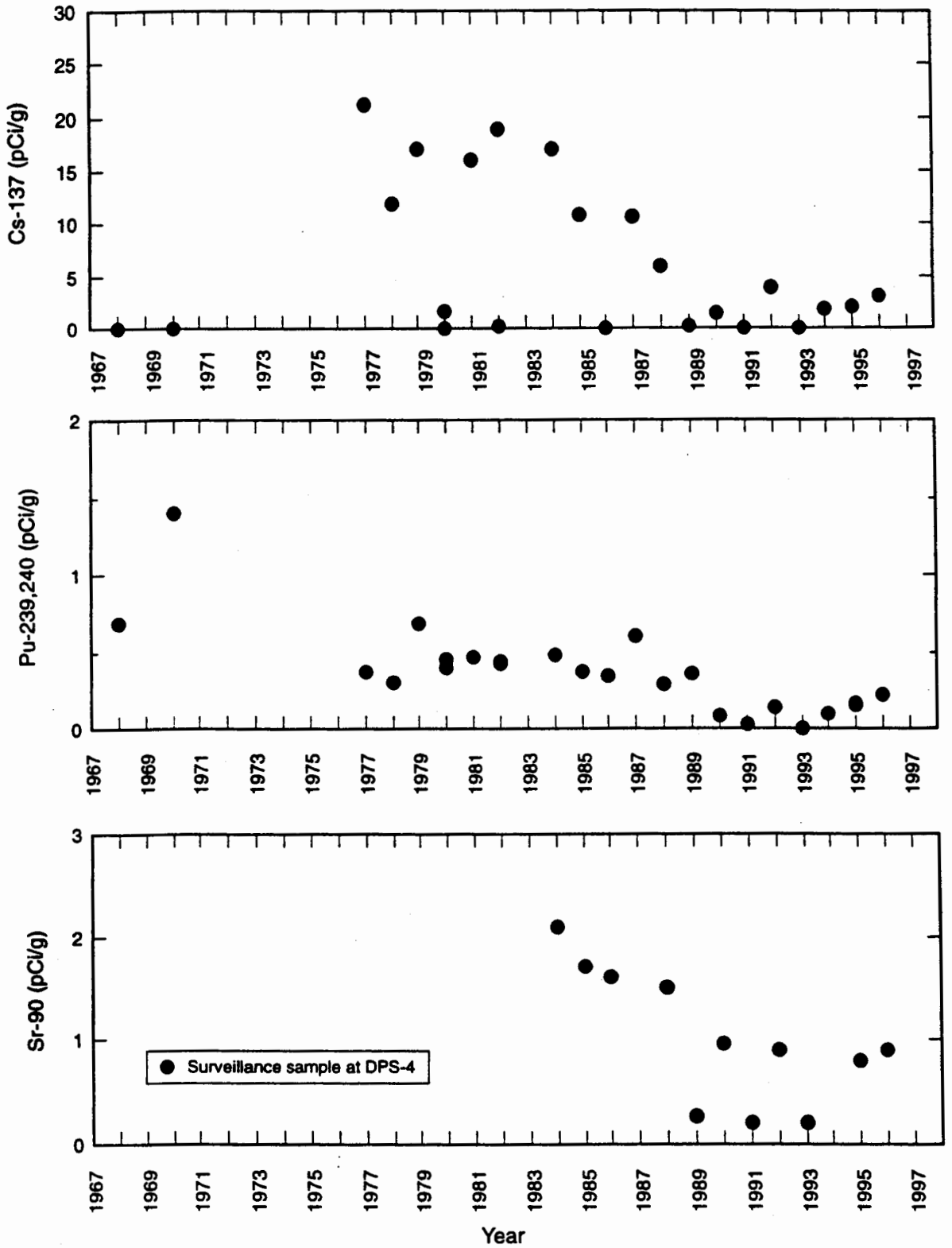
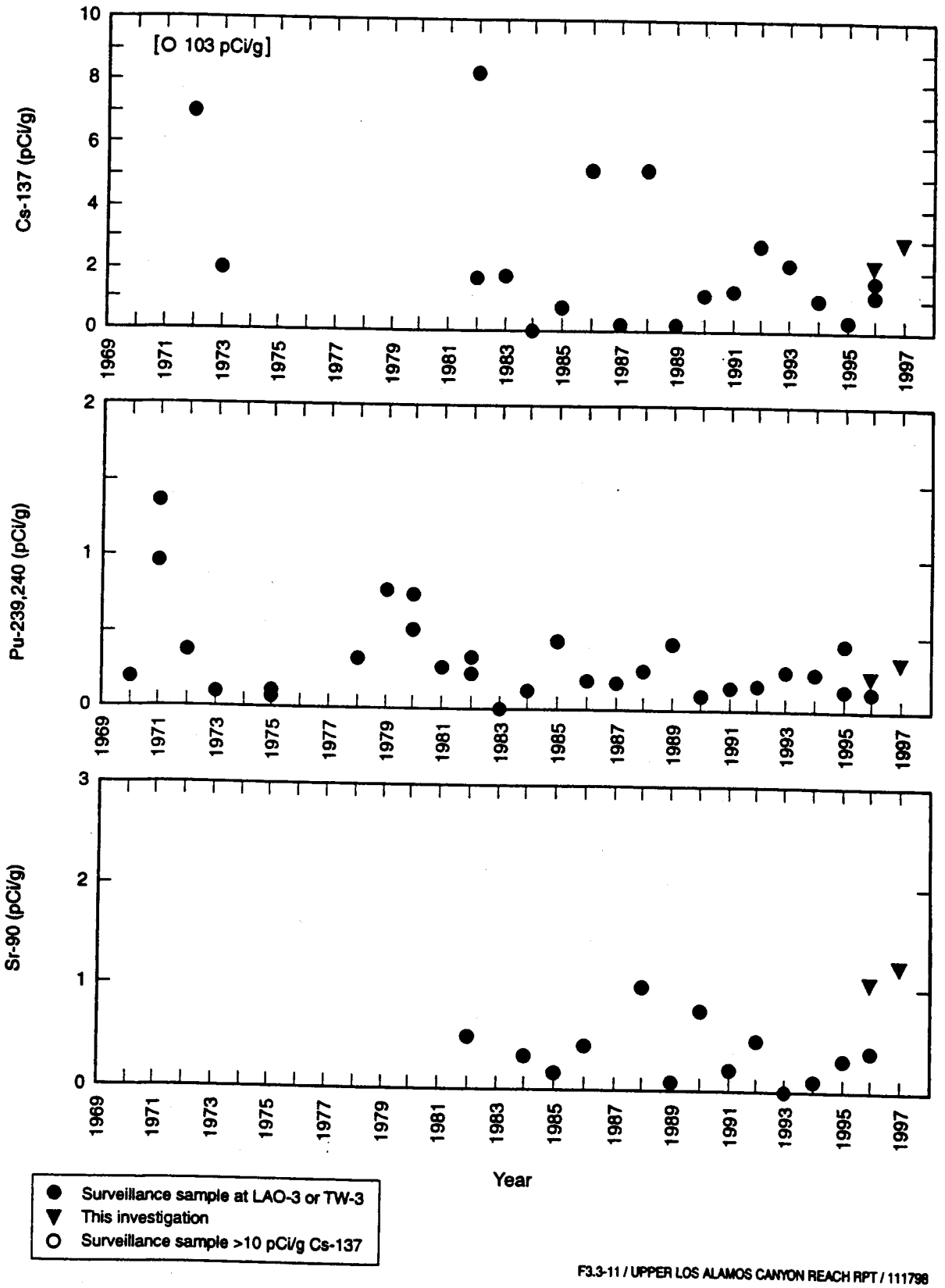


Figure 3.3-10. Relation of the concentrations of cesium-137; plutonium-239,240; and strontium-90 to age from active channel sediment samples collected from lower DP Canyon at environmental surveillance sampling station DPS-4.



F3.3-11 / UPPER LOS ALAMOS CANYON REACH RPT / 111798

Figure 3.3-11. Relation of the concentrations of cesium-137; plutonium-239,240; and strontium-90 to age from active channel sediment samples collected from reach LA-2 East.

Scatter plots of the concentrations of americium-241; cesium-137; plutonium-239,240; and strontium-90 versus particle size in LA-2 East indicate that radionuclide concentration generally increases with decreasing particle size, as seen in LA-1 and LA-3 (Figures B3-6 to B3-9). These relations are clearest when samples of similar age are examined, which reduces the influence of time-dependent trends in contaminant concentrations. Figure 3.3-12 shows the relations of the concentrations of each of these radionuclides to silt and clay content for the combined data set of all samples from the c1, c2, and c2b units, which is dominated by sediment deposited after 1978, and samples from the c3 unit, which was deposited before 1968. Samples from the younger sediments show the strongest relation between silt and clay content and radionuclide concentration, with americium-241 displaying the strongest relations and strontium-90 the poorest. Much more scatter is seen in these relations for samples from the older c3 sediments, which may in part reflect rapid temporal changes in radionuclide concentrations during this time period with high contaminant concentrations. Note that the vertical scales for cesium-137 and strontium-90 in Figure 3.3-12 vary by an order of magnitude between the younger and the older set of samples because of the much higher concentrations of these radionuclides in the older sediments.

3.3.3.3 Contaminant Inventory

The estimated cesium-137 and strontium-90 inventories in LA-2 East have very similar distributions due to the collocation of these radionuclides (Table 3.3-6). For these radionuclides, 69 to 72% are estimated to be contained within relatively fine-grained overbank facies sediment deposits and 28 to 31% to be contained within the coarser-grained channel facies sediment. The most important unit is the large c2 unit, which contains an estimated 43% of each radionuclide in the overbank facies sediments and 14 to 18% in the channel facies sediments. The small c3 unit contains an estimated 25% of the cesium-137 and 23% of the strontium-90 in LA-2 East, with approximately 60 to 65% of the total for each radionuclide occurring in relatively thin overbank sediment layers. Approximately 91 to 93% of the total inventory for each radionuclide is located adjacent to the active channel and is therefore judged to be susceptible to remobilization. Total cesium-137 inventory in LA-2 East is estimated at 66 mCi/km, and total strontium-90 inventory is estimated at 16 mCi/km. Inventories of these radionuclides were not estimated in LA-2 West because of their presence below background values. However, if these radionuclide were present at their background values in each unit, the cesium-137 and strontium-90 inventories would be approximately 3.4 mCi/km and 4.9 mCi/km, respectively.

The estimated americium-241 inventory in LA-2 East totals 19 mCi/km, of which 87% is within fine-grained overbank facies sediment and 13% is within coarse-grained channel facies sediment (Table 3.3-6). The distribution of the americium-241 inventory is significantly different than for cesium-137 and strontium-90, and an estimated 91% of the americium-241 is contained within the c2 unit adjacent to the active channel. Virtually all the americium-241, 99%, is in geomorphic units judged to be susceptible to remobilization.

The estimated plutonium-239,240 inventory in LA-2 is less than in most of the subreaches in LA-1: 4.3 mCi/km in LA-2 West and 7.2 mCi/km in LA-2 East (Table 3.3-6). The larger inventory in LA-2 East is due to a larger volume of post-1942 overbank facies sediment in LA-2 East than in LA-2 West, as average plutonium-239,240 concentrations are similar between the two subreaches. In both subreaches the largest part of the estimated plutonium-239,240 inventory is contained within overbank facies sediment of the c2 unit, which is located close to the channel. Larger percentages of the estimated plutonium inventory in both subreaches are contained within the coarse-grained channel facies sediment than upstream in the LA-1 subreaches, 40% in LA-2 West and 17% in LA-2 East. Virtually all of the plutonium-239,240 in LA-2 East (96%) is in geomorphic units judged to be susceptible to remobilization, but only 55% of the smaller estimated inventory in LA-2 West is in similar geomorphic units.

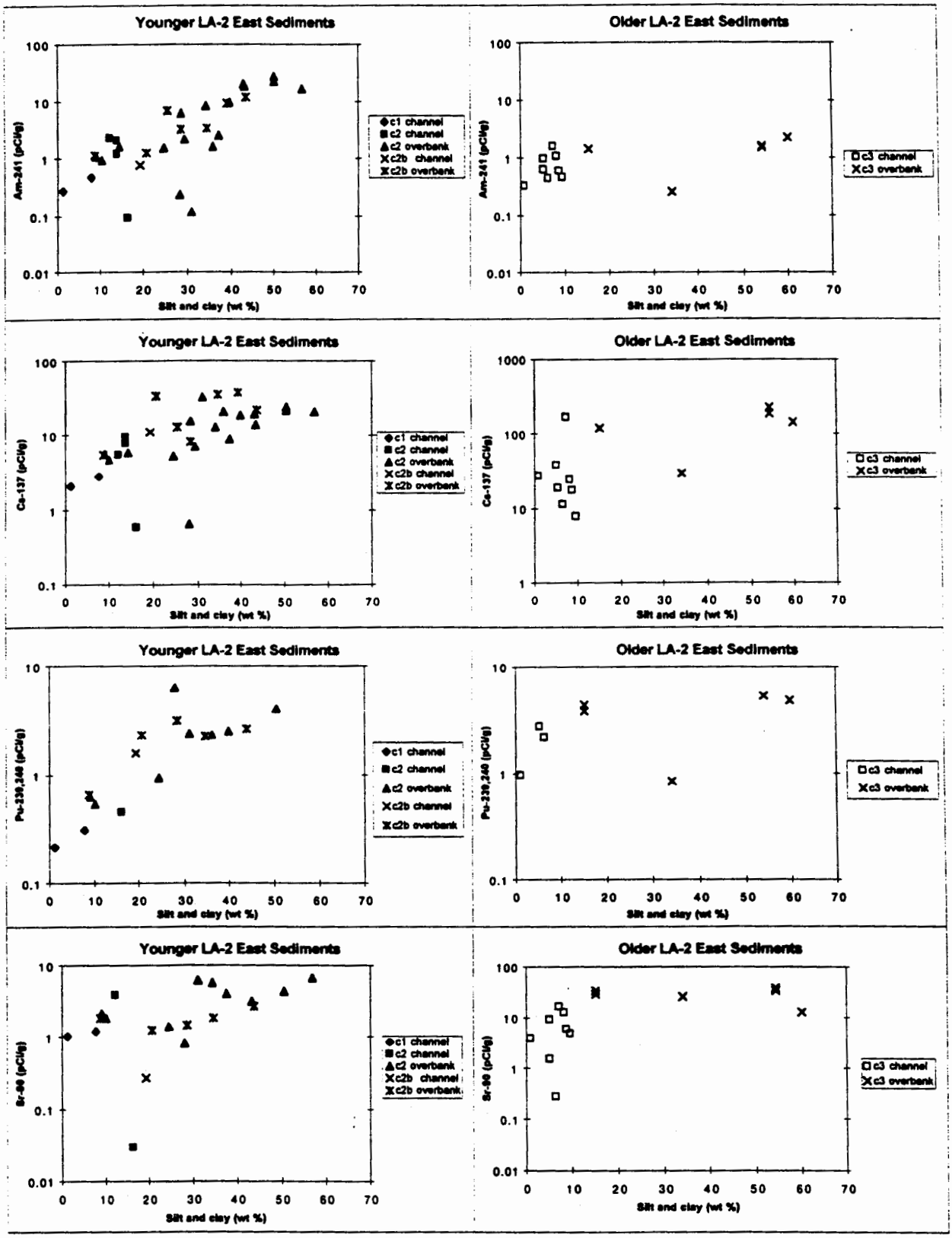


Figure 3.3-12. Scatter plots of radionuclide concentration against silt and clay content for all samples from (a) the c1, c2, and c2b units and (b) the c3 unit in LA-2 East.

TABLE 3.3-6

ESTIMATED RADIONUCLIDE INVENTORY IN REACH LA-2

Sediment Facies	Geomorphic Unit	Section	Area (m^2)	Estimated Average Thickness (m)	Estimated Volume (m^3)	Estimated Fraction <2 mm	Estimated Density (g/cm^3)	Estimated Average Concentration (pCi/g)	Estimated Radionuclide Inventory (mCi)	Percent of Total Subreach Inventory	Percent Potentially Susceptible to Remobilization	Estimated Inventory Most Susceptible to Remobilization (mCi)	Percent of Total Subreach Inventory Susceptible to Remobilization
LA-2 West Plutonium-239,240													
Channel	c1	All	349	0.5	175	0.5	1.23	0.21	0.02	2%	100%	0.02	2%
Channel	c2	Lower	510	0.5	255	0.5	1.23	0.72	0.11	10%	100%	0.11	10%
Channel	c3	Lower	1008	0.5	504	0.5	1.23	0.72	0.22	20%	20%	0.04	4%
Subtotal			**1867**		**934**				**0.36**	**33%**		**0.18**	**17%**
Overbank	c2	Upper	510	0.24	122	0.84	1.04	3.56	0.38	35%	100%	0.38	35%
Overbank	c3	Upper	1008	0.05	50	0.98	1.04	1.50	0.08	7%	20%	0.02	1%
Overbank	f1	All	1296	0.15	194	0.90	1.04	1.50	0.27	25%	10%	0.03	3%
Subtotal					**367**				**0.73**	**67%**		**0.4**	**39%**
Total									**1.09**	**100%**			**55%**
LA-2 East Plutonium-239,240													
Channel	c1	All	1321	0.5	661	0.5	1.23	0.27	0.11	2%	100%	0.11	2%
Channel	c2	Lower	3290	0.5	1645	0.5	1.23	0.45	0.46	9%	100%	0.46	9%
Channel	c2b	Lower	223	0.5	112	0.5	1.23	0.45	0.03	1%	100%	0.03	1%
Channel	c3 (NE)	Upper	173	0.65	112	0.8	1.23	0.95	0.11	2%	100%	0.11	2%
Channel	c3 (NE)	Lower	173	0.5	87	0.5	1.23	2.46	0.13	3%	100%	0.13	3%
Subtotal			**5180**		**2616**				**0.83**	**17%**		**0.83**	**17%**
Overbank	c2	Upper	3290	0.49	1612	0.85	1.04	2.35	3.35	69%	100%	3.35	69%
Overbank	c2b	Upper	223	0.30	67	0.92	1.04	2.35	0.15	3%	100%	0.15	3%
Overbank	c2b	Middle	223	0.25	56	0.92	1.04	2.28	0.12	2%	100%	0.12	2%
Overbank	c3 (NE)	Middle	173	0.20	35	0.76	1.04	4.72	0.13	3%	100%	0.13	3%
Overbank?	c3 (SW)	Upper	126	0.15	19	0.76	1.04	4.72	0.07	1%	100%	0.07	1%
Overbank	c3 (SW)	Lower	126	0.15	19	0.76	1.04	0.85	0.01	0%	100%	0.01	0%
Overbank	f1	All	1784	0.15	268	0.90	1.04	0.61	0.15	3%	10%	0.02	0%
Overbank	f1b	All	174	0.15	26	0.97	1.04	2.39	0.06	1%	0%	0.00	0%
Subtotal					**2101**				**4.05**	**83%**		**3.85**	**79%**
Total									**4.88**	**100%**			**96%**

TABLE 3.3-6 (continued)

ESTIMATED RADIONUCLIDE INVENTORY IN REACH LA-2

Sediment Facies	Geomorphic Unit	Section	Area (m^2)	Estimated Average Thickness (m)	Estimated Volume (m^3)	Estimated Fraction <2 mm	Estimated Density (g/cm^3)	Estimated Average Concentration (pCi/g)	Estimated Radionuclide Inventory (mCi)	Percent of Total Subreach Inventory	Percent Potentially Susceptible to Remobilization	Estimated Inventory Most Susceptible to Remobilization (mCi)	Percent of Total Subreach Inventory Susceptible to Remobilization
LA-2 East Cesium-137													
Channel	c1	All	1321	0.5	661	0.5	1.23	2.50	1.02	2%	100%	1.02	2%
Channel	c2	Lower	3290	0.5	1645	0.5	1.23	6.05	6.12	14%	100%	6.12	14%
Channel	c2b	Lower	223	0.5	112	0.5	1.23	11.20	0.77	2%	100%	0.77	2%
Channel	c3 (NE)	Upper	173	0.65	112	0.5	1.23	30.62	2.12	5%	100%	2.12	5%
Channel	c3 (NE)	Lower	173	0.5	87	0.5	1.23	45.30	2.41	5%	100%	2.41	5%
Subtotal			**5180**		**2616**				**12.43**	**28%**		**12.43**	**28%**
Overbank	c2	Upper	3290	0.49	1612	0.85	1.04	13.52	19.27	43%	100%	19.27	43%
Overbank	c2b	Upper	223	0.30	67	0.92	1.04	13.52	0.87	2%	100%	0.87	2%
Overbank	c2b	Middle	223	0.25	56	0.92	1.04	35.91	1.92	4%	100%	1.92	4%
Overbank	c3 (NE)	Middle	173	0.20	35	0.76	1.04	153.10	4.19	9%	100%	4.19	9%
Overbank?	c3 (SW)	Upper	126	0.15	19	0.76	1.04	153.10	2.29	5%	100%	2.29	5%
Overbank	c3 (SW)	Lower	126	0.15	19	0.76	1.04	29.50	0.44	1%	100%	0.44	1%
Overbank	f1	All	1784	0.15	268	0.90	1.04	7.31	1.83	4%	10%	0.18	0%
Overbank	f1b	All	174	0.15	26	0.97	1.04	54.50	1.43	3%	10%	0.14	0%
Subtotal					**2101**				**32.23**	**72%**		**29.29**	**66%**
Total									**44.66**	**100%**			**93%**
LA-2 East Americium-241													
Channel	c1	All	1321	0.5	661	0.5	1.23	0.31	0.13	1%	100%	0.13	1%
Channel	c2	Lower	3290	0.5	1645	0.5	1.23	1.42	1.44	11%	100%	1.44	11%
Channel	c2b	Lower	223	0.5	112	0.5	1.23	0.79	0.05	0%	100%	0.05	0%
Channel	c3 (NE)	Upper	173	0.65	112	0.5	1.23	0.89	0.06	0%	100%	0.06	0%
Channel	c3 (NE)	Lower	173	0.5	87	0.5	1.23	0.76	0.04	0%	100%	0.04	0%
Subtotal			**5180**		**2616**				**1.72**	**13%**		**1.72**	**13%**

TABLE 3.3-6 (continued)

ESTIMATED RADIONUCLIDE INVENTORY IN REACH LA-2

Sediment Facies	Geomorphic Unit	Section	Area (m^2)	Estimated Average Thickness (m)	Estimated Volume (m^3)	Estimated Fraction <2 mm	Estimated Density (g/cm^3)	Estimated Average Concentration (pCi/g)	Estimated Radionuclide Inventory (mCi)	Percent of Total Subreach Inventory	Percent Potentially Susceptible to Remobilization	Estimated Inventory Most Susceptible to Remobilization (mCi)	Percent of Total Subreach Inventory Susceptible to Remobilization
LA-2 East Americium-241													
Overbank	c2	Upper	3290	0.49	1612	0.85	1.04	7.19	10.25	80%	100%	10.25	80%
Overbank	c2b	Upper	223	0.30	67	0.92	1.04	7.19	0.46	4%	100%	0.46	4%
Overbank	c2b	Middle	223	0.25	56	0.92	1.04	4.70	0.25	2%	100%	0.25	2%
Overbank	c3 (NE)	Middle	173	0.20	35	0.76	1.04	1.81	0.05	0%	100%	0.05	0%
Overbank?	c3 (SW)	Upper	126	0.15	19	0.76	1.04	1.81	0.03	0%	100%	0.03	0%
Overbank	c3 (SW)	Lower	126	0.15	19	0.76	1.04	0.27	0.00	0%	100%	0.00	0%
Overbank	f1	All	1784	0.15	268	0.90	1.04	0.46	0.12	1%	10%	0.01	0%
Overbank	f1b	All	174	0.15	26	0.97	1.04	0.30	0.01	0%	10%	0.00	0%
Subtotal					**2101**				**11.16**	**87%**		**11.05**	**86%**
Total									**12.88**	**100%**			**99%**
LA-2 East Strontium-90													
Channel	c1	All	1321	0.5	661	0.5	1.23	1.13	0.46	4%	100%	0.46	4%
Channel	c2	Lower	3290	0.5	1645	0.5	1.23	1.99	2.01	18%	100%	2.01	18%
Channel	c2b	Lower	223	0.5	112	0.5	1.23	0.27	0.02	0%	100%	0.02	0%
Channel	c3 (NE)	Upper	173	0.65	112	0.5	1.23	8.74	0.60	5%	100%	0.60	5%
Channel	c3 (NE)	Lower	173	0.5	87	0.5	1.23	5.94	0.32	3%	100%	0.32	3%
Subtotal			**5180**		**2616**				**3.41**	**31%**		**3.41**	**31%**
Overbank	c2	Upper	3290	0.49	1612	0.85	1.04	3.37	4.80	43%	100%	4.80	43%
Overbank	c2b	Upper	223	0.30	67	0.92	1.04	3.37	0.22	2%	100%	0.22	2%
Overbank	c2b	Middle	223	0.25	56	0.92	1.04	1.58	0.08	1%	100%	0.08	1%
Overbank	c3 (NE)	Middle	173	0.20	35	0.76	1.04	27.75	0.76	7%	100%	0.76	7%
Overbank?	c3 (SW)	Upper	126	0.15	19	0.76	1.04	27.75	0.41	4%	100%	0.41	4%
Overbank	c3 (SW)	Lower	126	0.15	19	0.76	1.04	27.10	0.40	4%	100%	0.40	4%
Overbank	f1	All	1784	0.15	268	0.90	1.04	3.37	0.84	8%	10%	0.08	1%
Overbank	f1b	All	174	0.15	26	0.97	1.04	9	0.24	2%	10%	0.02	0%
Subtotal					**2101**				**7.76**	**69%**		**6.79**	**61%**
Total									**11.17**	**100%**			**91%**

3.3.4 Reach LA-3

3.3.4.1 Contaminant Concentrations

Most sediment samples collected from reach LA-3 contain cesium-137 at concentrations above the background value of 0.9 pCi/g (Table 3.3-7), and variations in cesium-137 between different sample sites are consistent with the field measurements of gross gamma radiation. The highest concentrations of cesium-137 occur within relatively fine-grained overbank facies sediment in the c3 unit, with a maximum concentration of 13.8 pCi/g, an average of 7.7 pCi/g, and a median of 6.1 pCi/g (Table 3.3-8). Overbank facies sediment samples from the younger c2 unit have a maximum cesium-137 concentration of 5.4 pCi/g, an average of 3.2 pCi/g, and a median of 3.2 pCi/g. Overbank sediments in the f1 unit have intermediate concentrations of cesium-137 and probably represent a combination of sediment found in the c2 and c3 units, with a maximum of 8.9 pCi/g, an average of 3.5 pCi/g, and a median of 2.1 pCi/g. Cesium-137 concentrations in relatively coarse-grained channel facies sediment samples are less than in associated overbank facies samples and are higher in the older deposits. Average cesium-137 concentration decreases from 3.3 pCi/g in c3 channel facies sediment to 2.4 pCi/g in c2 sediment and 1.0 pCi/g in c1 sediment.

Americium-241 shows similar variations in concentration to cesium-137 in LA-3, and the maximum values occur in the same sample (sample 04LA-97-0137 at location LA-0109, Table 3.3-7, Figure 3.3-13). The maximum americium-241 result is 11.8 pCi/g in c3 overbank facies sediment, the average in this unit is 3.1 pCi/g, and the median is 1.6 pCi/g (Table 3.3-8). Average americium-241 in overbank sediments in the c2 and f1 units are 0.9 and 0.5 pCi/g and medians are 0.9 and 0.3 pCi/g, respectively. Americium-241 has lower concentrations in the channel facies sediment samples, averaging 0.5 pCi/g in both the c2 and c3 units and 0.2 pCi/g in the c1 unit.

Fewer analyses were obtained for plutonium-239,240 than for cesium-137 and americium-241, but variations in plutonium-239,240 concentration are similar to variations in the other two radionuclides. The maximum value of 3.2 pCi/g was obtained from the same c3 overbank facies sample that had the highest levels of cesium-137 and americium-241 (sample 04LA-97-0137, Table 3.3-7, Figure 3.3-13), and the average concentration in the c3 overbank samples of 1.7 pCi/g is higher than in the c2 samples, 0.5 pCi/g (Table 3.3-8). One sample from an f2 surface (04LA-97-0131) has plutonium-239,240 above the background value (but at relatively low levels of 0.255 pCi/g) and cesium-137 below the background value. This is the only sample in LA-3 that may record a post-1942 flood that predated initial releases of cesium-137 from TA-21.

Strontium-90 in LA-3 in part shows the same variations in concentration as the other key radionuclides, although 11 of the 17 analyses are below the background value of 1.04 pCi/g; strontium-90 also has some anomalous results. In particular, the highest strontium-90 result, 7.0 pCi/g, was obtained from a c2 overbank facies sample and is the only sample in upper Los Alamos Canyon where the concentration of strontium-90 exceeds that of cesium-137 (sample 04LA-97-0134 at location LA-0111, Table 3.3-7, Figure 3.3-14). All other c2 samples have less than 2.0 pCi/g strontium-90, whereas several c3 samples exceeded 2.0 pCi/g. The average concentration in c2 overbank samples (2.0 pCi/g) is slightly higher than in the c3 overbank samples (1.6 pCi/g), but the median is lower in the c2 unit (0.5 versus 1.3 pCi/g; Table 3.3-8). All strontium-90 results from channel facies sediment samples in LA-3 are below the background value; therefore, these coarse-grained sediments are less important for strontium-90 than for the other key radionuclides.

TABLE 3.3-7

RADIONUCLIDE ANALYSES FROM REACH LA-3

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
c1	LA-0112	0–2	0–5	Channel	1	04LA-97-0109	NA[c]	0.153 (U)[d]	0.709	NA	NA	NA	vcs	gs	
c1	LA-0116	0–2	0–5	Channel	1	04LA-97-0150	0.125	0.058 (U)	0.729	0.0208	0.082	-0.02 (U)	cs	gs	Full-suite sample
c1	LA-0119	0–2	0–5	Channel	1	04LA-97-0110	NA	0.317	1.66	NA	NA	NA	cs	s	
c2	LA-0114	0–6.5	0–16	Overbank	1	04LA-97-0112	NA	0.981	3.23	NA	NA	NA	vfs	gsl	
		6.5–12.5	16–32	Overbank	1	04LA-97-0148	1.87	1.26	3.93	0.151	0.862	1.9	vfs	sl	Full-suite sample
		12.5–19	32–49	Overbank	1	04LA-97-0113	NA	1.82	4.96	NA	NA	NA	vfs	gsl	
		19–24	49–61	Channel	1	04LA-97-0114	NA	0.881	3.16	NA	NA	NA	cs	gs	
		24–35.5	61–90	Channel	1	04LA-97-0115	NA	0.473	2.4	NA	NA	NA	cs	gs	
c2	LA-0111	0–6.5	0–16	Overbank	1	04LA-97-0132	NA	0.371	1.29	0.021 (U)	0.232	0.5 (U)	fs	ls	Limited-suite sample
		6.5–11	16–28	Overbank	1	04LA-97-0133	NA	0.514 (U)	1.54	0.035	0.178	0.19 (U)	fs	sl	Limited-suite sample
		11–13.5	28–34	Overbank	1	04LA-97-0147	0.515	0.644 (U)	1.8	0.065	0.321	0.34 (U)	vfs	sl	Full-suite sample
		13.5–25	34–63	Overbank	1	04LA-97-0134	NA	0.853	5.44	0.068	0.741	7.03	fs	gsl	Limited-suite sample
		25–31.5	63–80	Channel	1	04LA-97-0135	NA	0.258	1.49	0.013 (U)	0.419	0.12 (U)	cs	gs	Limited-suite sample
c3	LA-0109	0–8.5	0–22	Overbank	1	04LA-97-0136	NA	1.09 (U)	4.04	0.108	0.54	0.62 (U)	fs	ls	Limited-suite sample
		8.5–12.5	22–32	Overbank	1	04LA-97-0137	NA	11.8	13.8	0.769	3.18	3.73	csl	sil	Limited-suite sample
		12.5–16	32–41	Overbank	1	04LA-97-0138	NA	9.49	13.3	0.404	2.64	2.19	csl	sil	Limited-suite sample
		16–19.5	41–50	Overbank	1	04LA-97-0143	2.59	1.54 (U)	11.7	0.219	1.95	1.93 (J+)[e]	csl	sil	Full-suite sample
		16–19.5	41–50	Overbank	1	04LA-97-0144	2.22	1.67	12	0.142	1.82	2.08 (J+)	NA	NA	QA duplicate
		19.5–25	50–62	Overbank	1	04LA-97-0139	NA	5.3	11.1	0.32	1.75	1.27	vfs	sl	Limited-suite sample
		25–31.5	62–80	Channel	1	04LA-97-0140	NA	0.705	6.7	0.045	0.471	0.31 (U)	ms	gs	Limited-suite sample
		31.5–34.5	80–88	Channel	1	04LA-97-0141	NA	0.874	4.66	0.048	0.31	0.2 (U)	ms	s	Limited-suite sample
		34.5–42.5	88–103	Channel	1	04LA-97-0142	NA	0.776	4.12	0.025 (U)	1.2	-0.24 (U)	cs	gs	Limited-suite sample
c3	LA-0110	0-5	0–13	Overbank	1	04LA-97-0105	NA	0.834 (U)	2.47	NA	NA	NA	fs	ls	

a. vcs = very coarse sand, cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csl = coarse silt

b. sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel

c. NA = not analyzed

d. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

e. J+ = The analyte was positively identified, and the reported value is an estimate and likely biased high.

TABLE 3.3-7 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-3

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
c3	LA-0110	7.5–11	19–28	Overbank	1	04LA-97-0106	NA[c]	1.62	5.7	NA	NA	NA	fs	ls	
		11–16	28–40	Overbank	1	04LA-97-0145	1.75	2.34	6.1	0.154	0.852	0.81 (U)[d]	fs	sl	Full-suite sample
		11–16	28–40	Overbank	1	04LA-97-0146	2.14	0.918	5.91	0.146	1.45	0.85 (U)	NA	NA	QA duplicate
		16–20.5	40–52	Overbank	1	04LA-97-0107	NA	2.96	8.68	NA	NA	NA	fs	gsl	
		21.5–31.5	55–80	Channel	1	04LA-97-0108	NA	0.078 (U)	0.524	NA	NA	NA	cs	gs	
c3	LA-0115	0–5	0–12	Overbank	1	04LA-97-0116	NA	0.223 (U)	1.49	NA	NA	NA	cs	s	
		5–11	12–28	Overbank	1	04LA-97-0117	NA	1.77	5.71	NA	NA	NA	vfs	sl	
		11–16	28–39	Overbank	1	04LA-97-0149	1.36	0.87 (U)	10.1	0.115	1.189	0.92 (J+)[e]	fs	sl	Full-suite sample
		15.5–21	39–53	Overbank	1	04LA-97-0118	NA	0.106 (U)	5.46	NA	NA	NA	fs	sl	
		21–29.5	53–75	Channel	1	04LA-97-0119	NA	0.058 (U)	0.305	NA	NA	NA	cs	gs	
f1? (c3?)	LA-0117	4–11	10–28	Overbank	1	04LA-97-0120	NA	2.25 (U)	6.14	NA	NA	NA	vfs	sl	
		11–18	28–46	Overbank	1	04LA-97-0121	NA	0.512	2.13	NA	NA	NA	fs	sl	
		18–29	46–74	Overbank	1	04LA-97-0122	NA	0.232	0.994	NA	NA	NA	fs	sl	
		18–29	46–74	Overbank	1	04LA-97-0123	NA	0.269 (U)	1.11	NA	NA	NA	NA	NA	QA duplicate
		29–36	74–92	Overbank	1	04LA-97-0124	NA	-0.024 (U)	1.62	NA	NA	NA	fs	gsl	
		36–47	92–120	Channel	1	04LA-97-0125	NA	0.377	1.85	NA	NA	NA	cs	gls	
f1	LA-0121	0–6.5	0–16	Overbank	1	04LA-97-0111	NA	0.18	3.17	NA	NA	NA	vfs	sl	
f1	LA-0118	0–6.5	0–17	Overbank	1	04LA-97-0126	NA	0.291	8.86	NA	NA	NA	fs	sl	
		6.5–18	17–46	Overbank	1	04LA-97-0127	NA	0.009 (U)	0.075	NA	NA	NA	vfs	sl	Background?
		6.5–18	17–46	Overbank	1	04LA-97-0128	NA	-0.23 (U)	0.067 (U)	NA	NA	NA	NA	NA	QA duplicate
		18–28	46–72	Channel	1	04LA-97-0129	NA	0.034 (U)	0.051 (U)	NA	NA	NA	cs	gs	Background?
F2	LA-0113	0–2	0–5	Overbank	1	04LA-97-0130	NA	0.017 (U)	0.563	-0.001 (U)	0.067	NA	fs	sl	Limited-suite sample
f2	LA-0120	0–3.5	0-9	Overbank	1	04LA-97-0131	NA	-0.025 (U)	0.162	-0.003 (U)	0.255	NA	fs	ls	Limited-suite sample

a. cs = coarse sand, fs = fine sand, vfs = very fine sand

b. sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel

c. NA = not analyzed

d. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

e. J+ = The analyte was positively identified, and the reported value is an estimate and likely biased high.

TABLE 3.3-8

SUMMARY OF BINNED ANALYSES IN REACH LA-3

Geomorphic Unit and Sediment Facies	Summary Statistic	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]	Pu-239/238 Ratio	Am-241/ Pu-239 Ratio[c]	Cs-137/ Am-241 Ratio
c1 channel	average	0.18	1.03	0.021	0.082	-0.020	cs	0.817	gs	4	0.7	6
	std. dev.	0.13	0.54	N/A[d]	N/A	N/A						
	maximum	0.32	1.66	N/A	N/A	N/A						
	minimum	0.06	0.71	N/A	N/A	N/A						
	median	0.15	0.73	N/A	N/A	N/A						
	n	3	3	1	1	1						
c2 overbank	average	0.92	3.17	0.07	0.47	1.99	vfs	0.119	sl	7	1.6	3
	std. dev.	0.50	1.68	0.05	0.31	2.90						
	maximum	1.82	5.44	0.15	0.86	7.03						
	minimum	0.37	1.29	0.02	0.18	0.19						
	median	0.85	3.23	0.07	0.32	0.50						
	n	7	7	5	5	5						
c2 channel	average	0.54	2.35	0.013	0.42	0.12	cs	0.549	gs	32	0.6	4
	std. dev.	0.32	0.84	N/A	N/A	N/A						
	maximum	0.88	3.16	N/A	N/A	N/A						
	minimum	0.26	1.49	N/A	N/A	N/A						
	median	0.47	2.40	N/A	N/A	N/A						
	n	3	3	1	1	1						
c3 overbank	average	3.07	7.67	0.30	1.73	1.64	vfs	0.113	sl	6	2.7	2
	std. dev.	3.65	4.06	0.23	0.95	1.09						
	maximum	11.80	13.80	0.77	3.18	3.73						
	minimum	0.11	1.49	0.11	0.54	0.62						
	median	1.62	6.10	0.22	1.75	1.27						
	n	13	13	7	7	7						

a. cs = coarse sand, vfs = very fine sand

b. sl = sandy loam, s = sand, g = ≥20% gravel

c. These ratios calculated only for samples or paired samples from same sediment layer that have both analyses.

d. N/A = not applicable

TABLE 3.3-8 (continued)

SUMMARY OF BINNED ANALYSES IN REACH LA-3

Geomorphic Unit and Sediment Facies	Summary Statistic	Am-241 (gamma spec) (pCi/g)	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]	Pu-239/238 Ratio	Am-241/ Pu-239 Ratio[c]	Cs-137/ Am-241 Ratio
c3 channel	average	0.50	3.26	0.039	0.66	0.09	ms	0.475	gs	17	1.2	7
	std. dev.	0.40	2.77	0.013	0.47	0.29						
	maximum	0.87	6.70	0.048	1.20	0.31						
	minimum	0.06	0.31	0.025	0.31	-0.24						
	median	0.71	4.12	0.045	0.47	0.20						
	n	5	5	3	3	3						
f1 overbank and channel	average	0.55	3.54	NA[d]	NA	NA	fs	0.166	gsl	NA	NA	6
	std. dev.	0.77	2.89	NA	NA	NA						
	maximum	2.25	8.86	NA	NA	NA						
	minimum	-0.02	0.99	NA	NA	NA						
	median	0.29	2.13	NA	NA	NA						
	n	7	7	0	0	0						
f2 overbank	average	-0.004	0.363	-0.002	0.161	NA	fs	0.152	sl	N/A[e]	N/A	-91
	std. dev.	0.030	0.284	0.001	0.133	NA						
	max	0.017	0.563	-0.001	0.255	NA						
	min	-0.025	0.162	-0.003	0.067	NA						
	median	-0.004	0.363	-0.002	0.161	NA						
	n	2	2	2	2	0						
background?[f]	average	0.022	0.063	NA	NA	NA	fs	0.228	sl	NA	NA	3
	std. dev.	0.018	0.017	NA	NA	NA						
	max	0.034	0.075	NA	NA	NA						
	min	0.009	0.051	NA	NA	NA						
	median	0.022	0.063	NA	NA	NA						
	n	2	2	0	0	0						

a. ms = medium sand, fs = fine sand

b. sl = sandy loam, s = sand, g = ≥20% gravel

c. These ratios calculated only for samples or paired samples from same sediment layer that have both analyses.

d. NA = not analyzed

e. N/A = not applicable

f. Samples inferred to represent background have <0.1 pCi/g Cs-137 and are from subsurface layers in the f1 unit.

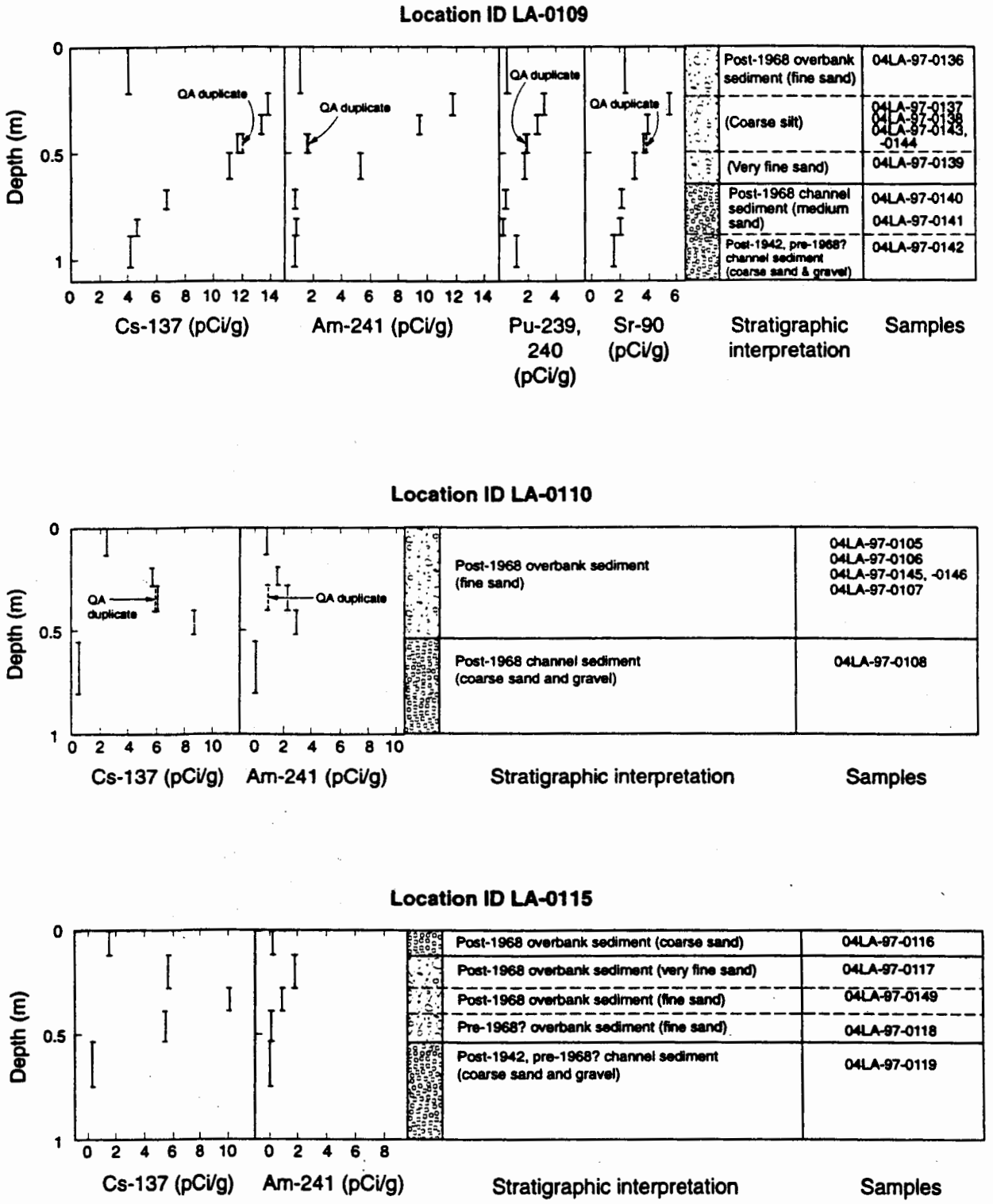


Figure 3.3-13. Depth variations in cesium-137; americium-241; plutonium-239,240; and strontium-90 concentrations at sample sites in the c3 unit in reach LA-3.

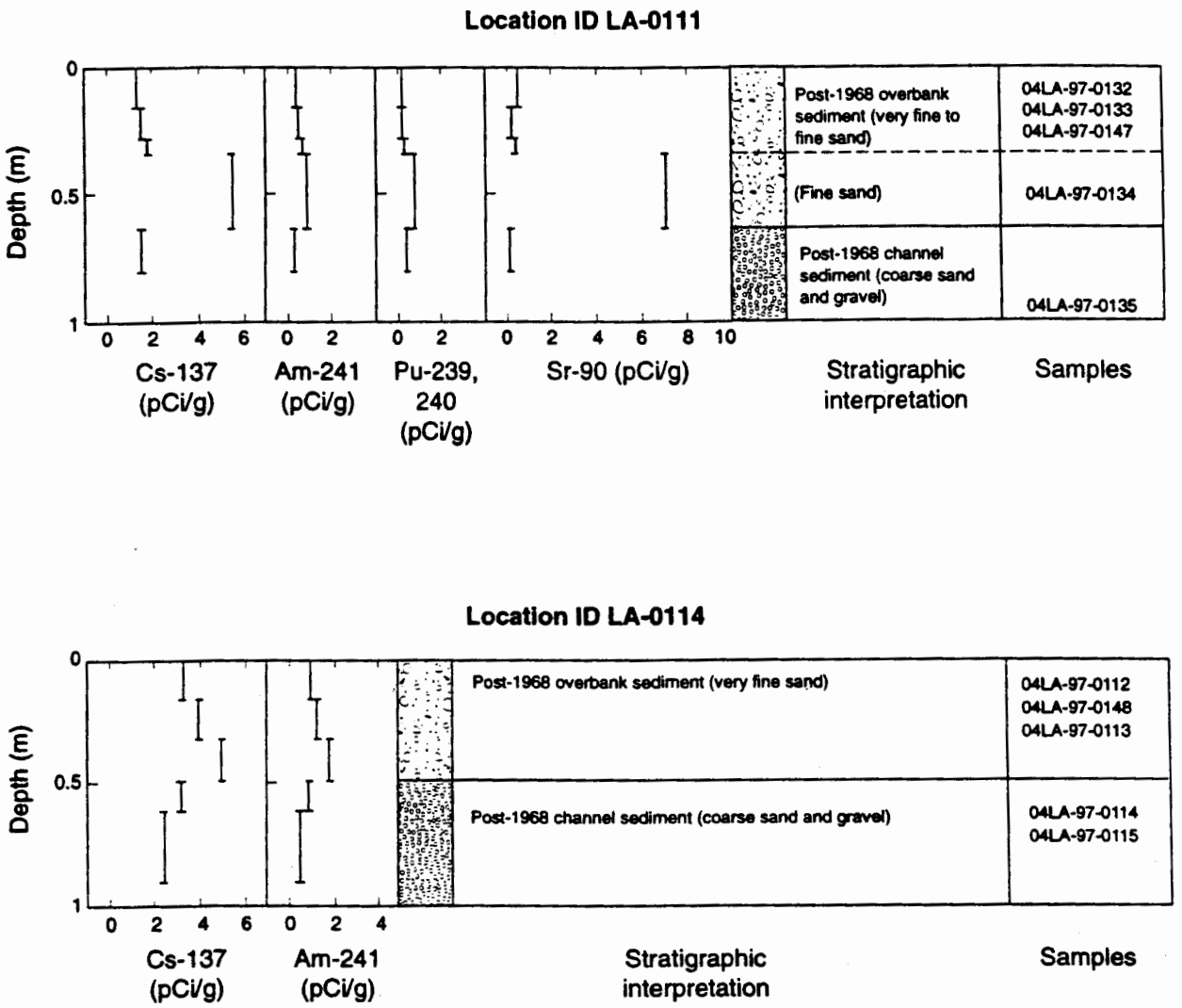


Figure 3.3-14. Depth variations in cesium-137; americium-241; plutonium-239,240; and strontium-90 concentrations at sample sites in the c2 unit in reach LA-3.

3.3.4.2 Age and Particle Size Relations

General time-dependent trends in contaminant concentration in LA-3 are provided by comparison of overbank facies sediments in the older, higher c3 unit and texturally similar sediments in the lower, younger c2 unit. Concentrations of americium-241, cesium-137, plutonium-238, and plutonium-239,240 in the c2 unit are each present at levels only 29 to 42% of that in the c3 unit, documenting general decreases over time. The plutonium 239/238 and cesium/americium isotopic ratios both indicate that the typical sediment in both units is related to overbank sediments in the c2 and c2b units of LA-2 East (Section 3.3.4.2) and are thus younger than 1968. Only a few samples have isotopic ratios indicative of post-1942 pre-1968 sediments (e.g., sample locations LA-0109, LA-0115, and LA-0118, Figures 3.3-13 and 3.3-15), and concentrations of the key radionuclides in these layers are relatively low.

Vertical variations in radionuclide concentrations also provide some evidence for decreases in contaminant concentration during the past several decades. For example, the highest concentrations of all key radionuclides in the c2 unit are from subsurface layers, and shallower younger sediment layers that have similar particle size characteristics have lower concentrations (Figure 3.3-14). Samples from the c3 unit at location LA-0110 also show increases in radionuclide concentration with depth that suggest decreases over time (Figure 3.3-13), although at other sites such relations are not clearly displayed.

Additional data on possible time-dependent trends in radionuclide concentrations in LA-3 sediments are available from samples collected from the environmental surveillance sampling station at state road NM 4 immediately downstream of LA-3 that dates back to 1970 (e.g., Environmental Surveillance and Compliance Programs 1997, 56684) (Figure 3.3-16). Large amounts of variability are seen in this data set, although decreases in the concentration of cesium-137 are suggested. Specifically, all samples collected between 1989 and 1997, including samples from this investigation, have concentrations of cesium-137 less than 2 pCi/g, whereas most samples collected before 1989 have concentrations greater than 2 pCi/g. The trends suggested by these data are greater than what would occur because of the radioactive decay of cesium-137, although such decay would have decreased cesium-137 concentrations by half since 1968. Data on plutonium-239,240 are less conclusive in terms of possible trends over time, and most samples from the 1970s have concentrations similar to samples from the 1990s (Figure 3.3-16).

Scatter plots of the concentrations of americium-241; cesium-137; plutonium-239,240; and strontium-90 versus particle size in LA-3 indicate that radionuclide concentration generally increases with decreasing particle size, as seen in LA-1 and LA-2 (Figures B3-10 to B3-13). Figure 3.3-17 shows the relations of the concentrations of each of these radionuclides to silt and clay content for all samples from the c1, c2, and c3 units, illustrating both the similarity in trends between different radionuclides and also differences between geomorphic units. Specifically, for samples with similar silt and clay content, the older c3 sediment tends to have higher radionuclide concentrations than younger c2 sediment, which is consistent with contaminant concentrations declining over time. The only exception is strontium-90, where the highest concentration was obtained from a c2 sample with relatively low silt and clay content (sample 04LA-97-0134, 29% silt and clay). The reason for this discrepancy is not certain, although strontium-90 has a higher solubility than the other radionuclides and hence may have a different (but as yet undefined) transport history.

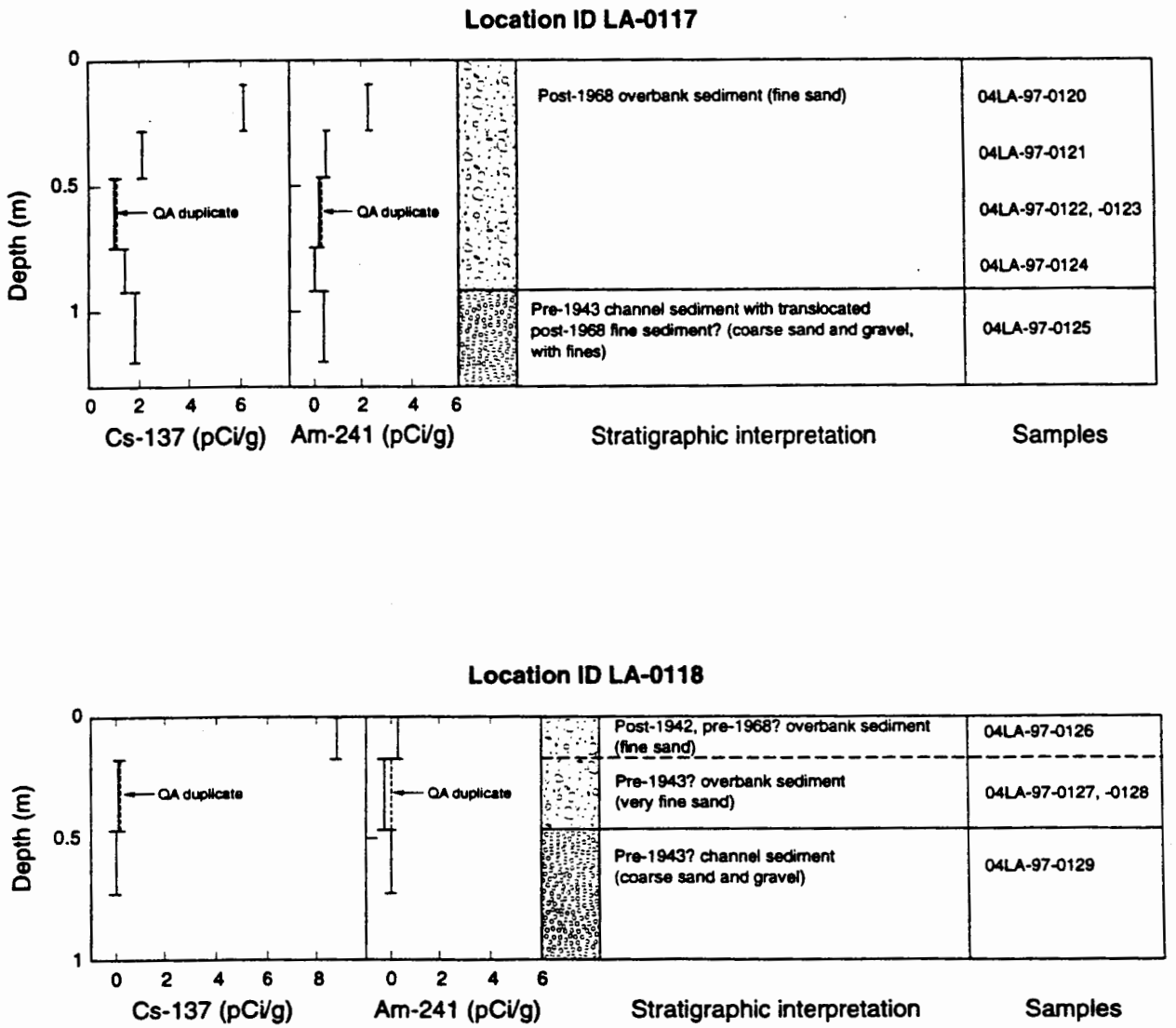
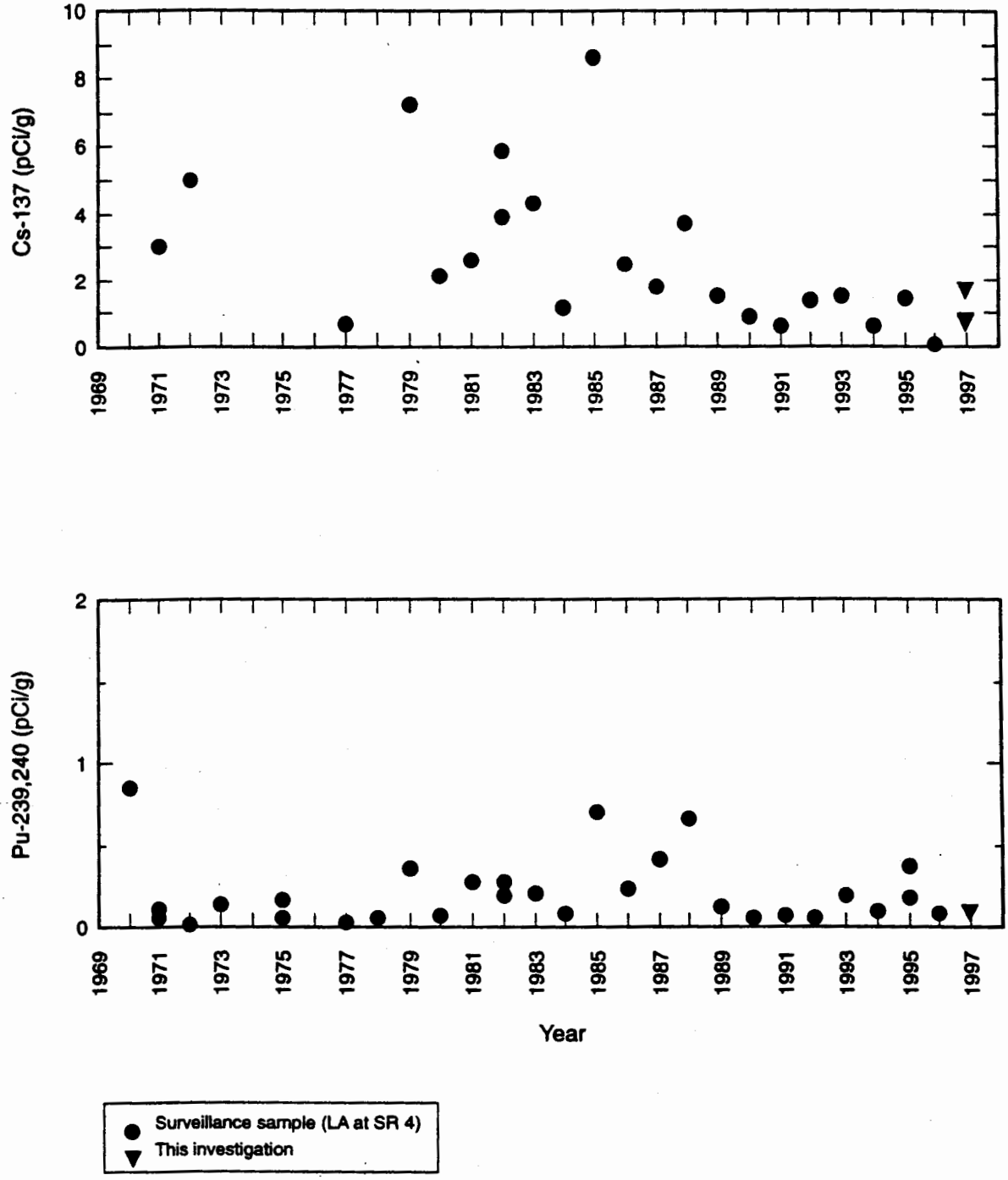


Figure 3.3-15. Depth variations in cesium-137 and americium-241 concentrations at sample sites in the f1 unit in reach LA-3.



F3.3-16 / UPPER LOS ALAMOS CANYON REACH RPT / 090298

Figure 3.3-16. Relation of the concentrations of cesium-137 and plutonium-239,240 from active channel sediment samples collected from reach LA-3.

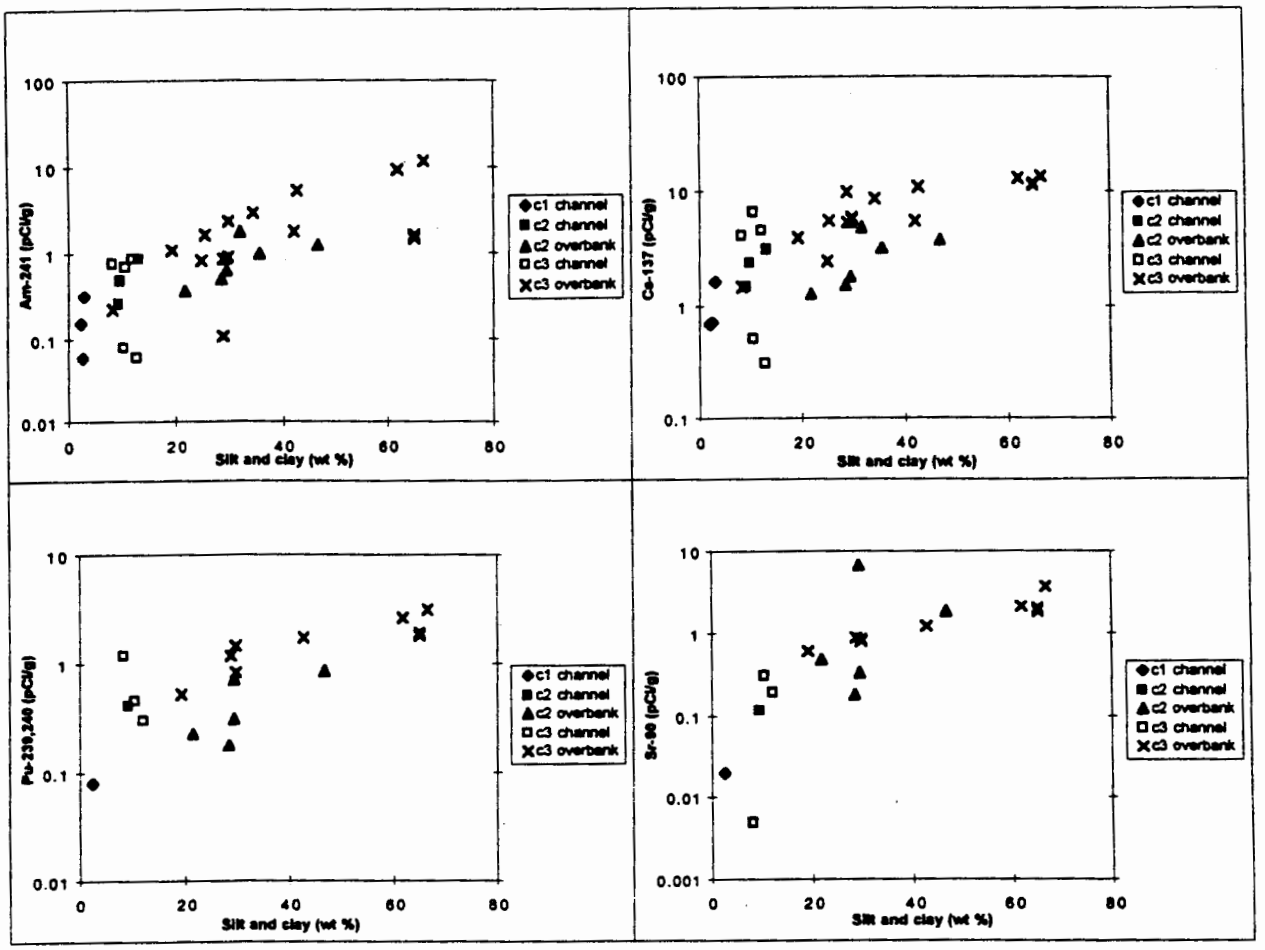


Figure 3.3-17. Scatter plots of radionuclide concentration against silt and clay content for all samples from the c1, c2, and c3 units in LA-3.

3.3.4.3 Contaminant Inventory

The estimated cesium-137 inventory in LA-3 is 13.9 mCi/km (Table 3.3-9), which is 22% of the estimated inventory in LA-2 East. Most of the estimated inventory, 74% , is contained within the relatively fine-grained overbank facies sediment deposits. The most important geomorphic unit is c3, which contains an estimated 68% of the cesium-137 in LA-3. Most of the estimated cesium-137 inventory in LA-3, 96%, is located in geomorphic units that are close to the active channel and are judged to be susceptible to remobilization during the next 50 years.

The estimated strontium-90 inventory in LA-3, 3.4 mCi/km (Table 3.3-9), is 21% of the estimated inventory in LA-2 East. This percentage is very similar to that estimated for cesium-137, consistent with the general collocation of these radionuclides, although the apparent distribution of strontium-90 in LA-3 differs in part from cesium-137 because there is not a perfect correlation between these two radionuclides. In particular, the available data indicate that only approximately 3% of the strontium-90 is contained within coarse-grained channel facies sediment, contrasting with the estimated 26% for cesium-137, reflecting lower strontium/cesium ratios in the coarse-grained sediment than in the fine-grained sediment. The c2 unit is also relatively more important for strontium-90 than cesium-137 in the estimated inventory, but the c2 estimate is biased by a single high strontium-90 value and therefore may not be reliable. Most of the estimated strontium-90 inventory (91%) is contained within units that are judged to be susceptible to remobilization.

TABLE 3.3-9

ESTIMATED CESIUM, AMERICIUM, PLUTONIUM, AND STRONTIUM INVENTORY IN REACH LA-3

Geomorphic Unit	Section	Sediment Facies	Area (m^2)	Estimated Average Thickness (m)	Estimated Volume (m^3)	Estimated Fraction <2 mm	Estimated Density (g/cm^3)	Estimated Average Concentration (pCi/g)	Estimated Radionuclide Inventory (mCi)	Percent of Total Subreach Inventory	Percent Potentially Susceptible to Remobilization	Estimated Inventory Most Susceptible to Remobilization (mCi)	Percent of Total Subreach Inventory Susceptible to Remobilization
LA-3 Cesium-137													
c1	All	Channel	897	0.5	449	0.5	1.23	1.03	0.28	5%	100%	0.28	5%
c1b	All	Channel	62	0.5	31	0.5	1.23	1.03	0.02	0%	100%	0.02	0%
c2	Lower	Channel	651	0.5	326	0.5	1.23	2.35	0.47	8%	100%	0.47	8%
c3	Lower	Channel	838	0.5	419	0.5	1.23	3.26	0.84	14%	100%	0.84	14%
Subtotal			**2448**		**1224**				**1.61**	**26%**		**1.61**	**26%**
c2	Upper	Overbank	651	0.41	267	0.82	1.04	3.17	0.7	12%	100%	0.72	12%
c3	Upper	Overbank	838	0.55	461	0.89	1.04	7.67	3.3	54%	100%	3.27	54%
f1	All	Overbank	362	0.42	152	0.88	1.04	3.50	0.5	8%	50%	0.24	4%
f2	All	Overbank	1015	0.05	51	0.96	1.04	0.36	0.0	0%	0%	0.00	0%
Subtotal					**931**				**4.50**	**74%**		**4.24**	**69%**
Total									**6.11**	**100%**			**96%**
LA-3 Strontium-90													
c1	All	Channel	897	0.5	449	0.5	1.23	0	0.00	0%	100%	0.00	0%
c1b	All	Channel	62	0.5	31	0.5	1.23	0	0.00	0%	100%	0.00	0%
c2	Lower	Channel	651	0.5	326	0.5	1.23	0.12	0.02	2%	100%	0.02	2%
c3	Lower	Channel	838	0.5	419	0.5	1.23	0.09	0.02	2%	100%	0.02	2%
Subtotal			**2448**		**1224**				**0.05**	**3%**		**0.05**	**3%**
c2	Upper	Overbank	651	0.41	267	0.82	1.04	1.99	0.5	31%	100%	0.45	31%
c3	Upper	Overbank	838	0.55	461	0.89	1.04	1.64	0.7	47%	100%	0.70	47%
f1	All	Overbank	362	0.42	152	0.88	1.04	1.99	0.3	19%	50%	0.14	9%
f2	All	Overbank	1015	0.05	51	0.96	1.04	0	0.0	0%	0%	0.00	0%
Subtotal					**931**				**1.43**	**97%**		**1.29**	**87%**
Total									**1.48**	**100%**			**91%**

TABLE 3.3-9 (continued)

ESTIMATED CESIUM, AMERICIUM, PLUTONIUM, AND STRONTIUM INVENTORY IN REACH LA-3

Geomorphic Unit	Section	Sediment Facies	Area (m^2)	Estimated Average Thickness (m)	Estimated Volume (m^3)	Estimated Fraction <2 mm	Estimated Density (g/cm^3)	Estimated Average Concentration (pCi/g)	Estimated Radionuclide Inventory (mCi)	Percent of Total Subreach Inventory	Percent Potentially Susceptible to Remobilization	Estimated Inventory Most Susceptible to Remobilization (mCi)	Percent of Total Subreach Inventory Susceptible to Remobilization
LA-3 Americium-241													
c1	All	Channel	897	0.5	449	0.5	1.23	0.18	0.05	3%	100%	0.05	3%
c1b	All	Channel	62	0.5	31	0.5	1.23	0.18	0.00	0%	100%	0.00	0%
LA-3 Americium-241													
c2	Lower	Channel	651	0.5	326	0.5	1.23	0.54	0.11	6%	100%	0.11	6%
c3	Lower	Channel	838	0.5	419	0.5	1.23	0.50	0.13	7%	100%	0.13	7%
Subtotal			**2448**		**1224**				**0.29**	**15%**		**0.29**	**15%**
c2	Upper	Overbank	651	0.41	267	0.82	1.04	0.92	0.2	11%	100%	0.21	11%
c3	Upper	Overbank	838	0.55	461	0.89	1.04	3.07	1.3	69%	100%	1.31	69%
f1	All	Overbank	362	0.42	152	0.88	1.04	0.55	0.1	4%	50%	0.04	2%
f2	All	Overbank	1015	0.05	51	0.96	1.04	0	0.0	0%	0%	0.00	0%
Subtotal					**931**				**1.60**	**85%**		**1.56**	**83%**
Total									**1.89**	**100%**			**98%**
LA-3 Plutonium-239,240													
c1	All	Channel	897	0.5	449	0.5	1.23	0.08	0.02	2%	100%	0.02	2%
c1b	All	Channel	62	0.5	31	0.5	1.23	0.08	0.00	0%	100%	0.00	0%
c2	Lower	Channel	651	0.5	326	0.5	1.23	0.42	0.08	7%	100%	0.08	7%
c3	Lower	Channel	838	0.5	419	0.5	1.23	0.66	0.17	14%	100%	0.17	14%
Subtotal			**2448**		**1224**				**0.28**	**23%**		**0.28**	**23%**
c2	Upper	Overbank	651	0.41	267	0.82	1.04	0.47	0.1	9%	100%	0.11	9%
c3	Upper	Overbank	838	0.55	461	0.89	1.04	1.73	0.7	62%	100%	0.74	62%
f1	All	Overbank	362	0.42	152	0.88	1.04	0.47	0.1	5%	50%	0.03	3%
f2	All	Overbank	1015	0.05	51	0.96	1.04	0.16	0.0	1%	0%	0.00	0%
Subtotal					**931**				**0.92**	**77%**		**0.88**	**73%**
Total									**1.20**	**100%**			**97%**

The estimated inventories of americium-241 and plutonium-239,240 show similar distributions in LA-3, with 85% and 77% being contained within the fine-grained overbank facies sediment deposits, respectively (Table 3.3-9). The most important geomorphic unit for each is c3, which contains an estimated 76% of their inventories. The estimated americium-241 inventory in LA-3 is 4.3 mCi/km, or 23% of that estimated in LA-2 East. The estimated plutonium-239,240 inventory is 2.7 mCi/km, or 38% of that estimated in LA-2 East. Virtually all the estimated inventories for americium-241 and plutonium-239,240 (97 to 98%), are contained within units that are judged to be susceptible to remobilization.

4.0 REVISED CONCEPTUAL MODEL

A key part of the technical approach for the evaluation of contamination in upper Los Alamos Canyon sediments, as presented in Chapter 5 of the work plan (LANL 1995, 50290), involved the collection of data to test hypotheses concerning the nature, distribution, and transport of contaminants associated with sediment. These hypotheses comprise components of a preliminary conceptual model and were developed based on results of prior investigations in upper Los Alamos Canyon and elsewhere, as discussed in Section 4.2 of the work plan. Because of the significant length of canyon floor affected by the transport and deposition of contaminated sediments and because of the complexity of sediment transport processes that have been operating since 1942, the validation and refinement of this conceptual model is necessary to perform a defensible quantitative evaluation of risk in the sampled reaches, to qualitatively evaluate risk in intervening unsampled areas, and to evaluate the future redistribution of contaminants and associated impacts.

This section presents the current conceptual model of contamination in upper Los Alamos Canyon sediments, which has been revised and refined from the preliminary conceptual model presented in Section 4.2 of the work plan (LANL 1995, 50290) based on the results of the investigations in reaches LA-1, LA-2, and LA-3 as discussed in Sections 2 and 3 of this report. This conceptual model includes discussions of the general nature and extent of contamination within the sediments, controlling factors for present-day contaminant distribution and variations in contaminant levels, geomorphic processes that redistribute these contaminants, and inferences about the fate and future transport of these contaminants.

4.1 Nature and Extent of Contamination

4.1.1 Analytes above Background Values

Forty-eight analytes are present within the sediments in upper Los Alamos Canyon at levels above or potentially above background values and are considered to be chemicals of potential concern (COPCs), as discussed in Section 3.2 and summarized in Table 4.1-1. The most significant contaminants are radionuclides that are associated with known effluent releases from the 21-011(k) outfall at Technical Area (TA) -21 into DP Canyon. Americium-241, cesium-137, plutonium-238, strontium-90, and tritium were all identified as COPCs in this investigation and have their primary source within the DP Canyon watershed, consistent with data from effluents at 21-011(k). Plutonium-239,240 was also released from 21-011(k), but its geographic distribution indicates that its primary source in the upper Los Alamos Canyon watershed was discharges from former TA-1 at Hillside 137, upstream from DP Canyon. Discharges from a laundry at TA-21 directly into Los Alamos Canyon were an additional source of plutonium-239,240 upstream from DP Canyon.

It is notable that cesium-137 and strontium-90 were both expected to be present as COPCs upstream from DP Canyon based on data from potential release sites (PRSs) at TA-2 (investigations described in LANL 1995, 52974) and on the presence of strontium-90 in alluvial groundwater downstream from TA-2 (Longmire et al. 1996, 54168). However, available data indicate that cesium-137 is present only at low concentrations above the background value and that strontium-90 is not a COPC in surface sediments upstream from DP Canyon. Strontium-90 was not found above the background value in sediment samples collected in reach LA-1 Central downstream from TA-2 either in this investigation or in prior Environmental Restoration Project investigations (LANL 1995, 52974), and some anomalous results above the background value from LA-2 West samples in this investigation could not be replicated upon resampling (Section 3.3.1.6). The strontium-90 in alluvial groundwater upstream from DP Canyon is apparently derived from contaminants in deeper alluvium at a leach field (PRS 02-009), and surface sediments are not contaminated with strontium-90.

TABLE 4.1-1

SUMMARY OF UPPER LOS ALAMOS CANYON COPCs

COPC and Units	Background Value or Estimated Quantitation Limit	Maximum Result*	Subreach with Maximum Result*	Geomorphic Unit and Sediment Facies with Maximum Result*	Inferred Primary Source(s)
Radionuclides (pCi/g)					
Americium-241	0.04	28	LA-2 East	c2, overbank	21-011(k)
Cesium-134	0.14	0.18	LA-2 East	c1, channel	Unknown, possibly background
Cesium-137	0.90	192.31	LA-2 East	c3, overbank	21-011(k)
Cobalt-60		0.206	LA-3	c2, overbank	TA-53
Europium-152	0.59	0.525 [0.59]	LA-3	c2, overbank	Unknown, possibly background
Plutonium-238	0.006	2.01	LA-2 East	c2b, overbank	21-011(k)
Plutonium-239,240	0.068	19.3	LA-1 East	f1, overbank	TA-1, TA-21
Strontium-90	1.03	39.56	LA-2 East	c3, overbank	21-011(k)
Thorium-228	2.28	2.9	LA-3	c2, overbank	TA-21, TA-1
Thorium-230	2.29	2.61	LA-3	c2, overbank	Unknown, possibly background (?)
Thorium-232	2.33	2.64	LA-3	c2, overbank	Unknown, possibly background (?)
Tritium	0.093	0.143 [0.454]	DP Canyon [LA-2 W]	c2b, overbank	21-011(k)
Uranium-234	2.59	2.6	LA-2 West	c2, overbank	TA-21, TA-1
Uranium-235	0.2	0.186	LA-2 East	c2, overbank	TA-21, TA-1
Uranium-238	2.29	2.52	LA-2 West	c2, overbank	TA-21, TA-1
Inorganic Chemicals (mg/kg)					
Antimony	0.83	0.5 [9.2]	LA-1 Central [LA-1 W]	c3, overbank	Possibly background
Cadmium	0.4	0.89	LA-2 East	c2, overbank	Unknown
Chromium, total	10.5	38.4	LA-2 East	c3, overbank	21-011(k), plus other sources
Copper	11.2	23.8	LA-1 East	f1, overbank	TA-21, plus other sources
Lead	19.7	61.9	LA-2 East	c3, overbank	TA-1, TA-21, and other sources
Mercury	0.1	0.31	LA-2 West	c2, overbank	TA-1, TA-21
Selenium	0.3	0.65 [1.4]	LA-2 East	c3, overbank	Possibly background
Silver	1.0	15.8	LA-2 West	c2, overbank	TA-1, TA-21
Uranium, total	6.99	6.9	LA-2 West	f1, overbank	21-011(k), plus other sources
Zinc	60.2	90.5	LA-2 East	c3, overbank	21-011(k), plus other sources

*Values in brackets indicate that the maximum result is reported as a nondetect.

TABLE 4.1-1 (continued)

SUMMARY OF UPPER LOS ALAMOS CANYON COPCs

COPC and Units	Background Value or Estimated Quantitation Limit	Maximum Result[a]	Subreach with Maximum Result[a]	Geomorphic Unit and Sediment Facies with Maximum Result[a]	Inferred Primary Source(s)
Organic Chemicals (mg/kg)					
Aroclor-1254	0.033	1.5	LA-1 West+	c3, overbank	Unknown (multiple sources? nps[b]?)
Aroclor-1260	0.033	1	LA-1 East	c3, overbank	Unknown (multiple sources? nps?)
α-Chlordane	0.0165	0.0072	LA-1 West	c2, overbank	Unknown (multiple sources? nps?)
γ-Chlordane	0.0165	0.0068	LA-1 West	c2, overbank	Unknown (multiple sources? nps?)
4,4'-DDE	0.033	0.033	LA-2 East	c3, overbank	Unknown (multiple sources? nps?)
4,4'-DDT	0.033	0.048	LA-1 Central	c3, overbank	Unknown (multiple sources? nps?)
Acenaphthene	0.33	0.26 [0.355]	LA-2 East	c2, overbank	Unknown (multiple sources? nps?)
Anthracene	0.33	0.096 [0.34]	DP Canyon [LA-3]	c2b, overbank	Unknown (multiple sources? nps?)
Benz(a)anthracene	0.33	0.368	LA-2 East	c2, overbank	Unknown (multiple sources? nps?)
Benzo(a)pyrene	0.33	0.655	LA-2 East	c2b, overbank	Unknown (multiple sources? nps?)
Benzo(b)fluoranthene	0.33	0.622	LA-2 East	c2, overbank	Unknown (multiple sources? nps?)
Benzo(g,h,i)perylene	0.33	0.298 [0.47]	LA-2 East	c2b, overbank	Unknown (multiple sources? nps?)
Benzo(k)fluoranthene	0.33	0.36	LA-3	c2, overbank	Unknown (multiple sources? nps?)
Chrysene	0.33	0.41	LA-2 East	c2, overbank	Unknown (multiple sources? nps?)
Dibenz(a,h)anthracene	0.33	0.029 [0.38]	LA-2 East [LA-2 W]	c2, overbank	Unknown (multiple sources? nps?)
Dibenzofuran	0.33	0.036 [0.355]	DP Canyon [LA-2 E]	c2b, overbank	Unknown (multiple sources? nps?)
Di-n-butylphthalate	0.33	0.055 [0.34]	DP Canyon, LA-2 E	c2, c2b, overbank	Unknown (multiple sources? nps?)
Fluoranthene	0.33	0.725	LA-2 East	c2, overbank	Unknown (multiple sources? nps?)
Fluorene	0.33	0.066 [0.0355]	DP Canyon	c2b, overbank	Unknown (multiple sources? nps?)
Indeno(1,2,3-cd)pyrene	0.33	0.341	LA-2 East	c2b, overbank	Unknown (multiple sources? nps?)
Naphthalene	0.33	0.2 [0.355]	LA-2 West [LA-2 E]	c2 overbank	Unknown (multiple sources? nps?)
Phenanthrene	0.33	0.432	DP Canyon	c2b, overbank	Unknown (multiple sources? nps?)
Pyrene	0.33	0.589	LA-2 East	c2b, overbank	Unknown (multiple sources? nps?)

a. Values in brackets indicate that the maximum result is reported as a nondetect.

b. nps = nonpoint sources

Six uranium and thorium isotopes were identified as COPCs in sediment samples from upper Los Alamos Canyon at relatively low levels above background. Both uranium-235 and isotopes in the uranium-238 decay chain (thorium-230, uranium-234, and uranium-238) are at least partially correlated with cesium-137, suggesting a primary source in the DP Canyon watershed. However, the maximum uranium-234 and uranium-238 concentrations are in a sample upstream from DP Canyon, indicating multiple sources for these isotopes. Isotopes in the thorium-232 decay chain (thorium-228 and thorium-232) are not correlated with cesium-137 and have maximum values downstream in reach LA-3; a laboratory bias is suspected for these results (Section 3.2.2).

Cobalt-60 was detected in five samples, with the four highest collected from reach LA-3 and the fifth from reach LA-2 East. The higher frequency of detects and the higher values from LA-3 are consistent with known releases from TA-53 (LANL 1998, 57666). Cobalt-60 does not have a background value, and the detection limit is used as a surrogate background level. Cobalt-60 is present only at low levels above detection limits in upper Los Alamos Canyon sediment samples, indicating that only small amounts of this radionuclide are present along the stream channel. However, samples have not been collected in the part of upper Los Alamos Canyon closest to the tributary drainage from TA-53, and cobalt-60 concentrations may be higher upstream from LA-3. Notably, this radionuclide has a short half-life of 5.3 years, and cobalt-60 concentrations will decrease relatively rapidly because of radioactive decay.

Two other radionuclide COPCs, cesium-134 and europium-152, had a very low frequency of detects. These radionuclides also do not have background values, and the detection limits are used as surrogate background levels. The detected results are within the range of nondetected results, and these data are not conclusive as to whether they represent releases into upper Los Alamos Canyon. These radionuclides also have relatively short half-lives (2.1 years for cesium-134 and 14 years for europium-152) and, if they represent releases from the Laboratory, they will decay relatively rapidly to values below the detection limit.

Inorganic chemicals identified as COPCs in this investigation include antimony, cadmium, chromium, copper, lead, mercury, selenium, silver, uranium, and zinc (Table 4.1-1). Most detected concentrations of these metals are less than background values, indicating that contaminant releases were relatively small. Seven of these inorganic COPCs appear to be correlated with either cesium-137, which suggests primary releases at the 21-011(k) outfall in DP Canyon, or with plutonium-239,240, which suggests primary releases upstream from DP Canyon. Chromium and uranium appear to be correlated with cesium-137, and copper, lead, mercury, silver, and zinc appear to be correlated with plutonium-239,240. Both copper and lead were detected above background values in LA-1 Far West, upstream from all PRSs at former TA-1, suggesting either releases from unidentified PRSs farther upstream or other sources such as residential areas in the Los Alamos townsite or road runoff. The other three inorganic COPCs (antimony, cadmium, and selenium) were not detected with sufficient frequency to draw conclusions about potential contaminant releases.

Twenty-three organic chemicals were identified as COPCs in this investigation (Table 4.1-1), as discussed in Section 3, but reported concentrations for all these analytes are relatively low, and their origin and distribution in upper Los Alamos Canyon sediments are uncertain. Interpretation of the organic chemical data is limited by poor spatial coverage of analyses, particularly because quality assurance and quality control problems forced all organic chemical data from reach LA-3 to be rejected (Appendix C-4.0). In addition, no semivolatile organic chemical analyses were obtained in reach LA-1, and geographic variations in contamination can be examined only for polychlorinated biphenyls (PCBs) and pesticides. PCBs and pesticides were detected in all subreaches in LA-1 and LA-2, and available data do not show any consistent geographic variations in these COPCs; instead, these data suggest multiple sources. For example, the highest value for the PCB Aroclor-1254 was obtained from reach LA-1 West+,

upstream from Hillside 137 at former TA-1, and the highest value for Aroclor-1260 was obtained more than 2 km downstream in reach LA-1 East. None of the organic COPCs are collocated with radionuclide or inorganic COPCs, suggesting different sources for the different suites of COPCs, including sources upstream from all PRSs at former TA-1.

4.1.2 Horizontal and Vertical Extent

The horizontal and vertical extent of contaminated sediments in upper Los Alamos Canyon have been defined using a combination of geomorphic mapping, field radiological measurements, and analytical results from sediment sampling in reaches LA-1, LA-2, and LA-3. Various radionuclide contaminants have been distributed by floods along the full length of upper Los Alamos Canyon downstream from former TA-1, a stream distance of approximately 10 km. Floods have also distributed contaminants laterally across the canyon floor in a belt that varies in width from less than 5 m to at least 25 m; these variations in width depend on the local morphology of the canyon floor. The area inundated by post-1942 floods averages 9 to 15 m wide in LA-1, LA-2, and LA-3 (Section 2.3).

The vertical extent of contamination in upper Los Alamos Canyon sediments ranges from depths of less than 5 cm to at least 1.5 m. The thinnest layers of contaminated sediment occur on floodplains that were probably only briefly inundated by one or more floods since 1942. In contrast, areas of active and abandoned post-1942 channels are commonly underlain by at least 0.5 to 1.0 m of sediment containing radionuclides above background values. The thicknesses of the relatively fine-grained overbank facies sediment, where contaminant concentrations are highest, is generally well constrained by both field evidence and analytical results. The vertical extent of contaminants in the coarser-grained channel facies sediment, where contaminant concentrations are lower, is not constrained by sediment sampling because it was not practical to sample at depth because of the coarse rocky nature of these deposits. However, contaminants could be present through the full thickness of the alluvium below the active and abandoned channels associated with both the translocation of contaminants adsorbed to sediment particles or organic colloids and with the transport of contaminants in solution. Evidence for translocation of contaminants adsorbed to sediment particles or organic colloids has been obtained in Pueblo Canyon (Reneau et al. 1998, 59159), and the same processes should be effective in upper Los Alamos Canyon. The transport of contaminants in solution, including chromium, strontium-90, and tritium, is shown by their occurrence in alluvial groundwater in upper Los Alamos Canyon (Longmire et al. 1996, 54168); strontium-90 has also been reported in solution in storm water samples (e.g., Dale 1996, 58930). The thickness of alluvium in upper Los Alamos Canyon has been reported at approximately 2 to 6 m (Purtymun 1995, 45344), providing an upper limit to the vertical extent of contaminated sediments. However, concentrations of sediment-bound contaminants in the channel facies sediment probably decrease with depth, as observed in Pueblo Canyon, and it is probable that only a small percentage of the total contaminant inventory is contained within these deep sediments. Concentrations of soluble contaminants such as strontium-90 should also be relatively low in sediments below the water table except in areas near TA-2 where strontium-90 was directly discharged into alluvium at a leach field (PRS 02-009).

4.2 Variations in Contamination

The present distribution of most COPCs and variations in contaminant concentration in upper Los Alamos Canyon sediments are largely controlled by sediment transport processes that have been operating during the past 55 years. Thus, sediment transport processes also affect spatial variations in any present or future risk that may be associated with these contaminants. Key components of the preliminary conceptual model that have been confirmed by this investigation include the occurrence of the highest concentrations of radionuclides in areas closest to the source, in relatively fine-grained sediment deposits, and in relatively old sediments (pre-1968). A major revision to the conceptual model involved

finding the highest concentrations of plutonium-239,240 upstream from DP Canyon, indicating that the 21-011(k) outfall was not the most important source for plutonium in upper Los Alamos Canyon as was previously believed. Variations in contaminant concentration as pertains to evaluating risk and understanding important transport processes are discussed in the following sections.

4.2.1 Relations to Particle Size Variations

Variations in particle size characteristics between sediment deposits of similar age have a major influence on vertical and horizontal variations in contaminant concentrations in upper Los Alamos Canyon and also have important implications for evaluating risk. In every reach, the maximum and average concentrations of the key radionuclides are higher in the relatively fine-grained overbank facies sediment deposits than in associated coarse-grained channel facies sediment deposits, as discussed in Section 3.3. Although the data sets for other COPCs such as mercury and PCBs are smaller, the highest concentrations of these COPCs also occur in the relatively fine-grained overbank facies sediment deposits. Within sediments of similar age in each reach, trends of increasing radionuclide concentration with increasing percentages of clay-sized particles and/or silt and clay particles are also evident (Section 3.3 and Appendix B-3), which explains some of the variation in radionuclide concentration within sediments in a reach.

The higher radionuclide concentrations in overbank facies sediment are also apparent in volume-weighted averages that combine data from all units in each reach, shown for cesium-137 and plutonium-239,240 in Table 4.2-1. Thus, the results of this investigation are consistent with previous investigations that showed the influence of particle size variations on contaminant concentrations (e.g., Nyhan et al. 1976, 11747) and support the collection of data on particle size distribution in sediment samples to understand the basis for variations in contamination. Importantly, contaminant concentrations in the respirable fraction (<10 micron size fraction, including fine silt and clay-sized particles) will be higher than those measured in a bulk sediment sample where less than 20% of the material is within this size range. The smaller size fractions will also be more likely to adhere to skin and potentially be ingested.

4.2.2 Age Trends

Evidence for trends in contaminant concentrations over time varies among the different key radionuclide contaminants in upper Los Alamos Canyon. Data obtained in this investigation show clear decreases in the concentrations of cesium-137 and strontium-90 during the last several decades, and the largest variations in the concentrations of these radionuclides can be attributed to differences in the age of the sampled sediment deposits. These decreases are too large to be attributable to radioactive decay, and instead they record dilution by the mixing with sediment containing lower radionuclide concentrations. Americium-241 and plutonium-238 concentration also vary with sediment age but are largely controlled by variations in releases from the 21-011(k) outfall, and trends that are related to sediment transport processes are less clear for these radionuclides. Evidence pertaining to plutonium-239,240 is less conclusive, with possible decreases in concentration over time seen in data from some areas, but with no trend being apparent in others.

The strongest relations between sediment age and radionuclide concentration were obtained in reach LA-2 East immediately downstream from DP Canyon using age control provided by variations in the ratios of different isotopes released from the 21-011(k) outfall (discussed in Sections 3.3.1.5 and 3.3.3.2). Figure 4.2-1 shows the average concentration of key radionuclides in overbank facies sediment from LA-2 East as a function of approximate sediment age. Based on isotopic ratios and the release history of 21-011(k), overbank sediments from the c3 unit are inferred to have been deposited between 1956 and 1968; subsurface sediments from the c2b unit are inferred to have been deposited between 1968 and 1978; and typical sediments in the c2 unit are inferred to have been deposited after 1978.

TABLE 4.2-1

SUMMARY OF GEOGRAPHIC AND RADIOLOGICAL CHARACTERISTICS OF UPPER LOS ALAMOS CANYON REACHES

Part 1

Reach	Approx. Stream Elevation, Upstream End (ft)	Approx. Distance from Los Alamos Canyon Bridge Upstream End [a] (km)	Approx. Length Sampled Reach (km)	Approx. Length Unsampled Reach (km)	Estimated Volume of Post-1942 Channel Facies Sediment (m^3/km)	Estimated Volume of Post-1942 Overbank Facies Sediment (m^3/km)	Estimated Total Inventory Sampled Reaches (mCi)	Estimated Total Inventory Unsampled Reaches (mCi)[b]
Cesium-137								
LA-1 Far West	7057	0.92	0.11		3364	1218	0.0	
LA-1 unsampled	7050	1.03		0.43				0.0
LA-1 West+	7005	1.46	0.14		2286	2236	0.1	
LA-1 unsampled	6993	1.60		0.04				0.0
LA-1 West	6989	1.64	0.37		3541	3830	0.6	
LA-1 unsampled	6957	2.01		1.14				1.7
LA-1 Central	6850	3.15	0.39		2892	1956	0.6	
LA-1 unsampled	6810	3.54		0.44				1.2
LA-1 East	6774	3.98	0.43		3216	3116	1.8	
LA-1 to LA-2	6738	4.41		1.49				3.7
LA-2 West	6630	5.90	0.21		4448	1748	0.3	
LA-2 East	6614	6.11	0.68		3847	3090	44.0	
LA-2 to LA-3	6567	6.79		2.67				104.9
LA-3	6396	9.46	0.44		2782	2116	6.1	
LA-3 to Pueblo	6370	9.90		1.53				21.2
Total Cesium-137			**2.77**	**7.74**			**53.4**	**132.8**

a. Approximate distances from Los Alamos Canyon bridge measured along the stream channel as depicted on 1:1200 scale FIMAD maps with 2-ft contour intervals

b. Preliminary estimate of inventory in unsampled reaches assumes either average inventories (mCi/km) of bounding sampled reaches or same inventory as adjacent reach near major tributary junctions

TABLE 4.2-1 (continued)

SUMMARY OF GEOGRAPHIC AND RADIOLOGICAL CHARACTERISTICS OF UPPER LOS ALAMOS CANYON REACHES

Part 1 continued

Reach	Approx. Stream Elevation, Upstream End (ft)	Approx. Distance From Los Alamos Canyon Bridge, Upstream End (km)[a]	Approx. Length Sampled Reach (km)	Approx. Length Unsampled Reach (km)	Estimated Volume of Post-1942 Channel Facies Sediment (m^3/km)	Estimated Volume of Post-1942 Overbank Facies Sediment (m^3/km)	Estimated Total Inventory (Sampled Reaches) (mCi)	Estimated Total Inventory (Unsampled Reaches) (mCi)[b]
Plutonium-239,240								
LA-1 Far West	7057	0.92	0.11		3364	1218	0.0	
LA-1 unsampled	7050	1.03		0.43				0.1
LA-1 West+	7005	1.46	0.14		2286	2236	0.1	
LA-1 unsampled	6993	1.60		0.04				0.4
LA-1 West	6989	1.64	0.37		3541	3830	6.5	
LA-1 unsampled	6957	2.01		1.14				13.5
LA-1 Central	6850	3.15	0.39		2892	1956	2.4	
LA-1 unsampled	6810	3.54		0.44				4.3
LA-1 East	6774	3.98	0.43		3216	3116	5.8	
LA-1 to LA-2	6738	4.41		1.49				13.9
LA-2 West	6630	5.90	0.21		4448	1748	1.1	
LA-2 East	6614	6.11	0.68		3847	3090	4.9	
LA-2 to LA-3	6567	6.79		2.67				13.2
LA-3	6396	9.46	0.44		2782	2116	1.2	
LA-3 to Pueblo	6370	9.90		1.53				4.2
Total Plutonium-239,240			**2.77**	**7.74**			**22.0**	**49.5**

a. Approximate distances from Los Alamos Canyon bridge measured along the stream channel as depicted on 1:1200 scale FIMAD maps with 2-ft contour intervals

b. Preliminary estimate of inventory in unsampled reaches assumes either average inventories (mCi/km) of bounding sampled reaches, or same inventory as adjacent reach near major tributary junctions

TABLE 4.2-1 (continued)

SUMMARY OF GEOGRAPHIC AND RADIOLOGICAL CHARACTERISTICS OF UPPER LOS ALAMOS CANYON REACHES

Part 2								
Reach	Estimated Total Inventory, Channel Facies (Sampled Reaches) (mCi/km)	Estimated Total Inventory, Overbank Facies (Sampled Reaches) (mCi/km)	Estimated Total Inventory (Sampled Reaches) (mCi/km)	Estimated Average Concentration in Post-1942 Channel Facies Deposits (pCi/g)	Estimated Average Concentration in Post-1942 Overbank Facies Deposits (pCi/g)	Estimated Inventory Susceptible to Remobilization (Sampled Reaches) (mCi)	Estimated Inventory Susceptible to Remobilization (Unsampled Reaches) (mCi)	Estimated Inventory Susceptible to Remobilization (Sampled Reaches) (mCi/km)
Cesium-137								
LA-1 Far West	0.1	0.3	0.4	0.00	0.10	0.0		0.2
LA-1 unsampled							0.1	
LA-1 West+	0.1	0.4	0.5	0.05	0.20	0.0		0.3
LA-1 unsampled							0.0	
LA-1 West	0.2	1.3	1.5	0.10	0.29	0.3		0.8
LA-1 unsampled							1.0	
LA-1 Central	0.3	1.1	1.4	0.16	0.58	0.4		0.9
LA-1 unsampled							0.8	
LA-1 East	0.4	3.8	4.2	0.20	1.44	1.1		2.5
LA-1 to LA-2							2.5	
LA-2 West	0.7	0.7	0.8	0.24	0.74	0.2		0.8
LA-2 East	18.3	46.4	64.7	7.73	17.17	41.1		60.4
LA-2 to LA-3							98.3	
LA-3	3.7	10.2	13.9	2.14	5.30	5.9		13.30
LA-3 to Pueblo							20.3	
Total Cesium-137						**48.9**	**123.1**	

TABLE 4.2-1 (continued)

SUMMARY OF GEOGRAPHIC AND RADIOLOGICAL CHARACTERISTICS OF UPPER LOS ALAMOS CANYON REACHES

Part 2 continued								
Reach	Estimated Total Inventory, Channel Facies (Sampled Reaches) (mCi/km)	Estimated Total Inventory, Overbank Facies (Sampled Reaches) (mCi/km)	Estimated Total Inventory (Sampled Reaches) (mCi/km)	Estimated Average Concentration in Post-1942 Channel Facies Deposits (pCi/g)	Estimated Average Concentration in Post-1942 Overbank Facies Deposits (pCi/g)	Estimated Inventory Susceptible to Remobilization (Sampled Reaches) (mCi)	Estimated Inventory Susceptible to Remobilization (Unsampled Reaches) (mCi)	Estimated Inventory Susceptible to Remobilization (Sampled Reaches) (mCi/km)
Plutonium-239,240								
LA-1 Far West	0.0	0.1	0.1	0.00	0.03	0.0	0.2	0.0
LA-1 unsampled				0.03	0.38	0.1		0.5
LA-1 West+	0.1	0.8	0.9				0.3	
LA-1 unsampled				0.39	4.59	5.3		14.4
LA-1 West	0.8	16.8	17.6					
LA-1 unsampled							10.6	
LA-1 Central	0.4	5.6	6.0	0.22	2.86	1.6		4.2
LA-1 unsampled							1.9	
LA-1 East	1.1	12.4	13.4	0.54	4.04	2.0		4.6
LA-1 to LA-2							5.5	
LA-2 West	1.7	3.5	5.2	0.62	2.19	0.6		2.8
LA-2 East	1.2	6.0	7.2	0.49	2.17	4.7		6.9
LA-2 to LA-3							12.7	
LA-3	0.6	2.1	2.7	0.37	1.08	1.2		2.6
LA-3 to Pueblo							4.0	
Total Plutonium-239,240						**15.4**	**35.2**	

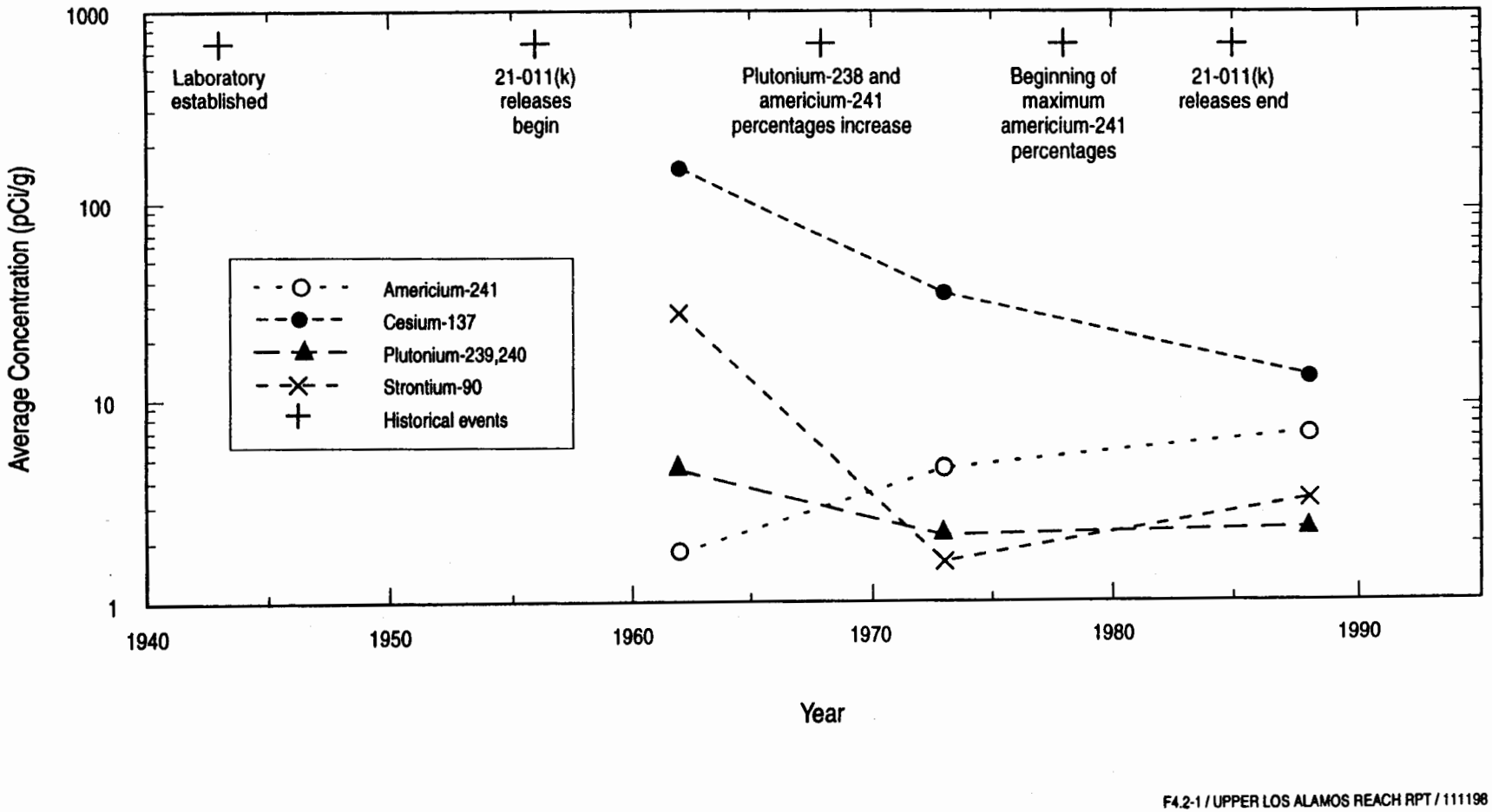


Figure 4.2-1. Estimated variations over time in average radionuclide concentration in overbank sediments in LA-2 East.

As shown in Figure 4.2-1, average cesium-137 concentrations in LA-2 East decreased by an order of magnitude between the pre-1968 c3 sediments and the post-1978 c2 sediments. Intermediate age c2b sediments have intermediate cesium-137 concentrations, consistent with a progressive decrease over time. Strontium-90 also decreased by an order of magnitude over this time period, although strontium-90 concentration is least in the subsurface c2b sediments; note that this strontium-90 average is based on only two samples and may not be reliable. A progressive increase in americium-241 concentration over time seen in Figure 4.2-1 can be directly related to the 21-011(k) release history. In Figure 4.2-1 a decrease in the concentration of plutonium-239,240 over time is suggested, although average concentrations in all units are relatively low (2.3 to 4.7 pCi/g); this apparent trend may not be significant.

Supplemental data on trends in radionuclide concentrations in LA-2 East sediments are provided by analyses from the Laboratory's environmental surveillance program (e.g., Environmental Surveillance and Compliance Programs 1997, 56684). Analyses from the lower DP Canyon channel (Figure 3.3-10) suggest that the concentrations of cesium-137; plutonium-239,240; and strontium-90 decreased between the mid 1980s, the time of the last effluent releases from 21-011(k), and 1990. Analyses from the Los Alamos Canyon channel immediately downstream from DP Canyon (Figure 3.3-11) also suggest decreases in cesium-137 concentration between the 1980s and the 1990s and in plutonium-239,240 concentration after 1980. These surveillance samples were all collected from active stream channels and may be dominated by coarse sand, although there are no particle size data on these samples; variability that might be related to varying portions of fine-grained sediment in these samples cannot be evaluated.

Data collected from reach LA-3 in this investigation indicate decreases in the concentrations of the key radionuclides over time in this area close to the Laboratory boundary. Concentrations of americium-241; cesium-137; plutonium-238; and plutonium-239,240 are less in the younger c2 sediments than in the older c3 sediments (Table 3.3-8). Isotopic ratios indicate that most of these sediments were deposited after 1968, but finer time resolution is not possible. Data from the environmental surveillance station at state road NM 4, immediately downstream from reach LA-3, suggest decreases in cesium-137 concentration between the 1980s and the 1990s (Figure 3.3-16), but no trends are suggested in the concentrations of other radionuclides.

Data collected from reach LA-1 in this investigation contrast with data from downstream reaches in providing no evidence for changes in radionuclide concentrations over time. The key radionuclide in LA-1, plutonium-239,240, has its maximum sample result in LA-1 West, close to the Hillside 137 contaminant source in former TA-1, in sediments deposited after 1974 (Section 3.3.2.2). The release history from TA-1 is not well constrained, but the buildings that contributed contaminants to Hillside 137 were vacated by the mid 1950s; therefore, plutonium-239,240 concentrations in LA-1 West were relatively high at least 20 years after the last releases. Although the reason for these unexpected results are not certain, one possibility is that much of the plutonium-239,240 released onto Hillside 137 between the mid 1940s and the mid 1950s was stored on the hillslope itself instead of reaching the main stream channel, and that this plutonium has been slowly transported to the channel over a period of decades associated with surface runoff and erosion on the hillside. If this hypothesis is correct, then erosion on Hillside 137 may have continued to provide plutonium-239,240 to the main channel at similar rates up to the present.

In summary, available data on radionuclides in the sediments of upper Los Alamos Canyon indicate that concentrations in LA-3 near the Laboratory boundary have decreased during the past 30 years. Because effluent releases stopped more than 10 years ago and concentrations in sediments in LA-2 East closer to the source have also generally been decreasing over time, there is no reason to expect concentrations at the Laboratory boundary to increase in the future.

4.2.3 Spatial Trends

Two key spatial trends in contamination in upper Los Alamos Canyon sediments are an integral part of the conceptual model describing contaminants in these sediments: spatial trends in contaminant concentration and spatial trends in contaminant inventory. Based on the results of prior investigations (e.g., Nyhan et al. 1975, 11746; Graf 1996, 55537), it was expected that contaminant concentrations would tend to decrease downstream from the source (LANL 1995, 50290). This component of the preliminary conceptual model was confirmed in this investigation, as discussed in Section 4.2.3.1, although revision of the conceptual model is necessary in regard to the primary source of the plutonium-239,240 in upper Los Alamos Canyon (Hillside 137 in TA-1 instead of the 21-011[k] outfall). Spatial trends in radionuclide inventories in upper Los Alamos Canyon were poorly constrained before this investigation, with the exception of a proposed decrease in the inventory of plutonium between DP Canyon and state road NM 4 (Graf 1995, 48851; Graf 1996, 55537). Data obtained in this investigation confirm this trend for plutonium and show that the inventories of the other key radionuclides also decrease between DP Canyon and state road NM 4, as discussed in Section 4.2.3.2. The preliminary conceptual model has also been revised to include the plutonium inventory upstream from DP Canyon.

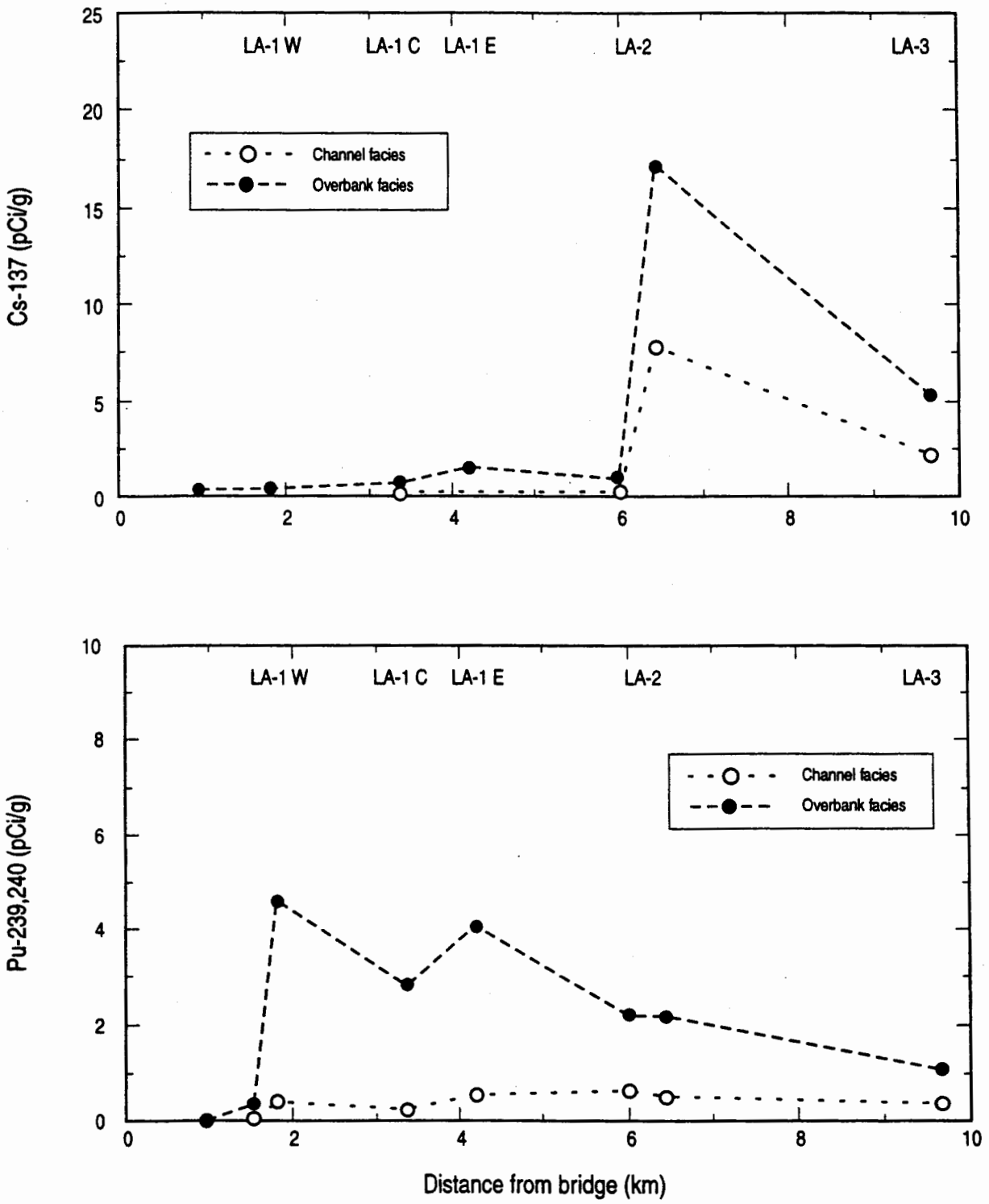
4.2.3.1 Spatial Trends in Radionuclide Concentration

Data collected in this investigation demonstrate clear decreases in the concentrations of key radionuclides in upper Los Alamos Canyon with progressive distance from the contaminant sources. Figure 4.2-2 shows estimated geographic variations in the average concentrations of cesium-137 and plutonium-239,240 in sediment in the upper Los Alamos Canyon reaches, including both channel facies and overbank facies sediment. These average concentrations are derived from the average values presented in Tables 3.3-3, 3.3-6, and 3.3-9 and are weighted by the estimated volume of sediment in each geomorphic unit.

Cesium-137 concentrations are highest in reach LA-2 East, immediately downstream from the confluence of DP Canyon and Los Alamos Canyon and are much lower downstream in reach LA-3 (Figure 4.2-2). Americium-241, plutonium-238, and strontium-90 display similar trends. Additional sources for cesium-137 upstream from DP Canyon are suggested by slight elevations of cesium-137 concentrations in LA-1 East relative to background values, although the amount of cesium-137 derived from such sources is apparently small.

Plutonium-239,240 concentrations are highest in reach LA-1 West immediately downstream from Hillside 137 and generally show progressive decreases downstream to LA-3 (Figure 4.2-2). A possible deviation from this downstream decrease in plutonium-239,240 concentration is seen at LA-1 East where average concentrations are somewhat higher than upstream in LA-1 Central. An increase in plutonium concentration in LA-1 East could be related to releases from the south side of TA-21, such as discharges from the old laundry. However, the estimated average plutonium-239,240 concentration in LA-1 East is biased by a single high value of 19.3 pCi/g that was more than three times greater than the next highest value (Section 3.3.2.1), and this apparent increase in concentration may not be reliable.

The occurrence of the highest concentrations of plutonium in reach LA-1 West, related to releases from former TA-1, was not expected based on the results of prior studies and constitutes a significant revision to the conceptual model. Previous reports on plutonium in upper Los Alamos Canyon had indicated that releases from the 21-011(k) outfall into DP Canyon were the primary source of plutonium contained in sediments along the main stream channel (e.g., Purtymun 1971, 4795; Nyhan et al. 1975, 11746; Graf 1996, 55537). Notably, data from this investigation indicate that there is no significant difference in average plutonium-239,240 concentrations in either channel facies or overbank facies sediment between LA-2 West and LA-2 East (Figure 4.2-2). This similarity in concentration upstream and downstream from DP Canyon suggests that plutonium-239,240 is supplied from DP Canyon in similar concentrations to that supplied from Los Alamos Canyon upstream from the confluence.



F4.2-2 / UPPER LOS ALAMOS REACH RPT / 111198

Figure 4.2-2. Variations in the estimated average cesium-137 and plutonium-239,240 concentration in post-1942 channel and overbank facies sediment in the upper Los Alamos Canyon reaches.

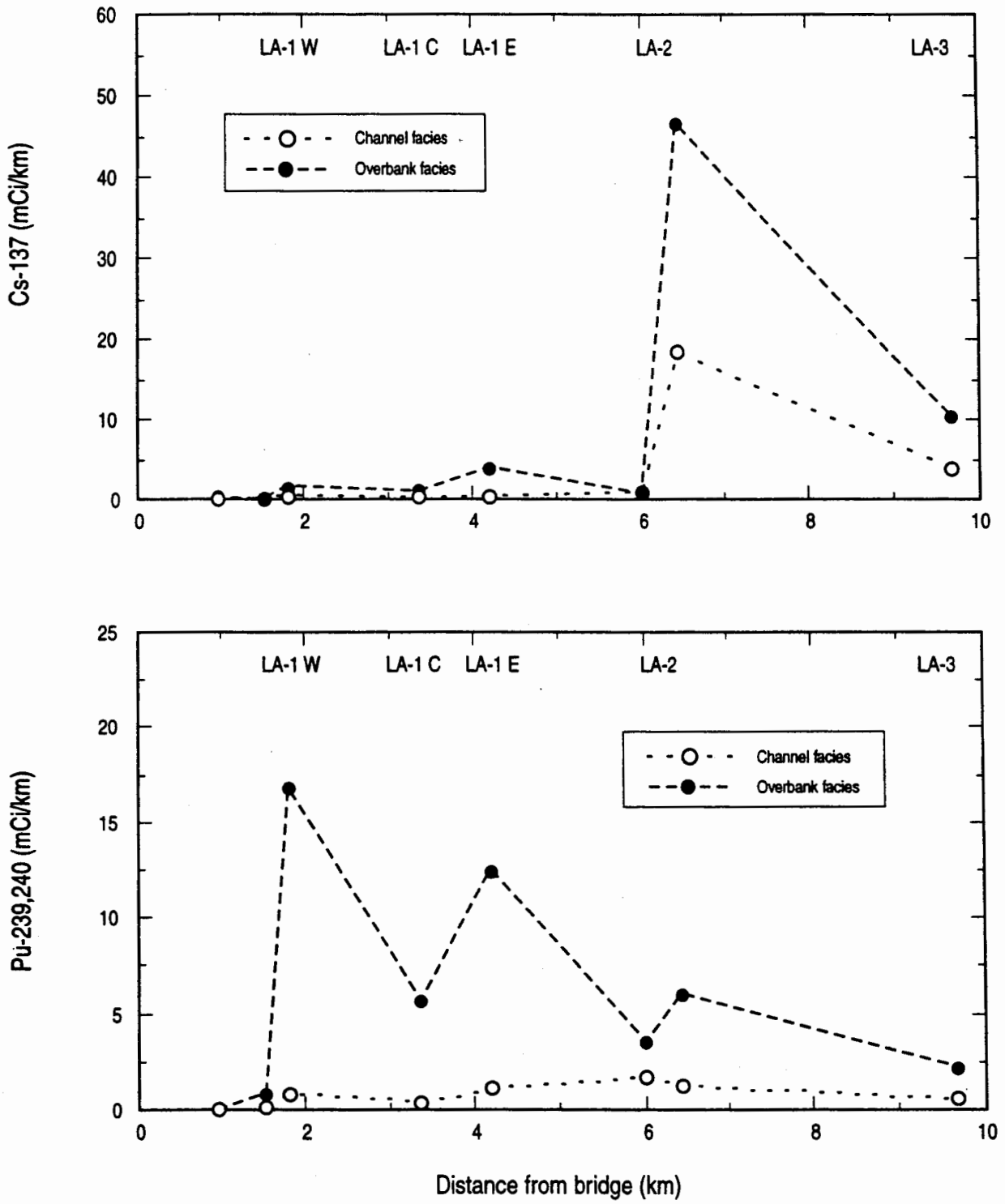
4.2.3.2 Spatial Trends in Radionuclide Inventory

Data collected in this investigation show that all key radionuclides have their highest inventories in the part of upper Los Alamos Canyon closest to their respective source areas and lower inventories in downstream reaches (Tables 3.3-3, 3.3-6, and 3.3-9). Figure 4.2-3 shows estimated geographic variations in the inventories of cesium-137 and plutonium-239,240 in sediment in the upper Los Alamos Canyon reaches, including both channel facies and overbank facies sediment. Americium-241, plutonium-238, and strontium-90 display trends similar to cesium-137 in having the largest inventory in reach LA-2 East, immediately downstream from DP Canyon. The largest plutonium-239,240 inventory is in LA-1 West, immediately downstream from Hillside 137 at former TA-1. Because there are relatively small differences in the volumes of post-1942 sediment among the different reaches, the geographic variations in inventory are similar to the geographic variations in radionuclide concentration shown in Figure 4.2.2, although greater variability is seen in the estimated inventory. The largest estimated volume of overbank facies sediment in any of the upper Los Alamos Canyon reaches is in LA-1 West (Table 4.2-1), which, in combination with its relatively high plutonium concentrations, enhances its importance as a deposition area for plutonium. The smallest estimated volume of post-1942 overbank facies sediment downstream from Hillside 137 is in LA-2 West, which results in a contrast between plutonium inventories upstream and downstream from DP Canyon despite the similar plutonium concentrations in these two subreaches.

A significant uncertainty in the conceptual model for contamination in the upper Los Alamos Canyon watershed is the percent of the total inventories of the key radionuclides contained within post-1942 sediments along the main stream channel and the percent that resides in other locations between the outfalls and the Los Alamos Canyon channel. (Note that this discussion considers only radionuclides accessible for surface transport and not the inventories contained in the material disposal areas at TA-21 or at other sites.) Other potentially important deposition sites for the key radionuclides include hillslopes below the outfalls and post-1942 sediments in DP Canyon. Some part of the inventory on the hillslope below the 21-011(k) outfall was excavated during an interim action in 1996 (LANL 1996, 55648), but no estimates of either the inventory that was excavated or the remaining inventory are available. Similarly, no estimate of the radionuclide inventory within sediment in DP Canyon is available, although investigations are currently in progress that will provide this information (LANL 1998, 56919).

4.3 Fate and Transport of Contaminants

The fate and transport of COPCs in upper Los Alamos Canyon sediments depend on sediment transport processes that will continue to redistribute these COPCs, geochemical characteristics of the COPCs and alluvial water, and radioactive decay. The COPC that presents the highest potential risk in upper Los Alamos Canyon, cesium-137, has a half-life of 30.2 years, and sediment deposited before 1968 (i.e., the c3 unit of LA-2 East) has present concentrations of cesium-137 that are less than half those in the original flood layers. Strontium-90 has a similar half-life of 28.6 years and will have experienced a similar amount of radioactive decay. Other radionuclides of concern have much longer half-lives and will not experience significant decreases in concentration because of radioactive decay over time scales that are relevant for evaluating risk (half-lives of 432 years for americium-241 and 24,000 years for plutonium-239,240).



F4.2-3 / UPPER LOS ALAMOS REACH RPT / 111198

Figure 4.2-3. Variations in the estimated average cesium-137 and plutonium-239,240 inventories in post-1942 channel and overbank facies sediment in the upper Los Alamos Canyon reaches.

The following sections discuss important transport processes occurring in upper Los Alamos Canyon and the likely effects of these processes on future levels of sediment contamination. Under natural conditions, future changes in contaminant levels from those documented in this investigation will be in large part the result of processes that transport or mix sediment, involving both sediment containing variable levels of contamination and sediment that is presently uncontaminated, in combination with radioactive decay. In addition to transport associated with sediment particles, some contaminants such as strontium-90 and tritium will also be transported as part of the dissolved load of surface water and groundwater; therefore, concentrations of these radionuclides in sediment will also be affected by interactions with surface water and alluvial groundwater.

4.3.1 Original Effluent Releases and Resultant Contaminant Distribution

Radionuclide contaminants in the upper Los Alamos Canyon watershed were originally supplied by effluent releases from a variety of sources. Discharges from the most important source, the 21-011(k) outfall, flowed first down a colluvial slope and then into the main stream channel in DP Canyon, and the effluent probably infiltrated into both the slope and the channel bed. Because of the nature of Laboratory operations, the radionuclides would have been largely in solution in the original effluent, but because of their geochemical characteristics most of them would have tended to adsorb onto sediment particles or organic colloids (e.g., Langmuir 1997, 56037). The exceptions include tritium, which will remain within the aqueous phase, and strontium-90, which has a high solubility but whose transport can also be retarded by cation exchange with sediment particles and organic matter (Longmire et al. 1996, 54168). Because of these differences in geochemical behavior, the ratios of different radionuclides in soils and sediment can vary from ratios in the original effluent. For example, the distribution coefficients for cesium-137 are much higher than for strontium-90, and less strontium-90 than cesium-137 will adsorb onto mineral surfaces (Brookins 1984, 12453); therefore, cesium/strontium ratios should be higher in soils and sediment below the 21-011(k) outfall than in the original effluent.

Radionuclides in effluent infiltrating into the colluvial slope below the 21-011(k) outfall would have preferentially adsorbed to organic matter in the soil and finer-grained particles because of their greater surface area and, in the case of clay minerals and solid organic matter, their high cation exchange capacity. Radionuclides in effluent infiltrating into the stream bed would have encountered mainly coarse-grained sediment, and adsorption of significant amounts of the radionuclides onto these larger particles may also have occurred because of the scarcity of more geochemically favorable materials within the active channel sediments. During the period of effluent releases, radionuclide inventories would have incrementally built up both on the slope and in the channel. The part of the inventory in the main channel might have been readily remobilized during floods, but the inventory on the slope might have been more stable initially. However, development of a gully on this slope allowed both excavation of some of the contaminated soil and easier transport of effluent from the top of the slope into the DP Canyon channel.

Radionuclides released in liquid discharges from other PRSs in the upper Los Alamos Canyon watershed should have behaved similarly to those released from the 21-011(k) outfall, although the other PRSs (e.g., Hillside 137) are at the tops of much longer canyon walls, and there might have been greater opportunity for infiltration into slopes. Therefore, subsequent erosion by surface runoff on these slopes may have been more important than on slopes below the 21-011(k) outfall in supplying radionuclides to the main channel. Evidence for the importance of such remobilization from slopes is provided by the relatively high concentrations of plutonium-239,240 in sediments in LA-1 West that are at least 20 years younger than the original discharges (Section 4.2.3.1).

4.3.2 Effects of Floods

Floods constitute the primary transport process for sediment and associated contaminants in upper Los Alamos Canyon, and the combined effects of numerous floods during the past 55 years have largely controlled the horizontal and vertical extent of contaminated sediments and variations in contaminant concentration. Indirectly, floods have therefore strongly affected any human and ecological exposure to contaminated sediments. Importantly, the present variations in radionuclide concentration in upper Los Alamos Canyon sediments, combined with evidence for the age of different sediment deposits, provide a geomorphic record of the past effects of floods and a means to forecast likely future changes in contamination.

Floods transport sediment from upstream to downstream parts of a watershed and in the process both redistribute mass and change the concentrations of contaminants in resultant sediment deposits. The sediment transported in each flood is derived from a variety of sources that include the bed and banks of the main stream channel and tributary drainage basins. The latter include major tributaries such as DP Canyon as well as rills and other small channels on canyon walls such as the Hillside 137 drainage channel.

A large part of the radionuclide inventory transported by floods during the time of the effluent releases from the 21-011(k) outfall may have been derived from scouring of the active stream bed in DP Canyon, although radionuclides would have become depleted from this source following termination of the effluent releases. After effluent releases ceased other contaminant deposition sites in the watershed likely became more important as sources of radionuclides carried by the stream. One source has been the erosion of soils on canyon walls downslope from outfalls, although it is not known how the supply of contaminants from these sites may have changed through time.

The other primary deposition sites for radionuclides that are accessible for transport are sediments in abandoned channel and floodplain units that continuously line the main stream channel in upper Los Alamos Canyon. Contaminants in these settings will be mostly remobilized by lateral bank erosion; thus, the location and rates of bank erosion will have a major influence on contaminant concentrations, and concentrations could vary significantly between floods. Preferential erosion of post-1942 deposits in a flood would result in higher radionuclide concentrations than preferential erosion of pre-1943 deposits. In addition, the relative amounts of sediment supplied by erosion of banks containing contaminants versus those supplied from other sources in individual floods will affect plutonium concentrations. For example, sediment in a flood in LA-1 West either might be largely derived from upstream of Hillside 137, resulting in relatively low plutonium concentrations, or might include large amounts of sediment supplied from Hillside 137 or from bank erosion in LA-1 West, resulting in relatively high plutonium concentrations.

Since the peak releases of cesium-137 and strontium-90 from the 21-011(k) outfall before 1968, the net effect of the mixing of sediment from a variety of sources has been to reduce contaminant concentrations transported by floods downstream from DP Canyon from those before 1968 (Section 4.2.2), and future decreases in the concentrations of these radionuclides can be expected. Data from LA-3 indicate that the concentrations of americium-241 have also been decreasing over time because of dilution. In contrast, there is no evidence for decreases in the concentration of plutonium-239,240 in LA-1, and it is possible that there has been an approximate balance between sediment supplied from the gradual erosion of Hillside 137 and that supplied from upstream in Los Alamos Canyon. If this is the case, then remedial actions at Hillside 137 might be effective at reducing contaminant concentrations carried by the stream, at least in areas near the source. However, the actual plutonium inventory on the hillside has not been

estimated; therefore, the significance of the remaining plutonium at Hillside 137 from a watershed perspective is unknown.

Sediments are sorted during floods, and contaminants associated with different size classes of sediment will be transported different distances and deposited in different locations. Coarse sand grains are largely transported by rolling or saltation (bouncing) along the stream bed and will tend to be transported relatively short distances in each flood and to be deposited on the stream bed, although large floods can also temporarily suspend coarse sand grains and deposit them in overbank settings near the stream channel. The finest particles (i.e., clay- and silt-sized particles) are easily suspended in floods and can be transported the longest distances in individual floods. Silt and clay particles carried in suspension can be deposited in the active channel by water that infiltrates the stream bed, deposited on adjacent surfaces inundated by overbank floodwaters, or carried directly downstream toward the Rio Grande. Radionuclide concentrations in sediment deposited by individual floods are generally highest in those locations where silt and clay percentages are the highest, although it is also possible that sediments with abundant silt- and clay-sized particles could have relatively low concentrations of contaminants if these particles are mostly derived from noncontaminated sources.

Average sediment residence times, or the average time between floods that remobilize specific sediment particles, will vary among sediment deposited in different geomorphic locations. Residence times for sediment in active channels will be relatively short, and sediment in these areas can be mobilized easily in floods. In contrast, residence times for sediment deposited on floodplains can exceed 100 years, based on the age of trees growing on these surfaces. Sediment in most of the abandoned channel units along the active channel of upper Los Alamos Canyon downstream from DP Canyon have estimated residence times of less than 30 years, based on isotopic ratios in the sediments, and it is inferred that similar short residence times also characterize most abandoned channel units upstream from DP Canyon.

An additional effect of the erosion of banks by floods is to allow contaminants that had been previously stored in unsaturated sediment to interact with surface water. Tritium contained within the interstitial water in unsaturated sediment would immediately become part of the floodwaters and would accumulate only in sediment deposits downstream if these waters infiltrated into unsaturated alluvium, such as on floodplains. Strontium-90 adsorbed onto sediment particles or solid organic matter would partially desorb and be transported in the dissolved load of the flood; the transport of strontium-90 within both the dissolved load and the suspended load of upper Los Alamos Canyon floods has been demonstrated by analyses of storm water samples (Dale 1996; 58930). The net effect of the remobilization and transport of sediment downstream from DP Canyon in multiple floods might be to progressively deplete the strontium-90 from the sediment, increasing the cesium/strontium ratio in sediments in downstream reaches. However, no decreases in cesium/strontium ratios in sediment are seen between reaches LA-2 East and LA-3, and it is possible that a longer transport distance is needed to cause a noticeable depletion of strontium-90 from the sediment carried by floods.

4.3.3 Effects of Bioturbation

Burrowing mammals and other fauna can be very effective at mixing soils and thus locally changing concentrations of contaminants. Such biological mixing processes are collectively known as bioturbation, a term that also includes mixing by plants, including disruption caused by toppling trees. Bioturbation affects contaminant levels over a range of time frames and spatial scales. Bioturbation can locally increase contaminant levels in soils by transporting sediment that is contaminated into subsurface layers or onto surfaces that are uncontaminated or that contain contaminants at lower levels. However, bioturbation will also locally decrease contaminant levels by mixing uncontaminated soils, such as those

present in pre-1943 deposits, into post-1942 sediment deposits containing radionuclides above background values. In general, the net effect over time is to reduce the vertical stratification in contamination that resulted from original deposition of sediment layers with varying radionuclide levels, producing more homogeneous contaminant concentrations in sediments. Where bioturbation is restricted to the depth of post-1942 sediment packages, resulting average contaminant levels for such sediment packages should be similar to those estimated in Section 3.3. Alternatively, where bioturbation extends to greater depths, the effect of such mixing will be to reduce average radionuclide concentrations while increasing the volume of contaminated soils.

An additional effect of bioturbation is to bring fresh, loose material to the surface. Such loose material is more susceptible to redistribution by rainsplash, wind, or aboveground animals than adjacent areas that may be well vegetated or otherwise resistant to erosion. Thus, bioturbation contributes to other transport pathways and exposure pathways. Rainsplash of this loose material causes only very local redistribution, but it is important in the context of transferring contaminated material onto plant surfaces where it can be absorbed by the plants or ingested by animals or humans. Wind and animals can potentially transport contaminated material onto uncontaminated geomorphic units, and of these processes wind is likely more significant.

4.3.4 Transport by Wind

Wind may be an important process for at least local redistribution of contaminants within upper Los Alamos Canyon, in addition being an important part of the exposure pathways included in the Section 5.1 risk assessments. Recently deposited, unvegetated, fine-grained overbank sediment may provide a source for wind-transported sediment with contaminant levels above background, as has been documented in other regions (e.g., Lechler et al. 1997, 58475). Areas disturbed by burrowing mammals may provide an additional source, as discussed in Section 4.3.3. However, wind transport may be of relatively limited importance in upper Los Alamos Canyon because overbank settings are generally well vegetated or covered with litter, and wind velocities may also be less in this narrow forested canyon floor than in more open areas. In addition, it is important to note that eolian sediment derived from post-1942 deposits will also be mixed with material eroded from uncontaminated areas, resulting in dilution. Sources of eolian sediment during or between wind storms may be extremely variable, and no attempt has been made to evaluate the relative contributions of contaminated and uncontaminated areas in providing eolian sediment in upper Los Alamos Canyon.

4.3.5 Transport by Alluvial Groundwater

The relative importance of the transport and redistribution of contaminants by alluvial groundwater in upper Los Alamos Canyon varies among contaminants depending on their geochemical behavior. Tritium is the most mobile of the COPCs identified in upper Los Alamos Canyon sediments because it is part of the aqueous phase, and the transport rate of tritium will equal that of groundwater. Strontium-90 is very soluble but will be partially removed from solution by cation exchange, adsorbing to particles in the alluvium (Longmire et al. 1996, 54168). The concentrations of both of these radionuclides in alluvial groundwater in upper Los Alamos Canyon have been decreasing over time (Longmire et al. 1996, 54168). In contrast to tritium and strontium-90, most other COPCs in upper Los Alamos Canyon sediments, such as cesium-137, will tend to be adsorbed onto sediment particles or organic colloids (e.g., Langmuir 1997, 56037) and be transported at much slower rates. Although translocation of these contaminants into the alluvium probably occurs, as inferred for plutonium in Pueblo Canyon (Reneau et al. 1998, 59159), this transport is expected to be minor.

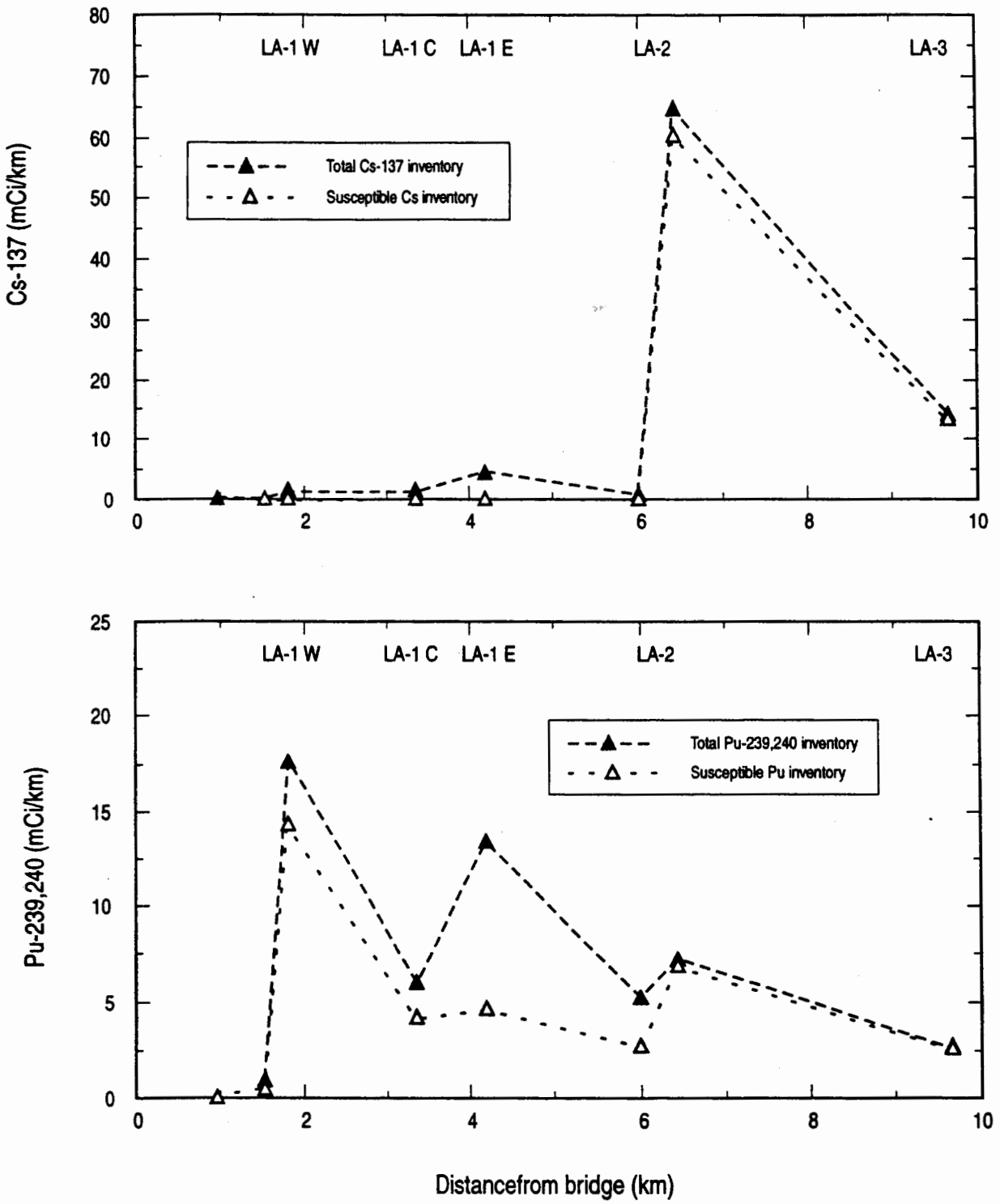
4.3.6 Future Remobilization and Transport of Contaminants

A general evaluation of the effects of future remobilization and transport of contaminated sediment by natural processes can be made based on the results of this investigation, particularly using data on important transport processes and resultant changes in radionuclide concentration and distribution since 1942, as discussed in previous sections. A time frame of approximately 50 years is chosen for this evaluation because, due to the releases of radionuclides that can be used as tracers, available data are best suited for understanding sediment transport processes in upper Los Alamos Canyon over this temporal scale.

Future floods will continue to redistribute radionuclides within upper Los Alamos Canyon and to transport some of these radionuclides into lower Los Alamos Canyon. This redistribution will reduce the radionuclide inventory in some reaches and perhaps increase the inventory in some downstream areas. The radionuclides most susceptible to remobilization are in that part of the total inventory contained within the presently active channel (c1) and within geomorphic units adjacent to the active channel, such as the typical c2 and c3 units. In these areas average sediment residence times downstream from DP Canyon are generally less than 30 years, and remobilization of most of this sediment is considered to be very likely during the next 50 years.

Preliminary evaluations of the susceptibility to remobilization of post-1942 sediment deposits in the upper Los Alamos Canyon reaches (Tables 3.3-3, 3.3-6, and 3.3-9) suggest that approximately 90% of the cesium-137 and 70% of the plutonium-239,240 is susceptible to remobilization during the next 50 years (Table 4.2-1, Figure 4.3-1). The percentages for americium-241 and strontium-90 are similar to those for cesium-137. Although some undefined percentage of the remobilized radionuclides will be redeposited downstream within upper Los Alamos Canyon, most of this sediment would also be susceptible to remobilization because the primary deposition sites are close to the active channel. Therefore, it should be assumed that most of the radionuclides present within upper Los Alamos Canyon could be transported downstream into lower Los Alamos Canyon during the next 50 years, although because of the relatively short half-lives of cesium-137 and strontium-90 (30.2 and 28.6 years, respectively) the inventory of these radionuclides will be significantly reduced by radioactive decay.

Currently it is not possible to determine which geomorphic units in which part of the canyon are the most important sources for radionuclides transported from upper Los Alamos Canyon into lower Los Alamos Canyon during individual floods. Although contaminated sediment remobilized in LA-3 would have to be transported relatively short distances before reaching the Laboratory boundary, radionuclide concentrations in the sediments here are much less than in upstream sediments. It is possible that remobilization of post-1942 sediments closer to DP Canyon, where radionuclide concentrations are higher, is a more important source for radionuclides crossing the Laboratory boundary.



F4.3-1 / UPPER LOS ALAMOS REACH RPT / 111198

Figure 4.3-1. Variations in the estimated cesium-137 and plutonium-239,240 inventories and the fraction of the inventory considered to be susceptible to remobilization during the next 50 years in the upper Los Alamos Canyon reaches.

5.0 SITE ASSESSMENTS

5.1 Preliminary Human Health Risk Assessment

5.1.1 Scope and Objectives

The purpose of this section is to evaluate the data on contaminants in upper Los Alamos Canyon sediments relative to potential human health effects. The emphasis of this analysis is to determine whether a site management decision to mitigate potential human health risks is warranted at present. This analysis uses present-day contaminant concentrations and reasonable present-day exposure scenarios and does not assess the possible effects of future contaminant redistribution or potential future land uses.

The assessment in this interim report is focused on risks resulting from direct exposures to contaminants in sediments via ingestion, inhalation, and dermal contact and indirect exposures through consuming foodstuffs that have grown on contaminated sediments or meat from animals that have consumed plants in these areas. Data are not presently available to perform assessments that include water pathways, but water pathways will be included in more comprehensive risk assessments in one or more future reports on Los Alamos Canyon.

5.1.2 Comparison with Core Document Risk Approach

Chapter 6 of the *Core Document for Canyons Investigations* ("the core document") (LANL 1997, 55622) proposes risk assessments that include sediments, surface water, groundwater, and air particulates. These media were proposed to be evaluated in nine exposure scenarios over three land uses. The continued Laboratory land use includes a construction worker scenario and an on-site worker scenario. The recreational land use has both a trail user scenario and a camper scenario. The American Indian land use consists of scenarios for residential use, ranching, hunting, traditional uses, and use of the Rio Grande and Cochiti Lake.

The assessment in this report uses scenarios for a trail user, a resource user (incorporating aspects of a ranching or hunting scenario), and a construction worker. These scenarios are considered to be inclusive of realistic present-day potential exposure activities in upper Los Alamos Canyon. The bases of primary and secondary exposures are the concentrations of contaminants in sediments. The other scenarios proposed in the core document are not currently active in Los Alamos Canyon and will not be evaluated in this interim report.

Development of an American Indian land use scenario is proposed in the core document. The intent of that land use scenario is to uniquely define the parameters of exposure pathways that reflect the activities of the local American Indian populations. However, the American Indian scenario is not sufficiently developed to be applied in this report. An approximation of the American Indian scenario could be achieved by combining a residential scenario with the resource user scenario, although a residential scenario is not included in this report because it is not a reasonable present-day scenario for upper Los Alamos Canyon.

Each of the exposure scenarios evaluated in this report is applied over the entire area of each reach. This means that an average contaminant concentration is calculated for each reach and is used for the potential risk estimate. The method of averaging is addressed in Section 5.1.6. This method is in contrast

to the approach proposed in the core document, which involves using different size exposure areas for different scenarios. The trail use, resource use, and construction activity would likely occur along a whole reach. Therefore, it is reasonable to use the whole reach averages as a means for estimating exposure. Scale issues related to the other scenarios in the core document will be addressed when those scenarios are evaluated in future assessments.

Human health risks for this report are estimated by comparing the maximum values, and for key radionuclides the average values, for each of the chemicals of potential concern (COPCs) with preliminary remediation goal (PRG) values. The PRGs are generated by using the parameters associated with each of the scenarios, as described in Section 5.1.4 and Perona et al. (1998, 62049), and computing the contaminant concentration that would result in a threshold risk. This is consistent with the Environmental Protection Agency (EPA) manual *Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals)* (RAGS) (EPA 1991, 58234). An example of a threshold is EPA's guidance that 15 mrem/yr is a protective dose limit for radionuclides (EPA 1997, 58693). This is more conservative than the dose limit of 25 mrem/yr proposed by the Nuclear Regulatory Commission for unrestricted use of a site (10 CFR 20) and the limit of 100 mrem/yr in Department of Energy (DOE) Order 5400.5, "Radiation Protection of the Public and the Environment."

An example of the use of PRGs in this report follows. Given the description of the trail user scenario in Section 5.1.4, the concentration of plutonium-239 in the sediments that results in an exposure of 15 mrem/yr is 440 pCi/g, which constitutes the PRG. The measured maximum value for plutonium-239,240 in upper Los Alamos Canyon is 19 pCi/g. Therefore, the PRG is more than 20 times the measured maximum value. Based on this initial screening assessment using maximum sample results, plutonium-239,240 does not pose an unacceptable potential human health risk to the present-day trail user. (Note that dose conversion factors for plutonium-239 are used for the plutonium-239,240 data obtained in this investigation because high precision analyses have indicated that only low percentages of plutonium-240 are present in sediments at the Laboratory [Gallaher et al. 1997, 59165].) Further assessments using average values are performed using the key radionuclides.

The PRG concentrations for chemical carcinogens are based on a potential risk of 10^{-6}. The noncarcinogen PRGs are based on a hazard quotient (HQ) of 1. The maximum contaminant values are compared with the PRGs to determine which contaminants are likely risk drivers. The contaminant averages are used for estimating exposures supporting decisions regarding risk management or risk mitigation for the key radionuclide COPCs. The concentration averages are often referenced to sediment packages, which are combinations of geomorphic units and sediment facies presented in Tables 3.3-2, 3.3-5, and 3.3-8.

Approaching risk characterization in this manner supports site management decisions about present-day potential risks and the possible need for remediation of sediments. This is a deterministic approach that uses the contaminant concentration data to make individual contaminant assessments. Where contaminants are collocated, the percent of PRGs can be summed to estimate the integrated potential exposures. Performing stochastic uncertainty and sensitivity analyses is deferred to later reports when sufficient data are available to evaluate the surface water and groundwater exposure pathways.

5.1.3 Selection of COPCs

Section 3.1 provides an analysis of the contaminant data from upper Los Alamos Canyon sediment samples and a selection of the COPCs that warrant further consideration in site management decisions.

There are 22 organic chemicals, 9 inorganic chemicals, and 15 radionuclides recommended for further evaluation (Table 5.1-1). A primary focus of the investigation in upper Los Alamos Canyon was to determine the concentrations and distributions of cesium-137 and plutonium-239,240, which were selected as key contaminants based on the results of previous investigations and the full-suite analyses conducted in this investigation. Additional analyses were obtained to assess the presence of additional COPCs and to evaluate possible collocation of other contaminants with cesium-137 and plutonium-239,240.

TABLE 5.1-1

SCREENING ASSESSMENT
UPPER LOS ALAMOS CANYON MAXIMUM CONTAMINANT VALUES
AND EXPOSURE SCENARIO PRGs[a]

COPC	Upper Los Alamos Canyon Maximum Value[b]	Trail User PRG	Resource User PRG	Construction User PRG
Organic Chemicals				
Aroclor-1254	1.5	16	16	2.6
Aroclor-1260	1.0	**0.95**[c]	**0.95**	4.5
α-Chlordane	0.0072	3.6	3.6	20
γ-Chlordane	0.0068	3.6	3.6	20
4,4'-DDT + 4,4'-DDE	0.081	3.7	3.7	21
Acenaphthene	0.26	32000	32000	6100
Anthracene	0.096	32000	32000	6100
Benz(a)anthracene	0.37	1.7	1.7	9.7
Benzo(a)pyrene	0.66	**0.17**	**0.17**	0.97
Benzo(b)fluoranthene	0.66	1.7	1.7	9.7
Benzo(g,h,i)perylene	0.30	N.A.[d]	N.A.	N.A.
Benzo(k)fluoranthene	0.019	17	17	97
Chrysene	0.41	170	170	970
Dibenz(a,h)anthracene	0.029	0.17	0.17	0.97
Dibenzofuran	0.036	2200	2200	400
Di-n-butylphthalate	0.055	53000	53000	10000
Fluoranthene	0.73	22000	22000	4000
Fluorene	0.066	22000	22000	4000
Indeno(1,2,3-cd)pyrene	0.34	1.7	1.7	9.7
Naphthalene	0.20	2200	2200	400
Phenanthrene	0.43	16000	16000	3000
Pyrene	0.59	66000	66000	3000

a. Values for organic and inorganic chemicals are expressed in mg/kg; values for radionuclides are expressed in pCi/g.

b. Maximum values are rounded to two significant figures.

c. Boldface values indicate PRGs that are exceeded by the maximum result.

d. N.A. = not available

TABLE 5.1-1 (continued)

SCREENING ASSESSMENT
UPPER LOS ALAMOS CANYON MAXIMUM CONTAMINANT VALUES
AND EXPOSURE SCENARIO PRGs[a]

COPC	Upper Los Alamos Canyon Maximum Value[b]	Trail User PRG	Resource User PRG	Construction User PRG
Inorganic Chemicals				
Antimony	ND[c] [14][d]	890	48	77
Cadmium	0.89	520	6.6	180
Chromium, total	38	78	78	88
Copper	24	87000	250	7700
Lead	62	400	400	400
Mercury	0.31	660	**0.22[e]**	57
Selenium	0.65	11000	6.7	960
Silver	16	11000	61	960
Zinc	91	560000	330	57000
Radionuclides				
Americium-241	28	420	160	**23**
Cesium-134	0.18	180	43	6.9
Cesium-137	230	510	**71**	**19**
Cobalt-60	0.21	110	60	4.1
Europium-152	0.47	250	250	9.4
Plutonium-238	2.0	480	170	26
Plutonium-239,240[f]	19	440	150	24
Strontium-90	40	11000	**12**	610
Thorium-228[g]	2.9	5	5	5
Thorium-230[g]	2.6	5	5	5
Thorium-232[g]	2.6	5	5	5
Tritium	0.45	2300000	3100	1100000
Uranium-234	2.8	3300	720	150
Uranium-235	0.19	1400	570	57
Uranium-238	2.5	2800	720	120

a. Values for organic and inorganic chemicals are expressed in mg/kg; values for radionuclides are expressed in pCi/g.

b. Maximum values are rounded to two significant figures.

c. ND = not detected

d. Maximum nondetected value

e. Boldface values indicate PRGs that are exceeded by the maximum result.

f. PRGs for plutonium-239,240 are calculated using the toxicity value for plutonium-239.

g. Thorium PRG values are taken from DOE Order 5400.5, "Radiation Protection of the Public and the Environment," Chapter IV, Residual Radioactive Material.

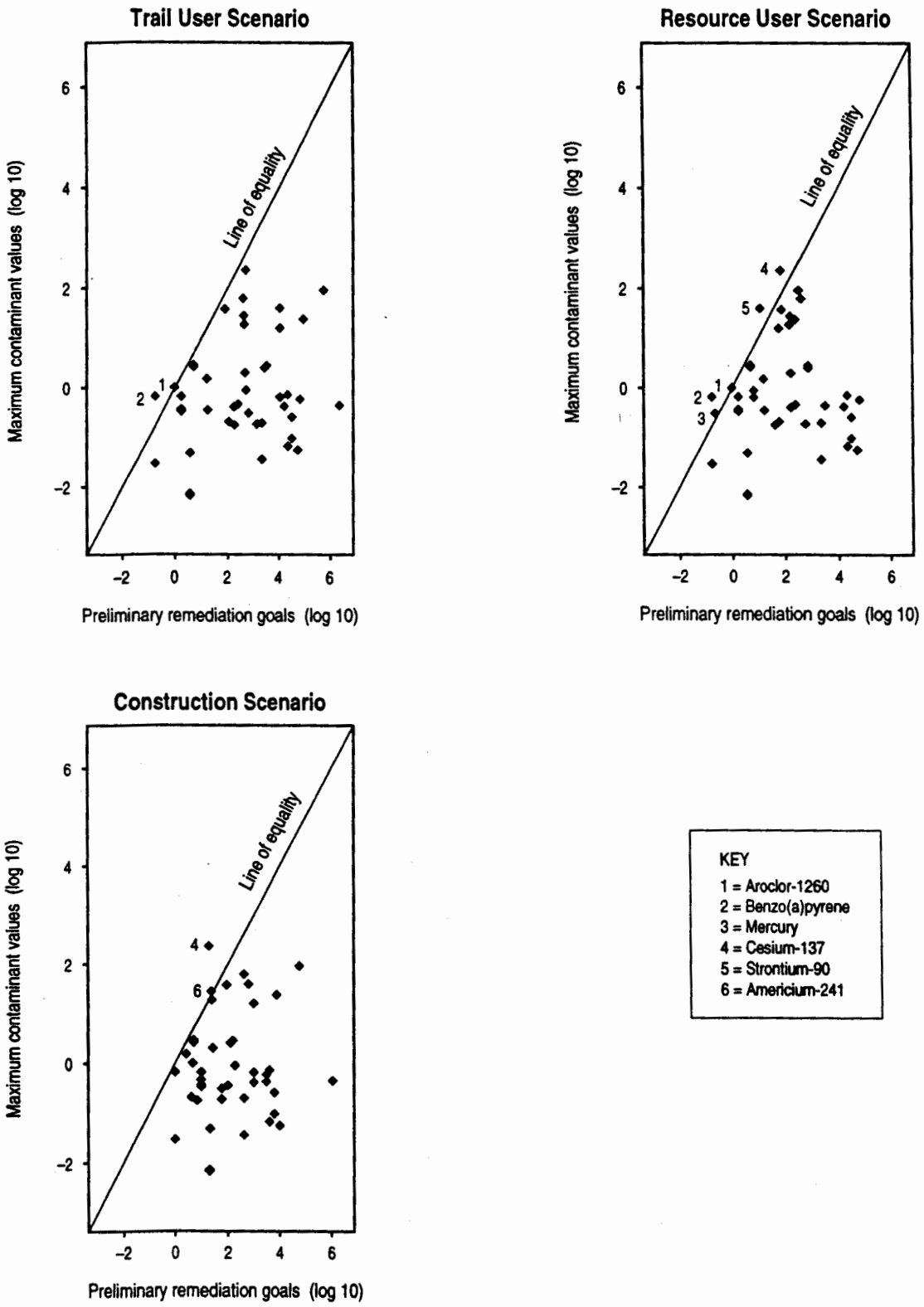
A screening assessment of the other COPCs using maximum values and PRGs is presented in Figure 5.1-1. The lines of equality in these plots separate the plot regions into two areas. Points that plot to the right of the lines of equality are maximum COPC values that are less than their PRGs. Points that plot to the left of the lines of equality exceed PRGs and are evaluated further. The COPCs that exceed their PRGs are mercury, cesium-137, and strontium-90 for the resource user scenario and americium-241 and cesium-137 for the construction worker scenario. In addition, benzo(g,h,i)perylene is detected in upper Los Alamos Canyon. Toxicity criteria are not presently available for this contaminant, preventing a comparison with PRGs. This issue is discussed below. Plutonium-239,240 is pervasively detected above background value in the three reaches but does not exceed any of the PRGs. Plutonium-239,240 is carried forward in the multiradionuclide assessment to confirm that the additive potential exposures to radionuclides do not exceed the criterion of 15 mrem per year. An assessment for americium-241; cesium-137; plutonium-239,240; and strontium-90 is presented in Sections 5.1.6, 5.1.7, and 5.1.8.

Uranium can be measured in a sample either as a metal using inorganic analytical methods or as a suite of isotopes using radioanalytic methods. The analytical data for upper Los Alamos Canyon include both types of results. Uranium was detected slightly above background value in one of the 18 samples analyzed for metallic uranium (7.2 mg/kg, in comparison with the background value of 6.99 mg/kg), which, in combination with a statistical distribution shift, led to identification of metallic uranium as a COPC in Section 3.1. However, EPA has not published toxicity information for uranium as a metal, and radioanalytic methods for isotopic uranium are more sensitive to low concentrations. Therefore, it is more appropriate to evaluate potential human health risk using isotopic uranium results than using metallic uranium results. The comparison of the maximum isotopic uranium values with the PRGs in Table 5.1-1 shows that uranium levels in upper Los Alamos Canyon sediments do not pose a significant human health risk.

Polycyclic aromatic hydrocarbons (PAHs) are commonly found in association with petroleum products and are due to incomplete combustion of organic substances. PAHs for which EPA has published toxicity values are generally classified for carcinogenic potential as either class B2 (possible human carcinogen) or class D (inadequate data to determine carcinogenicity). The EPA cancer classification for benzo(a)pyrene is class B2. The EPA cancer classification for benzo(g,h,i)perylene is class D. Other common PAHs that share a class D carcinogenicity classification include acenaphthene, anthracene, fluoranthene, fluorene, naphthalene, and pyrene (EPA 1998). (Note that data on PAHs are available only for reach LA-2 because the SVOC analyses from reach LA-3 were rejected, as discussed in Section 3.1 and Appendix C.)

Benzo(g,h,i)perylene was detected in 5 of 11 samples. This organic chemical does not have specific published toxicity criteria. EPA has published noncancer oral toxicity values (reference doses) for acenaphthene, anthracene, fluoranthene, fluorene, naphthalene, and pyrene. These reference dose values are generally associated with an allowable chemical intake that is orders of magnitude larger than those for potent PAH carcinogens such as benzo(a)pyrene and dibenz(a,h)anthracene when these are evaluated at a target risk level of one excess cancer per million. For example, compare the soil PRGs for these PAHs presented in Table 5.1-1.

Although EPA has not published a chemical-specific toxicity value for benzo(g,h,i)perylene, the significance of this PAH relative to the other PAHs with which it is associated in the environment can be inferred from the comparison of soil criteria, evaluation of co-occurrence, and comparison of sample values. The human health impacts associated with exposure to PAHs in the environment can be assessed in the absence of specific information on benzo(g,h,i)perylene by assuming the same PRGs as the other detected class D PAHs. Soil criteria associated with the PAHs for which EPA has published slope factor and/or unit risk values are likely to be protective for concomitant exposure to PAHs for which toxicity values have not been derived. The minimum PRG for other class D PAHs in Table 5.1-1 is 400 mg/kg for naphthalene. Therefore, because the maximum result for benzo(g,h,i)perylene is only 0.3 mg/kg, it is dropped as a COPC for the assessment in this report.



F5.1-1 / UPPER LOS ALAMOS CANYON REACH RPT / 111698

Figure 5.1-1. Comparisons of maximum values with PRGs by scenario.

Eleven samples were analyzed for benzo(a)pyrene in reach LA-2 and lower DP Canyon. Nine of the samples had detectable concentrations of benzo(a)pyrene; seven of the sample results equaled or exceeded the PRGs for trail user and resource user. The constraining pathway for benzo(a)pyrene is dermal absorption. The parameters associated with this pathway are very conservative because the dermal uptake factors have been assumed to be equal to the ingestion uptake factors. Therefore, while the screening PRGs have been exceeded, it is considered unlikely that a human health risk exists at these locations that warrants immediate mitigation. Available data are insufficient to carry this contaminant forward in an assessment for upper Los Alamos Canyon; therefore, this COPC is dropped from the assessment in this report. However, benzo(a)pyrene should be considered in future investigations and assessments in upper Los Alamos Canyon.

Aroclor-1260 was detected in 25 of 38 samples in reaches LA-1 and LA-2. A single value of 1.0 exceeded the PRGs of 0.95 for the trail user and resource user scenarios. The next highest value is 0.59, or 62% of the PRG. Immediate action to mitigate risk is not warranted for this contaminant, based on the available data. This COPC is dropped from further consideration in this interim report because the sampling coverage is inadequate for calculating reliable average concentrations in the different reaches. Additional sampling in upper Los Alamos Canyon is recommended to provide the data necessary for future risk assessments.

Mercury was detected in 22 of 49 samples. Reach LA-1 had 15 detected values out of 27 samples; reach LA-2 had 6 detected values out of 14 samples; and reach LA-3 had 1 detected value out of 8 samples. Background comparisons show that 2 samples in LA-1, 3 samples in LA-2, and 1 sample in LA-3 exceeded the background value of 0.1 mg/kg (Section 3.1.1). The most restrictive PRG for mercury is 0.22 mg/kg for the resource user scenario. This PRG is constrained by the meat ingestion pathway. A single sample result of 0.33 mg/kg in LA-2 West exceeds the PRG. The next highest mercury value is 73% of the PRG (0.16 mg/kg). The 6 mercury values that are above background do not show any particular pattern of occurrence, being spread among all reaches. The low frequency of detection above background values and the even lower rate of exceeding the PRGs supports dropping mercury as a COPC for upper Los Alamos Canyon.

The dose characterization presented in Section 5.1.6 includes plutonium-239,240 for all three reaches and americium-241, cesium-137, and strontium-90 for reaches LA-2 East and LA-3.

5.1.4 Exposure Assessment

The following exposure scenarios are developed using standard EPA default parameter values, when available. These values are consistent with the parameters for reasonable maximum exposure assessments. Where EPA default parameters are not available, professional judgement has been used in selecting conservative values from other publications or setting site-specific assumptions. Soil ingestion rates are taken from RAGS (EPA 1991, 58234). The exposure duration of 30 years for the trail user and resource user and the construction work year of 250 days are also taken from RAGS. Soil inhalation and adult intake rates for fruit, vegetables, and meat are taken from the *Exposure Factors Handbook* (EFH) (EPA 1990, 58694). The proportion of meat (75%) for the resource user is taken from EFH. The trail use and resource use exposure frequencies and durations (75 days per year, one hour per day), the proportion of fruits and vegetables from a reach (10%), the average construction time of one year, and the eight-hour work day are based on professional judgement.

5.1.4.1 Trail User Scenario

The trail user is defined as an adult who uses a given reach 75 days per year during a 30-year period. Each visit to the reach has a duration of one hour. During each hike, the individual ingests 100 mg of soil and inhales 0.25 mg of soil as suspended dust. This scenario is conservative in that it assumes all soil taken into the body originates within geomorphic units that have been inundated by post-1942 floods and thus contain contaminants above background values, although large areas of the canyon floor in each reach are actually uncontaminated.

5.1.4.2 Resource User Scenario

The resource user scenario employs the same temporal parameters as for the trail user and adds the consumption of fruits, vegetables, and meat. The parameters used for adult consumption of fruits, vegetables, and meat are 51 kg/yr, 73 kg/yr, and 36.5 kg/yr, respectively (EFH). The resource users are assumed to obtain 10% of their fruits and vegetables (5.1 kg/yr and 7.3 kg/yr) and 75% of their meat (27 kg/yr) from the reach. These consumption rates are integrated over 30 years, which is consistent with the activity component of the pathway. The fruits and vegetables are assumed to grow in sediments that have the average concentrations of contaminants, and the animals that provide meat are assumed to range and graze exclusively in areas of contaminated sediments; therefore, these assumptions provide conservative estimates of risk.

5.1.4.3 Construction Worker Scenario

The construction worker scenario assumes a 250-day work year with eight-hour days. The duration of the scenario is one year, and all activities are assumed to occur within geomorphic units that contain contaminants above background values. The individual is assumed to ingest soil at a rate of 480 mg/day and to inhale soil as airborne dust at a rate of 2 mg/day. Possible construction activities in upper Los Alamos Canyon under present-day land use conditions include the construction or maintenance of roads and the excavation of trenches for sewer lines or other purposes. These activities would likely involve uncontaminated parts of the canyon floor as well as contaminated areas and would likely have actual durations of less than one year; therefore, this assessment provides conservative estimates of risk.

5.1.5 Toxicity Assessment

The dose conversion factors used in this assessment for americium-241, cesium-137, plutonium-239, and strontium-90 are taken from the *Manual for Implementing Residual Radioactive Material Guidelines Using RESRAD, Version 5.0* (Yu et al. 1993, 58695). These dose conversion factors are referenced to the DOE publications *External Dose-Rate Conversion Factors for Calculation of Dose to the Public* (DOE 1988, 58691) and *Internal Dose Conversion Factors for Calculation of Dose to the Public* (DOE 1988, 58692). The dose conversion factor for plutonium-239 is applied to the plutonium-239,240 results because available data indicate that plutonium-239 is much more abundant than plutonium-240 in sediments at the Laboratory (Gallaher et al 1997, 59165).

5.1.6 Dose Characterization

Dose characterization in this report is presented in the form of the ratio of the average concentration for the reach or sediment package to the concentration that would result in a dose of 15 mrem/yr for each of the land use scenarios. The dose criterion of 15 mrem/yr follows that recommended by EPA in the memorandum *Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination* (EPA

1997, 58693). DOE also has dose-based standards for contaminated sites (100 mrem/yr; DOE Order 5400.5, "Radiation Protection of the Public and the Environment."), and these standards apply for as long as DOE maintains administrative control of the site. When DOE transfers land, the EPA standards gain primacy. The EPA standard of 15 mrem/yr is used in this report because part of upper Los Alamos Canyon is being considered for potential land transfer (DOE 1998, 58671). In addition, there is unrestricted access to most of upper Los Alamos Canyon on Laboratory property. The concentrations of single radionuclides (americium-241; cesium-137; plutonium-239,240; or strontium-90) that would result in a dose of 15 mrem/yr for each of the exposure scenarios are provided in Table 5.1-1. Note that DOE Order 5400.5 also provides criteria for evaluating "hot spots," although the sampling density for data collected in this investigation is not sufficient to define such hot spots as discussed in DOE Order 5400.5.

Two weighted averages are calculated for each reach. One is an area-weighted average that uses present-day estimates of average contaminant concentrations in the uppermost sediment packages in each geomorphic unit, as presented in Section 3.3, and unit areas, as presented in Section 2.3. The other is a volume-weighted average that uses vertically weighted concentration estimates where sediment packages are superimposed, using estimated average thicknesses of each package as presented in Section 3.3, and then computes a volume-weighted average concentration to represent the reach. In the area-weighted average all human activity is assumed to be restricted to the area containing contaminated sediments. In the volume-weighted average all human activity is assumed to be restricted to the depths where contamination is above background values, with no mixing with underlying uncontaminated materials. Thus, both averages provide conservative estimates of risk.

These two estimates are necessary to support the dose assessment for the three scenarios. The present-day trail user is exposed to the area-weighted average. The present-day resource user consumes fruits, vegetables, and meat animals that graze on plants growing in the contaminated sediments thereby getting a secondary exposure to the volume-weighted estimate of the contaminant concentrations. The construction worker digging through the sediments would also be exposed to the volume-weighted concentration. An additional consideration for the trail user is that burrowing animal activity eventually results in the vertical averaging of contaminant concentrations, as discussed in Section 4.3.3. There is abundant burrowing animal activity in Los Alamos Canyon, suggesting that the trail user will be potentially exposed to the volume-weighted concentrations sometime in the future.

The sampling and analysis results for LA-1, the uppermost reach, identified plutonium-239,240 as the only contaminant that is pervasively above background values. None of the plutonium results exceed the exposure scenario PRGs. The results provided below document the assessment of potential exposures for LA-1.

The results for reaches LA-2 and LA-3 show that americium-241, cesium-137, and strontium-90 are present above background values in addition to plutonium-239,240. The assessments presented below sum the percent PRGs across these radionuclides. The rationale for this approach is that exposure at a given location is to all the contaminants present at that location. The summing is performed within the sediment packages in each geomorphic unit, as described in Sections 2.3 and 3.3.

5.1.7 Dose Assessment Results

The dose assessment results for each reach are presented in Tables 5.1-2 through 5.1-8. Each table consists of three parts. The first part is a schematic cross section showing the relative locations of each sediment package in relation to the active channel (c1) and the ground surface. The identifier "ch" refers to channel facies sediment packages, and the identifier "ob" refers to overbank facies sediment packages. The second part in reaches LA-1 West+, West, Central, and East and LA-2 West is a table that shows the average plutonium-239,240 concentrations for each of the geomorphic units in each reach and the fraction of the PRGs for each of the exposure scenarios. The analytical results, and consequently the averages, are for plutonium-239,240. The PRG fractions are the average concentrations divided by the PRG for plutonium-239 because previous analyses have shown that plutonium-239 is present at much higher concentrations than plutonium-240 in sediments at the Laboratory (Gallaher et al 1997, 59165). The tables for reaches LA-2 East and LA-3 do not show concentrations because the percent PRGs are sums across four radionuclides. Instead, the weighted average contaminant concentrations for each of the four radionuclides are presented for LA-2 East and LA-3. The third part is a summary of the surface aggregates and the volume aggregates across the exposure scenarios. Contributions of individual sediment package averages are weighted by relative area for the surface aggregate. Relative volume is used for weighting the volume aggregate.

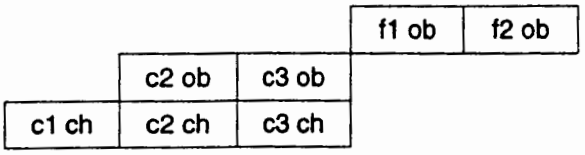
The key information on potential human health risk in each reach is presented in the third part of the dose assessment tables, where a value exceeding 1.0 would indicate a potential dose exceeding 15 mrem/yr and thus exceeding the EPA dose limit. These values are surface-averaged and volume-averaged concentrations presented as fractions of the PRGs for each scenario. The text that follows distinguishes these values as surface PRG sums and volume PRG sums. The highest values for each scenario are found in reach LA-2 East (Table 5.1-7); none of these values exceed 1.0. The maximum value for the trail user scenario is a surface PRG sum of 0.04, or only 4% of 15 mrem/yr, and the maximum value for a resource user is a surface PRG sum of 0.52. The highest potential risk from contaminants in the sediments of upper Los Alamos Canyon is associated with the construction worker scenario. The surface PRG sum is 0.94 and the volume PRG sum is 0.83. Because of the conservative assumptions built into this scenario, the actual risk to a construction worker would likely be less. In summary, these calculations indicate that the levels of contaminants in the sediments of upper Los Alamos Canyon are not high enough to constitute an unacceptable human health risk under conditions of present-day land use. Thus, there is no need for immediate remedial actions from the standpoint of human health.

The dose ratios presented in the second part of the dose assessment tables for reaches LA-1 and LA-2 West indicate the estimated dose that would exist if all exposure under each scenario occurred solely within single geomorphic units. Because activities would actually occur in some combination of units, these values clearly provide unrealistic estimates of risk, although they are valuable in indicating the relative importance of the different units. None of the PRG ratios in these tables exceed 1.0, indicating that exposures within these geomorphic units are acceptable with the given scenarios.

TABLE 5.1-2

DOSE CALCULATION RESULTS FOR REACH LA-1 WEST+

Part 1. Schematic Cross Section



ch = channel facies
ob = overbank facies

Part 2. Average Concentration and Fraction of Plutonium-239 Preliminary Remediation Goal by Unit and Exposure Scenario

Unit	Concentration (pCi/g)	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)
c1 ch	0.02	0.00	0.00	0.00
c2 ch	0.04	0.00	0.00	0.00
c3 ch	0.04	0.00	0.00	0.00
c2 ob	0.38	0.00	0.00	0.02
c3 ob	0.38	0.00	0.00	0.02
f1 ob	0.38	0.00	0.00	0.02
f2 ob	0.38	0.00	0.00	0.02

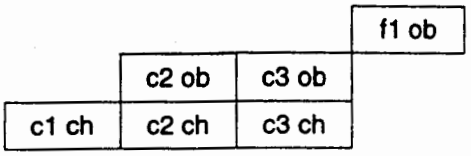
Part 3. Surface and Volume Aggregate Concentrations for Plutonium-239,240 and Fraction of the PRGs for Plutonium-239

Reach	Aggregate Concentration (pCi/g)	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)
LA-1 West+ surface	0.34	0.00	0.00	0.01
LA-1 West+ volume	0.20	0.00	0.00	0.01

TABLE 5.1-3

DOSE CALCULATION RESULTS FOR Reach LA-1 West

Part 1. Schematic Cross Section



ch = channel facies
ob = overbank facies

Part 2. Average Concentration and Fraction of Plutonium-239 Preliminary Remediation Goal by Unit and Exposure Scenario

Unit	Concentration (pCi/g)	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)
c1 ch	0.12	0.00	0.00	0.01
c2 ch	0.49	0.00	0.00	0.02
c3 ch	0.49	0.00	0.00	0.02
c2 ob	6.88	0.02	0.05	0.29
c3 ob	6.88	0.02	0.05	0.29
f1 ob	2.02	0.01	0.01	0.08

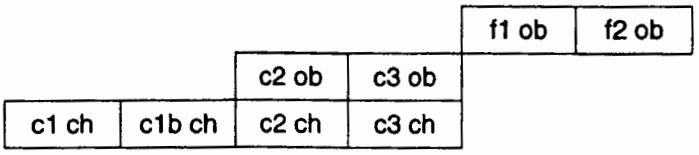
Part 3. Surface and Volume Aggregate Concentrations for Plutonium-239,240 and Fraction of the PRGs for Plutonium-239

Reach	Aggregate Concentration (pCi/g)	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)
LA-1 West surface	3.50	0.01	0.02	0.15
LA-1 West volume	2.60	0.01	0.02	0.11

TABLE 5.1-4

DOSE CALCULATION RESULTS FOR REACH LA-1 CENTRAL

Part 1. Schematic Cross Section



ch = channel facies
ob = overbank facies

Part 2. Average Concentration and Fraction of Plutonium-239 Preliminary Remediation Goal by Unit and Exposure Scenario

Unit	Concentration (pCi/g)	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)
c1 ch	0.08	0.00	0.00	0.00
c1b ch	0.08	0.00	0.00	0.00
c2 ch	0.36	0.00	0.00	0.01
c3 ch	0.21	0.00	0.00	0.01
c2 ob	4.06	0.01	0.03	0.17
c3 ob	2.27	0.01	0.01	0.10
f1 ob	2.27	0.01	0.01	0.10
f2 ob	2.27	0.01	0.01	0.10

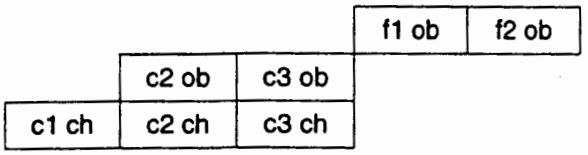
Part 3. Surface and Volume Aggregate Concentrations for Plutonium-239,240 and Fraction of the PRGs for Plutonium-239

Reach	Aggregate Concentration (pCi/g)	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)
LA-1 Central surface	2.30	0.01	0.02	0.09
LA-1 Central volume	1.30	0.00	0.01	0.05

TABLE 5.1-5

DOSE CALCULATION RESULTS FOR REACH LA-1 EAST

Part 1. Schematic Cross Section



ch = channel facies
ob = overbank facies

Part 2. Average Concentration and Fraction of Plutonium-239 Preliminary Remediation Goal by Unit and Exposure Scenario

Unit	Concentration (pCi/g)	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)
c1 ch	0.09	0.00	0.00	0.00
c2 ch	0.18	0.00	0.00	0.01
c3 ch	1.27	0.00	0.01	0.05
c2 ob	1.87	0.00	0.01	0.08
c3 ob	1.87	0.00	0.01	0.08
f1 ob	5.82	0.01	0.04	0.24
f2 ob	5.82	0.01	0.04	0.24

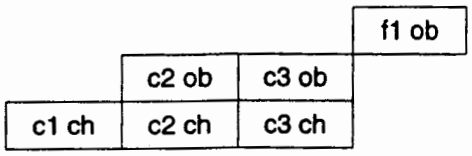
Part 3. Surface and Volume Aggregate Concentrations for Plutonium-239,240 and Fraction of the PRGs for Plutonium-239

Reach	Aggregate Concentration (pCi/g)	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)
LA-1 East surface	4.20	0.01	0.03	0.18
LA-1 East volume	2.30	0.01	0.02	0.09

TABLE 5.1-6

DOSE CALCULATION RESULTS FOR REACH LA-2 WEST

Part 1. Schematic Cross Section



ch = channel facies
ob = overbank facies

Part 2. Average Concentration and Fraction of Plutonium-239 Preliminary Remediation Goal by Unit and Exposure Scenario

Unit	Concentration (pCi/g)	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)
c1 ch	0.21	0.00	0.00	0.01
c2 ch	0.72	0.00	0.00	0.03
c3 ch	0.72	0.00	0.00	0.03
c2 ob	3.56	0.01	0.02	0.15
c3 ob	1.50	0.00	0.01	0.06
f1 ob	1.50	0.00	0.01	0.06

Part 3. Surface and Volume Aggregate Concentrations for Plutonium-239,240 and Fraction of the PRGs for Plutonium-239

Reach	Aggregate Concentration (pCi/g)	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)
LA-2 West surface	1.69	0.00	0.01	0.07
LA-2 West volume	1.02	0.00	0.01	0.04

TABLE 5.1-7

DOSE CALCULATION RESULTS FOR REACH LA-2 EAST

Part 1. Schematic Cross Section

					f1 ob	f1b ob
			c3 NEu ch	c3 SWu ob		
	c2 ob	c2b ob	c3 NEm ob	c3 SWl ob		
c1 ch	c2 ch	c2b ch	c3 NE ch			

ch = channel facies
ob = overbank facies

Part 2. Average Reach Concentrations Weighted by Surface Area and Volume of Sediment Units*

Reach	Pu-239,240	Cs-137	Am-241	Sr-90
LA-2 East surface aggregate	1.53	13.58	3.69	3.66
LA-2 East volume aggregate	1.24	11.93	3.18	3.06
*pCi/g				

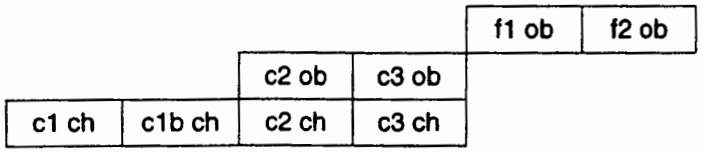
Part 3. Summed Fractions of PRGs Based on Surface and Volume Aggregate Concentrations

Reach	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)
LA-2 East surface	0.04	0.52	0.94
LA-2 East volume	0.03	0.45	0.83

TABLE 5.1-8

DOSE CALCULATION RESULTS FOR REACH LA-3

Part 1. Schematic Cross Section



ch = channel facies
ob = overbank facies

Part 2. Average Reach Concentrations Weighted by Surface Area and Volume of Sediment Units*

Reach	Pu-239,240	Cs-137	Am-241	Sr-90
LA-3 surface aggregate	0.57	2.90	0.93	0.89
LA-3 volume aggregate	0.67	3.51	1.03	0.77
*pCi/g				

Part 3. Summed Fractions of PRGs Based on Surface and Volume Aggregate Concentrations

Reach	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)
LA-3 surface	0.01	0.12	0.21
LA-3 volume	0.01	0.12	0.25

The surface and volume aggregate results for reach LA-2 East have the highest values for upper Los Alamos Canyon. The construction worker and resource user scenarios all have ratios of less than 1.0, indicating that a risk-based decision to remediate sediment is not warranted at this time. However, if a decision is made in the future to excavate contaminated sediment to reduce potential human health risk, additional data analyses were performed that would aid in selecting which areas to excavate. These analyses evaluate the volume of the sediment subunits and the relative contributions that each subunit makes to the summed PRG ratio. The results of this analyses are presented graphically in Figures 5.1-2 through 5.1-5. The y-axis in these plots shows the ascending contribution to the overall PRG sum. A sediment package that plots lower on the y-axis contributes less to the PRG sum than a package that plots above it. The x-axis shows the summed volumes of the sediment packages that contribute to the PRG sum. Each sediment package is plotted in the figure as a rectangle representing its volume and contribution to the PRG sum. If a decision were made to remove sediment packages to reduce the PRG sum, then the most efficiency would be gained by removing packages that make large contributions to the sum and have small volumes.

The sediment package contributions to the construction worker scenario are shown in Figure 5.1-2. The largest contributions to the PRG sum are c2u and c2l (the upper and lower sediments of the c2 unit). These sediment packages also represent 70% of the total sediment volume for the investigated reaches, making them relatively expensive candidates for removal. Five packages, ranging from c2bm (the middle layer in c2b) to c3NEm (the middle layer in c3 [NE]) on the plot have an estimated aggregated volume of 310 m^3 and contribute 0.21 to the total PRG sum of 0.94. Removal of the c2bm unit would require removing the c2bu unit as well. This would increase the total volume to 375 m^3 and make the PRG sum reduction 0.22, leaving an estimated PRG sum of 0.72 for the construction worker scenario. Figures 5.1-2 through 5.1-5 show the sediment package contributions to the construction worker and resource user scenarios for all the sediment packages and for the surface sediment packages.

The total PRG sum includes americium-241; cesium-137; plutonium-239,240; and strontium-90. Cesium and strontium are relatively short-lived radionuclides with half-lives of 30.2 and 28.6 years, respectively. Plutonium-239,240 and americium-241 have much longer half-lives of 24,131 and 432 years, respectively. Figure 5.1-6 presents the PRG sums by sediment package and by relative contributions from the long-lived and short-lived isotopes. Each sediment package has a horizontal line on each of the plots. Longer lines represent larger contributions to the sum. Each line is also located on a vertical cursor that splits the contribution between the long-lived isotopes and the short-lived isotopes. This information can be useful in making remediation decisions for locations that can be controlled administratively to reduce exposures. Potential exposures that are dominated by short-lived radionuclides could be controlled by restricting certain land uses while the radionuclides naturally decay to concentrations below concern. However, this strategy would not be effective for long-lived radionuclides. The trail user scenario is not presented because the maximum PRG fraction is only 0.04. The horizontal lines for each of the sediment packages are barely distinguishable and decisions to reduce trail user doses are very unlikely.

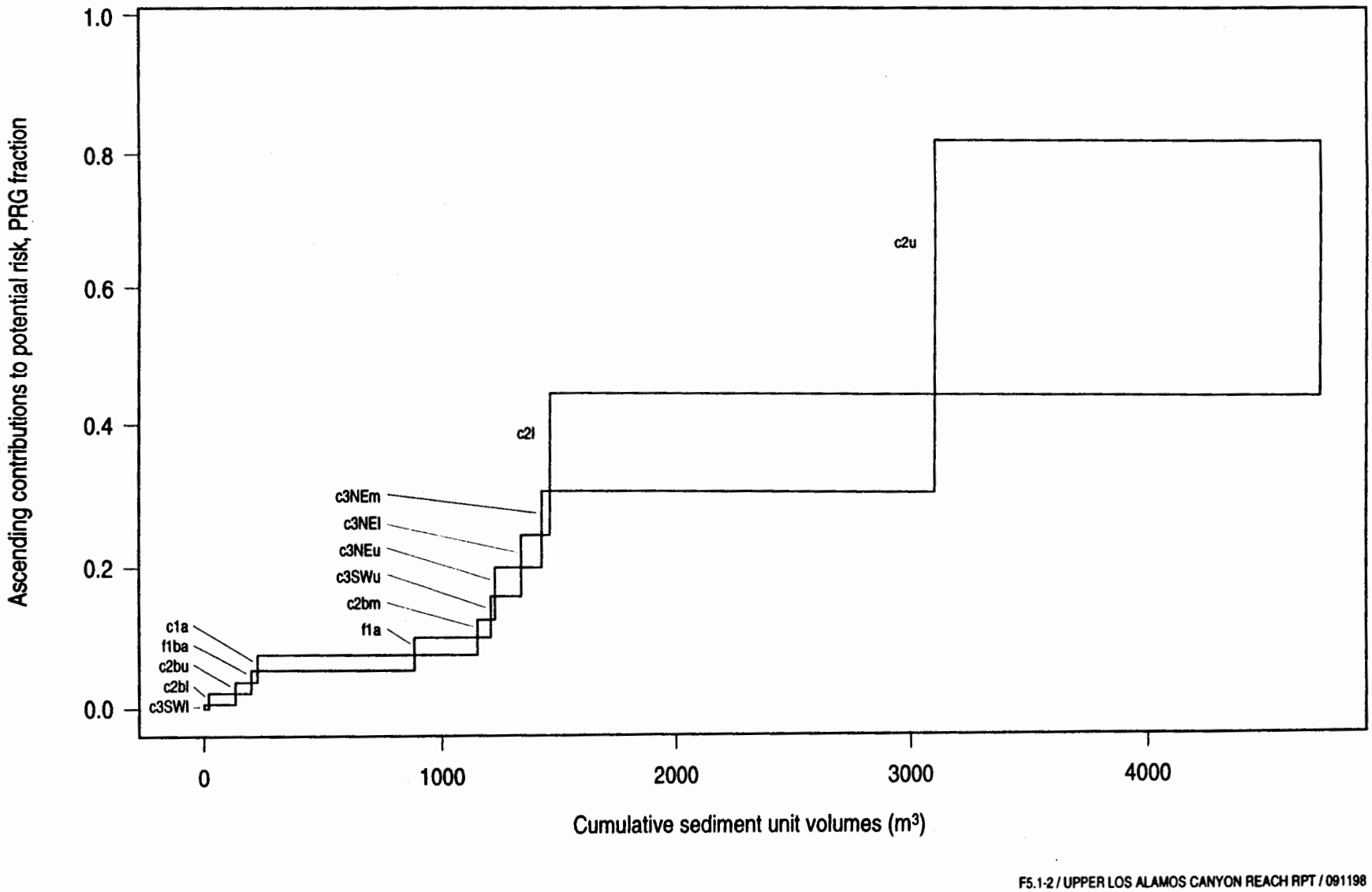
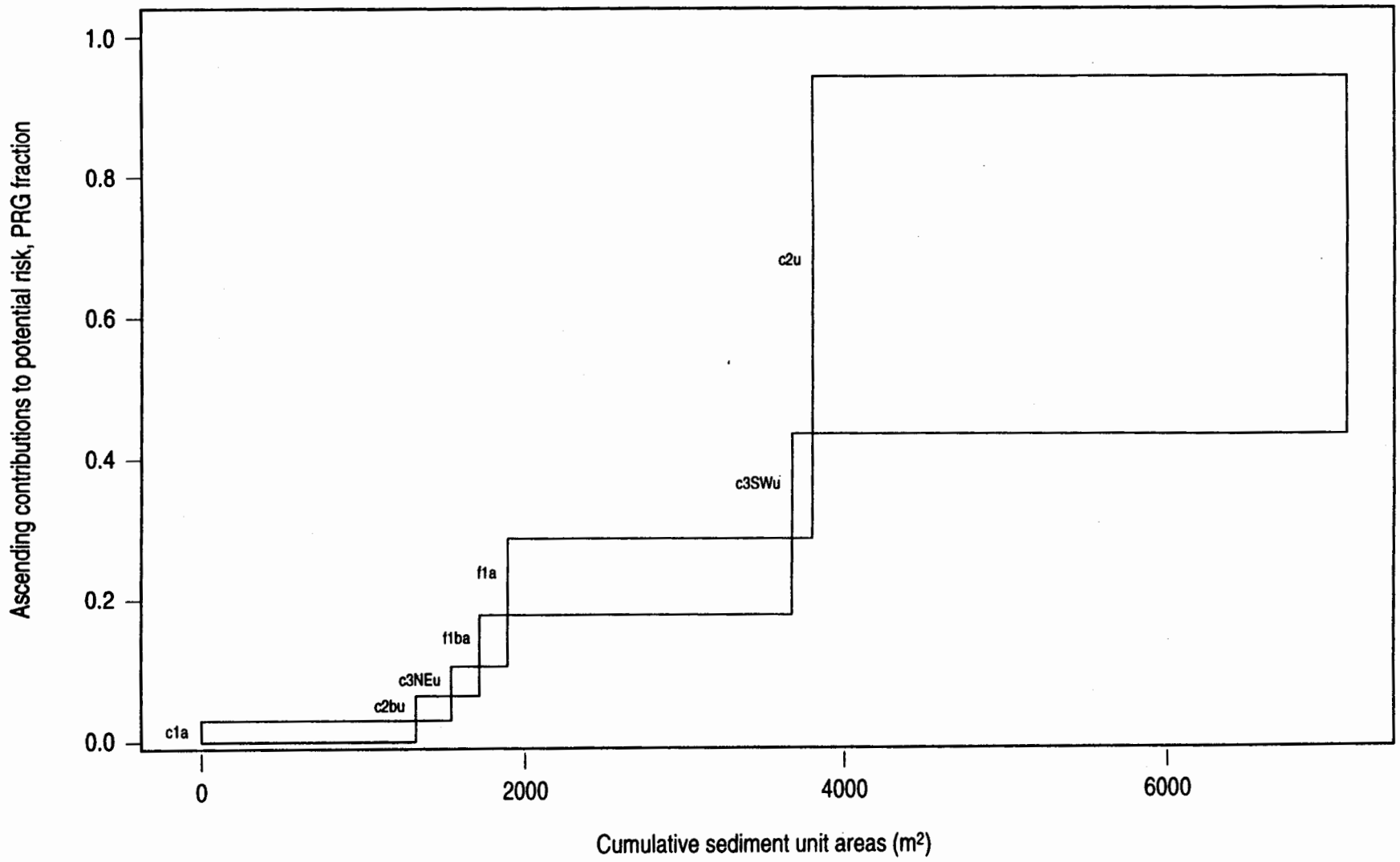


Figure 5.1-2. Los Alamos Canyon sediment package contributions to PRG fraction for the construction worker scenario.



F5.1-3 / UPPER LOS ALAMOS CANYON REACH RPT / 091198

Figure 5.1-3. Los Alamos Canyon surface sediment package contributions to PRG fraction for the construction worker scenario.

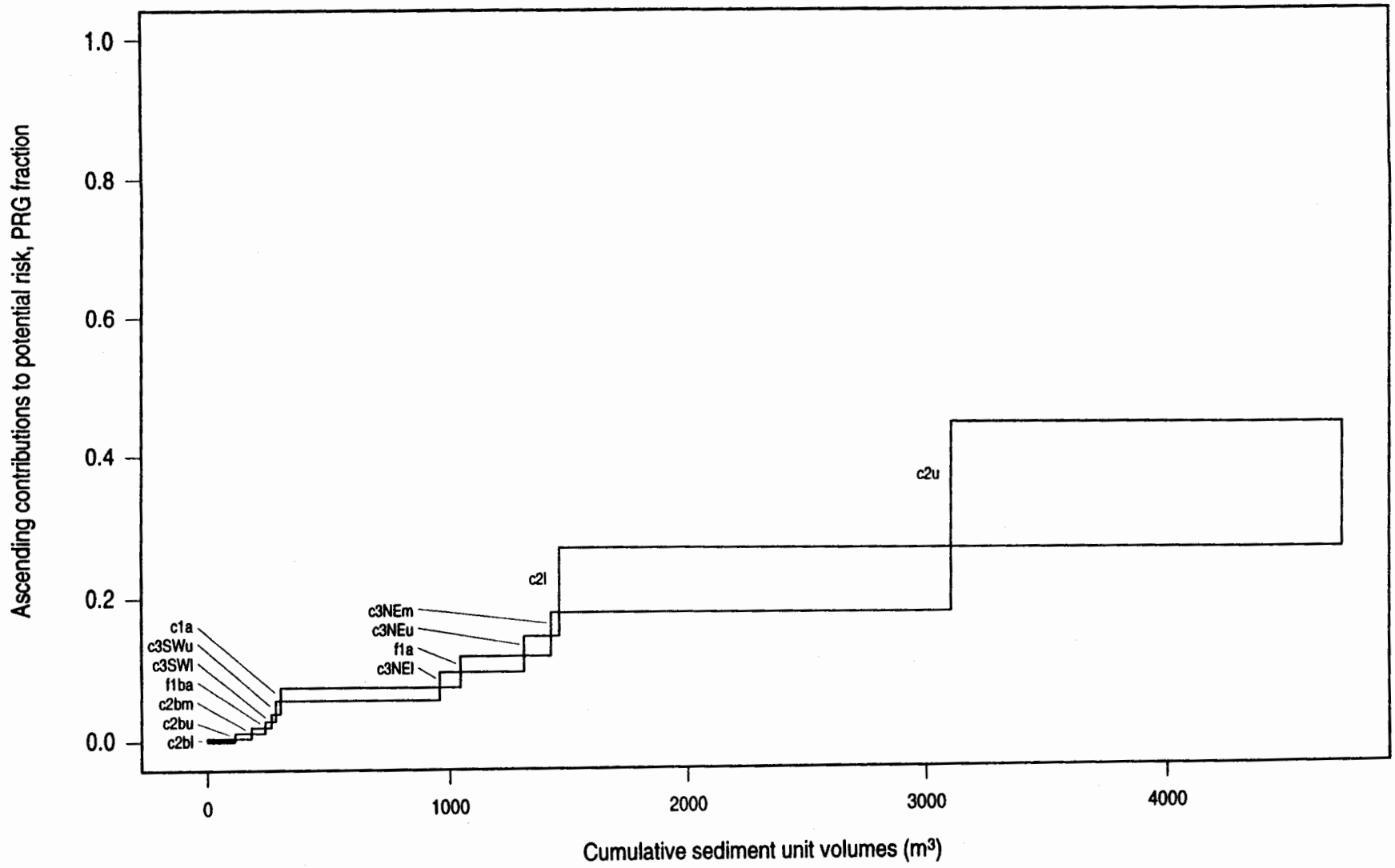
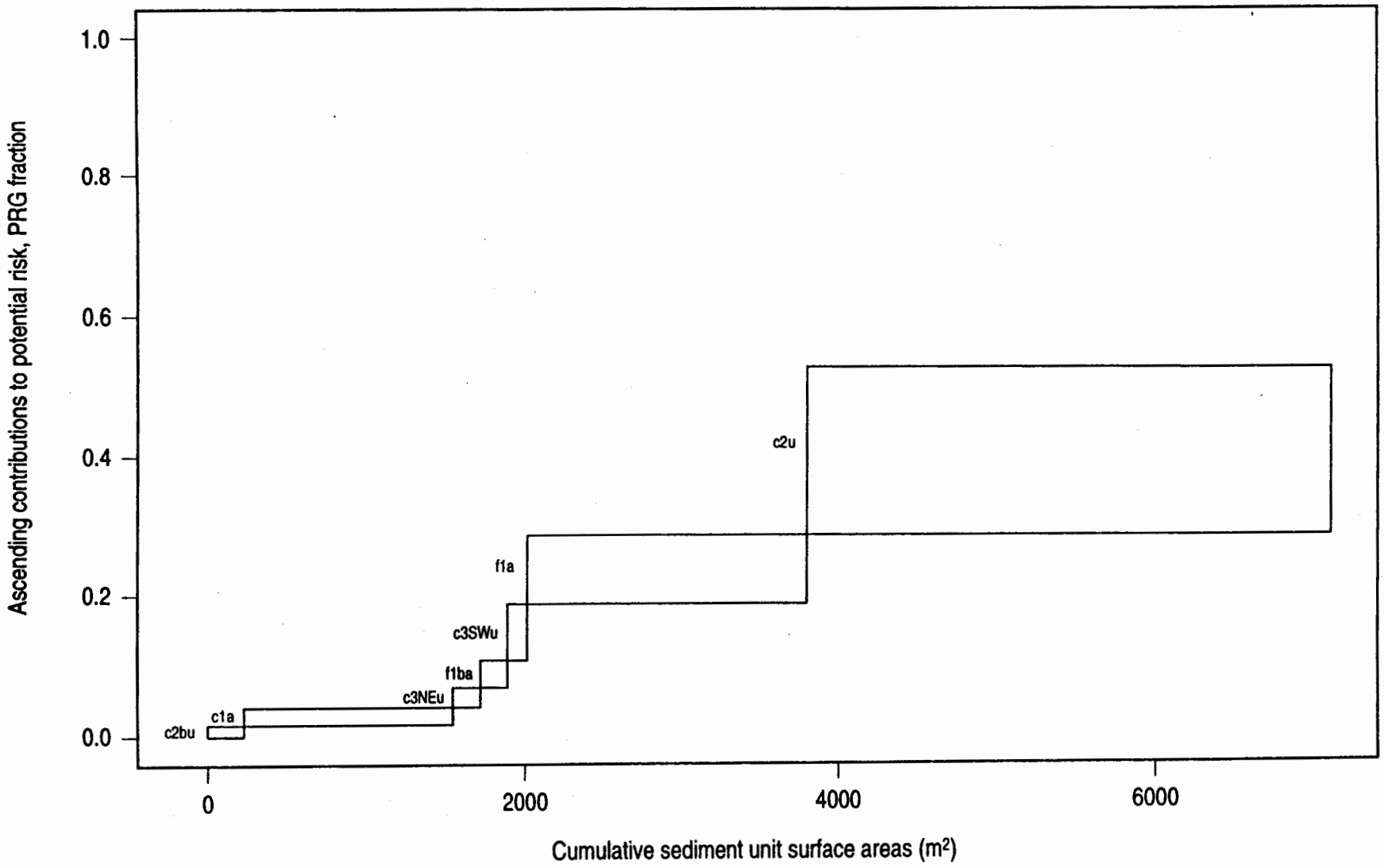


Figure 5.1-4. Los Alamos Canyon sediment package contributions to PRG fraction for the resource user scenario.



F5.1-5 / UPPER LOS ALAMOS CANYON REACH RPT / 091198

Figure 5.1-5. Los Alamos Canyon surface sediment package contributions to PRG fraction for the resource user scenario.

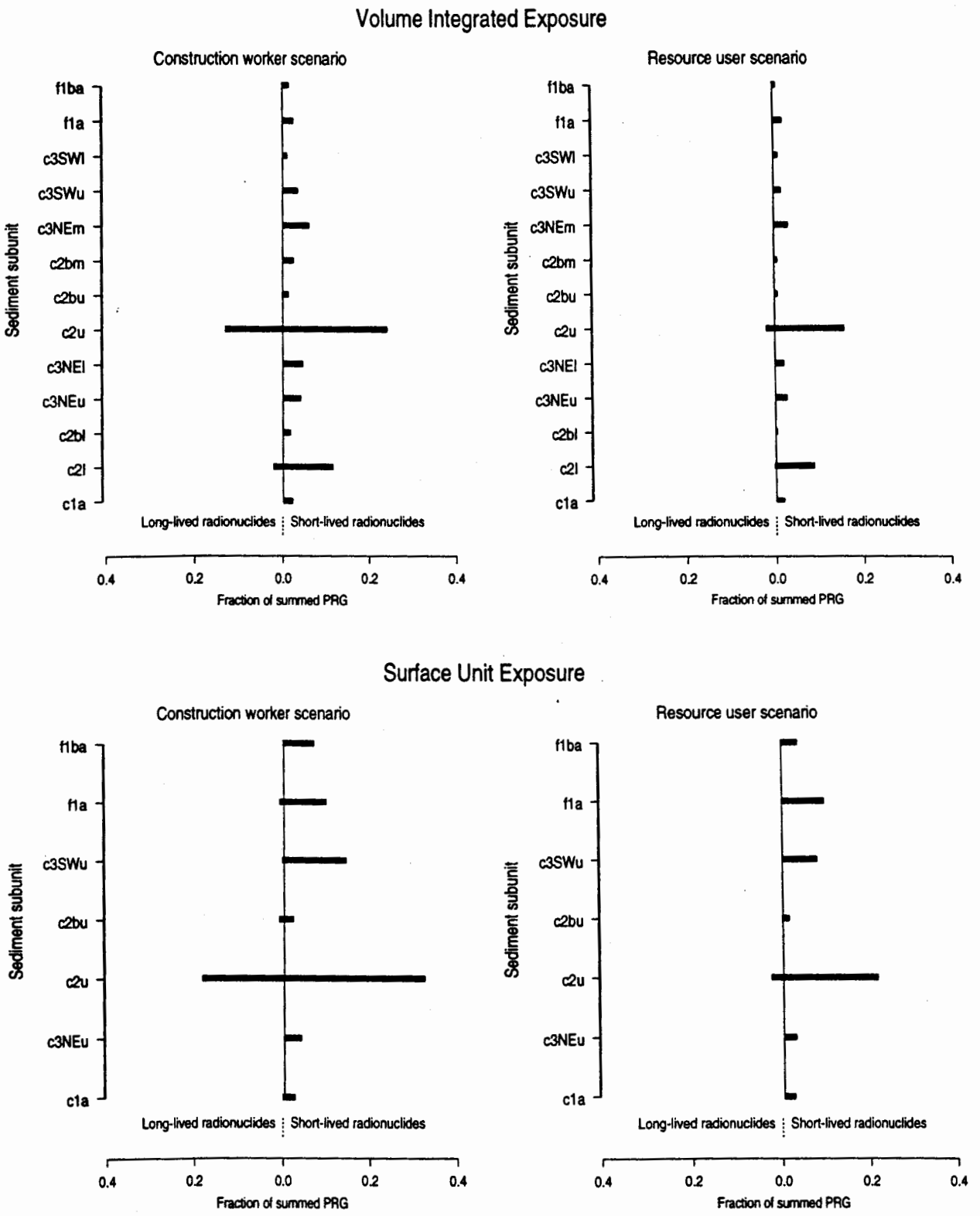


Figure 5.1-6. Long-lived and short-lived isotope contributions to PRG fractions by sediment subunit and exposure scenario.

5.1.8 Uncertainty Analysis

The conclusions of the COPC evaluation and the preliminary human health risk analysis are that there is no immediate need for remedial action in upper Los Alamos Canyon based on the contaminant data collected during this investigation. Principal sources of uncertainty in these conclusions include using the analyzed reaches to represent the entire length of upper Los Alamos Canyon, relying on cesium-137 and plutonium-239,240 to guide sediment sampling in upper Los Alamos Canyon, and estimating area and volume for the sediment packages. Additional sources of uncertainty include the dose conversion factors for radionuclides, slope factors for carcinogens, reference concentrations for noncarcinogens, and exposure factors and uptake ratios for plant and animals. These latter sources of uncertainty will be addressed in future reports when all pathways, including surface water and groundwater, are addressed. For this report, values for these parameters were used that are conservative and therefore protective of human health.

The primary source of uncertainty about the conclusion that there is no need for immediate remedial action is whether the areas with highest contaminant concentrations have been identified in upper Los Alamos Canyon. Within the sampled reaches, which represent 26% of the total length of upper Los Alamos Canyon downstream from Hillside 137 in former Technical Area (TA) -1, it is considered unlikely that contaminant concentrations in any area greatly exceed those measured at sample sites, particularly in reaches downstream from DP Canyon where field measurements of gross gamma radiation allowed precise mapping of variations in cesium-137 concentration. In addition, if higher levels of contaminants exist in sampled reaches, the area and volumes of such sediment would be small and unlikely to significantly affect average concentrations for the reach. Larger uncertainties exist concerning the unsampled reaches, as discussed below.

The highest concentrations of cesium-137 and strontium-90 occur in sediments that were deposited during the period of peak releases from the 21-011(k) outfall at TA-21 (approximately 1956 to 1968), represented by the small c3 unit in reach LA-2 East. It is possible that there are sediment deposits in the 2.7 km of canyon between LA-2 and LA-3 that date to this period and that either contain higher concentrations of these radionuclides, occupy larger percentages of the canyon floor, or are significantly thicker, hence posing a higher potential risk. This possibility is suggested by data from an aerial radiological survey conducted in 1982 that indicated areas of elevated gamma radiation between LA-2 and LA-3 that may equal or exceed the levels of radiation in LA-2 East (Fritzsche 1990, 58971). However, the resolution of this aerial survey is limited, and gross gamma walkover data collected in the area between LA-2 and LA-3 during this investigation, covering 18% of the length of the unsampled area, indicated a general downstream decrease in gamma radiation (Section 2.3.4). In addition, this apparent downstream decrease in contaminant concentrations is consistent with the expected effects of sediment transport processes, as discussed in Section 4.0. Therefore, available data suggest that there are not areas of elevated radiation between LA-2 and LA-3 with sufficient radionuclide concentration, area, and/or volume to cause exceedances of PRGs. Confirming the conceptual model for the area between LA-2 and LA-3 and the inference that PRGs are not exceeded would require additional field investigations.

Uncertainties concerning the use of cesium-137 and plutonium-239,240 analyses to identify sites containing other COPCs are considered minor because the pervasive occurrence of plutonium-239,240 above background values in reaches LA-1 and LA-2 West and cesium-137 in reaches LA-2 East and LA-3 allows the extent of contaminated sediments to be confidently identified. Uncertainties concerning the specific locations where the other COPCs have their highest concentrations depend on the degree to which the COPCs are collocated, which varies among the different analytes. Concentrations of one of the COPCs whose maximum value exceeds PRGs, strontium-90, is strongly correlated with cesium-137

concentration, and its maximum concentration in LA-2 East is probably well constrained. Another COPC, americium-241, had its peak releases after the peak releases of cesium-137 (Section 3.3.1.5); therefore, the maximum concentrations of these COPCs do not occur in the same sediment deposits. However, americium-241 and cesium-137 are generally well correlated within the younger sediments of the c2 unit in LA-2 East, and the maximum americium-241 concentrations are also fairly well constrained. The inorganic COPCs are generally correlated with the key radionuclides, as discussed in Section 3.2.1; therefore, maximum concentrations for these COPCs are fairly well constrained.

In contrast to the evidence for at least partial collocation between radionuclide and inorganic COPCs in upper Los Alamos Canyon, there is no good evidence for collocation between the key radionuclides and the organic COPCs, and the maximum and average concentrations for the organic COPCs may not be well constrained. In particular, concentrations of organic COPCs tend to increase upstream, and no semivolatile organic compound (SVOC) analyses were obtained in reach LA-1 (Section 3.2.3). Therefore, SVOC concentrations in LA-1 could be higher than those measured downstream in reach LA-2. However, concentrations of all organic COPCs are relatively low, and the available data indicate that there is negligible SVOC contamination in upper Los Alamos Canyon.

Additional uncertainty in this analysis pertains to the area- and volume-weighted estimates of contaminant concentrations. This uncertainty has not been quantitatively evaluated, but the conservative biases discussed here are considered adequate to support the conclusion that PRGs would not be exceeded. The area-weighted averages are believed to be more accurate than the volume-weighted averages because sampling tended to be biased toward upper sediment layers and because the surface areas of geomorphic units are usually well defined. Uncertainties in the depth estimates for the finer-grained overbank facies sediment packages that contain the highest concentrations of contaminants are well constrained, but the depth estimates for the coarser-grained channel facies sediment are more difficult to ascertain. Depths were biased to higher values to avoid underestimating contaminant inventories, and volume-weighted averages may tend to be weighted too heavily toward the thickest units. However, volume-weighted radionuclide concentrations in geomorphic units with thin layers of contaminated sediment would tend to be overestimated because of the assumption that there was no mixing with deeper uncontaminated sediment. In summary, the assumptions used in these calculations result in sufficiently conservative estimates of risk, and there is no need for immediate remedial action with regard to potential human health risk.

5.2 Ecological Screening Assessment

There are two phases of the ecological screening assessment as presented in Kelly et al. (1998, 57916) and followed in this report: the scoping evaluation and the screening evaluation. The scoping evaluation includes (1) the data assessment step, which identifies the list of COPCs for the reaches; (2) the problem formulation step for the specific reaches under investigation; and (3) the bioaccumulation evaluation step, which evaluates the level of concern for persistent bioaccumulation and/or biomagnification from contaminants in the reaches. The basis for upper Los Alamos Canyon-specific problem formulation is found in the scoping checklist in Appendix F. The scoping checklist is a useful tool for organizing existing ecological information and focusing the site visit on the information needed to develop the site conceptual model (SCM). The scoping checklist also provides the basis for evaluating the adequacy of the data for ecological risk screening.

The screening evaluation includes the calculation of HQs and hazard indices (HIs) for all COPCs and all appropriate screening receptors. The HQ can be thought of as the ratio of the calculated exposure dose to the receptor (based on contaminant levels in the reach) to a dose that has been determined to be

acceptable (based on toxicity studies for the receptor). An HI is a sum of HQs, across contaminants with like effects, for a given screening receptor. An HQ or HI greater than 1 is considered an indicator of potential adverse impacts, and the chemical constituents resulting in an HQ or HI greater than 1 are identified as contaminants of potential ecological concern (COPECs). HQ calculations require toxicity, bioconcentration, and bioaccumulation information for all chemicals for all receptors. This report will not include a quantitative screening evaluation because the required toxicity, bioconcentration, and bioaccumulation information are not available for aquatic receptors. To provide some information for a qualitative uncertainty analysis, maximum COPC concentrations were compared with the ecological screening levels for the most sensitive terrestrial receptors.

An uncertainty analysis follows the COPEC identification, which describes the key sources of uncertainty in the screening assessment. The uncertainty analysis can result in adding chemical constituents to or removing them from the list of COPECs. This report contains a qualitative uncertainty analysis to help understand potential data gaps associated with evaluating ecological risk.

The last part of the screening assessment is to interpret screening results in the context of a risk management decision. In general, possible decisions include a recommendation of the appropriate corrective action, in terms of ecological concerns. Possible recommendations include ecological no further action (NFA), voluntary corrective action (VCA), expedited cleanup (EC), voluntary corrective measure (VCM), and corrective measures study (CMS), any of which would be incorporated into an integrated risk management decision to include human health risk evaluations, groundwater and surface water issues, and other applicable regulations. In this report, the interpretation section will be used to recommend the type of additional data for the upper Los Alamos Canyon reaches that are needed for ecological risk characterization.

5.2.1 Scoping

5.2.1.1 Data Assessment

The approach taken to characterize the sediments in upper Los Alamos Canyon was designed to provide information on the nature and extent of contamination. By using laboratory analytical data and information on known contaminant sources, the COPC list for upper Los Alamos Canyon sediments was established in Section 3.1. The COPCs have been established based on statistical and graphical analysis of the data at a reach level. The main outstanding uncertainties associated with the sediment sample data are the lack of SVOC analyses from reach LA-1 and the lack of PCB/pesticide and SVOC data for reach LA-3 (due to the LA-3 organic chemical results being rejected).

5.2.1.2 Problem Formulation

The purpose of the screening-level ecological risk problem formulation for the canyons is to provide information to (1) determine if ecological receptors can be affected by a release; (2) determine how the sediments should be aggregated spatially for screening and to establish the functional/operational boundaries of the assessment; and (3) gather information to develop the SCM (e.g., what are the contaminant sources, dominant transport pathways and exposure routes, and potential receptors).

Terrestrial ecological receptors are abundant throughout upper Los Alamos Canyon, where the dominant plants include ponderosa pine, fir, piñon pine, juniper, shrub oak, apache plume, forbs, and grasses. Some areas of upper Los Alamos Canyon also have riparian plants (e.g., cottonwood and water birch).

Many areas, especially noted in parts of reach LA-3, have evidence of burrowing mammals, which represents both a potentially exposed animal population and a mechanism for contaminant redistribution (Section 4.3.3). The western part of reach LA-1 is the only area included in this report that has perennial or nearly perennial surface water flow and aquatic ecological receptors. The surface water in reach LA-1 originates from a combination of natural sources, including springs and runoff upstream from the Los Alamos Reservoir and is mediated by the reservoir. Spring snow melt runoff is a typical source of water in reach LA-1 and is less common in reaches LA-2 and LA-3. Storm water runoff is a another source of ephemeral water in upper Los Alamos Canyon. Physical disturbance is minimal throughout most of upper Los Alamos Canyon; some very localized areas have been disturbed recently by installation of underground gas lines or disturbed earlier for road construction. These localized disturbed areas were noted to have early successional plant species (grasses and forbs). The area surrounding TA-2 and TA-41 also have some physical disturbance and habitat modification resulting from construction of Laboratory buildings.

Threatened and endangered (T&E) species are potential receptors for contaminant releases in upper Los Alamos Canyon sediments. Specifically, the Mexican spotted owl and the peregrine falcon may roost or forage in upper Los Alamos Canyon (Koch 1998, 59115). The probability of bald eagles foraging in upper Los Alamos Canyon is low, and is not considered to be relevant to this screening-level ecological risk assessment. Thus, the kestrel screening receptor with an all flesh diet will serve as a surrogate for these avian T&E receptors in the screening calculations.

Sediment data were collected on a reach basis, and within reaches samples were collected from a variety of geomorphic units and sediment facies. The reaches were selected to reflect the range in contaminant concentrations present within upper Los Alamos Canyon sediments and to represent west-to-east geographic variations in the size of contaminated geomorphic units.

Historical contaminant releases that affected the sediments in upper Los Alamos Canyon could have occurred from a series of potential release sites (PRSs) in the upper Los Alamos Canyon watershed, as summarized in Section 1.3.2; that information will not be repeated here. The most significant contaminant sources in the watershed were the radioactive liquid waste outfall at TA-21 (PRS 21-011[k]) and the TA-1 hillsides. Other contaminant sources include surface impoundments at TA-53 and other outfalls at TA-21.

For the upper Los Alamos Canyon investigation, the primary impacted media are (1) surface soil in the canyon floodplain; (2) sediment in the active channel and adjacent abandoned channel surfaces (c1, c2, and c3 geomorphic units); and (3) surface water derived from seeps, springs, snow melt runoff, or storm water runoff. In addition, the shallow alluvial groundwater in parts of upper Los Alamos Canyon are known to contain dissolved contaminants (e.g., strontium-90).

The most important transport mechanism for contaminants in channel and floodplain units is lateral and vertical erosion of historical sediment deposits by surface water runoff, particularly in floods. Uncontaminated surface water could become contaminated by suspension or dissolution of contaminated soil or sediment. Another transport mechanism is the suspension of dry particulates by eolian processes, which makes air a secondary contaminated media. Contaminated shallow alluvial groundwater, which can emerge as surface water, is available to ecological receptors that are found in or use surface water in the stream channel.

The ecological SCM is presented graphically in Figure 5.2-1. The SCM identifies which exposure pathways represent major, minor, unlikely, or no pathway to ecological receptors. Exposure pathways to terrestrial receptors can occur through air (inhalation or deposition of particulates); surface soil (root uptake and rainsplash on plants' food web transport to plants and animals, incidental ingestion of soil, dermal contact with contaminated soil, and external radiation); and surface water or active channel sediments (root uptake and rainsplash on plants, food web transport to animals, incidental ingestion of water and sediment, dermal contact with contaminated water or sediment, and external radiation from sediment). The major soil-related exposure pathways are expected to be food web transport, incidental ingestion of contaminated soil, and external gamma radiation exposure. The major sediment/surface water -related exposure pathways are expected to be food web transport, incidental ingestion of contaminated sediment/water, and external gamma radiation exposure. However, the importance of the water/sediment pathways are questionable because of the limited extent of active channel sediments and surface water along the entire length of upper Los Alamos Canyon. Exposure to vapors is not a complete pathway because of the lack of volatile contaminants. Exposure to airborne particulates is expected to be a minor pathway because of the limited amount of contamination on the ground surface. Lastly, the remaining pathways that are related to exposure to surface soil (root uptake/rainsplash and dermal contact) and surface water/sediment (dermal contact) are expected to be minor or unlikely because of the limited amount of contamination expressed at the ground surface. The root uptake pathway could be more important in areas where cesium-137 or strontium-90 are the dominant contaminants (LA-2 East and LA-3) compared with areas where plutonium-239,240 is the dominant contaminant (LA-1 and LA-2 West) because of the low absorption potential through roots of plutonium-239,240 relative to cesium-137.

Typically all complete exposure pathways should be at least qualitatively evaluated in the screening evaluation. However, because of the lack of screening values for aquatic receptors, the screening evaluation presented below will evaluate only soil-related exposure pathways to terrestrial receptors (exclusive of dermal exposure and inhalation of particulates).

5.2.1.3 Bioaccumulator Evaluation

Several analytes detected above background values in the upper Los Alamos Canyon reaches are potential bioaccumulators (see Table 5.2-1). However, most of these COPCs are measured at values only marginally above detection limits or background values. Thus, it is unlikely that significant bioaccumulation will occur for most of these chemicals. To better address the impact of the potential bioaccumulating chemicals and other COPCs on ecological receptors, a screening-level ecological risk assessment is appropriate. The significance of bioaccumulation will be an important topic in the uncertainty analysis of this screening-level risk assessment.

5.2.2 Screening Evaluation

The formal, quantitative screening evaluation will be made after ecological screening levels (ESLs) are calculated for aquatic receptors. However, to help support an evaluation of the adequacy of the existing data in future canyon-wide ecological risk assessments, the *relative* hazard posed by COPCs to terrestrial ecological receptors was assessed. This analysis will help identify which COPECs represent potential terrestrial ecological risk drivers. Thus, these COPECs may require additional data collection to address only ecological risk uncertainties.

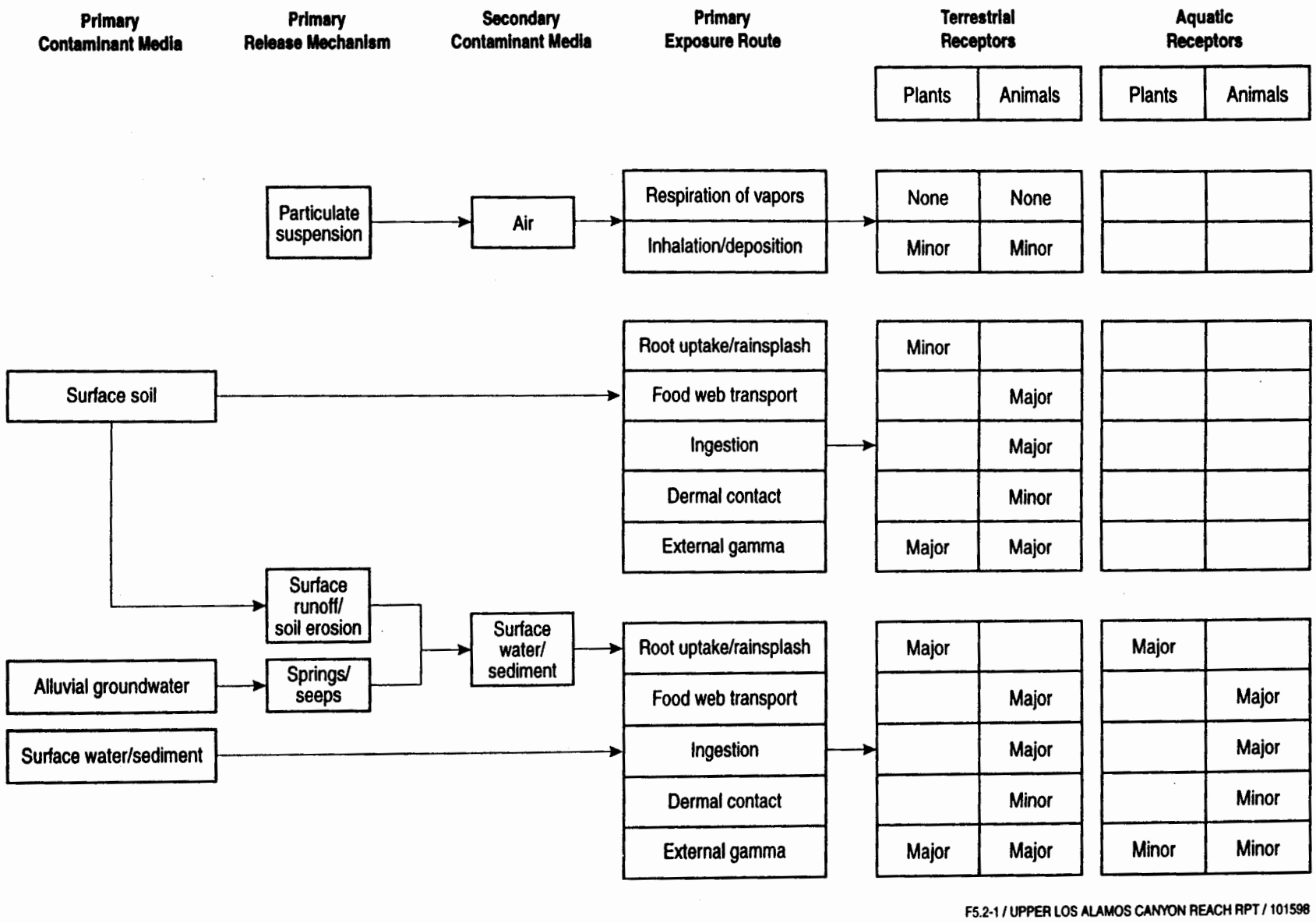


Figure 5.2-1. Conceptual site model of ecological receptors.

TABLE 5.2-1

COPCs FOR THE ECOLOGICAL SCREENING EVALUATION

Analyte Group	Analytes
Inorganic chemicals	Antimony, cadmium*, total chromium, copper*, lead*, mercury*, selenium*, silver, uranium, zinc
Radionuclides	Americium-241*; cesium-134; cesium-137*; cobalt-60; europium-152; plutonium-238*; plutonium-239,240*; strontium-90*; thorium-228*; thorium-230*; thorium-232*; tritium; uranium-234*; uranium-235*; uranium-238*
Pesticides	α-Chlordane*, γ-chlordane*, 4,4'-DDE*, 4,4'-DDT*
PCBs	Aroclor-1254*; Aroclor-1260*
Semivolatile organic compounds	Acenaphthene*, anthracene*, benz(a)anthracene*, benzo(a)pyrene*, benzo(b)fluoranthene*, benzo(g,h,i)perylene*, benzo(k)fluoranthene*, chrysene*, dibenz(a,h)anthracene*, dibenzofuran*, di-n-butylphthalate*, fluoranthene*, fluorene*, indeno(1,2,3-cd)pyrene*, naphthalene, phenanthrene*, pyrene*
*Potential persistent bioaccumulator as defined by the New Mexico Environment Department	

Table 5.2-2 provides the maximum detected sample result (except for antimony, which was never detected and for which the maximum detection limit is provided) for each upper Los Alamos Canyon COPC and the corresponding minimum terrestrial ESL. This same information is presented graphically in Figure 5.2-2, where the x-axis plots the maximum value for each COPC in upper Los Alamos Canyon and the y-axis plots the minimum terrestrial ESL[1]. The y-axis represents a conservative estimate of the exposure point concentrations for ecological receptors, and the future canyon-wide assessments will use more realistic estimates of exposure. Symbols that plot above the dashed line (the line of equality or y = x) represent chemicals (COPECs) that pose potential ecological risk (or HQ > 1). These analytes will be considered COPECs for the qualitative uncertainty analysis and interpretation sections below. This COPEC list is considered only preliminary because aquatic receptors and pathways have not been evaluated. Thus, other COPECs will likely be identified in the canyon-wide ecological assessment of sediment and surface water contamination in the upper Los Alamos Canyon watershed. The 13 COPECs that represent the highest potential risk to terrestrial ecological receptors, listed in order of HQ, are total chromium; mercury; dichloro diphenyl trichloroethane (DDT); antimony; Aroclor-1254; uranium-234; silver; uranium-238; Aroclor-1260; cesium-137; zinc; uranium; and lead. The qualitative uncertainty analysis and interpretation sections of the screening-level ecological risk assessment will focus on these 13 COPECs.

Because of the potential T&E species exposure to these COPCs, it is important to note those COPCs where the surrogate ecological receptor (kestrel with a flesh diet) has the lowest ESL. No COPC has the kestrel as the screening receptor with the lowest ESL (Table 5.2-2).

5.2.2.1 Uncertainty Analysis

This qualitative uncertainty analysis will consider the 13 COPECs identified in the qualitative screening evaluation section. These COPECs include four radionuclides, six inorganic chemicals, and three organic chemicals. Nine of these chemicals are also considered potentially persistent bioaccumulators. Each of these COPECs is briefly discussed below.

[1] The ratio of the y-axis to the x-axis value is equivalent to the HQ discussed above, and all supporting information for the derivation of terrestrial ESLs is postponed until the complete ecological risk assessment can be done that covers both terrestrial and aquatic receptors. Readers can review the basic models to calculate terrestrial ESLs in Kelly et al. (1998, 57916, Chapter 4).

TABLE 5.2-2

MAXIMUM DETECTED SEDIMENT CONCENTRATIONS AND ECOLOGICAL SCREENING LEVELS

Analyte	Maximum Sample Result (mg/kg)	Minimum ESL (mg/kg)	Screening Receptor with Minimum ESL[a]
Inorganic Chemicals			
Antimony[b]	14	1.0	Mouse
Cadmium	0.89	3.0	Plant
Chromium, total	38.4	0.4	Invertebrate
Copper	23.8	50	Invertebrate
Lead	61.9	50	Plant
Mercury	0.31	0.012	Robin
Selenium	0.65	0.85	Robin
Silver	15.8	2.0	Plant
Uranium	7.2	5.0	Plant
Zinc	90.5	50	Plant
PCB/Pesticide Organic Chemicals			
Aroclor-1254	1.5	0.14	Robin
Aroclor-1260	1	0.15	Shrew
α-Chlordane	0.0072	1.66	Robin
γ-Chlordane	0.0068	1.66	Robin
4,4'-DDE	0.033	19	Fox
4,4'-DDT	0.048	0.0021	Robin
Semivolatile Organic Compounds			
Acenaphthene	0.26	4.5	Mouse
Anthracene	0.096	440	Mouse
Benz(a)anthracene	0.368	3.9	Shrew
Benzo(a)pyrene	0.655	3.8	Shrew
Benzo(b)fluoranthene	0.66	3.7	Shrew
Benzo(g,h,i)perylene	0.298	2.2	Fox
Benzo(k)fluoranthene	0.019	3.7	Shrew
Chrysene	0.41	3.9	Shrew
Di-n-butylphthalate	0.055	0.10	Robin
Dibenz(a,h)anthracene	0.029	2.2	Fox
Dibenzofuran	0.036	100	Plant
Fluoranthene	0.725	53	Shrew
Fluorene	0.066	30	Invertebrate
Indeno(1,2,3-cd)pyrene	0.341	2.5	Fox
Naphthalene	0.2	21	Mouse
Phenanthrene	0.432	4.4	Mouse
Pyrene	0.589	32	Shrew

a. ESLs are calculated based on the methodology presented in Kelly et al. (1998, 57916).

b. Antimony result is *not* a detect.

TABLE 5.2-2 (continued)

MAXIMUM DETECTED SEDIMENT CONCENTRATIONS AND ECOLOGICAL SCREENING LEVELS

Analyte	Maximum Sample Result (pCi/g)	Minimum ESL (pCi/g)	Screening Receptor with Minimum ESL*
Radionuclides			
Americium-241	28	47	Robin
Cesium-134	0.18	16	Robin
Cesium-137	230	42	Robin
Cobalt-60	0.206	93	Robin
Europium-152	0.492	3.5	Robin
Plutonium-238	2.01	31	Robin
Plutonium-239,240	19.3	332	Robin
Strontium-90	39.56	150	Robin
Thorium-228	2.9	38	Robin
Thorium-230	2.61	36	Robin
Thorium-232	2.64	27	Robin
Tritium	0.143	410	Mouse
Uranium-234	2.8	0.29	Robin
Uranium-235	0.186	0.32	Robin
Uranium-238	2.52	0.33	Robin

*ESLs are calculated based on the methodology presented in Kelly et al. (1998, 57916).

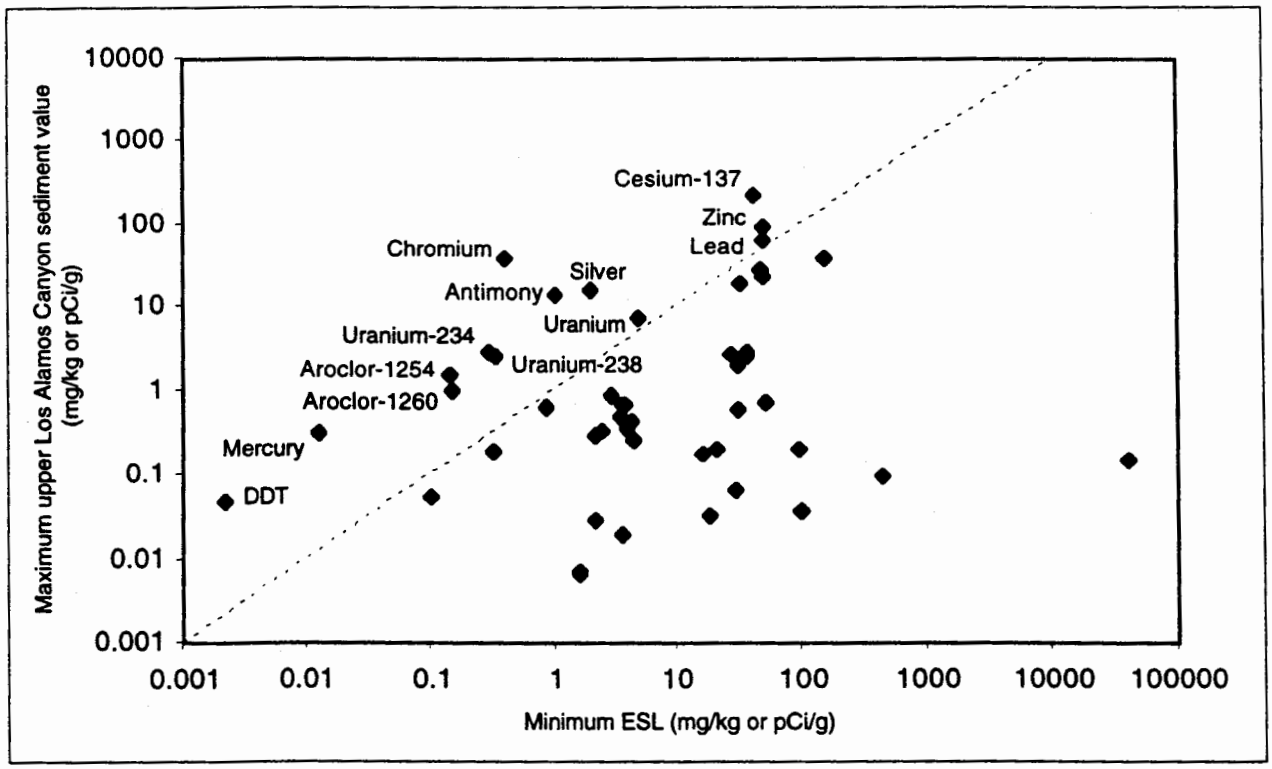


Figure 5.2-2. Preliminary comparison of the relative hazard posed by upper Los Alamos Canyon COPCs to terrestrial ecological receptors.

Cesium-137. Because of the extensive discussion of cesium-137 in the human health risk evaluation and the large database for this COPEC, additional discussion of the uncertainty relative to ecological receptors is not needed. Thus, it is assumed that uncertainties associated with regard to cesium-137 for evaluating ecological risk are acceptable. In particular, there should be sufficient data to calculate representative concentrations to better estimate exposure to ecological receptors.

Isotopic Uranium (Uranium-234 and Uranium-238) and Inorganic Uranium. Uranium sample results, whether reported as isotopic activity or total metal mass, are greater than background values only in reach LA-2. The magnitude that uranium exceeds background is also small (see discussion in Section 3.2). It appears that uranium concentration is correlated with cesium-137 concentration, which indicates that cesium-137 sample results can be used to estimate uranium concentrations in sediment deposits with few uranium analyses. Thus, the extensive information on cesium-137 (59 samples in reach LA-2) can supplement the more limited information available for uranium (14 isotopic uranium analyses and 10 total uranium analyses in reach LA-2). Thus, it is assumed that uncertainties associated with uranium for evaluating ecological risk are acceptable. In particular, there should be sufficient data to calculate representative concentrations to better estimate exposure to ecological receptors.

Antimony. No antimony detects were observed in the upper Los Alamos Canyon sediment samples, and it is retained for data assessment only because of elevated detection limits that were higher than the background value. However, detection limits were not elevated in 18 of 39 inorganic chemical analyses from the upper Los Alamos Canyon sediments, and these results are below the background value. This evidence suggests that antimony is probably not present as a contaminant and does not warrant a detailed analysis in the site assessments. The existing set of antimony sample results, accounting for the rejected antimony sample results for reach LA-2, should be adequate for evaluating exposure for ecological receptors.

Total Chromium. Total chromium had 7 results above the background value out of 49 samples, with the maximum value from reach LA-2 East. Chromium sample results above the background value were obtained from all three reaches. Because of the high frequency of nondetects, the amount of chromium associated with Laboratory releases seems to be small. In addition, total chromium concentration is correlated with cesium-137 concentration, which indicates that cesium-137 sample results can be used to estimate total chromium concentrations in sediment deposits with few total chromium analyses. Thus, the extensive information on cesium-137 (59 samples in reach LA-2) can supplement the more limited information available for total chromium (14 analyses in reach LA-2). The high HQ for total chromium is based on the assumption that chromium exists in its most toxic form, as hexavalent chromium. However, analyses of contaminated sediments at TA-2 indicate that less than 5% of the chromium is in its hexavalent form and that more than 95% is trivalent chromium (Longmire 1998, 59363). Therefore, the potential risk due to chromium has been overestimated by this assessment, and this Los Alamos Canyon-specific chromium speciation information will be included in further evaluations of ecological risk. All uncertainties associated with total chromium for evaluating ecological risk are considered acceptable, and there should be sufficient data to estimate exposure to ecological receptors.

Mercury. Mercury was detected above the background value in 6 sample results from locations in all three reaches. The importance of mercury as a potential risk to ecological receptors depends on whether it exists as organic mercury (methyl mercury) or elemental mercury. Methyl mercury is readily absorbed by animals, and it is more potent toxicologically in this form. Uncertainty could be reduced through further sediment analyses to determine the form of mercury present. Determination of the form of mercury is most appropriate for the upper reaches of Los Alamos Canyon (i.e., LA-1 West) where conversion of inorganic to organic mercury is more likely than in dry or moist sediments down canyon, although the

maximum mercury result was obtained in a drier reach (LA-2 West). The correlation of mercury with plutonium-239,240 suggests that plutonium-239,240 sample results can be used to estimate mercury concentrations in sediment deposits with few mercury analyses. Thus, the extensive information on isotopic plutonium (e.g., 85 samples in reach LA-1) can supplement the more limited information available for mercury (27 analyses in reach LA-1). Except for the organic mercury question, it is assumed that uncertainties associated with mercury for evaluating ecological risk are acceptable. In particular, there should be sufficient data to calculate representative concentrations to better estimate exposure to ecological receptors.

Lead. Lead was measured at up to three times the background value in reach LA-2, and it was also measured above the background value in reaches LA-1 and LA-3. The chemical form of lead is important to the bioavailability and toxicity of lead in the environment. The correlation of lead with plutonium-239,240 suggests that plutonium-239,240 sample results can be used to estimate lead concentrations in sediment deposits with few lead analyses. Thus, the extensive information on isotopic plutonium (e.g., 55 samples in reach LA-2) can supplement the more limited information available for lead (14 analyses in reach LA-2). Thus, it is assumed that uncertainties associated with lead for evaluating ecological risk are acceptable. In particular, there should be sufficient data to calculate representative concentrations to better estimate exposure to ecological receptors.

Zinc. Zinc is elevated above the background value only in reach LA-2 where there are five sample results above the background value, but the maximum result is less than twice the background value. Thus, widespread concentrations of zinc above background are not suggested by these data. It also appears that zinc concentration is correlated with cesium-137 concentration, which suggests that cesium-137 sample results can be used to estimate zinc concentrations in sediment deposits with few zinc analyses. Thus, the extensive information on cesium-137 (59 samples in reach LA-2) can supplement the more limited information available for zinc (14 analyses in reach LA-2). Thus, it is assumed that uncertainties associated with zinc for evaluating ecological risk are acceptable. In particular, there should be sufficient data to calculate representative concentrations to better estimate exposure to ecological receptors.

DDT. DDT was detected in 12 of 27 sample results in upper Los Alamos Canyon, and 10 of these detected sample results were from samples collected in reach LA-1. There are no DDT sample results for reach LA-3 because the organic chemical results for reach LA-3 were rejected. DDT concentrations do not exhibit positive correlations with either plutonium-239,240 or cesium-137, and the source for the DDT is unknown, but DDT does show significant decreases in concentration between LA-1 and downstream reaches. DDT has known ecological effects (especially for birds) and is a potentially persistent bioaccumulator. Because upper Los Alamos Canyon is potential foraging habitat for avian T&E species (peregrine falcon and Mexican spotted owl), uncertainties in the contaminant source and exposure concentration should be reduced. The potential for DDT bioaccumulation could be addressed through literature searches of existing data sources. However, the lack of DDT sample results for reach LA-3 represents a data gap that should be filled by collecting additional samples for DDT analyses.

Polychlorinated Biphenyls (PCBs) (Aroclor-1254 and Aroclor-1260). Aroclor-1254 was detected only in reach LA-1, and Aroclor-1260 was detected in both reaches LA-1 and LA-2. There are no PCB sample results for reach LA-3 because the organic chemical results for reach LA-3 were rejected. The spatial distribution of these COPECs does not correlate with either plutonium-239,240 or cesium-137, the source for the PCBs is unknown, and the lack of sample data for reach LA-3 limits the ability to develop upper Los Alamos Canyon watershed spatial trends. There is some uncertainty in PCB concentrations upstream of the sampled reaches as PCBs were detected in a sample collected from the most upstream reach (LA-1 Far West); concentrations would presumably be highest closest to the source. Uncertainty in PCB

bioaccumulation could be addressed through literature searches of existing data sources. However, the lack of PCB sample results for reach LA-3 represents a data gap that should be filled by collecting additional samples for PCB analyses.

5.2.2.2 Interpretation

Several COPECs have been identified in upper Los Alamos Canyon sediments, and further assessments of ecological risk will be performed. However, the lack of obvious contaminant-related ecological impacts in upper Los Alamos Canyon suggests that there is no need for immediate remedial action with regard to ecological risk.

Uncertainties in potential ecological risk should be addressed through collection of a limited number of sediment samples to determine the form of mercury present if a significant potential for risk is indicated by further assessments that address risk to aquatic and terrestrial receptors from all relevant pathways. Literature searches of existing data sources could also help estimate bioaccumulation of mercury, PCBs, and DDT in the upper Los Alamos Canyon food web. There is some uncertainty in the maximum value and representative concentrations of the SVOCs because no semivolatile analyses were obtained for reach LA-1, and the source of the detected SVOCs in reach LA-2 is unknown. There is also some uncertainty in the maximum value and representative concentrations of DDT and PCBs because the source for these organic COPECs has not been identified.

The lack of organic data for reach LA-1 (SVOC data) and LA-3 (PCB/pesticide and SVOC data) represent data gaps that prevent a complete screening-level ecological risk assessment. These data gaps should be filled with additional analyses. Another obvious data gap in upper Los Alamos Canyon is analytical results on surface water from any of the reaches. Surface water data would be useful for developing a comprehensive ecological risk assessment of upper Los Alamos Canyon. A screening-level ecological risk assessment should be completed as soon as these data gaps are filled.

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6.0 CONCLUSIONS AND RECOMMENDATIONS

This section summarizes conclusions from this investigation, highlights key remaining uncertainties related to contaminated sediments in upper Los Alamos Canyon, and provides recommendations concerning possible additional assessments, data collection, and remedial action. The human health and ecological screening assessments presented in this report are preliminary and are intended to identify any need for immediate remedial action or additional data collection from the standpoint of potential current risk. The preliminary human health risk assessment considers only present-day land use scenarios and the potential risk resulting from exposure to contaminated sediments. More comprehensive risk assessments will be presented in one or more future reports on Los Alamos Canyon that will incorporate the results of ongoing groundwater investigations and any additional sediment investigations and that may consider other land use scenarios.

6.1 Nature and Sources of Contaminants

The primary chemicals of potential concern (COPCs) in the sediments of upper Los Alamos Canyon are radionuclides that were discharged from the 21-011(k) outfall at Technical Area (TA) -21 into DP Canyon between 1956 and 1985. The most significant radionuclide in terms of potential human health risk is cesium-137. Other radionuclide COPCs that were also discharged from the 21-011(k) outfall and are detected above background values are americium-241; plutonium-238; plutonium-239,240; strontium-90; thorium-230; tritium; uranium-234; uranium-235; and uranium-238. Radionuclides were also released from other sites in the upper Los Alamos Canyon watershed upstream from DP Canyon, including former TA-1, TA-2, and TA-21. Americium-241; cesium-137; plutonium-238; plutonium-239,240; uranium-234; and uranium-238 were detected above background values in upstream reaches. The most significant of these radionuclides is plutonium-239,240, and the distribution of plutonium-239,240 in upper Los Alamos Canyon sediments suggest that the most important source is Hillside 137 at former TA-1. One radionuclide, cobalt-60, appears to have a source downstream from DP Canyon, which is consistent with known releases from TA-53, although cobalt-60 is present only at low levels in upper Los Alamos Canyon sediments.

A series of inorganic COPCs have been identified in the sediments of upper Los Alamos Canyon, and most of these appear to be collocated with radionuclide COPCs, suggesting common release histories and similar transport mechanisms. Chromium and uranium appear to be correlated with cesium-137, which suggests primary releases at the 21-011(k) outfall in DP Canyon. Copper, lead, mercury, silver, and zinc appear to be correlated with plutonium-239,240, which suggests primary releases upstream from DP Canyon. Most detected concentrations of these metals are less than background values, indicating that contaminant releases were relatively small. Both copper and lead were detected above background values upstream from all potential release sites (PRSs) at former TA-1, suggesting either releases from unidentified PRSs farther upstream or other sources such as residential areas in the Los Alamos townsite or road runoff. Three other inorganic COPCs (antimony, cadmium, and selenium) were not detected with sufficient frequency to draw conclusions about potential contaminant releases.

Twenty-three organic COPCs have been measured at low concentrations in the sediments of upper Los Alamos Canyon and appear to have been derived from multiple sources. These chemicals include polychlorinated biphenyls (PCBs), pesticides, plasticizers, and polycyclic aromatic hydrocarbons (PAHs); they are not collocated with either radionuclide or inorganic COPCs. The sources, distribution, and maximum concentrations of the organic COPCs are poorly constrained because of gaps in data coverage. Additional sampling and analysis for organic chemicals will be required to adequately evaluate these COPCs and perform future risk assessments.

6.2 Present Distribution of Contaminants

Radionuclide COPCs and other contaminants within upper Los Alamos Canyon have been widely distributed by floods during the past 55 years. Sediment with radionuclide concentrations above background values is present along the full length of upper Los Alamos Canyon downstream from former TA-1, a distance of more than 10 km. The part of the canyon floor containing radionuclides above background values ranges in width from less than 5 m to at least 25 m, averaging 9 to 15 m in the sampling reaches. The horizontal and vertical extent of contaminated sediments are well defined in the reaches selected for investigation, particularly downstream from DP Canyon where cesium-137 concentrations are high enough to allow the horizontal extent of contaminated sediment to be mapped using radiological field instruments. If needed, the area containing significant cesium-137 concentrations in unsampled reaches could be readily determined using field instruments. The horizontal extent of contaminated sediments in unsampled reaches upstream from DP Canyon could be estimated based solely on geomorphic mapping.

Concentrations of the primary radionuclide COPCs in post-1942 sediment deposits show substantial variability both within reaches and between reaches, having a range of more than two orders of magnitude within some reaches. The highest concentrations of cesium-137, strontium-90, and tritium occur in fine-grained sediments close to the confluence with DP Canyon; they were probably deposited concurrently with or soon after the peak contaminant releases from the 21-011(k) outfall (sometime between 1956 and 1968). Coarse-grained sediment in the same geomorphic units also generally have higher concentrations of these radionuclides than are found in younger sediments. These relatively old post-1956 sediments are found in geographically small areas that can be readily identified using field instruments.

Concentrations of americium-241 and plutonium-238 are highest in the same reach as cesium-137, strontium-90, and tritium (LA-2 East), but the maximum concentrations occur in younger sediments in different geomorphic units. These time-dependant variations in concentration can be directly related to variations in releases at the 21-011(k) outfall, and the peak releases for americium-241 and plutonium-238 occurred after 1968. In contrast, concentrations of plutonium-239,240 are highest farther upstream, in reach LA-1 West.

Most inorganic COPCs in upper Los Alamos Canyon appear to be collocated with the primary radionuclide COPCs; therefore, their distribution and general variations in concentration can be estimated using data on the radionuclides. In contrast, the organic COPCs are not collocated with the key radionuclides, and it is not possible at present to systematically identify where concentrations of the organic COPCs are highest, although general conclusions can be made. Specifically, the highest concentrations of the organic COPCs can be expected to occur in upstream areas in relatively fine-grained post-1942 sediment deposits, but because the sources for these COPCs have not been identified it is not possible to predict more precisely where maximum concentrations could be found. Therefore, if risk assessments identify that specific organic COPCs may be of concern, additional sediment sampling and analysis would be required to understand their distribution and focus potential remedial actions.

6.3 Preliminary Human Health Risk Results

The preliminary human health risk assessment presented in Section 5.1 evaluated the radiation dose that could be received by trail users, resource users, and construction workers in upper Los Alamos Canyon under present-day conditions of contamination and land use. A screening assessment indicated

that several radionuclides, dominated by cesium-137, contribute to potential human health risk in upper Los Alamos Canyon. The combined doses derived from americium-241; cesium-137; plutonium-239,240; and strontium-90 in sediments were evaluated in this report because all these radionuclides are widely distributed in the sediments of upper Los Alamos Canyon at levels above background values. The assessment indicated that nowhere in the upper Los Alamos Canyon reaches did conservative estimates of dose exceed the preliminary remediation goal (PRG) of 15 mrem/yr proposed by the Environmental Protection Agency, although estimated doses reached 94% of the PRG for a conservative construction worker scenario. Therefore, the results of this investigation indicate no immediate risk to human health resulting from the levels of contamination in upper Los Alamos Canyon sediments and no need for immediate remedial action in the context of human health risk. However, data are not sufficient to rule out the possibility of a higher potential risk in an unsampled area between reaches LA-2 and LA-3. Because cesium-137 concentrations are readily estimated with field instruments at levels that are useful for comparisons with PRGs, collection of additional field radiological data would be an effective method to assess the possibility of unacceptable human health risk in this unsampled area.

Two of the most important radionuclide COPCs in upper Los Alamos Canyon, cesium-137 and strontium-90, have relatively short half-lives of 29 to 30 years, and significant decreases in concentration because of radioactive decay will occur over time frames relevant for evaluating risk. Therefore, implementing institutional controls that limit possible land uses until significant radioactive decay has occurred could be an effective risk mitigation technique if measures to reduce risk are necessary.

Two organic COPCs were identified in the human health screening assessment as having maximum values exceeding PRGs for both the trail user and the resource user scenarios: the PCB Aroclor-1260 and the PAH benzo(a)pyrene. Although Aroclor-1260 was widely detected in reaches LA-1 and LA-2, only one result exceeded the PRGs, and it is unlikely that levels of this PCB are high enough to pose a significant human health risk under the scenarios evaluated in this report. However, no PCB data are available for reach LA-3, and PCB analyses from LA-3 are needed to confirm that this COPC is not present at higher concentrations in that part of upper Los Alamos Canyon. Benzo(a)pyrene was detected in most PAH analyses in reach LA-2, and more than half of the results exceeded PRGs; although this suggests an unacceptable potential for human health risk, the uptake factors for benzo(a)pyrene are very conservative, and it is unlikely that this PAH actually poses an unacceptable risk. However, because of gaps in data coverage, more PAH analyses are needed to evaluate concentrations of this COPC in upper Los Alamos Canyon.

The only other COPC that was identified in the human health screening assessment as having a maximum value exceeding its PRG is mercury for the resource user scenario, and only one mercury value exceeded the PRG. Mercury appears to be collocated with plutonium-239,240 in the sediments of upper Los Alamos Canyon; therefore, data on plutonium-239,240 concentrations could be used to estimate the concentrations and inventory of mercury contained within the post-1942 sediment deposits. In addition, the low frequency of mercury results above the detection limit and the occurrence of only a single value above the PRG indicate that mercury poses no significant human health risk in upper Los Alamos Canyon.

The human health risk assessment presented in this report evaluated only the risk due to contaminants in sediments, and additional risk assessments will be required that incorporate surface water and/or groundwater exposure pathways. Data on water quality are currently being collected from upper Los Alamos Canyon by the Environmental Restoration Project for use in these future assessments. Additional risk assessments may also be required to evaluate different land use and exposure scenarios, such as residential scenarios, if it is decided that such assessments are appropriate.

6.4 Preliminary Ecological Risk Results

Potential ecological risk is incompletely defined in upper Los Alamos Canyon because of the limited scope of the ecological screening assessment that was possible in the context of this report. Because the Laboratory has not compiled information on the toxicity of upper Los Alamos Canyon contaminants of potential ecological concern (COPECs) to aquatic receptors or on the concentration of COPECs in surface water, the assessment presented in Section 5.2 evaluated only the potential risk to terrestrial receptors from contaminants contained within the sediments. In addition, this preliminary assessment used only maximum values obtained for each COPC within upper Los Alamos Canyon and made no attempt to estimate average concentrations or to evaluate risk on a reach basis or a watershed basis. Nevertheless, this assessment indicates that several contaminants present within the sediments of upper Los Alamos Canyon pose potential ecological risk to terrestrial receptors and thus will require additional assessment. This assessment also identifies some specific data needs. However, the lack of obvious contaminant-related ecological impacts in upper Los Alamos Canyon suggests that there is no need for immediate remedial action with regard to ecological risk.

The screening assessment performed in this investigation identified 13 COPECs within the sediments of upper Los Alamos Canyon, including 7 inorganic COPECs, 3 organic COPECs, and 3 radionuclide COPECs. Two metals, chromium and mercury, were identified as presenting the highest potential ecological risk. Available data indicate that both of these COPECs have multiple sources within the watershed and that both are generally correlated with either cesium-137 or plutonium-239,240. Therefore, their concentrations can be estimated using data on radionuclide concentrations. The relatively high potential risk attributed to these inorganic COPCs is related to assumptions that they consist entirely of their most toxic forms (hexavalent chromium and methyl mercury). Data from contaminated sediments in upper Los Alamos Canyon show that this assumption is incorrect for chromium and that less than 5% is in its hexavalent form. Future ecological risk assessments will incorporate this information. No similar data are available for mercury, and uncertainties in ecological risk would be reduced by determining its actual chemical form.

Two organic COPECs were identified as having the next highest potential ecological risk: dichloro diphenyl trichloroethane (DDT) and the PCB Aroclor-1254. Available data suggest that both of these COPECs may have multiple sources within the watershed, including sources upstream of all PRSs at former TA-1, and that there is no correlation between them and the key radionuclides. Specific sources are not certain. Concentrations are higher in upstream reaches than downstream near the Laboratory boundary, suggesting sources in the upper watershed, but it is not possible to predict where concentrations would be the highest in the sediments of upper Los Alamos Canyon. However, concentrations of both of these COPECs are low, indicating that releases were small.

6.5 Future Remobilization and Transport of Contaminated Sediments

Floods constitute the primary transport mechanism for contaminants in upper Los Alamos Canyon and, under natural conditions, floods will continue to redistribute these contaminants. Future effects of floods can be estimated based on the geomorphic record of the effects of floods that have occurred during the past 55 years. Each flood redistributes part of the contaminant inventory within the watershed and also mixes contaminated sediment with uncontaminated sediment derived from various parts of the watershed. This mixing of sediment from different sources has reduced the concentration of the most important COPC, cesium-137, transported by floods over time. Cesium-137 concentrations in sediment transported during floods were highest during the early period of releases of radioactive effluent from the 21-011(k) outfall at TA-21, between 1956 and 1968, and concentrations dropped rapidly after 1968

following reductions in the discharge of cesium-137. Cesium-137 concentrations in sediment have been stable or have declined since that time; therefore, concentrations can be expected to remain stable or to decline during the next several decades. Thus, remedial actions to reduce cesium-137 concentrations in sediment transported during floods will be necessary only if it is determined that present-day concentrations pose an unacceptable human health or ecological risk or are otherwise deemed to be unacceptable.

Most of the radionuclide COPCs contained within sediments in upper Los Alamos Canyon are located in geomorphic units that are adjacent to the active channel and that are considered to be very susceptible to remobilization by lateral bank erosion during the next 30 to 50 years, as discussed in Section 4.3.6. Although part of these remobilized contaminants will be redeposited downstream within upper Los Alamos Canyon, the primary deposition sites are close to the active channel; therefore, these contaminants will also be susceptible to remobilization during additional floods. Because of this high susceptibility for remobilization, it should be considered that most of the radionuclide inventory in upper Los Alamos Canyon could be transported into lower Los Alamos Canyon during the next 50 years. However, because cesium-137 and strontium-90 both have relatively short half-lives of approximately 30 years, significant reductions in inventory will occur by radioactive decay during this time frame. It is also worth noting that, because of radioactive decay, the concentration and inventory of these radionuclides in pre-1968 deposits has already been reduced by approximately 50% from original levels.

Despite the evidence for probable remobilization of contaminated sediments in upper Los Alamos Canyon and their transport into lower Los Alamos Canyon, no immediate remedial action is considered necessary in regard to this remobilization because no regulatory standards are being exceeded, and available assessments indicate that contaminant concentrations in downstream areas, presently and in the future, will not pose unacceptable human health risks under current land use conditions.

If it is determined that concentrations of cesium-137 and associated radionuclides or the total amount of these radionuclides in sediments leaving upper Los Alamos Canyon are unacceptable by other criteria, the areas downstream from DP Canyon containing sediment deposited between 1956 and 1968 would be clear targets for remediation. These are areas that both contain a significant amount of the total cesium-137 inventory within a relatively small volume of sediment (including approximately 25% of the estimated inventory in reach LA-2 East) and are in geomorphic settings susceptible to remobilization during floods. As part of any plans for contaminant mitigation, areas with cesium-137 concentrations above a given threshold could be readily identified in areas that have not yet been investigated using field measurements of gross gamma radiation.

Currently it is not possible to quantitatively predict (1) the rate that cesium-137 and other contaminants will be transported out of upper Los Alamos Canyon and into lower Los Alamos Canyon, (2) contaminant concentrations within sediments carried by future floods (except in the short term), or (3) the effects of possible remedial actions on contaminant loads in floods. Quantitative predictions would require a defensible model that can incorporate the remobilization of contaminated sediment from a variety of geomorphic units, which have variable sediment residence times; the mixing of sediment from both contaminated and uncontaminated sources; and the redistribution of this sediment by floods with varying recurrence intervals. Such a model should allow an evaluation of the effects of various remedial actions over a variety of time scales and be tailored for the parameter of interest (i.e., concentration or mass). Because of the probabilistic nature of floods, a probabilistic sediment transport model would be most appropriate. Therefore, if it is foreseen that remedial actions may be warranted in the future to reduce either the concentrations or mass of radionuclides leaving upper Los Alamos Canyon, development of a

probabilistic sediment transport model tailored to the conditions in upper Los Alamos Canyon should be pursued.

6.6 Summary of Recommendations

The preliminary assessments of potential human health and ecological risk presented in this report indicate that levels of contamination in the sediments of upper Los Alamos Canyon do not require immediate remedial actions with regard to present-day risk. Similarly, the geomorphic assessments indicate that the concentrations of contaminants in sediments carried by floods have been stable or have declined for decades, and the redistribution of contaminated sediments will not result in future increases in contaminant concentrations in downstream areas. Therefore, no remedial actions are proposed at this time, although remedial actions may be warranted in the future following additional assessments.

Additional risk assessments will be required beyond what was possible in the context of this report, including both human health and ecological risk, and additional data collection is needed to support these assessments. Large gaps in sample coverage exist for organic chemicals in upper Los Alamos Canyon, and collection of additional sediment samples is needed to evaluate the distribution and concentration of organic chemicals. COPC concentrations in surface water are also needed for both human health and ecological risk assessments, and continued collection of sufficient data to perform risk assessments is considered a priority. In addition, collection of radiological field data in the unsampled area between reaches LA-2 and LA-3 would allow confirmation of the interpretation that radiation levels in this area do not pose a significant human health risk.

Decision points concerning the transport of contaminants from upper Los Alamos Canyon into lower Los Alamos Canyon and toward the Rio Grande have yet to be defined; thus, it is uncertain if remedial actions may be required to reduce either the concentrations of contaminants in sediments carried by floods or the total mass (inventory) of contaminants transported downstream over various time frames. Therefore, decisions concerning the possible need for remedial action in this context will depend on the development of specific decision criteria. If it is determined that concentrations of cesium-137 exceed certain decision criteria and require remedial actions, specific areas for remediation downstream from DP Canyon could be readily identified using field instruments. In addition, if it is necessary to make better quantitative predictions concerning off-site transport, development of a defensible sediment transport model should be pursued that could also evaluate the effects of a variety of possible remedial actions.

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Appendix A

Acronyms and Unit Conversions

APPENDIX A LIST OF ACRONYMS AND UNIT CONVERSIONS

A-1.0 LIST OF ACRONYMS

BKG	background data
CMS	corrective measures study
COPC	chemical of potential concern
COPEC	contaminant of potential ecological concern
cpm	counts per minute
CRDL	contract required detection limits
CVAA	cold vapor atomic absorption
D&D	decontamination and decommissioning
DDT	dichloro diphenyl trichloroethane
DOE	Department of Energy
EC	expedited cleanup
EFH	Exposure Factors Handbook
EPA	Environmental Protection Agency
EQL	estimated quantitation limit
ER	Environmental Restoration
ESL	ecological screening level
FIMAD	Facility for Information Management, Analysis, and Display
FUSRAP	Formerly Utilized Sites Remedial Action Program
GFAA	graphite furnace atomic absorption
HI	hazard index
HQ	hazard quotient
HSWA	Hazardous and Solid Waste Amendments
ICP	inductively coupled plasma
ICPES	inductively coupled plasma emission spectroscopy
ICPMS	inductively coupled plasma mass spectrometry
IDL	instrument detection limit
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.

LCS	laboratory control sample
MDA	minimum detectable activity
MF	moisture fraction
NFA	no further action
NFG	national functional guidelines
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PESTPCB	pesticide and polychlorinated biphenyl
PRG	preliminary remediation goal
PRS	potential release site
QA	quality assurance
QC	quality control
R	The sample results are rejected because of serious deficiencies in the ability to analyze the sample and meet the quality control criteria; presence or absence cannot be verified.
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RN	request number
RPD	relative percent difference
SAL	screening action level
SCM	site conceptual model
SOW	statement of work
SVOC	semivolatile organic compound
TA	Technical Area
TAL	target analyte list
TCMX	tetrachloro-m-xylene
T&E	threatened and endangered
TPU	total propagated uncertainty
TW	test well
U	The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

UJ	The analyte was analyzed for but not detected. Reported value is an estimate of the sample-specific quantitation limit or detection limit.
UTL	upper tolerance limit
VCA	voluntary corrective action
VCM	voluntary corrective measure
WRS	Wilcoxon Rank System

A-2.0 METRIC TO ENGLISH CONVERSIONS AND METRIC PREFIXES

TABLE A2-1

METRIC TO ENGLISH CONVERSIONS

Multiply SI (Metric) Unit	by	To Obtain US Customary Unit
kilometers (km)	0.622	miles (mi)
kilometers (km)	3281	feet (ft)
meters (m)	3.281	feet (ft)
meters (m)	39.37	inches (in.)
centimeters (cm)	0.03281	feet (ft)
centimeters (cm)	0.394	inches (in.)
millimeters (mm)	0.0394	inches (in.)
micrometers or microns (μm)	0.0000394	inches (in.)
square kilometers (km^2)	0.3861	square miles (mi^2)
square meters (m^2)	10.764	square feet (ft^2)
cubic meters (m^3)	35.31	cubic feet (ft^3)
kilograms (kg)	2.2046	pounds (lb)
grams (g)	0.0353	ounces (oz)
grams per cubic centimeter (g/cm^3)	62.422	pounds per cubic foot (lb/ft^3)
milligrams per kilogram (mg/kg)	1	parts per million (ppm)
degrees Celsius (°C)	9/5 + 32	degrees Fahrenheit (°F)

TABLE A2-2

METRIC PREFIXES

Term	Power of 10	Symbol
mega-	10^6	M
kilo-	10^3	k
deci-	10^{-1}	d
centi-	10^{-2}	c
milli-	10^{-3}	m
micro-	10^{-6}	μ
nano-	10^{-9}	n
pico-	10^{-12}	p

Appendix B

Characterization of Geomorphic Units

APPENDIX B CHARACTERIZATION OF GEOMORPHIC UNITS

This appendix presents supplemental information on the characteristics of the geomorphic units in the upper Los Alamos Canyon reaches.

B-1.0 DENDROCHRONOLOGICAL ANALYSES

Trees were cored in each of the upper Los Alamos Canyon reaches for dendrochronological analyses (tree-ring dating) to provide age constraints for geomorphic units and for specific sediment deposits. Sediments burying trees of known age are constrained to be younger than the trees, and sediments beneath the base of trees are constrained to be older. In some cases, nearby trees of different age can provide more precise determination of the ages of sediment deposits. Two adjacent trees of different age can be buried by different thicknesses of sediment recording a variable number of floods since the germination of each tree and approximate ages for such floods (e.g., if 20 cm of sediment buries a 20-year-old tree and 40 cm of sediment buries a 30-year-old tree, then this records at least one flood layer between 20 and 30 years ago and another flood layer within the past 20 years). Alternatively, different age trees can be buried by the same thickness of sediment recording the absence of deposition during specific time periods.

Cores were collected from 41 individual trees using a 5-mm-diameter increment borer (Table B1-1). Most of these trees were ponderosa pines (*Pinus ponderosa*), although Douglas fir (*Pseudotsuga menziesii*) and Rocky Mountain juniper (*Juniperus scopulorum*) were also cored. Each tree was assigned a unique three-letter three-number identifier following the convention used by the Laboratory of Tree-Ring Research at the University of Arizona, with the designation "ULA" chosen to indicate trees cored in upper Los Alamos Canyon. These trees are located at or near sediment sample sites, and data on the tree diameter and the thickness of sediment burying each tree were recorded. To best constrain the germination age of each tree, the trees were cored as close to the ground as was feasible, and an attempt was made to core through the pith or core as close as possible to the pith for each tree. Bark was included at the outside edge of the core wherever possible to confirm the completeness of the tree-ring record. A minimum of two cores were collected from each tree, typically at right angles to one another, to provide checks on the accuracy of the tree-ring dating. After cores were extracted from the increment borer, an estimated age of each tree was obtained by visual inspection of the core, either with the naked eye or using a 10x hand lens, to guide further field work. Cores were then placed in paper soda straws, labeled, and allowed to dry for a minimum of four days before final sample preparation.

After drying, properly oriented cores were mounted in grooved, wooden strips approximately 9.5 by 14.3 mm in cross section using the methodology described in Stokes and Smiley (1968, 57644) and Phipps (1985, 58477). Mounted cores were allowed to dry a minimum of one day before surfacing. Cores were surfaced by first treating the core with a 50% glycerin and water solution, heating, and then slicing the core with a heavy duty carpet blade. Cores were then sanded with progressively finer-grit sandpaper; typically progressing from 220 through 1000 grit paper, with two intermediate stages. As a final step, cores were wiped with isopropyl alcohol and buffed using suede leather.

TABLE B1-1

DENDROCHRONOLOGICAL ANALYSES FROM UPPER LOS ALAMOS CANYON TREE CORES*

Tree ID	Subreach	Geomorphic Unit	Species	Tree Diameter at 1 m (cm)	Date Cored	Date of Innermost Ring	Estimated Date of Pith	Height of Core (cm)	Depth of Burial (cm)	Notes
ULA-001	LA-3	Qt	P. ponderosa	?	8/27/97	1931	1924	?	0	Near LA-0110 sample site, bank
ULA-002	LA-1 Central	f1	Pseudotsuga	30	10/28/97	1928	1928	?	20	Near LA-0151 sample site
ULA-003	LA-1 Central	f1	P. ponderosa	63	10/28/97	1850	1845	?	36 (12?)	LA-0152 sample site
ULA-004	LA-1 Central	c3/f1	P. ponderosa	27	10/28/97	1943	1938	38	72	4 m west of LA-0155 sample site
ULA-005	LA-1 Central	c3/f1	P. ponderosa	12	10/28/97	1965	1961	30	38	6 m west of LA-0155 sample site
ULA-006	LA-1 Central	f1	P. ponderosa	40	10/28/97	1863	1853	44	50	LA-0156 sample site
ULA-007	LA-1 East	f1	P. ponderosa	40	10/28/97	1888	1875	52	20	10 m east of LA-0157 sample site
ULA-008	LA-1 East	f1	P. ponderosa	16	10/28/97	1941	1940	62	23	13 m east of LA-0157 sample site
ULA-009	LA-1 East	f1	P. ponderosa	13	10/28/97	1952	1952	40	18	4 m east of LA-0158 sample site
ULA-010	LA-1 East	f1	P. ponderosa	?	10/29/97	1844	1844	80	48	10.5 m east of LA-0158 sample site
ULA-011	LA-1 East	f1	P. ponderosa	15	10/29/97	1947 or 1951	1947 or 1951	35	35	13.5 m east of LA-0158 sample site
ULA-012	LA-1 East	f1	P. ponderosa	30	10/29/97	1928	1924	27	0	Near LA-0162 sample site; higher surface
ULA-013	LA-1 East	c3	P. ponderosa	?	10/29/97	1937	1936	67	50	Near LA-0162 sample site; same surface
ULA-014	LA-2 West	c2	P. ponderosa	8	10/29/97	1982 or 1984	1982 or 1984	37	14	15 m west of LA-0092 sample site
ULA-015	LA-2 East	c2	P. ponderosa	44	10/29/97	1900	1890	76	44	19 m east of LA-0019 sample site
ULA-016	LA-2 East	f1	P. ponderosa	13	10/29/97	1926?	1925?	33	20	LA-0108 sample site
ULA-017	LA-2 East	f1	P. ponderosa	23	10/29/97	1930	1921	36	25	10 m west of LA-0108 sample site
ULA-018	LA-1 West	c3 (f1?)	P. ponderosa	48	11/4/97	1922	1918	77	44–50	12 m east of LA-0147 sample site
ULA-019	LA-1 West	c3 (f1?)	P. ponderosa	7	11/4/97	1979	1978	?	30	10 m east of LA-0147 sample site; poor dating because of injury to tree
ULA-020	LA-1 West	c3 (f1?)	Pseudotsuga	6	11/4/97	1980	1980	29	0	9 m east of LA-0147 sample site

*Trees were cored by Paul Drakos, Steven Reneau, Danny Katzman, and Bill Phillips. Dendrochronological analyses were performed by Paul Drakos.

TABLE B1-1 (continued)

DENDROCHRONOLOGICAL ANALYSES FROM UPPER LOS ALAMOS CANYON TREE CORES*

Tree ID	Subreach	Geomorphic Unit	Species	Tree Diameter at 1 m (cm)	Date Cored	Date of Innermost Ring	Estimated Date of Pith	Height of Core (cm)	Depth of Burial (cm)	Notes
ULA-021	LA-1 West	f1	P. ponderosa	35	11/4/97	1947	1942	71	26	3 m east of LA-0145 sample site
ULA-022	LA-1 West	c3	P. ponderosa	15	11/4/97	1977	1974	79	50	4 m west of LA-0143 sample site
ULA-023	LA-1 West	c3	P. ponderosa	11	11/4/97	1978	1978	73	40	5 m west of LA-0143 sample site
ULA-024	LA-1 Central	f1	P. ponderosa	33	11/12/97	1856?	1846	47	57	LA-0180 sample site
ULA-025	LA-1 Central	f1	P. ponderosa	12	11/12/97	1947 or 1950?	1946 or 1949?	52	20	Next to LA-0180 sample site
ULA-026	LA-1 Central	c3?	J. scopulorum	19	11/12/97	1947 or 1948?	1941 or 1942?	?	0	Next to LA-0183 sample site; core cannot be cross-dated
ULA-027	LA-1 East	c3?	P. ponderosa	32	11/12/97	1947	1942	54	28	Near sample site LA-0188
ULA-028	LA-1 East	c3?	P. ponderosa	30	11/12/97	1955	1955	45	18	LA-0186 sample site
ULA-029	LA-2 West	f1	P. ponderosa	12	11/13/97	1949 or 1952?	1949 or 1952?	20	12	LA-0018 sample site
ULA-030	LA-2 West	f1	J. scopulorum	14	11/13/97	1961	1957	36	0	LA-0193 sample site; poor cross-dating
ULA-031	LA-2 West	f1	Pseudotsuga	17	11/13/97	1955	1954	31	6	43 m west of LA-0193 sample site
ULA-032	LA-2 West	f1	P. ponderosa	59	11/13/97	1846	1837	44	20	39 m west of LA-0193 sample site
ULA-033	LA-2 West	c3	P. ponderosa	18	11/13/97	1967	1967	58	18	LA-0190 sample site
ULA-034	LA-2 West	c3	P. ponderosa	27	11/13/97	1955	1955	42	20	LA-0191 sample site
ULA-035	LA-2 West	c3	P. ponderosa	11	11/13/97	1978	1976	32	0	Near LA-0191 sample site
ULA-036	LA-1 East	f1	Pseudotsuga	18	11/14/97	1972	1968	60	0	Bank at 1946 photo location by TA-21 laundry outfall channel
ULA-037	LA-1 East	f1	Pseudotsuga	29	11/14/97	1952	1948	40	7	Near LA-0184 sample site
ULA-038	LA-1 East	f1	P. ponderosa	12	11/14/97	1953	1948	44	9	LA-0184 sample site
ULA-039	LA-1 East	f1	P. ponderosa	12	11/14/97	1949	1946	28	9	Near LA-0184 sample site
ULA-040	LA-1 Central	c3	P. ponderosa	13	11/14/97	1970	1970	59	22	LA-0181 sample site
ULA-041	LA-1 Central	c3	P. ponderosa	5	11/14/97	1969	1969	30	12	Near LA-0181 sample site

*Trees were cored by Paul Drakos, Steven Reneau, Danny Katzman, and Bill Phillips. Dendrochronological analyses were performed by Paul Drakos.

After preparation, cores were examined under a binocular microscope. When possible, cores were cross-dated using methods described in Glock (1937, 58476); Stokes and Smiley (1968, 57644); and Phipps (1985, 58477) to provide an absolute date for the innermost ring in a given specimen. Cores were cross-dated against local records of the growth response of trees to climatic variations as contained within the Bandelier National Monument master chronology and the Bandelier-Frijolito watershed piñon pine master chronology. Approximately 49% of samples exhibited a good correlation with the master chronologies for this area, whereas approximately 24% of samples did not correlate with the master chronologies (Table B1-1). The remaining 27% of the cores exhibited a fair correlation with the Bandelier National Monument master chronology. When the pith was encountered in a core and the core fit the master chronology, the absolute age of the pith at the height the tree was cored could be determined with a high level of confidence. If the pith was not encountered, the age of the pith was estimated using one of three plots of concentric circles with spacings of 0.25, 0.5, and 1 mm. The number of missing rings between the innermost ring visible in a given core and the pith was estimated by matching the arc of a circle of appropriate scale to the arc of the inner ring and counting the number of circles between the inner ring and an imaginary pith at the center of the series of circles.

Uncertainties in cross dating are due to a variety of factors, including an abundance of false rings in the relatively young trees targeted for this study; the location of trees on canyon floors where environmental stresses are lessened and climatic variations may not be as evident as in trees growing in harsher settings (e.g., on hillsides with thin soils); coring of trees whose growth is suppressed by nearby larger trees; and the fact that not all trees in a given area will fit a master chronology. A false ring superficially appears as a separate ring but is in fact contained within an annual growth increment (Phipps 1985, 58477); young trees, such as those used for this study, exhibit a relative abundance of false rings. Trees growing along canyon floors are more likely to have a continuous spring and summer moisture supply than are trees growing on hillslopes, which could lead to a complacent ring series. However, it is apparent from the trees collected in this study that, in general, moisture does not occur in sufficient quantity or duration along the upper Los Alamos Canyon drainage to produce an abundance of complacent trees. Trees growing in dense stands (i.e., suppressed trees) are problematic because "it has been found that competition among closely growing trees may modify or change the ring pattern from that of a 'normal precipitation pattern'" (Stokes and Smiley 1968, 57644, p. 31). Despite these problems, it is apparent that many of the trees growing in upper Los Alamos Canyon and other canyons on the Pajarito Plateau are suitable for cross dating and thus provide accurate tree-ring dating.

B-2.0 THICKNESS OF POST-1942 SEDIMENT DEPOSITS

The thickness of post-1942 sediment was measured in each of the upper Los Alamos Canyon reaches to calculate the volume of sediment in the different geomorphic units and the associated radionuclide inventory. Thickness measurements were focused on the relatively fine-grained overbank facies sediment because of the higher levels of radionuclides in these sediments than in the coarser-grained channel facies sediment and their resultant importance in estimating radionuclide inventory and in evaluating potential risk. In addition, the thickness of post-1942 overbank facies sediment can be determined with greater confidence than the thickness of associated channel facies sediment because of the general absence of clear stratigraphic markers in the latter and the difficulty in confidently determining the contact with underlying pre-1943 sediment. Thickness measurements for each of the upper Los Alamos Canyon reaches are presented in Figures B2-1 through B2-5. Few measurements were made in units that had small areas, and these are not presented in the figures in this appendix. Estimated thicknesses for all geomorphic units and all sediment facies in each reach are presented in Tables 2.3-1, 2.3-2, 2.3-3, 3.3-3, 3.3-6, and 3.3-9.

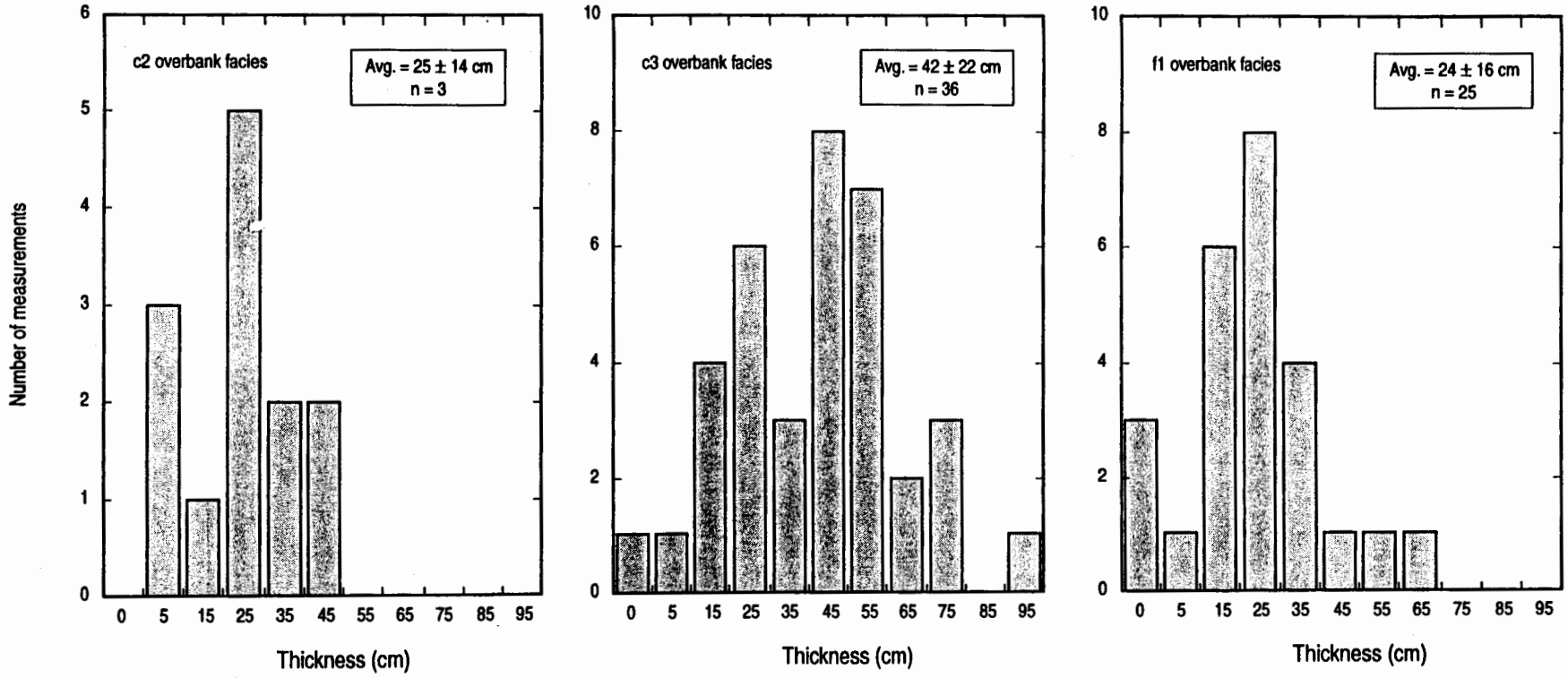
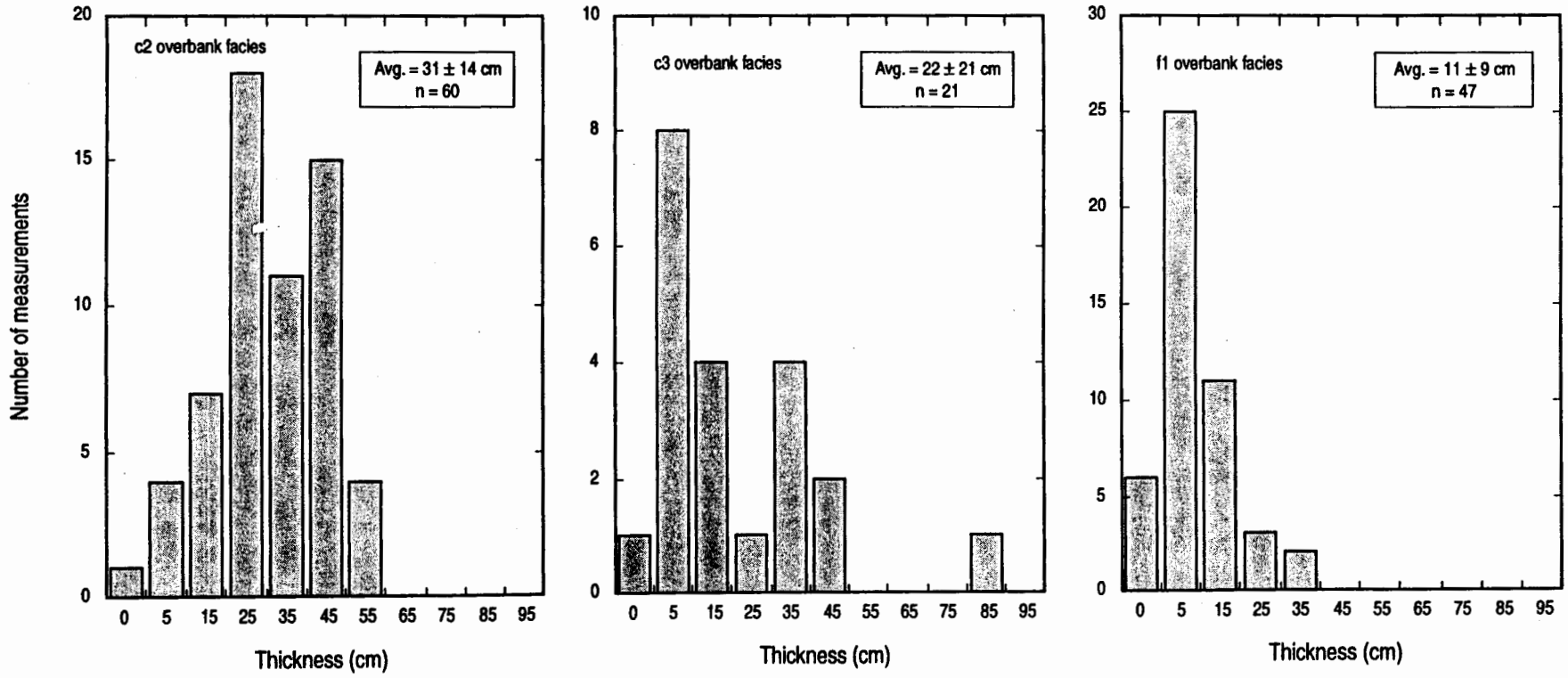


Figure B2-1. Histograms showing thickness measurements in reach LA-1 West.



FB2-2 / UPPER LOS ALAMOS REACH RPT / 110998

Figure B2-2. Histograms showing thickness measurements in reach LA-1 Central.

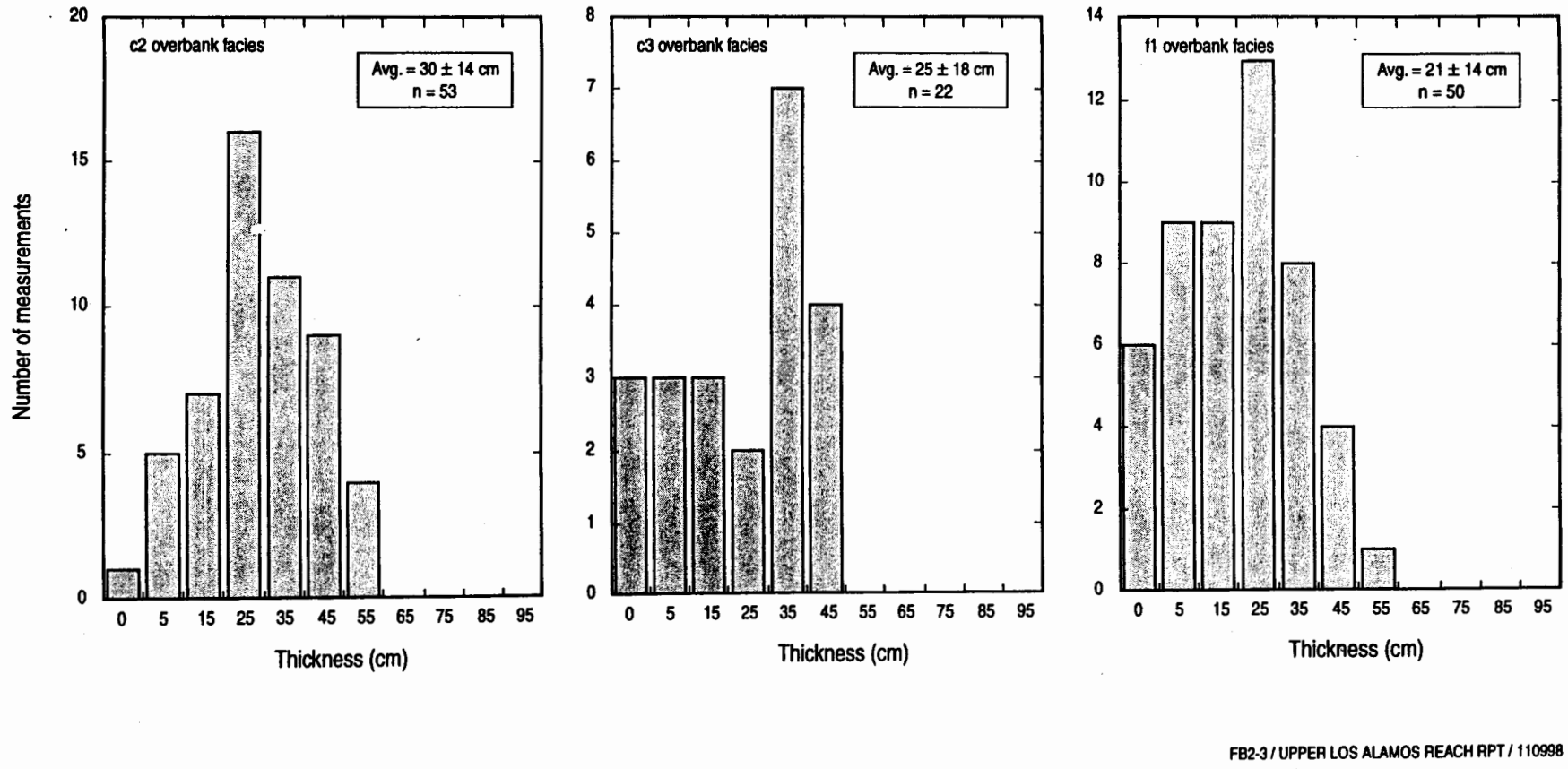
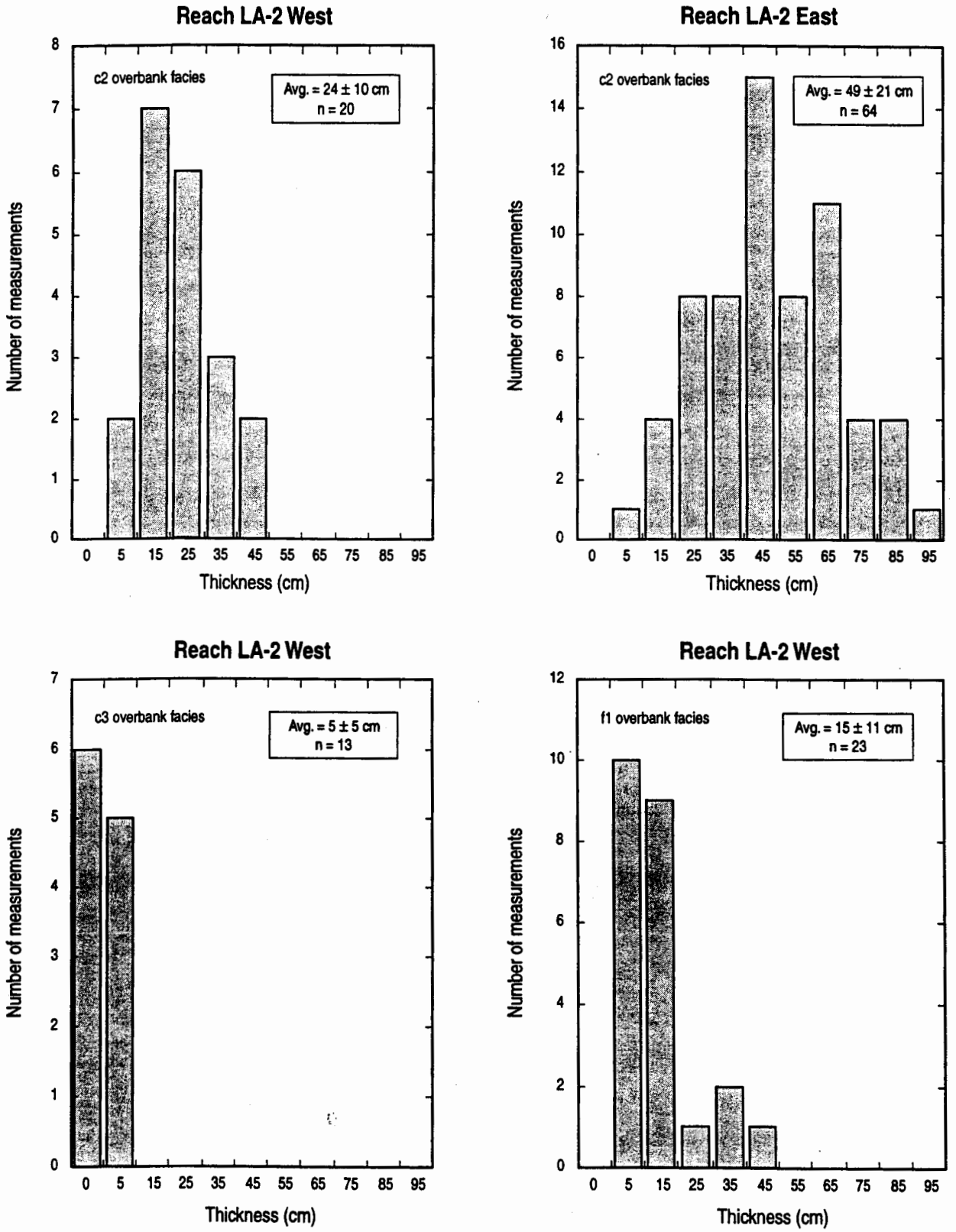


Figure B2-3. Histograms showing thickness measurements in reach LA-1 East.



FB2-4 / UPPER LOS ALAMOS REACH RPT / 090398

Figure B2-4. Histograms showing thickness measurements in reach LA-2.

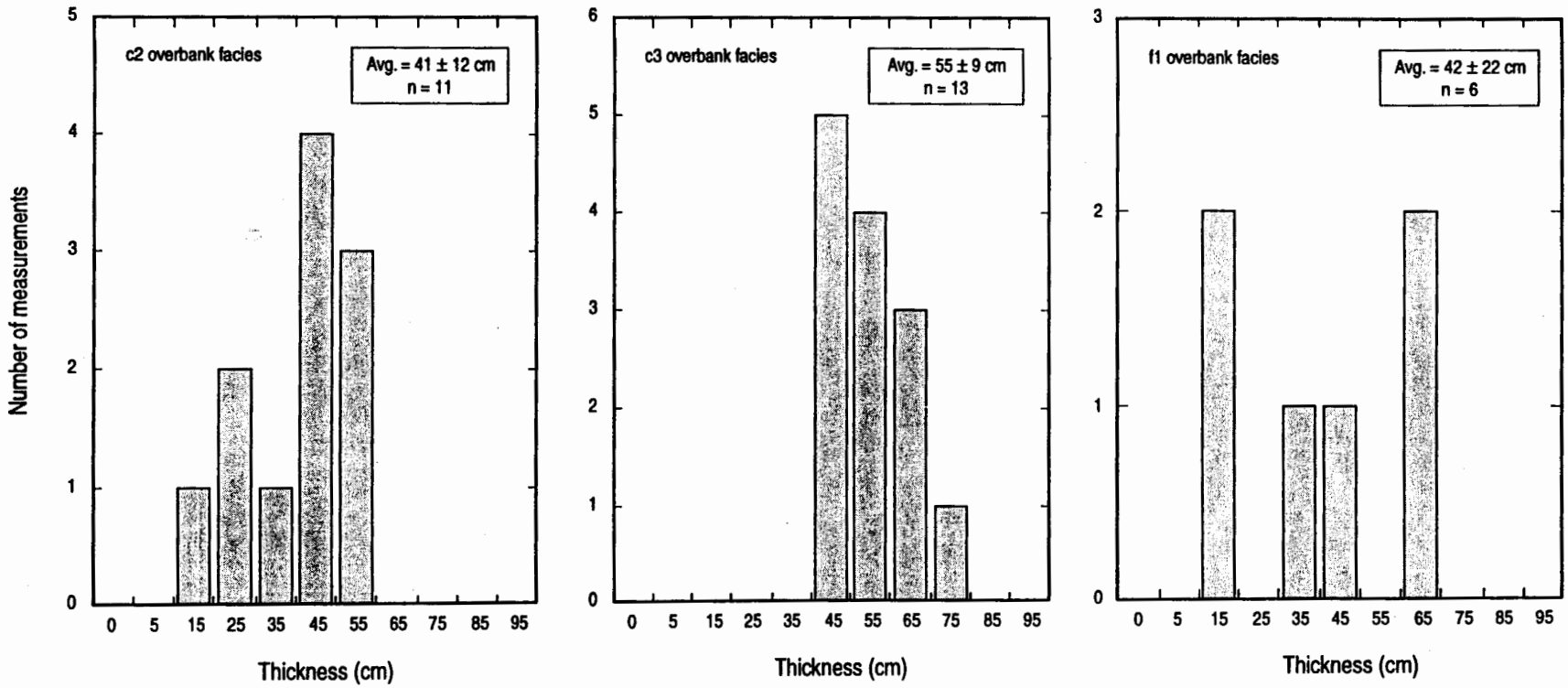


Figure B2-5. Histograms showing thickness measurements in reach LA-3.

B-3.0 PARTICLE SIZE AND ORGANIC MATTER DATA

Each layer that was sampled for analysis of potential contaminants was also sampled for analysis of particle size distribution to evaluate possible relations between contaminant levels and size characteristics. Samples collected in 1996 were analyzed by the laboratories of Rust Geotech (full-suite samples) or Roy F. Weston, Inc. (remaining samples) in accordance with the American Society for Testing and Materials (ASTM) method D 422-63, which is tailored to engineering applications. Samples collected in 1997 were analyzed by the Soil Characterization and Quaternary Pedology Laboratory of the Desert Research Institute, following procedures recommended by the United States Geological Survey (USGS) for geological applications (Janitzky 1986, 57674). One primary difference between these methods is in the way percentages of silt and clay size fractions are determined, with the ASTM procedure using an approximate hydrometer method and the USGS procedure using a more precise pipette method. An additional difference is in the methods used for dispersing the samples before analysis, with the USGS recommending a gentle dispersing procedure that is less likely to physically abrade friable gravel (such as tuff fragments) than the ASTM procedure. After the results of the 1996 sampling indicated that data on silt and clay percentages could be very important in understanding variations in contaminant levels, the Canyons Focus Area technical team decided to analyze subsequent samples using the more precise USGS procedure.

Data on organic matter content were also obtained on most of the samples collected for analysis of potential contamination to evaluate potential relations between contaminant concentrations and organic matter. Analyses used a loss-on-ignition method in which, after drying at low temperature to remove water, the percentage of sample lost by combustion after heating at 400°C for four hours was calculated.

Data on particle size distribution and organic matter content for the upper Los Alamos Canyon sediment samples are shown in Tables B3-1 through B3-3. Summaries of the particle size and organic matter data for each geomorphic unit are shown in Tables B3-4 through B3-6. Percentages of sand, silt, and clay size fractions are calculated from the <2 mm size fraction. For the <2 mm size fraction, the median particle size class, the median particle size, and the soil texture are shown to facilitate comparison of the particle size characteristics of the different samples and the different geomorphic units. Because particle size distributions are traditionally shown on semilogarithmic plots, the median particle size is calculated in these tables by extrapolating between boundaries of size classes using a logarithmic transformation. Calculation of soil texture follows standard procedures used by soil scientists (e.g., Nyhan et al. 1978, 5702, p. 19). Percentages of gravel in these tables are lower than in the actual sampled layer for many samples because only gravel that would fit into the sample bottles was collected (<5 cm). Average gravel percentages for the coarse channel facies deposits are thus routinely underestimated, although gravel percentages for overbank facies deposits are generally accurate.

The relations of the concentrations of key radionuclides to various particle size parameters and organic matter content for each reach were examined using a series of scatter plots. Particle size parameters chosen were the median particle size and the percent finer than each break between size classes (e.g., percent clay [<2 micron size fraction] and percent clay plus fine silt [<15 micron size fraction]). On each of the scatter plots, different symbols were used to distinguish samples from the different geomorphic units and different sediment facies to visually examine which subsets of the samples within each reach shared similar relations of particle size to radionuclide concentration. The most useful plots were found to be of radionuclide concentration against median particle size, percent clay, and percent silt plus clay (<0.0625 mm or <62.5 microns), and these are presented in Figures B3-1 through B3-13. For reaches where discrete populations could be identified that had different radionuclide concentrations for a given particle size, corresponding to older and younger subsets of post-1942 sediment, these subsets are shown on different plots.

TABLE B3-1

REACH LA-1 PARTICLE SIZE AND ORGANIC MATTER DATA

Sample ID	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (15–2 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
04LA-97-0236	3.2	3.1	7.8	17.0	16.2	13.7	22.5	11.9	7.4	4.5	vfs	0.093	sl
04LA-97-0237	20.1	6.5	6.1	11.7	14.5	14.3	24.5	13.5	8.8	3.7	vfs	0.072	gsl
04LA-97-0238	1.0	2.0	2.7	10.6	19.9	19.4	27.0	11.6	6.7	4.3	vfs	0.074	sl
04LA-97-0239	3.4	3.4	6.8	13.3	16.3	16.1	26.2	10.9	6.7	3.7	vfs	0.081	sl
04LA-97-0240	3.4	1.6	2.0	6.5	12.5	20.3	36.8	12.4	7.9	3.7	csl	0.047	l
04LA-97-0241	40.7	71.4	23.0	2.7	0.6	0.3	0.8	0.7	0.5	0.8	vcs	1.231	gs
04LA-97-0242	1.6	1.5	1.0	6.0	22.5	21.9	31.7	9.3	6.0	3.9	vfs	0.068	sl
04LA-97-0243	9.3	4.9	9.2	17.0	17.3	13.3	20.1	10.4	7.7	3.3	vfs	0.115	sl
04LA-97-0244	13.8	7.3	12.3	12.8	10.7	11.1	24.2	12.2	9.2	2.9	vfs	0.081	sl
04LA-97-0245	27.3	3.9	5.3	8.3	8.9	11.1	31.3	18.8	12.8	4.1	csl	0.035	gsl
04LA-97-0246	22.0	5.4	7.2	9.8	11.3	14.7	29.1	12.8	9.4	3.1	csl	0.058	gl
04LA-97-0247	52.1	26.3	26.5	17.7	6.9	4.4	7.3	5.2	5.5	1.2	cs	0.539	gls
04LA-97-0249	8.3	4.8	7.1	7.2	8.5	18.4	34.8	9.9	9.2	2.6	csl	0.012	l
04LA-97-0250	33.6	21.6	23.8	13.1	6.9	5.8	14.0	8.2	6.5	2.4	ms	0.393	gsl
04LA-97-0251	54.9	28.0	23.7	13.4	7.1	5.5	10.4	6.7	5.2	1.5	cs	0.525	gls
04LA-97-0252	19.1	7.0	11.6	20.9	18.5	12.6	17.6	6.2	5.6	2.8	fs	0.169	sl
04LA-97-0253	46.3	46.2	29.9	16.7	3.9	0.7	1.3	0.8	0.4	0.6	cs	0.916	gs
04LA-97-0254	5.3	3.0	5.9	19.1	22.1	15.7	21.8	7.2	5.2	2.9	fs	0.125	sl
04LA-97-0255	3.3	2.8	2.9	10.6	19.6	20.1	29.6	7.8	6.5	3.2	vfs	0.077	sl
04LA-97-0256	2.4	2.0	3.9	16.0	20.3	16.8	28.0	7.4	5.6	2.7	vfs	0.091	sl
04LA-97-0257	1.8	2.0	4.2	14.0	23.0	19.5	25.0	6.8	5.3	2.5	vfs	0.098	sl
04LA-97-0258	69.6	25.2	25.9	20.5	11.3	5.2	6.7	2.9	2.2	1.1	cs	0.515	gls
04LA-97-0259	2.4	5.3	6.0	6.9	9.6	16.1	35.5	14.7	5.4	7.6	csl	0.049	sil
04LA-97-0261	3.4	1.7	4.5	18.4	28.8	20.8	18.2	3.7	3.8	2.2	fs	0.136	ls
04LA-97-0264	38.0	47.9	40.6	8.7	1.0	0.3	0.5	0.5	0.5	0.7	cs	0.964	gs
04LA-97-0265	53.3	34.8	34.0	15.7	3.8	1.5	3.5	2.8	3.9	1.4	cs	0.734	gs
04LA-97-0266	7.0	32.0	43.1	16.7	3.8	0.9	0.6	0.9	2.1	0.7	cs	0.748	s
04LA-97-0267	18.8	2.9	11.4	22.4	18.1	14.0	18.2	6.0	6.7	2.7	fs	0.150	sl

a. vcs = very coarse sand, cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csl = coarse silt

b. l = loam, sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel

TABLE B3-1 (continued)

REACH LA-1 PARTICLE SIZE AND ORGANIC MATTER DATA

Sample ID	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (15–2 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
04LA-97-0268	13.0	26.3	20.9	13.0	8.0	6.2	12.6	7.2	5.6	3.1	ms	0.432	sl
04LA-97-0269	10.8	3.5	7.0	13.9	15.3	14.3	28.2	10.7	6.8	3.8	vfs	0.076	sl
04LA-97-0270	3.5	1.2	2.7	8.9	16.7	21.0	35.9	7.0	6.4	2.7	vfs	0.064	sl
04LA-97-0271	4.7	2.0	6.4	16.1	15.7	15.4	29.7	7.5	7.0	1.9	vfs	0.081	sl
04LA-97-0272	0.8	0.5	0.7	2.5	13.2	30.6	40.6	5.2	6.5	2.4	csi	0.057	sl
04LA-97-0273	1.9	1.6	3.3	9.2	13.8	16.2	37.5	10.5	7.7	3.5	csi	0.050	l
04LA-97-0274	28.4	35.7	41.0	18.4	2.6	0.4	0.1	0.8	1.0	0.6	cs	0.784	gs
04LA-97-0275	23.7	1.5	2.3	6.3	11.2	16.0	38.2	15.5	8.7	5.9	csi	0.038	gsil
04LA-97-0276	7.2	2.0	7.3	17.8	18.8	16.3	25.5	7.0	5.2	2.7	vfs	0.105	sl
04LA-97-0277	52.1	38.8	29.2	14.6	4.9	2.3	4.6	2.7	2.8	1.0	cs	0.766	gs
04LA-97-0278	57.8	25.0	27.5	20.6	9.2	4.5	5.5	3.2	4.3	2.6	cs	0.533	gs
04LA-97-0279	1.3	0.9	2.1	9.7	23.4	24.0	28.3	6.0	5.5	2.7	vfs	0.084	sl
04LA-97-0280	1.0	1.1	3.2	12.9	18.5	18.0	33.5	7.0	6.1	2.5	vfs	0.072	sl
04LA-97-0568	6.6	5.4	11.8	19.4	17.5	12.7	20.8	6.3	6.1	2.4	fs	0.147	sl
04LA-97-0573	2.9	4.0	7.7	15.0	15.9	12.3	25.3	10.0	9.5	2.8	vfs	0.082	sl
04LA-97-0574	35.6	25.7	43.7	23.1	4.5	1.1	1.3	0.3	0.6	0.4	cs	0.681	gs
04LA-97-0575	0.5	3.4	12.9	26.3	18.2	10.6	15.5	6.7	6.3	0.4	fs	0.189	sl
04LA-97-0576	1.3	6.1	18.2	23.7	14.3	9.3	14.8	6.5	7.2	2.4	ms	0.235	sl
04LA-97-0577	5.8	11.7	17.5	15.0	13.2	10.7	18.0	6.5	7.5	2.2	fs	0.184	sl
04LA-97-0578	2.4	8.4	25.1	25.8	14.8	6.8	9.6	5.1	4.6	1.8	ms	0.321	ls
04LA-97-0579	18.6	34.7	36.8	19.7	3.7	0.9	1.6	1.5	1.3	1.9	ms	1.064	s
04LA-97-0580	7.3	12.0	18.1	16.5	9.3	8.1	20.5	10.1	5.4	4.1	fs	0.193	sl
04LA-97-0581	4.1	2.5	3.9	5.9	12.7	17.0	36.5	11.5	10.3	2.5	csi	0.045	l
04LA-97-0582	0.2	1.6	2.0	4.3	10.2	14.8	48.2	10.5	8.9	2.4	csi	0.037	sil
04LA-97-0583	15.7	4.2	5.9	8.9	12.0	13.9	30.9	12.8	11.2	3.1	csi	0.049	l
04LA-97-0584	8.8	3.1	3.8	8.5	15.5	17.4	31.7	10.6	9.3	3.5	csi	0.058	l
04LA-97-0585	2.4	3.4	7.3	22.4	24.6	14.3	17.7	5.0	5.2	2.9	fs	0.155	sl
04LA-97-0586	11.4	7.5	9.2	10.3	9.9	13.0	31.0	11.1	7.7	2.7	vfs	0.063	l

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csi = coarse silt

b. l = loam, sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel

TABLE B3-1 (continued)

REACH LA-1 PARTICLE SIZE AND ORGANIC MATTER DATA

Sample ID	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (15–2 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
04LA-97-0587	0.2	2.6	4.1	8.1	9.3	13.2	40.6	13.2	9.3	3.1	csi	0.040	sil
04LA-97-0588	78.5	47.9	19.5	9.3	3.4	1.7	4.9	6.4	6.9	2.0	cs	0.927	gls
04LA-97-0589	3.9	12.4	15.4	15.6	13.4	10.7	18.8	7.0	6.6	3.4	fs	0.178	sl
04LA-97-0590	0.6	5.0	9.5	17.4	15.7	12.1	23.3	10.3	7.3	5.2	fs	0.112	sl
04LA-97-0592	59.1	30.1	32.9	18.2	6.5	3.1	4.4	3.0	1.7	1.3	cs	0.657	gs
04LA-97-0593	12.3	31.0	43.8	17.5	2.8	0.7	0.6	1.6	2.0	0.6	cs	0.741	s
04LA-97-0594	57.9	40.8	34.8	11.3	2.3	0.8	1.9	2.3	2.3	0.9	cs	0.832	gs
04LA-97-0595	2.3	3.8	10.9	23.5	21.3	12.5	17.1	5.6	5.6	2.5	fs	0.170	sl
04LA-97-0596	1.4	2.2	2.9	4.4	19.3	28.5	31.8	5.9	4.6	2.4	vfs	0.075	sl
04LA-97-0597	0.3	1.4	2.3	10.6	16.6	17.6	35.4	9.1	6.8	3.4	csi	0.059	sl
04LA-97-0598	2.3	2.5	4.1	6.3	12.5	19.4	36.5	10.4	8.2	4.8	csi	0.051	l
04LA-97-0599	1.4	2.8	4.8	14.6	18.1	15.6	27.3	10.1	6.7	3.0	vfs	0.081	sl
04LA-97-0600	53.1	44.5	33.7	11.4	3.1	1.4	3.4	1.5	0.7	0.6	cs	0.894	gs
04LA-97-0601	0.4	0.9	2.1	4.1	6.9	14.6	46.5	14.0	10.1	2.7	csi	0.032	sil
04LA-97-0602	0.4	1.3	2.5	7.0	11.4	17.5	41.8	11.4	6.9	3.8	csi	0.043	sil
04LA-97-0603	3.6	6.5	17.3	24.1	15.6	10.3	16.7	5.3	4.4	2.8	fs	0.228	ls
04LA-97-0604	4.7	5.8	11.5	19.8	15.3	10.4	21.5	9.4	6.1	2.9	fs	0.140	sl
04LA-97-0605	16.2	5.0	12.7	20.3	15.1	9.9	20.8	9.3	7.0	2.5	fs	0.144	sl
04LA-97-0606	5.7	13.8	26.2	22.1	12.6	7.0	11.6	3.7	3.0	1.7	ms	0.365	ls
04LA-97-0607	0.5	1.4	1.9	8.5	15.2	18.2	37.9	11.1	5.7	3.2	csi	0.052	sl
04LA-97-0608	1.6	2.1	3.8	12.7	16.8	16.6	31.2	9.8	7.0	2.8	vfs	0.068	l
04LA-97-0609	69.8	43.5	26.3	10.3	5.1	2.3	4.6	3.2	4.6	0.7	cs	0.842	gls
04LA-97-0613	4.3	7.1	15.4	26.3	18.8	9.7	13.3	5.0	4.2	2.6	fs	0.239	ls
04LA-97-0622	2.1	3.5	5.0	11.1	14.3	13.0	31.8	12.8	8.4	4.1	csi	0.054	l
04LA-97-0623	2.9	3.3	6.9	20.0	20.9	15.6	23.2	5.2	5.0	2.6	fs	0.130	sl
04LA-97-0624	3.4	2.6	3.1	7.6	11.8	17.9	40.0	8.9	8.0	2.7	csi	0.048	l
04LA-97-0625	23.1	7.2	9.5	12.8	13.1	13.2	24.6	10.9	8.9	2.7	vfs	0.085	gsl

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csi = coarse silt

b. l = loam, sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel

TABLE B3-2

REACH LA-2 PARTICLE SIZE AND ORGANIC MATTER DATA

Sample ID	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (15–2 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
04LA-96-0140	22.9	1.8	10.1	23.6	23.7	18.5	12.4	6.9	3.0	0.8	fs	0.164	gls
04LA-96-0141	1.5	35.6	49.0	14.8	0.5	0.0	0.0	0.0	0.2	0.1	cs	0.815	s
04LA-96-0142	9.0	3.8	11.3	17.3	21.6	19.9	15.8	7.5	2.8	1.0	fs	0.142	ls
04LA-96-0143	8.8	4.4	17.4	34.3	24.1	10.9	6.1	1.6	1.2	0.6	ms	0.283	s
04LA-96-0144	14.4	2.8	18.9	35.2	23.4	11.2	5.6	1.9	1.1	0.5	ms	0.286	s
04LA-96-0145	3.6	3.4	12.8	23.6	22.5	17.3	11.1	5.7	3.8	0.6	fs	0.182	ls
04LA-96-0146	11.2	8.7	24.6	29.4	17.4	9.8	6.0	2.8	1.3	0.4	ms	0.337	s
04LA-96-0147	0.0	39.7	39.6	15.0	3.9	0.8	1.0	0.0	0.0	0.1	cs	0.835	s
04LA-96-0148	4.8	29.1	48.1	17.8	3.4	0.8	0.9	0.0	0.0	0.4	cs	0.740	s
04LA-96-0149	8.9	21.7	21.4	8.2	5.7	7.7	14.5	12.9	7.8	2.5	ms	0.279	sl
04LA-96-0205	5.2	0.7	3.2	17.8	20.1	8.2	30.0	13.0	7.0	NA[c]	vfs	0.063	l
04LA-96-0206	1.8	1.4	4.6	12.7	17.6	20.7	30.9	5.9	6.2	NA	vfs	0.079	sl
04LA-96-0207	57.0	33.8	28.5	15.3	7.0	3.3	3.2	4.3	4.5	NA	cs	0.674	gs
04LA-96-0211	7.2	1.2	6.4	26.1	28.4	12.8	14.6	4.9	5.5	NA	fs	0.168	sl
04LA-96-0212	4.5	2.0	7.7	23.0	21.0	7.2	18.4	11.8	8.9	NA	fs	0.141	sl
04LA-96-0215	2.4	0.4	2.3	11.6	22.6	21.3	30.8	5.0	6.0	NA	vfs	0.082	sl
04LA-96-0216	4.6	3.4	11.4	24.2	17.3	12.5	19.5	6.3	5.5	NA	fs	0.161	sl
04LA-96-0217	38.6	25.6	30.6	17.5	6.4	2.8	5.3	6.7	5.2	NA	cs	0.575	gls
04LA-96-0218	63.9	23.4	23.0	18.9	10.2	4.5	5.3	7.7	7.0	NA	ms	0.438	gls
04LA-96-0220	11.4	28.8	32.9	21.6	6.8	1.8	0.0	3.2	5.2	NA	cs	0.640	s
04LA-96-0221	15.2	47.9	29.7	11.9	3.9	1.5	0.0	1.8	4.0	NA	cs	0.952	s
04LA-96-0222	30.3	3.5	3.2	5.0	10.3	5.1	31.0	25.9	16.0	NA	csi	0.021	gsil
04LA-96-0223	15.2	42.0	33.8	12.6	3.0	1.5	0.2	2.9	4.0	NA	cs	0.849	s
04LA-96-0224	18.0	20.0	25.9	30.8	11.2	3.5	2.3	3.0	3.3	NA	ms	0.456	s
04LA-96-0225	5.1	0.7	3.5	19.0	30.8	12.0	18.8	8.6	6.6	NA	fs	0.137	sl
04LA-96-0226	6.2	1.8	2.9	5.3	11.9	21.3	38.4	12.7	5.7	NA	csi	0.048	sil
04LA-96-0227	6.2	2.1	5.2	14.9	21.8	18.8	22.3	7.3	7.6	NA	vfs	0.100	sl

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csi = coarse silt

b. l = loam, sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel

c. NA = not analyzed

TABLE B3-2 (continued)

REACH LA-2 PARTICLE SIZE AND ORGANIC MATTER DATA

Sample ID	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (15–2 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
04LA-96-0229	48.4	26.5	31.8	21.3	8.0	3.0	1.6	3.9	3.9	NA[c]	cs	0.599	gs
04LA-97-0052	13.6	4.6	10.2	17.3	16.4	14.2	21.9	8.7	6.3	3.0	vfs	0.116	sl
04LA-97-0053	44.6	1.8	1.6	6.0	13.6	26.6	35.1	10.3	5.5	4.2	csl	0.061	gsl
04LA-97-0054	32.7	13.6	22.3	28.7	14.3	6.1	7.9	3.8	3.2	2.1	ms	0.356	gls
04LA-97-0056	4.1	7.2	15.0	16.3	13.7	13.7	22.7	6.2	5.0	2.3	fs	0.140	sl
04LA-97-0057	45.4	3.7	2.1	4.8	13.6	15.8	33.3	16.8	9.7	5.4	csl	0.040	gsil
04LA-97-0058	7.8	31.9	40.3	18.7	3.1	0.9	1.7	1.4	2.0	0.5	cs	0.732	s
04LA-97-0059	34.0	43.7	34.9	10.8	3.1	1.3	2.2	1.7	2.2	0.8	cs	0.882	gs
04LA-97-0060	10.4	25.8	31.2	23.7	8.5	3.1	3.1	2.1	2.4	1.1	cs	0.584	s
04LA-97-0061	3.7	4.0	9.2	18.3	21.5	18.8	19.2	4.7	4.4	2.3	fs	0.137	sl
04LA-97-0062	9.4	2.0	2.7	8.0	17.4	26.4	31.6	6.6	5.3	3.0	vfs	0.074	sl
04LA-97-0063	12.6	7.1	11.5	13.1	16.6	17.3	22.3	6.4	5.5	2.4	vfs	0.117	sl
04LA-97-0064	55.3	33.8	28.3	11.8	4.4	2.4	4.9	5.3	9.1	1.8	cs	0.673	gls
04LA-97-0065	4.2	5.5	9.8	20.7	22.8	16.8	15.6	4.5	4.2	3.1	fs	0.164	ls
04LA-97-0066	9.3	9.2	17.0	17.9	12.6	12.5	21.0	4.9	4.7	1.9	fs	0.181	sl
04LA-97-0067	7.3	5.7	20.6	26.9	11.8	7.2	15.8	5.7	6.4	1.9	ms	0.271	sl
04LA-97-0068	45.3	23.0	29.1	19.9	7.7	4.1	7.5	3.7	5.0	1.6	cs	0.525	gls
04LA-97-0071	3.4	3.2	3.4	4.9	11.1	24.5	40.1	6.3	6.5	3.2	csl	0.056	sl
04LA-97-0072	1.8	1.7	1.2	4.8	14.4	25.3	36.0	9.0	7.7	3.6	csl	0.056	l
04LA-97-0073	1.9	3.1	25.1	39.2	16.0	6.2	5.6	1.9	2.9	1.3	ms	0.340	s
04LA-97-0074	10.8	8.2	15.4	20.4	12.6	6.1	30.1	3.8	3.4	2.8	fs	0.179	sl
04LA-97-0075	27.4	2.9	7.4	13.8	16.8	19.6	28.6	5.5	5.2	2.5	vfs	0.091	gsl
04LA-97-0076	65.8	3.4	6.1	17.7	21.8	15.3	25.8	5.3	5.0	3.1	vfs	0.119	gsl
04LA-97-0077	11.2	2.9	1.4	5.1	19.8	25.8	30.9	8.3	5.6	4.8	vfs	0.071	sl
04LA-97-0078	23.4	6.1	6.9	14.2	18.6	15.6	23.2	8.7	6.7	4.8	vfs	0.104	gsl
04LA-97-0085	72.0	26.5	31.2	18.5	6.6	3.5	6.3	3.6	3.8	1.1	cs	0.593	gls
04LA-97-0087	1.3	2.0	8.4	21.9	20.8	17.7	19.9	4.7	4.3	2.0	fs	0.139	sl

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csl = coarse silt

b. l = loam, sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel

c. NA = not analyzed

TABLE B3-2 (continued)

REACH LA-2 PARTICLE SIZE AND ORGANIC MATTER DATA

Sample ID	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (15–2 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
04LA-97-0088	21.9	3.3	6.5	14.1	16.5	16.6	28.9	8.3	5.9	2.6	vfs	0.083	gsl
04LA-97-0089	51.1	33.7	31.6	13.4	5.2	2.4	3.4	3.5	6.9	1.4	cs	0.699	gls
04LA-97-0090	3.7	3.4	14.5	35.7	22.2	10.0	8.2	2.8	3.2	1.7	ms	0.268	s
04LA-97-0091	21.6	6.4	9.9	21.4	21.2	12.8	17.0	6.3	5.0	3.1	fs	0.167	gsl
04LA-97-0096	19.7	6.4	12.0	17.3	15.4	14.0	21.4	7.3	6.0	2.7	fs	0.131	sl
04LA-97-0098	58.1	3.8	11.4	21.9	15.6	9.5	16.9	11.9	9.0	3.2	fs	0.140	gsl
04LA-97-0099	50.6	42.2	33.6	11.2	2.4	0.6	1.7	3.6	4.7	1.2	cs	0.852	gs
04LA-97-0100	6.1	3.5	10.2	24.7	22.5	14.4	15.2	4.6	4.8	3.1	fs	0.175	ls
04LA-97-0103	23.1	8.0	11.1	15.6	14.0	12.4	21.9	9.1	7.6	5.3	vfs	0.117	gsl
04LA-97-0104	12.9	3.5	5.1	12.0	18.1	15.9	34.2	7.6	3.3	3.9	vfs	0.077	sl
04LA-97-0610	8.3	8.8	13.1	16.4	17.6	15.1	20.7	4.7	3.9	1.8	fs	0.157	sl
04LA-97-0611	5.1	3.3	4.6	7.9	12.2	17.0	38.8	9.4	6.7	2.1	csl	0.052	sl
04LA-97-0612	2.1	4.8	4.1	6.6	12.5	17.6	38.1	10.0	6.2	2.7	csl	0.053	sl
04LA-97-0614	56.8	26.0	15.7	12.9	10.9	8.2	16.5	5.5	4.3	1.8	ms	0.320	gsl
04LA-97-0615	3.4	3.0	6.5	13.1	15.8	14.6	28.9	11.4	6.6	3.2	vfs	0.072	sl
04LA-97-0616	10.5	3.3	4.6	15.3	20.9	15.8	24.1	7.2	8.5	3.8	vfs	0.097	sl
04LA-97-0618	37.8	22.2	24.4	16.0	9.4	6.2	11.4	5.1	5.2	1.4	ms	0.431	gls
04LA-97-0620	3.6	5.0	7.6	8.4	8.5	12.8	34.4	15.3	8.0	5.3	csl	0.045	sil

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csl = coarse silt

b. sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel

TABLE B3-3

REACH LA-3 PARTICLE SIZE AND ORGANIC MATTER DATA

Sample ID	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (15–2 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
04LA-97-0105	10.5	2.9	9.0	22.7	23.6	17.0	16.7	4.8	3.7	2.5	fs	0.159	ls
04LA-97-0106	11.1	2.9	11.6	24.2	19.9	16.2	18.4	3.8	2.9	1.5	fs	0.168	ls
04LA-97-0107	36.9	7.6	9.6	14.9	17.9	15.6	21.3	7.9	5.1	2.4	fs	0.125	gsl
04LA-97-0108	58.4	39.5	30.5	13.3	4.4	2.1	3.2	2.7	4.2	1.5	cs	0.788	gs
04LA-97-0109	33.0	61.8	26.8	7.5	1.5	0.4	0.9	0.8	0.5	0.6	vcs	1.141	gs
04LA-97-0110	10.4	33.4	36.8	19.4	6.2	1.3	1.3	0.9	0.7	0.8	cs	0.732	s
04LA-97-0111	6.0	2.9	5.6	17.3	20.9	18.7	24.2	6.1	4.4	2.6	vfs	0.110	sl
04LA-97-0112	21.7	4.1	3.6	10.1	23.4	23.3	26.2	5.9	3.5	3.3	vfs	0.096	gsl
04LA-97-0113	38.0	13.6	8.1	7.1	18.8	20.7	22.5	5.3	3.9	2.3	vfs	0.115	gsl
04LA-97-0114	54.7	25.4	28.3	15.7	11.9	5.8	6.3	3.7	2.9	1.6	cs	0.548	gs
04LA-97-0115	53.1	19.0	33.1	27.0	8.5	2.7	3.7	3.0	3.2	1.0	cs	0.522	gs
04LA-97-0116	4.9	12.5	37.8	29.1	9.3	3.3	3.9	2.6	1.3	1.7	cs	0.503	s
04LA-97-0117	5.5	2.6	3.1	8.8	19.7	23.7	30.0	7.3	4.4	4.1	vfs	0.079	sl
04LA-97-0118	14.7	4.3	8.0	18.7	23.4	16.8	19.2	4.6	4.9	2.0	fs	0.143	sl
04LA-97-0119	69.9	22.7	32.3	20.9	8.0	3.5	5.1	3.1	4.4	1.3	cs	0.557	gs
04LA-97-0120	7.6	2.8	3.3	10.5	19.1	20.9	30.3	8.2	4.8	3.4	vfs	0.078	sl
04LA-97-0121	18.5	7.2	12.2	16.1	16.6	15.5	19.8	6.7	5.7	2.7	fs	0.137	sl
04LA-97-0122	9.2	9.2	18.1	17.3	15.6	13.1	15.1	5.3	6.4	1.5	fs	0.196	sl
04LA-97-0124	39.4	12.6	18.9	17.6	14.3	10.3	14.0	5.3	6.9	2.0	fs	0.240	gsl
04LA-97-0125	71.4	48.2	19.3	11.4	6.5	2.3	2.9	2.3	7.2	1.5	cs	0.936	gls
04LA-97-0126	3.3	2.0	7.0	21.1	23.7	18.7	19.1	4.2	4.2	2.4	fs	0.140	sl
04LA-97-0127	2.4	2.7	5.1	11.6	17.2	19.4	31.1	7.4	5.5	2.2	vfs	0.077	sl

a. vcs = very coarse sand, cs = coarse sand, fs = fine sand, vfs = very fine sand

b. sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel

TABLE B3-3 (continued)

REACH LA-3 PARTICLE SIZE AND ORGANIC MATTER DATA

Sample ID	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (15–2 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
04LA-97-0129	66.8	37.2	28.6	11.8	6.3	4.0	6.0	3.6	2.6	1.1	cs	0.733	gs
04LA-97-0130	4.1	6.0	12.3	20.4	19.0	12.9	19.4	5.6	4.5	2.4	fs	0.165	sl
04LA-97-0131	3.0	1.4	3.0	22.4	28.9	18.8	17.0	4.2	4.1	2.3	fs	0.144	ls
04LA-97-0132	7.3	4.7	8.8	23.2	26.4	15.4	13.7	4.1	3.5	3.9	fs	0.176	ls
04LA-97-0133	14.1	8.4	11.8	16.2	20.0	15.2	16.8	6.8	4.8	3.3	fs	0.156	sl
04LA-97-0134	30.3	7.2	12.2	18.0	18.3	15.0	17.5	7.0	4.7	2.6	fs	0.156	gsl
04LA-97-0135	28.2	20.6	36.6	22.4	7.7	3.5	3.7	2.3	3.2	0.9	cs	0.574	gs
04LA-97-0136	5.1	3.2	13.5	32.7	20.8	10.7	11.4	4.0	3.7	1.9	fs	0.245	ls
04LA-97-0137	16.3	4.3	1.5	2.8	8.1	16.7	42.7	17.4	6.3	4.7	csl	0.035	sil
04LA-97-0138	1.4	2.0	0.4	1.5	10.7	23.6	44.0	10.7	7.0	3.3	csl	0.042	sil
04LA-97-0139	12.3	4.8	7.6	12.9	16.7	15.2	24.7	9.7	8.2	2.6	vfs	0.087	sl
04LA-97-0140	67.5	18.2	18.7	29.2	17.0	6.6	2.7	2.7	4.9	1.6	ms	0.366	gs
04LA-97-0141	13.2	3.0	19.7	42.2	17.5	5.7	5.1	2.4	4.3	1.1	ms	0.319	s
04LA-97-0142	40.4	21.0	34.8	24.2	9.4	2.5	2.6	1.9	3.4	1.0	cs	0.562	gs
04LA-97-0143	13.2	1.9	1.4	5.2	10.3	16.2	37.1	17.2	10.5	4.1	csl	0.035	sil
04LA-97-0145	8.1	3.9	11.4	25.7	18.9	10.6	19.2	5.0	5.3	2.3	fs	0.180	sl
04LA-97-0147	5.5	4.1	6.7	15.9	22.6	21.4	20.3	5.3	4.2	2.9	vfs	0.122	sl
04LA-97-0148	7.2	2.9	3.0	5.7	14.6	27.3	33.4	7.4	5.7	3.5	vfs	0.068	sl
04LA-97-0149	2.9	4.3	10.7	17.9	22.3	16.3	19.1	4.2	5.3	2.3	fs	0.147	sl
04LA-97-0150	38.9	23.1	45.2	24.2	4.2	1.0	1.4	0.4	0.5	0.4	cs	0.662	gs

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csl = coarse silt

b. sl = sandy loam, ls = loamy sand, s = sand, sil = silt loam, g = ≥20% gravel

TABLE B3-4

REACH LA-1 PARTICLE SIZE SUMMARY

Geomorphic Unit	Sediment Facies	Summary Statistic	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (152 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
LA-1 Far West, LA-1 West+, and LA-1 West (downstream of bridge, upstream of TA-41)															
c1	Channel	average	35.3	44.5	33.4	15.6	3.2	0.7	1.2	0.8	0.7	0.9	cs	0.892	gs
		std. dev.	12.0	19.8	8.9	9.0	1.8	0.3	0.3	0.5	0.4	0.7			
		n	4	4	4	4	4	4	4	4	4	4			
c2	Overbank	average	12.9	5.9	10.1	17.0	16.2	12.7	22.1	8.3	7.5	2.7	fs	0.121	sl
		std. dev.	9.7	1.5	1.9	3.8	2.4	0.4	3.6	2.5	2.0	0.2			
		n	4	4	4	4	4	4	4	4	4	4			
c3	Channel	average	46.9	25.3	24.7	14.7	7.0	5.2	10.6	6.7	5.7	1.7	cs	0.500	gls
		std. dev.	11.6	3.3	1.6	2.6	0.1	0.7	3.4	1.5	0.7	0.6			
		n	3	3	3	3	3	3	3	3	3	3			
c3	Overbank	average	9.3	4.8	8.6	13.8	14.0	14.0	25.8	10.6	8.3	3.0	fs	0.081	sl
		std. dev.	8.5	2.4	4.7	6.3	4.1	3.2	7.9	3.6	1.9	1.0			
		n	15	15	15	15	15	15	15	15	15	15			
f1	Overbank	average	4.1	4.8	8.4	11.7	14.5	14.5	28.8	10.0	7.3	3.4	vfs	0.075	sl
		std. dev.	4.1	3.7	8.2	7.0	4.5	5.0	10.8	2.0	1.9	1.1			
		n	9	9	9	9	9	9	9	9	9	9			
LA-1 Central (downstream of TA-2)															
c1	Channel	average	38.0	47.9	40.6	8.7	1.0	0.3	0.5	0.5	0.5	0.7	cs	0.964	gs
		n	1	1	1	1	1	1	1	1	1	1			
c2	Overbank	average	1.3	1.9	3.7	11.2	16.5	17.2	33.5	9.4	6.7	3.0	vfs	0.063	sl
		std. dev.	1.8	0.6	1.1	6.3	10.7	3.8	13.3	5.0	2.8	0.8			
		n	3	3	3	3	3	3	3	3	3	3			
c2	Channel	average	68.2	44.3	27.1	10.3	2.9	1.3	3.4	4.3	4.6	1.5	cs	0.865	gls
		std. dev.	14.6	5.0	10.8	1.4	0.8	0.7	2.2	2.9	3.2	0.8			
		n	2	2	2	2	2	2	2	2	2	2			
c3	Overbank	average	5.4	3.5	8.6	17.4	18.8	16.5	23.2	6.3	5.6	2.7	vfs	0.116	sl
		std. dev.	7.6	2.2	5.8	9.4	1.7	7.3	9.8	1.6	1.2	0.4			
		n	5	5	5	5	5	5	5	5	5	5			

a. cs = coarse sand, fs = fine sand, vfs = very fine sand

b. sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel

TABLE B3-4 (continued)

REACH LA-1 PARTICLE SIZE SUMMARY

Geomorphic Unit	Sediment Facies	Summary Statistic	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (152 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
LA-1 Central (downstream of TA-2)															
c3	Channel	average	24.2	32.6	40.3	16.6	3.5	1.0	1.6	1.8	2.7	0.9	cs	0.741	gs
		std. dev.	25.3	2.0	5.4	0.9	0.6	0.4	1.6	0.9	1.1	0.5			
c3		n	3	3	3	3	3	3	3	3	3	3			
f1	Overbank	average	5.4	7.2	8.3	13.7	16.4	14.9	24.9	8.6	5.9	3.7	vfs	0.101	sl
		std. dev.	4.2	8.5	6.4	3.7	5.7	4.6	7.1	2.8	0.7	1.6			
		n	8	8	8	8	8	8	8	8	8	8			
f1	Channel	average	64.3	27.6	29.4	19.4	8.9	4.2	5.5	2.9	1.9	1.2	ms	0.643	gls
		std. dev.	7.4	3.5	4.9	1.6	3.4	1.5	1.6	0.1	0.3	0.1			
		n	2	2	2	2	2	2	2	2	2	2			
LA-1 East (downstream of TA-21 laundry outfall)															
c1	Channel	average	28.4	35.7	41.0	18.4	2.6	0.4	0.1	0.8	1.0	0.6	cs	0.784	gs
		n	1	1	1	1	1	1	1	1	1	1			
c2	Overbank	average	6.0	4.2	10.1	19.4	17.3	13.0	22.5	7.7	5.7	2.8	fs	0.130	sl
		std. dev.	5.4	1.8	4.6	3.1	2.4	3.1	3.7	2.2	1.0	0.2			
		n	6	6	6	6	6	6	6	6	6	6			
c2	Channel	average	52.6	41.7	31.4	13.0	4.0	1.8	4.0	2.1	1.8	0.8	cs	0.832	gs
		std. dev.	0.7	4.1	3.2	2.2	1.3	0.6	0.9	0.8	1.5	0.3			
		n	2	2	2	2	2	2	2	2	2	2			
c3	Overbank	average	1.8	3.4	6.4	11.6	15.4	15.9	31.6	9.2	6.5	2.8	vfs	0.070	sl
		std. dev.	1.8	4.7	8.8	5.5	5.1	5.2	10.6	3.8	2.3	0.7			
		n	7	7	7	7	7	7	7	7	7	7			
c3	Channel	average	63.8	34.3	26.9	15.4	7.1	3.4	5.1	3.2	4.5	1.6	cs	0.666	gls
		std. dev.	8.5	13.0	0.9	7.2	2.9	1.5	0.7	0.0	0.2	1.4			
		n	2	2	2	2	2	2	2	2	2	2			
f1	Overbank	average	6.2	1.6	3.3	8.2	13.9	19.8	36.4	9.4	7.4	3.5	csl	0.055	l
		std. dev.	8.7	0.7	1.9	4.6	2.1	5.7	3.7	3.7	0.9	1.5			
		n	6	6	6	6	6	6	6	6	6	6			

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand, csl = coarse silt

b. l = loam, sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel

TABLE B3-5

REACH LA-2 PARTICLE SIZE SUMMARY

Geomorphic Unit	Sediment Facies	Summary Statistic	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (152 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
LA-2 West (upstream from DP Canyon)															
c1	Channel	average	1.5	35.6	49.0	14.8	0.5	0.0	0.0	0.0	0.2	0.1	cs	0.815	s
		n	1	1	1	1	1	1	1	1	1	1			
c2	Overbank	average	16.0	3.5	8.3	17.3	17.7	14.5	23.4	8.3	6.9	3.2	vfs	0.108	sl
		std. dev.	19.6	1.8	3.9	4.5	2.9	3.6	5.0	2.6	1.4	0.4			
		n	7	7	7	7	7	7	7	7	7	5			
c2	Channel	average	47.7	28.3	27.9	15.9	7.1	3.5	5.9	5.8	5.5	1.3	cs	0.584	gls
		std. dev.	12.3	9.4	5.0	3.4	3.5	2.4	4.0	1.8	1.0	0.1			
		n	4	4	4	4	4	4	4	4	4	2			
c3	Overbank	average	12.7	5.5	6.8	11.4	14.9	15.3	31.4	8.9	5.7	4.0	vfs	0.074	sl
		std. dev.	10.5	2.3	3.8	4.5	2.9	2.6	8.5	1.2	2.1	1.3			
		n	3	3	3	3	3	3	3	3	3	3			
c3	Channel	average	56.8	26.0	15.7	12.9	10.9	8.2	16.5	5.5	4.3	1.8	ms	0.320	gsl
		n	1	1	1	1	1	1	1	1	1	1			
f1	Overbank	average	6.5	5.2	9.1	12.5	15.0	16.2	27.4	9.2	5.3	2.6	vfs	0.088	sl
		std. dev.	2.6	2.5	3.8	5.0	5.8	3.0	10.9	4.5	2.4	1.9			
		n	4	4	4	4	4	4	4	4	4	4			
Qt2	Overbank	average	6.1	3.5	10.2	24.7	22.5	14.4	15.2	4.6	4.8	3.1	fs	0.175	ls
		n	1	1	1	1	1	1	1	1	1	1			
LA-2 East (downstream from DP Canyon)															
c1	Channel	average	5.2	32.7	35.4	19.4	6.2	2.0	2.0	1.1	2.4	0.6	cs	0.713	s
		std. dev.	7.4	9.8	5.9	6.2	3.2	1.6	1.5	1.5	1.7	0.7			
		n	2	2	2	2	2	2	2	2	2	2			
c2	Overbank	average	14.8	3.7	9.6	19.4	19.0	15.1	21.7	6.5	5.0	2.3	fs	0.133	sl
		std. dev.	17.3	2.6	6.8	8.5	5.0	5.3	9.7	3.2	1.8	1.1			
		n	17	17	17	17	17	17	17	17	17	12			

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand

b. sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel

TABLE B3-5 (continued)

REACH LA-2 PARTICLE SIZE SUMMARY

Geomorphic Unit	Sediment Facies	Summary Statistic	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (152 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
LA-2 East (downstream from DP Canyon)															
c2	Channel	average	56.4	29.2	30.1	16.8	6.6	3.3	5.1	3.7	5.0	1.4	cs	0.620	ls
		std. dev.	11.5	5.4	1.5	3.0	1.0	0.7	2.1	0.4	1.3	0.3			
		n	4	4	4	4	4	4	4	4	4	3			
c2b	Overbank	average	7.9	3.2	9.9	21.0	21.5	15.8	17.5	6.0	4.9	1.8	fs	0.150	sl
		std. dev.	4.4	1.9	5.2	8.9	3.9	6.2	8.3	3.0	2.3	1.1			
		n	7	7	7	7	7	7	7	7	7	5			
c2b	Channel	average	55.3	33.8	28.3	11.8	4.4	2.4	4.9	5.3	9.1	1.8	cs	0.673	gls
		n	1	1	1	1	1	1	1	1	1	1			
c3	Overbank	average	24.3	10.0	12.8	12.6	11.5	9.7	21.9	13.1	8.4	3.1	vfs	0.100	gsl
		std. dev.	17.3	7.7	9.7	10.1	3.6	4.8	10.8	8.8	4.9	1.6			
		n	5	5	5	5	5	5	5	5	5	4			
c3	Channel	average	19.3	33.7	34.7	18.2	5.3	1.8	1.1	2.6	3.5	0.6	cs	0.722	s
		std. dev.	14.6	9.7	6.8	6.6	3.0	1.0	1.0	0.9	1.1	0.2			
		n	8	8	8	8	8	8	8	7	7	3			
f1	Overbank	average	9.6	3.5	8.7	15.8	17.2	18.2	23.9	7.0	5.7	3.6	vfs	0.104	sl
		std. dev.	10.2	1.9	11.3	16.2	2.4	9.3	13.3	3.4	2.1	1.7			
		n	4	4	4	4	4	4	4	4	4	4			
f1b	Overbank	average	3.4	3.2	3.4	4.9	11.1	24.5	40.1	6.3	6.5	3.2	csi	0.056	sl
		n	1	1	1	1	1	1	1	1	1	1			
Qt3	Overbank	average	10.8	8.2	15.4	20.4	12.6	6.1	30.1	3.8	3.4	2.8	fs	0.179	sl
		n	1	1	1	1	1	1	1	1	1	1			
DP Canyon															
c2b	Overbank	average	22.9	1.8	10.1	23.6	23.7	18.5	12.4	6.9	3.0	0.8	fs	0.164	ls
		n	1	1	1	1	1	1	1	1	1	1			

a. cs = coarse sand, fs = fine sand, vfs = very fine sand, csi = coarse silt

b. sl = sandy loam, ls = loamy sand, s = sand, g = ≥20% gravel

TABLE B3-6

REACH LA-3 PARTICLE SIZE SUMMARY

Geomorphic Unit	Sediment Facies	Summary Statistic	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1 mm) (wt %)	Coarse Sand (1–0.5 mm) (wt %)	Medium Sand (0.5–0.25 mm) (wt %)	Fine Sand (0.25–0.125 mm) (wt %)	Very Fine Sand (0.125–0.0625 mm) (wt %)	Coarse Silt (62.5–15 µm) (wt %)	Fine Silt (152 µm) (wt %)	Clay (<2 µm) (wt %)	Organic Matter (wt %)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
c1	Channel	average	27.4	39.4	36.2	17.0	4.0	0.9	1.2	0.7	0.6	0.6	cs	0.817	gs
		std. dev.	15.0	20.0	9.2	8.6	2.4	0.4	0.3	0.3	0.1	0.2			
		n	3	3	3	3	3	3	3	3	3	3			
c2	Overbank	average	17.7	6.4	7.7	13.8	20.6	19.8	21.5	6.0	4.3	3.1	vfs	0.119	sl
		std. dev.	12.7	3.7	3.6	6.3	3.9	4.8	6.6	1.2	0.8	0.6			
		n	7	7	7	7	7	7	7	7	7	7			
c2	Channel	average	45.3	21.7	32.7	21.7	9.4	4.0	4.6	3.0	3.1	1.2	cs	0.549	gs
		std. dev.	14.8	3.4	4.2	5.7	2.2	1.6	1.5	0.7	0.1	0.4			
		n	3	3	3	3	3	3	3	3	3	3			
c3	Overbank	average	11.0	4.4	9.7	16.7	17.1	15.5	23.7	7.6	5.3	2.7	vfs	0.113	sl
		std. dev.	9.1	2.9	9.5	10.1	5.6	5.3	11.8	4.9	2.4	1.0			
		n	13	13	13	13	13	13	13	13	13	13			
c3	Channel	average	49.9	20.9	27.2	26.0	11.3	4.1	3.7	2.6	4.3	1.3	ms	0.475	gs
		std. dev.	23.5	13.0	7.5	10.7	5.8	2.0	1.3	0.4	0.5	0.3			
		n	5	5	5	5	5	5	5	5	5	5			
f1	Overbank	average	12.3	5.6	10.0	15.9	18.2	16.7	22.0	6.2	5.4	2.4	vfs	0.124	sl
		std. dev.	13.0	4.1	6.4	3.7	3.3	3.8	6.8	1.4	1.0	0.6			
		n	7	7	7	7	7	7	7	7	7	7			
f1	Channel	average	69.1	42.7	23.9	11.6	6.4	3.1	4.4	2.9	4.9	1.3	cs	0.809	gs
		std. dev.	3.2	7.8	6.6	0.3	0.2	1.2	2.2	0.9	3.3	0.3			
		n	2	2	2	2	2	2	2	2	2	2			
f2	Overbank	average	3.5	3.7	7.7	21.4	23.9	15.9	18.2	4.9	4.3	2.3	fs	0.152	sl
		std. dev.	0.8	3.2	6.5	1.5	7.0	4.2	1.7	1.0	0.3	0.1			
		n	2	2	2	2	2	2	2	2	2	2			

a. cs = coarse sand, ms = medium sand, fs = fine sand, vfs = very fine sand
b. sl = sandy loam, s = sand, g = ≥20% gravel

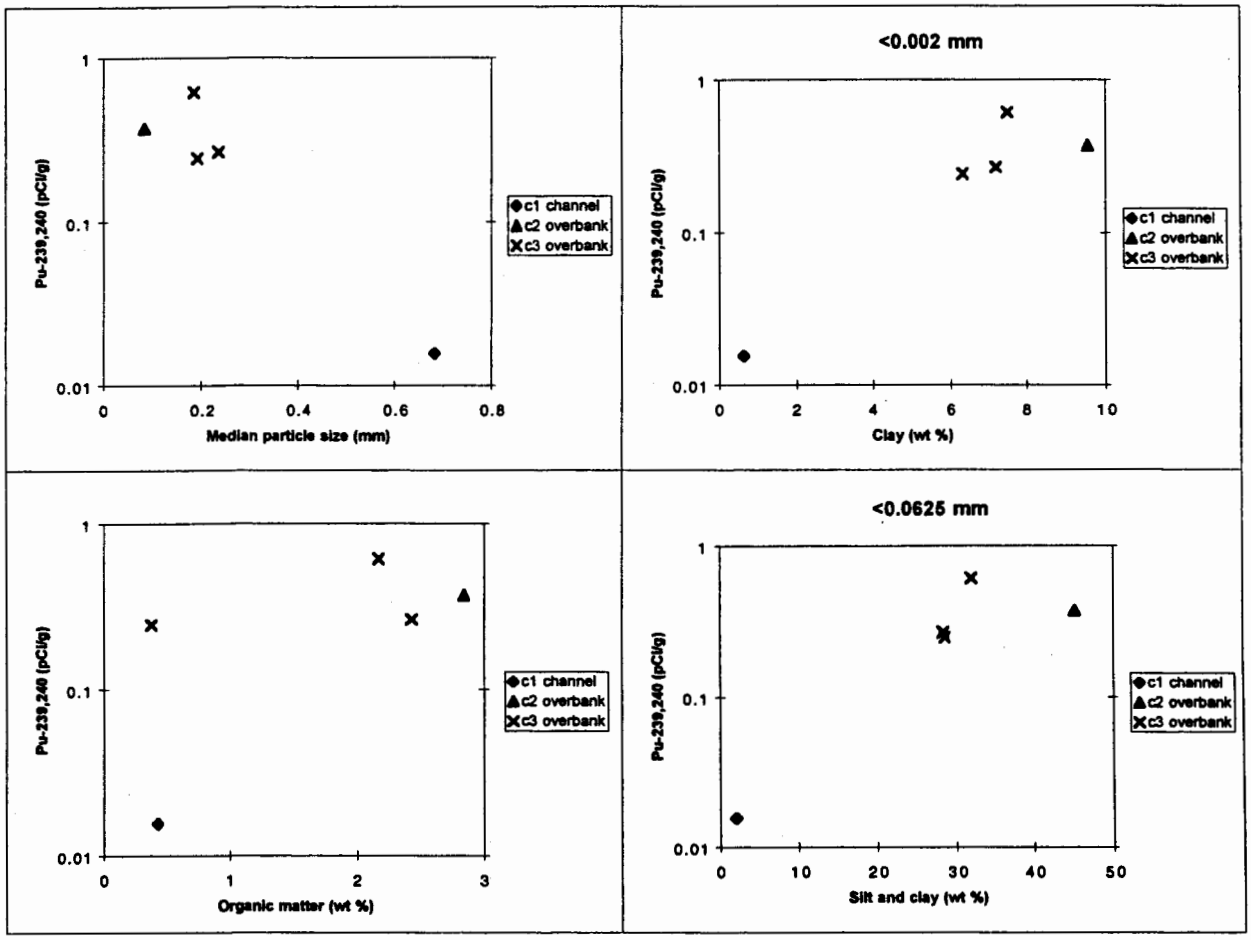


Figure B3-1. Scatter plots showing relations of plutonium-239,240 concentration to median particle size, silt and clay content, and organic matter content in reach LA-1 West+.

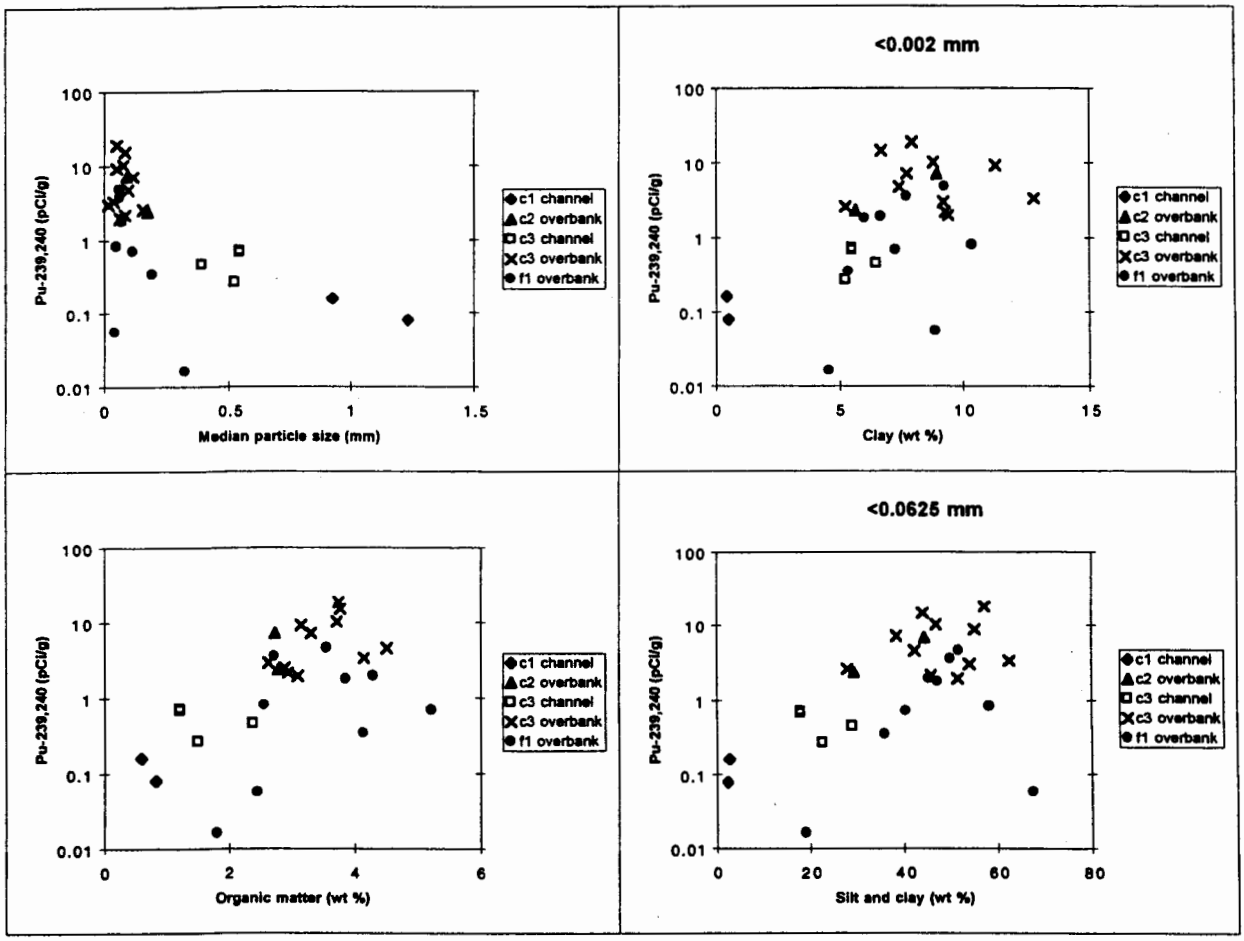


Figure B3-2. Scatter plots showing relations of plutonium-239,240 concentration to median particle size, silt and clay content, and organic matter content in reach LA-1 West.

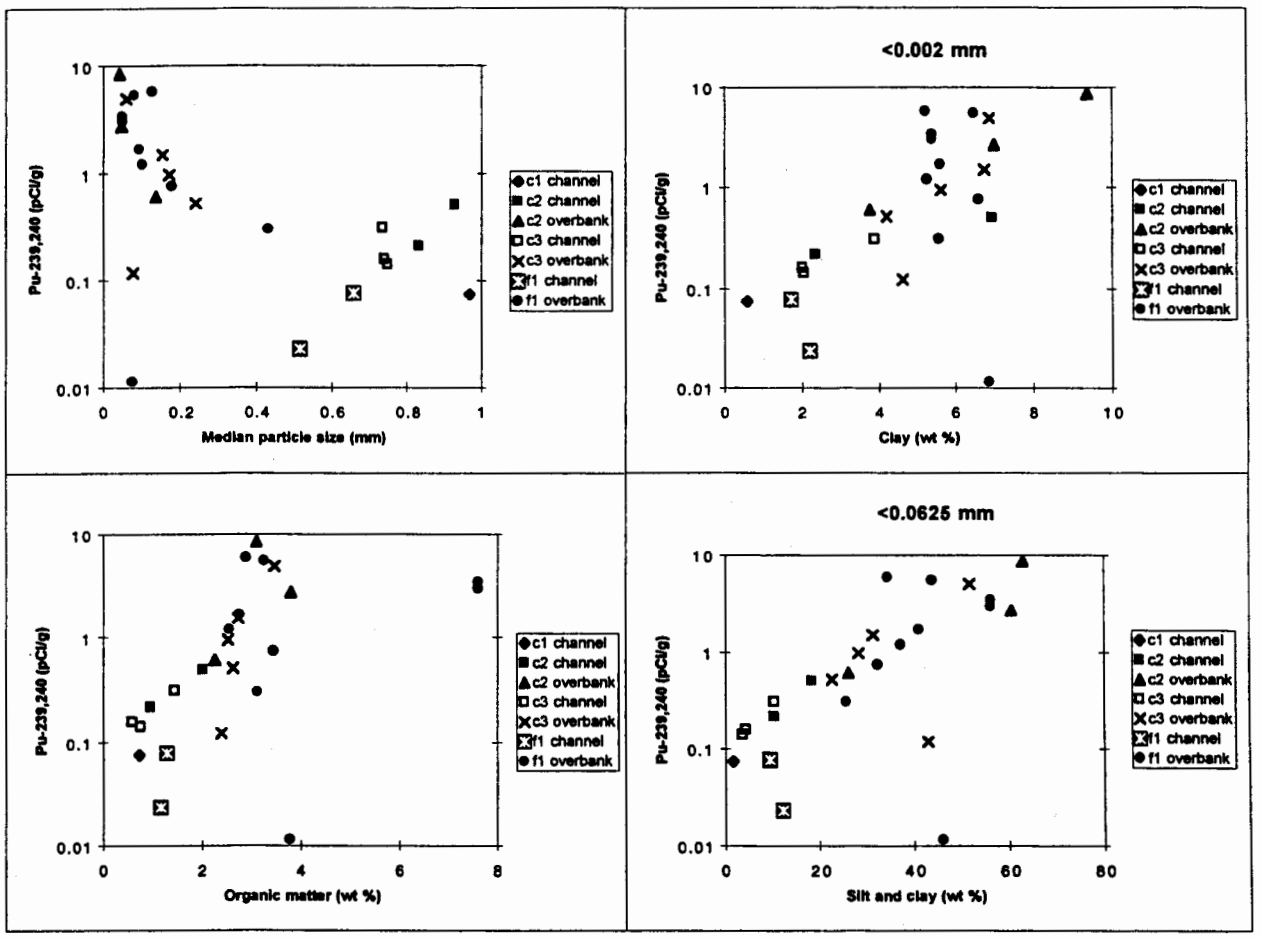


Figure B3-3. Scatter plots showing relations of plutonium-239,240 concentration to median particle size, silt and clay content, and organic matter content in reach LA-1 Central.

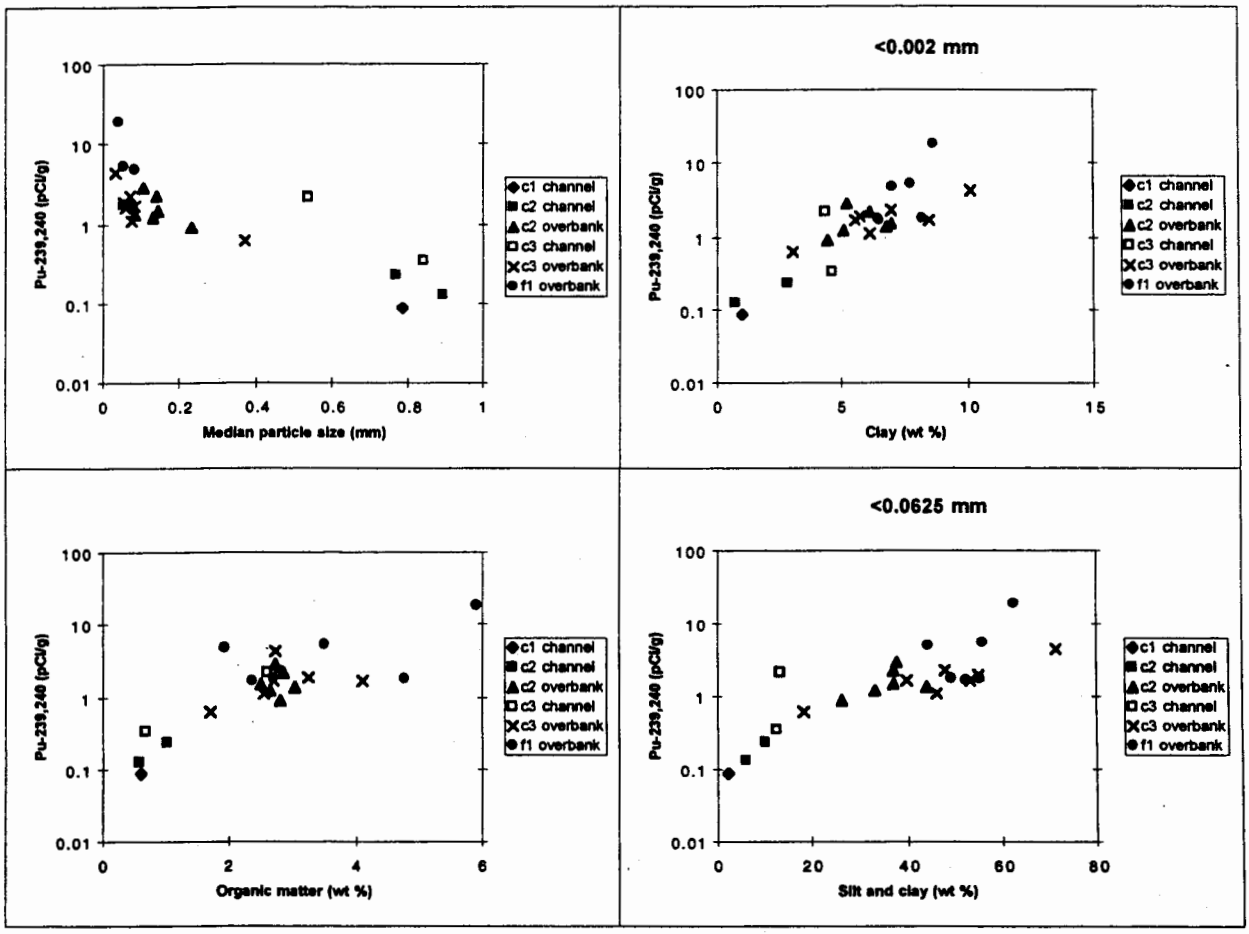


Figure B3-4. Scatter plots showing relations of plutonium-239,240 concentration to median particle size, silt and clay content, and organic matter content in reach LA-1 East.

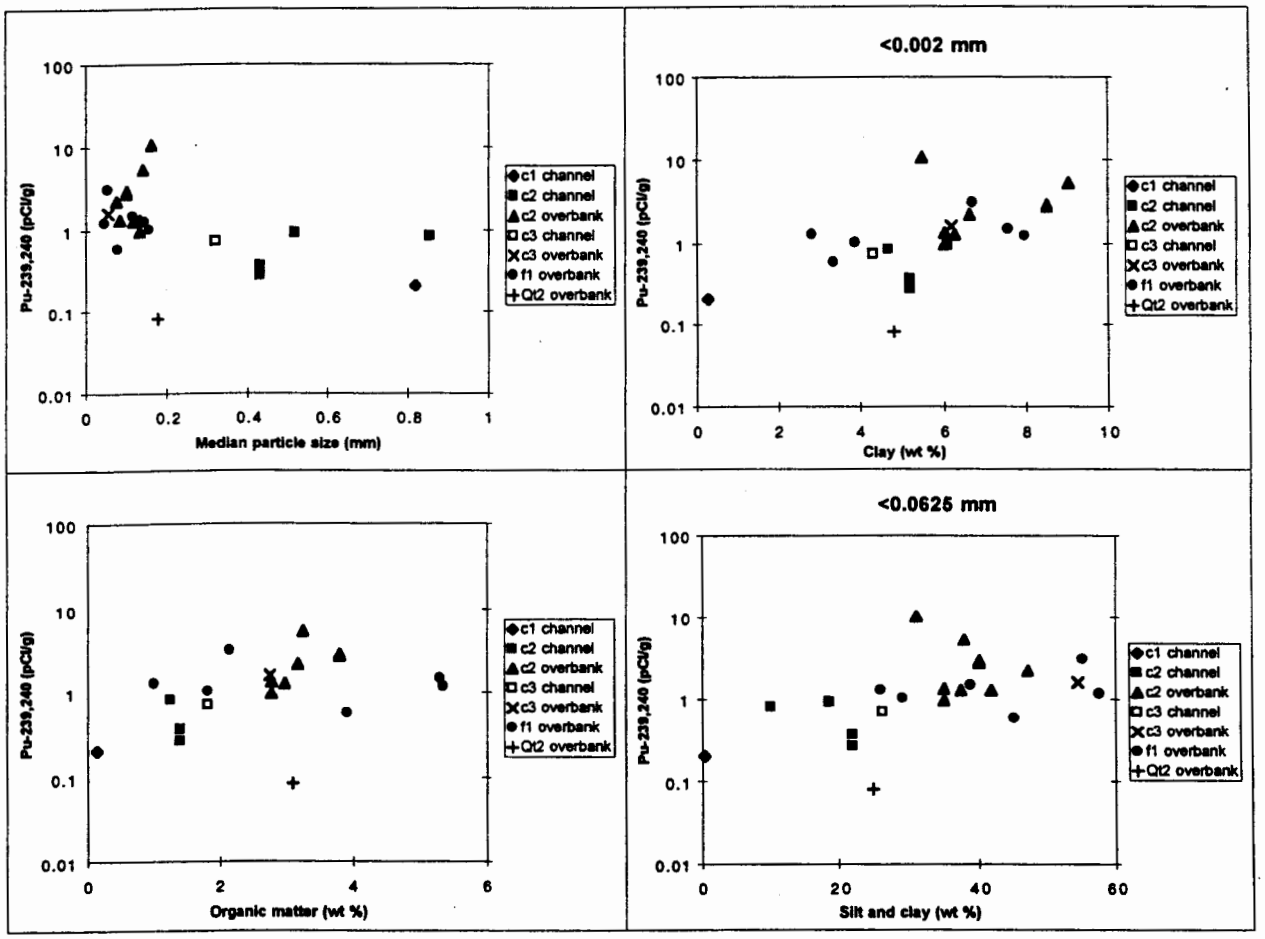


Figure B3-5. Scatter plots showing relations of plutonium-239,240 concentration to median particle size, silt and clay content, and organic matter content in reach LA-2 West.

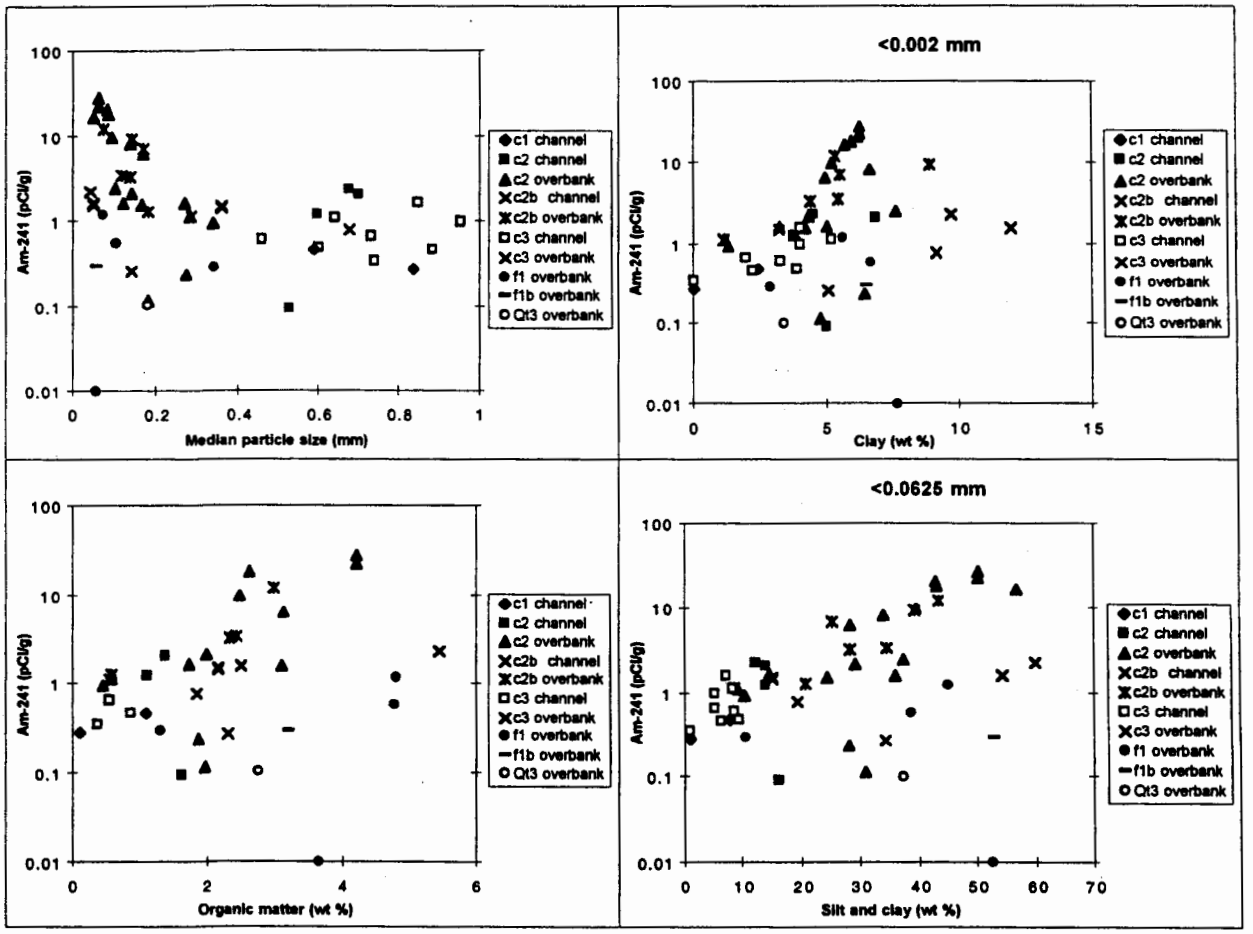


Figure B3-6. Scatter plots showing relations of americium-241 concentration to median particle size, silt and clay content, and organic matter content in reach LA-2 East.

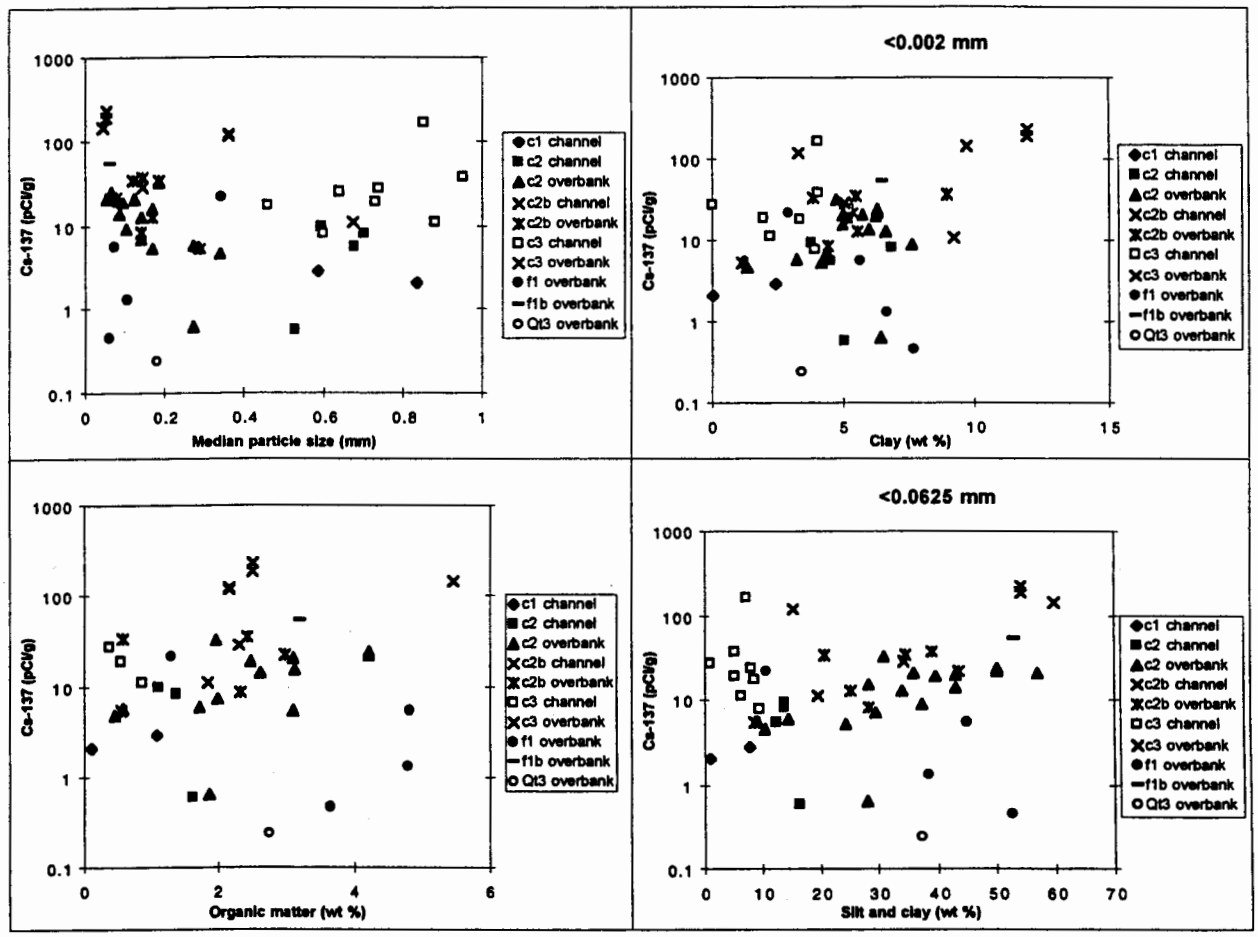


Figure B3-7. Scatter plots showing relations of cesium-137 concentration to median particle size, silt and clay content, and organic matter content in reach LA-2 East.

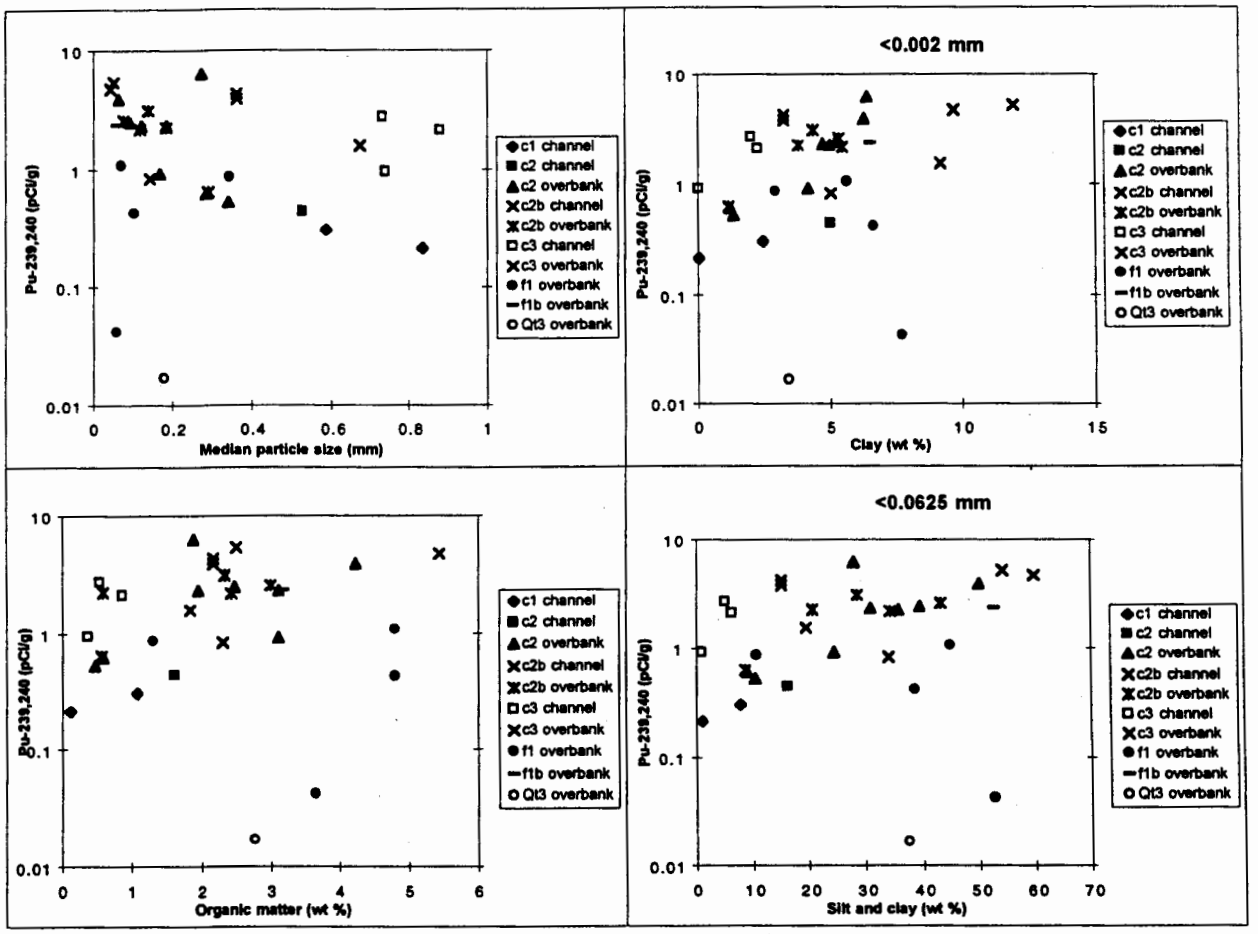


Figure B3-8. Scatter plots showing relations of plutonium-239,240 concentration to median particle size, silt and clay content, and organic matter content in reach LA-2 East.

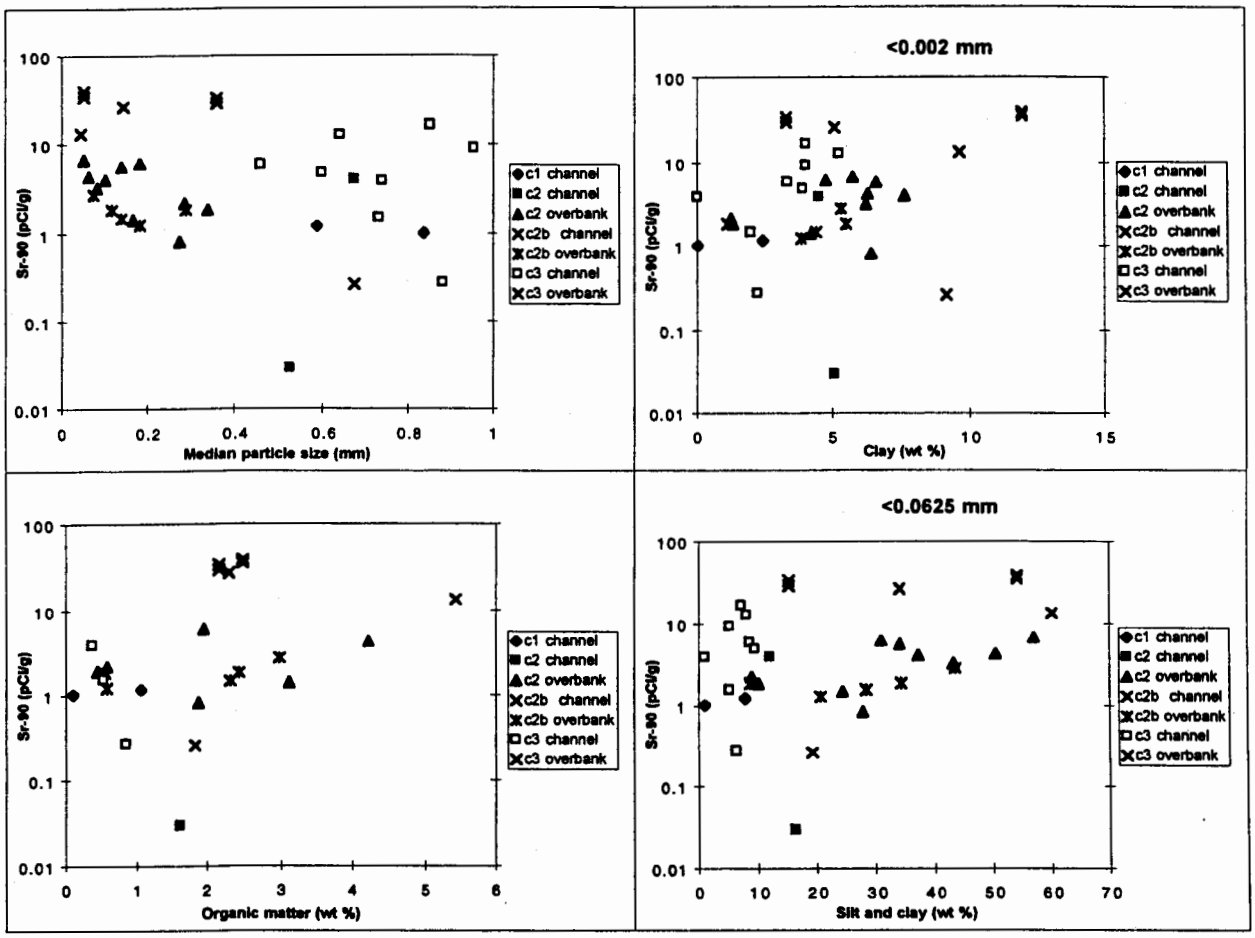


Figure B3-9. Scatter plots showing relations of strontium-90 concentration to median particle size, silt and clay content, and organic matter content in reach LA-2 East.

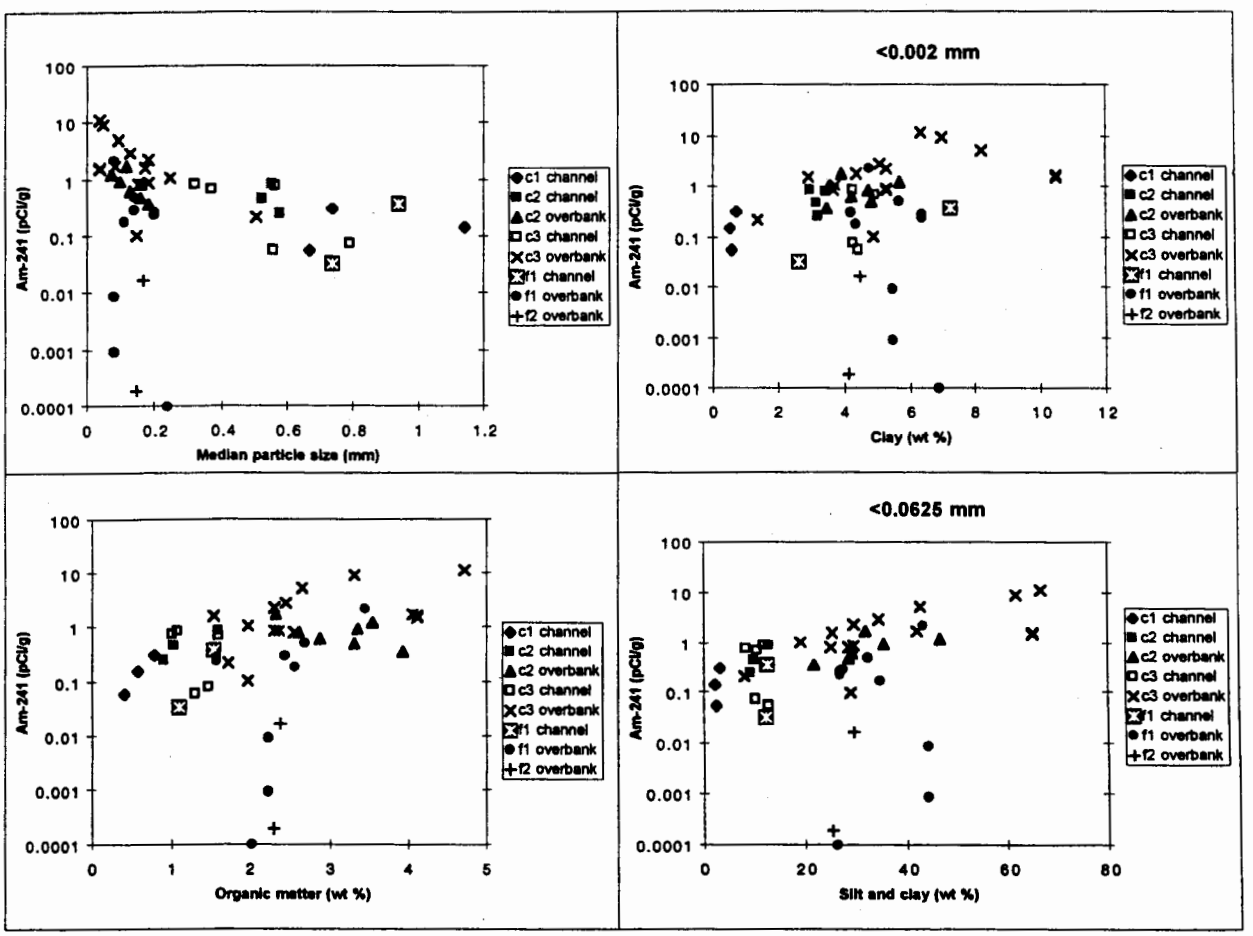


Figure B3-10. Scatter plots showing relations of cesium-137 concentration to median particle size, silt and clay content, and organic matter content in reach LA-3.

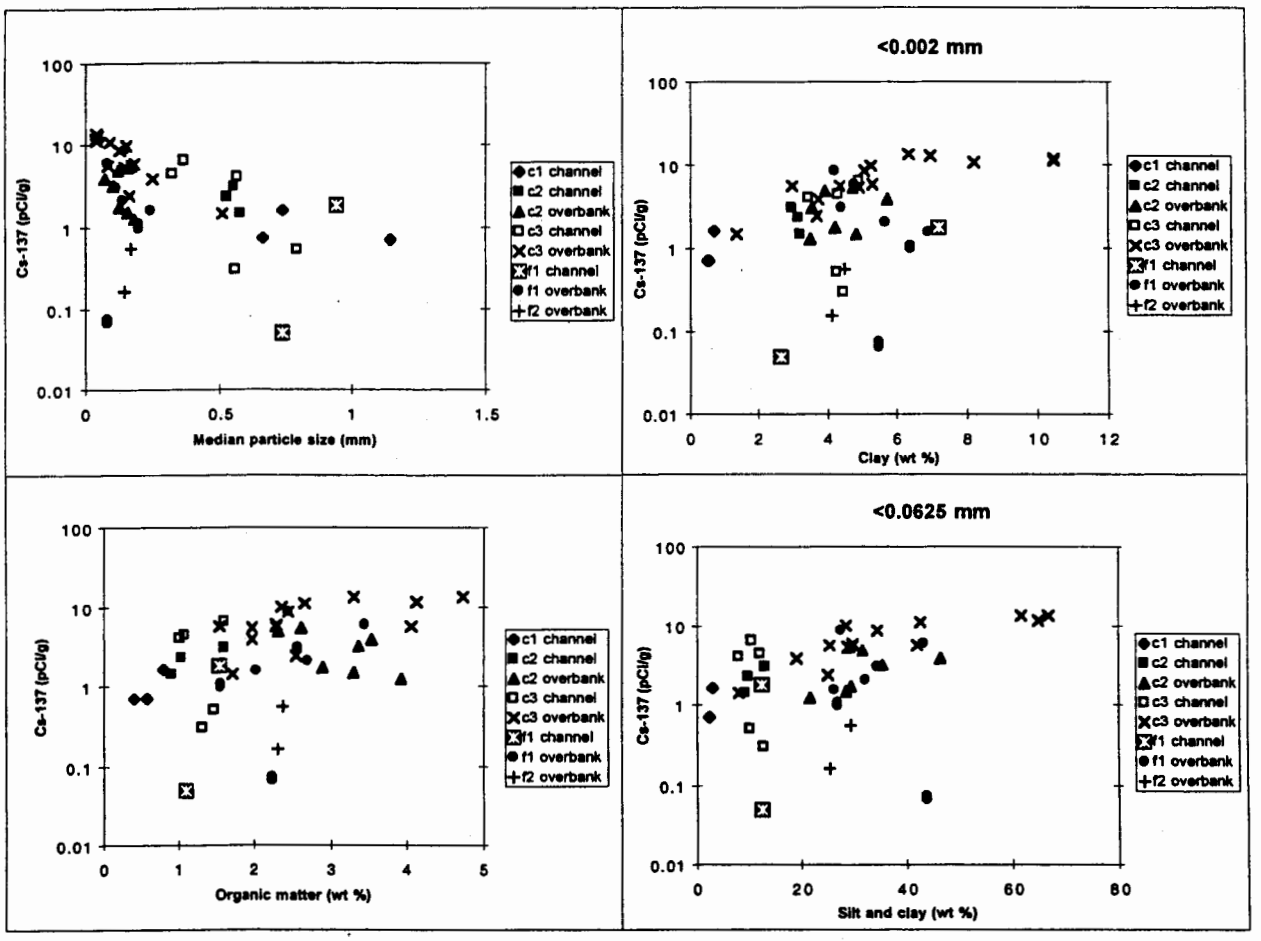


Figure B3-11. Scatter plots showing relations of americium-241 concentration to median particle size, silt and clay content, and organic matter content in reach LA-3.

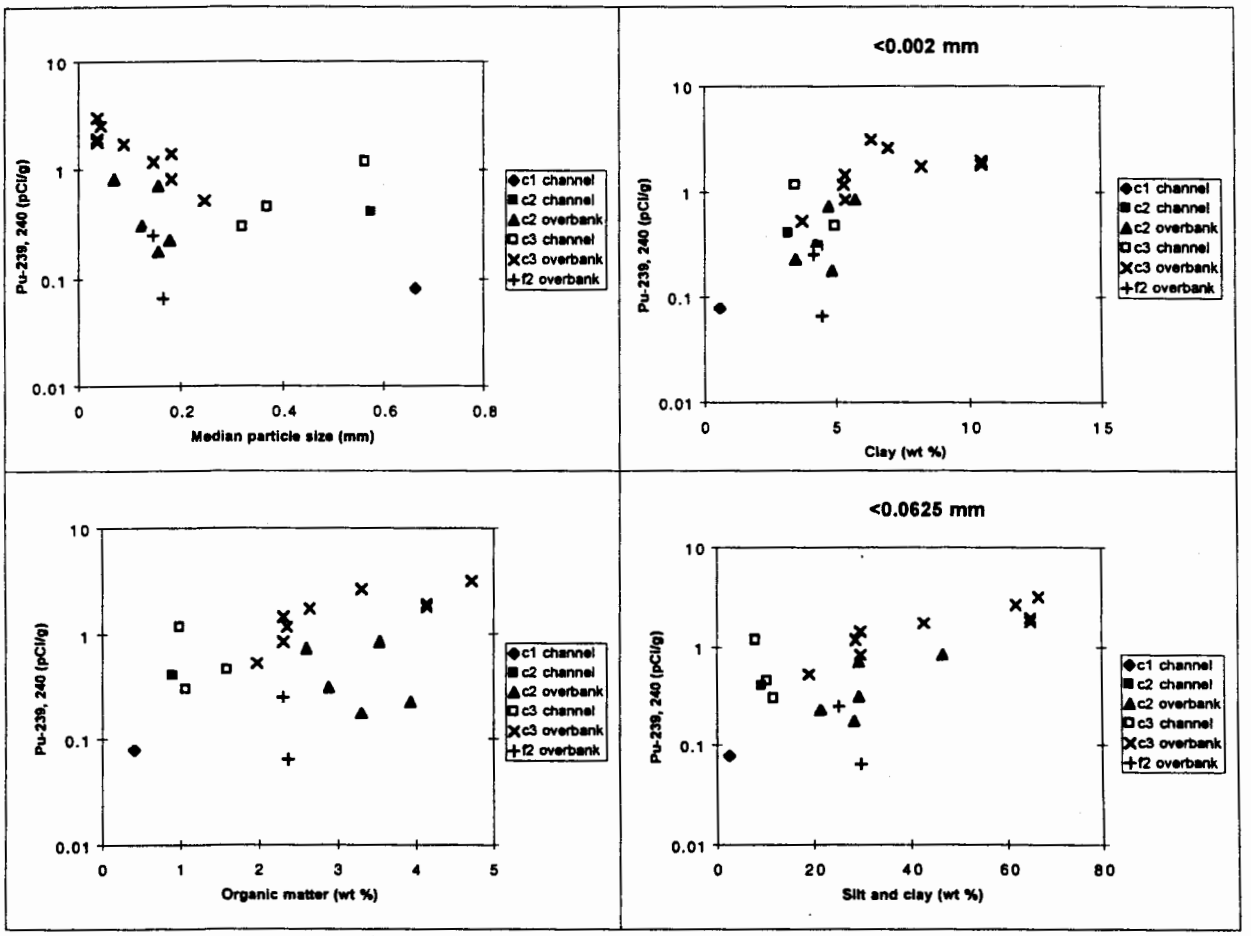


Figure B3-12. Scatter plots showing relations of plutonium-239,240 concentration to median particle size, silt and clay content, and organic matter content in reach LA-3.

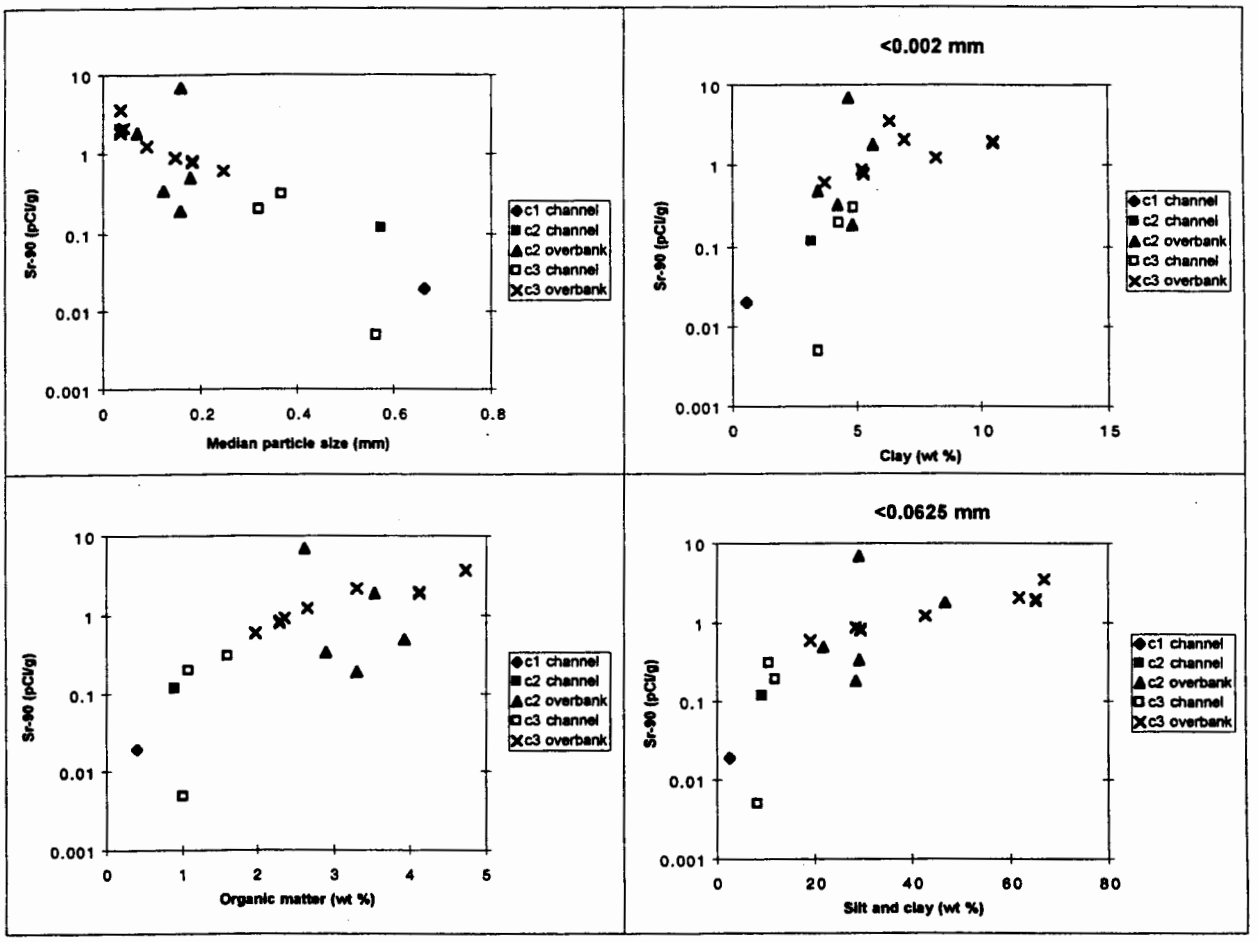


Figure B3-13. Scatter plots showing relations of strontium-90 concentration to median particle size, silt and clay content, and organic matter content in reach LA-3.

Positive correlations between radionuclide concentration and organic matter content were also seen in many subsets of the upper Los Alamos Canyon data, and these plots are presented in this Appendix. However, these relations are often weak and may be spurious, reflecting higher organic matter content in sediment with higher silt and clay content and no direct relation between organic matter and radionuclides.

B-4.0 RADIOLOGICAL FIELD MEASUREMENTS

B-4.1 Instrument Calibration and Use

B-4.1.1 Gross Gamma Radiation Walkover Surveys

The initial gross gamma radiation walkover survey in reach LA-2 was conducted by the Environmental Restoration Group (ERG) of Albuquerque, New Mexico, using Ludlum Model 44-10 detectors (2-in. by 2-in. sodium iodide [NaI] scintillation probes) with Ludlum Model 2221 scaler/ratemeters (single channel analyzers). A subsequent gross gamma radiation walkover survey in reach LA-2 and surveys in reaches LA-1 Central and LA-3 were conducted by CHEMRAD (Oak Ridge, Tennessee) using Ludlum Model 44-2 detectors (1-in. by 1-in. NaI probes) with Ludlum Model 3 scaler/ratemeters (single channel analyzers). Note that the actual values obtained during the ERG and CHEMRAD surveys cannot be directly compared because they used different sized probes, although both are effective in delineating variations in gamma radiation.

Before and after each day's use, each instrument's response was checked by collecting a 1-min measurement of a cesium-137 source of known activity and comparing it with the acceptable range (average ± 20%). At the same time, five 1-min instrument calibration measurements were collected at a local field site; the average of these readings was compared with an acceptable range (average ± 3 sigma). The calibration measurements were taken each day at the same place in an area that was not likely to have been radioactively contaminated by Laboratory activities. During these measurements, source-to-detector geometry was kept as consistent as possible. Scaler/ratemeter battery voltage, operating high voltage, threshold setting, and window configuration (as appropriate for the scaler/ratemeter) were also checked twice daily.

The surveys were conducted by walking slowly with the probe face held approximately 1 ft from the ground surface. In the initial reach LA-2 walkover survey by ERG, gamma radiation measurements (counts per minute [cpm]) were collected every 2 seconds and correlated to location as determined by a global positioning system (GPS). Accurate and continuous GPS measurements required that several satellites be visible to the instruments, and measurements were slowed down considerably because of the common presence of large ponderosa pine trees. As a result, use of a GPS was discontinued in upper Los Alamos Canyon. In subsequent surveys by CHEMRAD in reaches LA-1 Central, LA-2, and LA-3, gamma radiation measurements (collected every 1 second) were located with the ultrasonic ranging and data system (USRADS). USRADS relies on a local triangulation network of receivers that record ultrasonic signals emitted from the location of the NaI probe. The USRADS method is slower than the GPS method in open areas but allows measurements under tree cover.

Modifications were made to the gross gamma walkover survey procedure after it was realized that the walkover surveys could provide very rapid data on variations in radiation between different geomorphic units within a reach or between different reaches, but there were several major limitations to the use of this method in upper Los Alamos Canyon. One limitation involved the small size of most individual

geomorphic units and the poor precision of the topographic map under forest cover, such that the walkover data could not be easily and confidently assigned to specific geomorphic units. A second limitation was that both the GPS and the USRADS methods were very slow because of tree cover for the GPS measurements and because of the time needed to set up triangulation networks for the USRADS measurements. In the modifications to the walkover methodology, the ERG instruments were used but with the GPS turned off. The operator walked a set distance within a specific geomorphic unit, collecting measurements every 2 seconds, and the ends of these measured transects were approximately mapped by hand on topographic maps with 2-ft contour intervals. Each set of measurements could then be related to a specific location along the stream channel and to a specific geomorphic unit, and the average gamma radiation could be calculated from each set of data. These measurements were used to compare radiation in the active stream channel, dominated by coarse-grained sediment, with radiation in adjacent units (dominantly c2 units) that are underlain by finer grained sediments, and also to examine longitudinal variations in gamma radiation. Measurements were made in this manner from reach LA-1 Central to reach LA-3, including areas within the sampling reaches as well as between reaches; these measurements are discussed in Section 2.3.4. One limitation of this method is that some of the gamma radiation measured by the instrument may be from adjacent geomorphic units because of the narrow widths that are typical of many units. For example, the active channel in upper Los Alamos Canyon averages only 1.5 to 2 m in width, and the instrument may in part record radiation from adjacent stream banks which can be either in post-1942 sediments that contain higher levels of cesium-137 than the active channel or in pre-1943 material that contains virtually no cesium-137. Despite this limitation, these walkover measurements are still useful for identifying general trends in radiation and for identifying specific areas with relatively high levels of gamma radiation.

B-4.1.2 Gross Beta Radiation Walkover Survey

A gross beta radiation walkover survey was conducted in reach LA-1 Central by CHEMRAD (Oak Ridge, Tennessee) using a Ludlum Model 44-40 Pancake Geiger-Müller (GM) detector (shield removed) with a Ludlum Model 12 scalar/ratemeter. Before and after each day's use, the instrument's response was checked by collecting a 1-min measurement of a cesium-137 source of known activity and comparing it with the acceptable range (average ± 20%). At the same time, five 1-min instrument calibration measurements were collected at a local field site; the average of these readings was compared with an acceptable range (average ± 3 sigma). The calibration measurements were taken each day at the same place in an area that was not likely to have been radioactively contaminated by Laboratory activities. During these measurements, source-to-detector geometry was kept as consistent as possible. Scaler/ratemeter battery voltage and operating high voltage were also checked twice daily. The gross beta radiation survey was conducted simultaneously with the gross gamma radiation walkover survey. The gross beta radiation survey also used 1-second count times, and the measurement points were located with USRADS.

B-4.1.3 Fixed-Point Alpha, Beta, and Gamma Radiation Surveys

Alpha, beta, and gamma radiation were measured at fixed locations in reach LA-2 using

- for alpha radiation, a Ludlum Model 43-1 detector (zinc sulfide scintillation probe) with a Ludlum Model 2221 scaler/ratemeter;
- for beta radiation, a Ludlum Model 44-116 detector (plastic scintillation probe) with a Ludlum Model 2221 scaler/ratemeter; and

- for gamma radiation, a Ludlum Model 44-10 detector encased in a lead- and copper-lined, polyethylene shield with a Ludlum Model 2221 scaler/ratemeter.

Fixed-point gamma radiation measurements were also made in reach LA-3 using the same instrument.

Before and after each day's use, each instrument's response was checked by collecting a 1-min measurement of a thorium-232 source (for alpha radiation response) and a cesium-137 source (for beta and gamma radiation response) of known activity and compared with the acceptable range (average ± 20%). At the same time, each instrument was used to collect five 1-min instrument calibration measurements at a local field site, as discussed for the gross gamma walkover survey. Scaler/ratemeter battery voltage, operating high voltage, threshold setting, and window configuration were also checked twice daily.

The measurement locations were chosen to include all geomorphic units identified in reaches LA-2 and LA-3 and specific sites of relatively high gross gamma radiation as identified in the gamma walkover surveys. In addition, measurements of different stratigraphic layers exposed in stream banks were made at selected locations to evaluate depth variations. Beta and gamma measurements were conducted by placing the probe face on the soil surface (horizontal for surface measurements, vertical for depth measurements) and collecting 5-min timed measurements (counts per 5 min) for all beta radiation measurements and some of the gamma radiation measurements in LA-2. Because of the decision to focus most fixed-point measurements on gamma radiation downstream from DP Canyon (with fewer numbers of alpha and beta radiation measurements) the measurement time was decreased to 1 min because this length of time provided a sufficient number of counts for statistical purposes (>5000 counts). Gamma radiation measurements in vertical exposures were usually made at the surface and at 10 cm intervals, although some measurements were centered on specific sediment layers. For the alpha measurements in LA-2, sediment from selected layers was spread 1 to 3 cm deep on pie tins to provide a smoother surface, which helped prevent the Mylar polyester film on the instrument detector from breaking and improved the quality of the measurements. The alpha measurements used 5-min count times.

In both reaches LA-2 and LA-3 fixed-point gamma radiation measurements at individual locations were made during different time periods for a variety of purposes. Some 1996 LA-2 locations were remeasured during 1997 to check the comparability of 1996 LA-2 measurements with 1997 LA-3 measurements. These LA-2 measurements were made at sites with analytical data to allow approximate correlations of field gamma radiation measurements with cesium-137 concentration, which were then used to estimate cesium-137 concentrations in LA-3 before sediment sampling. In addition, some LA-3 locations were measured in both May and June 1997, with the latter measurements immediately preceding sediment sampling. These June 1997 LA-3 measurements were used to confirm the specific layers in a series of stratigraphic sections that had the highest levels of gamma radiation, and these layers were then selected for full-suite analyses.

It should be stressed that field radiation measurements vary with soil moisture content because the attenuation of particles emitted by radioactive decay varies with soil density. Wet soils are denser than dry soils; therefore, a wet soil will provide a lower number of counts than a dry soil with the same concentration of radionuclides. Thus, field measurements made at different locations with different moisture content or at the same location during different time periods may not be comparable, although the relative levels of radiation between different locations can still be determined. During this investigation field radiation measurements in reaches LA-2 and LA-3 were made during May 1996 and May and June 1997. May 1996 was a dry period following a dry winter when there was no flowing stream in LA-2; in contrast, a stream was continuously flowing through both LA-2 and LA-3 during May 1997, and soils

adjacent to the channel were relatively moist. By late June 1997 the stream had stopped flowing in LA-3, and the soils were drier than in May, resulting in consistently higher radiation measurements.

B-4.1.4 *In Situ* Gamma Spectroscopy Survey

Gamma radiation was measured at selected fixed-point locations in reach LA-2 using an EG&G Ortec Nomad Plus portable spectroscopy system comprising a Model GMX-30210-P-S PopTop high-purity germanium detector and Maestro II gamma spectroscopy software. This system allows *in situ* quantification of specific radioisotopes where concentrations are sufficiently high. Measurement locations were chosen to include sites representative of both widespread geomorphic units and potential elevated radiation as measured with the fixed-point instruments. The survey was conducted by placing the detector, mounted on a tripod, 1 m from the ground surface and collecting a 15-min timed measurement. This arrangement detected gamma radiation from an area of >300 m^2 (>10 m radius), with >50% of the signal received from within 30 m^2 (~3 m radius). In most cases, because of the size of geomorphic units, the measurements sampled multiple units.

The gamma spectroscopy software collects a gamma radiation spectrum by recording the number of ionizing events that occur in each energy interval. The events surrounding a given energy interval constitute a photopeak. The software performs a photopeak search and identifies the radionuclide that produced each photopeak by comparing the photopeak energy with a predetermined library of energies of gamma-emitting radionuclides (EG&G Ortec library). The height of the photopeak is proportional to the concentration of the corresponding radionuclide. The software quantifies the radionuclide (pCi/g) by applying a conversion factor to the number of events recorded at each photopeak. One source of potential error in these calculations is the incorrect assignment of photopeaks when the peaks from different radionuclides are similar, requiring checking by the user before the data can be accepted. Before and after each day's use, the instrument's calibration was checked by collecting a 15-min measurement of a radium source and a cesium-137 source of known activity. At the same time, the instrument was used to collect a 15-min measurement of local background radiation, as discussed for the gross gamma radiation walkover surveys.

B-4.2 Results

B-4.2.1 Reach LA-1

B-4.2.1.1 Gross Gamma Radiation Walkover Survey

Gross gamma radiation data were obtained in May 1996 from 12,423 points in reach LA-1 Central using 1-second count times and the USRADS location system. Locations of the measurement points are shown on Figure B4-1, and the raw data are archived in the Facility for Information Management, Analysis, and Display (FIMAD). No areas of gamma radiation that were clearly above background values were identified in this survey, and the mean gamma radiation in this survey (3279 cpm) was less than that measured at a Pueblo Canyon calibration site (3867 cpm) but slightly higher than that measured at a local calibration site in reach LA-2 West (3043 cpm). The highest value (5160 cpm) was from an area of fill material close to the Technical Area (TA) -2 security fence and not from sediment. The highest frequency of values greater than 4000 cpm are also from this area of fill, and other readings greater than 4000 cpm are scattered throughout LA-1 Central with no apparent pattern. All of these measurements are probably within the range of local background radiation.

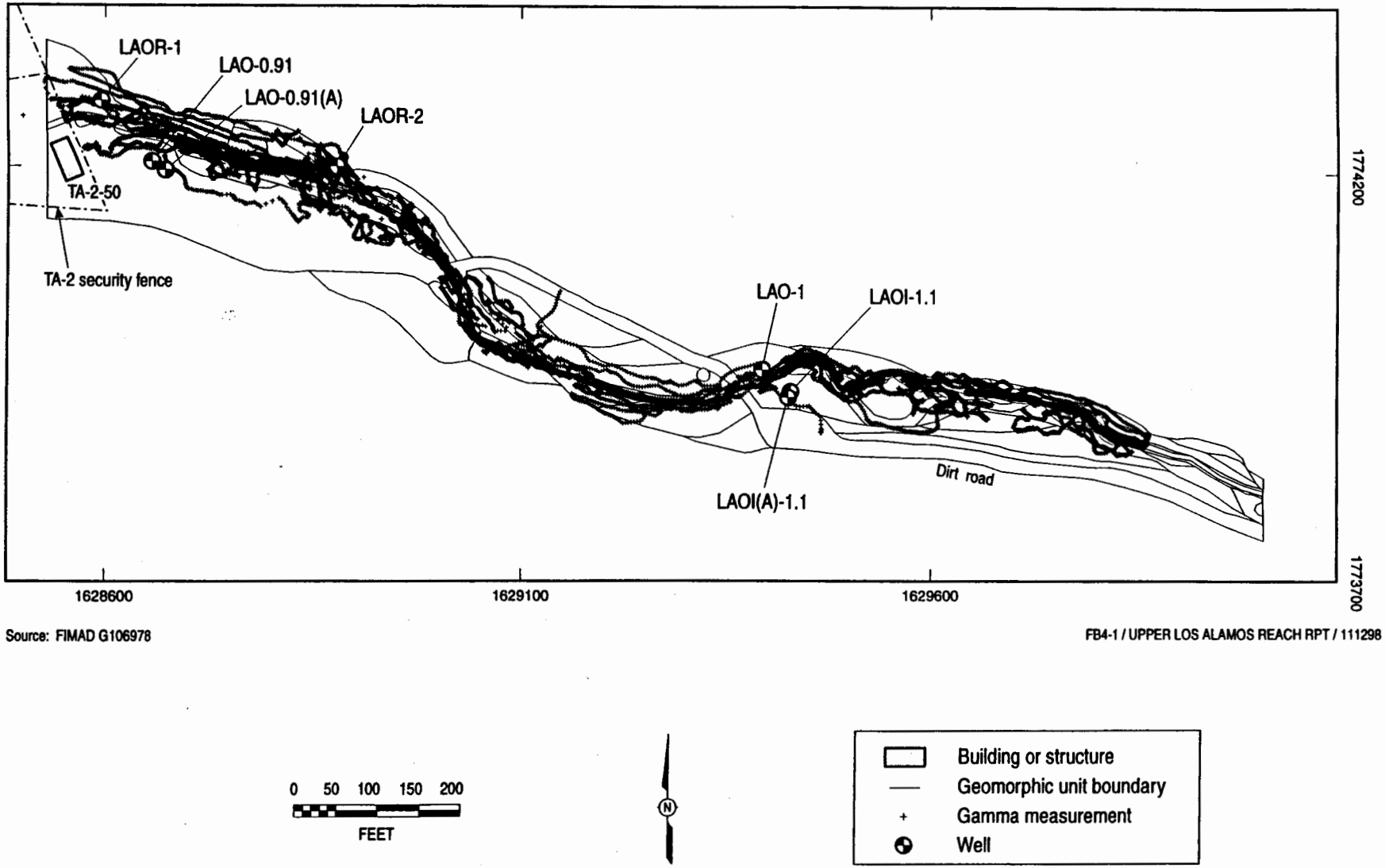


Figure B4-1. Map of reach LA-1 Central showing locations of gross gamma radiation walkover measurements.

B-4.2.1.2 Gross Beta Radiation Walkover Survey

Gross beta radiation data were obtained in May 1996 from 7933 points in reach LA-1 Central using 1-second count times and the USRADS location system. This technique was attempted in LA-1 Central because of the possibly that strontium-90, a beta-emitting radionuclide, was present because of releases from TA-2 but that cesium-137, the primary gamma-emitting radionuclide in reach LA-2 East, was not. Locations of the measurement points coincide with the gamma radiation measurement points in the west part of Figure B4-1, and the raw data are archived in FIMAD. No areas of beta radiation that were clearly above background values were identified in this survey, and the mean beta radiation in this survey (114 cpm) was less than that measured at a local reference site (123 cpm). The highest value, 340 cpm, was only slightly higher than the maximum at the reference site (300 cpm), and all of these values may be within background levels.

B-4.2.2 Reach LA-2

B-4.2.2.1 Gross Gamma Radiation Walkover Surveys

Gross gamma radiation walkover surveys were performed in reach LA-2 using both the GPS method (by ERG) and the USRADS method (by CHEMRAD) to compare the utility of these two methods in a deep canyon with tall ponderosa pine trees. Both methods showed the same general pattern of radiation and clearly identified the c3 unit as having the highest levels of radiation, but the USRADS method provided a greater density of points and more complete coverage and hence far greater resolution. Even in open areas the GPS method appeared to have low precision, as seen by repeat measurements at a control point, and the inability to precisely reproduce the control point was inferred to be caused by interference between the GPS signal and the steep canyon walls. However, it was also noted that the USRADS method sometimes provided incorrect locations in areas near the limits of the triangulation network or when tree cover was dense, but in general the quality of the USRADS locations appeared to be excellent.

The ERG survey was conducted in March 1996, and 2812 measurements were obtained using 2-second count times. Locations and values are archived in FIMAD. The maximum gamma radiation value in this survey was 86,781 cpm in the c3 NE unit.

The CHEMRAD survey was conducted in April 1996, and 49,570 measurements were obtained using 1-second count times. Locations of the measurement points are shown on Figures 2.3-12 and 2.3-13, and the raw data are archived in FIMAD. The maximum gamma radiation value in this survey was 16,700 cpm in the c3 NE unit, very close to the location of the highest ERG reading. The CHEMRAD measurements are discussed further in Section 2.3.2.2.

B-4.2.2.2 Fixed-Point Alpha, Beta, and Gamma Radiation Surveys

Fixed-point radiation data were obtained from 89 sites in reach LA-2 (Figures B4-2 and B4-3; Table B4-1). These include 6 sites in lower DP Canyon, 22 sites in LA-2 West, and 61 sites in LA-2 East. A total of 108 fixed-point alpha radiation measurements, 81 beta radiation measurements, and 351 gamma radiation measurements were made. Local background values for radiation in the young sediments of upper Los Alamos Canyon are probably represented by the measurements made in LA-2 West, upstream from DP Canyon, because of the low levels of radionuclide contaminants present there.

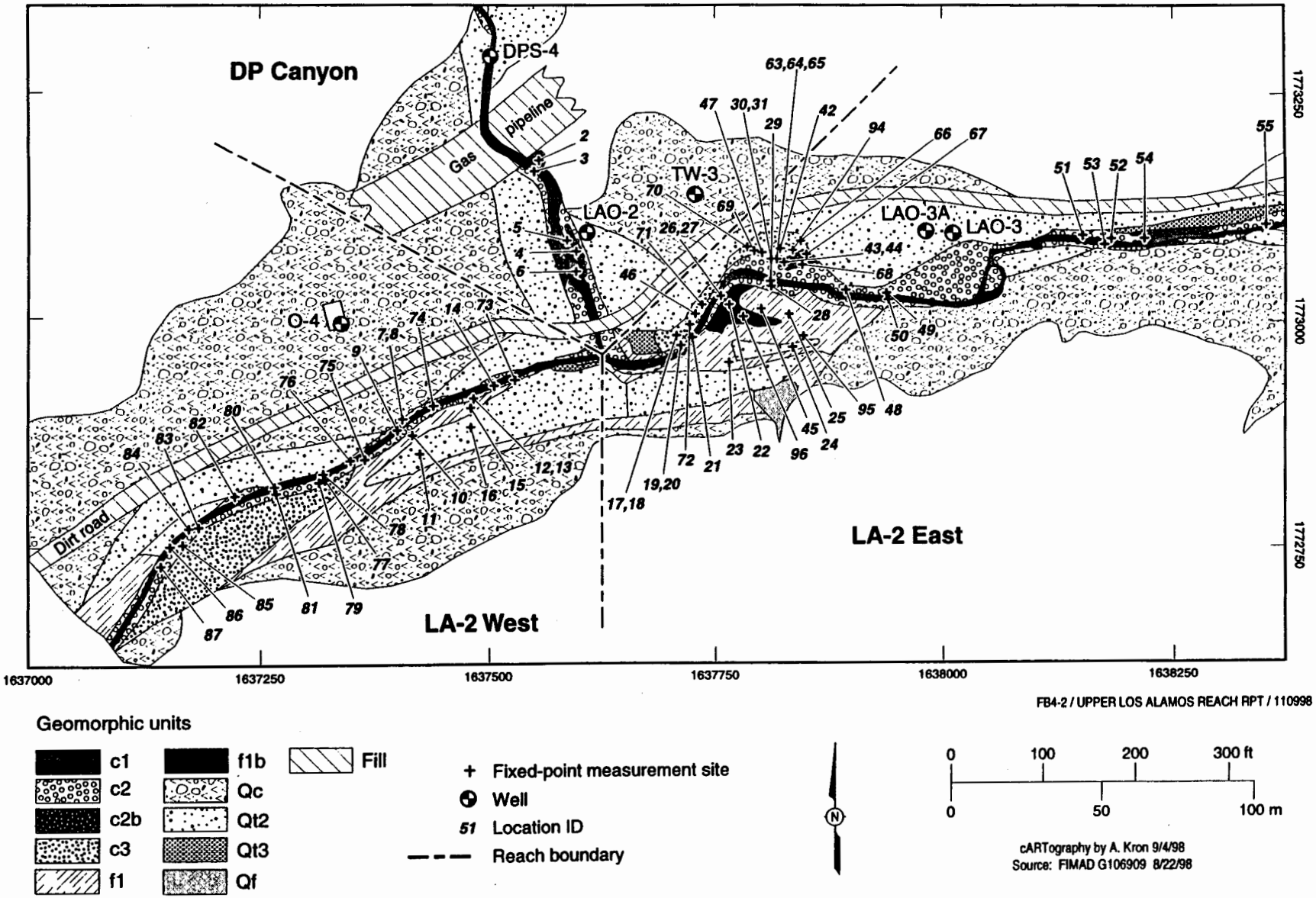


Figure B4-2. Map of west half of reach LA-2 showing fixed-point radiation measurement sites.

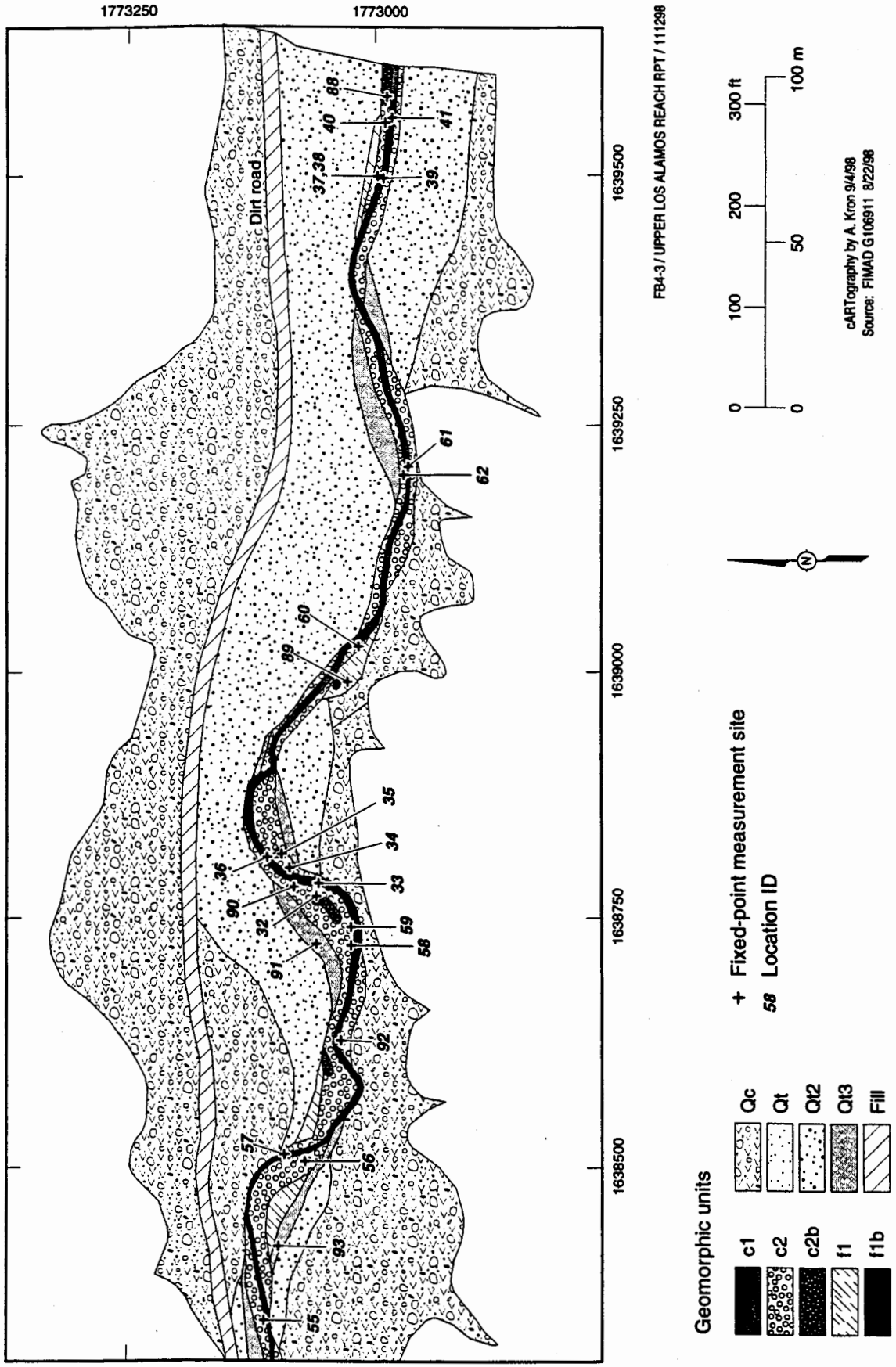


Figure B4-3. Map of east half of reach LA-2 showing fixed-point radiation measurement sites.

TABLE B4-1

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-2

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Alpha Radiation (cpm)	Beta Radiation (cpm)	Gamma Radiation (cpm)	Date
LA2-1			DP Canyon	c3?	0	10.2	922	26246	5/8/96
LA2-2			DP Canyon	c2b	0	6.6	811	28678	5/8/96
LA2-3			DP Canyon	c1	0	4.0	450	7201	5/8/96
LA2-4		LA-0016	DP Canyon	c2b	0	9.6	991	20857	5/8/96
					0	0.0			5/14/96
					20	0.0			5/14/96
LA2-5			DP Canyon	c2	0	5.0	541	10843	5/8/96
LA2-6			DP Canyon	c1	0	3.8	417	8280	5/8/96
LA2-7 (+8)			LA-2 West	c2	0	8.4	409	6285	5/8/96
					20			6423	5/8/96
					20	0.0			5/14/96
LA2-9		LA-0017	LA-2 West	c1	0	7.6	404	6204	5/8/96
LA2-10		LA-0018	LA-2 West	f1	0	10.8	424	6209	5/8/96
LA2-11			LA-2 West	Qt2	0	9.8	403	6358	5/8/96
LA2-12 (+13)		LA-0041	LA-2 West	c2	0	7.8	422	6740	5/8/96
					0			5843	5/28/97
					10			5032	5/28/97
					23			6535	5/8/96
LA2-14			LA-2 West	c1	0	6.4	391	5963	5/8/96
LA2-15			LA-2 West	f1	0	8.6	421	6514	5/8/96
LA2-16		LA-0095	LA-2 West	Qt2	0	6.4	418	6385	5/8/96
LA2-17 (+18)	LA2-S1	LA-0096	LA-2 East	c3 (SW)	0	10.6	1031	27982	5/8/96
					13			22146	5/8/96
					3			21824	5/9/96
					10			23118	5/9/96
					20			19779	5/9/96
					30			14648	5/9/96
					40			12866	5/9/96
					50			11239	5/9/96
					60			11015	5/9/96
					18	0.0			5/14/96
					10	10.6			5/20/96
					10	0.0			5/20/96
LA2-19 (+20)		LA2-S2	LA-2 East	c2	0	6.6	468	11347	5/8/96
					24			11883	5/8/96
					10			10080	5/9/96
					20			10680	5/9/96
					30			11786	5/9/96
					40			11794	5/9/96
					50			11343	5/9/96
					60			10489	5/9/96
					70			9479	5/9/96
					80			9098	5/9/96
					90			9743	5/9/96
					100			9348	5/9/96
					110			9048	5/9/96

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-2

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Alpha Radiation (cpm)	Beta Radiation (cpm)	Gamma Radiation (cpm)	Date
LA2-19 (+20)		LA2-S2	LA-2 East	c2	120			9338	5/9/96
					35	8.2			5/20/96
LA2-21			LA-2 East	c1	0	5.6	377	7119	5/8/96
LA2-22			LA-2 East	f1b	0	8.2	667	15677	5/8/96
LA2-23			LA-2 East	f1	0	9.4	447	8439	5/8/96
LA2-24			LA-2 East	Qt2	0	11.0	364	5967	5/8/96
LA2-25			LA-2 East	f1	0	10.4	444	8997	5/8/96
LA2-26 (+27)		LA2-S3	LA-2 East	c2	0	8.4	411	10389	5/8/96
					12			10267	5/8/96
					10			9472	5/9/96
					20			10325	5/9/96
					30			9765	5/9/96
					40			9279	5/9/96
					50			8930	5/9/96
					60			8202	5/9/96
					70			7596	5/9/96
					80			7417	5/9/96
					90			7405	5/9/96
					100			7454	5/9/96
					110			7367	5/9/96
					20	12.4			5/20/96
					30	7.8			5/20/96
LA2-28			LA-2 East	c1	0	7.8	343	7236	5/8/96
LA2-29			LA-2 East	c1	0	3.6	315	6276	5/8/96
LA2-30 (+31)	LA2-S4	LA-0024 (+0025)	LA-2 East	c3 (NE)	0	5.8	533	17871	5/8/96
					70			46404	5/8/96
					10			18978	5/9/96
					20			21990	5/9/96
					30			25586	5/9/96
					40			29072	5/9/96
					50			37541	5/9/96
					60			41846	5/9/96
					70			46701	5/9/96
					75	4.0			5/9/96
					80			41920	5/9/96
					90			36891	5/9/96
					100			37365	5/9/96
					110			24326	5/9/96
					120			20661	5/9/96
					40	7.0			5/20/96
					70	9.6			5/20/96
					110	9.8			5/20/96
					0			15601	5/28/97
					10			21274	5/28/97
					20			26212	5/28/97
					30			30942	5/28/97

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-2

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Alpha Radiation (cpm)	Beta Radiation (cpm)	Gamma Radiation (cpm)	Date
LA2-30 (+31)	LA2-S4	LA-0024 (+0025)	LA-2 East	c3 (NE)	130			18260	5/9/96
					40			35562	5/28/97
					50			41547	5/28/97
					60			44915	5/28/97
					70			46404	5/28/97
					7.5			18429	6/3/97
					75			45763	6/3/97
					118			24750	6/3/97
LA2-31 (2mW)		LA2-S5	LA-2 East	c3 (NE)	10			18943	5/9/96
					20			28603	5/9/96
					30			34281	5/9/96
					40			35555	5/9/96
					50			35707	5/9/96
					60			37714	5/9/96
					70			38599	5/9/96
					80			30410	5/9/96
					90			27800	5/9/96
					100			25097	5/9/96
					110			24249	5/9/96
					70	7.0			5/20/96
LA2-32			LA-2 East	c2b	0	13.8	617	14377	5/8/96
LA2-33			LA-2 East	c1	0	5.2	359	6155	5/8/96
LA2-34			LA-2 East	c2	0	9.0	459	9279	5/8/96
LA2-35			LA-2 East	c2b	0	11.0	534	12607	5/8/96
LA2-36			LA-2 East	c1	0	4.4	342	6950	5/8/96
LA2-37 (+38)	LA2-S18	LA-0105	LA-2 East	c2	0	8.4	414	10472	5/8/96
					20			10356	5/8/96
					10			9832	5/9/96
					20			10959	5/9/96
					30			10452	5/9/96
					40			9455	5/9/96
					50			8574	5/9/96
					60			8158	5/9/96
					70			8186	5/9/96
					80			8035	5/9/96
LA2-39			LA-2 East	c1	0	3.4	375	7050	5/8/96
LA2-40			LA-2 East	c2	0	11.2	433	11269	5/8/96
LA2-41			LA-2 East	c1	0	4.4	343	7376	5/8/96
LA2-42			LA-2 East	c3 (NE)	0	6.8	718	23785	5/8/96
LA2-43 (+44)		LA2-S6	LA-2 East	c2b	0	7.8	531	14528	5/8/96
					56			18497	5/8/96
					10			14223	5/9/96
					20			16990	5/9/96
					30			19989	5/9/96
					40			21068	5/9/96
					50			20454	5/9/96

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-2

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Alpha Radiation (cpm)	Beta Radiation (cpm)	Gamma Radiation (cpm)	Date
LA2-43 (+44)		LA2-S6	LA-2 East	c2b	60			18314	5/9/96
					70			15756	5/9/96
					80			15774	5/9/96
					90			15544	5/9/96
					100			15470	5/9/96
					40	6.6			5/20/96
LA2-45			LA-2 East	f1	0	5.8	534	12661	5/8/96
LA2-46			LA-2 East	c3 (SW)	0	14.0	1237	27571	5/8/96
LA2-47			LA-2 East	c3 (NE)	0	7.2	841	23976	5/9/96
LA2-48	LA2-S7	LA-0019 (+0043)	LA-2 East	c2	0	8.0	428	9283	5/9/96
					10			8947	5/9/96
					20			10288	5/9/96
					30			11410	5/9/96
					40			11956	5/9/96
					50			10919	5/9/96
					60			10374	5/9/96
					70			10088	5/9/96
					80			9847	5/9/96
					95			9546	5/9/96
					105			8908	5/9/96
					40	0.0			5/14/96
					30	15.0			5/20/96
					40	8.8			5/20/96
					0			8049	5/28/97
					10			8103	5/28/97
					20			9210	5/28/97
					30			9825	5/28/97
					40			10325	5/28/97
LA2-49		LA2-S8	LA-2 East	c2	0	11.4	444	9374	5/9/96
					10			8579	5/9/96
					20			9925	5/9/96
					30			11250	5/9/96
					40			12288	5/9/96
					50			12240	5/9/96
					60			12352	5/9/96
					70			11346	5/9/96
					80			10811	5/9/96
					90			9729	5/9/96
					0	9.4			5/14/96
					0	0.4			5/14/96
					30	5.2			5/14/96
					30	9.0			5/20/96
					60	3.6			5/20/96
LA2-50			LA-2 East	c1	0	4.8	371	7124	5/9/96
LA2-51		LA2-S9	LA-2 East	c2	0	11.6	422	9597	5/9/96
					10			9127	5/9/96

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-2

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Alpha Radiation (cpm)	Beta Radiation (cpm)	Gamma Radiation (cpm)	Date
LA2-51		LA2-S9	LA-2 East	c2	20			9406	5/9/96
					30			10249	5/9/96
					40			10330	5/9/96
					50			9986	5/9/96
					60			9245	5/9/96
					70			8777	5/9/96
					80			8354	5/9/96
					90			8198	5/9/96
LA2-52		LA2-S10	LA-2 East	c2	0	10.2	470	9919	5/9/96
					10			9061	5/9/96
					20			10539	5/9/96
					30			11471	5/9/96
					40			11821	5/9/96
					50			11024	5/9/96
					60			10645	5/9/96
					70			9875	5/9/96
					80			9760	5/9/96
					90			9726	5/9/96
LA2-53			LA-2 East	c1	0	3.0	395	6938	5/9/96
LA2-54	LA2-S11	LA-0020 (+0021 and 0040)	LA-2 East	c2b	0	9.4	460	10394	5/9/96
					10			10012	5/9/96
					20			12177	5/9/96
					30			14941	5/9/96
					40			17070	5/9/96
					50			19490	5/9/96
					60			19718	5/9/96
					70			20259	5/9/96
					80			19098	5/9/96
					90			15355	5/9/96
					100			13203	5/9/96
					110			10424	5/9/96
					120			9559	5/9/96
					0			11206	6/3/97
					10			11670	6/3/97
					20			14287	6/3/97
					30			15968	6/3/97
					40			18252	6/3/97
					40			17469	6/3/97
					50			18890	6/3/97
					60			22861	6/3/97
					70			24480	6/3/97
LA2-55		LA2-S12	LA-2 East	c2	0	10.2	504	9242	5/9/96
					10			9980	5/9/96
					20			10741	5/9/96
					30			12126	5/9/96
					40			12507	5/9/96

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-2

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Alpha Radiation (cpm)	Beta Radiation (cpm)	Gamma Radiation (cpm)	Date
LA2-55		LA2-S12	LA-2 East	c2	50			12230	5/9/96
					60			11697	5/9/96
					70			11080	5/9/96
					80			10879	5/9/96
					90			10534	5/9/96
					100			10308	5/9/96
					110			10593	5/9/96
LA2-56	LA2-S13	LA-0107	LA-2 East	c2	0	7.4	426	9839	5/9/96
					10			9048	5/9/96
					20			10734	5/9/96
					30			11821	5/9/96
					40			12384	5/9/96
					50			12897	5/9/96
					60			11611	5/9/96
					70			10671	5/9/96
					80			9424	5/9/96
					90			8588	5/9/96
					100			7751	5/9/96
					7.5			7857	6/3/97
					21.5			9280	6/3/97
					39.5			10308	6/3/97
					52			10049	6/3/97
LA2-57			LA-2 East	c1	0	4.0	350	6865	5/9/96
LA2-58		LA2-S14	LA-2 East	c2	0	10.8	461	10852	5/9/96
					10			9750	5/9/96
					20			11330	5/9/96
					30			11970	5/9/96
					40			11901	5/9/96
					50			11487	5/9/96
					60			10390	5/9/96
					70			9382	5/9/96
					80			8312	5/9/96
					90			7856	5/9/96
					100			7423	5/9/96
					110			7606	5/9/96
LA2-59		LA2-S15	LA-2 East	c2	0	11.2	496	10340	5/9/96
					10			9433	5/9/96
					20			10524	5/9/96
					30			10678	5/9/96
					40			10279	5/9/96
					50			9745	5/9/96
					60			10136	5/9/96
					70			10495	5/9/96
					80			10350	5/9/96
					90			10531	5/9/96
					40	6.8			5/14/96

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-2

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Alpha Radiation (cpm)	Beta Radiation (cpm)	Gamma Radiation (cpm)	Date
LA2-60		LA2-S16	LA-2 East	c2	0	8.4	476	10400	5/9/96
					10			10066	5/9/96
					20			10993	5/9/96
					30			11547	5/9/96
					40			10772	5/9/96
					50			9286	5/9/96
					60			8146	5/9/96
					70			8474	5/9/96
					28	6.0			5/14/96
LA2-61		LA-0023	LA-2 East	c1	0	5.6	386	7693	5/9/96
LA2-62	LA2-S17	LA-0022 (+0039)	LA-2 East	c2	0	15.4	473	9932	5/9/96
					10			10050	5/9/96
					20			11998	5/9/96
					30			12718	5/9/96
					40			12549	5/9/96
					50			11738	5/9/96
					60			10286	5/9/96
					70			9330	5/9/96
					80			9093	5/9/96
					90			8307	5/9/96
					100			7904	5/9/96
					30	0.0			5/14/96
					0			9908	6/3/97
					4			9242	6/3/97
					10			9494	6/3/97
					15			10037	6/3/97
					20			10520	6/3/97
					25			10698	6/3/97
					30			11076	6/3/97
					40			10774	6/3/97
					44.5			10967	6/3/97
					50			9974	6/3/97
LA2-63			LA-2 East	c3 (NE)	0	11.0	1223	31601	5/20/96
LA2-64			LA-2 East	c3 (NE)	0	8.8	1306	35307	5/20/96
LA2-65			LA-2 East	c3 (NE)	0	11.0	819	18174	5/20/96
LA2-66			LA-2 East	c3 (NE)	0	9.2	1189	29926	5/20/96
LA2-67			LA-2 East	c2b	0	9.6	630	15295	5/20/96
LA2-68			LA-2 East	c2b	0	10.6	568	11579	5/20/96
LA2-69			LA-2 East	c3 (NE)	0	10.6	820	19443	5/20/96
LA2-70		LA-0097	LA-2 East	c3 (NE)	0	14.0	984	23458	5/20/96
LA2-71			LA-2 East	c3 (SW)	0	9.6	1496	37711	5/20/96
LA2-72			LA-2 East	c3 (SW)	0	7.8	1169	26194	5/20/96
LA2-73			LA-2 West	c2	0	7.0	314	6297	5/20/96
LA2-74			LA-2 West	c1	0	6.0	306	5354	5/20/96
LA2-75			LA-2 West	c2	0	2.2	373	6567	5/20/96
					0	7.6			5/20/96

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-2

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Alpha Radiation (cpm)	Beta Radiation (cpm)	Gamma Radiation (cpm)	Date
LA2-76			LA-2 West	c1	0	6.0	346	5629	5/20/96
LA2-77			LA-2 West	c2	0	10.2	354	6610	5/20/96
LA2-78			LA-2 West	c1	0	6.8	331	5809	5/20/96
LA2-79			LA-2 West	c2	0	7.0	362	6599	5/20/96
LA2-80			LA-2 West	c1	0	7.8	341	6147	5/20/96
LA2-81			LA-2 West	c2	0	6.6	376	6955	5/20/96
LA2-82			LA-2 West	c2	0	8.6	369	6568	5/20/96
LA2-83		LA-0092	LA-2 West	c2	0	7.2	388	6808	5/20/96
LA2-84			LA-2 West	c1	0	4.2	367	6398	5/20/96
LA2-85			LA-2 West	c2	0	4.8	374	6834	5/20/96
LA2-86			LA-2 West	c1	0	5.0	351	5949	5/20/96
LA2-87		LA-0192	LA-2 West	c2	0	11.2	393	6653	5/20/96
LA2-88	LA2-S19	LA-0104	LA-2 East	c2b	0			11257	6/3/97
					10			11727	6/3/97
					20			13398	6/3/97
					30			13011	6/3/97
					40			12352	6/3/97
					50			10429	6/3/97
					60			9756	6/3/97
					70			9006	6/3/97
					80			8883	6/3/97
					90			8359	6/3/97
					100			8398	6/3/97
LA2-89		LA-0101	LA-2 East	f1	0			11304	6/3/97
LA2-90	LA2-S20	LA-0106	LA-2 East	c2	0			11660	6/3/97
					10			10381	6/3/97
					20			10676	6/3/97
					30			9873	6/3/97
					40			9065	6/3/97
					50			8539	6/3/97
					60			8516	6/3/97
					70			7999	6/3/97
					80			8357	6/3/97
LA2-91		LA-0102	LA-2 East	Qt3	0			7584	6/3/97
LA2-92	LA2-S21	LA-0103	LA-2 East	c2	0			10334	6/3/97
					10			9726	6/3/97
					20			10314	6/3/97
					30			9971	6/3/97
					40			9452	6/3/97
LA2-92	LA2-S21	LA-0103	LA-2 East	c2	50			9282	6/3/97
LA2-93			LA-2 East	Qt3	0			7700	6/3/97
LA2-94		LA2-S22	LA-2 East	c3 (NE)	0			32157	6/3/97
					10			33928	6/3/97
					20			38884	6/3/97
					30			40125	6/3/97
					40			41127	6/3/97

TABLE B4-1 (continued)

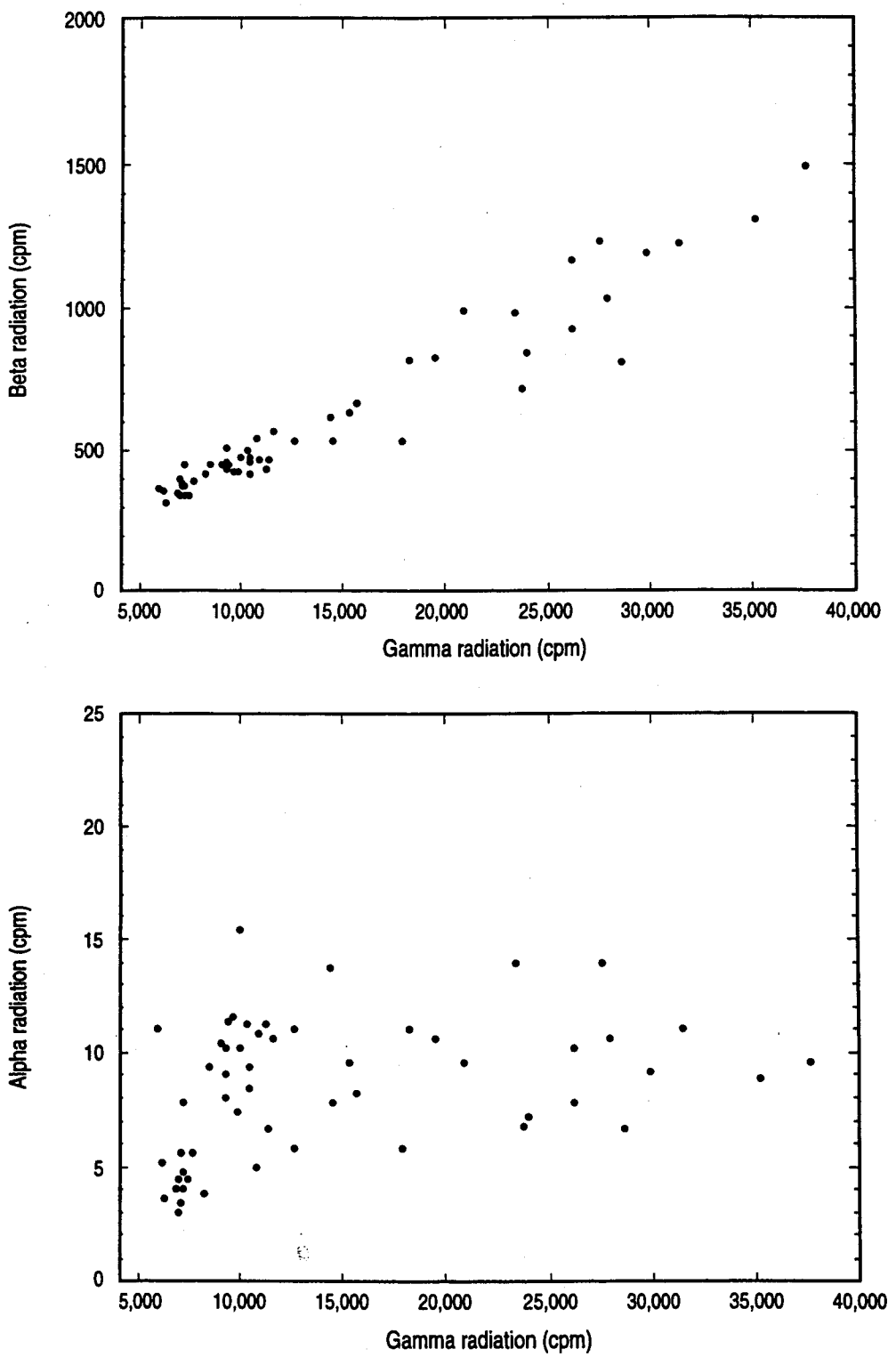
FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-2

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Alpha Radiation (cpm)	Beta Radiation (cpm)	Gamma Radiation (cpm)	Date
LA2-94		LA2-S22	LA-2 East	c3 (NE)	50			32413	6/3/97
					60			28164	6/3/97
					70			19454	6/3/97
					80			15200	6/3/97
					90			13518	6/3/97
					100			13338	6/3/97
LA2-95		LA-0100	LA-2 East	f1	0			8170	6/3/97
LA2-96		LA-0099	LA-2 East	f1b	0			13996	6/3/97

Alpha radiation in reach LA-2 West ranged from 0 to 11.2 cpm (25 measurements), and in the larger data set from reach LA-2 East (73 measurements) 8 measurements exceeded 11.2 cpm (Table B4-1). However, analytical data indicate that these measurements probably represent background variations because of the low levels of alpha-emitting radionuclides reported. For example, the highest alpha radiation measurement, 15.4 cpm, was made from the surface of a c2 unit at fixed-point site LA2-62, and plutonium-239,240 was reported at only 0.54 pCi/g and americium-241 at 0.95 pCi/g in a sample from this layer (sample 04LA-96-0146, Table 3.3-4). None of the measurements in DP Canyon exceeded 11 cpm.

Beta radiation in reach LA-2 West ranged from 306 to 424 cpm (23 measurements, Table B4-1). Beta radiation was clearly elevated above background value in reach LA-2 East, where 35 of 50 measurements exceeded 424 cpm, and in DP Canyon, where 5 of 6 measurements exceeded 424 cpm. The highest beta radiation measurement was 1496 cpm from the surface of the c3 unit of LA-2 East at fixed-point location LA2-71, which is also the unit that yielded the highest gamma radiation and the highest cesium-137 and strontium-90 results. A nearby sample site provided strontium-90 analyses of 30 to 35 pCi/g from the surface of this unit (samples 04LA-97-0054 and 04LA-97-0055), which is slightly less than the highest strontium-90 measured in LA-2 east (39.5 pCi/g). Beta radiation in LA-2 is well correlated to gamma radiation (Figure B4-4); therefore, the beta radiation provides no additional information for site characterization. Beta radiation due to chemicals of potential concern (COPCs) in Los Alamos Canyon is probably related to both strontium-90 and cesium-137. The concentrations of these two radionuclides are well correlated in upper Los Alamos Canyon (Section 3.2), which probably contributes to the correlation of beta and gamma radiation seen in these data.

Gamma radiation in reach LA-2 West ranged from 5032 to 6955 cpm (27 measurements, Table B4-1). Gamma radiation was clearly elevated above background values in reach LA-2 East, where only 6 of 316 measurements were less than 7000 cpm, and in DP Canyon, where all 6 measurements exceeded 7000 cpm. The highest gamma radiation measurement was 46,701 cpm from the c3 unit of LA-2 East, from a layer that yielded the highest cesium-137 concentration in Los Alamos Canyon (192 and 230 pCi/g in two sampling events, samples 04PU-96-0149 and 04PU-96-0222, Table 3.3-4). Gamma radiation measurements were made in 22 vertical sections at stream bank exposures in the c2, c2b, and c3 units of LA-2 East to define vertical variations in gamma radiation and to help select sample sites (Table B4-1). These depth profiles are shown in Figure B4-5 and are discussed further in Section 2.3.2.2.



FB4-4 / UPPER LOS ALAMOS CANYON REACH RPT / 110998

Figure B4-4. Scatter plots showing relationship of fixed-point alpha, beta, and gamma radiation measurements in reach LA-2.

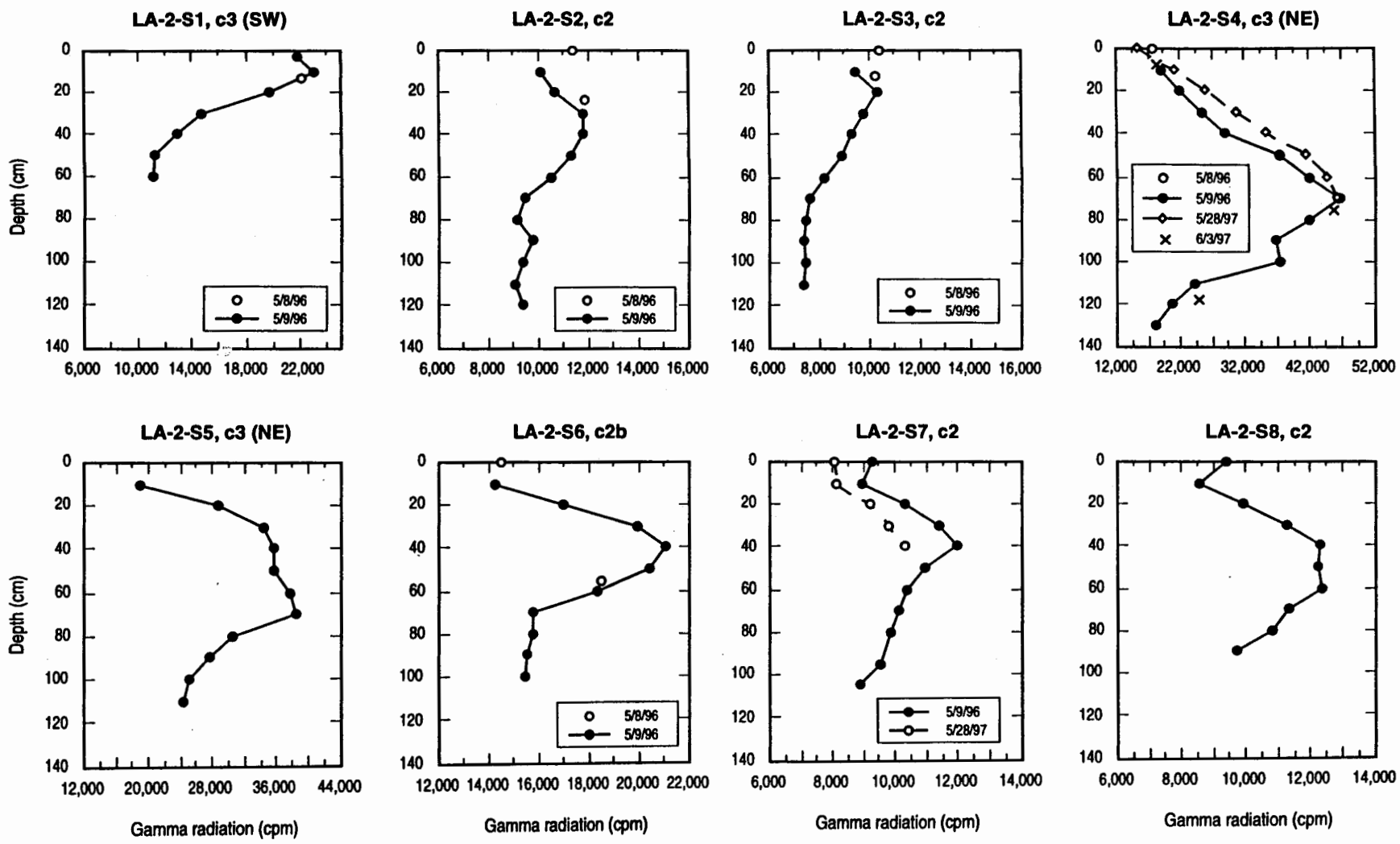


Figure B4-5a. Plots of gamma radiation versus depth for the c2, c2b, and c3 units in reach LA-2.

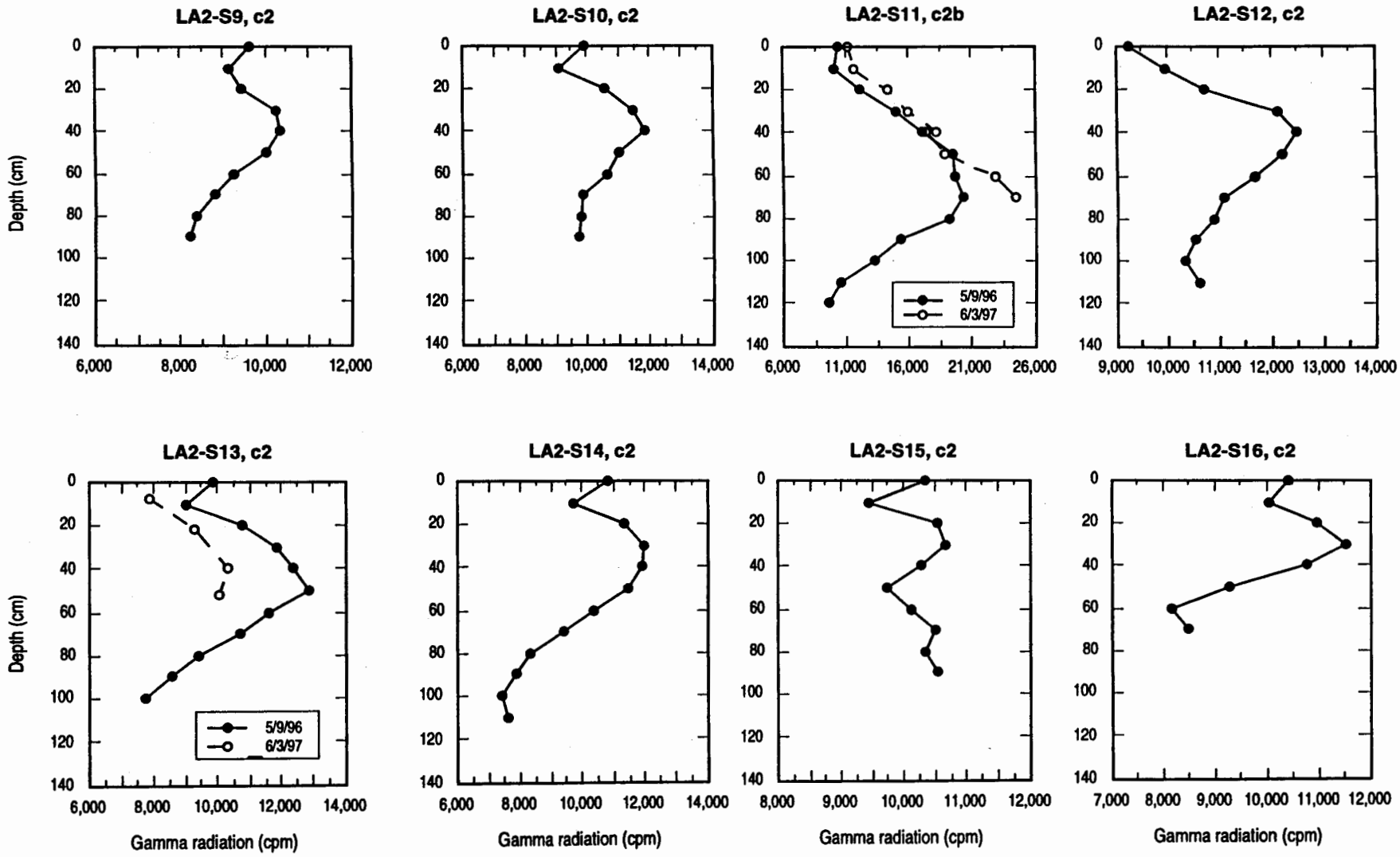
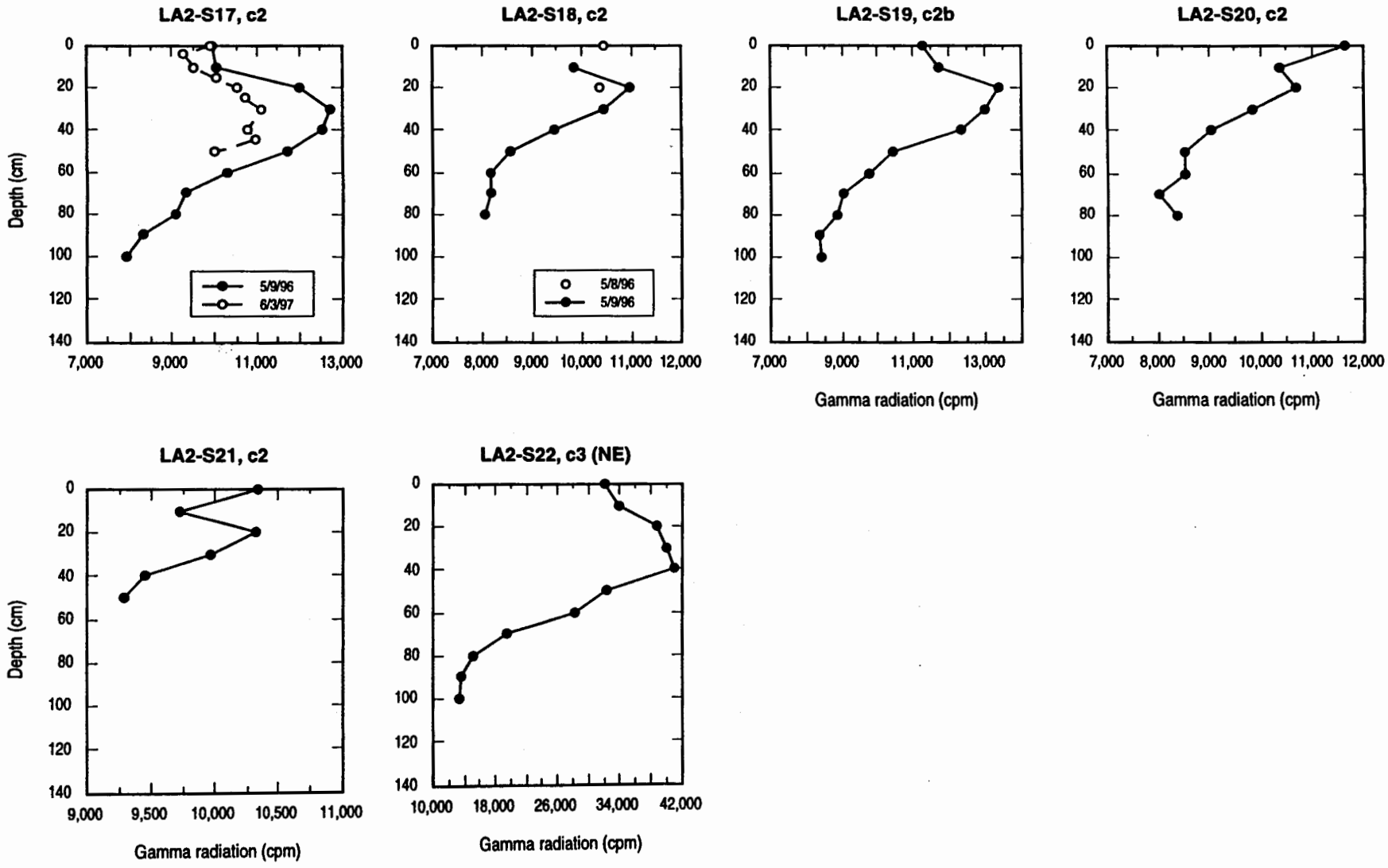


Figure B4-5b. Plots of gamma radiation versus depth for the c2, c2b, and c3 units in reach LA-2.



FB4-5c / UPPER LOS ALAMOS CANYON REACH RPT / 111198

Figure B4-5c. Plots of gamma radiation versus depth for the c2, c2b, and c3 units in reach LA-2.

B-4.2.2.3 *In Situ* Gamma Spectroscopy Survey

Thirteen *in situ* gamma spectroscopy measurements were made in reach LA-2 West, reach LA-2 East, and DP Canyon, in part to test the utility of this instrument in providing rapid estimates of the amount of gamma-emitting radionuclides present within the sediment. Two analytes were identified in the gamma spectroscopy analyses that are potential contaminants in upper Los Alamos Canyon: americium-241 and cesium-137. Cesium-137 was reported in every analysis at levels of from 0.2 to 53 pCi/g, and the relative variations in cesium-137 as estimated from the gamma spectroscopy measurements were consistent with measurements from fixed analytical laboratories (Table B4-2). The *in situ* measurements significantly underestimated the actual cesium-137 concentration by a factor of two or more at the sites with the highest concentrations of this radionuclide, but this may be due to the larger size of the gamma spectroscopy measurement area than the typical size of individual geomorphic units. Americium-241 was reported only in one *in situ* gamma spectroscopy measurement at a level of 0.0009 pCi/g. This was the measurement site where americium-241 was highest in the fixed laboratory analysis, although the fixed laboratory reported a much higher concentration of americium-241 (3.35 pCi/g, Table B4-2). Americium-241 was not detected using the *in situ* instrument at other sites where americium-241 was present at concentrations of up to 1.46 pCi/g. However, the ability to detect americium-241 may have been affected by the 1-m instrument height, and lowering the instrument might improve the accuracy of americium-241 measurements as well as the cesium-137 measurements.

TABLE B4-2

***IN SITU* GAMMA SPECTROSCOPY MEASUREMENTS IN REACH LA-2[a]**

Fixed-Point Site	Sample Location ID	Subreach	Geomorphic Unit	Cs-137	Am-241
LA2-4	LA-0016	DP Canyon	c2b	22 [87.82][b]	0.0009 [3.35]
LA2-9	LA-0017	LA-2 West	c1	0.214 [0.12]	ND[c] [0.034]
LA2-10	LA-0018	LA-2 West	f1	0.82 [1.6]	ND [0.043]
LA2-17	LA-0096	LA-2 East	c3 (SW)	53 [121]	ND [1.46]
LA2-30	LA-0024	LA-2 East	c3 (NE)	30.8 [27.85]	ND [0.348]
LA2-32		LA-2 East	c2b	15.0	ND
LA2-33		LA-2 East	c1	2.61	ND
LA2-41		LA-2 East	c1	22.0	ND
LA2-42		LA-2 East	c3 (NE)	38.6	ND
LA2-43		LA-2 East	c2b	23.2	ND
LA2-48	LA-0019	LA-2 East	c2	4.88 [5.77]	ND [1.13]
LA2-61	LA-0023	LA-2 East	c1	6.1 [2.12]	ND [0.278]
LA2-62	LA-0022	LA-2 East	c2	5.5 [4.76]	ND [0.95]

a. pCi/g
b. Values in brackets from fixed laboratory analysis for comparison with the gamma spectroscopy analysis
c. ND = not detected

B-4.2.3 Reach LA-3

B-4.2.3.1 Gross Gamma Radiation Walkover Survey

A gross gamma radiation walkover survey was performed in reach LA-3 in April 1996 using the USRADS method (by CHEMRAD), and gross gamma radiation data were obtained from 17,128 points using 1-second count times. Locations of the measurement points are shown on Figures 2.3-18 and 2.3-19, and the raw data are archived in FIMAD. The highest value, 6840 cpm, was from the c3 unit and is comparable to measurements from the c2b unit in LA-2 East. These measurements are discussed further in Section 2.3.3.2.

B-4.2.3.2 Fixed-Point Gamma Radiation Survey

A total of 307 fixed-point gross gamma radiation measurements were made at 82 sites in reach LA-3 (Figures B4-6 and B4-7; Table B4-3). These sites included 31 vertical sections through stream banks in the c2, c3, f1, and Qt units (Figure B4-8). Local background values for gamma radiation in the young sediments of LA-3 may be largely similar to those in reach LA-2 West where gamma radiation ranged from approximately 5000 to 7000 cpm (Section B-4.2.2.2), although some higher measurements were obtained from pre-1942 sediments in LA-3. Surface measurements from the Qt unit of LA-3 ranged from 6471 to 6955 cpm, but values exceeded 8000 cpm at depths of 0.7 to 0.9 m in two Qt sections (fixed-point sites LA3-16 and LA3-19). An increase in radiation with depth was consistent in both of these Qt sections and may be due to geometric effects and not to increases in radionuclides in these layers.

The highest gamma radiation measurement in reach LA-3 was 11,038 cpm from a depth of 0.45 m in the c3 unit at fixed-point site LA3-7. This is the same site that provided the highest cesium-137 concentration (13.8 pCi/g in sample 04LA-97-0137, Table 3.3-7), although this cesium-137 value was obtained from a shallower layer (0.22 to 0.32 m). It is notable that in five of the six sampled sections in LA-3 the layer with the highest field gamma measurement did not correspond to the layer with the highest cesium-137, indicating that the gamma measurements are not reliable at this level of detail in LA-3. However, the field measurements were accurate in indicating the sections with higher levels of cesium-137, which validated the use of the field instruments in defining geomorphic mapping units (i.e., distinguishing c2 from c3 based on higher levels of gamma radiation in the latter). The fixed-point gamma radiation measurements are discussed further in Section 2.3.3.2.

B-5.0 SEDIMENT SAMPLING EVENTS

Sediment sampling in this investigation followed a phased approach, which focused on sequentially reducing uncertainties about the nature and extent of contamination in each reach and on testing components of the conceptual model. The chronology of sampling events in upper Los Alamos Canyon and the primary goals of each sampling event are summarized in Table B5-1.

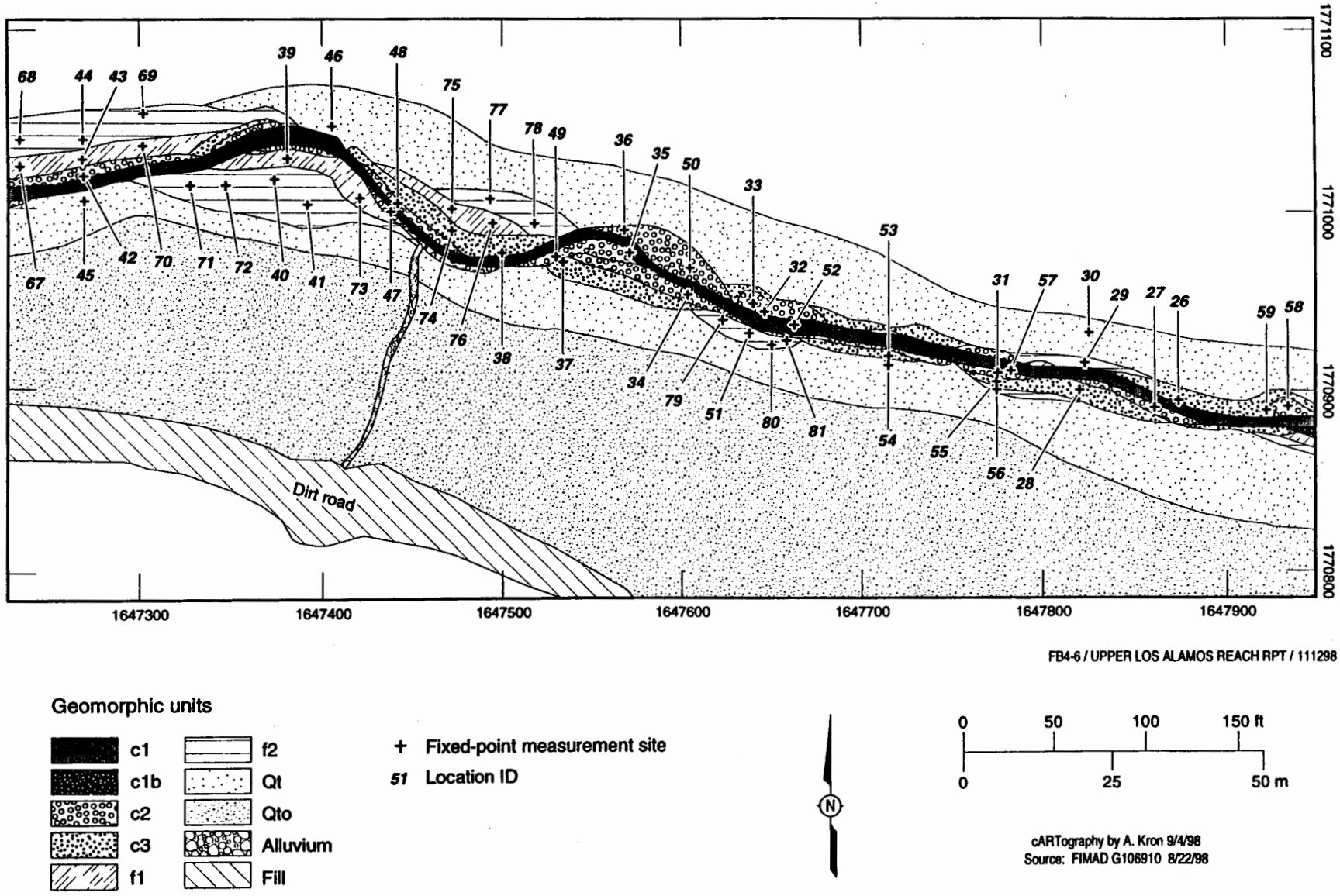


Figure B4-6. Map of west half of reach LA-3 showing fixed-point radiation measurement sites.

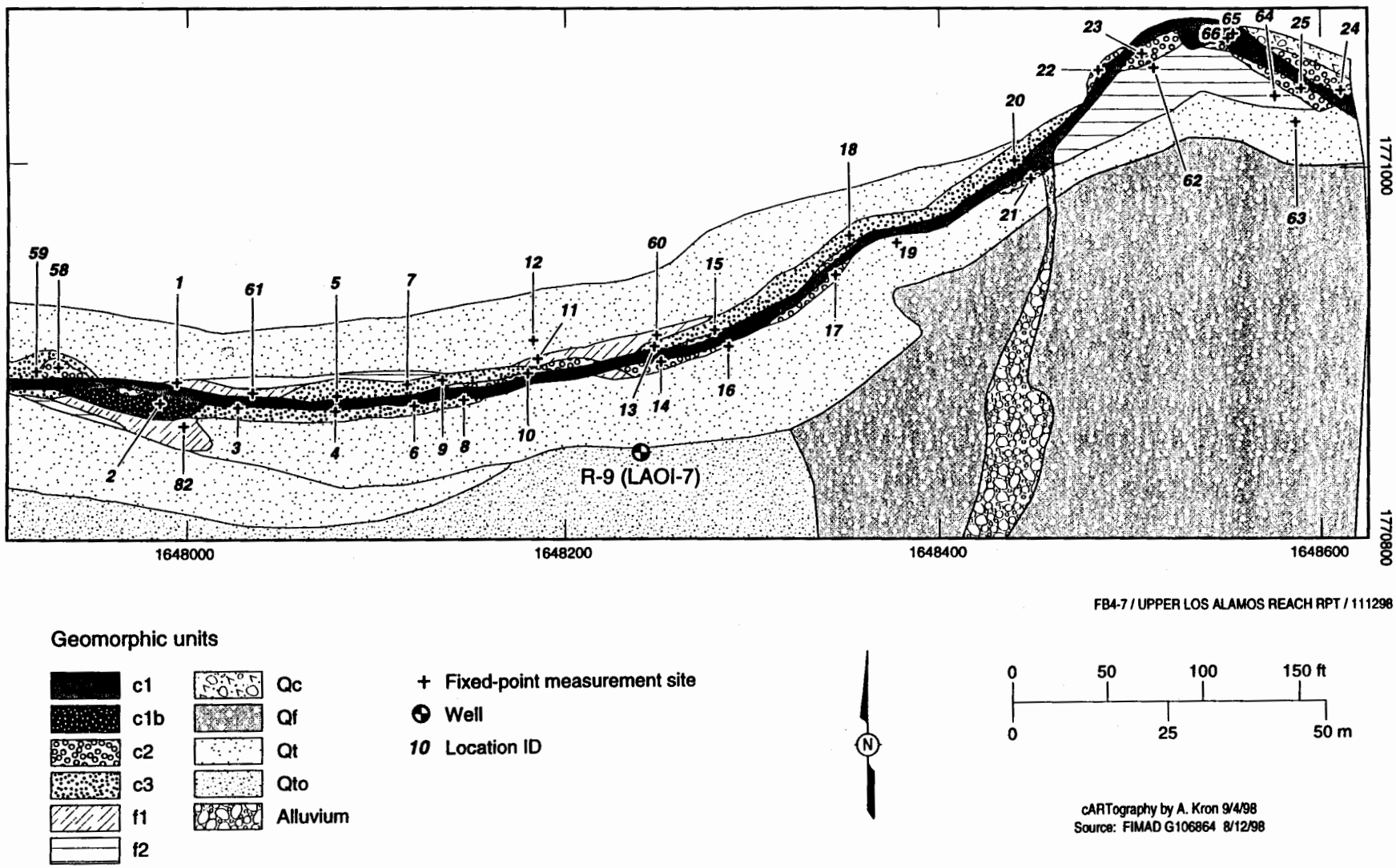


Figure B4-7. Map of east half of reach LA-3 showing fixed-point radiation measurement sites.

TABLE B4-3

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-3

Fixed-Point Site	Section ID	Profile Bin	Sample Location ID	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)	Date
LA3-1	LA3 S1	5	LA-0117	f1? (c3?)	0	7173	5/28/97
					10	7443	5/28/97
					20	7629	5/28/97
					30	7837	5/28/97
					40	8159	5/28/97
					50	8212	5/28/97
					60	7898	5/28/97
					70	8058	5/28/97
					19	8403	6/27/97
					37	8618	6/27/97
					60	8500	6/27/97
					83	8385	6/27/97
LA3-2				c1b	0	6636	5/28/97
LA3-3	LA3 S2	1		c3	0	7978	5/28/97
					10	8287	5/28/97
					20	9294	5/28/97
					30	9552	5/28/97
					40	9153	5/28/97
					50	8598	5/28/97
					60	8246	5/28/97
LA3-4	LA3 S3			c3	0	8357	5/28/97
					10	8208	5/28/97
					20	10363	5/28/97
					30	10537	5/28/97
					40	10011	5/28/97
					50	9495	5/28/97
					60	8748	5/28/97
					70	8987	5/28/97
LA3-5				c3?	0	9041	5/28/97
LA3-6	LA3 S4	3		c3?	0	8536	5/28/97
					10	8001	5/28/97
					20	9307	5/28/97
					30	9222	5/28/97
					40	8879	5/28/97
					50	8536	5/28/97
					60	8519	5/28/97
LA3-7	LA3 S5	1	LA-0109	c3	0	7828	5/28/97
					10	8400	5/28/97
					20	9545	5/28/97
					30	10305	5/28/97
					40	10695	5/28/97
					50	10337	5/28/97
					60	10194	5/28/97

TABLE B4-3 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-3

Fixed-Point Site	Section ID	Profile Bin	Sample Location ID	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)	Date
LA3-7	LA3 S5	1	LA-0109	c3	70	9698	5/28/97
					80	8879	5/28/97
					90	8767	5/28/97
					100	8627	5/28/97
					11	9494	6/27/97
					27	10783	6/27/97
					36.5	10809	6/27/97
					45.5	11038	6/27/97
					56	10784	6/27/97
					71	10611	6/27/97
					84	11036	6/27/97
					95.5	10587	6/27/97
LA3-8	LA3 S6	4		c3?	0	7789	5/28/97
					10	7556	5/28/97
					20	8765	5/28/97
					30	8882	5/28/97
					40	8379	5/28/97
					50	8082	5/28/97
					60	7956	5/28/97
					70	7946	5/28/97
					80	8001	5/28/97
LA3-9				c3?	0	9140	5/28/97
LA3-10				c2	0	6254	5/28/97
LA3-11				f1	0	6763	5/28/97
LA3-12				Qt	0	6868	5/28/97
LA3-13	LA3 S7	3		c3?	0	8543	5/28/97
					10	8733	5/28/97
					20	9043	5/28/97
					30	8976	5/28/97
					40	8716	5/28/97
					50	8403	5/28/97
					60	8391	5/28/97
LA3-14				c2	0	7646	5/28/97
LA3-15	LA3 S8	4		c3?	0	7492	5/28/97
					10	7686	5/28/97
					20	8794	5/28/97
					30	8861	5/28/97
					40	9002	5/28/97
					50	8828	5/28/97
					60	8481	5/28/97
					70	8456	5/28/97

TABLE B4-3 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-3

Fixed-Point Site	Section ID	Profile Bin	Sample Location ID	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)	Date
LA3-16	LA3 S9	B		Qt	0	6760	5/28/97
					10	6649	5/28/97
					20	6567	5/28/97
					30	6684	5/28/97
					40	6961	5/28/97
					50	6791	5/28/97
					60	6908	5/28/97
					70	7135	5/28/97
					80	7631	5/28/97
					90	8049	5/28/97
LA3-17	LA3 S10	5		c2	0	7775	5/28/97
					10	7732	5/28/97
					20	7897	5/28/97
					30	8082	5/28/97
					40	7826	5/28/97
LA3-18	LA3 S11	4	LA-0110	c3?	0	7585	5/28/97
					10	7738	5/28/97
					20	8443	5/28/97
					30	8826	5/28/97
					40	9106	5/28/97
					50	8900	5/28/97
					60	8673	5/28/97
					70	8351	5/28/97
					6.5	8474	6/27/97
					16	8694	6/27/97
					23.5	9226	6/27/97
					34	9309	6/27/97
					46	9233	6/27/97
					67.5	8652	6/27/97
LA3-19	LA3 S12	B		Qt	0	6955	5/28/97
					10	6503	5/28/97
					20	7128	5/28/97
					30	7472	5/28/97
					40	7832	5/28/97
					50	7867	5/28/97
					60	7826	5/28/97
					70	8111	5/28/97
					80	8131	5/28/97
LA3-20	LA3 S13	2		c3?	0	8455	5/28/97
					10	8516	5/28/97
					20	9108	5/28/97
					30	9719	5/28/97
					40	9754	5/28/97

TABLE B4-3 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-3

Fixed-Point Site	Section ID	Profile Bin	Sample Location ID	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)	Date
LA3-20	LA3 S13	2		c3?	50	9701	5/28/97
					60	9045	5/28/97
					70	8762	5/28/97
					80	8766	5/28/97
					90	8198	5/28/97
LA3-21	LA3 S14	5		c2	0	8094	5/28/97
					10	7797	5/28/97
					20	7938	5/28/97
					30	8302	5/28/97
					40	8247	5/28/97
LA3-22	LA3 S15	6		c2	0	7313	5/28/97
					10	6855	5/28/97
					20	6999	5/28/97
					30	7602	5/28/97
LA3-23	LA3 S16	5		c2	0	7525	5/28/97
					10	7425	5/28/97
					20	7880	5/28/97
					30	8111	5/28/97
					40	8215	5/28/97
LA3-24	LA3 S17	5	LA-0111	c2	0	7769	5/28/97
					10	7585	5/28/97
					20	8209	5/28/97
					30	8546	5/28/97
					40	8415	5/28/97
					50	7866	5/28/97
					60	7634	5/28/97
					70	8021	5/28/97
					80	7614	5/28/97
					8	8778	6/27/97
					22	9249	6/27/97
					31	9481	6/27/97
					48.5	9291	6/27/97
					71.5	8269	6/27/97
LA3-25	LA3 S18	6		c2	0	7712	5/28/97
					10	6732	5/28/97
					20	6925	5/28/97
					30	6814	5/28/97
					40	7314	5/28/97
LA3-26	LA3 S19	3		c3	0	8134	5/28/97
					10	8169	5/28/97
					20	9180	5/28/97
					30	9165	5/28/97
					40	8924	5/28/97

TABLE B4-3 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-3

Fixed-Point Site	Section ID	Profile Bin	Sample Location ID	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)	Date
LA3-26	LA3 S19	3		c3	50	8939	5/28/97
					60	8945	5/28/97
					70	9227	5/28/97
LA3-27	LA3 S20	5		c2	0	7365	5/28/97
					10	7011	5/28/97
					20	7690	5/28/97
					30	7825	5/28/97
					40	8088	5/28/97
LA3-28	LA3 S21	3	LA-0115	c3	0	7747	5/28/97
					10	7989	5/28/97
					20	8800	5/28/97
					30	9205	5/28/97
					40	9457	5/28/97
					50	9357	5/28/97
					60	8814	5/28/97
LA3-29				f2	0	6867	5/28/97
LA3-30				Qt	0	6471	5/28/97
LA3-31				c2	0	6648	5/28/97
LA3-32	LA3 S22	5		c2	0	7093	5/28/97
					10	7100	5/28/97
					20	7704	5/28/97
					30	8329	5/28/97
					40	8057	5/28/97
LA3-33	LA3 S23	5		c2	0	7422	5/28/97
					10	7240	5/28/97
					20	7564	5/28/97
					30	7866	5/28/97
					40	7970	5/28/97
					50	8276	5/28/97
LA3-34	LA3 S24	5		c2	0	8055	5/28/97
					10	7598	5/28/97
					20	8015	5/28/97
					30	8325	5/28/97
					40	8250	5/28/97
					50	8168	5/28/97
LA3-35	LA3 S25	6	LA-0114	c2	0	7474	5/28/97
					10	7395	5/28/97
					20	7369	5/28/97
					30	7256	5/28/97
					40	7584	5/28/97
					50	7063	5/28/97
					60	6892	5/28/97
					70	6997	5/28/97

TABLE B4-3 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-3

Fixed-Point Site	Section ID	Profile Bin	Sample Location ID	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)	Date
LA3-35	LA3 S25	6	LA-0114	c2	8	7722	6/27/97
					24	8882	6/27/97
					40.5	8359	6/27/97
					55	7832	6/27/97
					75.5	8003	6/27/97
LA3-36				c2	0	7267	5/28/97
LA3-37	LA3 S26	4		c3?	0	8067	5/28/97
					10	8349	5/28/97
					20	8256	5/28/97
					30	8672	5/28/97
					40	9143	5/28/97
					50	8792	5/28/97
LA3-38	LA3 S27	2		c3	0	7548	5/28/97
					10	7601	5/28/97
					20	8625	5/28/97
					30	8881	5/28/97
					40	9559	5/28/97
					50	9856	5/28/97
LA3-39	LA3 S28	5	LA-0118	f1	0	8643	5/28/97
					10	7650	5/28/97
					20	7880	5/28/97
					30	8380	5/28/97
					40	8213	5/28/97
					50	8134	5/28/97
					60	8190	5/28/97
					8.5	8204	6/27/97
					31.5	8288	6/27/97
					59	8088	6/27/97
LA3-40			LA-0120	f2	0	6700	5/28/97
					0	7140	6/27/97
LA3-41				f2	0	6725	5/28/97
					0	6927	6/27/97
LA3-42	LA3 S29	5		c2	0	7451	5/28/97
					10	7642	5/28/97
					20	8209	5/28/97
					30	8195	5/28/97
					40	8064	5/28/97
LA3-43				f1	0	7384	5/28/97
LA3-43				f1	0	8196	6/27/97
LA3-44				f2	0	6709	5/28/97
					0	7216	6/27/97
LA3-45				Qt	0	6969	5/28/97

TABLE B4-3 (continued)

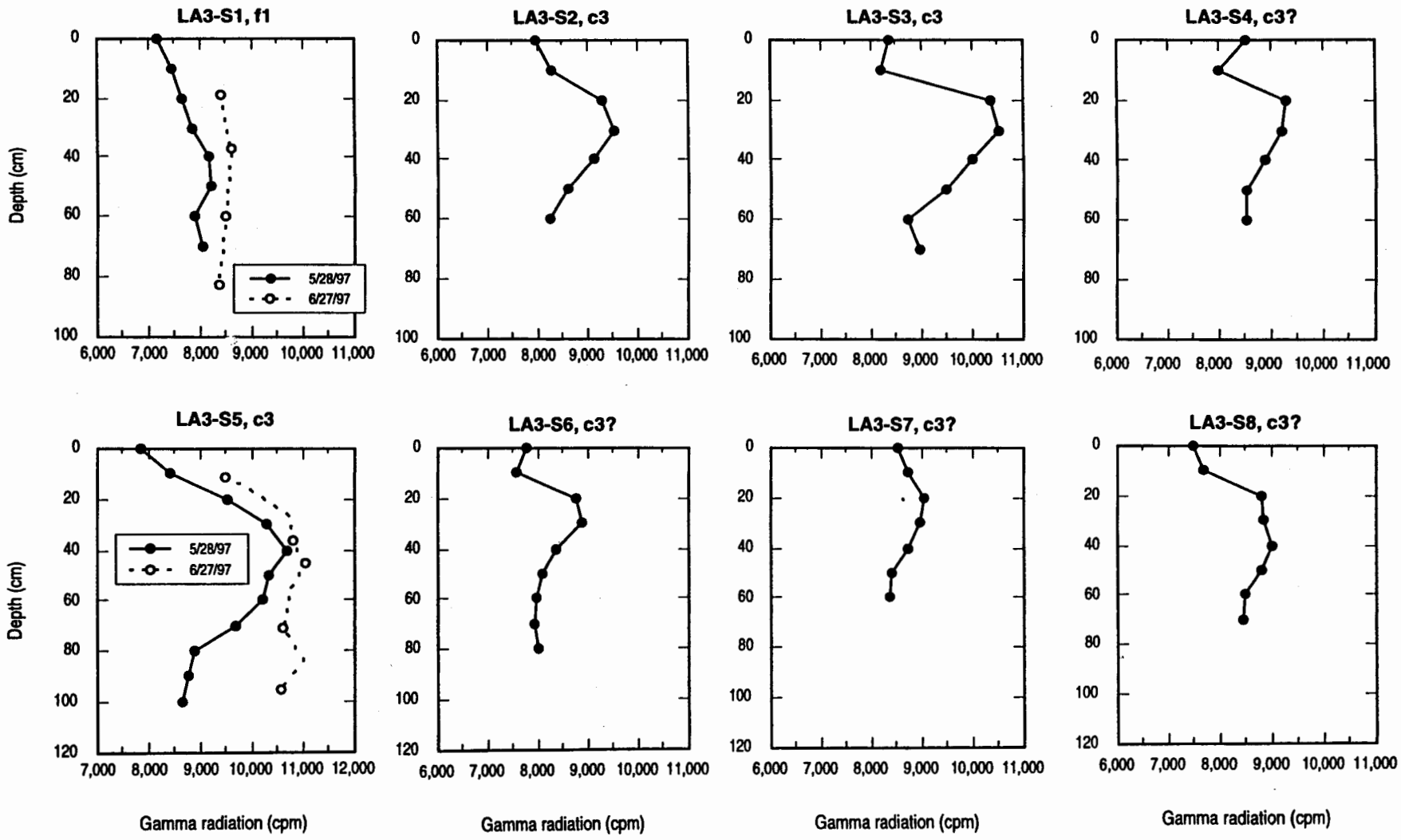
FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-3

Fixed-Point Site	Section ID	Profile Bin	Sample Location ID	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)	Date
LA3-46				Qt	0	6510	5/28/97
LA3-47	LA3 S30	5		c2	0	7305	5/28/97
					10	7320	5/28/97
					20	7808	5/28/97
					30	8156	5/28/97
					40	8096	5/28/97
					50	8016	5/28/97
					60	7823	5/28/97
LA3-48				c2	0	7100	5/28/97
LA3-49				c2	0	6887	5/28/97
LA3-50				c2	0	6779	5/28/97
LA3-51				f2	0	6683	5/28/97
LA3-52				c1	0	6410	5/28/97
LA3-53				c3?	0	7435	5/28/97
LA3-54				Qt	0	6534	5/28/97
LA3-55				c3?	0	7936	5/28/97
LA3-56				f2	0	6605	5/28/97
LA3-57				c1	0	6543	5/28/97
LA3-58				c2	0	7749	5/28/97
LA3-59				c3?	0	8338	5/28/97
LA3-60				f1	0	7525	5/28/97
LA3-61	LA3 S31	4-5		f1	0	7652	5/28/97
					10	8099	5/28/97
					20	8643	5/28/97
					30	8684	5/28/97
					40	8346	5/28/97
					50	8278	5/28/97
					60	8016	5/28/97
					70	7718	5/28/97
					80	8048	5/28/97
LA3-62			LA-0113	f2	0	6979	5/28/97
LA3-63				Qt	0	6846	5/28/97
LA3-64				f2	0	6911	5/28/97
LA3-65				c1	0	5723	5/28/97
					0	7120	6/27/97
LA3-66			LA-0112	c1	0	7049	6/27/97
LA3-67				f1	0	8975	6/27/97
LA3-68				f2	0	6965	6/27/97
LA3-69				f2?	0	7598	6/27/97
LA3-70				f1	0	8770	6/27/97
LA3-71				f2	0	6987	6/27/97
LA3-72				f2	0	7078	6/27/97

TABLE B4-3 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-3

Fixed-Point Site	Section ID	Profile Bin	Sample Location ID	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)	Date
LA3-73				f1	0	8165	6/27/97
LA3-74				c3	0	8885	6/27/97
LA3-75				f1	0	8571	6/27/97
LA3-76			LA-0121	f1	0	8157	6/27/97
LA3-77				f2?	0	7146	6/27/97
LA3-78				f2?	0	6898	6/27/97
LA3-79				f2	0	7164	6/27/97
LA3-80				f2	0	6768	6/27/97
LA3-81				f2	0	7502	6/27/97
LA3-82				f1	0	7966	6/27/97



FB4-8a / UPPER LOS ALAMOS CANYON REACH RPT / 111098

Figure B4-8a. Plots of average gamma radiation versus depth for the c3 and f1 units in reach LA-3.

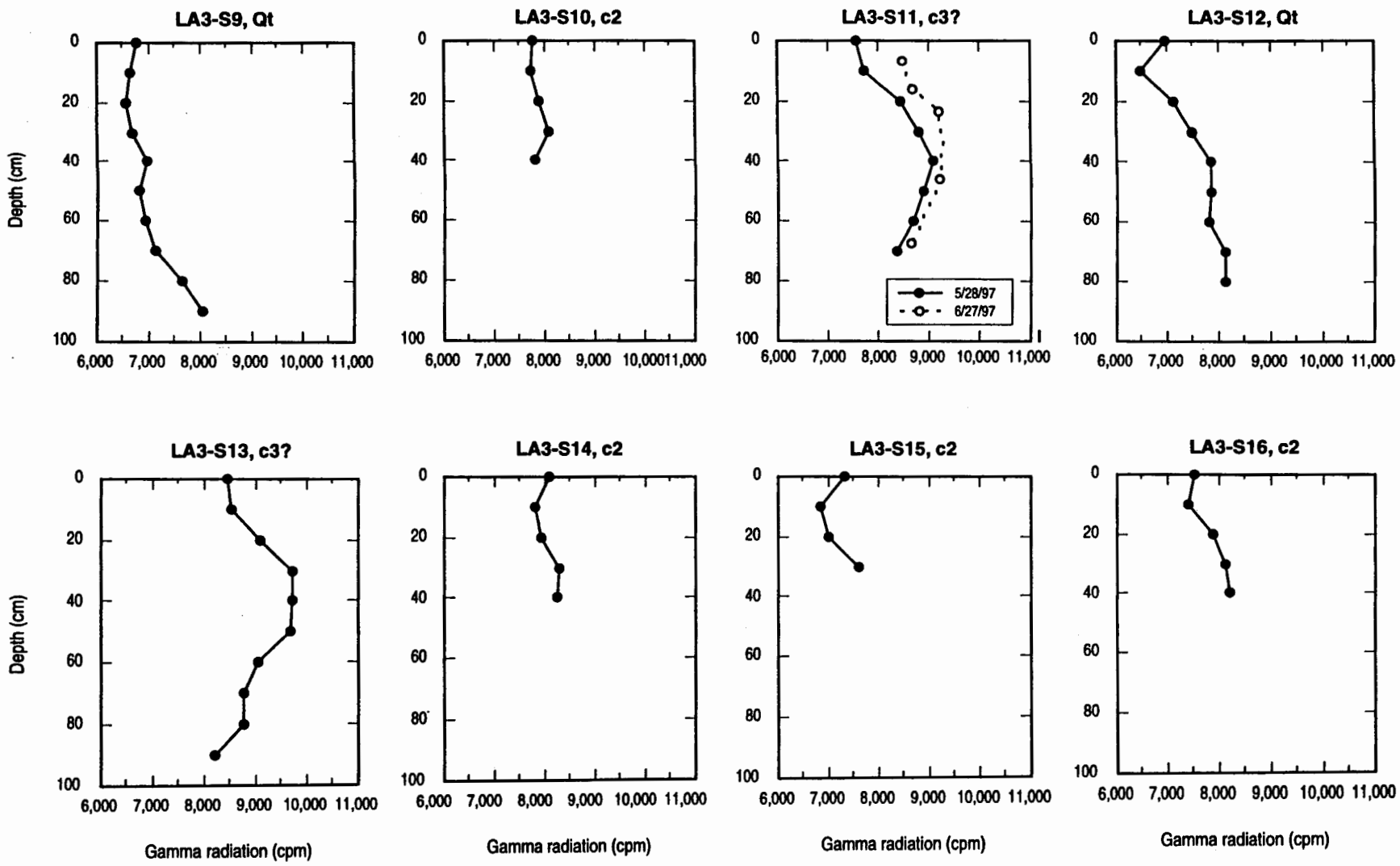


Figure B4-8b. Plots of average gamma radiation versus depth for the c2, c3, and Qt units in reach LA-3.

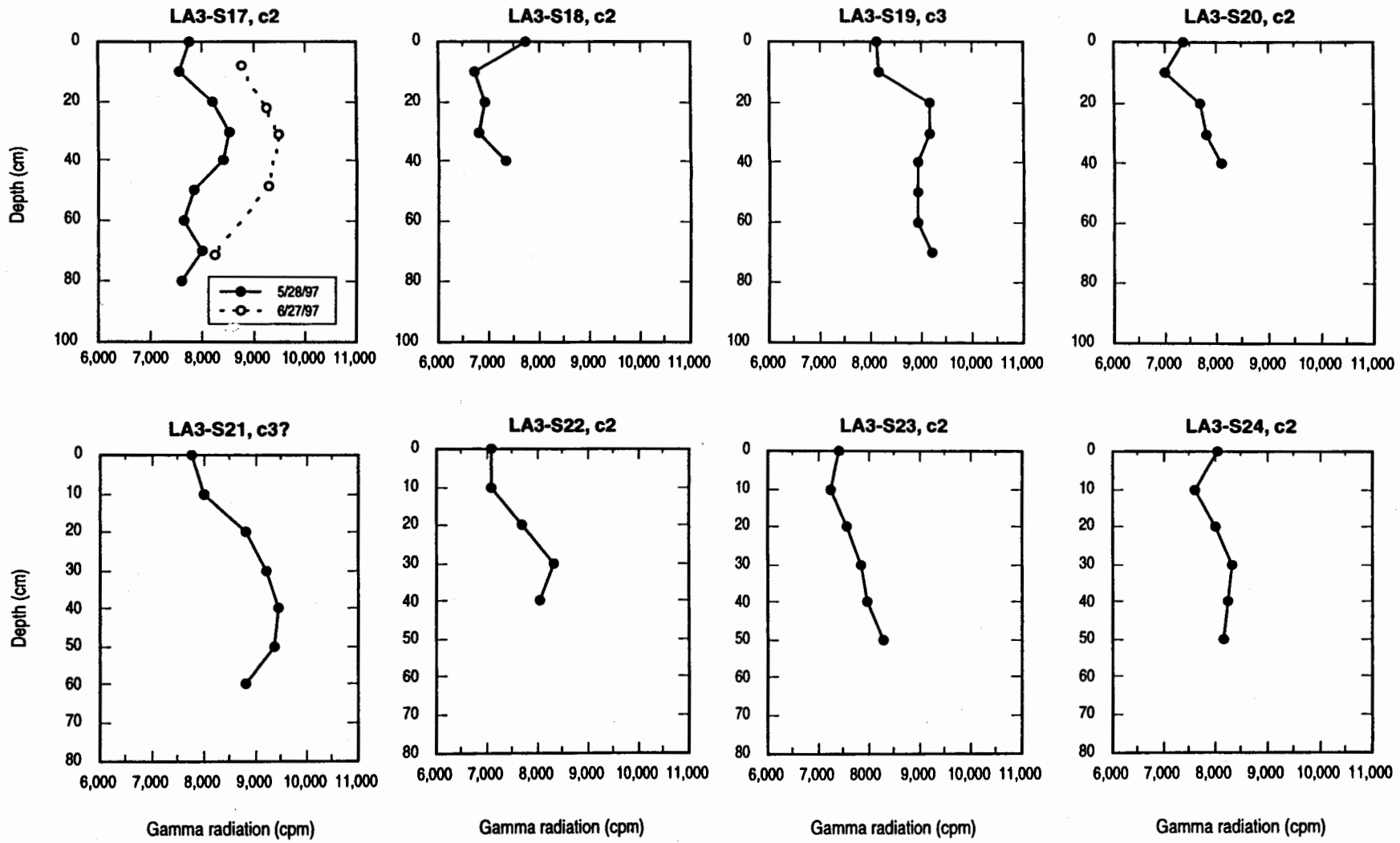
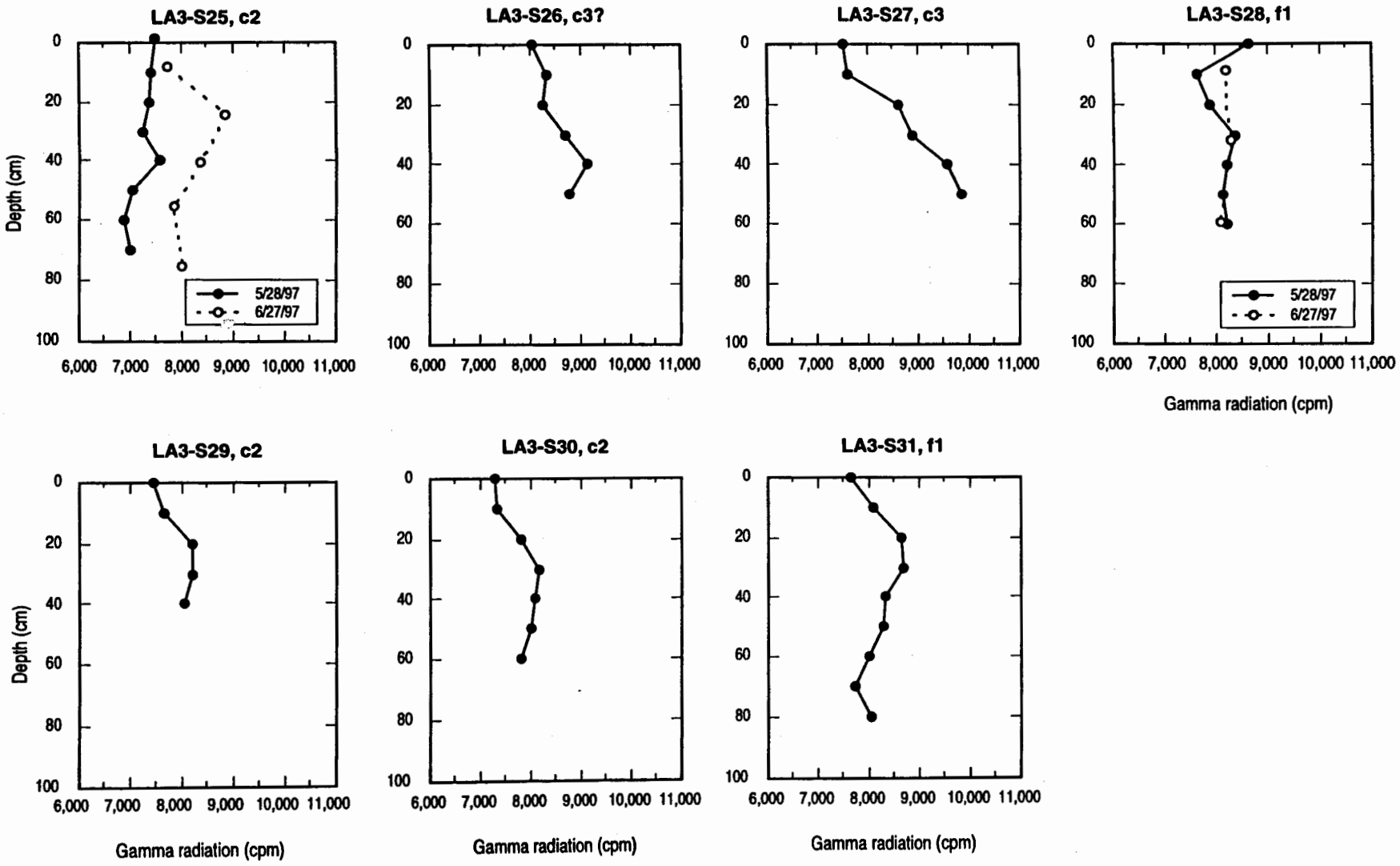


Figure B4-8c. Plots of average gamma radiation versus depth for the c2 and c3 units in reach LA-3.



FB4-8d / UPPER LOS ALAMOS CANYON REACH RPT / 111198

Figure B4-8d. Plots of average gamma radiation versus depth for the c2, c3, and f1 units in reach LA-3.

TABLE B5-1

SUMMARY OF SEDIMENT SAMPLING EVENTS IN UPPER LOS ALAMOS CANYON

Reach	Sampling Event	Sampling Dates	Number of Samples Collected*	Type of Analyses and Primary Goals
LA-1	1	9/11/97–9/12/97	41	Plutonium analyses plus limited-suite analyses on 11 samples; examine general variations in contaminants between geomorphic units and between subreaches and sources for contaminants; evaluate vertical variations in plutonium concentration; provide initial estimate of plutonium inventory; determine contaminants present above background values
LA-1	2	11/18/97–11/19/97	44	Plutonium analyses plus limited-suite analyses on 16 samples; evaluate concentrations of limited-suite analytes in all subreaches and sources for contaminants in LA-1 West; reduce uncertainty in plutonium inventory
LA-2	1	5/15/97	10	Full-suite analyses; determine contaminants present above background values and primary risk drivers; examine general variations in contaminants between geomorphic units
LA-2	2	9/24/96	18	Cesium analyses plus 15 strontium-90 analyses; evaluate vertical variations in cesium concentration; provide estimate of cesium inventory; evaluate collocation of cesium and strontium
LA-2	3	6/5/97–6/6/97	36	Cesium analyses on 30 samples, plutonium analyses on 30 samples, strontium-90 analyses on 22 samples, plus other limited-suite analyses on 2 samples; reduce uncertainty in cesium inventory in LA-2 East; evaluate horizontal and vertical distribution of plutonium and strontium-90 in LA-2 West; evaluate collocation of cesium and strontium in LA-2 East; use isotopic ratios to evaluate sediment age in LA-2 East
LA-2	4	11/19/97	13	Plutonium analyses plus limited-suite analyses on 2 samples; reduce uncertainty in plutonium inventory in LA-2 West; evaluate reliability of earlier strontium-90 analyses and concentrations of limited-suite analytes
LA-3	1	7/7/97–7/8/97	42	Cesium analyses plus full-suite analyses on 6 samples and limited-suite analyses on 13 additional samples; confirm horizontal and vertical variations in cesium concentration as estimated from field radiation measurements; provide estimate of cesium inventory; determine suite of contaminants above background values at Laboratory boundary; evaluate possible additions of contaminants downstream from LA-2; evaluate collocation of contaminants; use isotopic ratios to evaluate sediment age

*Number of samples does not include quality assurance duplicates.

Appendix C

Results of Quality Assurance/Quality Control Activities

APPENDIX C RESULTS OF QUALITY ASSURANCE/QUALITY CONTROL ACTIVITIES

C-1.0 SUMMARY OF QUALITY ASSURANCE/QUALITY CONTROL ACTIVITIES

The upper Los Alamos Canyon data set consists of analytical results from sediment samples collected from reaches LA-1, LA-2, and LA-3, as described in the body of this report. Most of the data set for upper Los Alamos Canyon is composed of isotopic and gamma-emitting radionuclides. Selected samples were also analyzed for inorganic chemicals, semivolatile organic compounds (SVOCs), organochlorine pesticides, and polychlorinated biphenyls (PCBs). The summary of the analytical suites and method descriptions are included in Sections C-2.0, C-3.0, and C-4.0.

A total of five different off-site fixed laboratories performed the analyses for samples collected from upper Los Alamos Canyon. Quality assurance (QA), quality control (QC), and data validation procedures were implemented in accordance with the requirements of the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* (LANL 1995, 50290), the *Quality Assurance Project Plan Requirements for Sampling and Analysis* (LANL 1996, 54609), and the Laboratory Environmental Restoration (ER) Project analytical services statement of work (SOW) for contract laboratories (LANL 1995, 49738).

The results of the QA/QC activities were used to estimate accuracy, bias, and precision of the analytical measurements. QC samples including laboratory blank samples, surrogates, matrix spikes, and laboratory control samples (LCSs) were used to assess accuracy and bias. Duplicate QC samples were used to determine precision. The type and frequency of QC analyses are described in the ER Project analytical services SOW (LANL 1995, 49738). Other QC factors such as sample preservation and holding times were also assessed. The requirements for sample preservation and holding times are given in the ER Project standard operating procedure LANL-ER-SOP-1.02, Rev. 0, "Sample Containers and Preservation." Evaluating these QC indicators allows estimates to be made of the accuracy, bias, and precision of the analytical suites.

The results for individual samples were qualified, as necessary, using the ER Project data validation process by assessing the QC parameters listed above. The ER Project data validation process adheres to the Environmental Protection Agency (EPA) *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (NFG) (EPA 1994, 48639) for data validation and incorporates Laboratory-specific reason codes for qualifying data. Data packages received from each analytical laboratory were reviewed with respect to the NFG and Laboratory quality procedures for data validation. Data validation results, including sample IDs and their associated qualifiers, are located in Section C-5.0.

A focused data validation was also performed for most of the data packages (also referred to as request numbers [RN]), including those listed in the following sections. The focused validation followed the same procedure discussed above and included a more detailed review of the raw data results generated by the analytical laboratories. In some cases, manual calculations were performed or reviewed to confirm QC results.

In general, the data appear to be of acceptable quality, and most of the data, including the qualified data, are usable for evaluation and interpretive purposes. As discussed in the following text, some of the qualified data should be considered estimated (J-qualified). Overall, the entire data set meets the standards set for use in this report with the exception of the rejection of all organic data from reach LA-3 and most antimony data from reach LA-2. Discussions of data usability are addressed in Section 3.1, and definitions of the qualifiers used in the analyses are presented in Section C-5.0.

C-1.1 Samples Collected

A total of 246 field samples were submitted for analysis at off-site fixed laboratories The number of samples collected and analyzed from each reach is summarized in Table C1-1.

TABLE C1-1

NUMBER OF SAMPLES COLLECTED BY REACH AND ANALYTICAL SUITE

Analytical Suite	Reach			Total
	LA-1	LA-2	LA-3	
PCBs	9	2	0	11
Pesticides and PCBs	16	12	8	36
SVOCs	0	12	8	20
Inorganic chemicals	27	14	8	49
Cyanide	0	10	8	18
Uranium, titanium	0	10	8	18
Boron	0	8	0	8
Americium-241 (by alpha spectroscopy)	11	12	8	31
Gross alpha/beta radiation	0	10	8	18
Gross gamma radiation	0	10	8	18
Gamma spectroscopy radionuclides	11	59	46	116
Tritium	0	12	8	20
Isotopic plutonium	85	55	21	161
Isotopic thorium	0	10	8	18
Isotopic uranium	20	14	8	42
Radium-226	0	2	0	2
Strontium-90	3	51	19	73

Summaries of the analytical methods and suites are provided in the following sections for inorganic chemical, radiochemical, and organic chemical analyses. The contract required detection limit (CRDL), also referred to as the maximum estimated quantitation limit (EQL), for each of the analytes listed is provided in Appendix D-1.0. These limits are also detailed in the ER Project analytical services SOW (LANL 1995, 49738).

C-2.0 INORGANIC CHEMICAL ANALYSES

C-2.1 General

A total of 49 surface and subsurface sediment samples were collected in upper Los Alamos Canyon for inorganic chemical analyses. The total includes 27 samples from LA-1, 14 samples from LA-2, and 8 samples from LA-3. These samples were analyzed by one or more of the following EPA SW-846 methods: Method 6010A (inductively coupled plasma emission spectroscopy [ICPES]), Method 6020 (inductively coupled plasma mass spectrometry [ICPMS]), Method 7000-series (graphite furnace atomic absorption [GFAA]), and Method 7471 (cold vapor atomic absorption [CVAA]) (EPA 1987, 57589). The

methods are summarized in Table C2-1. The EPA SW-846 analyses were performed at off-site fixed laboratories. Holding times were met for all inorganic chemical analyses.

TABLE C2-1

ANALYTICAL METHODS FOR INORGANIC CHEMICAL ANALYSES*

Analytical Method	Analytical Description	Analytical Suite
EPA SW-846 Method 6010 (3050A)	Inductively coupled plasma emission spectroscopy (ICPES)	Aluminum, antimony, arsenic, barium, beryllium, boron, calcium, cadmium, cobalt, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, selenium, sodium, silver, thallium, titanium, vanadium, and zinc
EPA SW-846 Method 6020 (3050A)	Inductively coupled plasma mass spectrometry (ICPMS)	Uranium (extractable)
EPA Method 200.8	Inductively coupled plasma mass spectrometry (ICPMS) flow injection analysis	Total uranium
EPA SW-846 Method 7000-series	Graphite furnace atomic absorption (GFAA)	Arsenic, lead, selenium, and thallium
EPA SW-846 Method 7471	Cold vapor atomic absorption (CVAA)	Mercury

*Sample preparation methods are listed in parentheses.

The maximum allowable EQLs defined by the ER Project analytical services SOW (LANL 1995, 49738) for inorganic chemicals are provided in Table D1-1 in Appendix D. All detection limits were below background values except for selected antimony, arsenic, cadmium, mercury, selenium, and thallium analyses using ICPES. Most of the analyses for antimony, arsenic, selenium, and thallium were performed using the GFAA method (EPA SW-846 7000-series) and yielded detection limits below background values. Mercury was also analyzed using the CVAA method (EPA SW-846 7471) to attain detection limits below 0.1 mg/kg.

Results for individual sediment samples within a sample delivery group were evaluated and qualified using the ER Project validation process, which is based on the criteria in the NFG (EPA 1994, 48639). Qualifiers for individual samples can be found in Section C-5.0.

C-2.2 Discussion of Inorganic Quality Assurance/Quality Control Samples

LCSs, blanks, matrix spike samples, laboratory duplicate samples, and serial dilution samples were analyzed to assess accuracy and precision for inorganic chemical analyses. Each of these sample types is defined in the ER Project analytical services SOW (LANL 1995, 49738) and described briefly in the sections below.

C-2.2.1 Laboratory Control Samples

The LCS serves as a monitor of the overall performance of each step during the analysis, including sample preparation. The analytical results for the field samples were qualified according to NFG if the individual LCSs indicated an unacceptable bias in the measurement of individual analytes. The average

recoveries and the one-sigma standard error indicate acceptable LCS recoveries between 80 and 120% for all samples, with the following exception.

- RN 3938R – LCS recoveries for antimony and copper were outside control limits (79 to 125%). No special qualifiers were associated with antimony, but copper was regarded as estimated (J+ qualified) with a potential high bias.

C-2.2.2 Blanks

Preparation and calibration blanks are used as a measurement of bias and potential cross contamination. The blank results for inorganic chemical analyses were within acceptable limits for most of the analyses with the following exceptions.

- RN 2104 – Sample results for analytes including arsenic, boron, nickel, sodium, and thallium were less than five times the amount reported in the associated preparation blank. These results were qualified as not detected.

- RN 3728R – Sample results for selenium were less than five times the amount reported in the associated preparation blank. These results were qualified as not detected.

- RN 3938R – Sample results for analytes including chromium (one sample) and selenium (all samples) were less than five times the amount reported in the associated preparation blank. These results were qualified as not detected.

C-2.2.3 Matrix Spikes

Accuracy for inorganic chemical analyses in all reaches were also assessed using matrix spike samples. A matrix spike sample is designed to provide information about the effect of each sample matrix on the sample preparation procedures and measurement methodology. The average recovery and one-sigma standard error indicated acceptable recoveries between 75 and 125% for all spike samples with the following exceptions.

- RN 2104 – Spike results were outside the recovery limit for antimony (0%) and titanium (154%). Zero recoveries were noted for antimony. Sample results for these analytes associated with this RN were qualified as rejected (R) for antimony and estimated with a potential high bias (J+) for titanium.

- RN 3205R – Spike results were outside the acceptable recovery range for antimony (47%) and mercury (70%). Sample results for these analytes associated with this RN were qualified as (UJ), not detected, but the associated value is an estimate.

- RN 3313R – Spike results were outside the acceptable recovery range for antimony (57%), manganese (56%), and selenium (53%). Sample results for antimony and selenium were qualified as not detected, but the associated value is an estimate (UJ), and manganese results were qualified as estimated with a potential low bias (J-).

The qualified results for the samples and analytes from the RNs listed above are reported in Section C-5.0.

C-2.2.4 Laboratory Duplicates

Analyzing laboratory duplicate samples assessed precision of inorganic chemical analyses performed at off-site fixed laboratories. The results for laboratory duplicate samples were reported as part of the data set for the three reaches. The average relative percent difference (RPD) between the samples and the laboratory duplicate sample exceeded 35% for the following samples.

- RN 3728R – 35% RPD was exceeded for aluminum and iron. Sample results were J-qualified.
- RN 3938R – 35% RPD was exceeded for lead. Sample results were J-qualified.

C-2.2.5 Inductively Coupled Plasma Serial Dilutions

The serial dilution samples determine whether physical or chemical matrix interferences were encountered during analysis. If the sample concentration is sufficiently high (> 50 times the instrument detection limit (IDL) then the serial dilution analysis should agree within 10% of the initial sample result. The percent difference between the initial sample results and the serial dilutions exceeded 10% for the following samples.

- RN 3938R – Percent difference was exceeded for nickel, vanadium, potassium, and sodium (12, 13, 49 and 181%). Sample results for these analytes under this RN were estimated (J-qualified).

The qualified results for the samples and analytes from the RNs listed above are reported in Section C-5.0.

C-3.0 RADIOCHEMICAL ANALYSES

C-3.1 General

A total of 212 surface and subsurface sediment samples were collected in the upper Los Alamos Canyon reaches for radiochemical analyses, including a total of 87, 79, and 46 samples for reaches LA-1, LA-2, and LA-3, respectively. The samples were analyzed by one or more of the methods listed in Table C3-1.

TABLE C3-1

ANALYTICAL METHODS FOR RADIOCHEMICAL ANALYSES

Radionuclide(s)	Analytical Technique
Gamma-emitting (includes cesium-137 and cobalt-60)	Gamma spectroscopy
Isotopic plutonium	Alpha spectroscopy
Tritium	Liquid scintillation counting
Strontium-90	Gas proportional counting
Americium-241	Alpha spectroscopy and gamma spectroscopy
Gross alpha	Gas proportional counting
Gross beta	Gas proportional counting
Isotopic uranium	ICPMS and alpha spectroscopy

The results for the gamma spectroscopy analyses were reviewed with respect to their uncertainty values and parent decay series. Each sample analyte result was compared with its corresponding total propagated uncertainty (TPU). If the gamma spectroscopy result was not greater than three times the TPU, it was qualified as not detected. Each analyte in each of the thorium-232, uranium-238, and uranium-235 decay series was reviewed based on the activity of the parent (i.e., thorium-232, uranium-238, and uranium-235) assuming secular equilibrium. It was concluded that the majority of the gamma spectroscopy analytes were within expected background ranges based on this review. These results are discussed in more detail in Section 3.1.

Tritium results may be expressed in units of pCi/g of dry soil or pCi/ml of soil moisture. The analytical results in units of pCi/ml were multiplied by the moisture fraction (MF) of the sample and divided by the product of the moisture density [=(rw) x 1 – MF]. For most samples, including all the samples analyzed for this report, rw is set equal to 1 g/ml.

C-3.1.1 Detection Limits

The detection status for radiochemical analyses was determined by comparing the sample result with the minimum detectable activity (MDA) for all samples and analytes unless otherwise noted. The maximum allowable EQLs as defined in the ER Project analytical services SOW for radiochemicals are provided in Table D-1.2 in Appendix D. Deviations from the required EQL are noted where applicable for a sample.

It should be noted that in almost all cases the MDA was substantially less than the required EQL. For example, typical MDAs for plutonium and americium were less than or equal to 0.01 pCi/g, whereas the required EQLs for these isotopes are 0.1 pCi/g. All MDAs for radiochemical analyses were equal to or less than the required EQL with the following exceptions.

- RN 2104 – The MDAs reported for the gross alpha results were greater than the required EQL for all samples. All gross alpha results were J-qualified.
- RN 2104 – Two samples associated with this RN had tritium MDAs reported above the EQL of 300 pCi/L. These results were qualified as estimated.

The qualified results for the samples and analytes from the RNs listed above are reported in Section C-5.0.

Numerous sample results were qualified as not detected based on the reported MDA for the sample. All request numbers had one or more samples qualified as not detected based on the MDA. The samples and their associated analytes are listed in the tables in Section C-5.0.

C-3.2 Discussion of Radiochemical Quality Assurance/Quality Control Samples

Precision and bias of radiochemical analyses performed at off-site fixed laboratories were assessed using matrix spike samples, laboratory control samples, method blanks, duplicates, and tracers.

The ER Project analytical services SOW (LANL 1995, 49738) specifies that spike sample recoveries should be within ± 25% of the certified value. All spike samples had acceptable recoveries with the following exceptions.

- RN 3206R – Strontium-90 and tritium matrix spikes were not analyzed. There is no effect on the data, and no special qualifiers were reported.

The analytical results for all remaining individual spike samples were all within the ± 25% recovery control limit.

LCSs were analyzed to assess accuracy for radionuclide analyses. The LCSs serve as a monitor of the overall performance of each step during the analysis, including the sample preparation. The ER Project analytical services SOW (LANL 1995, 49738) specifies that LCS recoveries should be within ± 25% of the certified value. The analytical results for individual LCSs were all within the ± 25% recovery control limit with the following exception.

- RN 2104 – The LCSs for the thorium-228 and thorium-232 isotopes were not reported. Results for these isotopes appear to be satisfactory as reported.

Method blanks are also used to assess bias. The ER Project analytical services SOW (LANL 1995, 49738) specifies that the method blank concentration should not exceed the required EQL. All method blanks met these criteria.

Laboratory duplicate sample analyses were evaluated to determine precision in the analyses. Results are evaluated based on a three-sigma agreement. All results reported for laboratory duplicate samples were within three-sigma of the original sample result with the following exceptions.

- RN 3206R – The laboratory duplicate sample was not analyzed for radium-226. No special qualifiers are associated with this analyte.
- RN 3337R – The strontium-90 RPD exceeds the criteria for batch number G84223. No special qualifiers are associated with this batch.
- RN 3968R – The laboratory duplicate sample for plutonium-239,240 did not meet criteria. The result was greater than the EQL, and the difference was greater than two times the EQL. The results were estimated for these samples.

Radionuclide tracers and carriers are used to track the course (accuracy and bias) of the analytical measurement. Tracers are used for alpha spectroscopy analyses. Tracers are designed to provide information about the effect of each sample matrix on the sample preparation procedures and measurement methodology. The ER Project analytical services SOW (LANL 1995, 49738) specifies the required tracer recoveries for alpha emitters should be between 30 and 110%. Carrier recoveries should be between 40 and 110%. Carriers are used for strontium-90 analyses. Sample results are adjusted for tracer/carrier recoveries as required by standard protocol. All tracer and carrier recoveries are within these guidelines.

- RNs 2833 and 3314R – Because of the presence of other radioisotopes of strontium, a high bias may be associated with the measured strontium-90 concentrations. Sample results reported as detected for these RNs were qualified as biased high (J+ qualified).

C-4.0 ORGANIC CHEMICAL ANALYSES

A total of 36 surface and subsurface samples were collected and analyzed for SVOCs and/or pesticides and polychlorinated biphenyls (PESTPCBs) at off-site fixed laboratories. The summaries for these analyses are presented in the sections below. All extraction and analysis procedures, QC procedures,

and acceptance criteria were followed as required in the ER Project analytical services SOW (LANL 1995, 49738).

All data was usable with the following exception for request number 3312R. All samples associated with this RN were rejected (R-qualified) due to incorrect percent solids reporting (100%) which affects results for all analytes. Also, blank analysis dates did not match sample analysis dates and some of the analytes were not indicated in the LCS or the matrix spike.

C-4.1 Semivolatile Organic Chemical Analysis

Analyses for SVOCs were performed on 20 samples at off-site fixed laboratories. Analyses were performed using the EPA SW-846 Method 3540 to extract samples and EPA SW-846 Method 8270 for SVOC analyses. The SVOC analyte lists including the corresponding required EQLs are provided in Appendix D, and the methods are listed in Table C4-1. All holding times for extraction and analyses were met for the SVOC analyses. All other QC criteria were met for the SVOC analyses with the following exceptions.

- RN 2103 – The analyte bis(2-ethylhexyl)phthalate was detected in the blank. Results should be regarded as not detected because the sample was less than five times the concentration of the analyte in the blank.

- RN 3204R – Low surrogate recoveries were noted for all polycyclic aromatic hydrocarbons (PAHs). Samples are (J-) qualified because of a potential low bias.

TABLE C4-1

ANALYTICAL METHODS FOR ORGANIC CHEMICAL ANALYSES

Analytical Method*	Analytical Description	Analytical Suite
EPA SW-846 Method 8081 (3540)	Organochlorine pesticides and PCBs	See Table D1-4 in Appendix D
EPA SW-846 Method 8270 (3540)	SVOCs	See Table D1-3 in Appendix D
*Sample preparation methods are listed in parentheses.		

Accuracy of SVOC analyses performed at off-site fixed laboratories was determined using internal standards and surrogate recoveries. The recoveries for all surrogates and analyses of internal standards were within EPA guidelines.

Matrix spike analyses for SVOCs met the required criteria for all samples with the following exceptions.

- RN 3204R – Matrix and matrix spike sample duplicate results were slightly outside the acceptable recovery range. No qualifiers were associated with these samples because of matrix interference.

C-4.2 Organochlorine Pesticides and Polychlorinated Biphenyl Chemical Analysis

Analyses for PESTPCBs were performed on 36 samples at off-site fixed laboratories. Analyses were performed using the EPA SW-846 Method 3540 to extract samples and EPA SW-846 Method 8081 for

PESTPCB analysis. All holding times for extraction and analyses were met for the PESTPCB analyses with the following exceptions.

- Sample numbers 04LA-96-0255 and 04LA-96-0272 missed holding times during re-extraction. Data from these two samples were reported from the original extraction that was analyzed within the acceptable holding time.

All other QC criteria were met for the PESTPCB analyses with the following exceptions.

- RN 2103 – For sample number 04LA-96-0144, the surrogate Aroclor-1260 was outside the required retention time range of 0.05 minutes. All of the analyses for this sample were qualified as not detected. Manual examination of the chromatographic peaks was not performed.

- RN 3727R – Surrogate analyses for tetrachloro-m-xylene (TCMX) and dichlorobenzene (DCB) for sample number 04LA-96-0272 had recoveries above the acceptable criteria (190 and 177%, respectively). Analytes detected for this sample was qualified as estimated with a potential high bias (J+).

- RN 3937R – One of the two surrogate analyses (TCMX) for sample number 04LA-96-0622 had recoveries below the acceptance criteria. The EPA contract laboratory program guidelines require only one surrogate in the acceptance range. Therefore, no qualifiers were associated with this sample.

C-5.0 DATA VALIDATION

The following tables present the data qualifiers applied to each analyte for a given sample. The data qualifiers are defined in Table C5-1. Tables C5-2 through C5-4 list the qualifiers for each of the three reaches in upper Los Alamos Canyon.

TABLE C5-1

EXPLANATION OF DATA QUALIFIERS USED IN THE DATA VALIDATION PROCEDURE

Qualifier	Explanation
U	The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.
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.
UJ	The analyte was analyzed for but not detected. Reported value is an estimate of the sample-specific quantitation limit or detection limit.
R	The sample results are rejected because of serious deficiencies in the ability to analyze the sample and meet quality control criteria; presence or absence cannot be verified.

TABLE C5-2

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-1

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3728R	04LA-97-0236 -0237 -0243 -0244 -0245 -0255 -0256 -0257 -0272 -0273 -0279	Aluminum, iron	J	Metals	The duplicate results for aluminum and iron were outside control limits; sample results were qualified and estimated (J).
3728R	04LA-97-0236 -0237 -0243 -0244 -0245 -0255 -0256 -0257 -0272 -0273 -0279	Selenium	U	Metals	The sample results should be regarded as nondetected (U) because the sample results are greater than the EDL but less than five times the concentration of the related analyte in the blank.
3728R	04LA-97-0236	Silver, beryllium, cobalt, copper, potassium, magnesium, sodium, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3728R	04LA-97-0237 -0243 -0244 -0255 -0256 -0273	Silver, beryllium, cobalt, potassium, magnesium, sodium, nickel, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3728R	04LA-97-0245	Silver, cobalt, potassium, magnesium, sodium, nickel, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3728R	04LA-97-0257	Silver, beryllium, cobalt, chromium (total), potassium, magnesium, sodium, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3728R	04LA-97-0272	Silver, beryllium, cobalt, mercury, potassium, magnesium, sodium, nickel, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3728R	04LA-97-0279	Silver, beryllium, calcium, cobalt, potassium, magnesium, sodium, nickel, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-1

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3938R	04LA-97-0568 -0569 -0570 -0571 -0572 -0573 -0574 -0575 -0576 -0577 -0579 -0590 -0602 -0613 -0622 -0623 -0624 -0625	Copper	J+	Metals	The results should be regarded as high bias (J+) because the spike recovery exceeded the upper limit and the results exceed the EDL.
3938R	04LA-97-0568 -0569 -0570 -0571 -0572 -0573 -0574 -0575 -0576 -0577 -0579 -0590 -0602 -0613 -0622 -0623 -0624 -0625	Lead	J	Metals	The duplicate result for lead was outside control limits; sample results were qualified and estimated (J).
3938R	04LA-97-0568 -0569 -0570 -0571 -0572 -0573 -0576 -0577 -0579 -0590 -0602 -0622 -0623 -0624 -0625	Selenium	U	Metals	The sample results should be regarded as nondetected (U) because the sample results are greater than the EDL but less than five times the concentration of the related analyte in the blank.
3938R	04LA-97-0579	Chromium	U	Metals	The sample results should be regarded as nondetected (U) because the sample results are greater than the EDL but less than five times the concentration of the related analyte in the blank.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-1

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3938R	04LA-97-0568 -0569 -0570 -0571 -0572 -0573 -0574 -0575 -0576 -0577 -0579 -0590 -0602 -0613 -0622 -0623 -0624 -0625	Potassium, nickel, sodium, vanadium	J	Metals	The results should be regarded as estimated (J) because the percent difference for the soil inductively coupled plasma serial dilution was greater than the 10% value that is required.
3727R	04LA-96-0272	Aroclor-1260	J+	Pesticides and PCBs	The results should be regarded as high bias (J+) because both surrogate recoveries exceeded the upper limits. A potential high bias or false positive in the results is possible.
3729R	04LA-97-0255 -0256 -0257	Strontium-90	U	Strontium-90	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3729R	04LA-97-0269	Plutonium-239,240	U	Isotopic plutonium	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-1

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3729R	04LA-97-0238 -0241 -0244 -0245 -0246 -0247 -0248 -0249 -0250 -0251 -0252 -0253 -0254 -0256 -0257 -0258 -0259 -0260 -0261 -0264 -0265 -0266 -0267 -0268 -0269 -0270 -0271 -0272 -0274 -0276 -0277 -0278 -0279 -0280	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3968R	04LA-97-0568 -0623	Americium-241	U	Alpha spectroscopy	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3968R	04LA-97-0570	Strontium-90	U	Strontium-90	The results should be regarded as nondetected because the result was less than three times the TPU, and the duplicate result was not within the acceptable range.
3968R	04LA-97-0569	Strontium-90	U	Strontium-90	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3968R	04LA-97-0579 -0623	Uranium-235	U	Isotopic uranium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-1

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3968R	04LA-97-0568 -0569 -0573 -0574 -0575 -0576 -0577 -0579 -0580 -0582 -0584 -0586 -0588 -0589 -0590 -0592 -0594 -0595 -0598 -0600 -0601 -0602 -0606 -0609 -0610 -0613 -0614 -0616 -0618 -0619 -0620 -0621 -0623 -0624	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3968R	04LA-97-0622	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3968R	04LA-97-0578	Plutonium-239	U	Isotopic plutonium	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3968R	04LA-97-0574 -0579	Plutonium-239	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-1

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3968R	04LA-97-0568	Plutonium-239	J	Isotopic plutonium	The results should be regarded as estimated (J) because the sample and sample duplicate did not meet the criteria.
	-0569				
	-0570				
	-0573				
	-0575				
	-0576				
	-0577				
	-0582				
	-0583				
	-0584				
	-0585				
	-0586				
	-0587				
	-0588				
	-0589				
	-0590				
	-0592				
	-0593				
	-0595				
	-0596				
	-0597				
	-0598				
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TABLE C5-2 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-1

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3968R	04LA-97-0568	Barium-140, cerium-139, cerium-144, cobalt-57, cobalt-60, cesium-134, europium-152, mercury-203, lanthanum-140, sodium-22, protactinium-233, protactinium-234m, lead-211, radon-219, ruthenium-106, tin-113, strontium-85, thorium-227, thorium-234, uranium-235, yttrium-88, zinc-65	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3968R	04LA-97-0568	Americium-241, bismuth-211, bismuth-212, cadmium-109, cesium-137, manganese-54, neptunium-237, protactinium-231, radium-223, radium-226, selenium-75, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3968R	04LA-97-0571	Barium-140, bismuth-212, cerium-139, cerium-144, cobalt-57, cobalt-60, cesium-134, mercury-203, manganese-54, sodium-22, neptunium-237, protactinium-233, protactinium-234m, lead-211, radium-223, radon-219, selenium-75, tin-113, strontium-85, thorium-227, thallium-208, yttrium-88, zinc-65	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3968R	04LA-97-0571	Americium-241, bismuth-211, cadmium-109, europium-152, lanthanum-140, protactinium-231, radium-226, ruthenium-106, thorium-234, uranium-235, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3968R.	04LA-97-0572	Americium-241, barium-140, bismuth-212, cerium-139, cobalt-60, cesium-134, mercury-203, manganese-54, sodium-22, neptunium-237, protactinium-233, protactinium-234m, lead-211, radium-223, radon-219, selenium-75, tin-113, strontium-85, thorium-227, yttrium-88, zinc-65, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3986R	04LA-97-0572	bismuth-211, cadmium-109, cerium-144, europium-152, anthanum-140, protactinium-231, ruthenium-106, thorium-234	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-1

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3986R	04LA-97-0579	Americium-241, barium-140, bismuth-211, bismuth-212, cadmium-109, cerium-139, cerium-144, cobalt-60, cesium-134, cesium-137, mercury-203, manganese-54, sodium-22, neptunium-237, protactinium-231, protactinium-233, lead-211, radium-226, radon-219, ruthenium-106, selenium-75, tin-113, strontium-85, thorium-227, thorium-234, uranium-235, yttrium-88, zinc-65, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3968R	04LA-97-0579	Actinium-228, europium-152, lanthanum-140, protactinium-234m, radium-223	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3968R	04LA-97-0590	Barium-140, bismuth-212, cerium-139, cerium-144, cobalt-57, cobalt-60, cesium-134, europium-152, mercury-203, lanthanum-140, manganese-54, sodium-22, neptunium-237, protactinium-234m, lead-211, radium-223, radon-219, ruthenium-106, tin-113, strontium-85, thorium-227, thorium-234, yttrium-88, zinc-65	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3968R	04LA-97-0590	Americium-241, cadmium-109, protactinium-231, protactinium-233, radium-224, selenium-75, uranium-235, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3968R	04LA-97-0602	Americium-241, barium-140, bismuth-211, bismuth-212, bismuth-214, cadmium-109, cerium-139, cerium-144, cobalt-57, cobalt-60, cesium-134, europium-152, lanthanum-140, manganese-54, sodium-22, neptunium-237, protactinium-231, protactinium-233, protactinium-234m, lead-211, radium-223, radon-219, ruthenium-106, selenium-75, tin-113, strontium-85, thorium-227, thorium-234, uranium-235, Yttrium-88, zinc-65, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3968R	04LA-97-0602	Actinium-228, mercury-203, radium-226	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-1

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3968R	04LA-97-0613	Americium-241, barium-140, bismuth-211, bismuth-212, cerium-139, cobalt-57, cobalt-60, cesium-134, duropium-152, mercury-203, lanthanum-140, manganese-54, sodium-22, neptunium-237, protactinium-233, protactinium-234m, lead-211, radium-223, ruthenium-106, selenium-75, tin-113, strontium-85, thorium-227, thorium-234, yttrium-88, zinc-65	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3968R	04LA-97-0613	Cadmium-109, cerium-144, radon-219, uranium-235, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3968R	04LA-97-0622	Americium-241, barium-140, bismuth-212, cerium-139, cerium-144, cobalt-60, cesium-134, europium-152, mercury-203, lanthanum-140, manganese-54, sodium-22, neptunium-237, protactinium-234m, radium-223, radon-219, ruthenium-106, selenium-75, strontium-85, thorium-227, thorium-234, zinc-65, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3968R	04LA-97-0622	Cadmium-109, protactinium-231, protactinium-233, lead-211, radium-226, tin-113, yttrium-88	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3968R	04LA-97-0623	Americium-241, bismuth-211, bismuth-212, cerium-139, cerium-144, cobalt-57, cobalt-60, cesium-134, europium-152, mercury-203, lanthanum-140, manganese-54, sodium-22, neptunium-237, protactinium-231, protactinium-233, protactinium-234m, radium-223, radon-219, ruthenium-106, selenium-75, tin-113, strontium-85, thorium-227, yttrium-88	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3968R	04LA-97-0623	Barium-140, cadmium-109, lead-211, thorium-234, uranium-235, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-1

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3968R	04LA-97-0624	Americium-241, barium-140, bismuth-211, bismuth-212, cerium-139, cerium-144, cobalt-60, cesium-134, mercury-203, sodium-22, neptunium-237, protactinium-234m, lead-211, radium-223, radium-224, radon-219, selenium-75, strontium-85, thorium-227, thorium-234, uranium-235, yttrium-88, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3968R	04LA-97-0624	Cadmium-109, cobalt-57, cesium-137, lanthanum-140, europium-152, manganese-54, protactinium-231, ruthenium-106, tin-113, zinc-65	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3968R	04LA-97-0625	Americium-241, barium-140, bismuth-212, cerium-139, cerium-144, cobalt-57, cesium-134, europium-152, mercury-203, lanthanum-140, manganese-54, protactinium-233, protactinium-234m, lead-211, radium-223, radium-224, radon-219, ruthenium-106, selenium-75, strontium-85, thorium-227, yttrium-88, zinc-65, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3968R	04LA-97-0625	Bismuth-211, cadmium-109, cobalt-60, sodium-22, neptunium-237, protactinium-231, tin-113, thorium-234, uranium-235	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.

TABLE C5-3

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-2

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
2104	04LA-96-0140 -0141 -0142 -0143 -0144 -0145 -0146 -0147 -0148 -0149	Antimony	R	Metals	Data were rejected because of zero recoveries in the matrix spike.
2104	04LA-96-0140 -0141 -0142 -0143 -0144 -0145 -0146 -0147 -0148 -0149	Titanium	J+	Metals	The results should be regarded as high bias (J+) because the spike recovery (154%) exceeded the upper limit and the results were greater than the EDL.
2104	04LA-96-0140 -0142	Sodium	U	Metals	The sample results should be regarded as nondetected (U) because the sample results are greater than the EDL but less than five times the concentration of the related analyte in the blank.
2104	04LA-96-0141 -0143 -0144 -0146 -0148	Arsenic	U	Metals	The sample results should be regarded as nondetected (U) because the sample results are greater than the EDL but less than five times the concentration of the related analyte in the blank.
2104	04LA-96-0141 -0143 -0147 -0148	Nickel	U	Metals	The sample results should be regarded as nondetected (U) because the sample results are greater than the EDL but less than five times the concentration of the related analyte in the blank.
2104	04LA-96-0145 -0149	Thallium	U	Metals	The sample results should be regarded as nondetected (U) because the sample results are greater than the EDL but less than five times the concentration of the related analyte in the blank.
2104	04LA-96-0140 -0141 -0142 -0143 -0144 -0145 -0146 -0147 -0148 -0149	Boron	U	Metals	The sample results should be regarded as nondetected (U) qualified because the sample results are greater than the EDL but less than five times the concentration of the related analyte in the blank.
2104	04LA-96-0140	Cyanide (total), cobalt, mercury	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-2

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
2104	04LA-96-0141	Cyanide (total), beryllium, cobalt, uranium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
2104	04LA-96-0142	Cobalt, nickel, selenium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
2104	04LA-96-0143	Cyanide (total), cobalt, sodium, selenium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
2104	04LA-96-0144	Cobalt	J	Metals	The results should be regarded as estimated (J) because this analyte was detected below the MDL but above the IDL.
2104	04LA-96-0145	Cyanide (total), cobalt, selenium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
2104	04LA-96-0146	Cyanide (total), cobalt, nickel, selenium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
2104	04LA-96-0147 -0148	Cyanide (total), beryllium, cobalt, magnesium, uranium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
2104	04LA-96-0149	Cyanide (total), cobalt	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3205R	04LA-97-0052 -0053	Antimony, mercury	UJ	Metals	The results should be regarded as nondetected and an estimate (UJ) because the spike recovery is between 30 and 74%, and the results are less than the EDL.
2103	04LA-96-0140 -0142 -0143 -0144 -0146 -0147 -0148 -0149	Bis(2-ethylhexyl)phthalate	U	Semivolatile organic compounds	The results should be regarded as nondetected (U) because the sample was less than the EQL and less than five times the concentration of the analyte in the blank, which indicates the detected result was indistinguishable from blank contamination.
2103	04LA-96-0145	Bis(2-ethylhexyl)phthalate	U	Semivolatile organic compounds	The results should be regarded as nondetected (U) because the sample was greater than EQL and less than 5 times the concentration of the analyte in the blank, which indicates the detected result was indistinguishable from blank contamination.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-2

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
2103	04LA-96-0140	Anthracene, dibenzofuran, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene, chrysene, benzo(a)pyrene, benz(a)anthracene, acenaphthene, fluorene, naphthalene	J	Semivolatile organic compounds	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
2103	04LA-96-0142	Pyrene, fluoranthene, phenanthrene	J	Semivolatile organic compounds	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
2103	04LA-96-0143 -0144	Anthracene, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene, chrysene, benzo(a)pyrene, benz(a)anthracene, phenanthrene	J	Semivolatile organic compounds	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
2103	04LA-96-0145	Anthracene, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene, benz(a)anthracene, phenanthrene	J	Semivolatile organic compounds	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
2103	04LA-96-0146	Anthracene, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene	J	Semivolatile organic compounds	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
2103	04LA-96-0147 -0149	Anthracene, pyrene, benzo(b)fluoranthene, fluoranthene, chrysene, benzo(a)pyrene, benz(a)anthracene, phenanthrene	J	Semivolatile organic compounds	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3204R	04LA-97-0052	Anthracene, pyrene, indeno(1,2,3-cd)pyrene, benzo(b)fluoranthene, fluoranthene, benzo(k)fluoranthene, chrysene, benzo(a)pyrene, benz(a)anthracene, acenaphthene, phenanthrene, fluorene, naphthalene	J-	Semivolatile organic compounds	The results should be regarded as low bias (J-) because the surrogate recovery was greater than 10% but less than the lower limit; low bias potential is possible.
3204R	04LA-97-0053	Anthracene, pyrene, indeno(1,2,3-cd)pyrene, benzo(b)fluoranthene, fluoranthene, benzo(k)fluoranthene, chrysene, benzo(a)pyrene, dibenz(a,h)anthracene, benz(a)anthracene, acenaphthene, phenanthrene, fluorene, naphthalene	J-	Semivolatile organic compounds	The results should be regarded as low bias (J-) because the surrogate recovery was greater than 10% but less than the lower limit; low bias potential is possible.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-2

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
2104	04LA-96-0140 -0141 -0142 -0143 -0144 -0145 -0146 -0147 -0148 -0149	Gross alpha radiation	J	Gross alpha radiation	The results should be regarded as estimated (J) qualified because all the results indicated MDAs greater than the EQL.
2104	04LA-96-0141 -0142	Strontium-90	U	Strontium-90	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
2104	04LA-96-0141	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
2104	04LA-96-0142 -0147 -0148	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
2104	04LA-96-0141 -0148	Tritium	J	Tritium	The results should be regarded as estimated (J) qualified because all the results indicated MDAs greater than the EQL.
2104	04LA-96-0140 -0141 -0142 -0143 -0144 -0145 -0146 -0147 -0148 -0149	Uranium-235	J	Isotopic uranium	The results should be regarded as estimated (J) because this analyte was above the MDA but less then the EQL.
2104	04LA-96-0140	Gamma spectroscopy suite (except actinium-228, americium-241, bismuth-214, cesium-137, potassium-40, lead-212, lead-214, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2104	04LA-96-0141	Gamma spectroscopy suite (except potassium-40, lead-212, lead-214, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2104	04LA-96-0142	Gamma spectroscopy suite (except actinium-228, bismuth-214, cesium-137, potassium-40, lead-212, lead-214, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-2

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
2104	04LA-96-0143 -0144 -0145	Gamma spectroscopy suite (except actinium-228, americium-241, bismuth-214, cesium-137, potassium-40, lead-212, lead-214, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2104	04LA-96-0146	Gamma spectroscopy suite (except americium-241, bismuth-214, cesium-137, potassium-40, lead-212, lead-214, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2104	04LA-96-0147	Gamma spectroscopy suite (except actinium-228, cesium-134, cesium-137, potassium-40, lead-212, lead-214, radium-226)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2104	04LA-96-0148	Gamma spectroscopy suite (except actinium-228, cesium-137, potassium-40, lead-212, lead-214, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2104	04LA-96-0149	Gamma spectroscopy suite (except actinium-228, americium-241, cesium-137, potassium-40, lead-212, lead-214, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2104	04LA-96-0141 -0142	Americium-241	U	Alpha spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
2833	04LA-96-0206 -0207 -0215 -0216 -0217 -0218 -0220 -0221 -0222 -0223 -0224 -0225 -0226 -0227 -0229	Strontium-90	J+	Strontium-90	The results should be regarded as high bias (J+) because the presence of other radioisotopes of strontium may cause high bias in the measured strontium concentration.
2833	04LA-96-0205 -0211 -0212 -0220 -0221 -0222 -0223 -0225	Iodine-129, lead-210	J	Gamma spectroscopy	The results should be regarded as estimated (J) because these analytes were above the MDA but less then the EQL.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-2

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
2833	04LA-96-0206 -0207 -0226 -0227 -0229	Iodine-129, lead-210, yttrium-88	J	Gamma spectroscopy	The results should be regarded as estimated (J) because these analytes were above the MDA but less then the EQL.
2833	04LA-96-0215 -0217 -0218	Cesium-137, iodine-129, lead-210, yttrium-88	J	Gamma spectroscopy	The results should be regarded as estimated (J) because these analytes were above the MDA but less then the EQL.
2833	04LA-96-0216	Cesium-137, iodine-129, yttrium-88	J	Gamma spectroscopy	The results should be regarded as estimated (J) because these analytes were above the MDA but less then the EQL.
2833	04LA-96-0224	Americium-241, iodine-129, lead-210, yttrium-88	J	Gamma spectroscopy	The results should be regarded as estimated (J) because these analytes were above the MDA but less then the EQL.
2833	04LA-96-0205	Gamma spectroscopy suite (except americium-241, cesium-137, potassium-40, lead-212, radium-226, lead-214, thallium-208, iodine-129, lead-210)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0206	Gamma spectroscopy suite (except actinium-228, americium-241, bismuth-212, bismuth-214, cesium-137, potassium-40, lead-210, lead-212, lead-214, iodine-129, radium-226, thallium-208, yttrium-88)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0207	Gamma spectroscopy suite (except actinium-228, americium-241, cesium-137, potassium-40, lead-210, lead-212, lead-214, iodine-129, radium-226, thallium-208, yttrium-88)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0211	Gamma spectroscopy suite (except americium-241, cesium-137, potassium-40, lead-210, lead-212, protactinium-234m, iodine-129, radium-224)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0212	Gamma spectroscopy suite (except americium-241, cesium-137, potassium-40, lead-210, lead-212, Lead-214, protactinium-234m, iodine-129, radium-226)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-2

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
2833	04LA-96-0215	Gamma spectroscopy suite (except actinium-228, cesium-137, potassium-40, neptunium-237, lead-210, lead-212, lead-214, iodine-129, radium-226, thallium-208, yttrium-88)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0216	Gamma spectroscopy suite (except actinium-228, bismuth-212, bismuth-214, cesium-137, mercury-203, potassium-40, neptunium-237, lead-212, lead-214, iodine-129, radium-226, thallium-208, yttrium-88)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0217	Gamma spectroscopy suite (except actinium-228, bismuth-212, bismuth-214, cesium-137, potassium-40, neptunium-237, lead-210, lead-212, lead-214, iodine-129, radium-226, thallium-208, yttrium-88)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0218	Gamma spectroscopy suite (except actinium-228, bismuth-212, bismuth-214, cesium-137, potassium-40, sodium-22, neptunium-237, lead-210, lead-212, Lead-214, iodine-129, radium-224, radium-226, thallium-208, yttrium-88)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0220	Gamma spectroscopy suite (except bismuth-212, bismuth-214, cadmium-109, cerium-139, cerium-144, cobalt-57, cobalt-60, cesium-134, cesium-137, mercury-203, potassium-40, lead-210, iodine-129)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0221	Gamma spectroscopy suite (except cesium-137, potassium-40, lead-210, iodine-129)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0222	Gamma spectroscopy suite (except cesium-137, potassium-40, lead-210, lead-212, iodine-129)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0223	Gamma spectroscopy suite (except cesium-137, potassium-40, lead-210, lead-212, iodine-129, radium-226, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-2

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
2833	04LA-96-0224	Gamma spectroscopy suite (except actinium-228, americium-241, bismuth-212, bismuth-214, cesium-137, potassium-40, sodium-22, neptunium-237, lead-210, lead-212, lead-214, iodine-129, radium-226, thallium-208, yttrium-88)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0225	Gamma spectroscopy suite (except americium-241, cesium-137, potassium-40, lead-210, lead-212, lead-214, iodine-129, radium-226)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0226	Gamma spectroscopy suite (except actinium-228, americium-241, bismuth-212, bismuth-214, cesium-137, potassium-40, neptunium-237, lead-210, lead-211, iodine-129, radium-226, yttrium-88)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0227	Gamma spectroscopy suite (except actinium-228, americium-241, cesium-137, potassium-40, lead-210, lead-212, lead-214, iodine-129, radium-226, thallium-208, yttrium-88)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2833	04LA-96-0229	Gamma spectroscopy suite (except actinium-228, bismuth-211, cesium-137, potassium-40, neptunium-237, lead-210, lead-212, lead-214, iodine-129, radium-226, thallium-208, yttrium-88)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3206R	04LA-97-0052	Strontium-90	U	Strontium-90	The result should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3206R	04LA-97-0053	Radium-226	U	Radium-226	The result should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3206R	04LA-97-0052	Radium-226	U	Radium-226	The result should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty
3206R	04LA-97-0052	Plutonium-238	U	Isotopic plutonium	The result should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3206R	04LA-97-0053	Tritium	U	Tritium	The result should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-2

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3206	04LA-97-0052	Tritium	U	Tritium	The result should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3206R	04LA-97-0052	Americium-241, cerium-144, cobalt-57, cobalt-60, europium-152, iodine-129, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3206R	04LA-97-0053	Cerium-144, cobalt-57, cobalt-60, europium-152, iodine-129, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3223R	04LA-97-0059 -0064 -0068 -0096 -0097 -0098 -0099 -0100 -0103 -0104	Strontium-90	U	Strontium-90	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3223R	04LA-97-0056 -0059 -0067 -0068 -0072 -0073 -0074 -0096 -0097 -0099 -0100 -0104	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3223R	04LA-97-0074	Plutonium-239,240	U	Isotopic plutonium	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3223R	04LA-97-0099	Plutonium-239,240	U	Isotopic plutonium	The result should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3223R	04LA-97-0054 -0058 -0064 -0067 -0076 -0077 -0085 -0087 -0090 -0091	Cerium-144, cobalt-57, cobalt-60, europium-152, iodine-129, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-2

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3223R	04LA-97-0055 -0057 -0059 -0062 -0063 -0065 -0073 -0088 -0089	Cerium-144, cobalt-57, cobalt-60, europium-152, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3223R	04LA-97-0056 -0060 -0066 -0071 -0072 -0074	Americium-241, cerium-144, cobalt-57, cobalt-60, europium-152, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3223R	04LA-97-0061	Cerium-144, cobalt-57, cobalt-60, cesium-137, europium-152, iodine-129, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3223R	04LA-97-0068	Americium-241, cerium-144, cobalt-57, europium-152, iodine-129, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3223R	04LA-97-0075	Cerium-144, cobalt-57, cobalt-60, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3223R	04LA-97-0078	Americium-241, cerium-144, cobalt-57, cobalt-60, europium-152, iodine-129, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.

TABLE C5-4

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-3

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3312R	All	All	R	SVOCs, pesticides, PCBs	All data were rejected because of erroneous percent solids reporting, blank analyses not performed on the same day, and missing LCS and matrix spike peaks.
3313R	04LA-97-0143, -0144, -0145, -0146, -0147, -0148, -0149, -0150	Manganese	J-	Metals	The results should be regarded as estimated low bias (J-) because the spike recovery was less than the lower limit, and the results are greater than the EDL.
3313R	04LA-97-0143, -0144, -0145, -0146, -0147, -0148, -0149, -0150	Antimony, selenium	UJ	Metals	The results should be regarded as nondetected and estimated (UJ) because the spike recovery is between 30 and 74%, and the results are less than the EDL.
3313R	04LA-97-0143, -0148	Arsenic, beryllium, cobalt, sodium, nickel	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3313R	04LA-97-0144	Beryllium, cobalt, sodium, nickel	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3313R	04LA-97-0145, -0149	arsenic, beryllium, cobalt, potassium, magnesium, sodium, nickel, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3313R	04LA-97-0146	Arsenic, beryllium, cobalt, magnesium, sodium, nickel	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3313R	04LA-97-0147	Arsenic, beryllium, cobalt, magnesium, sodium, nickel, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3313R	04LA-97-0150	Arsenic, barium, beryllium, calcium, cobalt, copper, potassium, magnesium, sodium, nickel, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the IDL.
3337R	04LA-97-0133, -0135, -0141, -0142	Strontium-90	U	Strontium-90	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3337R	04LA-97-0132, -0136, -0140	Strontium-90	U	Strontium-90	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.

TABLE C5-4 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-3

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3337R	04LA-97-0130, -0131, -0132, -0135	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3337R	04LA-97-0142	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3337R	04LA-97-0105, -0116, -0120	Americium-241, cerium-144, cobalt-57, europium-152, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3337R	04LA-97-0106, -0107, -0110, -0111, -0113, -0114, -0115, -0117, -0121, -0122, -0125, -0126, -0134, -0138, -0139, -0142	Cerium-144, cobalt-57, cobalt-60, europium-152, iodine-129, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3337R	04LA-97-0108, -0109, -0118, -0119, -0123, -0127, -0131, -0136	Americium-241, cerium-144, cobalt-57, cobalt-60, europium-152, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3337R	04LA-97-0112	Cerium-144, cobalt-57, europium-152, iodine-129, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3337R	04LA-97-0124	Americium-241, cerium-144, cobalt-57, cobalt-60, europium-152, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3337R	04LA-97-0124	Sodium-22	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3337R	04LA-97-0128	Americium-241, cerium-144, cobalt-57, cobalt-60, cesium-137, europium-152, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.

TABLE C5-4 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-3

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3337R	04LA-97-0129	Americium-241, cerium-144, cobalt-57, cobalt-60, cesium-137, europium-152, iodine-129, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3337R	04LA-97-0130	Americium-241, cerium-144, cobalt-57, cobalt-60, europium-152, iodine-129, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3337R	04LA-97-0132, -0141	Cerium-144, cobalt-57, cobalt-60, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3337R	04LA-97-0133	Americium-241, cerium-144, cobalt-57, cobalt-60, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3337R	04LA-97-0133	Europium-152	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3337R	04LA-97-0135	Cerium-144, cobalt-57, cobalt-60, europium-152, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3337R	04LA-97-0137, -0140	Cerium-144, cobalt-57, cobalt-60, europium-152, sodium-22, neptunium-237, ruthenium-106	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3314R	04LA-97-0143, -0144, -0145, -0146, -0147, -0148, -0149, -0150	Tritium	U	Tritium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3314R	04LA-97-0143, -0144, -0148, -0149	Strontium-90	J+	Strontium-90	The results should be regarded as estimated high bias (J+) because the presence of other radioisotopes of strontium may cause high bias in the measured strontium concentration.
3314R	04LA-97-0145, -0147, -0150,	Strontium-90	U	Strontium-90	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3314R	04LA-97-0146	Strontium-90	U	Strontium-90	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3314R	04LA-97-0145, -0150	Uranium-235, uranium-236	U	Isotopic uranium	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.

TABLE C5-4 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-3

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3314R	04LA-97-0143	Barium-140, bismuth-211, bismuth-212, cobalt-57, cesium-134, mercury-203, lanthanum-140, manganese-54, sodium-22, neptunium-237, protactinium-233, protactinium-234m, lead-211, radon-219, selenium-75, tin-113, strontium-85, thorium-227, thorium-234, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3314R	04LA-97-0143	Americium-241, cadmium-109, cerium-139, cerium-144, cobalt-60, europium-152, radium-223, radium-226, ruthenium-106, yttrium-88, zinc-65	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3314R	04LA-97-0144	Bismuth-212, cerium-139, cobalt-57, cobalt-60, cesium-134, europium-152, lanthanum-140, manganese-54, sodium-22, neptunium-237, protactinium-234m, lead-211, radium-224, ruthenium-106, tin-113, strontium-85, uranium-235, yttrium-88, zinc-65	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3314R	04LA-97-0144	Barium-140, cadmium-109, cerium-144, mercury-203, protactinium-231, protactinium-233, radium-223, radon-219, selenium-75, thorium-227, thorium-234, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3314R	04LA-97-0145	Bismuth-211, bismuth-212, cerium-139, cerium-144, cobalt-57, cesium-134, europium-152, lanthanum-140, sodium-22, lead-211, radium-223, radon-219, ruthenium-106, selenium-75, tin-113, strontium-85, thorium-227, thorium-234, uranium-235, yttrium-88, zinc-65	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3314R	04LA-97-0145	Barium-140, cadmium-109, cobalt-60, manganese-54, neptunium-237, protactinium-231, protactinium-233, protactinium-234m, radium-224, radium-226	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.

TABLE C5-4 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-3

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3314R	04LA-97-0146	Barium-140, bismuth-211, bismuth-212, cerium-139, cerium-144, cobalt-57, cobalt-60, cesium-134, europium-152, lanthanum-140, manganese-54, protactinium-233, protactinium-234m, radium-223, radon-219, tin-113, strontium-85, thorium-227, thorium-234, yttrium-88, zinc-65	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3314R	04LA-97-0146	Cadmium-109, mercury-203, sodium-22, neptunium-237, protactinium-231, lead-211, radium-226, ruthenium-106, selenium-75, uranium-235, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3314R	04LA-97-0147	Barium-140, bismuth-212, cerium-144, cobalt-57, cesium-134, europium-152, mercury-203, lanthanum-140, manganese-54, neptunium-237, protactinium-233, protactinium-234m, radium-223, radon-219, ruthenium-106, selenium-75, Tin-113, strontium-85, thorium-227, thorium-234, yttrium-88, zinc-65	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3314R	04LA-97-0147	Americium-241, bismuth-211, cadmium-109, cerium-139, cobalt-60, sodium-22, protactinium-231, lead-211, radium-224, uranium-235, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3314R	04LA-97-0148	Bismuth-212, cerium-139, cerium-144, cobalt-57, europium-152, manganese-54, neptunium-237, protactinium-231, lead-211, radium-223, radon-219, selenium-75, Tin-113, strontium-85, yhorium-227, yttrium-88	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3314R	04LA-97-0148	Barium-140, bismuth-211, cadmium-109, cobalt-60, cesium-134, mercury-203, lanthanum-140, sodium-22, protactinium-233, protactinium-234m, radium-224, ruthenium-106, thorium-234, uranium-235, zinc-65, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.

TABLE C5-4 (continued)

DATA QUALIFIERS FOR LOS ALAMOS CANYON REACH LA-3

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3314R	04LA-97-0149	Barium-140, cerium-139, cerium-144, cobalt-57, cobalt-60, cesium-134, europium-152, lanthanum-140, manganese-54, sodium-22, neptunium-237, protactinium-231, protactinium-233, protactinium-234m, lead-211, radium-223, radon-219, ruthenium-106, tin-113, strontium-85, thorium-227, thorium-234, yttrium-88	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3314R	04LA-97-0149	Americium-241, bismuth-211, bismuth-212, cadmium-109, mercury-203, selenium-75, uranium-235, zinc-65, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3314R	04LA-97-0150	Cobalt-60, thorium-227	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma uncertainty.
3314R	04LA-97-0150	Americium-241, barium-140, bismuth-212, cadmium-109, cerium-139, cerium-144, cobalt-57, cesium-134, europium-152, mercury-203, lanthanum-140, manganese-54, sodium-22, neptunium-237, protactinium-231, protactinium-233, protactinium-234m, lead-211, radium-223, radium-224, radium-226, radon-219, ruthenium-106, selenium-75, tin-113, strontium-85, thorium-234, uranium-235, yttrium-88, zinc-65, annihilation radiation	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.

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Appendix D

Analytical Suites and Results

APPENDIX D ANALYTICAL SUITES AND RESULTS

D-1.0 TARGET ANALYTES AND DETECTION LIMITS

Tables D1-1 through D1-4 include the maximum required detection limits or quantitation limits in accordance with the Environmental Restoration Project analytical services statement of work for contract laboratories (LANL 1995, 49738) and the *Quality Assurance Project Plan Requirements for Sampling and Analysis* (LANL 1996, 54609). In most cases, the limits for the analytes were significantly lower than the detection or quantitation limits reported in these tables. The sample-specific detection or quantitation limits for each analyte are accessible in the Facility for Information Management, Analysis, and Display (FIMAD) database. In addition, summary tables presented throughout this report also include these limits as appropriate.

Efforts were made to ensure that detection limits for inorganic analytes were below Laboratory background values. Instances in which the detection limits were greater than the background values are noted and discussed in Section 3.1.

TABLE D1-1

TARGET ANALYTES AND MAXIMUM REQUIRED DETECTION LIMITS FOR INORGANIC CHEMICAL ANALYSES

Analyte	EPA Sample Preparation Method	Analytical Technique	EDL[a] (mg/kg) ICPES[b]/ICPMS[c]	EDL (mg/kg) GFAA[d]/other
Aluminum	3050A	ICPES	40	
Antimony	3050A	ICPES	12	
Arsenic	7060/3050A	GFAA/ICPES	NR[e]	2
Barium	3050A	ICPES	40	
Beryllium	3050A	ICPES	1	
Cadmium	3050A	ICPES	1	
Calcium	3050A	ICPES	1000	
Chromium	3050A	ICPES	2	
Cobalt	3050A	ICPES	10	
Copper	3050A	ICPES	5	
Cyanide	9012	Colorimetric	N/A[f]	0.05
Iron	3050A	ICPES	20	
Lead	7421/3050A	GFAA/ICPES	0.6	0.2
Magnesium	3050A	ICPES	1000	
Manganese	3050A	ICPES	3	
Mercury	7471	CVAA[g]	N/A	0.1
Nickel	3050A	ICPES	8	
Potassium	3050A	ICPES	1000	
Selenium	7740/3050A	GFAA/ICPES	NR	1
Silver	3050A	ICPES	2	
Sodium	3050A	ICPES	1000	
Thallium	7841/3050A	GFAA/ICPES	NR	2
Uranium	3050A	ICPMS	0.5	
Vanadium	3050A	ICPES	10	
Zinc	3050A	ICPES	4	

a. EDL = estimated detection limit
b. ICPES = inductively coupled plasma emission spectroscopy by EPA Method 6010
c. ICPMS = inductively coupled plasma mass spectrometry by EPA Method 6020
d. GFAA = graphite furnace atomic absorption spectroscopy by EPA Methods 7000-series
e. NR = not recommended, EDLs are sample-specific
f. N/A = not applicable
g. CVAA = cold vapor atomic absorption spectroscopy

TABLE D1-2

TARGET ANALYTES AND MAXIMUM REQUIRED QUANTITATION LIMITS FOR RADIOCHEMICAL ANALYSES

Analyte	Sediment/Soil EQL (pCi/g)	EPA Preparation Method (if applicable)	Analytical Technique[a]
Gross alpha/beta	10.0		Gas-proportional
Strontium-90[b]	2.0		Gas-proportional
Americium-241	0.1		Alpha spectroscopy
Plutonium-238; -239,240	0.1		Alpha spectroscopy
Thorium-228, -230, -232	0.1		Alpha spectroscopy and ICPMS[c]-FIA[d]
Uranium-234, -235, -238	0.1		Alpha spectroscopy and ICPMS-FIA
Tritium	300 pCi/L		Liquid scintillation
Gamma-emitting isotopes[e]	Am-241: 1 Cs-137: 1 Pb-210: 2 Ra-226: 1 Th-234: 1		Gamma spectroscopy
Total and extractable uranium	0.5 mg/kg	EPA SW-846 200.8/3050	ICPMS

a. The Los Alamos National Laboratory methods for these analytes are contained in *Health and Environmental Chemistry: Analytical Techniques, Data Management, and Quality Assurance* (LANL 1993, 31793).

b. It may be presumed that strontium-89 is not present.

c. ICPMS = inductively coupled plasma mass spectrometry

d. FIA = flame ionization analysis

e. Estimated quantitation limits (EQLs) are not specified for the other 41 gamma-emitting isotopes commonly analyzed; they are determined on a case-specific basis.

TABLE D1-3

TARGET ANALYTES AND MAXIMUM REQUIRED QUANTITATION LIMITS FOR SVOC ANALYSES[a]

Target Analyte	Sediment/Soil EQL[b] (mg/kg)	Target Analyte	Sediment/Soil EQL[b] (mg/kg)
Acenaphthene	330	4,6-Dinitro-2-methylphenol	1600
Acenaphthylene	330	2,4-Dinitrotoluene	330
Aniline	660	2,6-Dinitrotoluene	330
Anthracene	330	Di-n-octyl phthalate	330
Azobenzene	660	Bis(2-ethylhexyl)phthalate	330
Benz(a)anthracene	330	Fluoranthene	330
Benzoic acid	3300	Fluorene	330
Benzo(b)fluoranthene	330	Hexachlorobenzene	330
Benzo(k)fluoranthene	330	Hexachlorobutadiene	330
Benzo(g,h,i)perylene	330	Hexachlorocyclopentadiene	330
Benzo(a)pyrene	330	Hexachloroethane	330
Benzyl alcohol	1300	Indeno(1,2,3-cd)pyrene	330
Bis(2-chloroethoxy)methane	330	Isophorone	330
Bis(2-chloroethyl)ether	330	2-Methylnaphthalene	330
4-Bromophenyl phenylether	330	2-Methylphenol	330
Butylbenzylphthalate	330	4-Methylphenol	330
4-Chloroaniline	1300	Naphthalene	330
4-Chloro-3-methylphenol	660	2-Nitroaniline	1600
2-Chloronaphthalene	330	3-Nitroaniline	1600
2-Chlorophenol	330	4-Nitroaniline	660
4-Chlorophenyl phenylether	330	Nitrobenzene	330
Chrysene	330	2-Nitrophenol	330
Dibenz(a,h)anthracene	330	4-Nitrophenol	1600
Dibenzofuran	330	N-Nitrosodimethylamine	330
1,2-Dichlorobenzene	330	N-Nitrosodiphenylamine	330
1,3-Dichlorobenzene	330	N-Nitroso-di-n-propylamine	330
1,4-Dichlorobenzene	330	2,2'-oxybis(1-Chloropropane)	330
3,3'-Dichlorobenzidine	660	Pentachlorophenol	1600
2,4-Dichlorophenol	330	Phenanthrene	330
Diethylphthalate	330	Phenol	330
Dimethyl phthalate	330	Pyrene	330
2,4-Dimethylphenol	330	1,2,4-Trichlorobenzene	330
2,4-Dinitrophenol	1600	2,4,5-Trichlorophenol	1600
Di-n-butylphthalate	330	2,4,6-Trichlorophenol	330

a. All analyses were done by EPA contract laboratory program Method OLM02.0 or the equivalent EPA Method 8270. These methods are based on solvent extraction, concentration, and gas chromatography/mass spectrometry detection and quantitation.

b. Estimated quantitation limits (EQLs) for the sediment samples are based on no gel permeation chromatography (GPC) cleanup being performed. The laboratories' GPC equipment determines the sample-specific EQL based on the volume of extract the GPC equipment uses. However, the laboratories are requested, if possible, to report sample-specific EQLs of no more than twice the value listed in the table.

TABLE D1-4

TARGET ANALYTES AND MAXIMUM REQUIRED QUANTITATION LIMITS FOR PESTICIDE/PCB ANALYSES[a]

Analyte	Sediments/Soils[b] EQL (µg/kg)
Aldrin	1.65
α-BHC	1.65
β-BHC	1.65
δ-BHC	1.65
γ-BHC (lindane)	1.65
α-Chlordane	1.65
γ-Chlordane	1.65
4,4'-DDD	3.3
4,4'-DDE	3.3
4,4'-DDT	3.3
Dieldrin	3.3
Endosulfan I	1.65
Endosulfan II	3.3
Endosulfan sulfate	3.3
Endrin	3.3
Endrin ketone	3.3
Endrin aldehyde	3.3
Heptachlor	1.65
Heptachlor epoxide	1.65
Methoxychlor	16.5
Toxaphene	165
Aroclor-1016	33
Aroclor-1221	66
Aroclor-1232	33
Aroclor-1242	33
Aroclor-1248	33
Aroclor-1254	33
Aroclor-1260	33

a. All analyses were done by EPA contract laboratory program Method OLM01.8 or the equivalent EPA Method 8081. These methods are based on solvent extraction, concentration, and gas chromatography/electron capture detection and quantitation.

b. Estimated quantitation limits (EQLs) for the sediment samples are based on no gel permeation chromatography (GPC) cleanup being performed. The laboratories' GPC equipment determines the sample-specific EQL based on the volume of extract the GPC equipment uses. However, the laboratories are requested, if possible, to report sample-specific EQLs of no more than twice the value listed in the table.

D-2.0 ANALYTE SUITES AND REQUEST NUMBERS

Table D2-1 presents the analyte suites and request numbers for each sample collected from upper Los Alamos Canyon during this investigation. Each request number includes a batch of samples sent to a specific off-site analytical laboratory for a specific suite of analyses, and the request numbers can be used to track the original data packages from the off-site analytical laboratories. Table D2-1 also presents additional information on each sample including the reach or subreach, location ID, geomorphic unit, and sediment facies of the samples. Table D2-2 presents the analytical laboratory that analyzed each request number.

TABLE D2-1

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 1

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Am-241	Gross Alpha and Beta	Gross Gamma	Gamma Spectroscopy	Tritium	Isotopic Pu	Isotopic Th	Isotopic U	Metals
04LA-96-0140	LA-0016	c2b	Overbank	DP Cyn	1	2104	2104	2104	2104	2104	2104	2104	2104	2104
04LA-96-0141	LA-0017	c1	Channel	LA-2 West	1	2104	2104	2104	2104	2104	2104	2104	2104	2104
04LA-96-0142	LA-0018	f1	Overbank	LA-2 West	1	2104	2104	2104	2104	2104	2104	2104	2104	2104
04LA-96-0143	LA-0019	c2	Overbank	LA-2 East	1	2104	2104	2104	2104	2104	2104	2104	2104	2104
04LA-96-0144	LA-0020	c2b	Overbank	LA-2 East	1	2104	2104	2104	2104	2104	2104	2104	2104	2104
04LA-96-0145	LA-0020 (0021)	c2b	Overbank	LA-2 East	1	2104	2104	2104	2104	2104	2104	2104	2104	2104
04LA-96-0146	LA-0022	c2	Overbank	LA-2 East	1	2104	2104	2104	2104	2104	2104	2104	2104	2104
04LA-96-0147	LA-0023	c1	Channel	LA-2 East	1	2104	2104	2104	2104	2104	2104	2104	2104	2104
04LA-96-0148	LA-0024	c3	Channel	LA-2 East	1	2104	2104	2104	2104	2104	2104	2104	2104	2104
04LA-96-0149	LA-0024 (0025)	c3	Overbank	LA-2 East	1	2104	2104	2104	2104	2104	2104	2104	2104	2104
04LA-96-0205	LA-0022 (0039)	c2	Overbank	LA-2 East	2				2833					
04LA-96-0206	LA-0022 (0039)	c2	Overbank	LA-2 East	2				2833					
04LA-96-0207	LA-0022 (0039)	c2	Channel	LA-2 East	2				2833					
04LA-96-0211	LA-0020 (0040)	c2b	Overbank	LA-2 East	2				2833					
04LA-96-0212	LA-0020 (0040)	c2b	Overbank	LA-2 East	2				2833					
04LA-96-0215	LA-0041	c2	Overbank	LA-2 West	2				2833					
04LA-96-0216	LA-0041	c2	Overbank	LA-2 West	2				2833					
04LA-96-0217	LA-0041	c2	Channel	LA-2 West	2				2833					
04LA-96-0218	LA-0041	c2	Channel	LA-2 West	2				2833					
04LA-96-0220	LA-0024	c3	Channel	LA-2 East	2				2833					
04LA-96-0221	LA-0024	c3	Channel	LA-2 East	2				2833					
04LA-96-0222	LA-0024	c3	Overbank	LA-2 East	2				2833					
04LA-96-0223	LA-0024	c3	Channel	LA-2 East	2				2833					
04LA-96-0224	LA-0024	c3	Channel	LA-2 East	2				2833					
04LA-96-0225	LA-0019 (0043)	c2	Overbank	LA-2 East	2				2833					
04LA-96-0226	LA-0019 (0043)	c2	Overbank	LA-2 East	2				2833					
04LA-96-0227	LA-0019 (0043)	c2	Overbank	LA-2 East	2				2833					

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 1 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Am-241	Gross Alpha and Beta	Gross Gamma	Gamma Spectroscopy	Tritium	Isotopic Pu	Isotopic Th	Isotopic U	Metals
04LA-96-0229	LA-0024	c3	Channel	LA-2 East	2				2833					
04LA-97-0052	LA-0092	c2	Overbank	LA-2 West	3	3206R			3206R	3206R	3206R		3206R	3205R
04LA-97-0053	LA-0022 (0039)	c2	Overbank	LA-2 East	3	3206R			3206R	3206R	3206R		3206R	3205R
04LA-97-0054	LA-0096	c3	Overbank?	LA-2 East	3				3223R		3223R			
04LA-97-0055	LA-0096	c3	Overbank?	LA-2 East	3				3223R		3223R			
04LA-97-0056	LA-0096	c3	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0057	LA-0097	c3	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0058	LA-0097	c3	Channel	LA-2 East	3				3223R		3223R			
04LA-97-0059	LA-0097	c3	Channel	LA-2 East	3				3223R		3223R			
04LA-97-0060	LA-0098	c1	Channel	LA-2 East	3				3223R		3223R			
04LA-97-0061	LA-0104	c2b	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0062	LA-0104	c2b	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0063	LA-0104	c2b	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0064	LA-0104	c2b	Channel	LA-2 East	3				3223R		3223R			
04LA-97-0065	LA-0106	c2	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0066	LA-0106	c2	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0067	LA-0106	c2	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0068	LA-0106	c2	Channel	LA-2 East	3				3223R		3223R			
04LA-97-0071	LA-0099	f1b	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0072	LA-0100	f1	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0073	LA-0101	f1	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0074	LA-0102	Qt3	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0075	LA-0105	c2	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0076	LA-0107	c2	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0077	LA-0108	f1	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0078	LA-0108	f1	Overbank	LA-2 East	3				3223R		3223R			
04LA-97-0085	LA-0103	c2	Channel	LA-2 East	3				3223R					

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 1 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Am-241	Gross Alpha and Beta	Gross Gamma	Gamma Spectroscopy	Tritium	Isotopic Pu	Isotopic Th	Isotopic U	Metals
04LA-97-0087	LA-0105	c2	Overbank	LA-2 East	3				3223R					
04LA-97-0088	LA-0105	c2	Overbank	LA-2 East	3				3223R					
04LA-97-0089	LA-0105	c2	Channel	LA-2 East	3				3223R					
04LA-97-0090	LA-0107	c2	Overbank	LA-2 East	3				3223R					
04LA-97-0091	LA-0107	c2	Overbank	LA-2 East	3				3223R					
04LA-97-0096	LA-0092	c2	Overbank	LA-2 West	3						3223R			
04LA-97-0097	LA-0092	c2	Overbank	LA-2 West	3						3223R			
04LA-97-0098	LA-0092	c2	Overbank	LA-2 West	3						3223R			
04LA-97-0099	LA-0092	c2	Channel	LA-2 West	3						3223R			
04LA-97-0100	LA-0095	Qt2	Overbank	LA-2 West	3						3223R			
04LA-97-0103	LA-0093	f1	Overbank	LA-2 West	3						3223R			
04LA-97-0104	LA-0094	f1	Overbank	LA-2 West	3						3223R			
04LA-97-0105	LA-0110	c3	Overbank	LA-3	1				3337R					
04LA-97-0106	LA-0110	c3	Overbank	LA-3	1				3337R					
04LA-97-0107	LA-0110	c3	Overbank	LA-3	1				3337R					
04LA-97-0108	LA-0110	c3	Channel	LA-3	1				3337R					
04LA-97-0109	LA-0112	c1	Channel	LA-3	1				3337R					
04LA-97-0110	LA-0119	c1	Channel	LA-3	1				3337R					
04LA-97-0111	LA-0121	f1	Overbank	LA-3	1				3337R					
04LA-97-0112	LA-0114	c2	Overbank	LA-3	1				3337R					
04LA-97-0113	LA-0114	c2	Overbank	LA-3	1				3337R					
04LA-97-0114	LA-0114	c2	Channel	LA-3	1				3337R					
04LA-97-0115	LA-0114	c2	Channel	LA-3	1				3337R					
04LA-97-0116	LA-0115	c3	Overbank	LA-3	1				3337R					
04LA-97-0117	LA-0115	c3	Overbank	LA-3	1				3337R					
04LA-97-0118	LA-0115	c3	Overbank	LA-3	1				3337R					
04LA-97-0119	LA-0115	c3	Channel	LA-3	1				3337R					

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 1 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Am-241	Gross Alpha and Beta	Gross Gamma	Gamma Spectroscopy	Tritium	Isotopic Pu	Isotopic Th	Isotopic U	Metals
04LA-97-0120	LA-0117	f1	Overbank	LA-3	1				3337R					
04LA-97-0121	LA-0117	f1	Overbank	LA-3	1				3337R					
04LA-97-0122	LA-0117	f1	Overbank	LA-3	1				3337R					
04LA-97-0123	LA-0117	f1	Overbank	LA-3	1				3337R					
04LA-97-0124	LA-0117	f1	Overbank?	LA-3	1				3337R					
04LA-97-0125	LA-0117	f1	Channel	LA-3	1				3337R					
04LA-97-0126	LA-0118	f1	Overbank	LA-3	1				3337R					
04LA-97-0127	LA-0118	f1	Overbank	LA-3	1				3337R					
04LA-97-0128	LA-0118	f1	Overbank	LA-3	1				3337R					
04LA-97-0129	LA-0118	f1	Channel	LA-3	1				3337R					
04LA-97-0130	LA-0113	f2	Overbank	LA-3	1				3337R		3337R			
04LA-97-0131	LA-0120	f2	Overbank	LA-3	1				3337R		3337R			
04LA-97-0132	LA-0111	c2	Overbank	LA-3	1				3337R		3337R			
04LA-97-0133	LA-0111	c2	Overbank	LA-3	1				3337R		3337R			
04LA-97-0134	LA-0111	c2	Overbank	LA-3	1				3337R		3337R			
04LA-97-0135	LA-0111	c2	Channel	LA-3	1				3337R		3337R			
04LA-97-0136	LA-0109	c3	Overbank	LA-3	1				3337R		3337R			
04LA-97-0137	LA-0109	c3	Overbank	LA-3	1				3337R		3337R			
04LA-97-0138	LA-0109	c3	Overbank	LA-3	1				3337R		3337R			
04LA-97-0139	LA-0109	c3	Overbank	LA-3	1				3337R		3337R			
04LA-97-0140	LA-0109	c3	Channel	LA-3	1				3337R		3337R			
04LA-97-0141	LA-0109	c3	Channel	LA-3	1				3337R		3337R			
04LA-97-0142	LA-0109	c3	Channel	LA-3	1				3337R		3337R			
04LA-97-0143	LA-0109	c3	Overbank	LA-3	1	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3313R
04LA-97-0144	LA-0109	c3	Overbank	LA-3	1	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3313R
04LA-97-0145	LA-0110	c3	Overbank	LA-3	1	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3313R
04LA-97-0146	LA-0110	c3	Overbank	LA-3	1	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3313R

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 1 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Am-241	Gross Alpha and Beta	Gross Gamma	Gamma Spectroscopy	Tritium	Isotopic Pu	Isotopic Th	Isotopic U	Metals
04LA-97-0147	LA-0111	c2	Overbank	LA-3	1	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3313R
04LA-97-0148	LA-0114	c2	Overbank	LA-3	1	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3313R
04LA-97-0149	LA-0115	c3	Overbank	LA-3	1	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3313R
04LA-97-0150	LA-0116	c1	Channel	LA-3	1	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3314R	3313R
04LA-97-0236	LA-0141	c3? (f1?)	Overbank	LA-1 West (u)	1						3729R		3729R	3728R
04LA-97-0237	LA-0141	c3? (f1?)	Overbank	LA-1 West (u)	1						3729R		3729R	3728R
04LA-97-0238	LA-0142	f1	Overbank	LA-1 West (u)	1						3729R			
04LA-97-0239	LA-0143	c3	Overbank	LA-1 West (u)	1						3729R			
04LA-97-0240	LA-0143	c3	Overbank	LA-1 West (u)	1						3729R			
04LA-97-0241	LA-0144	c1	Channel	LA-1 West (u)	1						3729R			
04LA-97-0242	LA-0145	f1	Overbank	LA-1 West (d)	1						3729R			
04LA-97-0243	LA-0146	c3	Overbank	LA-1 West (d)	1						3729R			3728R
04LA-97-0244	LA-0146	c3	Overbank	LA-1 West (d)	1						3729R			3728R
04LA-97-0245	LA-0146	c3	Overbank	LA-1 West (d)	1						3729R			3728R
04LA-97-0246	LA-0147	c3	Overbank	LA-1 West (d)	1						3729R			
04LA-97-0247	LA-0147	c3	Channel	LA-1 West (d)	1						3729R			
04LA-97-0248	LA-0147	c3	Channel	LA-1 West (d)	1						3729R			
04LA-97-0249	LA-0147	c3	Overbank	LA-1 West (d)	1						3729R			
04LA-97-0250	LA-0147	c3	Channel?	LA-1 West (d)	1						3729R			
04LA-97-0251	LA-0147	c3	Channel	LA-1 West (d)	1						3729R			
04LA-97-0252	LA-0148	c2	Overbank	LA-1 West (d)	1						3729R			
04LA-97-0253	LA-0149	c1	Channel	LA-1 West (d)	1						3729R			
04LA-97-0254	LA-0150	f1	Overbank	LA-1 Central	1						3729R			
04LA-97-0255	LA-0151	f1	Overbank	LA-1 Central	1						3729R			3728R
04LA-97-0256	LA-0151	f1	Overbank	LA-1 Central	1						3729R			3728R
04LA-97-0257	LA-0151	f1	Overbank	LA-1 Central	1						3729R			3728R
04LA-97-0258	LA-0151	f1	Channel	LA-1 Central	1						3729R			

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 1 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Am-241	Gross Alpha and Beta	Gross Gamma	Gamma Spectroscopy	Tritium	Isotopic Pu	Isotopic Th	Isotopic U	Metals
04LA-97-0259	LA-0152	f1	Overbank	LA-1 Central	1						3729R			
04LA-97-0260	LA-0152	f1	Overbank	LA-1 Central	1						3729R			
04LA-97-0261	LA-0153	c2	Overbank	LA-1 Central	1						3729R			
04LA-97-0264	LA-0154	c1	Channel	LA-1 Central	1						3729R			
04LA-97-0265	LA-0155	c3	Channel	LA-1 Central	1						3729R			
04LA-97-0266	LA-0155	c3	Channel	LA-1 Central	1						3729R			
04LA-97-0267	LA-0155	c3	Overbank	LA-1 Central	1						3729R			
04LA-97-0268	LA-0156	f1	Overbank	LA-1 Central	1						3729R			
04LA-97-0269	LA-0156	f1	Overbank	LA-1 Central	1						3729R			
04LA-97-0270	LA-0157	f1	Overbank	LA-1 East	1						3729R			
04LA-97-0271	LA-0157	f1	Overbank	LA-1 East	1						3729R			
04LA-97-0272	LA-0158	f1	Overbank	LA-1 East	1						3729R		3729R	3728R
04LA-97-0273	LA-0158	f1	Overbank	LA-1 East	1						3729R		3729R	3728R
04LA-97-0274	LA-0159	c1	Channel	LA-1 East	1						3729R			
04LA-97-0275	LA-0160	f1	Overbank	LA-1 East	1						3729R			
04LA-97-0276	LA-0161	c2? (c3?)	Overbank	LA-1 East	1						3729R			
04LA-97-0277	LA-0161	c2? (c3?)	Channel	LA-1 East	1						3729R			
04LA-97-0278	LA-0162	c3	Channel	LA-1 East	1						3729R			
04LA-97-0279	LA-0162	c3	Overbank	LA-1 East	1						3729R			3728R
04LA-97-0280	LA-0162	c3	Overbank	LA-1 East	1						3729R			
04LA-97-0568	LA-0170	c2	Overbank	LA-1 Far West	2	3968R			3968R		3968R		3968R	3938R
04LA-97-0569	LA-0041	c2	Overbank	LA-2 West	4	3968R					3968R		3968R	3938R
04LA-97-0570	LA-0041	c2	Overbank	LA-2 West	4	3968R					3968R		3968R	3938R
04LA-97-0571	LA-0143	c3	Overbank	LA-1 West (u)	2	3968R			3968R				3968R	3938R
04LA-97-0572	LA-0160	f1	Overbank	LA-1 East	2	3968R			3968R				3968R	3938R
04LA-97-0573	LA-0173	c2	Overbank	LA-1 West+	2	3968R					3968R		3968R	3938R
04LA-97-0574	LA-0174	c1	Channel	LA-1 West+	2	3968R					3968R		3968R	3938R

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 1 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Am-241	Gross Alpha and Beta	Gross Gamma	Gamma Spectroscopy	Tritium	Isotopic Pu	Isotopic Th	Isotopic U	Metals
04LA-97-0575	LA-0175	c3	Overbank	LA-1 West+	2	3968R					3968R		3968R	3938R
04LA-97-0576	LA-0175	c3	Overbank	LA-1 West+	2	3968R					3968R		3968R	3938R
04LA-97-0577	LA-0175	c3	Overbank	LA-1 West+	2	3968R					3968R		3968R	3938R
04LA-97-0578	LA-0176	f1	Overbank	LA-1 West (u)	2						3968R			
04LA-97-0579	LA-0171	c1	Channel	LA-1 Far West	2	3968R			3968R		3968R		3968R	3968R
04LA-97-0580	LA-0177	f1	Overbank	LA-1 West (u)	2						3968R			
04LA-97-0581	LA-0177	f1	Overbank	LA-1 West (u)	2						3968R			
04LA-97-0582	LA-0177	f1	Overbank	LA-1 West (u)	2						3968R			
04LA-97-0583	LA-0141	c3? (f1?)	Overbank	LA-1 West (u)	2						3968R			
04LA-97-0584	LA-0142	f1	Overbank	LA-1 West (u)	2						3968R			
04LA-97-0585	LA-0143	c3	Overbank	LA-1 West (u)	2						3968R			
04LA-97-0586	LA-0145	f1	Overbank	LA-1 West (d)	2						3968R			
04LA-97-0587	LA-0179	c2	Overbank	LA-1 Central	2						3968R			
04LA-97-0588	LA-0179	c2	Channel	LA-1 Central	2						3968R			
04LA-97-0589	LA-0180	f1	Overbank	LA-1 Central	2						3968R			
04LA-97-0590	LA-0176	f1	Overbank	LA-1 West (u)	2	3968R			3968R		3968R		3968R	3938R
04LA-97-0592	LA-0180	f1	Channel	LA-1 Central	2						3968R			
04LA-97-0593	LA-0181	c3	Channel	LA-1 Central	2						3968R			
04LA-97-0594	LA-0153	c2	Channel	LA-1 Central	2						3968R			
04LA-97-0595	LA-0182	c3? (f1?)	Overbank	LA-1 Central	2						3968R			
04LA-97-0596	LA-0182	c3? (f1?)	Overbank	LA-1 Central	2						3968R			
04LA-97-0597	LA-0183	c3? (f1?)	Overbank	LA-1 Central	2						3968R			
04LA-97-0598	LA-0184	f1	Overbank	LA-1 East	2						3968R			
04LA-97-0599	LA-0185	c2	Overbank	LA-1 East	2						3968R			
04LA-97-0600	LA-0185	c2	Channel	LA-1 East	2						3968R			
04LA-97-0601	LA-0186	c3	Overbank	LA-1 East	2						3968R			
04LA-97-0602	LA-0179	c2	Overbank	LA-1 Central	2	3968R			3968R		3968R		3968R	3938R

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 1 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Am-241	Gross Alpha and Beta	Gross Gamma	Gamma Spectroscopy	Tritium	Isotopic Pu	Isotopic Th	Isotopic U	Metals
04LA-97-0603	LA-0187	c2? (c3?)	Overbank	LA-1 East	2						3968R			
04LA-97-0604	LA-0187	c2? (c3?)	Overbank	LA-1 East	2						3968R			
04LA-97-0605	LA-0187	c2? (c3?)	Overbank	LA-1 East	2						3968R			
04LA-97-0606	LA-0188	c3	Overbank	LA-1 East	2						3968R			
04LA-97-0607	LA-0188	c3	Overbank	LA-1 East	2						3968R			
04LA-97-0608	LA-0188	c3	Overbank	LA-1 East	2						3968R			
04LA-97-0609	LA-0188	c3	Channel	LA-1 East	2						3968R			
04LA-97-0610	LA-0189	f1	Overbank	LA-2 West	4						3968R			
04LA-97-0611	LA-0189	f1	Overbank	LA-2 West	4						3968R			
04LA-97-0612	LA-0190	c3	Overbank	LA-2 West	4						3968R			
04LA-97-0613	LA-0181	c3	Overbank	LA-1 Central	2	3968R			3968R		3968R		3968R	3938R
04LA-97-0614	LA-0191	c3	Channel	LA-2 West	4						3968R			
04LA-97-0615	LA-0192	c2	Overbank	LA-2 West	4						3968R			
04LA-97-0616	LA-0192	c2	Overbank	LA-2 West	4						3968R			
04LA-97-0617	LA-0192	c2	Overbank	LA-2 West	4						3968R			
04LA-97-0618	LA-0192	c2	Channel	LA-2 West	4						3968R			
04LA-97-0619	LA-0192	c2	Channel	LA-2 West	4						3968R			
04LA-97-0620	LA-0193	f1	Overbank	LA-2 West	4						3968R			
04LA-97-0621	LA-0041	c2	Channel	LA-2 West	4						3968R			
04LA-97-0622	LA-0186	c3	Overbank	LA-1 East	2	3968R			3968R		3968R		3968R	3938R
04LA-97-0623	LA-0185	c2	Overbank	LA-1 East	2	3968R			3968R		3968R		3968R	3938R
04LA-97-0624	LA-0172	c3	Overbank	LA-1 Far West	2	3968R			3968R		3968R		3968R	3938R
04LA-97-0625	LA-0178	c2	Overbank	LA-1 West (u)	2	3968R			3968R		3968R		3968R	3938R

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 2

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Total Uranium	PAHs	PCBs	Pesticides and PCBs	Ra-226	SVOCs	Sr-90	Total Cyanide
04LA-96-0140	LA-0016	c2b	Overbank	DP Cyn	1				2103		2103	2104	2104
04LA-96-0141	LA-0017	c1	Channel	LA-2 West	1				2103		2103	2104	2104
04LA-96-0142	LA-0018	f1	Overbank	LA-2 West	1				2103		2103	2104	2104
04LA-96-0143	LA-0019	c2	Overbank	LA-2 East	1				2103		2103	2104	2104
04LA-96-0144	LA-0020	c2b	Overbank	LA-2 East	1				2103		2103	2104	2104
04LA-96-0145	LA-0020 (0021)	c2b	Overbank	LA-2 East	1				2103		2103	2104	2104
04LA-96-0146	LA-0022	c2	Overbank	LA-2 East	1				2103		2103	2104	2104
04LA-96-0147	LA-0023	c1	Channel	LA-2 East	1				2103		2103	2104	2104
04LA-96-0148	LA-0024	c3	Channel	LA-2 East	1				2103		2103	2104	2104
04LA-96-0149	LA-0024 (0025)	c3	Overbank	LA-2 East	1				2103		2103	2104	2104
04LA-96-0205	LA-0022 (0039)	c2	Overbank	LA-2 East	2								
04LA-96-0206	LA-0022 (0039)	c2	Overbank	LA-2 East	2							2833	
04LA-96-0207	LA-0022 (0039)	c2	Channel	LA-2 East	2							2833	
04LA-96-0211	LA-0020 (0040)	c2b	Overbank	LA-2 East	2								
04LA-96-0212	LA-0020 (0040)	c2b	Overbank	LA-2 East	2								
04LA-96-0215	LA-0041	c2	Overbank	LA-2 West	2							2833	
04LA-96-0216	LA-0041	c2	Overbank	LA-2 West	2							2833	
04LA-96-0217	LA-0041	c2	Channel	LA-2 West	2							2833	
04LA-96-0218	LA-0041	c2	Channel	LA-2 West	2							2833	
04LA-96-0220	LA-0024	c3	Channel	LA-2 East	2							2833	
04LA-96-0221	LA-0024	c3	Channel	LA-2 East	2							2833	
04LA-96-0222	LA-0024	c3	Overbank	LA-2 East	2							2833	
04LA-96-0223	LA-0024	c3	Channel	LA-2 East	2							2833	
04LA-96-0224	LA-0024	c3	Channel	LA-2 East	2							2833	
04LA-96-0225	LA-0019 (0043)	c2	Overbank	LA-2 East	2							2833	

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 2 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Total Uranium	PAHs	PCBs	Pesticides and PCBs	Ra-226	SVOCs	Sr-90	Total Cyanide
04LA-96-0226	LA-0019 (0043)	c2	Overbank	LA-2 East	2							2833	
04LA-96-0227	LA-0019 (0043)	c2	Overbank	LA-2 East	2							2833	
04LA-96-0229	LA-0024	c3	Channel	LA-2 East	2							2833	
04LA-97-0052	LA-0092	c2	Overbank	LA-2 West	3		3204R	3204R		3206R		3206R	
04LA-97-0053	LA-0022 (0039)	c2	Overbank	LA-2 East	3		3204R	3204R		3206R		3206R	
04LA-97-0054	LA-0096	c3	Overbank?	LA-2 East	3							3223R	
04LA-97-0055	LA-0096	c3	Overbank?	LA-2 East	3							3223R	
04LA-97-0056	LA-0096	c3	Overbank	LA-2 East	3							3223R	
04LA-97-0057	LA-0097	c3	Overbank	LA-2 East	3							3223R	
04LA-97-0058	LA-0097	c3	Channel	LA-2 East	3							3223R	
04LA-97-0059	LA-0097	c3	Channel	LA-2 East	3							3223R	
04LA-97-0060	LA-0098	c1	Channel	LA-2 East	3							3223R	
04LA-97-0061	LA-0104	c2b	Overbank	LA-2 East	3							3223R	
04LA-97-0062	LA-0104	c2b	Overbank	LA-2 East	3							3223R	
04LA-97-0063	LA-0104	c2b	Overbank	LA-2 East	3							3223R	
04LA-97-0064	LA-0104	c2b	Channel	LA-2 East	3							3223R	
04LA-97-0065	LA-0106	c2	Overbank	LA-2 East	3							3223R	
04LA-97-0066	LA-0106	c2	Overbank	LA-2 East	3							3223R	
04LA-97-0067	LA-0106	c2	Overbank	LA-2 East	3							3223R	
04LA-97-0068	LA-0106	c2	Channel	LA-2 East	3							3223R	
04LA-97-0071	LA-0099	f1b	Overbank	LA-2 East	3								
04LA-97-0072	LA-0100	f1	Overbank	LA-2 East	3								
04LA-97-0073	LA-0101	f1	Overbank	LA-2 East	3								
04LA-97-0074	LA-0102	Qt3	Overbank	LA-2 East	3								
04LA-97-0075	LA-0105	c2	Overbank	LA-2 East	3								
04LA-97-0076	LA-0107	c2	Overbank	LA-2 East	3								
04LA-97-0077	LA-0108	f1	Overbank	LA-2 East	3								

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 2 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Total Uranium	PAHs	PCBs	Pesticides and PCBs	Ra-226	SVOCs	Sr-90	Total Cyanide
04LA-97-0078	LA-0108	f1	Overbank	LA-2 East	3								
04LA-97-0085	LA-0103	c2	Channel	LA-2 East	3								
04LA-97-0087	LA-0105	c2	Overbank	LA-2 East	3								
04LA-97-0088	LA-0105	c2	Overbank	LA-2 East	3								
04LA-97-0089	LA-0105	c2	Channel	LA-2 East	3								
04LA-97-0090	LA-0107	c2	Overbank	LA-2 East	3								
04LA-97-0091	LA-0107	c2	Overbank	LA-2 East	3								
04LA-97-0096	LA-0092	c2	Overbank	LA-2 West	3							3223R	
04LA-97-0097	LA-0092	c2	Overbank	LA-2 West	3							3223R	
04LA-97-0098	LA-0092	c2	Overbank	LA-2 West	3							3223R	
04LA-97-0099	LA-0092	c2	Channel	LA-2 West	3							3223R	
04LA-97-0100	LA-0095	Qt2	Overbank	LA-2 West	3							3223R	
04LA-97-0103	LA-0093	f1	Overbank	LA-2 West	3							3223R	
04LA-97-0104	LA-0094	f1	Overbank	LA-2 West	3							3223R	
04LA-97-0105	LA-0110	c3	Overbank	LA-3	1								
04LA-97-0106	LA-0110	c3	Overbank	LA-3	1								
04LA-97-0107	LA-0110	c3	Overbank	LA-3	1								
04LA-97-0108	LA-0110	c3	Channel	LA-3	1								
04LA-97-0109	LA-0112	c1	Channel	LA-3	1								
04LA-97-0110	LA-0119	c1	Channel	LA-3	1								
04LA-97-0111	LA-0121	f1	Overbank	LA-3	1								
04LA-97-0112	LA-0114	c2	Overbank	LA-3	1								
04LA-97-0113	LA-0114	c2	Overbank	LA-3	1								
04LA-97-0114	LA-0114	c2	Channel	LA-3	1								
04LA-97-0115	LA-0114	c2	Channel	LA-3	1								
04LA-97-0116	LA-0115	c3	Overbank	LA-3	1								
04LA-97-0117	LA-0115	c3	Overbank	LA-3	1								

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 2 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Total Uranium	PAHs	PCBs	Pesticides and PCBs	Ra-226	SVOCs	Sr-90	Total Cyanide
04LA-97-0118	LA-0115	c3	Overbank	LA-3	1								
04LA-97-0119	LA-0115	c3	Channel	LA-3	1								
04LA-97-0120	LA-0117	f1	Overbank	LA-3	1								
04LA-97-0121	LA-0117	f1	Overbank	LA-3	1								
04LA-97-0122	LA-0117	f1	Overbank	LA-3	1								
04LA-97-0123	LA-0117	f1	Overbank	LA-3	1								
04LA-97-0124	LA-0117	f1	Overbank?	LA-3	1								
04LA-97-0125	LA-0117	f1	Channel	LA-3	1								
04LA-97-0126	LA-0118	f1	Overbank	LA-3	1								
04LA-97-0127	LA-0118	f1	Overbank	LA-3	1								
04LA-97-0128	LA-0118	f1	Overbank	LA-3	1								
04LA-97-0129	LA-0118	f1	Channel	LA-3	1								
04LA-97-0130	LA-0113	f2	Overbank	LA-3	1								
04LA-97-0131	LA-0120	f2	Overbank	LA-3	1								
04LA-97-0132	LA-0111	c2	Overbank	LA-3	1							3337R	
04LA-97-0133	LA-0111	c2	Overbank	LA-3	1							3337R	
04LA-97-0134	LA-0111	c2	Overbank	LA-3	1							3337R	
04LA-97-0135	LA-0111	c2	Channel	LA-3	1							3337R	
04LA-97-0136	LA-0109	c3	Overbank	LA-3	1							3337R	
04LA-97-0137	LA-0109	c3	Overbank	LA-3	1							3337R	
04LA-97-0138	LA-0109	c3	Overbank	LA-3	1							3337R	
04LA-97-0139	LA-0109	c3	Overbank	LA-3	1							3337R	
04LA-97-0140	LA-0109	c3	Channel	LA-3	1							3337R	
04LA-97-0141	LA-0109	c3	Channel	LA-3	1							3337R	
04LA-97-0142	LA-0109	c3	Channel	LA-3	1							3337R	
04LA-97-0143	LA-0109	c3	Overbank	LA-3	1	3314R			3312R		3312R	3314R	3313R
04LA-97-0144	LA-0109	c3	Overbank	LA-3	1	3314R			3312R		3312R	3314R	3313R

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 2 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Total Uranium	PAHs	PCBs	Pesticides and PCBs	Ra-226	SVOCs	Sr-90	Total Cyanide
04LA-97-0145	LA-0110	c3	Overbank	LA-3	1	3314R			3312R		3312R	3314R	3313R
04LA-97-0146	LA-0110	c3	Overbank	LA-3	1	3314R			3312R		3312R	3314R	3313R
04LA-97-0147	LA-0111	c2	Overbank	LA-3	1	3314R			3312R		3312R	3314R	3313R
04LA-97-0148	LA-0114	c2	Overbank	LA-3	1	3314R			3312R		3312R	3314R	3313R
04LA-97-0149	LA-0115	c3	Overbank	LA-3	1	3314R			3312R		3312R	3314R	3313R
04LA-97-0150	LA-0116	c1	Channel	LA-3	1	3314R			3312R		3312R	3314R	3313R
04LA-97-0236	LA-0141	c3? (f1?)	Overbank	LA-1 West (u)	1			3727R					
04LA-97-0237	LA-0141	c3? (f1?)	Overbank	LA-1 West (u)	1			3727R					
04LA-97-0238	LA-0142	f1	Overbank	LA-1 West (u)	1								
04LA-97-0239	LA-0143	c3	Overbank	LA-1 West (u)	1								
04LA-97-0240	LA-0143	c3	Overbank	LA-1 West (u)	1								
04LA-97-0241	LA-0144	c1	Channel	LA-1 West (u)	1								
04LA-97-0242	LA-0145	f1	Overbank	LA-1 West (d)	1								
04LA-97-0243	LA-0146	c3	Overbank	LA-1 West (d)	1								
04LA-97-0244	LA-0146	c3	Overbank	LA-1 West (d)	1								
04LA-97-0245	LA-0146	c3	Overbank	LA-1 West (d)	1			3727R					
04LA-97-0246	LA-0147	c3	Overbank	LA-1 West (d)	1								
04LA-97-0247	LA-0147	c3	Channel	LA-1 West (d)	1								
04LA-97-0248	LA-0147	c3	Channel	LA-1 West (d)	1								
04LA-97-0249	LA-0147	c3	Overbank	LA-1 West (d)	1								
04LA-97-0250	LA-0147	c3	Channel?	LA-1 West (d)	1								
04LA-97-0251	LA-0147	c3	Channel	LA-1 West (d)	1								
04LA-97-0252	LA-0148	c2	Overbank	LA-1 West (d)	1								
04LA-97-0253	LA-0149	c1	Channel	LA-1 West (d)	1								
04LA-97-0254	LA-0150	f1	Overbank	LA-1 Central	1								
04LA-97-0255	LA-0151	f1	Overbank	LA-1 Central	1			3727R				3729R	
04LA-97-0256	LA-0151	f1	Overbank	LA-1 Central	1			3727R				3729R	

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 2 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Total Uranium	PAHs	PCBs	Pesticides and PCBs	Ra-226	SVOCs	Sr-90	Total Cyanide
04LA-97-0257	LA-0151	f1	Overbank	LA-1 Central	1			3727R				3729R	
04LA-97-0258	LA-0151	f1	Channel	LA-1 Central	1								
04LA-97-0259	LA-0152	f1	Overbank	LA-1 Central	1								
04LA-97-0260	LA-0152	f1	Overbank	LA-1 Central	1								
04LA-97-0261	LA-0153	c2	Overbank	LA-1 Central	1								
04LA-97-0264	LA-0154	c1	Channel	LA-1 Central	1								
04LA-97-0265	LA-0155	c3	Channel	LA-1 Central	1								
04LA-97-0266	LA-0155	c3	Channel	LA-1 Central	1								
04LA-97-0267	LA-0155	c3	Overbank	LA-1 Central	1								
04LA-97-0268	LA-0156	f1	Overbank	LA-1 Central	1								
04LA-97-0269	LA-0156	f1	Overbank	LA-1 Central	1								
04LA-97-0270	LA-0157	f1	Overbank	LA-1 East	1								
04LA-97-0271	LA-0157	f1	Overbank	LA-1 East	1								
04LA-97-0272	LA-0158	f1	Overbank	LA-1 East	1			3727R					
04LA-97-0273	LA-0158	f1	Overbank	LA-1 East	1			3727R					
04LA-97-0274	LA-0159	c1	Channel	LA-1 East	1								
04LA-97-0275	LA-0160	f1	Overbank	LA-1 East	1								
04LA-97-0276	LA-0161	c2? (c3?)	Overbank	LA-1 East	1								
04LA-97-0277	LA-0161	c2? (c3?)	Channel	LA-1 East	1								
04LA-97-0278	LA-0162	c3	Channel	LA-1 East	1								
04LA-97-0279	LA-0162	c3	Overbank	LA-1 East	1			3727R					
04LA-97-0280	LA-0162	c3	Overbank	LA-1 East	1								
04LA-97-0568	LA-0170	c2	Overbank	LA-1 Far West	2				3937R				
04LA-97-0569	LA-0041	c2	Overbank	LA-2 West	4				3937R			3968R	
04LA-97-0570	LA-0041	c2	Overbank	LA-2 West	4				3937R			3968R	
04LA-97-0571	LA-0143	c3	Overbank	LA-1 West (u)	2				3937R				
04LA-97-0572	LA-0160	f1	Overbank	LA-1 East	2				3937R				

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 2 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Total Uranium	PAHs	PCBs	Pesticides and PCBs	Ra-226	SVOCs	Sr-90	Total Cyanide
04LA-97-0573	LA-0173	c2	Overbank	LA-1 West+	2				3937R				
04LA-97-0574	LA-0174	c1	Channel	LA-1 West+	2				3937R				
04LA-97-0575	LA-0175	c3	Overbank	LA-1 West+	2				3937R				
04LA-97-0576	LA-0175	c3	Overbank	LA-1 West+	2				3937R				
04LA-97-0577	LA-0175	c3	Overbank	LA-1 West+	2				3937R				
04LA-97-0578	LA-0176	f1	Overbank	LA-1 West (u)	2				3937R				
04LA-97-0579	LA-0171	c1	Channel	LA-1 Far West	2								
04LA-97-0580	LA-0177	f1	Overbank	LA-1 West (u)	2								
04LA-97-0581	LA-0177	f1	Overbank	LA-1 West (u)	2								
04LA-97-0582	LA-0177	f1	Overbank	LA-1 West (u)	2								
04LA-97-0583	LA-0141	c3? (f1?)	Overbank	LA-1 West (u)	2								
04LA-97-0584	LA-0142	f1	Overbank	LA-1 West (u)	2								
04LA-97-0585	LA-0143	c3	Overbank	LA-1 West (u)	2								
04LA-97-0586	LA-0145	f1	Overbank	LA-1 West (d)	2								
04LA-97-0587	LA-0179	c2	Overbank	LA-1 Central	2								
04LA-97-0588	LA-0179	c2	Channel	LA-1 Central	2								
04LA-97-0589	LA-0180	f1	Overbank	LA-1 Central	2								
04LA-97-0590	LA-0176	f1	Overbank	LA-1 West (u)	2				3937R				
04LA-97-0592	LA-0180	f1	Channel	LA-1 Central	2								
04LA-97-0593	LA-0181	c3	Channel	LA-1 Central	2								
04LA-97-0594	LA-0153	c2	Channel	LA-1 Central	2								
04LA-97-0595	LA-0182	c3? (f1?)	Overbank	LA-1 Central	2								
04LA-97-0596	LA-0182	c3? (f1?)	Overbank	LA-1 Central	2								
04LA-97-0597	LA-0183	c3? (f1?)	Overbank	LA-1 Central	2								
04LA-97-0598	LA-0184	f1	Overbank	LA-1 East	2								
04LA-97-0599	LA-0185	c2	Overbank	LA-1 East	2								
04LA-97-0600	LA-0185	c2	Channel	LA-1 East	2								

TABLE D2-1 (continued)

UPPER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

Part 2 continued

Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Reach or Subreach	Sampling Event	Total Uranium	PAHs	PCBs	Pesticides and PCBs	Ra-226	SVOCs	Sr-90	Total Cyanide
04LA-97-0601	LA-0186	c3	Overbank	LA-1 East	2								
04LA-97-0602	LA-0179	c2	Overbank	LA-1 Central	2				3937R				
04LA-97-0603	LA-0187	c2? (c3?)	Overbank	LA-1 East	2								
04LA-97-0604	LA-0187	c2? (c3?)	Overbank	LA-1 East	2								
04LA-97-0605	LA-0187	c2? (c3?)	Overbank	LA-1 East	2								
04LA-97-0606	LA-0188	c3	Overbank	LA-1 East	2								
04LA-97-0607	LA-0188	c3	Overbank	LA-1 East	2								
04LA-97-0608	LA-0188	c3	Overbank	LA-1 East	2								
04LA-97-0609	LA-0188	c3	Channel	LA-1 East	2								
04LA-97-0610	LA-0189	f1	Overbank	LA-2 West	4								
04LA-97-0611	LA-0189	f1	Overbank	LA-2 West	4								
04LA-97-0612	LA-0190	c3	Overbank	LA-2 West	4								
04LA-97-0613	LA-0181	c3	Overbank	LA-1 Central	2				3937R				
04LA-97-0614	LA-0191	c3	Channel	LA-2 West	4								
04LA-97-0615	LA-0192	c2	Overbank	LA-2 West	4								
04LA-97-0616	LA-0192	c2	Overbank	LA-2 West	4								
04LA-97-0617	LA-0192	c2	Overbank	LA-2 West	4								
04LA-97-0618	LA-0192	c2	Channel	LA-2 West	4								
04LA-97-0619	LA-0192	c2	Channel	LA-2 West	4								
04LA-97-0620	LA-0193	f1	Overbank	LA-2 West	4								
04LA-97-0621	LA-0041	c2	Channel	LA-2 West	4								
04LA-97-0622	LA-0186	c3	Overbank	LA-1 East	2				3937R				
04LA-97-0623	LA-0185	c2	Overbank	LA-1 East	2				3937R				
04LA-97-0624	LA-0172	c3	Overbank	LA-1 Far West	2				3937R				
04LA-97-0625	LA-0178	c2	Overbank	LA-1 West (u)	2				3937R				

TABLE D2-2

UPPER LOS ALAMOS CANYON REQUEST NUMBERS AND ANALYTICAL LABORATORIES

Request Number	Analytical Laboratory
2103	Rust Geotech[a]
2104	Rust Geotech
2833	Thermo Nutech[b]
3204R	Kemron Environmental Services[c]
3205R	Thermo Nutech
3206R	QST Environmental[d]
3223R	QST Environmental
3312R	Kemron Environmental Services
3313R	Weston/Recra[e]
3314R	Paragon Analytics, Inc.[f]
3337R	QST Environmental
3727R	Weston/Recra
3728R	Weston/Recra
3729R	Paragon Analytics, Inc.
3937R	Paragon Analytics, Inc.
3938R	Paragon Analytics, Inc.
3968R	Paragon Analytics, Inc.

a. Rust Geotech laboratory located in Grand Junction, Colorado

b. Thermo Nutech laboratory located in Oak Ridge, Tennessee

c. Kemron Environmental Services laboratory located in Marietta, Ohio

d. QST Environmental laboratory located in Gainesville, Florida; formerly Environmental Science and Engineering (ESE)

e. Weston/Recra laboratory located in Lionville, Pennsylvania

f. Paragon Analytics, Inc., laboratory located in Fort Collins, Colorado; formerly ATI laboratory

D-3.0 SUMMARY OF UPPER LOS ALAMOS CANYON ANALYSES

Tables D3-1 through D3-3 present summaries of the inorganic chemical, radionuclide, and organic chemical analyses for samples from the upper Los Alamos Canyon reaches. These tables show the number of samples, detection frequency, and concentration range for each analyte.

TABLE D3-1

SUMMARY OF INORGANIC CHEMICAL ANALYSES FROM UPPER LOS ALAMOS CANYON REACHES

Analyte Name	Total Count	Nondetects			Detects		
		Count	Min (mg/kg)	Max (mg/kg)	Count	Min (mg/kg)	Max (mg/kg)
Aluminum	49	N/A*	N/A	N/A	49	744	14300
Antimony	39	39	0.37	14	N/A	N/A	N/A
Arsenic	49	5	1.3	2.1	44	0.49	4.7
Barium	49	N/A	N/A	N/A	49	10.4	132
Beryllium	49	2	0.6	0.68	47	0.04	1.4
Boron	10	10	1.2	5.9	N/A	N/A	N/A
Cadmium	49	45	0.02	0.8	4	0.03	0.89
Calcium	49	N/A	N/A	N/A	49	361	5740
Chromium, total	49	1	1.3	1.3	48	2.1	38.4
Cobalt	49	N/A	N/A	N/A	49	0.81	4.1
Copper	49	N/A	N/A	N/A	49	2.8	23.8
Cyanide, total	18	10	0.15	0.27	8	0.15	0.36
Iron	49	N/A	N/A	N/A	49	2090	13600
Lead	49	N/A	N/A	N/A	49	6	61.9
Magnesium	49	N/A	N/A	N/A	49	236	1950
Manganese	49	N/A	N/A	N/A	49	103	457
Mercury	49	27	0.01	0.14	22	0.01	0.31
Nickel	49	6	1.9	3.1	43	1.2	9
Potassium	49	N/A	N/A	N/A	49	182	2250
Selenium	49	43	0.2	1.4	6	0.23	0.65
Silver	49	36	0.08	2.7	13	0.52	15.8
Sodium	49	2	385	415	47	28.3	893
Thallium	49	47	0.15	0.41	2	0.35	0.48
Titanium	10	N/A	N/A	N/A	10	88.8	409
Uranium	10	N/A	N/A	N/A	10	0.21	2.9
Uranium, total	18	N/A	N/A	N/A	18	1.31	7.2
Vanadium	49	N/A	N/A	N/A	49	3	21.9
Zinc	49	N/A	N/A	N/A	49	14.1	90.5

*N/A = not applicable

TABLE D3-2

SUMMARY OF RADIONUCLIDE ANALYSES FROM UPPER LOS ALAMOS CANYON REACHES

Tech Code	Analyte Name	Total Count	Nondetects			Detects		
			Count	Min (pCi/g)	Max (pCi/g)	Count	Min (pCi/g)	Max (pCi/g)
AM241	Americium-241	31	4	0.034	0.043	27	0.0283	3.954
GROSSAB	Gross alpha radiation	18	8	0.68	7	10	18.04	80.92
GROSSAB	Gross beta radiation	18	5	0.86	8.5	13	10.3	300
GROSSG	Gross gamma radiation	16	N/A*	N/A	N/A	16	0	24.73
GSCAN	Actinium-228	47	12	0	0.797	35	0.391	2.41
GSCAN	Americium-241	116	53	-0.23	2.25	63	0.18	28
GSCAN	Annihilation radiation	29	29	-0.259	0.37	N/A	N/A	N/A
GSCAN	Barium-140	29	29	-1.645	0.59	N/A	N/A	N/A
GSCAN	Bismuth-211	47	43	0	2.11	4	0.332	1.887
GSCAN	Bismuth-212	47	43	-2.81	8.9	4	2	2.7
GSCAN	Bismuth-214	47	17	0	0.53	30	0.433	2.13
GSCAN	Cadmium-109	47	47	0	6.56	N/A	N/A	N/A
GSCAN	Cerium-139	47	47	-0.0342	0.2	N/A	N/A	N/A
GSCAN	Cerium-144	116	116	-5.08	5.6	N/A	N/A	N/A
GSCAN	Cesium-134	47	46	-0.108	0.14	1	0.18	0.18
GSCAN	Cesium-137	116	7	-0.0054	8.53	109	0.075	230
GSCAN	Cobalt-57	116	113	-0.051	0.11	3	0.0241	0.0299
GSCAN	Cobalt-60	116	111	-0.1048	0.16	5	0.116	0.206
GSCAN	Europium-152	116	112	-0.145	0.59	4	0.383	0.525
GSCAN	Iodine-129	62	62	-3.52	0.606	N/A	N/A	N/A
GSCAN	Lanthanum-140	29	29	-95.046	34.155	N/A	N/A	N/A
GSCAN	Lead-210	28	28	0	3.39	N/A	N/A	N/A
GSCAN	Lead-211	47	47	-1.83	9.83	N/A	N/A	N/A
GSCAN	Lead-212	47	3	0.33	2.3	44	0.429	3.5
GSCAN	Lead-214	47	7	0	1.7	40	0.381	3.6
GSCAN	Manganese-54	47	47	-0.0695	0.12	N/A	N/A	N/A
GSCAN	Mercury-203	47	46	-0.079	0.24	1	0.079	0.079
GSCAN	Neptunium-237	116	116	-0.89	1.98	N/A	N/A	N/A
GSCAN	Potassium-40	116	N/A	N/A	N/A	116	9.9	33.9
GSCAN	Protactinium-231	47	45	-1.21	10.1	2	4.65	5.46
GSCAN	Protactinium-233	47	46	-0.077	0.46	1	0.1713	0.1713
GSCAN	Protactinium-234M	47	46	-15.77	18.1	1	24	24
GSCAN	Radium-223	47	47	-1.3	2.88	N/A	N/A	N/A
GSCAN	Radium-224	47	35	-13	8.9	12	0.395	13
GSCAN	Radium-226	47	22	0	5.97	25	0.67	6.21
GSCAN	Radon-219	47	47	-0.811	5.25	N/A	N/A	N/A
GSCAN	Ruthenium-106	116	116	-0.526	1.5	N/A	N/A	N/A
GSCAN	Selenium-75	47	47	-0.1071	0.34	N/A	N/A	N/A
GSCAN	Sodium-22	116	116	-0.1146	0.1175	N/A	N/A	N/A
GSCAN	Strontium-85	47	47	-0.224	0.26	N/A	N/A	N/A

*N/A = not applicable

TABLE D3-2 (continued)

SUMMARY OF RADIONUCLIDE ANALYSES FROM UPPER LOS ALAMOS CANYON REACHES

Tech Code	Analyte Name	Total Count	Nondetects			Detects		
			Count	Min (pCi/g)	Max (pCi/g)	Count	Min (pCi/g)	Max (pCi/g)
GSCAN	Thallium-208	47	9	0	4.7	38	0.1656	3.2
GSCAN	Thorium-227	47	47	-5.62	3.02	N/A*	N/A	N/A
GSCAN	Thorium-234	47	47	-3.26	6.17	N/A	N/A	N/A
GSCAN	Tin-113	47	47	-0.148	0.36	N/A	N/A	N/A
GSCAN	Uranium-235	47	44	-0.0273	1.34	3	0.1975	0.2899
GSCAN	Yttrium-88	47	47	-0.1223	0.1129	N/A	N/A	N/A
GSCAN	Zinc-65	47	46	-0.125	0.42	1	0.325	0.325
H3	Tritium	20	10	-0.01	0.454	10	0.007	0.143
ISOPU	Plutonium-238	161	90	-0.011	0.035	71	0.0105	2.01
ISOPU	Plutonium-239,240	161	6	0.0006	0.843	155	0.0204	19.3
ISOTH	Thorium-228	18	N/A	N/A	N/A	18	0.728	2.9
ISOTH	Thorium-230	18	N/A	N/A	N/A	18	0.574	2.61
ISOTH	Thorium-232	18	N/A	N/A	N/A	18	0.703	2.64
ISOU	Uranium-234	42	N/A	N/A	N/A	42	0.336	2.8
ISOU	Uranium-235	42	4	0.018	0.036	38	0.027	0.186
ISOU	Uranium-238	42	N/A	N/A	N/A	42	0.304	2.52
RA226	Radium-226	2	2	0.107	0.367	N/A	N/A	N/A
SR90	Strontium-90	73	28	-0.24	0.85	45	0.45	39.56

*N/A = not applicable

TABLE D3-3

SUMMARY OF ORGANIC CHEMICAL ANALYSES FROM UPPER LOS ALAMOS CANYON REACHES

Tech Code	Analyte Name	Total Count	Nondetects			Detects		
			Count	Min (mg/kg)	Max (mg/kg)	Count	Min (mg/kg)	Max (mg/kg
PCB/PEST	Aldrin	27	27	0.0015	0.0024	N/A*	N/A	N/A
PCB/PEST	Aroclor-1016	38	38	0.019	0.39	N/A	N/A	N/A
PCB/PEST	Aroclor-1221	38	38	0.019	0.77	N/A	N/A	N/A
PCB/PEST	Aroclor-1232	38	38	0.019	0.39	N/A	N/A	N/A
PCB/PEST	Aroclor-1242	38	38	0.019	0.39	N/A	N/A	N/A
PCB/PEST	Aroclor-1248	38	38	0.019	0.39	N/A	N/A	N/A
PCB/PEST	Aroclor-1254	38	31	0.03	0.39	7	0.16	1.5
PCB/PEST	Aroclor-1260	38	12	0.037	0.37	26	0.016	1
PCB/PEST	α-BHC	27	27	0.0015	0.0024	N/A	N/A	N/A
PCB/PEST	β-BHC	27	27	0.0015	0.0024	N/A	N/A	N/A
PCB/PEST	δ-BHC	27	27	0.0015	0.0024	N/A	N/A	N/A
PCB/PEST	γ-BHC	27	27	0.0015	0.0024	N/A	N/A	N/A
PCB/PEST	α-Chlordane	27	26	0.0015	0.0024	1	0.0072	0.0072
PCB/PEST	γ-Chlordane	27	26	0.0015	0.0024	1	0.0068	0.0068
PCB/PEST	4,4'-DDD	27	27	0.003	0.0049	N/A	N/A	N/A
PCB/PEST	4,4'-DDE	27	22	0.003	0.0046	5	0.0055	0.033
PCB/PEST	4,4'-DDT	27	15	0.003	0.0044	12	0.0059	0.048
PCB/PEST	Dieldrin	27	27	0.003	0.0049	N/A	N/A	N/A
PCB/PEST	Endosulfan I	27	27	0.0015	0.0024	N/A	N/A	N/A
PCB/PEST	Endosulfan II	27	27	0.003	0.0049	N/A	N/A	N/A
PCB/PEST	Endosulfan sulfate	27	27	0.003	0.0049	N/A	N/A	N/A
PCB/PEST	Endrin	27	27	0.003	0.0049	N/A	N/A	N/A
PCB/PEST	Endrin aldehyde	27	27	0.003	0.0049	N/A	N/A	N/A
PCB/PEST	Endrin ketone	27	27	0.003	0.0049	N/A	N/A	N/A
PCB/PEST	Heptachlor	27	27	0.0015	0.0024	N/A	N/A	N/A
PCB/PEST	Heptachlor epoxide	27	27	0.0015	0.0024	N/A	N/A	N/A
PCB/PEST	4,4'-Methoxychlor	27	27	0.015	0.024	N/A	N/A	N/A
SVOC	Acenaphthene	11	8	0.322	0.355	3	0.067	0.26
SVOC	Acenaphthylene	11	11	0.322	0.47	N/A	N/A	N/A
SVOC	Aniline	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Anthracene	11	2	0.322	0.324	9	0.026	0.096
SVOC	Azobenzene	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Benz(a)anthracene	11	2	0.322	0.324	9	0.026	0.368
SVOC	Benzo(a)pyrene	11	2	0.322	0.324	9	0.059	0.655
SVOC	Benzo(b)fluoranthene	11	2	0.322	0.324	9	0.065	0.66
SVOC	Benzo(g,h,i)perylene	11	6	0.322	0.47	5	0.146	0.298
SVOC	Benzo(k)fluoranthene	11	9	0.322	0.355	2	0.017	0.019

*N/A = not applicable

TABLE D3-3 (continued)

SUMMARY OF ORGANIC CHEMICAL ANALYSES FROM UPPER LOS ALAMOS CANYON REACHES

Tech Code	Analyte Name	Total Count	Nondetects			Detects		
			Count	Min (mg/kg)	Max (mg/kg)	Count	Min (mg/kg)	Max (mg/kg
SVOC	Benzoic acid	9	9	0.782	0.861	N/A*	N/A	N/A
SVOC	Benzyl alcohol	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Bis(2-chloroethoxy)methane	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Bis(2-chloroethyl)ether	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Bis(2-ethylhexyl)phthalate	9	9	0.322	0.457	N/A	N/A	N/A
SVOC	4-Bromophenylphenyl ether	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Butylbenzylphthalate	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	4-Chloro-3-methylphenol	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	4-Chloroaniline	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	2-Chloronaphthalene	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	2-Chlorophenol	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	4-Chlorophenylphenyl ether	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Chrysene	11	2	0.322	0.324	9	0.073	0.41
SVOC	Di-n-butylphthalate	9	3	0.322	0.329	6	0.037	0.055
SVOC	Di-n-octylphthalate	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Dibenz(a,h)anthracene	11	10	0.322	0.38	1	0.029	0.029
SVOC	Dibenzofuran	9	8	0.322	0.355	1	0.036	0.036
SVOC	1,2-Dichlorobenzene	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	1,3-Dichlorobenzene	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	1,4-Dichlorobenzene	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	3,3'-Dichlorobenzidine	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	2,4-Dichlorophenol	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Diethylphthalate	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Dimethyl phthalate	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	2,4-Dimethylphenol	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	4,6-Dinitro-2-methylphenol	9	9	0.782	0.861	N/A	N/A	N/A
SVOC	2,4-Dinitrophenol	9	9	0.782	0.861	N/A	N/A	N/A
SVOC	2,4-Dinitrotoluene	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	2,6-Dinitrotoluene	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Fluoranthene	11	1	0.322	0.322	10	0.053	0.725
SVOC	Fluorene	11	8	0.322	0.355	3	0.01	0.066
SVOC	Hexachlorobenzene	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Hexachlorobutadiene	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Hexachlorocyclopentadiene	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Hexachloroethane	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Indeno(1,2,3-cd)pyrene	11	4	0.322	0.33	7	0.13	0.341
SVOC	Isophorone	9	9	0.322	0.355	N/A	N/A	N/A

*N/A = not applicable

TABLE D3-3 (continued)

SUMMARY OF ORGANIC CHEMICAL ANALYSES FROM UPPER LOS ALAMOS CANYON REACHES

Tech Code	Analyte Name	Total Count	Nondetects			Detects		
			Count	Min (mg/kg)	Max (mg/kg)	Count	Min (mg/kg)	Max (mg/kg
SVOC	2-Methylnaphthalene	9	9	0.322	0.355	N/A*	N/A	N/A
SVOC	2-Methylphenol	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	4-Methylphenol	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Naphthalene	11	8	0.322	0.355	3	0.083	0.2
SVOC	2-Nitroaniline	9	9	0.782	0.861	N/A	N/A	N/A
SVOC	3-Nitroaniline	9	9	0.782	0.861	N/A	N/A	N/A
SVOC	4-Nitroaniline	9	9	0.782	0.861	N/A	N/A	N/A
SVOC	Nitrobenzene	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	2-Nitrophenol	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	4-Nitrophenol	9	9	0.782	0.861	N/A	N/A	N/A
SVOC	N-Nitroso-di-n-propylamine	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	N-Nitrosodimethylamine	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	N-Nitrosodiphenylamine	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	2,2'-Oxybis(1-chloropropane)	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Pentachlorophenol	9	9	0.782	0.861	N/A	N/A	N/A
SVOC	Phenanthrene	11	1	0.322	0.322	10	0.036	0.432
SVOC	Phenol	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	Pyrene	11	1	0.322	0.322	10	0.05	0.589
SVOC	Toxaphene (technical grade)	27	27	0.15	0.24	N/A	N/A	N/A
SVOC	1,2,4-Trichlorobenzene	9	9	0.322	0.355	N/A	N/A	N/A
SVOC	2,4,5-Trichlorophenol	9	9	0.782	0.861	N/A	N/A	N/A
SVOC	2,4,6-Trichlorophenol	9	9	0.322	0.355	N/A	N/A	N/A

*N/A = not applicable

D-4.0 ANALYTICAL RESULTS FOR UPPER LOS ALAMOS CANYON COPCs

Tables D4-1 through D4-4 present analytical results for the analytes identified as chemicals of potential concern (COPCs) in the upper Los Alamos Canyon reaches, except for the plutonium-238 and plutonium-239,240 analyses, which are presented in Section 3.3. The data qualifiers are discussed in Appendix C.

TABLE D4-1

ANALYTICAL RESULTS FOR INORGANIC COPCs IN UPPER LOS ALAMOS CANYON[a]

Reach or Subreach	Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Depth (in.)	Antimony	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Silver	Uranium	Total Uranium	Zinc
LA-1 Far West	04LA-97-0568	LA-0170	c2	Overbank	0–12	0.39 (U)[b]	0.02 (U)	3.5	13.5 (J+)[c]	39.3 (J)[d]	0.01 (U)	0.76 (U)	0.08 (U)	NA[e]	NA	35.5
LA-1 Far West	04LA-97-0579	LA-0171	c1	Channel	0–2	0.45 (U)	0.03 (U)	1.3 (U)	7.8 (J+)	10.8 (J)	0.01 (U)	0.58 (U)	0.09 (U)	NA	NA	17.5
LA-1 Far West	04LA-97-0624	LA-0172	c3	Overbank	1.5–15.5	0.42 (U)	0.02 (U)	3.4	5 (J+)	16.3 (J)	0.01	0.66 (U)	0.09 (U)	NA	NA	26.9
LA-1 West+	04LA-97-0573	LA-0173	c2	Overbank	0–9.5	0.46 (U)	0.03 (U)	6.5	6.4 (J+)	41.2 (J)	0.03	1 (U)	0.09 (U)	NA	NA	47.5
LA-1 West+	04LA-97-0574	LA-0174	c1	Channel	0–2	0.43 (U)	0.03 (U)	2.3	6.8 (J+)	7.4 (J)	0.01 (U)	0.33 (U)	0.09 (U)	NA	NA	14.1
LA-1 West+	04LA-97-0575	LA-0175	c3	Overbank	0–7	0.38 (U)	0.02 (U)	6.2	9.3 (J+)	37.4 (J)	0.01	0.63	0.08 (U)	NA	NA	31.9
LA-1 West+	04LA-97-0576	LA-0175	c3	Overbank	7–15.5	0.37 (U)	0.02 (U)	3.9	8.8 (J+)	34 (J)	0.03	0.58 (U)	0.08 (U)	NA	NA	35.7
LA-1 West+	04LA-97-0577	LA-0175	c3	Overbank	15.5–20.5	0.37 (U)	0.02 (U)	3.5	7 (J+)	29 (J)	0.09	0.55 (U)	0.08 (U)	NA	NA	41.7
LA-1 West (u)	04LA-97-0236	LA-0141	c3? (f1?)	Overbank	0–4	8.8 (U)	0.76 (U)	4.3	6.1	28.6	0.06 (U)	0.65 (U)	1	NA	NA	38.8
LA-1 West (u)	04LA-97-0237	LA-0141	c3? (f1?)	Overbank	4–14	8.7 (U)	0.75 (U)	3.9	11.3	36.8	0.06 (U)	0.51 (U)	0.82	NA	NA	39.9
LA-1 West (u)	04LA-97-0571	LA-0143	c3	Overbank	13–21	0.47 (U)	0.03 (U)	5	7.2 (J+)	39.2 (J)	0.06	0.68 (U)	0.1 (U)	NA	NA	50.6
LA-1 West (u)	04LA-97-0590	LA-0176	f1	Overbank	0–6.5	0.38 (U)	0.02 (U)	3.4	6.4 (J+)	19 (J)	0.03	0.77 (U)	0.08 (U)	NA	NA	31.4
LA-1 West (u)	04LA-97-0625	LA-0178	c2	Overbank	0–7.5	0.41 (U)	0.02 (U)	4.8	13.1 (J+)	43.7 (J)	0.05	0.89 (U)	0.08 (U)	NA	NA	44.2
LA-1 West (d)	04LA-97-0243	LA-0146	c3	Overbank	0–11	8.4 (U)	0.73 (U)	4.7	8.5	40.4	0.06 (U)	0.65 (U)	1.4	NA	NA	37
LA-1 West (d)	04LA-97-0244	LA-0146	c3	Overbank	11–19.5	9.2 (U)	0.8 (U)	4.8	9.6	36.4	0.16	0.38 (U)	1.7	NA	NA	54.5
LA-1 West (d)	04LA-97-0245	LA-0146	c3	Overbank	19.5–28	8.9 (U)	0.77 (U)	4.6	8.4	36.7	0.07 (U)	0.3 (U)	0.86	NA	NA	45.4
LA-1 Central	04LA-97-0255	LA-0151	f1	Overbank	0–7	8.1 (U)	0.7 (U)	2.7	7.6	18	0.06 (U)	0.38 (U)	0.52	NA	NA	24.7
LA-1 Central	04LA-97-0256	LA-0151	f1	Overbank	7–11.5	7.9 (U)	0.68 (U)	2.7	6.9	10.2	0.06 (U)	0.45 (U)	0.53	NA	NA	21.9
LA-1 Central	04LA-97-0257	LA-0151	f1	Overbank	11.5–14.5	7.9 (U)	0.68 (U)	2.1	8	9.1	0.06 (U)	0.31 (U)	0.83	NA	NA	22.9
LA-1 Central	04LA-97-0602	LA-0179	c2	Overbank	0–9.5	0.46 (U)	0.03 (U)	8.6	16.8 (J+)	38.8 (J)	0.11	0.89 (U)	0.09 (U)	NA	NA	53.6
LA-1 Central	04LA-97-0613	LA-0181	c3	Overbank	0–4	0.5 (U)	0.03 (U)	6.6	15.7 (J+)	20.7 (J)	0.07	0.38 (U)	0.1 (U)	NA	NA	39.3
LA-1 East	04LA-97-0272	LA-0158	f1	Overbank	0–13.5	8.6 (U)	0.74 (U)	3.1	13.3	14.3	0.07	0.41 (U)	0.59	NA	NA	30.8
LA-1 East	04LA-97-0279	LA-0162	c3	Overbank	12.5–18.5	7.6 (U)	0.66 (U)	6.5	7.7	12.5	0.06 (U)	0.46 (U)	0.86	NA	NA	20
LA-1 East	04LA-97-0572	LA-0160	f1	Overbank	0–10.5	0.43 (U)	0.03 (U)	4.3	23.8 (J+)	20 (J)	0.07	0.8 (U)	0.65	NA	NA	40.8
LA-1 East	04LA-97-0622	LA-0186	c3	Overbank	0–7	0.43 (U)	0.05	10.6	7.7 (J+)	29.4 (J)	0.1	0.81 (U)	0.09 (U)	NA	NA	45.5

a. mg/kg
b. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.
c. J+ = The analyte was positively identified, and the reported value is an estimate and likely biased high.
d. 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.
e. NA = not analyzed

TABLE D4-1 (continued)

ANALYTICAL RESULTS FOR INORGANIC COPCs IN UPPER LOS ALAMOS CANYON[a]

Reach or Subreach	Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Depth (in.)	Antimony	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Silver	Uranium	Total Uranium	Zinc
LA-1 East	04LA-97-0623	LA-0185	c2	Overbank	0–9	0.46 (U)[b]	0.03 (U)	10.1	11.4 (J+)[c]	30 (J)[d]	0.1	1.1 (U)	0.09 (U)	NA[e]	NA	52.3
LA-2 West	04LA-96-0141	LA-0017	c1	Channel	0–3	(R)[f]	0.2 (U)	4.4	2.9	12.2	0.02 (U)	0.2 (U)	0.1 (U)	0.3 (J)	2.7	38.3
LA-2 West	04LA-96-0142	LA-0018	f1	Overbank	0–3	(R)	0.2 (U)	5.5	4.9	18.8	0.05	0.23	0.1 (U)	2.5	6.9	46.7
LA-2 West	04LA-97-0052	LA-0092	c2	Overbank	5.5–12.5	12 (UJ)[g]	0.6 (U)	10	10	27	0.12 (UJ)	1.2 (U)	2.4 (U)	NA	NA	46
LA-2 West	04LA-97-0569	LA-0041	c2	Overbank	0–5	0.43 (U)	0.06	11	8 (J+)	30.1 (J)	0.16	0.87 (U)	0.09 (U)	NA	NA	59.5
LA-2 West	04LA-97-0570	LA-0041	c2	Overbank	8–11	0.43 (U)	0.03	19.5	12.5 (J+)	46.9 (J)	0.31	1 (U)	15.8	NA	NA	81.7
DP Cyn	04LA-96-0140	LA-0016	c2b	Overbank	0–3	(R)	0.2 (U)	5.8	7.7	42.4	0.03	0.2 (U)	0.1 (U)	1.3	6.8	53.5
LA-2 East	04LA-96-0143	LA-0019	c2	Overbank	0–6	(R)	0.2 (U)	4.8	4.8	23	0.02 (U)	0.28	0.1 (U)	0.82	5.3	44.7
LA-2 East	04LA-96-0144	LA-0020	c2b	Overbank	0–6	(R)	0.2 (U)	6.7	4.7	24.4	0.02 (U)	0.2 (U)	0.1 (U)	0.75	5.1	56.7
LA-2 East	04LA-96-0145	LA-0020 (0021)	c2b	Overbank	25–29	(R)	0.2 (U)	18.9	9.3	36.1	0.06	0.37	0.1 (U)	1.1	6.4	62
LA-2 East	04LA-96-0146	LA-0022	c2	Overbank	0–3	(R)	0.2 (U)	6.5	6.6	29.3	0.02 (U)	0.25	0.1 (U)	0.63	5.4	60.5
LA-2 East	04LA-96-0147	LA-0023	c1	Channel	0–4	(R)	0.2 (U)	6.3	3	14.3	0.02 (U)	0.2 (U)	0.1 (U)	0.21 (J)	4	72.8
LA-2 East	04LA-96-0148	LA-0024	c3	Channel	0–6	(R)	0.2 (U)	4.7	2.8	12.8	0.02 (U)	0.2 (U)	0.1 (U)	0.39 (J)	3	39.4
LA-2 East	04LA-96-0149	LA-0024 (0025)	c3	Overbank	26–32	(R)	0.2 (U)	38.4	13.9	61.9	0.14	0.65	0.1 (U)	2.9	7.2	90.5
LA-2 East	04LA-97-0053	LA-0022 (0039)	c2	Overbank	8–12	14 (UJ)	0.89	7.8	7.1	51	0.14 (UJ)	1.4 (U)	2.7 (U)	NA	NA	60
LA-3	04LA-97-0143	LA-0109	c3	Overbank	16–19.5	6.5 (UJ)	0.54 (U)	10.6	10.5	36.9	0.05 (U)	0.3 (UJ)	1.9 (U)	NA	4.46	51.5
LA-3	04LA-97-0144	LA-0109	c3	Overbank	16–19.5	6.4 (UJ)	0.53 (U)	12.2	11.6	44.2	0.05 (U)	0.25 (UJ)	1.9 (U)	NA	4.468	51.6
LA-3	04LA-97-0145	LA-0110	c3	Overbank	11–16	5.8 (UJ)	0.48 (U)	4.3	5	19.4	0.05 (U)	0.24 (UJ)	1.7 (U)	NA	3.731	39.7
LA-3	04LA-97-0146	LA-0110	c3	Overbank	11–16	5 (UJ)	0.41 (U)	4.9	5.2	22.3	0.05 (U)	0.27 (UJ)	1.5 (U)	NA	4.022	42.4
LA-3	04LA-97-0147	LA-0111	c2	Overbank	11–13.5	6.1 (UJ)	0.51 (U)	5	6.2	22.8	0.14	0.28 (UJ)	1.8 (U)	NA	6.482	33.5
LA-3	04LA-97-0148	LA-0114	c2	Overbank	6.5–12.5	6.3 (UJ)	0.52 (U)	7.5	15.4	32.6	0.05 (U)	0.29 (UJ)	1.8 (U)	NA	5.554	49.5
LA-3	04LA-97-0149	LA-0115	c3	Overbank	11–16	6 (UJ)	0.5 (U)	5.7	6.2	21.4	0.05 (U)	0.26 (UJ)	1.8 (U)	NA	4.034	35.8
LA-3	04LA-97-0150	LA-0116	c1	Channel	0–2	5.1 (UJ)	0.42 (U)	2.2	3.2	6	0.05 (U)	0.24 (UJ)	1.5 (U)	NA	1.31	33.3

a. mg/kg
b. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.
c. J+ = The analyte was positively identified, and the reported value is an estimate and likely biased high.
d. 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.
e. NA = not analyzed
f. R = The sample results are rejected because of serious deficiencies in the ability to analyze the sample and meet quality control criteria; presence or absence cannot be verified.
g. UJ = The analyte was analyzed for but not detected. Reported value is an estimate of the sample-specific quantitation limit or detection limit.

TABLE D4-2

ANALYTICAL RESULTS FOR RADIONUCLIDE COPCs IN UPPER LOS ALAMOS CANYON[a,b,c]

Reach or Subreach	Sample ID	Location ID	Depth (in.)	Cesium-134	Cobalt-60	Europium-152	Thorium-228	Thorium-230	Thorium-232	Uranium-234	Uranium-235	Uranium-238	Tritium
LA-1 Far West	04LA-97-0568	LA-0170	0–12	0.0494 (U)[d]	0.0188 (U)	0.0644 (U)	NA[e]	NA	NA	0.634	0.027	0.68	NA
LA-1 Far West	04LA-97-0579	LA-0171	0–2	-0.009 (U)	-0.0586 (U)	0.1899 (U)	NA	NA	NA	0.457	0.0187 (U)	0.383	NA
LA-1 Far West	04LA-97-0624	LA-0172	1.5–15.5	0.0278 (U)	-0.1048 (U)	0.0926 (U)	NA	NA	NA	1.12	0.066	1.32	NA
LA-1 West+	04LA-97-0573	LA-0173	0–9.5	NA	NA	NA	NA	NA	NA	1.53	0.097	1.36	NA
LA-1 West+	04LA-97-0574	LA-0174	0–2	NA	NA	NA	NA	NA	NA	0.336	0.028	0.304	NA
LA-1 West+	04LA-97-0575	LA-0175	0–7	NA	NA	NA	NA	NA	NA	0.854	0.046	0.827	NA
LA-1 West+	04LA-97-0576	LA-0175	7–15.5	NA	NA	NA	NA	NA	NA	1.224	0.089	1.313	NA
LA-1 West+	04LA-97-0577	LA-0175	15.5–20.5	NA	NA	NA	NA	NA	NA	1.8	0.086	1.73	NA
LA-1 West	04LA-97-0236	LA-0141	0–4	NA	NA	NA	NA	NA	NA	1.018	0.039	0.948	NA
LA-1 West	04LA-97-0237	LA-0141	4–14	NA	NA	NA	NA	NA	NA	1.42	0.054	1.5	NA
LA-1 West	04LA-97-0571	LA-0019	13–21	0.0359 (U)	-0.0475 (U)	0.1327 (U)	NA	NA	NA	1.7	0.091	1.55	NA
LA-1 West	04LA-97-0590	LA-0176	0–6.5	-0.0133 (U)	0.0489 (U)	0.0047 (U)	NA	NA	NA	1.98	0.106	2.06	NA
LA-1 West	04LA-97-0625	LA-0178	0–7.5	-0.0177 (U)	0.1467 (U)	0.0728 (U)	NA	NA	NA	1.55	0.072	1.41	NA
LA-1 Central	04LA-97-0602	LA-0179	0–9.5	-0.108 (U)	-0.04 (U)	0.071 (U)	NA	NA	NA	1.346	0.05	1.36	NA
LA-1 Central	04LA-97-0613	LA-0181	0–4	-0.0582 (U)	0.0073 (U)	0.0344 (U)	NA	NA	NA	1.315	0.038	1.37	NA
LA-1 East	04LA-97-0272	LA-0158	0–13.54	NA	NA	NA	NA	NA	NA	1.64	0.073	1.67	NA
LA-1 East	04LA-97-0273	LA-0158	13.5–19	NA	NA	NA	NA	NA	NA	1.244	0.057	1.45	NA
LA-1 East	04LA-97-0572	LA-0160	0–10.5	-0.0379 (U)	-0.0307 (U)	0.1009 (U)	NA	NA	NA	2.28	0.098	2.31	NA
LA-1 East	04LA-97-0622	LA-0186	0–7	0.0084 (U)	0.0069 (U)	-0.0697 (U)	NA	NA	NA	2.27	0.146	2.21	NA
LA-1 East	04LA-97-0623	LA-0185	0–9	-0.0493 (U)	0.0164 (U)	0.0551 (U)	NA	NA	NA	1.257	0.018 (U)	1.084	NA
LA-2 West	04LA-96-0141	LA-0017	0–3	0.09 (U)	0.09 (U)	0.39 (U)	1.01	1.1	1.04	1.1	0.1	0.91	0.02 (J)[f]
LA-2 West	04LA-96-0142	LA-0018	0–3	0.1 (U)	0.16 (U)	0.35 (U)	1.71	1.85	1.78	2.2	0.15	2.3	0.053
LA-2 West	04LA-97-0052	LA-0092	5.5–12.5	NA	0.055 (U)	0.094 (U)	NA	NA	NA	0.968	0.088	0.776	0.454 (U)
LA-2 West	04LA-97-0569	LA-0041	0–5	NA	NA	NA	NA	NA	NA	1.43	0.052	1.219	NA
LA-2 West	04LA-97-0570	LA-0041	8–11	NA	NA	NA	NA	NA	NA	2.6	0.103	2.52	NA

a. Gamma spectroscopy analyses are only included for select samples, specifically those samples where either cesium-134, cobalt-60, or europium-152 were detected.
b. Results for americium-241; cesium-137; plutonium-238; plutonium-239,240; and strontium-90 are presented in Tables 3.3-1, 3.3-4, and 3.3-7.
c. pCi/g
d. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.
e. NA = not analyzed
f. 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.

TABLE D4-2 (continued)

ANALYTICAL RESULTS FOR RADIONUCLIDE COPCs IN UPPER LOS ALAMOS CANYON[a,b,c]

Reach or Subreach	Sample ID	Location ID	Depth (in.)	Cesium-134	Cobalt-60	Europium-152	Thorium-228	Thorium-230	Thorium-232	Uranium-234	Uranium-235	Uranium-238	Tritium
DP Canyon	04LA-96-0140	LA-0016	0–3	0.12 (U)[d]	0.12 (U)	0.59 (U)	1.93	2.2	2.11	2.8	0.15	2.3	0.143
LA-2 East	04LA-96-0143	LA-0019	0–6	0.14 (U)	0.06 (U)	0.47 (U)	1.9	1.8	1.98	1.7	0.14	1.8	0.06
LA-2 East	04LA-96-0144	LA-0020	0–6	0.08 (U)	0.11 (U)	0.34 (U)	1.86	1.66	1.82	1.7	0.12	1.7	0.03
LA-2 East	04LA-96-0145	LA-0020	25–29	0.14 (U)	0.08 (U)	0.45 (U)	2.104	2.442	2.016	2.2	0.15	2.1	0.121
LA-2 East	04LA-96-0146	LA-0022	0–4	0.11 (U)	0.08 (U)	0.45 (U)	1.85	1.69	1.87	1.7	0.13	1.8	0.023
LA-2 East	04LA-96-0147	LA-0023	0–4	0.18	0.1 (U)	0.35 (U)	1.36	1.16	1.3	1.2	0.11	1.3	0.017
LA-2 East	04LA-96-0148	LA-0024	0–6	0.08 (U)	0.08 (U)	0.36 (U)	1.182	1.131	1.115	0.87	0.1	1	0.007 (J)[e]
LA-2 East	04LA-96-0149	LA-0024	26–32	0.13 (U)	0.12 (U)	0.41 (U)	1.749	1.95	1.947	2.4	0.15	2.4	0.137
LA-2 East	04LA-97-0053	LA-0022	8–12	NA[f]	0.012 (U)	0.01 (U)	NA	NA	NA	2.16	0.186	0.946	0.311 (U)
LA-2 East	04LA-97-0068	LA-0106	21.5–31	NA	0.116	0.049 (U)	NA	NA	NA	NA	NA	NA	NA
LA-2 East	04LA-97-0075	LA-0105	7.5–12	NA	0.024 (U)	0.474 ()	NA	NA	NA	NA	NA	NA	NA
LA-3	04LA-97-0105	LA-0110	0–5	NA	0.192	0.281 (U)	NA	NA	NA	NA	NA	NA	NA
LA-3	04LA-97-0112	LA-0114	0–6.5	NA	0.206	0.372 (U)	NA	NA	NA	NA	NA	NA	NA
LA-3	04LA-97-0116	LA-0115	0–5	NA	0.181	0.198 (U)	NA	NA	NA	NA	NA	NA	NA
LA-3	04LA-97-0120	LA-0117	4–11	NA	0.12	0.49 (U)	NA	NA	NA	NA	NA	NA	NA
LA-3	04LA-97-0132	LA-0111	0–6.5	NA	-0.036 (U)	0.383	NA	NA	NA	NA	NA	NA	NA
LA-3	04LA-97-0133	LA-0111	6.5–11	NA	0.074 (U)	0.525	NA	NA	NA	NA	NA	NA	NA
LA-3	04LA-97-0141	LA-0109	31.5–34.5	NA	0.039 (U)	0.492	NA	NA	NA	NA	NA	NA	NA
LA-3	04LA-97-0143	LA-0109	16–19.5	0.034 (U)	0.062 (U)	0.178 (U)	2.03	1.63	1.8	1.61	0.111	1.6	0.03 (U)
LA-3	04LA-97-0144	LA-0109	16–19.5	0.031 (U)	-0.036 (U)	-0.145 (U)	2.09	1.86	2.06	1.61	0.093	1.38	0.02 (U)
LA-3	04LA-97-0145	LA-0110	11–16	0.033 (U)	0.038 (U)	-0.05 (U)	1.93	1.49	1.84	1.29	0.036 (U)	1.17	0.02 (U)
LA-3	04LA-97-0146	LA-0110	11–16	0.029 (U)	0.013 (U)	-0.068 (U)	1.7	1.9	1.8	1.23	0.125	1	0.01 (U)
LA-3	04LA-97-0147	LA-0111	11–13.5	-0.056 (U)	0.081 (U)	-0.037 (U)	2.9	2.61	2.64	1.94	0.109	1.83	0.02 (U)
LA-3	04LA-97-0148	LA-0114	6.5–12.5	0.09 (U)	0.105 (U)	0.065 (U)	2.01	1.97	2.25	1.68	0.117	1.46	0 (U)
LA-3	04LA-97-0149	LA-0115	11–16	0.019 (U)	-0.009 (U)	-0.07 (U)	2.08	1.7	1.99	1.13	0.143	1.26	0.01 (U)
LA-3	04LA-97-0150	LA-0116	0–2	0.019 (U)	0.04 (U)	0.013 (U)	0.728	0.574	0.703	0.386	0.025 (U)	0.37	-0.01 (U)

a. Gamma spectroscopy analyses are only included for select samples, specifically those samples where either cesium-134, cobalt-60, or europium-152 were detected.

b. Results for americium-241; cesium-137; plutonium-238; plutonium-239,240; and strontium-90 are presented in Tables 3.3-1, 3.3-4, and 3.3-7.

c. pCi/g

d. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

e. 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.

f. NA = not analyzed

TABLE D4-3

ANALYTICAL RESULTS FOR ORGANIC COPCs IN PESTICIDE AND PCB SUITE IN UPPER LOS ALAMOS CANYON[a]

Reach or Subreach	Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Depth (in.)	Aroclor-1254	Aroclor-1260	α-Chlordane	γ-Chlordane	4,4'-DDE	4,4'-DDT
LA-1 Far West	04LA-97-0568	LA-0170	c2	Overbank	0–12	0.038 (U)[b]	0.038 (U)	0.0019 (U)	0.0019 (U)	0.0038 (U)	0.0038 (U)
LA-1 Far West	04LA-97-0579	LA-0171	c1	Channel	0–2	0.044 (U)	0.044 (U)	0.0022 (U)	0.0022 (U)	0.0044 (U)	0.0044 (U)
LA-1 Far West	04LA-97-0624	LA-0172	c3	Overbank	1.5–15.5	0.041 (U)	0.14	0.002 (U)	0.002 (U)	0.0058	0.019
LA-1 West+	04LA-97-0573	LA-0173	c2	Overbank	0–9.5	0.045 (U)	0.15	0.0022 (U)	0.0022 (U)	0.0045 (U)	0.026
LA-1 West+	04LA-97-0574	LA-0174	c1	Channel	0–2	0.042 (U)	0.042 (U)	0.0021 (U)	0.0021 (U)	0.0042 (U)	0.0042 (U)
LA-1 West+	04LA-97-0575	LA-0175	c3	Overbank	0–7	0.037 (U)	0.11	0.0018 (U)	0.0018 (U)	0.0037 (U)	0.0059
LA-1 West+	04LA-97-0576	LA-0175	c3	Overbank	7–15.5	0.037 (U)	0.097	0.0018 (U)	0.0018 (U)	0.0055	0.02
LA-1 West+	04LA-97-0577	LA-0175	c3	Overbank	15.5–20.5	1.5	0.36 (U)	0.0018 (U)	0.0018 (U)	0.0036 (U)	0.0036 (U)
LA-1 West	04LA-97-0237	LA-0141	c3? (f1?)	Overbank	4–14	0.19	0.04 (U)	NA[c]	NA	NA	NA
LA-1 West	04LA-97-0571	LA-0143	c3	Overbank	13–21	0.046 (U)	0.066	0.0023 (U)	0.0023 (U)	0.0046 (U)	0.017
LA-1 West	04LA-97-0590	LA-0176	f1	Overbank	0–6.5	1.3	0.37 (U)	0.0019 (U)	0.0019 (U)	0.0037 (U)	0.0037 (U)
LA-1 West	04LA-97-0625	LA-0178	c2	Overbank	0–7.5	0.04 (U)	0.04 (U)	0.0072	0.0068	0.004 (U)	0.004 (U)
LA-1 West	04LA-97-0236	LA-0141	c3? (f1?)	Overbank	0–4	0.16	0.042 (U)	NA	NA	NA	NA
LA-1 West	04LA-97-0245	LA-0146	c3	Overbank	19.5–28	0.44	0.088 (U)	NA	NA	NA	NA
LA-1 Central	04LA-97-0255	LA-0151	f1	Overbank	0–7	0.47	0.076 (U)	NA	NA	NA	NA
LA-1 Central	04LA-97-0256	LA-0151	f1	Overbank	7–11.5	0.037 (U)	0.043	NA	NA	NA	NA
LA-1 Central	04LA-97-0257	LA-0151	f1	Overbank	11.5–14.5	0.037 (U)	0.037 (U)	NA	NA	NA	NA
LA-1 Central	04LA-97-0602	LA-0179	c2	Overbank	0–9.5	0.56	0.36	0.0023 (U)	0.0023 (U)	0.0045 (U)	0.025
LA-1 Central	04LA-97-0613	LA-0181	c3	Overbank	0–4	0.2 (U)	0.38	0.0024 (U)	0.0024 (U)	0.0085	0.048
LA-1 East	04LA-97-0272	LA-0158	f1	Overbank	0–13.5	0.04 (U)	0.052 (J+)[d]	NA	NA	NA	NA
LA-1 East	04LA-97-0273	LA-0158	f1	Overbank	13.5–19	0.04 (U)	0.04 (U)	NA	NA	NA	NA
LA-1 East	04LA-97-0279	LA-0162	c3	Overbank	12.5–18.5	0.39 (U)	1	NA	NA	NA	NA
LA-1 East	04LA-97-0572	LA-0160	f1	Overbank	0–10.5	0.042 (U)	0.076	0.0021 (U)	0.0021 (U)	0.0085	0.01
LA-1 East	04LA-97-0622	LA-0186	c3	Overbank	0–7	0.083 (U)	0.16	0.0021 (U)	0.0021 (U)	0.0042 (U)	0.012

a. mg/kg
b. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.
c. NA = not analyzed
d. J+ = The analyte was positively identified, and the reported value is an estimate and likely biased high.

TABLE D4-3 (continued)

ANALYTICAL RESULTS FOR ORGANIC COPCs IN PESTICIDE AND PCB SUITE IN UPPER LOS ALAMOS CANYON[a]

Reach or Subreach	Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Depth (in.)	Aroclor-1254	Aroclor-1260	α-Chlordane	γ-Chlordane	4,4'-DDE	4,4'-DDT
LA-1 East	04LA-97-0623	LA-0185	c2	Overbank	0–9	0.089 (U)[b]	0.4	0.0022 (U)	0.0022 (U)	0.0045 (U)	0.014
LA-2 West	04LA-96-0142	LA-0018	f1	Overbank	0–3	0.03 (U)	0.12	0.0016 (U)	0.0016 (U)	0.003 (U)	0.003 (U)
LA-2 West	04LA-97-0052	LA-0092	c2	Overbank	5.5–12.5	0.038 (U)	0.19	NA[c]	NA	NA	NA
LA-2 West	04LA-97-0569	LA-0041	c2	Overbank	0–5	0.17 (U)	0.59	0.0021 (U)	0.0021 (U)	0.0042 (U)	0.02
LA-2 West	04LA-97-0570	LA-0041	c2	Overbank	8–11	0.042 (U)	0.21	0.0021 (U)	0.0021 (U)	0.0042 (U)	0.01
DP Cyn	04LA-96-0140	LA-0016	c2b	Overbank	0–3	0.031 (U)	0.025	0.0016 (U)	0.0016 (U)	0.0031 (U)	0.0031 (U)
LA-2 East	04LA-96-0143	LA-0019	c2	Overbank	0–6	0.031 (U)	0.055	0.0016 (U)	0.0016 (U)	0.0031 (U)	0.0031 (U)
LA-2 East	04LA-96-0144	LA-0020	c2b	Overbank	0–6	0.032 (U)	0.051	0.0016 (U)	0.0016 (U)	0.0032 (U)	0.0032 (U)
LA-2 East	04LA-96-0145	LA-0020 (0021)	c2b	Overbank	25–29	0.034 (U)	0.23	0.0018 (U)	0.0018 (U)	0.0034 (U)	0.0034 (U)
LA-2 East	04LA-96-0146	LA-0022	c2	Overbank	0–3	0.032 (U)	0.05	0.0016 (U)	0.0016 (U)	0.0032 (U)	0.0032 (U)
LA-2 East	04LA-96-0147	LA-0023	c1	Channel	0–4	0.03 (U)	0.016	0.0015 (U)	0.0015 (U)	0.003 (U)	0.003 (U)
LA-2 East	04LA-96-0148	LA-0024	c3	Channel	0–6	0.031 (U)	0.042	0.0016 (U)	0.0016 (U)	0.0031 (U)	0.0031 (U)
LA-2 East	04LA-96-0149	LA-0024 (0025)	c3	Overbank	26–32	0.032 (U)	0.42	0.0017 (U)	0.0017 (U)	0.033	0.0032 (U)
LA-2 East	04LA-97-0053	LA-0022 (0039)	c2	Overbank	8–12	0.047 (U)	0.081	NA	NA	NA	NA
LA-3	04LA-97-0143	LA-0109	c3	Overbank	16–19.5	(R)[d]	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0144	LA-0109	c3	Overbank	16–19.5	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0145	LA-0110	c3	Overbank	11–16	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0146	LA-0110	c3	Overbank	11–16	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0147	LA-0111	c2	Overbank	11–13.5	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0148	LA-0114	c2	Overbank	6.5–12.5	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0149	LA-0115	c3	Overbank	11–16	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0150	LA-0116	c1	Channel	0–2	(R)	(R)	(R)	(R)	(R)	(R)

a. mg/kg

b. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

c. NA = not analyzed

d. R = The sample results are rejected because of serious deficiencies in the ability to analyze the sample and meet quality control criteria; presence or absence cannot be verified.

TABLE D4-4

ANALYTICAL RESULTS FOR ORGANIC COPCs IN SVOC SUITE IN UPPER LOS ALAMOS CANYON[a]

Part 1

Reach or Subreach	Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Depth (in.)	Acenaphthene	Anthracene	Benz(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene
LA-2 West	04LA-96-0142	LA-0018	f1	Overbank	0–3	0.324 (U)[b]	0.324 (U)	0.324 (U)	0.324 (U)	0.324 (U)	0.324 (U)
LA-2 West	04LA-97-0052	LA-0092	c2	Overbank	5.5–12.5	0.23 (J-)[c]	0.03 (J-)	0.028 (J-)	0.065 (J-)	0.065 (J-)	0.38 (U)
DP Cyn	04LA-96-0140	LA-0016	c2b	Overbank	0–3	0.067 (J)[d]	0.096 (J)	0.204 (J)	0.271 (J)	0.365	0.178 (J)
LA-2 East	04LA-96-0143	LA-0019	c2	Overbank	0–6	0.329 (U)	0.037 (J)	0.192 (J)	0.243 (J)	0.332	0.146 (J)
LA-2 East	04LA-96-0144	LA-0020	c2b	Overbank	0–6	0.328 (U)	0.055 (J)	0.276 (J)	0.312 (J)	0.483	0.205 (J)
LA-2 East	04LA-96-0145	LA-0020 (0021)	c2b	Overbank	25–29	0.355 (U)	0.069 (J)	0.346 (J)	0.655	0.66	0.298 (J)
LA-2 East	04LA-96-0146	LA-0022	c2	Overbank	0–3	0.329 (U)	0.064 (J)	0.368	0.393	0.622	0.288 (J)
LA-2 East	04LA-96-0147	LA-0023	c1	Channel	0–4	0.324 (U)	0.047 (J)	0.127 (J)	0.128 (J)	0.174 (J)	0.324 (U)
LA-2 East	04LA-96-0148	LA-0024	c3	Channel	0–6	0.322 (U)	0.322 (U)	0.322 (U)	0.322 (U)	0.322 (U)	0.322 (U)
LA-2 East	04LA-96-0149	LA-0024 (0025)	c3	Overbank	26–32	0.33 (U)	0.044 (J)	0.136 (J)	0.15 (J)	0.253 (J)	0.33 (U)
LA-2 East	04LA-97-0053	LA-0022 (0039)	c2	Overbank	8–12	0.26 (J-)	0.026 (J-)	0.026 (J-)	0.059 (J-)	0.067 (J-)	0.47 (U)
LA-3	04LA-97-0143	LA-0109	c3	Overbank	16–19.5	(R)[e]	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0144	LA-0109	c3	Overbank	16–19.5	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0145	LA-0110	c3	Overbank	11–16	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0146	LA-0110	c3	Overbank	11–16	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0147	LA-0111	c2	Overbank	11–13.5	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0148	LA-0114	c2	Overbank	6.5–12.5	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0149	LA-0115	c3	Overbank	11–16	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0150	LA-0116	c1	Channel	0–2	(R)	(R)	(R)	(R)	(R)	(R)

a. mg/kg

b. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

c. J- = The analyte was positively identified, and the reported value is an estimate and likely biased low.

d. 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.

e. R = The sample results are rejected because of serious deficiencies in the ability to analyze the sample and meet quality control criteria; presence or absence cannot be verified.

TABLE D4-4 (continued)

ANALYTICAL RESULTS FOR ORGANIC COPCs IN SVOC SUITE IN UPPER LOS ALAMOS CANYON[a]

Part 2

Reach or Subreach	Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Depth (in.)	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Dibenzofuran	Di-n-butylphthalate	Fluoranthene
LA-2 West	04LA-96-0142	LA-0018	f1	Overbank	0–3	0.324 (U)[b]	0.324 (U)	0.324 (U)	0.324 (U)	0.047	0.053 (J)[c]
LA-2 West	04LA-97-0052	LA-0092	c2	Overbank	5.5–12.5	0.017 (J-)[d]	0.073 (J-)	0.38 (U)	NA[e]	NA	0.098 (J-)
DP Cyn	04LA-96-0140	LA-0016	c2b	Overbank	0–3	0.325 (U)	0.261 (J)	0.325 (U)	0.036 (J)	0.055	0.489
LA-2 East	04LA-96-0143	LA-0019	c2	Overbank	0–6	0.329 (U)	0.223 (J)	0.329 (U)	0.329 (U)	0.329 (U)	0.384
LA-2 East	04LA-96-0144	LA-0020	c2b	Overbank	0–6	0.328 (U)	0.313 (J)	0.328 (U)	0.328 (U)	0.037	0.562
LA-2 East	04LA-96-0145	LA-0020 (0021)	c2b	Overbank	25–29	0.355 (U)	0.361	0.355 (U)	0.355 (U)	0.055	0.662
LA-2 East	04LA-96-0146	LA-0022	c2	Overbank	0–3	0.329 (U)	0.41	0.329 (U)	0.329 (U)	0.048	0.725
LA-2 East	04LA-96-0147	LA-0023	c1	Channel	0–4	0.324 (U)	0.128 (J)	0.324 (U)	0.324 (U)	0.324 (U)	0.226 (J)
LA-2 East	04LA-96-0148	LA-0024	c3	Channel	0–6	0.322 (U)	0.322 (U)	0.322 (U)	0.322 (U)	0.322 (U)	0.322 (U)
LA-2 East	04LA-96-0149	LA-0024 (0025)	c3	Overbank	26–32	0.33 (U)	0.164 (J)	0.33 (U)	0.33 (U)	0.053	0.296 (J)
LA-2 East	04LA-97-0053	LA-0022 (0039)	c2	Overbank	8–12	0.019 (J-)	0.076 (J-)	0.029 (J-)	NA	NA	0.1 (J-)
LA-3	04LA-97-0143	LA-0109	c3	Overbank	16–19.5	(R)[f]	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0144	LA-0109	c3	Overbank	16–19.5	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0145	LA-0110	c3	Overbank	11–16	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0146	LA-0110	c3	Overbank	11–16	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0147	LA-0111	c2	Overbank	11–13.5	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0148	LA-0114	c2	Overbank	6.5–12.5	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0149	LA-0115	c3	Overbank	11–16	(R)	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0150	LA-0116	c1	Channel	0–2	(R)	(R)	(R)	(R)	(R)	(R)

a. mg/kg
b. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.
c. 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.
d. J- = The analyte was positively identified, and the reported value is an estimate and likely biased low.
e. NA = not analyzed
f. R = The sample results are rejected because of serious deficiencies in the ability to analyze the sample and meet quality control criteria; presence or absence cannot be verified.

TABLE D4-4 (continued)

ANALYTICAL RESULTS FOR ORGANIC COPCs IN SVOC SUITE IN UPPER LOS ALAMOS CANYON[a]

Part 3

Reach or Subreach	Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Depth (in.)	Fluorene	Indeno(1,2,3-cd) pyrene	Naphthalene	Phenanthrene	Pyrene
LA-2 West	04LA-96-0142	LA-0018	f1	Overbank	0–3	0.324 (U)[b]	0.324 (U)	0.324 (U)	0.036 (J)[c]	0.05 (J)
LA-2 West	04LA-97-0052	LA-0092	c2	Overbank	5.5–12.5	0.01 (J-)[d]	0.19 (J-)	0.2 (J-)	0.13 (J-)	0.25 (J-)
DP Cyn	04LA-96-0140	LA-0016	c2b	Overbank	0–3	0.066 (J)	0.16 (J)	0.083 (J)	0.432	0.432
LA-2 East	04LA-96-0143	LA-0019	c2	Overbank	0–6	0.329 (U)	0.132 (J)	0.329 (U)	0.193 (J)	0.341
LA-2 East	04LA-96-0144	LA-0020	c2b	Overbank	0–6	0.328 (U)	0.184 (J)	0.328 (U)	0.266 (J)	0.476
LA-2 East	04LA-96-0145	LA-0020 (0021)	c2b	Overbank	25–29	0.355 (U)	0.341 (J)	0.355 (U)	0.325 (J)	0.589
LA-2 East	04LA-96-0146	LA-0022	c2	Overbank	0–3	0.329 (U)	0.266 (J)	0.329 (U)	0.33	0.576
LA-2 East	04LA-96-0147	LA-0023	c1	Channel	0–4	0.324 (U)	0.324 (U)	0.324 (U)	0.156 (J)	0.206 (J)
LA-2 East	04LA-96-0148	LA-0024	c3	Channel	0–6	0.322 (U)	0.322 (U)	0.322 (U)	0.322 (U)	0.322 (U)
LA-2 East	04LA-96-0149	LA-0024 (0025)	c3	Overbank	26–32	0.33 (U)	0.33 (U)	0.33 (U)	0.18 (J)	0.27 (J)
LA-2 East	04LA-97-0053	LA-0022 (0039)	c2	Overbank	8–12	0.011 (J-)	0.13 (J-)	0.11 (J-)	0.13 (J-)	0.13 (J-)
LA-3	04LA-97-0143	LA-0109	c3	Overbank	16–19.5	(R)[e]	(R)	(R)	(R)	(R)
LA-3	04LA-97-0144	LA-0109	c3	Overbank	16–19.5	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0145	LA-0110	c3	Overbank	11–16	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0146	LA-0110	c3	Overbank	11–16	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0147	LA-0111	c2	Overbank	11–13.5	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0148	LA-0114	c2	Overbank	6.5–12.5	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0149	LA-0115	c3	Overbank	11–16	(R)	(R)	(R)	(R)	(R)
LA-3	04LA-97-0150	LA-0116	c1	Channel	0–2	(R)	(R)	(R)	(R)	(R)

a. mg/kg

b. U = The analyte was analyzed for but not detected. Reported value is the sample-specific estimated quantitation limit or detection limit.

c. 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.

d. J- = The analyte was positively identified, and the reported value is an estimate and likely biased low.

e. R = The sample results are rejected because of serious deficiencies in the ability to analyze the sample and meet quality control criteria; presence or absence cannot be verified.

Appendix E

Statistical Analyses

APPENDIX E STATISTICAL ANALYSES

E-1.0 STATISTICAL EVALUATIONS OF INORGANIC CHEMICAL DATA

The objective of this section is to present detailed statistical and graphical analyses that compare inorganic chemical data from the upper Los Alamos Canyon reaches with Laboratory background data from sediments. These analyses are used to determine whether the reach data show evidence of contaminant releases through a systematic increase in concentration of one or more analytes over concentrations observed in the background data.

E-1.1 Methods

Three types of analyses were used to evaluate the concentrations of inorganic chemicals in the reach samples as compared with background data. The first type of analyses are graphical comparisons of reach and background sample results. Second, the results of formal statistical testing are presented. Third, relationships of inorganic chemicals to concentration of aluminum are graphically presented. Each of these methods is discussed below in more detail.

E-1.1.1 Comparisons of Inorganic Chemical Data by Reach

These comparisons use graphical displays called "box plots," which show the actual values for each inorganic chemical. The ends of each box represent the "interquartile" range of the data distribution, which is specified by the 25th percentile and 75th percentile of the data distribution. The horizontal line within each box is the median (50th percentile) of the data distribution. The horizontal line below each box represents the 10th percentile, and the horizontal line above each box represents the 90th percentile. Thus, each box indicates concentration values for the central half of the data, and concentration shifts can be readily assessed by comparing the boxes. If most of the data are represented by a single concentration value (usually the detection limit), the box is reduced to a single line. The horizontal line drawn across all the data groups represents the overall mean of all data (both reach and background data).

To the right of each box plot is another statistical graphic of the same data. This plot is known as a "normal quantile" plot that facilitates the interpretation of the statistical distribution of the data. For example, if the data originate from a normal statistical distribution, then the data (plotted as one of four symbols) will fall on a line. The normal quantile plot presents two types of information for each data group. A line is presented for each data group that is calculated based on the observed mean and standard deviation of the data. Also the actual sample results are plotted on the normal quantile scale, and line segments connect each result.

In these statistical plots a different symbol is used for the laboratory results for each reach and for the background data (BKG), and the symbols are used consistently in all statistical plots in this section. Background data are represented by a filled square, reach LA-1 data by a plus symbol, reach LA-2 data by an "x," and reach LA-3 data by a hollow square.

E-1.1.2 Statistical Testing

Because the data for these inorganic chemicals do not appear to typically satisfy conditions of statistical normality, nonparametric statistical tests are preferred for background comparisons. The Gehan test was used for statistical testing. The purpose of this test is to detect whether the reach data show evidence of a

release of any analyte through a systematic increase in concentration over that observed in the background data. The Gehan test pools site and background data into one aggregate set and determines whether the average rank of site data is greater than that of the background data. The Gehan test is most sensitive to detecting cases where most of the reach data are greater than the average or median value observed in the background data. More discussion of these tests is contained in Ryti et al. (1996, 53953).

The metrics used to determine if a statistically significant difference between reach data and site data exists are the calculated significance levels (p-values) for the tests. A low p-value (near zero) indicates that reach data are greater than background data, whereas a p-value approaching 1 indicates no difference between reach data and background data. If a p-value is less than some small probability (0.05), then there is some reason to suspect that the reach statistical distribution may be elevated above the background distribution; otherwise, no difference is indicated.

E-1.1.3 Interelement Correlations

One way to evaluate the applicability of Laboratory-wide background sediment data to reach sediment data is to evaluate the data through interelement correlations. Typically, there are significant correlations between major elements (aluminum, iron, and potassium) and trace elements (arsenic, beryllium, copper, nickel, vanadium, and zinc). The correlations are presented and the geochemical basis is discussed in *Natural Background Geochemistry and Statistical Analysis of Selected Soil Profiles, Sediments, and Bandelier Tuff, Los Alamos, New Mexico* (Longmire et al. 1995, 52227). For most inorganic chemicals, these strong correlations result in a consistent ratio of trace to major elements. A significantly elevated ratio of a given trace element to a major element can be used to indicate a release of that trace element. Scatter plots of trace elements to major elements are one way to visually display the ratios for background and reach data. Scatter plots of all inorganic chemicals versus aluminum are presented as a graphical assessment of the similarity between the reach data and the Laboratory-wide sediment background data. These plots show four groups of data: the Laboratory sediment background data, reach LA-1 data, reach LA-2 data , and reach LA-3 data. Aluminum was selected as the major element for these plots for two reasons. First, knowledge of Laboratory releases (see Section 1.3.2) have not implicated aluminum as a possible Laboratory contaminant. Second, the results of statistical testing of the upper Los Alamos Canyon reach data also suggest no evidence for aluminum concentrations to be shifted above background values (see Section E-1.2.1).

E-1.2 Results

The results of the statistical analyses are presented for each inorganic chemical, which includes discussion of statistical tests that compare sample results from each reach with sediment background data.

E-1.2.1 Aluminum

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-1) confirms these results. Thus, aluminum is not retained as a chemical of potential concern (COPC).

TABLE E1-1

SUMMARY OF THE P-VALUES FROM THE GEHAN STATISTICAL TESTING

Analyte	Reach LA-1	Reach LA-2	Reach LA-3
Aluminum	>0.999	0.879	0.345
Antimony	no background data	no background data	no background data
Arsenic	0.971	0.437	0.976
Barium	0.254	0.520	0.653
Beryllium	0.169	0.568	0.528
Boron	N.A.[a]	0.958	N.A.
Cadmium	N/A[b]	N/A	N/A
Calcium	0.290	0.718	0.345
Chromium, total	0.981	**0.017**[c]	0.377
Cobalt	0.161	0.653	0.243
Copper	**<0.001**	**0.013**	**0.014**
Cyanide, total	no reach data	0.987	0.984
Iron	>0.999	0.827	0.981
Lead	**<0.001**	**<0.001**	**<0.001**
Magnesium	0.989	0.78	0.438
Manganese	0.990	0.6343	0.907
Mercury	N/A	N/A	N/A
Nickel	>0.999	0.970	0.675
Potassium	>0.999	0.851	0.913
Selenium	N/A	N/A	N/A
Silver	N/A	N/A	N/A
Sodium	>0.999	0.630	0.994
Thallium	no background data	no background data	no background data
Titanium	N.A.	0.883	N.A.
Uranium, total	N.A.	**0.007**	N.A.
Uranium	N.A.	0.169	N.A.
Vanadium	0.996	0.639	0.875
Zinc	0.264	**<0.001**	**0.025**

a. N.A. = not available (no data for this analyte in this reach)

b. N/A = not applicable (statistical tests are not appropriate because of the high frequency of nondetected values)

c. Bolded values indicate that reach sample results are significantly greater than background values.

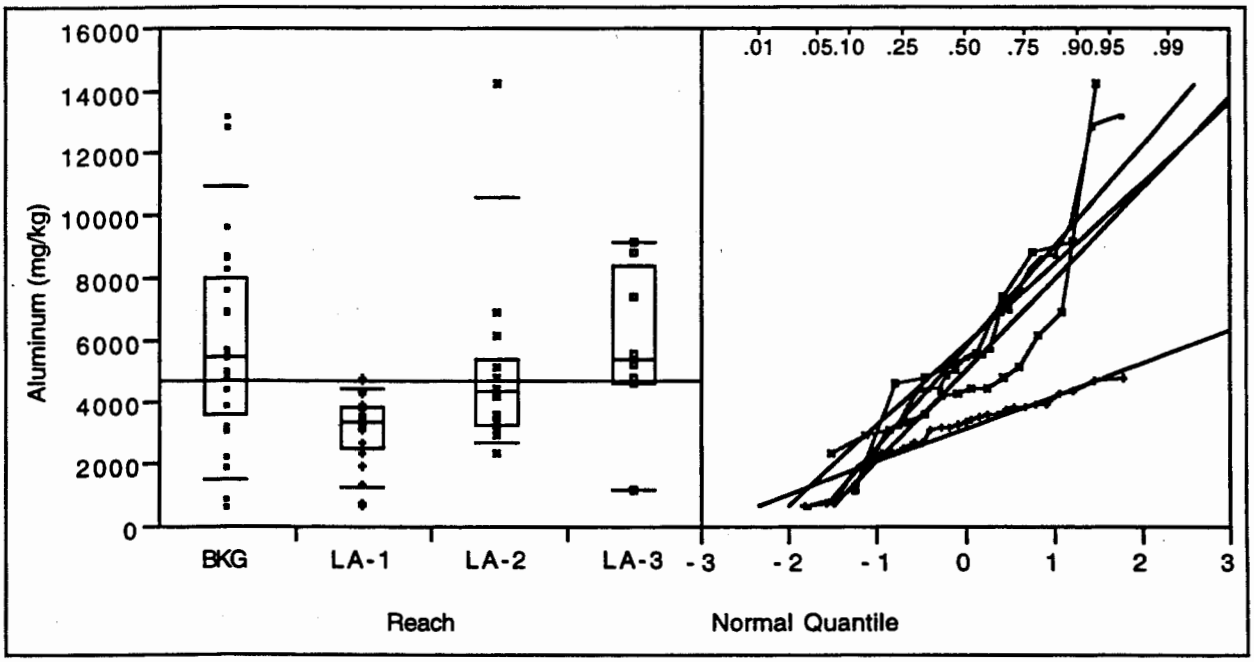

Figure E1-1. Box plot for aluminum.

E-1.2.2 Antimony

There are no antimony detects in any reach, thus statistical testing is not appropriate. Ten antimony sample results from request number (RN) 2104 (collected from reach LA-2) were rejected because of a serious quality control deficiency (see Appendix C for more information). The statistical plots show the range of the nondetected values by reach (Figure E1-2a) and the correlation of the nondetected values to aluminum (Figure E1-2b). Because some detection limits are greater than the antimony background value, antimony is retained as a COPC. There are some samples, within reaches LA-1 and LA-2, with detection limits less than the background value. Thus, it is quite likely that no antimony has been released into upper Los Alamos Canyon sediments.

E-1.2.3 Arsenic

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-3a) and versus aluminum (Figure E1-3b) confirms these results. Thus, arsenic is not retained as a COPC.

E-1.2.4 Barium

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-4a) confirms these results. The barium versus aluminum scatter plot (Figure E1-4b) suggests that five sample results in reach LA-1 could have elevated barium given the aluminum concentration measured in these samples. However, barium is not retained as a COPC because the box plots and statistical testing suggest that barium concentrations are not different from background.

E-1.2.5 Beryllium

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-5a) confirms these results. The beryllium versus aluminum scatter plot (Figure E1-5b) suggests that two sample results in reach LA-1 could have elevated beryllium given the aluminum concentration measured in these samples. However, beryllium is not retained as a COPC because the box plots and statistical testing suggest that beryllium concentrations are not different from background.

E-1.2.6 Boron

Boron analytical results were obtained from samples collected in reach LA-2. It is noted that all of the boron results were qualified as nondetect sample results because boron was found in the laboratory blank, which could suggest possible high laboratory bias for these samples. However, results of the statistical testing (Table E1-1) suggest there are no differences between these reach data and sediment background data. A review of the data plotted by reach (Figure E1-6a) and versus aluminum (Figure E1-6b) confirms these results. Thus, boron is not retained as a COPC.

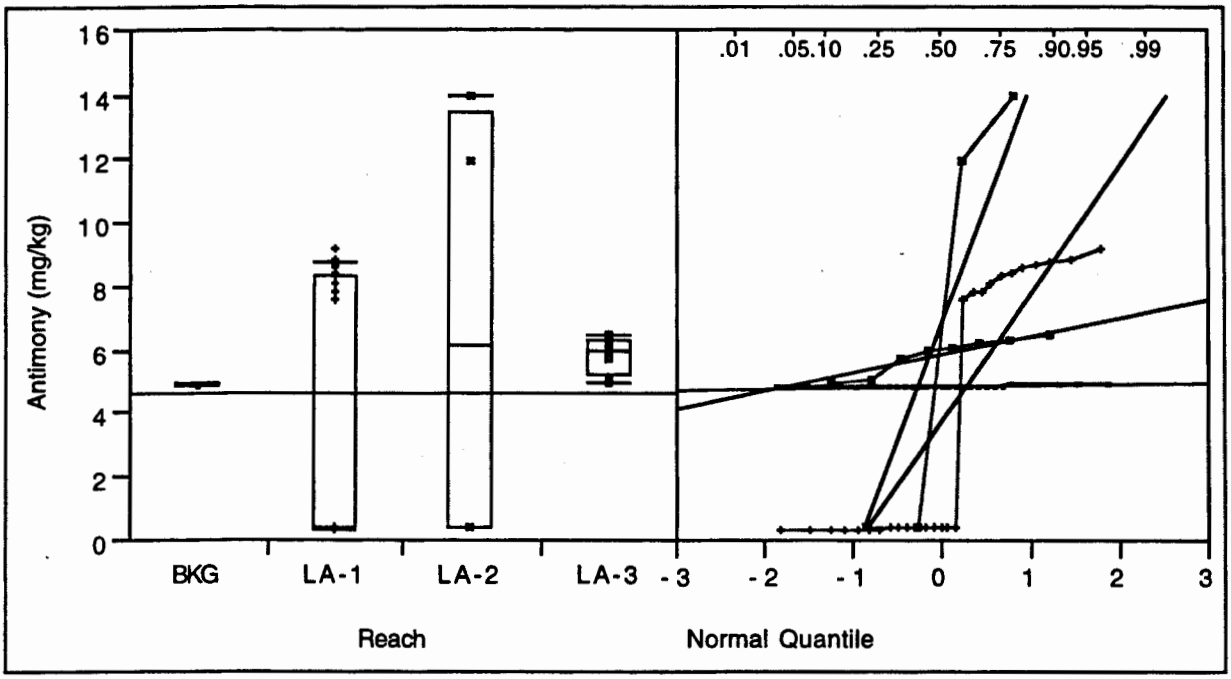

Figure E1-2a. Box plot for antimony.

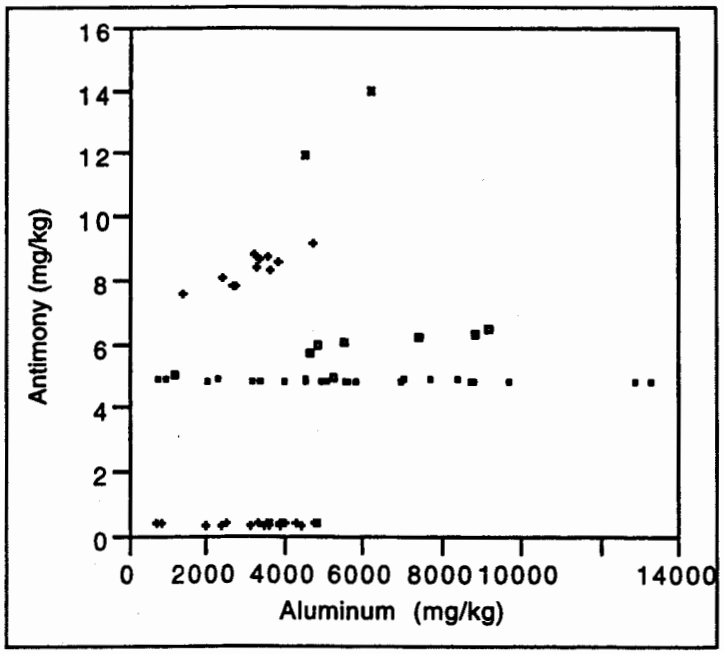

Figure E1-2b. Scatter plot for antimony versus aluminum.

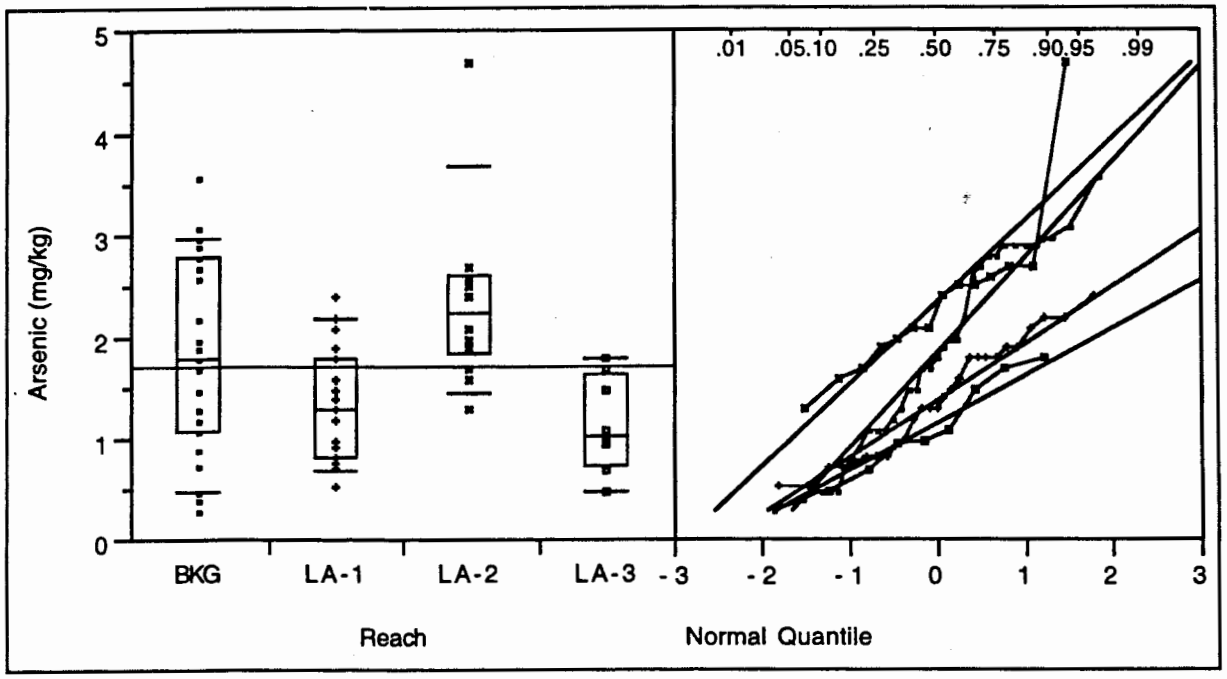

Figure E1-3a. Box plot for arsenic.

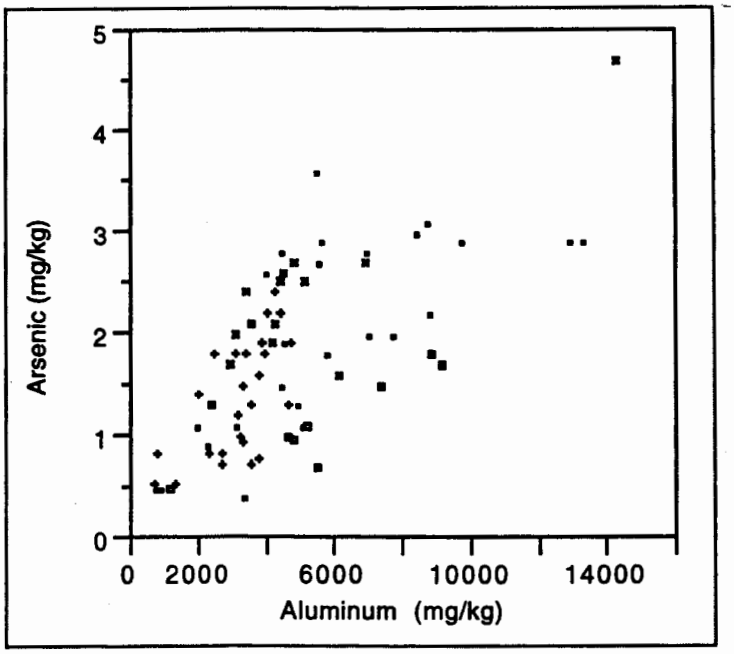

Figure E1-3b. Scatter plot for arsenic versus aluminum.

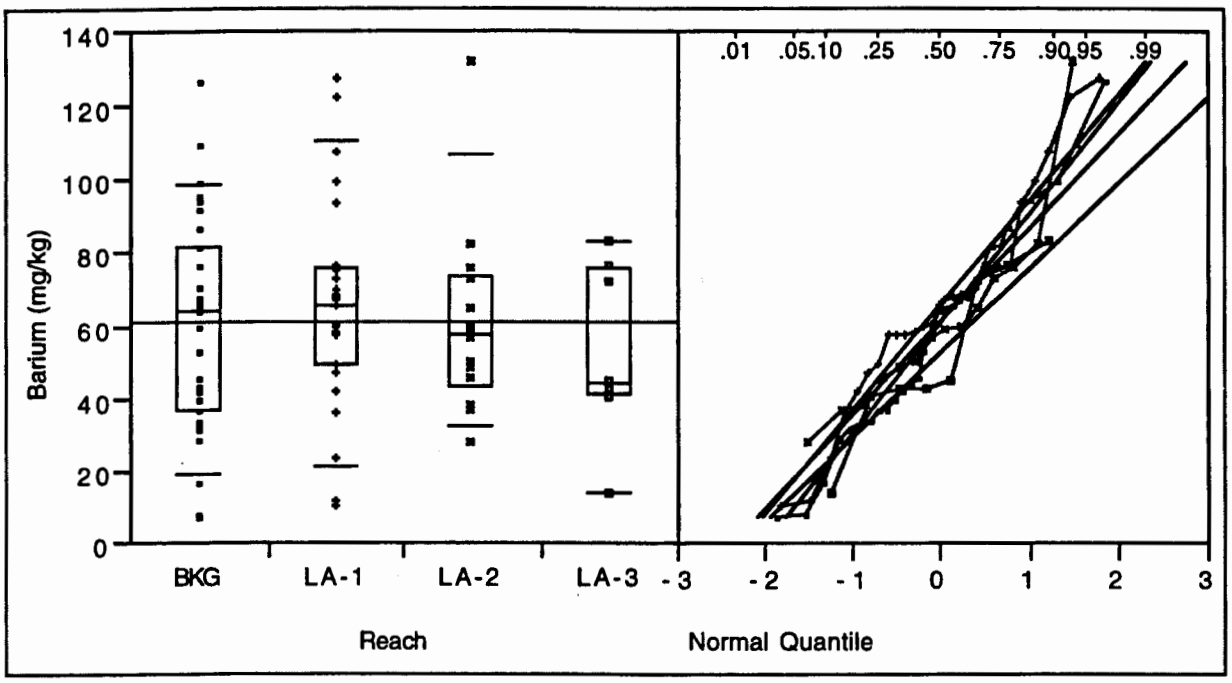

Figure E1-4a. Box plot for barium.

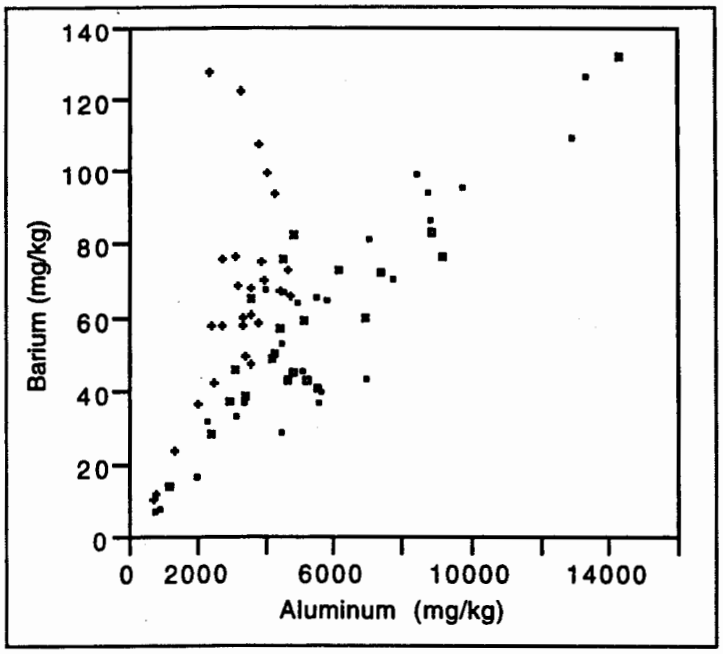

Figure E1-4b. Scatter plot for barium versus aluminum.

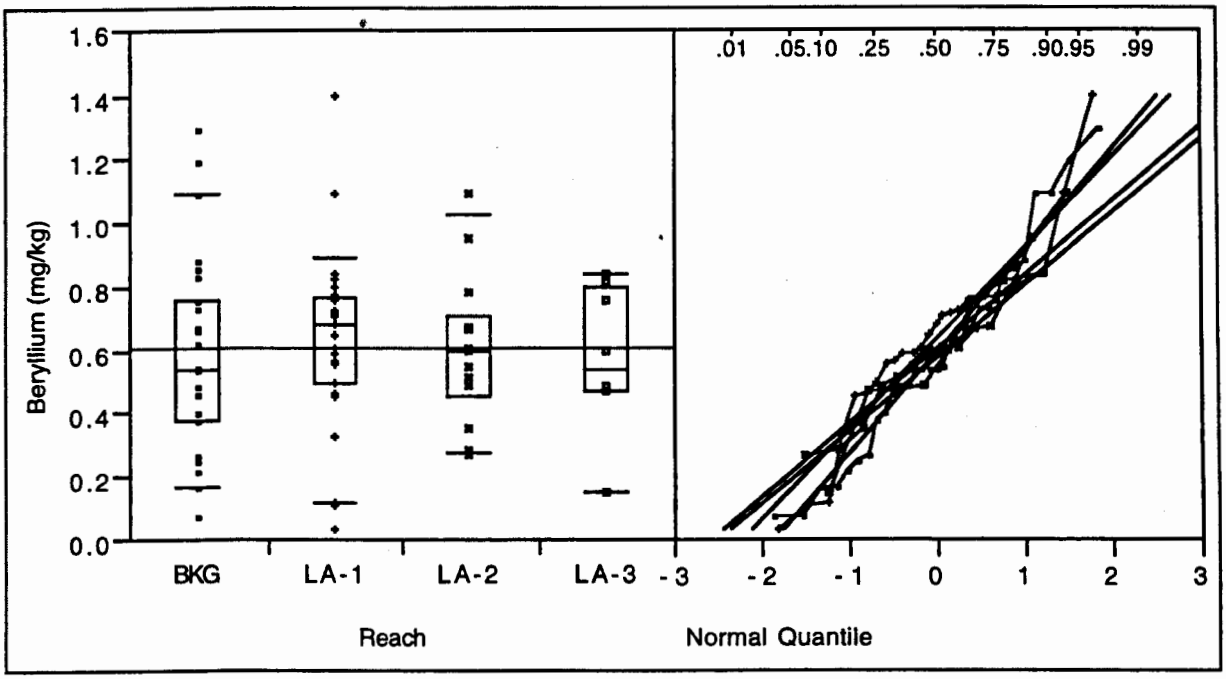

Figure E1-5a. Box plot for beryllium.

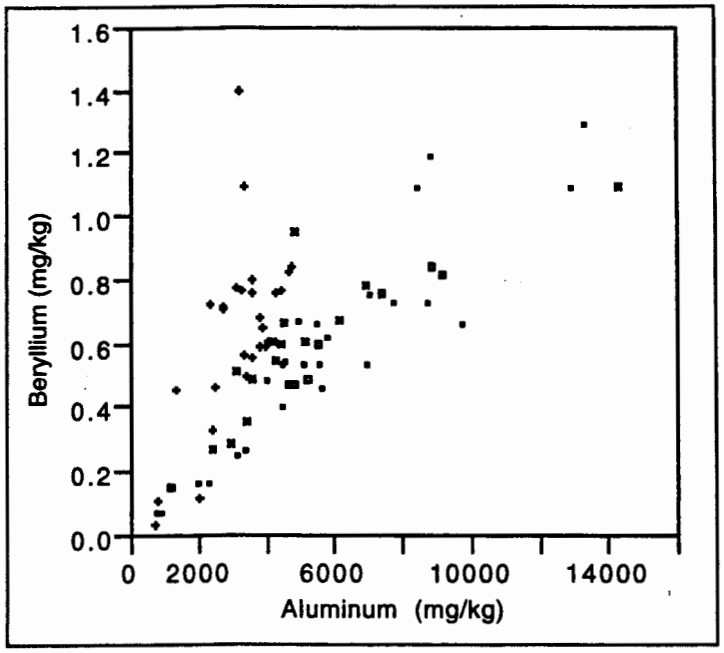

Figure E1-5b. Scatter plot for beryllium versus aluminum.

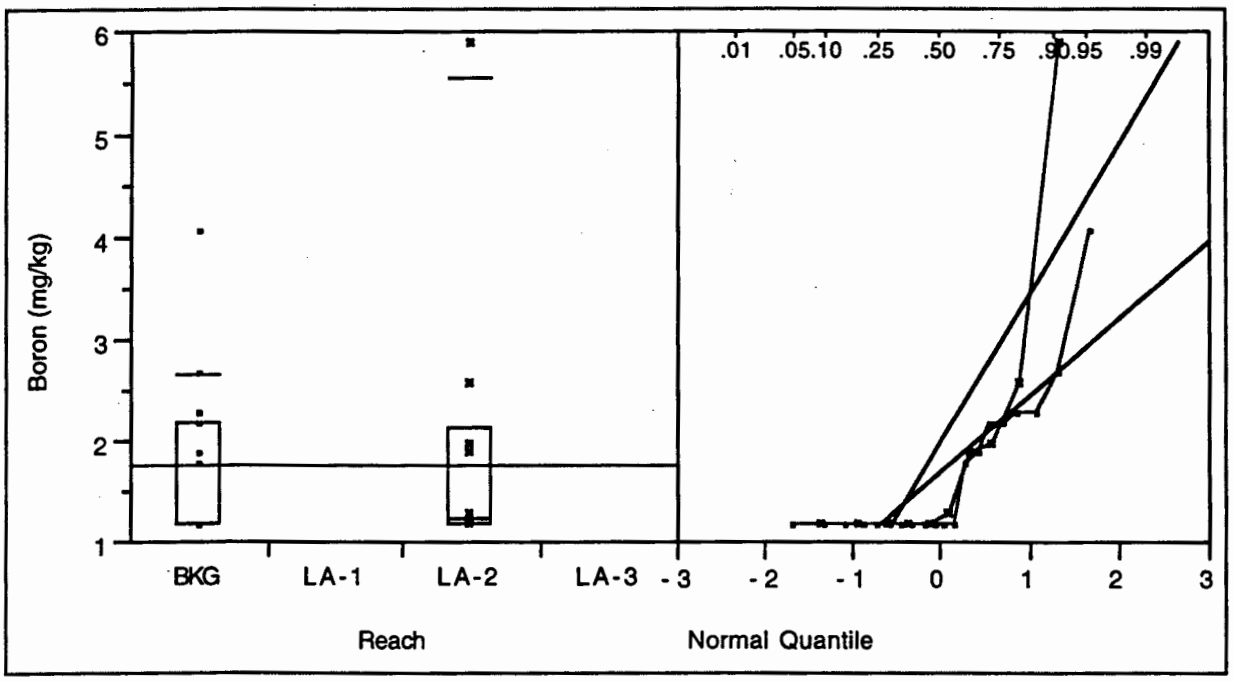

Figure E1-6a. Box plot for boron.

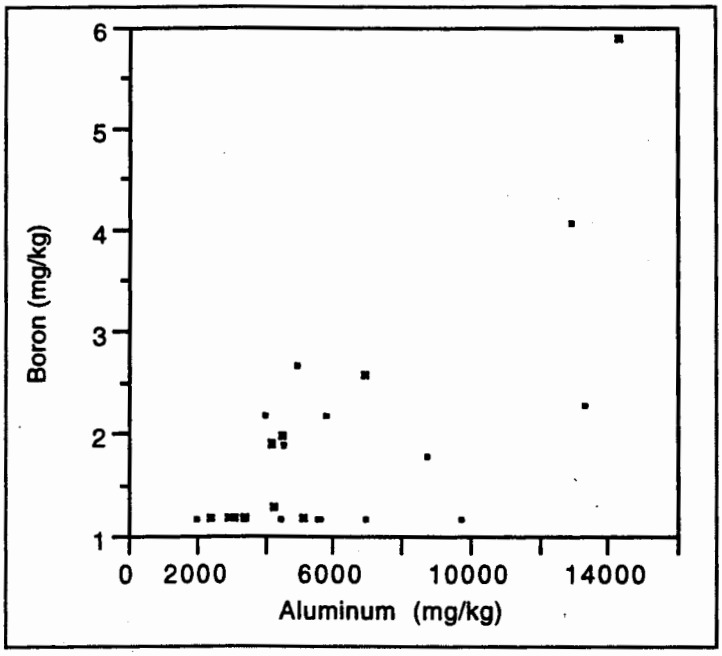

Figure E1-6b. Scatter plot for boron versus aluminum.

E-1.2.7 Cadmium

Cadmium was not usually detected in the reach or background samples, thus statistical testing is not appropriate. The statistical plots show the range of detected and nondetected values by reach (Figure E1-7a) and the correlation of the nondetected values to aluminum (Figure E1-7b). It is important to recognize that the apparently elevated sample results in reaches LA-1 and LA-3 are all nondetected values. The apparent correlation of these nondetect sample results with aluminum could indicate an analytical interference with iron or aluminum. Because some detected sample results and detection limits are greater than the cadmium background value of 0.4 mg/kg, cadmium is retained as a COPC.

E-1.2.8 Calcium

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-8a) and versus aluminum (Figure E1-8b) confirms these results. Thus, calcium is not retained as a COPC.

E-1.2.9 Chromium, Total

Results of the statistical testing (Table E1-1) suggest reach LA-2 sample results are greater than background. A review of the data plotted by reach (Figure E1-9a) and versus aluminum (Figure E1-9b) confirms these results. Thus, chromium is retained as a COPC.

E-1.2.10 Cobalt

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-10a) confirms these results. The cobalt versus aluminum scatter plot (Figure E1-10b) suggests that five sample results in reach LA-1 could have elevated cobalt given the aluminum concentration measured in these samples. However, cobalt is not retained as a COPC because the box plots and statistical testing suggest that cobalt concentrations are not different from background.

E-1.2.11 Copper

Results of the statistical testing (Table E1-1) suggest there are significant differences between all reach data (LA-1, LA-2, and LA-3) and background data. A review of the data plotted by reach (Figure E1-11a) and versus aluminum (Figure E1-11b) confirms these results but also shows that the overall magnitude of most background exceedances is small. Copper is retained as a COPC because of sample results greater than background the value in reaches LA-1, LA-2, and LA-3.

E-1.2.12 Cyanide, Total

Total cyanide analytical results were obtained from samples collected from reaches LA-2 and LA-3. Results of the statistical testing (Table E1-1) suggest there are no differences between these reach data and sediment background data. A review of the data plotted by reach (Figure E1-12a) and versus aluminum (Figure E1-12b) confirms these results. Thus, total cyanide is not retained as a COPC.

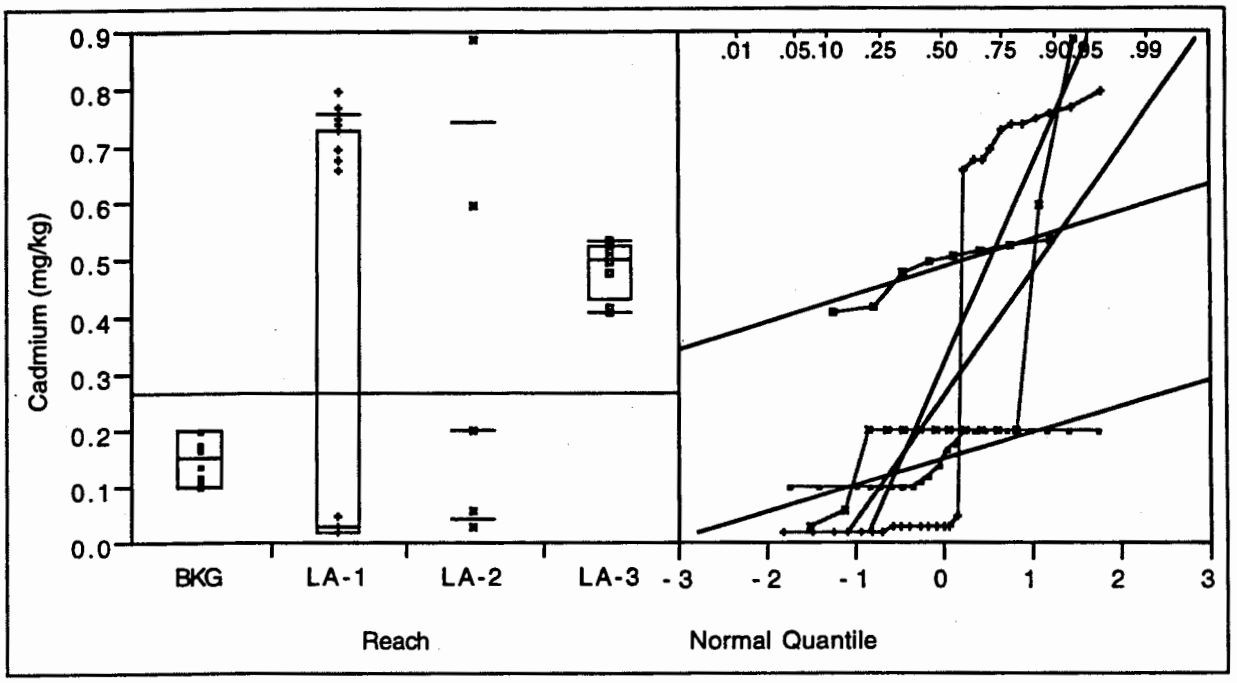

Figure E1-7a. Box plot for cadmium.

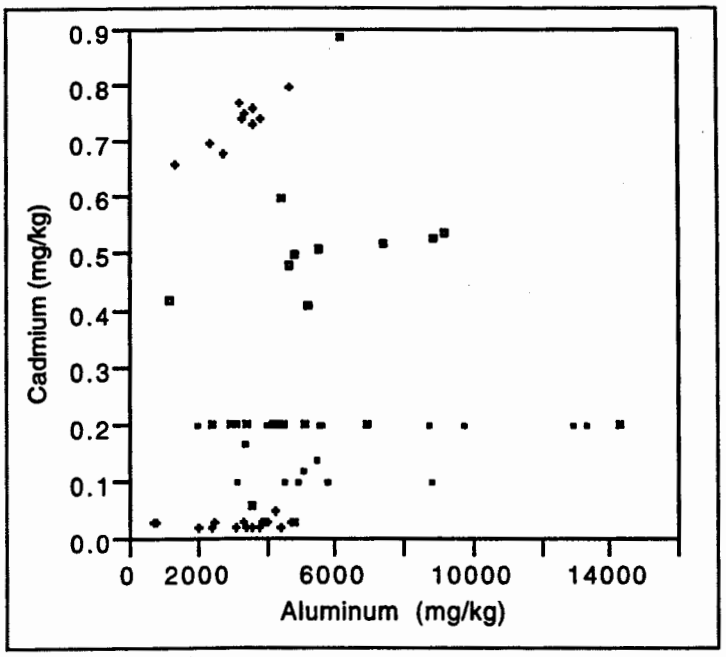

Figure E1-7b. Scatter plot for cadmium versus aluminum.

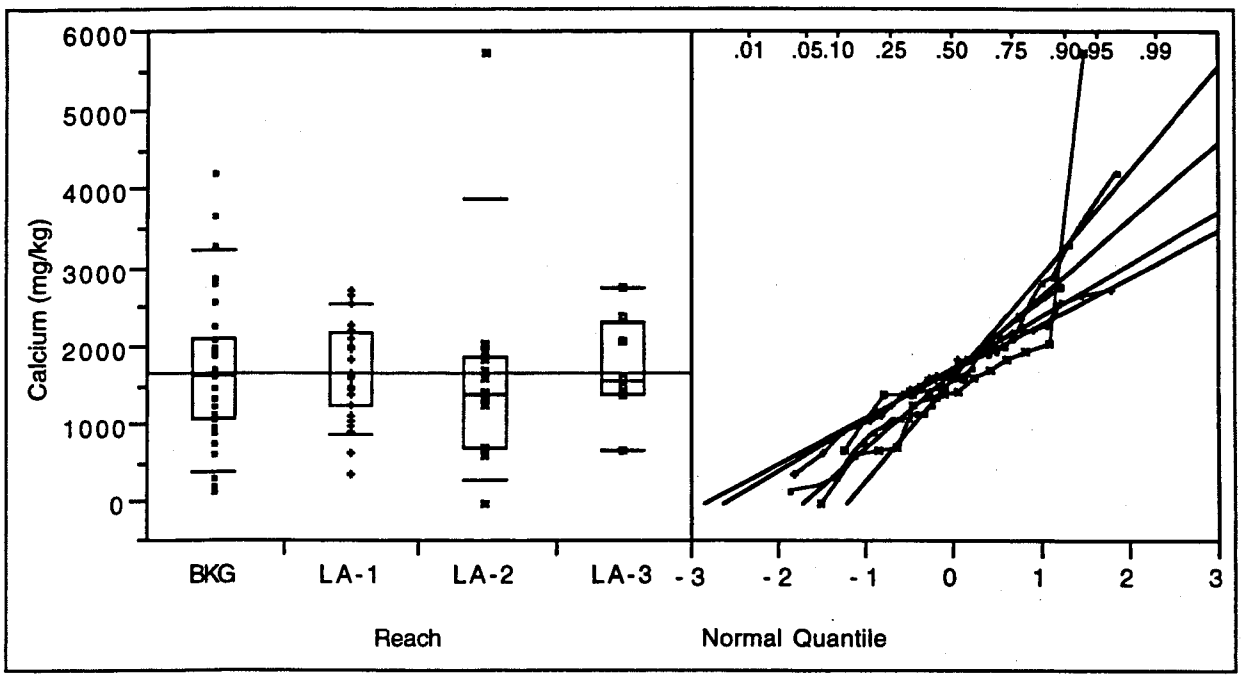

Figure E1-8a. Box plot for calcium.

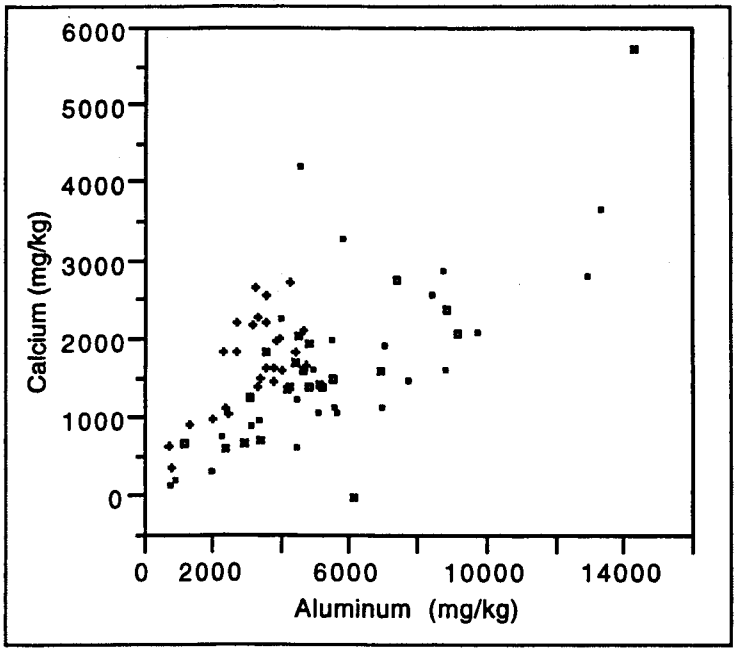

Figure E1-8b. Scatter plot for calcium versus aluminum.

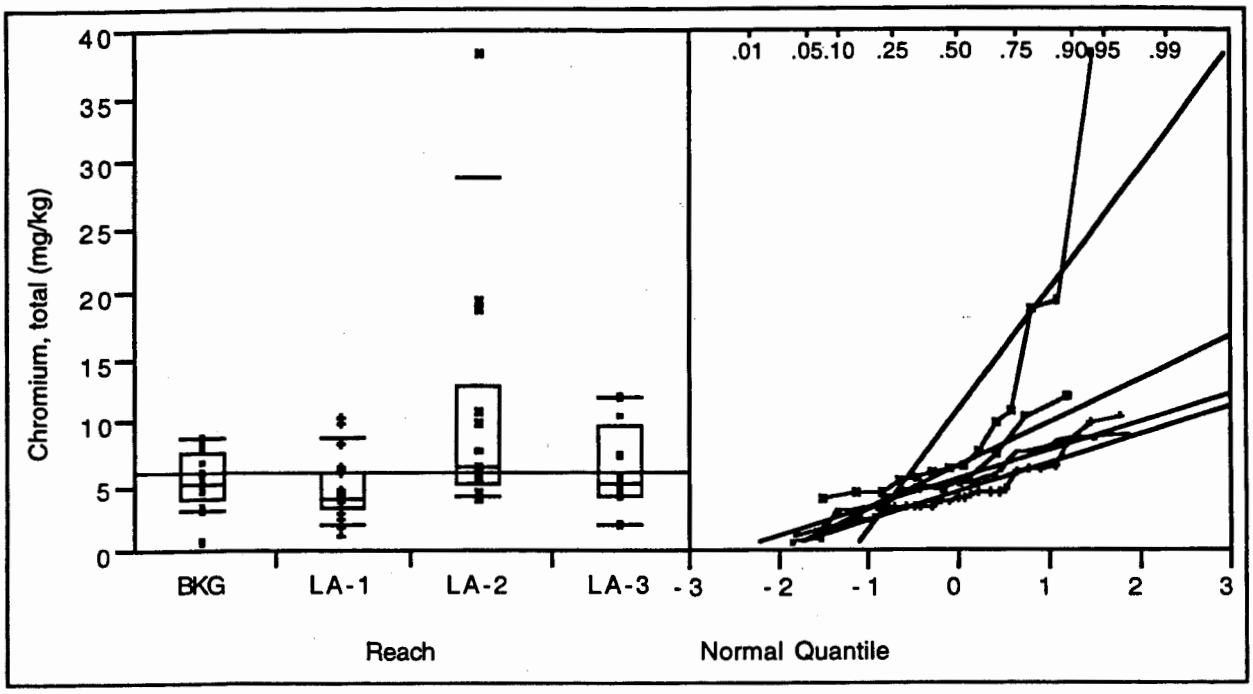

Figure E1-9a. Box plot for chromium.

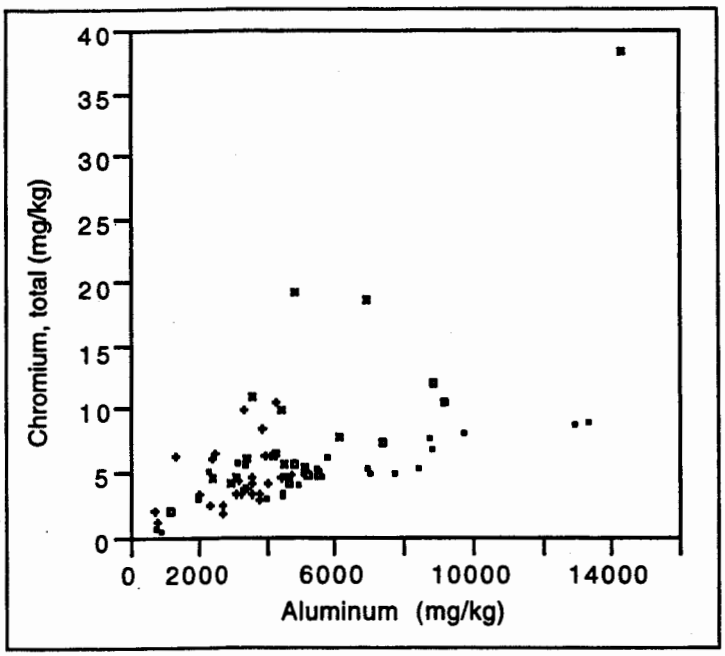

Figure E1-9b. Scatter plot for chromium versus aluminum.

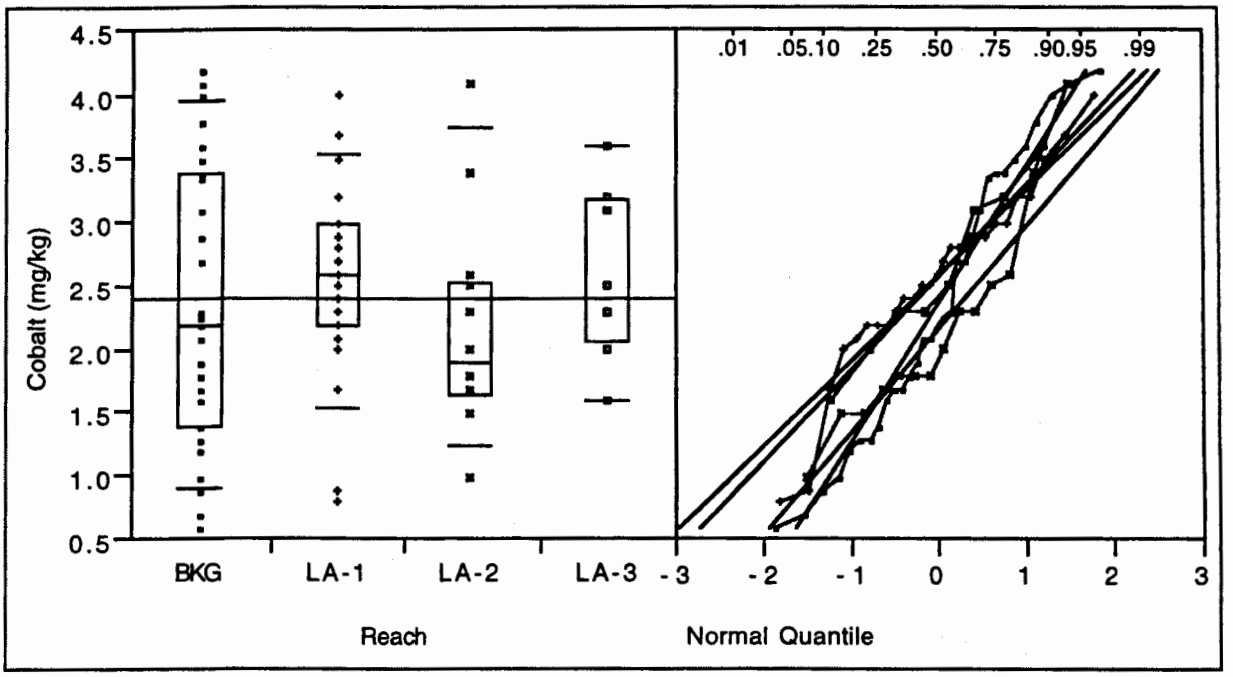

Figure E1-10a. Box plot for cobalt.

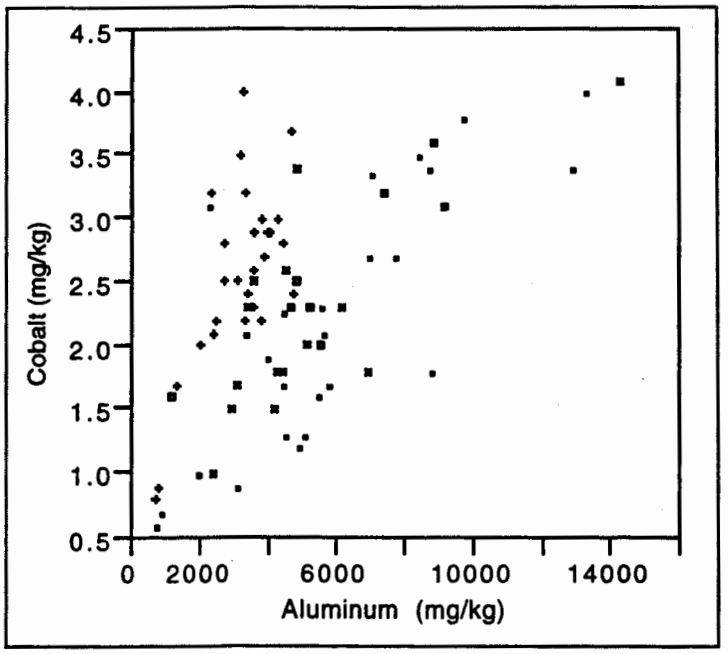

Figure E1-10b. Scatter plot for cobalt versus aluminum.

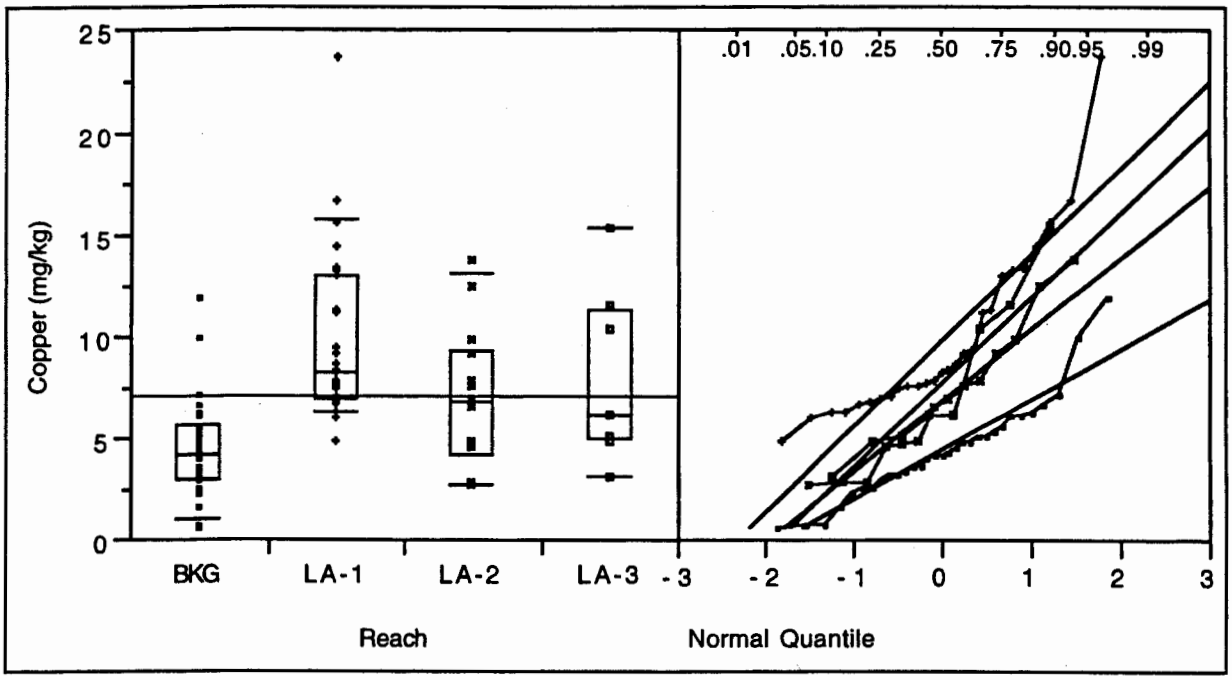

Figure E1-11a. Box plot for copper.

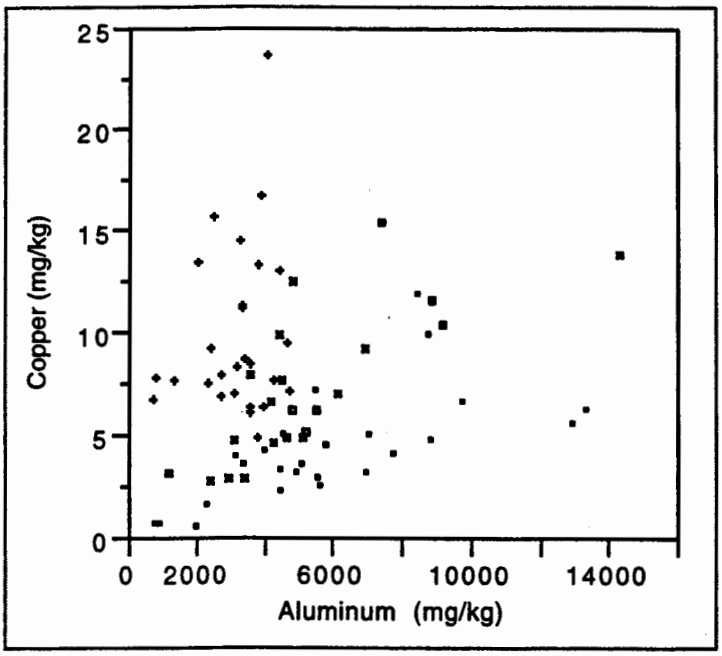

Figure E1-11b. Scatter plot for copper versus aluminum.

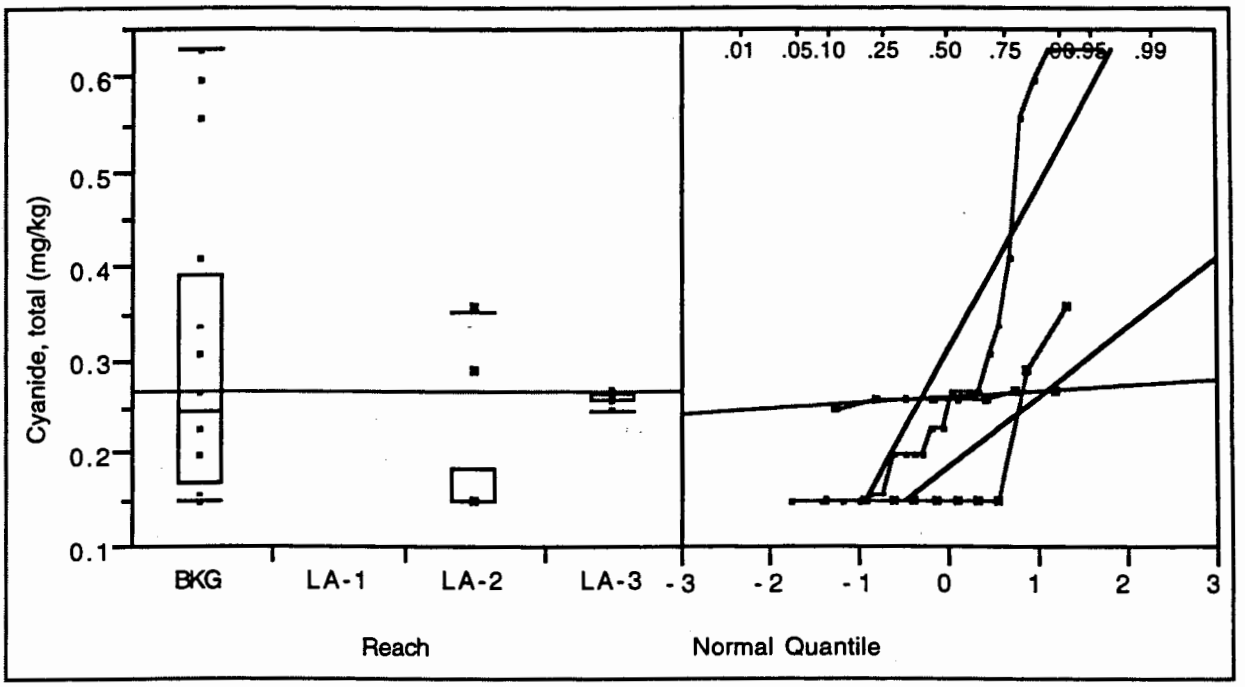

Figure E1-12a. Box plot for cyanide.

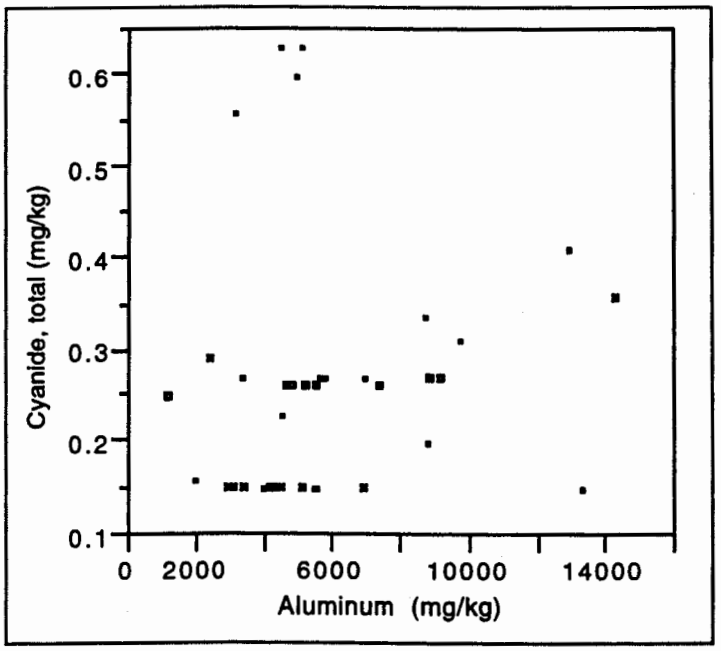

Figure E1-12b. Scatter plot for cyanide versus aluminum.

E-1.2.13 Iron

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-13a) confirms these results. The iron versus aluminum scatter plot (Figure E1-13b) suggests that one sample result in reach LA-2 could have elevated iron given the aluminum concentration measured in these samples. However, this high iron, low aluminum result is similar in composition to two background samples, which could suggest a sample that includes natural minerals, like magnetite, with high iron to aluminum ratios. Because the box plots and statistical testing suggest that iron concentrations are not different from background, iron is not retained as a COPC.

E-1.2.14 Lead

Results of the statistical testing (Table E1-1) suggest there are significant differences between all reach data (LA-1, LA-2, and LA-3) and background data. A review of the data plotted by reach (Figure E1-14a) and versus aluminum (Figure E1-14b) confirms these results. Lead is retained as a COPC because of sample results greater than the background value in reaches LA-1, LA-2, and LA-3.

E-1.2.15 Magnesium

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-15a) and versus aluminum (Figure E1-15b) confirms these results. Thus, magnesium is not retained as a COPC.

E-1.2.16 Manganese

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-16a) and versus aluminum (Figure E1-16b) confirms these results. Thus, manganese is not retained as a COPC.

E-1.2.17 Mercury

Mercury was not usually detected in the reach or background samples, thus statistical testing is not appropriate. The statistical plots show the range of detected and nondetected values by reach (Figure E1-17a) and the correlation of the nondetected values to aluminum (Figure E1-17b). Because some detected sample results and detection limits are greater than the mercury background value of 0.1 mg/kg, mercury is retained as a COPC.

E-1.2.18 Nickel

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-18a) and versus aluminum (Figure E1-18b) confirms these results. Thus, nickel is not retained as a COPC.

E-1.2.19 Potassium

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-19a) and versus aluminum (Figure E1-19b) confirms these results. Thus, potassium is not retained as a COPC.

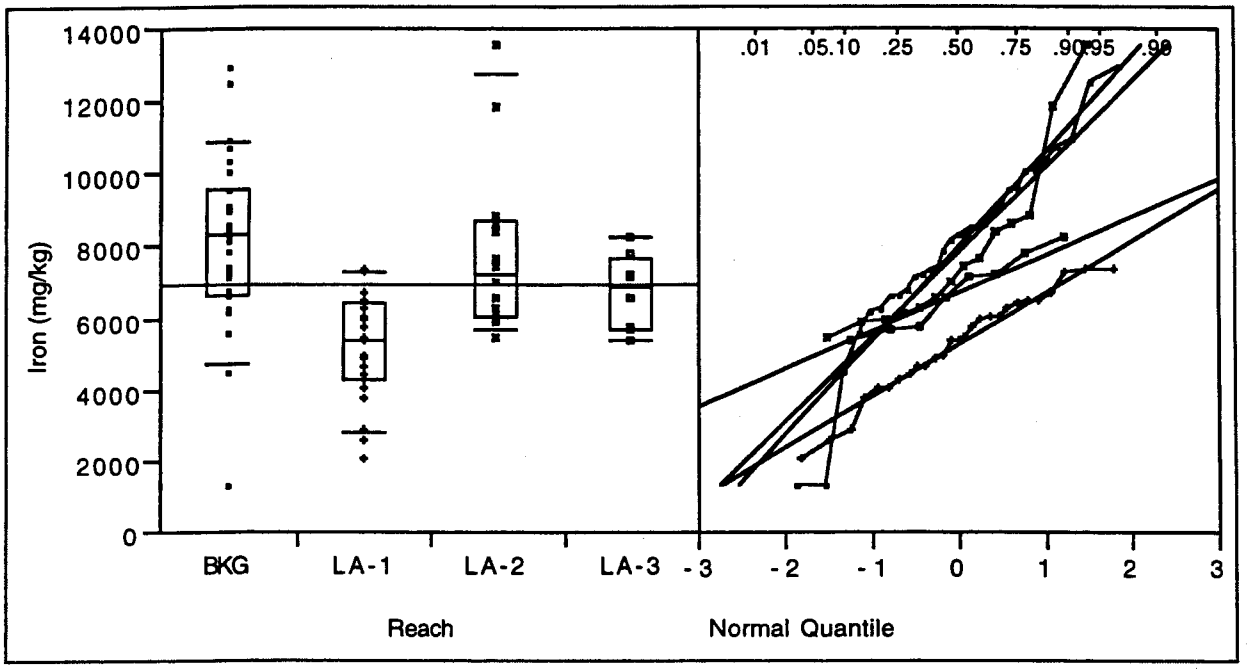

Figure E1-13a. Box plot for iron.

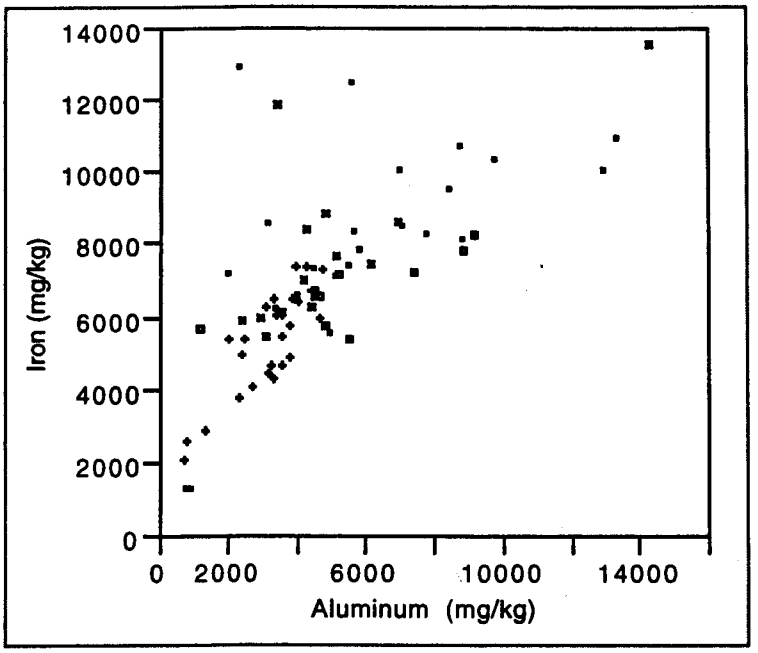

Figure E1-13b. Scatter plot for iron versus aluminum.

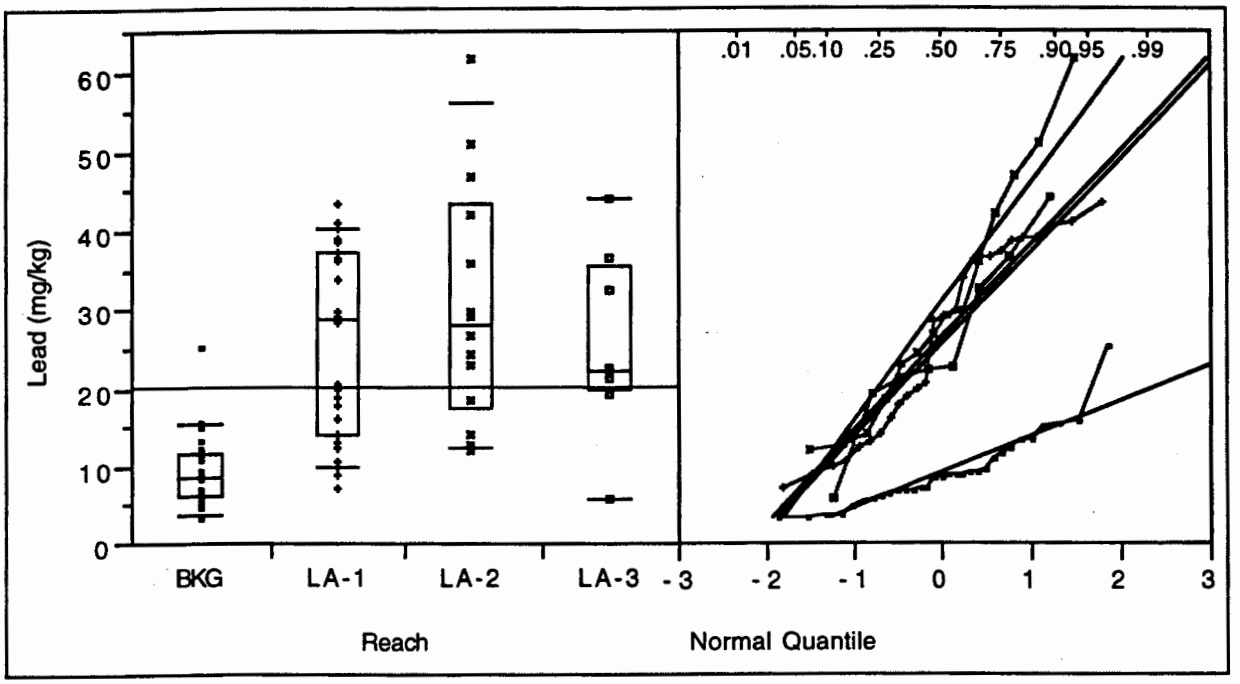

Figure E1-14a. Box plot for lead.

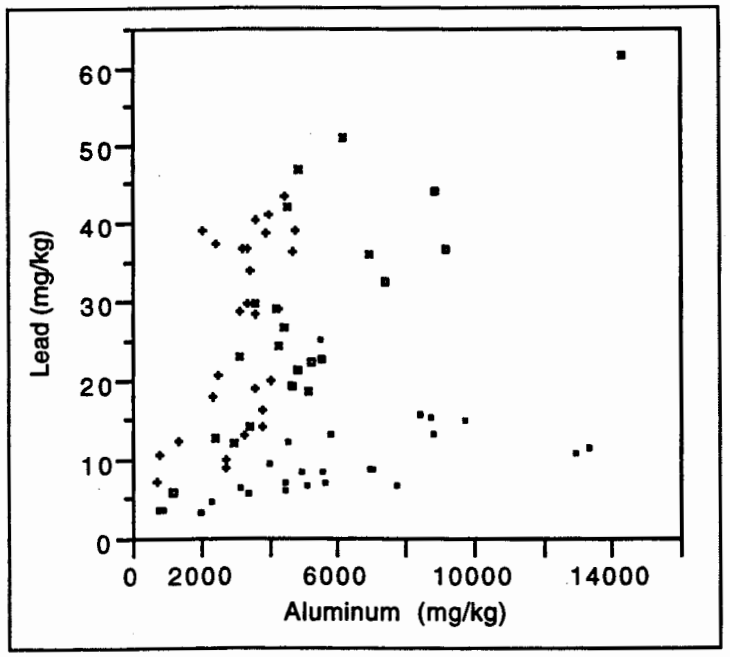

Figure E1-14b. Scatter plot for lead versus aluminum.

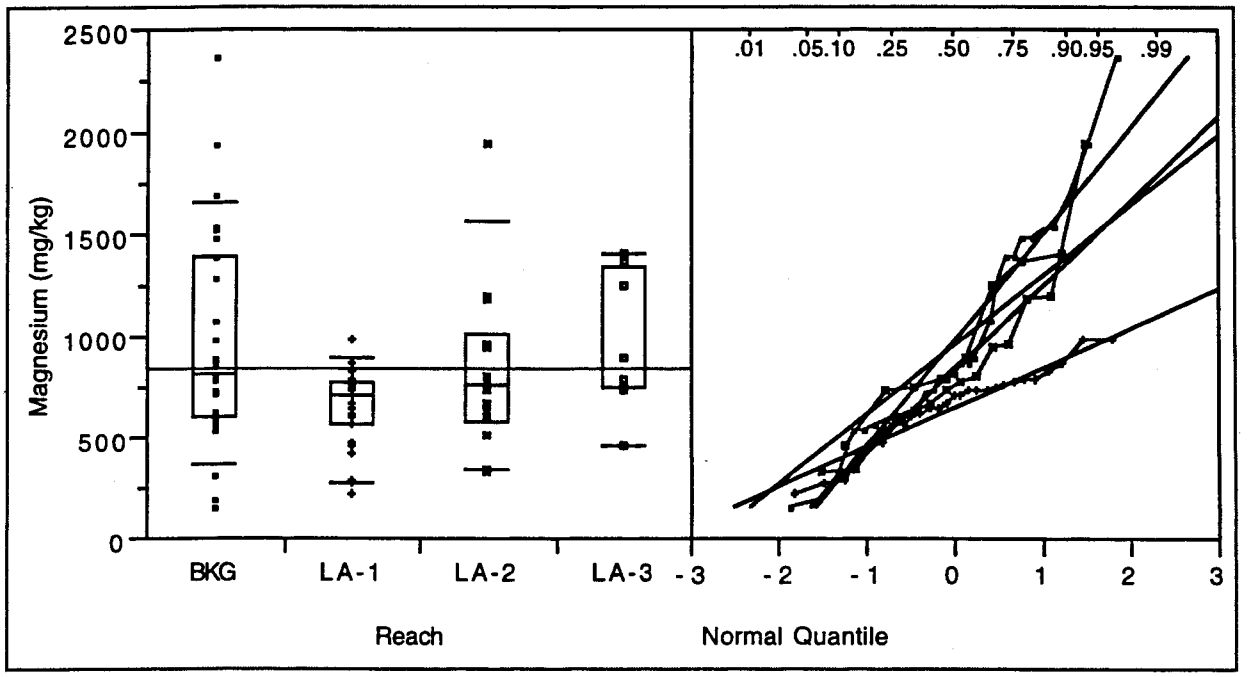

Figure E1-15a. Box plot for magnesium.

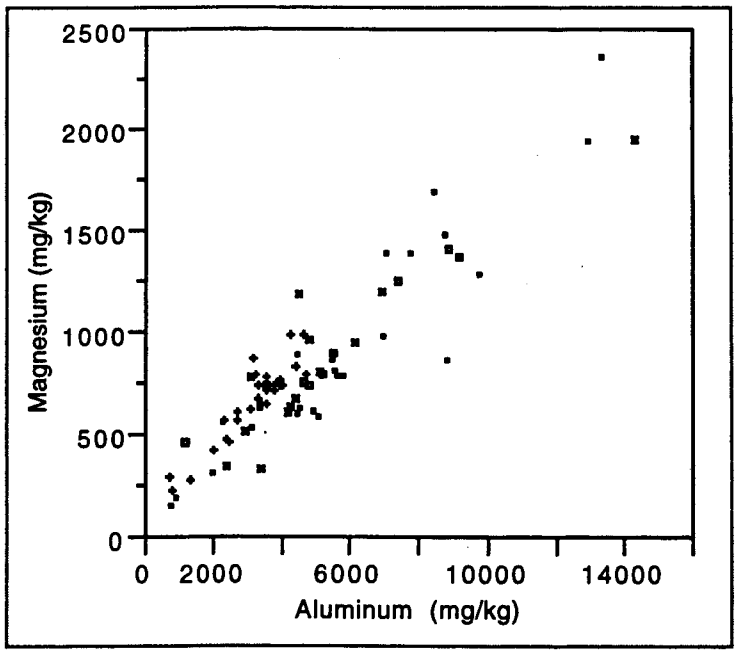

Figure E1-15b. Scatter plot for magnesium versus aluminum.

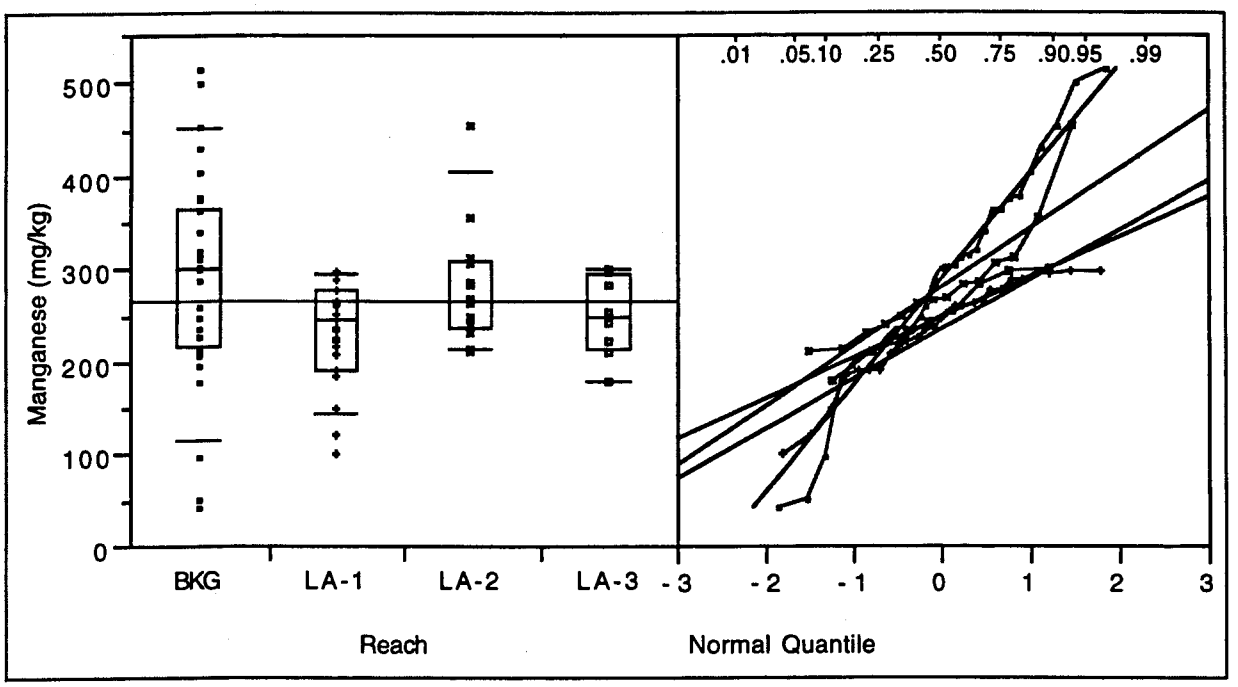

Figure E1-16a. Box plot for manganese.

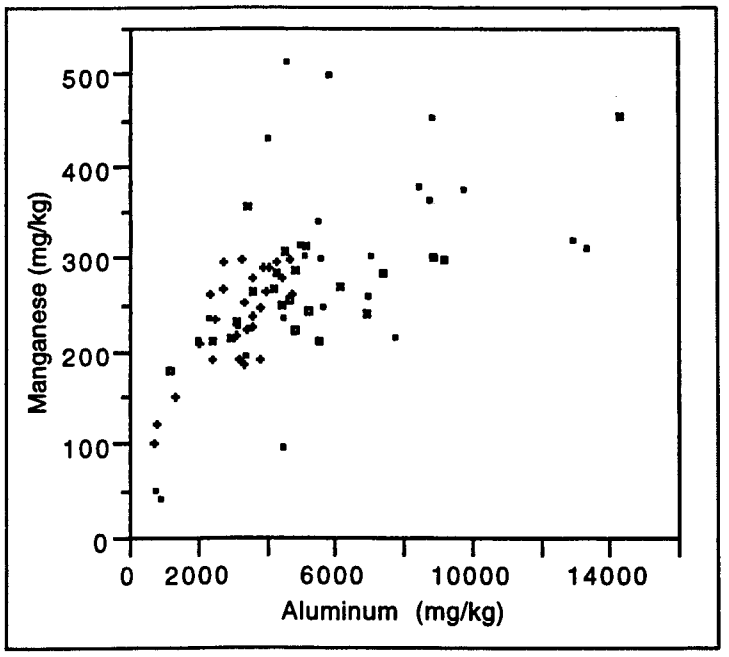

Figure E1-16b. Scatter plot for manganese versus aluminum.

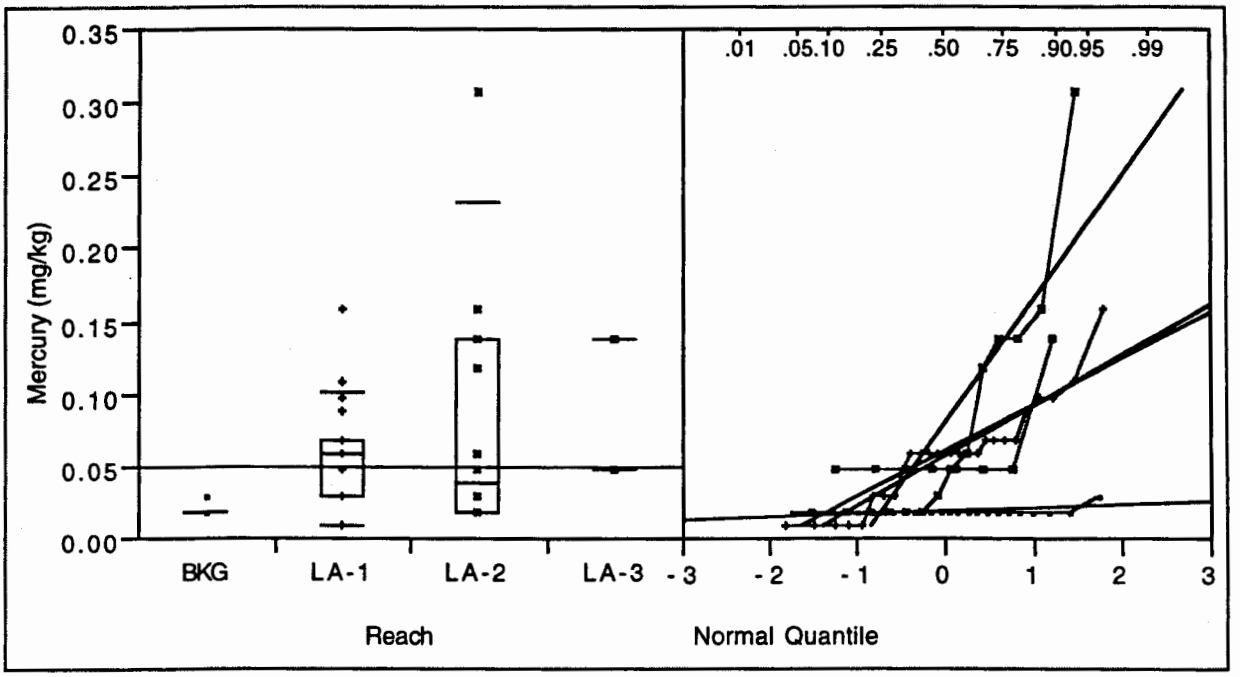

Figure E1-17a. Box plot for mercury.

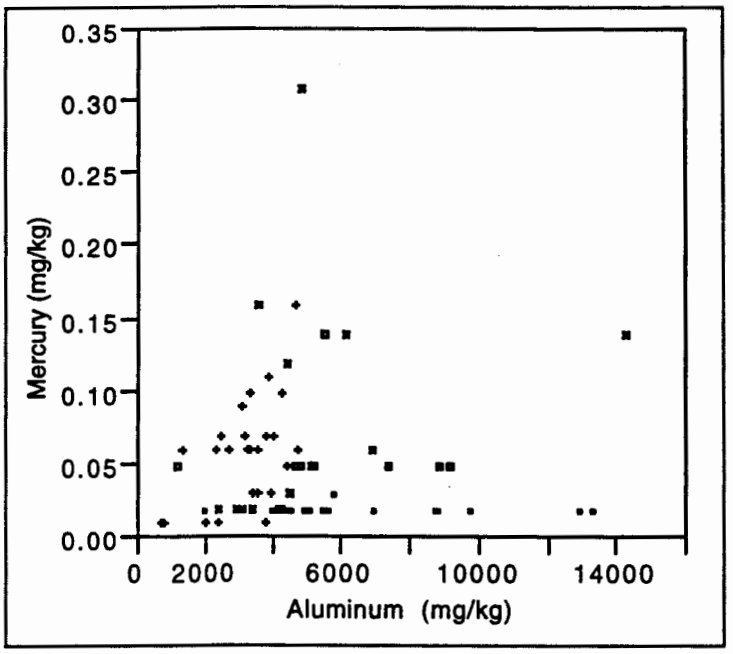

Figure E1-17b. Scatter plot for mercury versus aluminum.

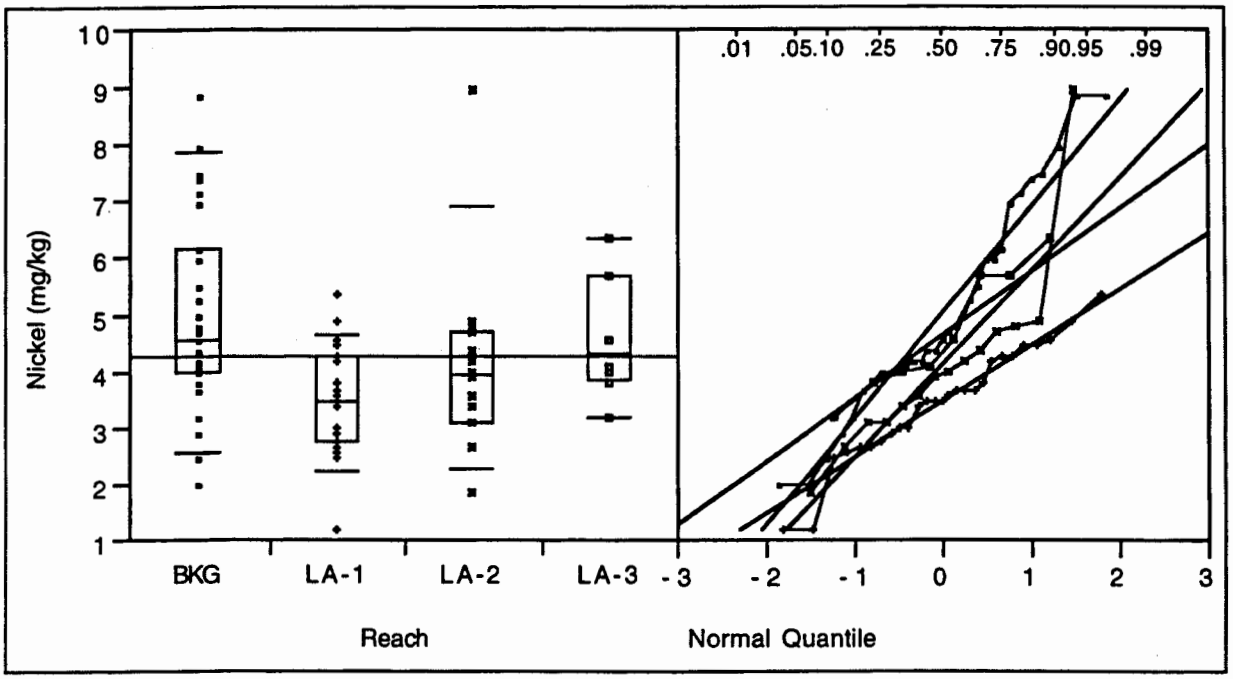

Figure E1-18a. Box plot for nickel.

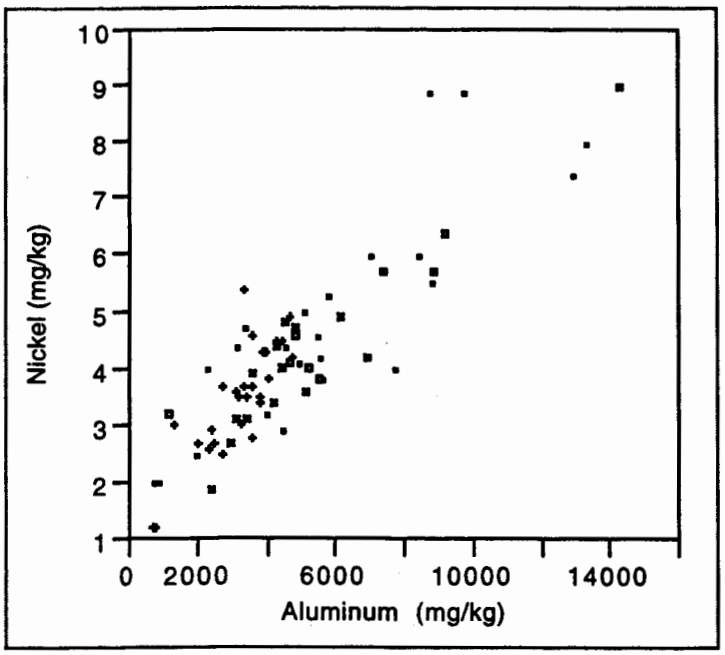

Figure E1-18b. Scatter plot for nickel versus aluminum.

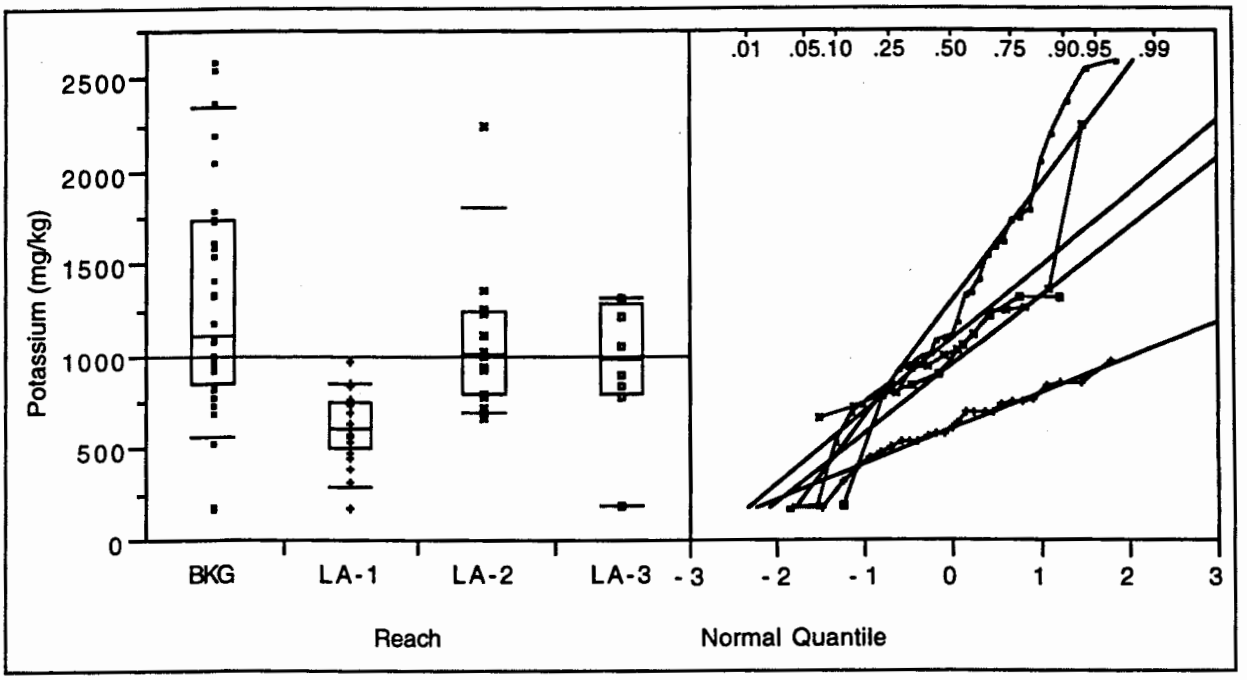

Figure E1-19a. Box plot for potassium.

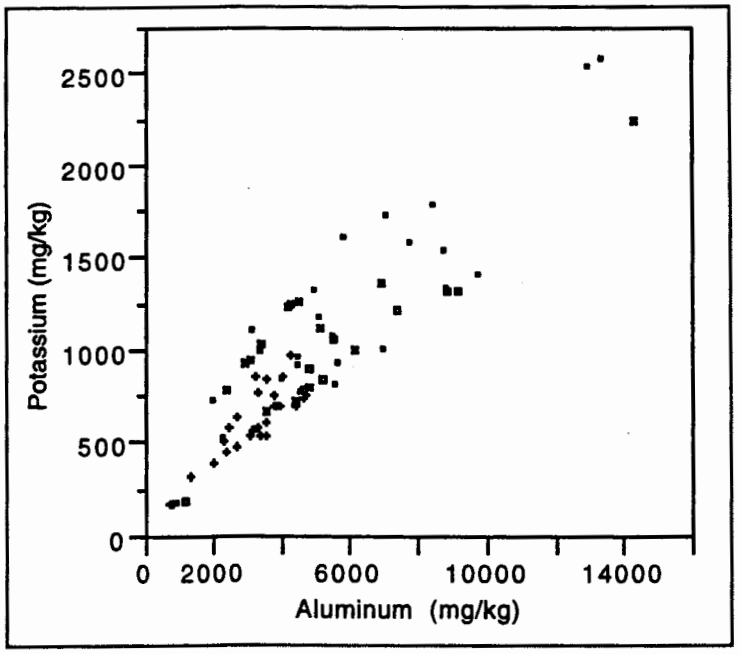

Figure E1-19b. Scatter plot for potassium versus aluminum.

E-1.2.20 Selenium

Selenium was not usually detected in the reach or background samples, thus statistical testing is not appropriate. The statistical plots show the range of detected and nondetected values by reach (Figure E1-20a) and the correlation of the nondetected values to aluminum (Figure E1-20b). It is important to recognize that most of the sample results that are apparently greater than the background value in reaches LA-1 and LA-2 are nondetected values. Because some detected sample results and detection limits are greater than the selenium background value of 0.3 mg/kg, selenium is retained as a COPC.

E-1.2.21 Silver

Silver was not usually detected in the reach or background samples, thus statistical testing is not appropriate. The statistical plots show the range of detected and nondetected values by reach (Figure E1-21a) and the correlation of the nondetected values to aluminum (Figure E1-21b). There is one sample result clearly greater than the background value for reach LA-2 (15.2 mg/kg in sample 04LA-97-0570). The remainder of the results are mostly nondetect values close to the silver background value of 1 mg/kg. Because some detected sample results and detection limits are greater than the silver background value of 1.0 mg/kg, silver is retained as a COPC.

E-1.2.22 Sodium

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-22a) and versus aluminum (Figure E1-22b) confirms these results. Thus, sodium is not retained as a COPC.

E-1.2.23 Thallium

Thallium was not detected in any reach sample, and all nondetected sample results were less than the thallium background value of 0.73 mg/kg (Figures E1-23a and E1-23b). Thus, thallium is not retained as a COPC.

E-1.2.24 Titanium

Titanium analytical results were obtained only from samples collected in reach LA-2. Results of the statistical testing (Table E1-1) suggest there are no differences between these reach data and sediment background data. A review of the data plotted by reach (Figure E1-24a) and versus aluminum (Figure E1-24b) confirms these results. Thus, titanium is not retained as a COPC.

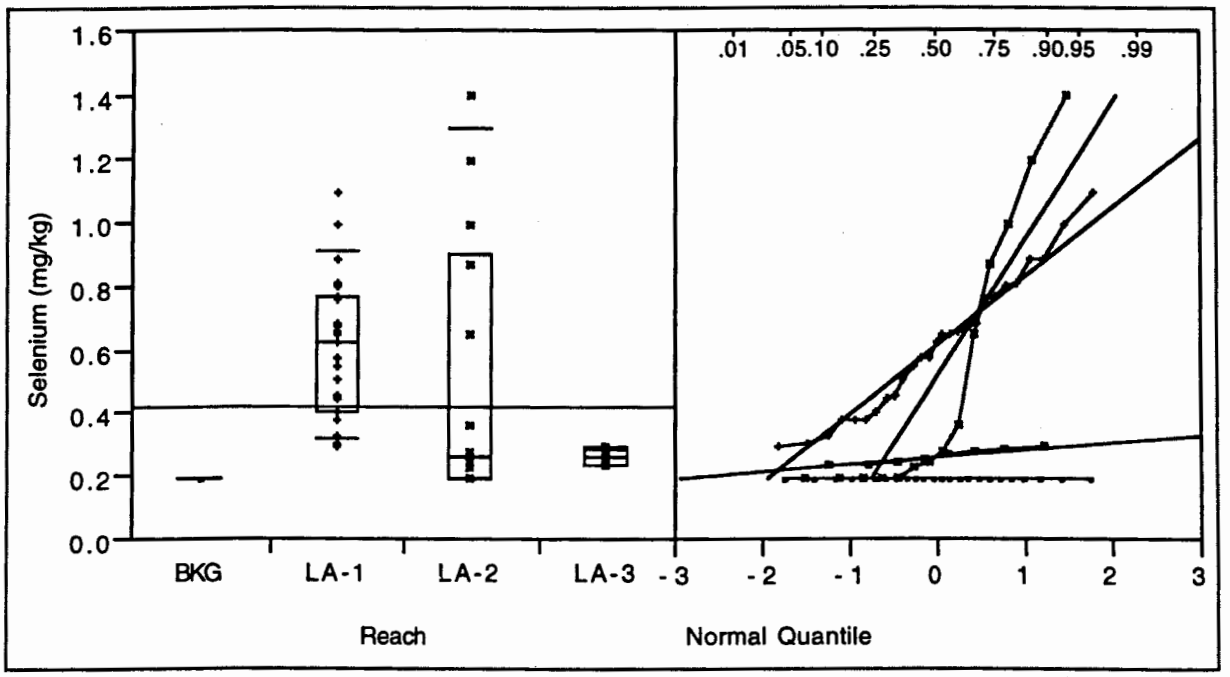

Figure E1-20a. Box plot for selenium.

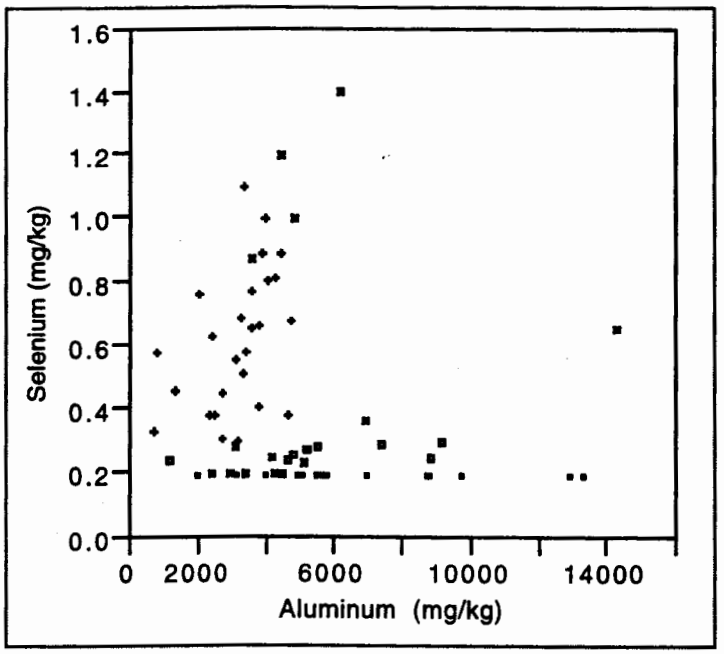

Figure E1-20b. Scatter plot for selenium versus aluminum.

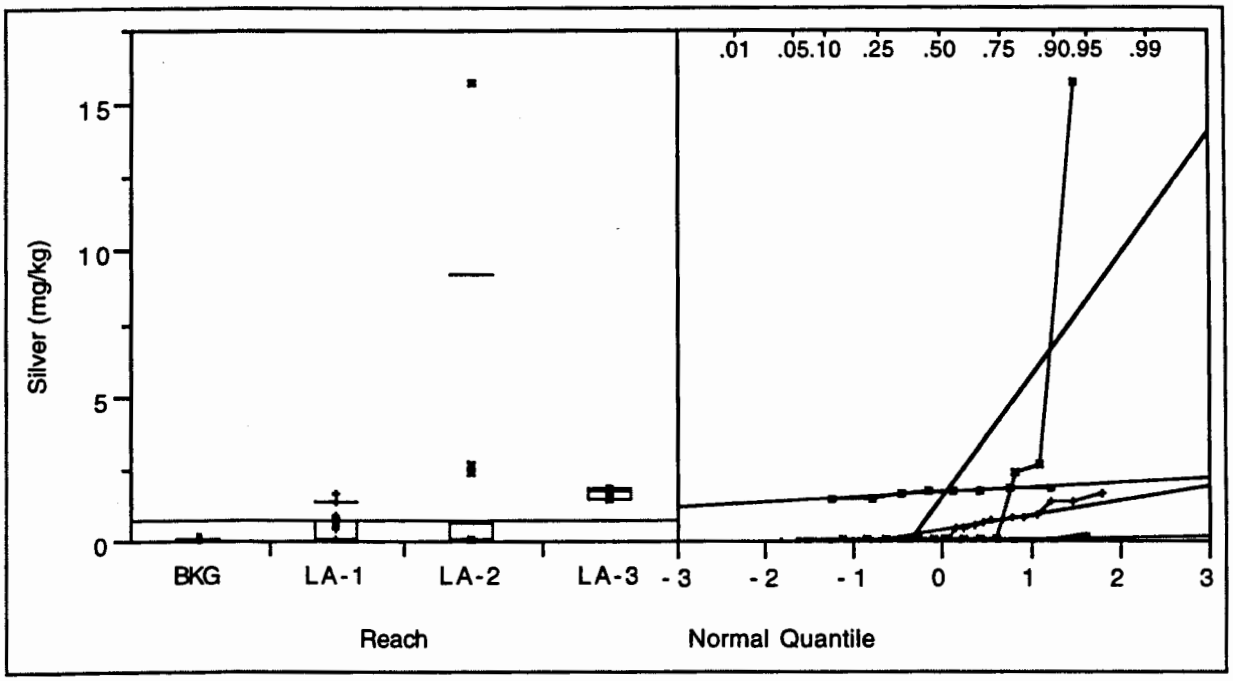

Figure E1-21a. Box plot for silver.

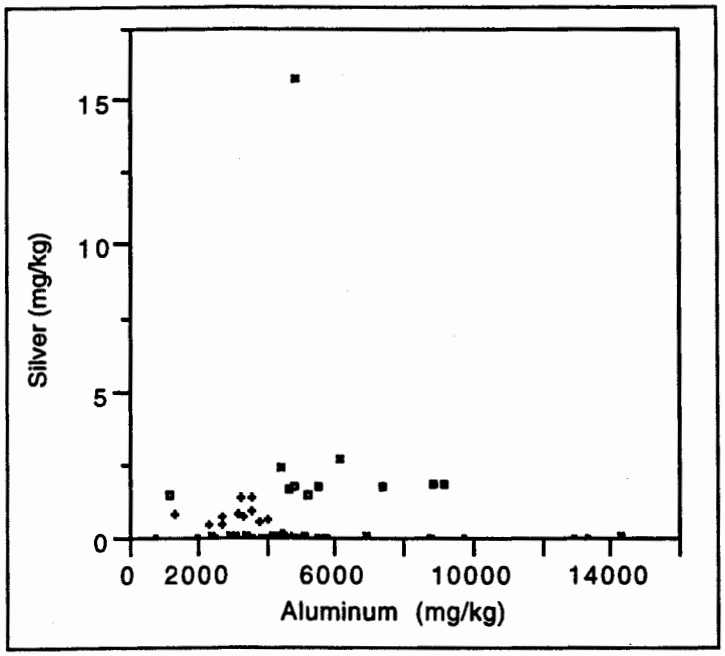

Figure E1-21b. Scatter plot for silver versus aluminum.

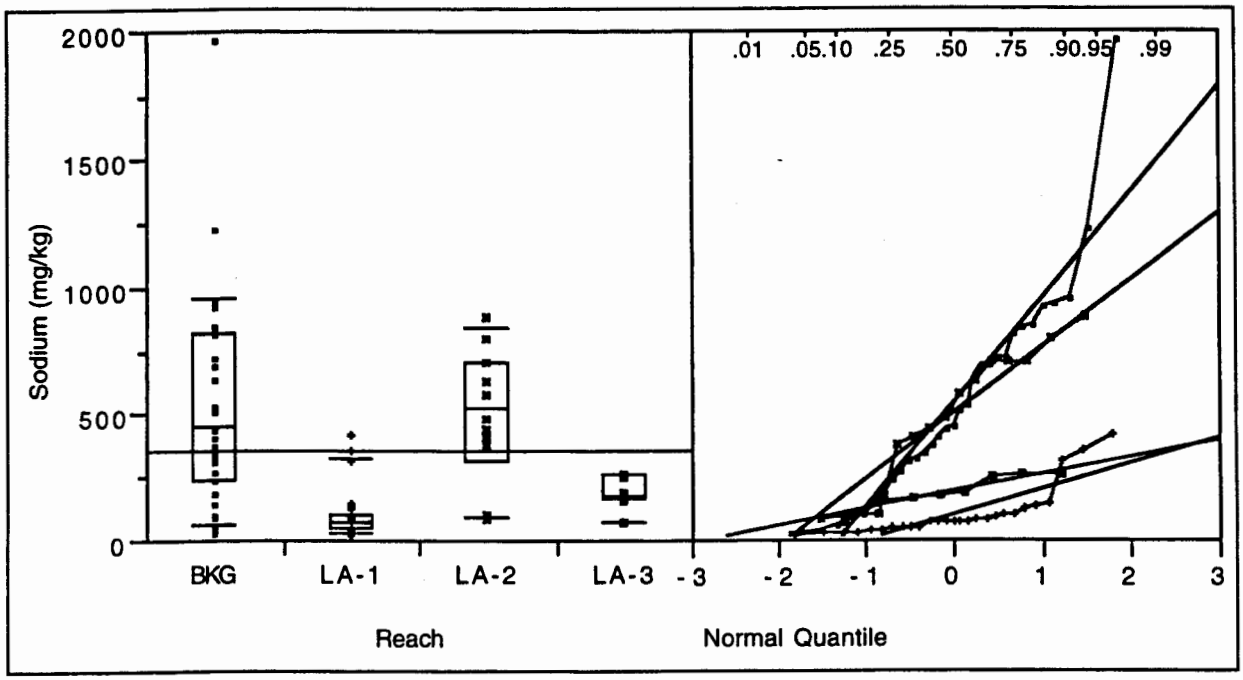

Figure E1-22a. Box plot for sodium.

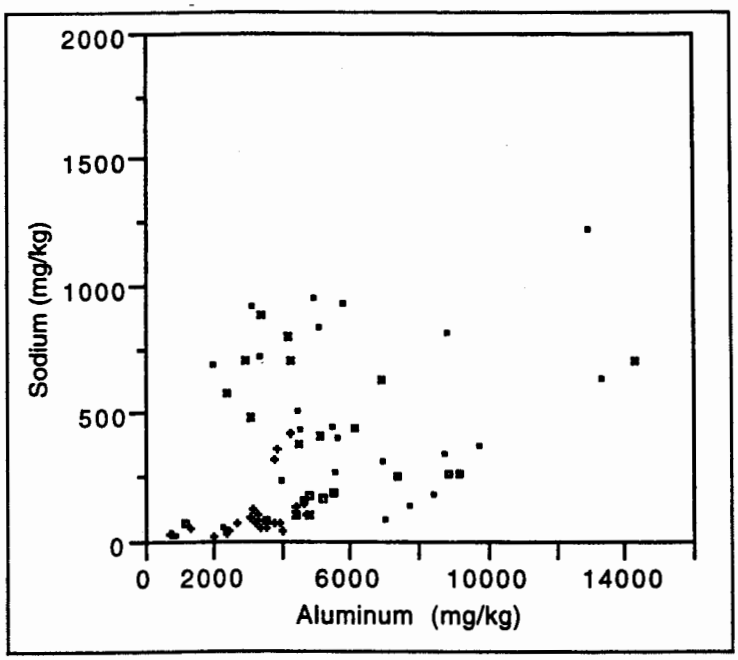

Figure E1-22b. Scatter plot for sodium versus aluminum.

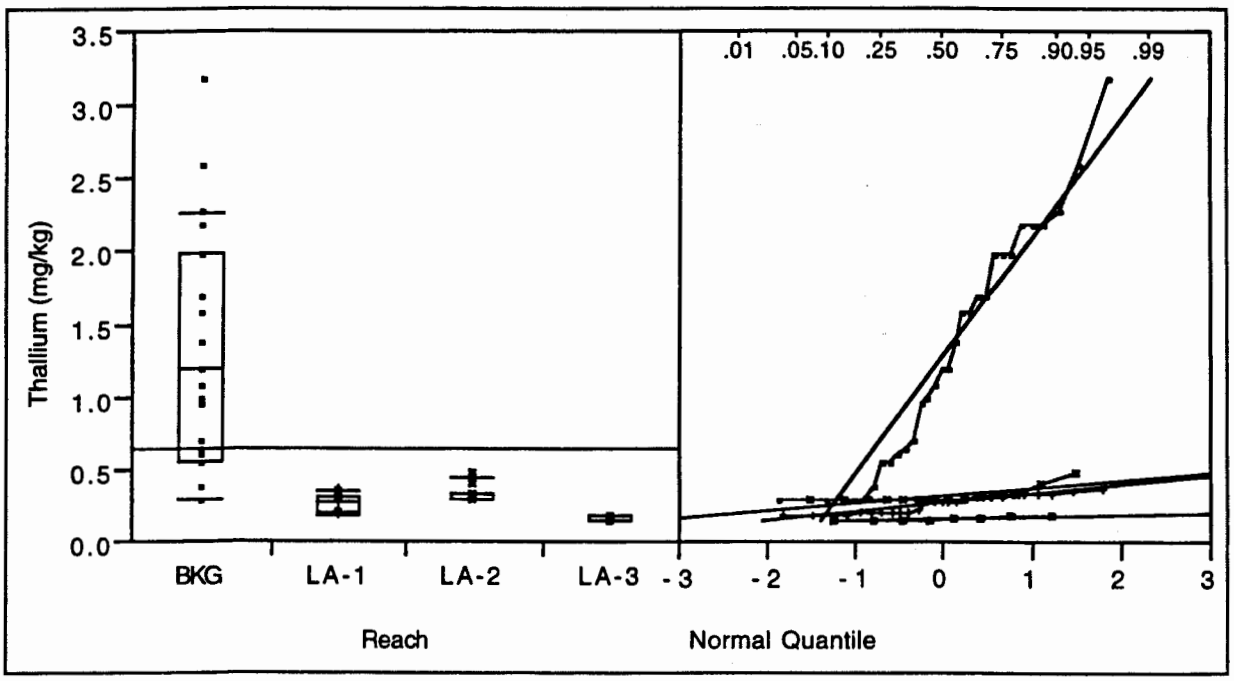

Figure E1-23a. Box plot for thallium.

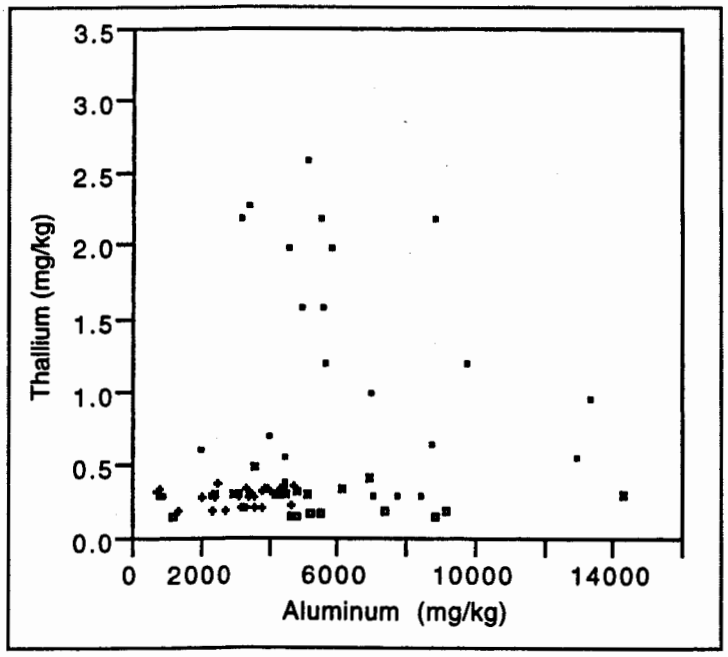

Figure E1-23b. Scatter plot for thallium versus aluminum.

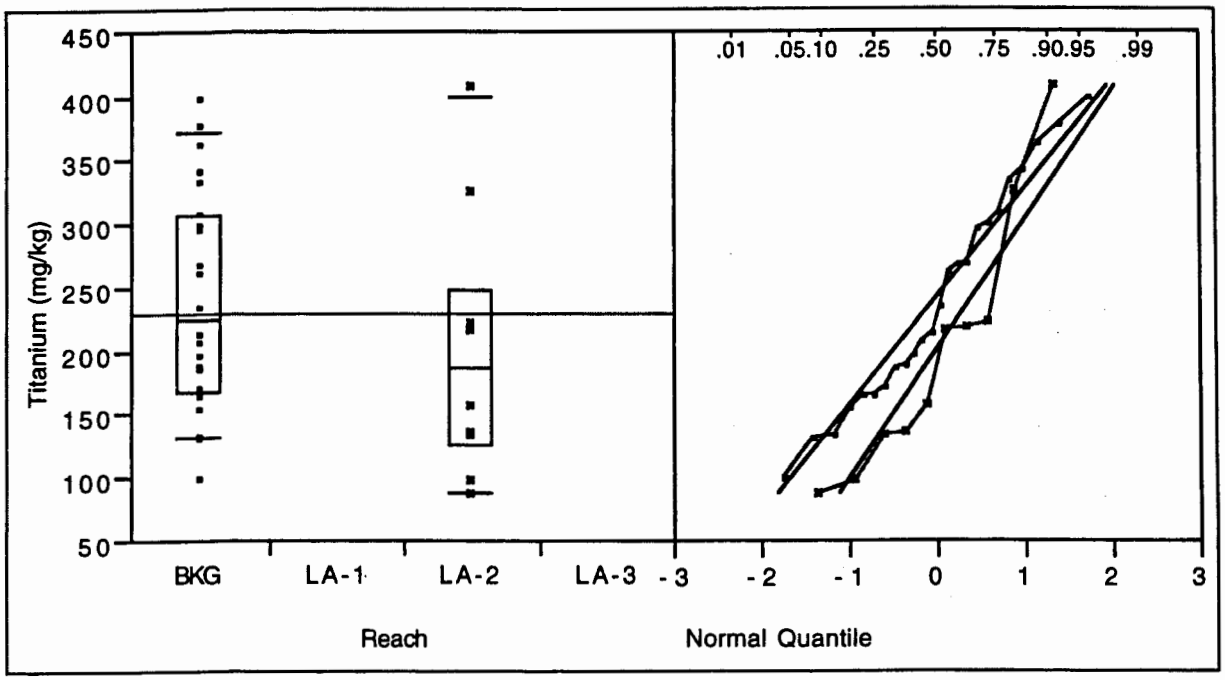

Figure E1-24a. Box plot for titanium.

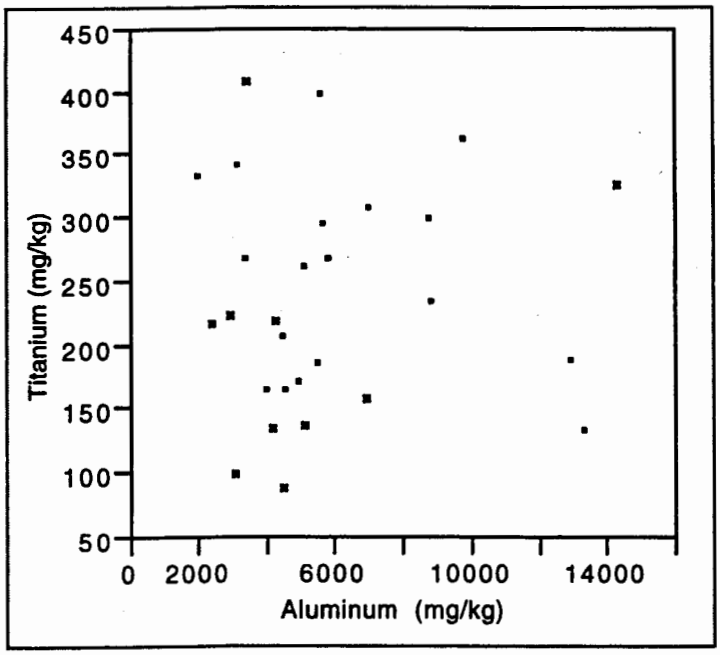

Figure E1-24b. Scatter plot for titanium versus aluminum.

E-1.2.25 Uranium

Uranium results were obtained by two analytical methods from samples collected in reach LA-1. One method produced an estimate of the "total uranium" in the sample, and the other produced an estimate of the "leachable uranium" (which will be referred to as "uranium"). Each type of uranium has a relevant sediment background data set for comparison. Statistical testing shows no difference between uranium results from the reaches and the background data set. A review of uranium data plotted by reach (Figure E1-25a) and versus aluminum (Figure E1-25b) confirms these results but does show some high uranium results for reach LA-2. Results of the statistical testing (Table E1-1) suggest that reach LA-2 total uranium results are greater than background values. Total uranium data plotted by reach (Figure E1-25c) and versus aluminum (Figure E1-25d) confirms these results. To further complicate the interpretation of the total uranium data for upper Los Alamos Canyon, it is noted that isotopic uranium analyses were obtained from samples in all three reaches. By using the specific activity of the isotopes (units of pCi/g), these isotopic measurements can be converted into a mass of total uranium. As discussed below (see Section E-2.2), these isotopic results confirm that reach LA-2 has concentrations of total uranium above background values. The isotopic uranium data also suggest that the maximum total uranium sample result for upper Los Alamos Canyon is from reach LA-2. The estimated total uranium concentrations from the maximum isotopic uranium results from each reach are 6.9 mg/kg in reach LA-1, 7.6 mg/kg in reach LA-2, and 5.5 mg/kg in reach LA-3. Thus, total uranium is identified as a COPC, and the measured total uranium results will be used in the site assessments.

E-1.2.26 Vanadium

Results of the statistical testing (Table E1-1) suggest there are no differences between the reach data and sediment background data. A review of the data plotted by reach (Figure E1-26a) and versus aluminum (Figure E1-26b) confirms these results. Thus, vanadium is not retained as a COPC.

E-1.2.27 Zinc

Results of the statistical testing (Table E1-1) suggest there are significant differences between some reach data (LA-2 and LA-3) and background data. A review of the data plotted by reach (Figure E1-27a) and versus aluminum (Figure E1-27b) confirms these results and also shows that some samples in reach LA-2 may have elevated zinc concentrations given the amount of aluminum present. Zinc is retained as a COPC because of sample results that are greater than the background value in reaches LA-2 and LA-3.

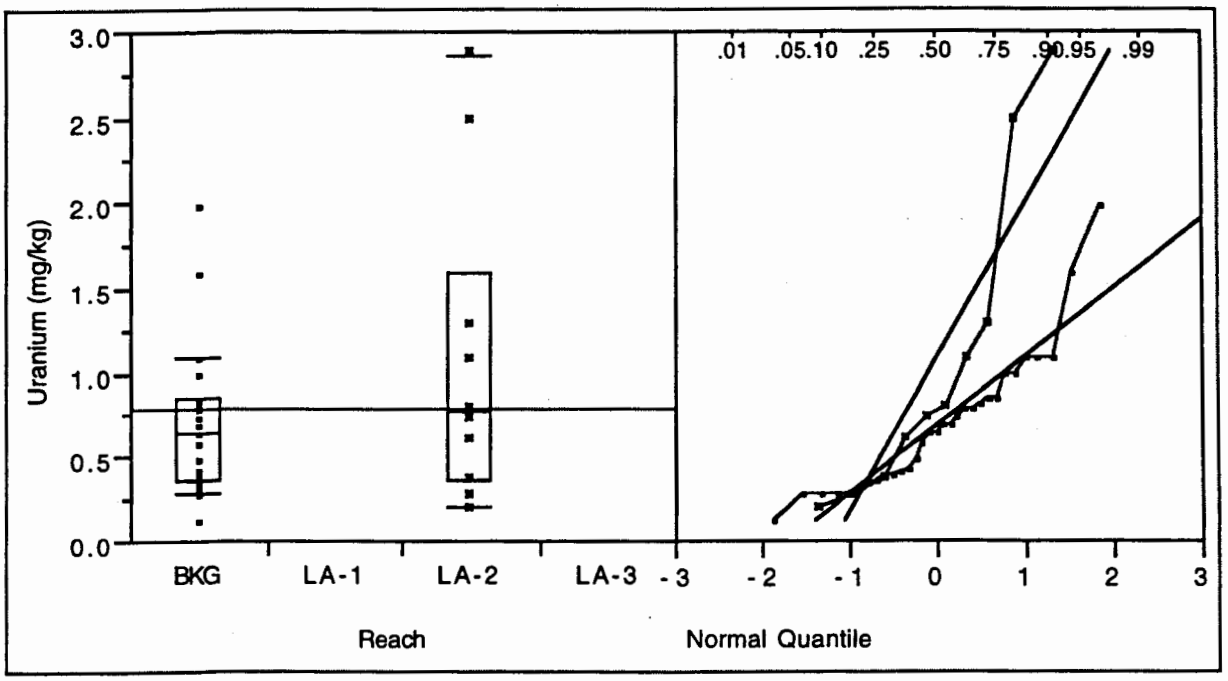

Figure E1-25a. Box plot for uranium.

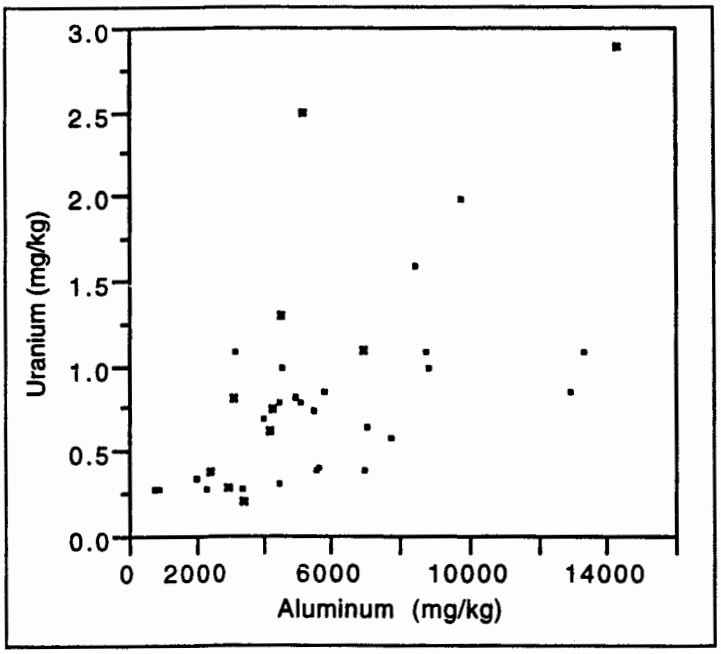

Figure E1-25b. Scatter plot for uranium versus aluminum.

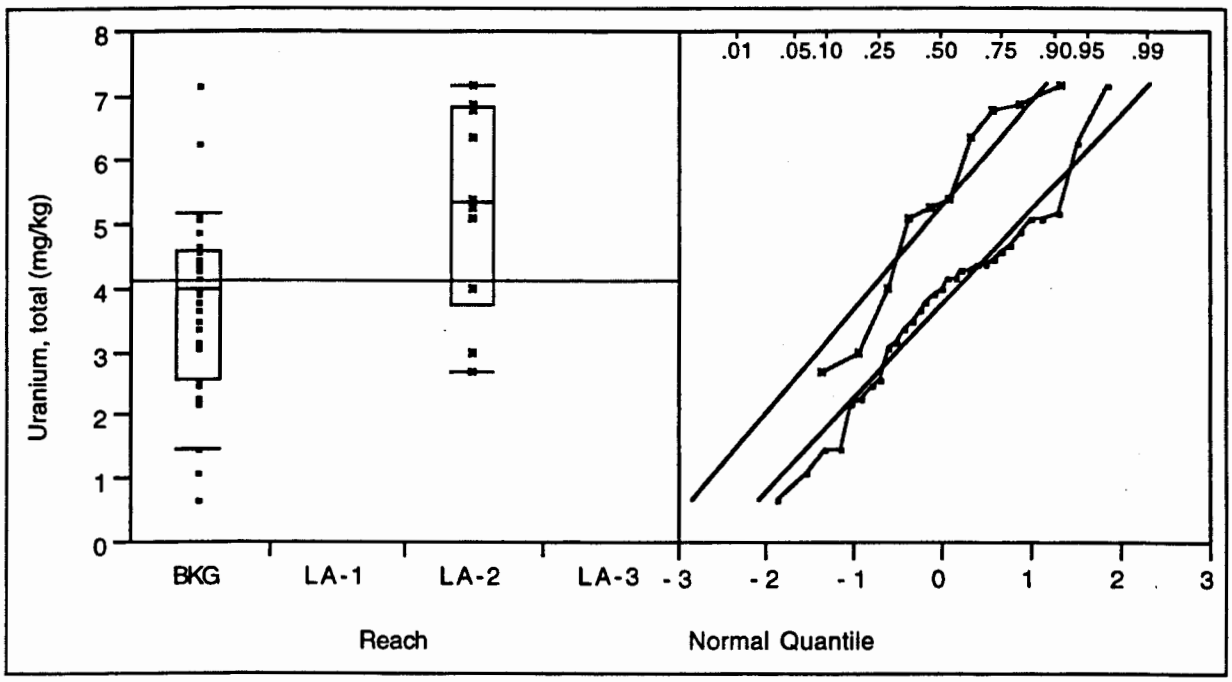

Figure E1-25c. Box plot for total uranium.

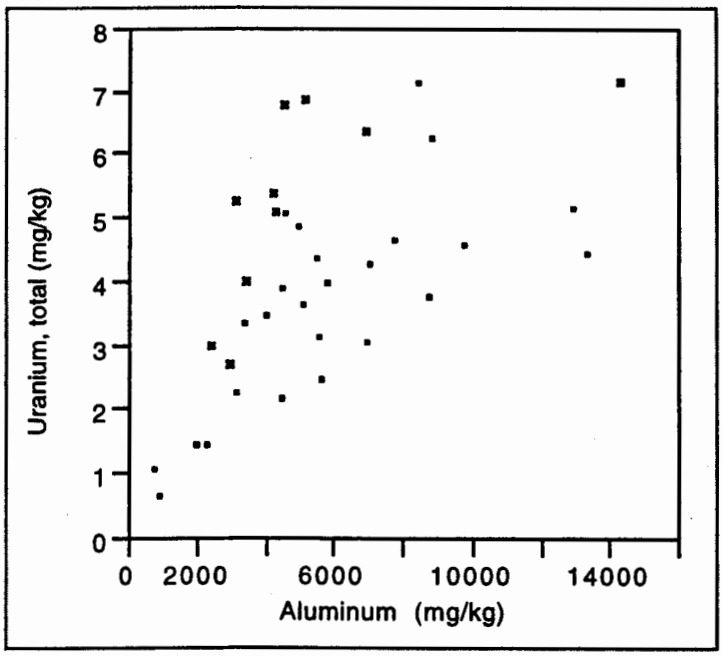

Figure E1-25d. Scatter plot for total uranium versus aluminum.

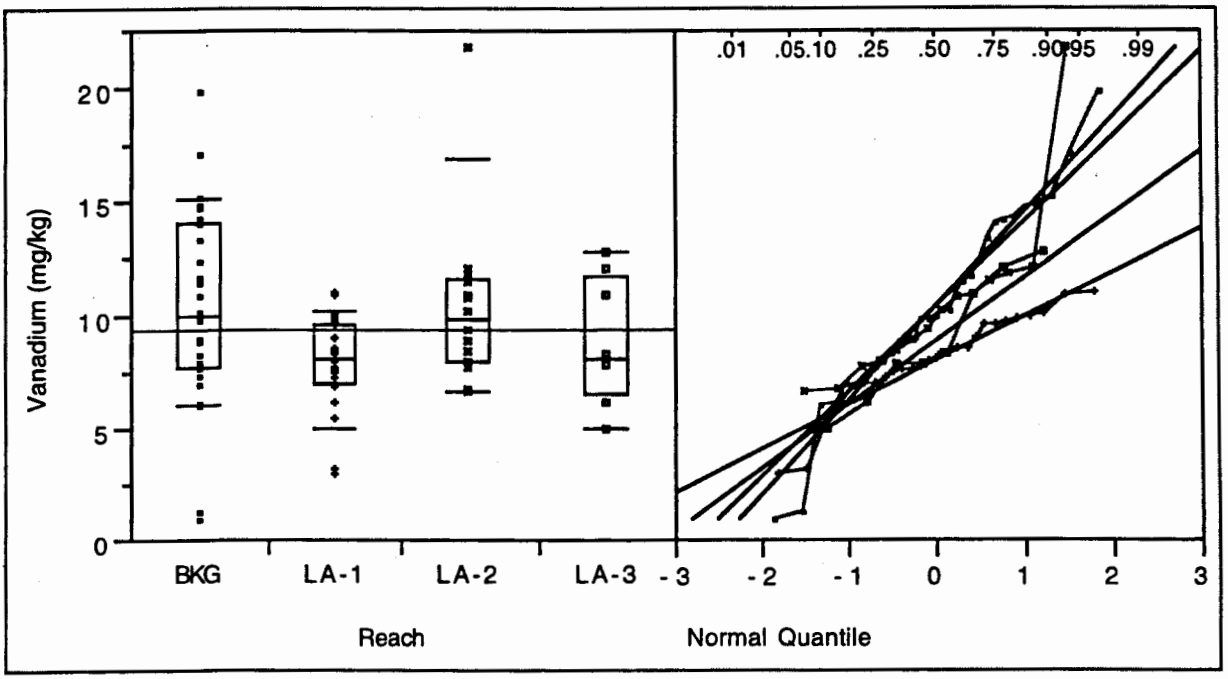

Figure E1-26a. Box plot for vanadium.

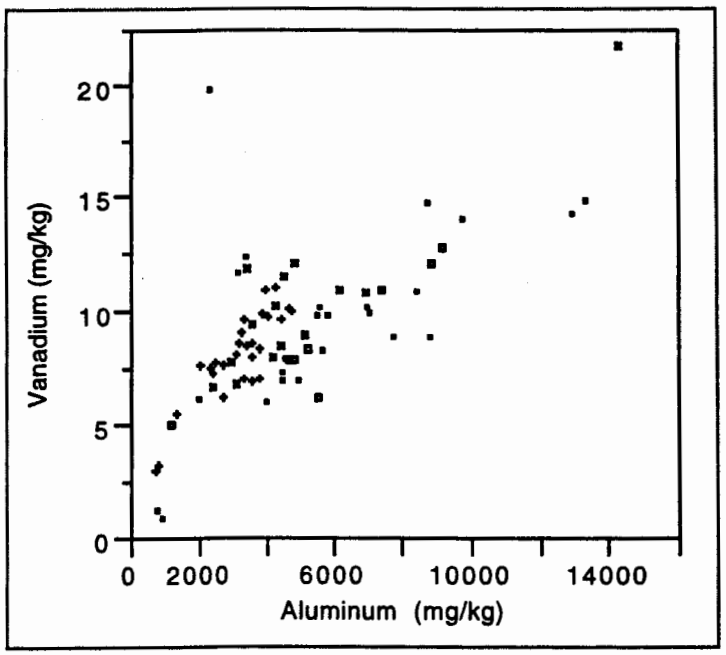

Figure E1-26b. Scatter plot for vanadium versus aluminum.

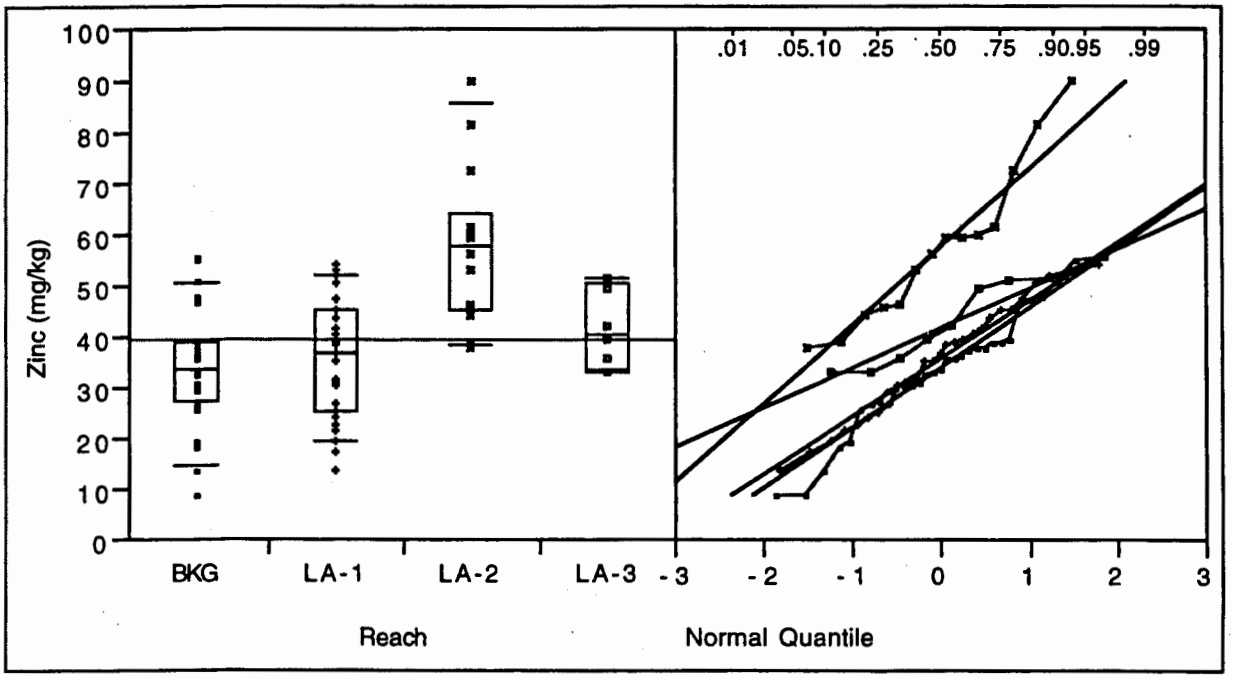

Figure E1-27a. Box plot for zinc.

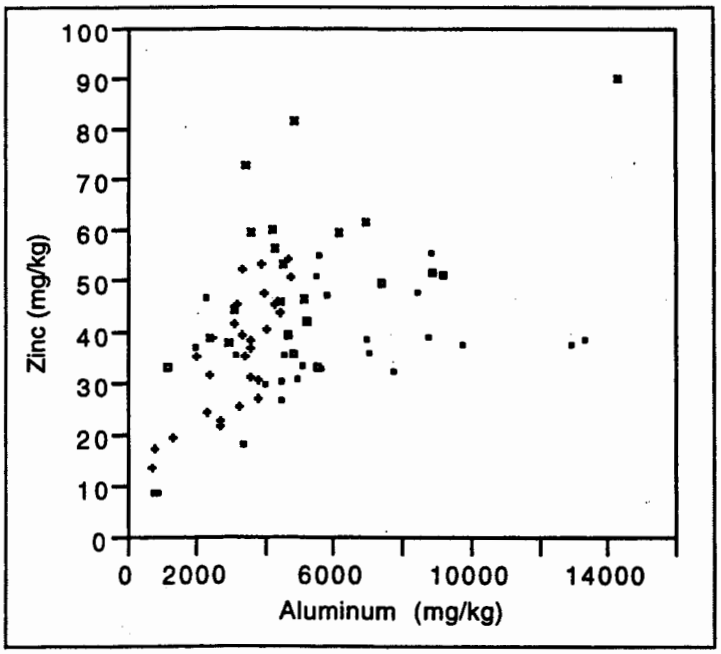

Figure E1-27b. Scatter plot for zinc versus aluminum.

E-2.0 STATISTICAL EVALUATIONS OF RADIONUCLIDE DATA

The objective of this section is to present graphical analyses that compare radionuclide data from upper Los Alamos Canyon sediment samples with Laboratory background sediment data. These analyses are used to determine whether the reach data show evidence of contaminant releases through a systematic increase in concentration of one or more analytes over concentrations observed in the background data. Formal statistical analyses were also used to help determine which radionuclides should be retained as COPCs.

E-2.1 Methods

Two types of graphical analyses and statistical distribution shift tests were used to evaluate the concentrations of radionuclides in sediment samples collected from the upper Los Alamos Canyon reaches; the samples were compared with concentrations in background sediment samples. Each method is briefly discussed below.

E-2.1.1 Comparisons of Radionuclide Data by Reach

This comparison uses graphical displays called "box plots," which show the actual values for each radionuclide. The ends of each box represent the "interquartile" range of the data distribution, which is specified by the 25th percentile and 75th percentile of the data distribution. The horizontal line within each box is the median (50th percentile) of the data distribution. The horizontal line below each box represents the 10th percentile, and the horizontal line above each box represents the 90th percentile. Thus, each box indicates concentration values for the central half of the data, and concentration shifts can be readily assessed by comparing the boxes. If most of the data are represented by a single concentration value (usually the detection limit), the box is reduced to a single line. The horizontal line drawn across all the data groups represents the overall mean of all data (both reach and background data).

To the right of each box plot is another statistical graphic of the same data. This plot is known as a "normal quantile" plot that facilitates the interpretation of the statistical distribution of the data. For example, if the data originate from a normal statistical distribution, then the data (plotted as one of four symbols) will fall on a line. The normal quantile plot presents two types of information for each data group. A line is presented for each data group that is calculated based on the observed mean and standard deviation of the data. Also the actual sample results are plotted on the normal quantile scale, and line segments connect each result.

In these statistical plots a different symbol is used for the laboratory results for each reach and for the BKG, and the symbols are used consistently in all statistical plots in this section. Background data are represented by a filled square, reach LA-1 data by a plus symbol, reach LA-2 data by an "x," and reach LA-3 data by a hollow square.

E-2.1.2 Statistical Testing

Because the data for these radionuclides do not appear to typically satisfy statistical assumptions of normality, nonparametric statistical tests are preferred for background comparisons. The Gehan or the Wilcoxon Rank Sum (WRS) tests were used for statistical testing. The purpose of these tests is to detect whether the reach data show evidence of contaminant releases through a systematic increase in concentration over that observed in the background sediment data. The Gehan and WRS tests pool reach and background data into one aggregate set and determine whether the average rank of reach

data is greater than that of the background data. The Gehan test WRS tests are most sensitive to detecting cases where most of the reach data are greater than the average or median value observed in the background data. The Gehan test differs from the WRS test by using a statistically robust method to rank nondetected sample results. Where there are no nondetected sample results, the Gehan test provides the same result as the WRS test. Additional discussions of these tests are presented in Ryti et al. (1996, 53953).

The metrics used to determine if a statistically significant difference between reach data and site data exists are the calculated significance levels (p-values) for the tests. A low p-value (near zero) indicates that reach data are greater than background data, whereas a p-value of 1 indicates no difference between reach data and background data. If a p-value is less than some small probability (0.05), then there is some reason to suspect that site distribution may be elevated above the background distribution; otherwise, no difference is indicated.

E-2.2 Results

E-2.2.1 Americium-241

Americium-241 was determined through two analytical methods: alpha spectroscopy and gamma spectroscopy. Alpha spectroscopy has lower detection limits and higher precision than gamma spectroscopy. Fewer samples were analyzed by alpha spectroscopy because the concentrations of americium-241 provided by the full-suite analyses indicated that the lower detection limit was not required. Americium-241 by alpha spectroscopy can be statistically compared with background data by the same method. Results of the statistical testing (Table E2-1) suggest there are significant differences between the alpha spectroscopy results and background data, and sample results from both methods showed detected values above background in all reaches (Figure E2-1a and E2-1b). Thus, americium-241 is retained as a COPC.

E-2.2.2 Cesium-134

Cesium-134 was detected in a single sample collected in reach LA-2. Because cesium-134 was not detected in the background samples, statistical testing is inappropriate. Figure E2-2 shows that the magnitude of the cesium-134 results in reach LA-2 are greater than in LA-1 or LA-3. This difference could be due to the greater gamma activity from cesium-137 in samples collected from reach LA-2. The radionuclide evaluation method is to retain detected radionuclides as COPCs if there are no background data available for comparison. Thus, cesium-134 is retained as a COPC.

E-2.2.3 Cesium-137

Results of the statistical testing (Table E2-1) indicate there are significant differences between some reach data for cesium-137 (LA-2 and LA-3) and background data. A review of the data plotted by reach (Figure E2-3) confirms these results. Thus, cesium-137 is retained as a COPC.

TABLE E2-1

SUMMARY OF P-VALUES FROM WRS STATISTICAL TESTS

Analyte	Reach LA-1	Reach LA-2	Reach LA-3
Americium-241 (alpha spectroscopy)	**<0.001**[a]	**<0.001**	**<0.001**
Americium-241 (gamma spectroscopy)	no background detects	no background detects	no background detects
Cesium-134	no background detects	no background detects	no background detects
Cesium-137	**0.002**	**<0.001**	**<0.001**
Cobalt-60	no background detects	no background detects	no background detects
Europium-152	no background detects	no background detects	no background detects
Plutonium-238	**<0.001**	**<0.001**	**<0.001**
Plutonium-239,240	**<0.001**	**<0.001**	**<0.001**
Strontium-90	0.952	**<0.001**	**0.002**
Thorium-228	N.A.[b]	**0.045**	**0.004**
Thorium-230	N.A.	**0.039**	**0.032**
Thorium-232	N.A.	0.058	**0.012**
Tritium	N.A.	**0.004**	0.884
Uranium-234	0.509	**0.032**	0.422
Uranium-235 (alpha spectroscopy)	0.998	**0.041**	0.664
Uranium-235 (gamma spectroscopy)	no background detects	no background detects	no background detects
Uranium-238	0.389	**0.039**	0.578

a. Bolded values indicate that reach sample results are significantly greater than background

b. N.A. = not available (no data for this analyte in this reach)

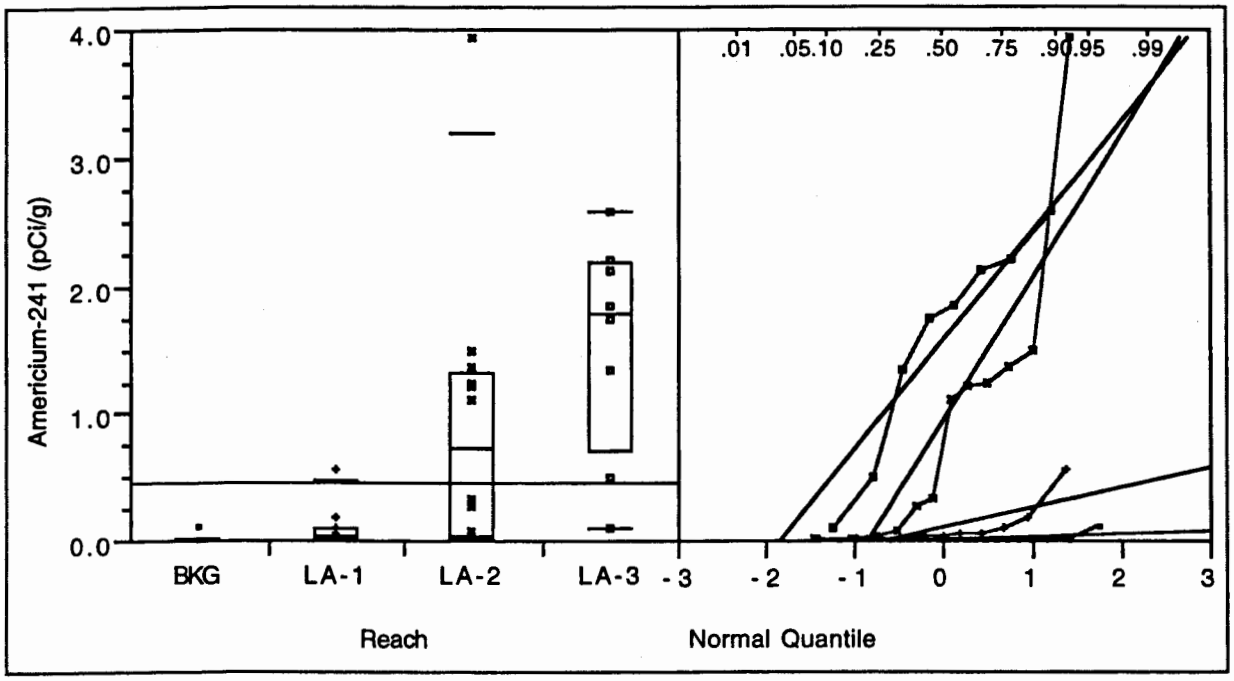

Figure E2-1a. Box plot for americium-241 by alpha spectroscopy.

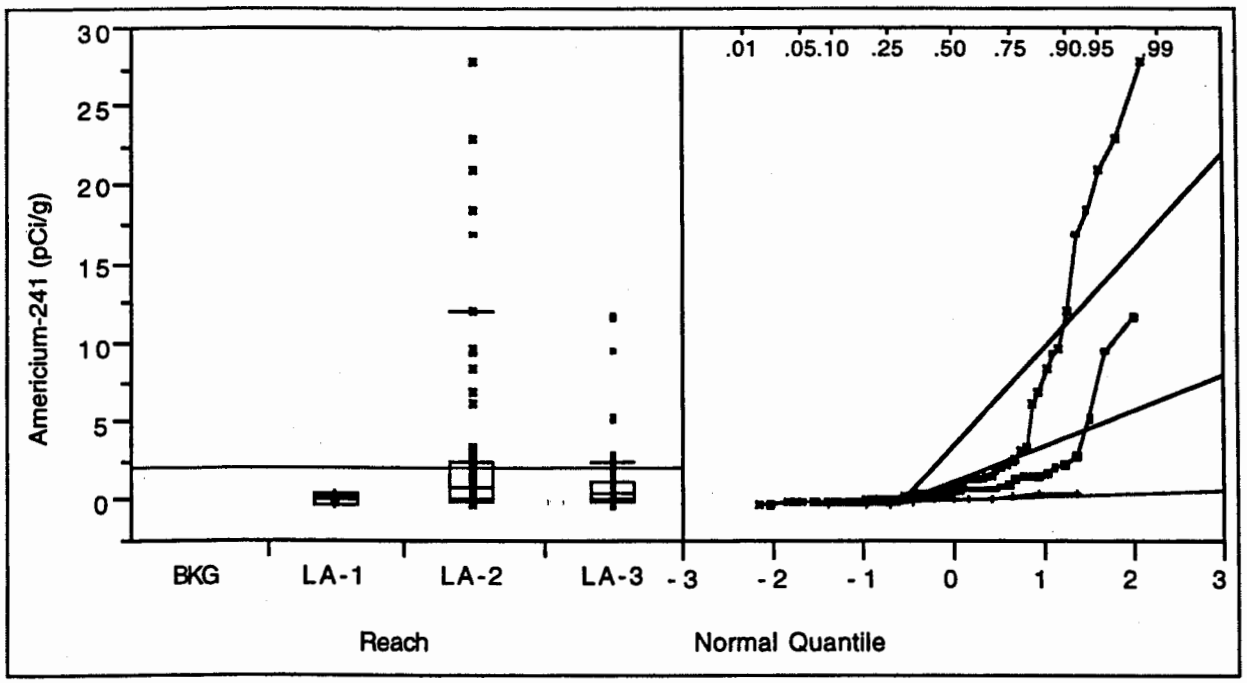

Figure E2-1b. Box plot for americium-241 by gamma spectroscopy.

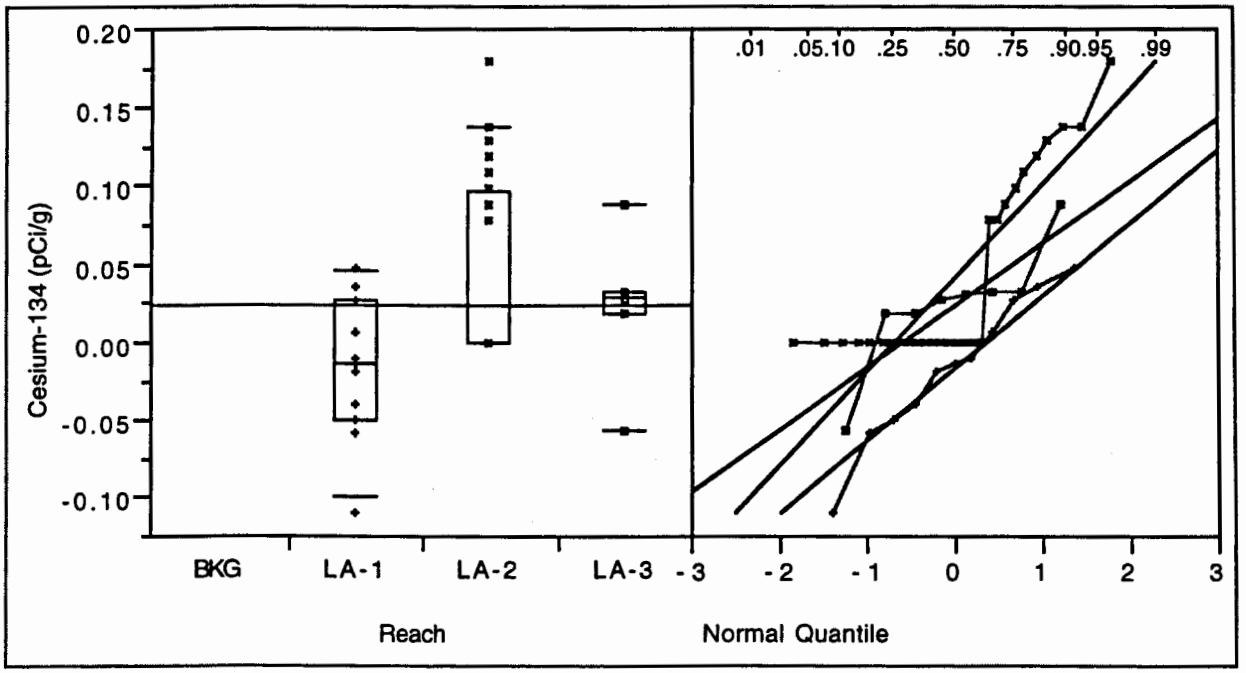

Figure E2-2. Box plot for cesium-134.

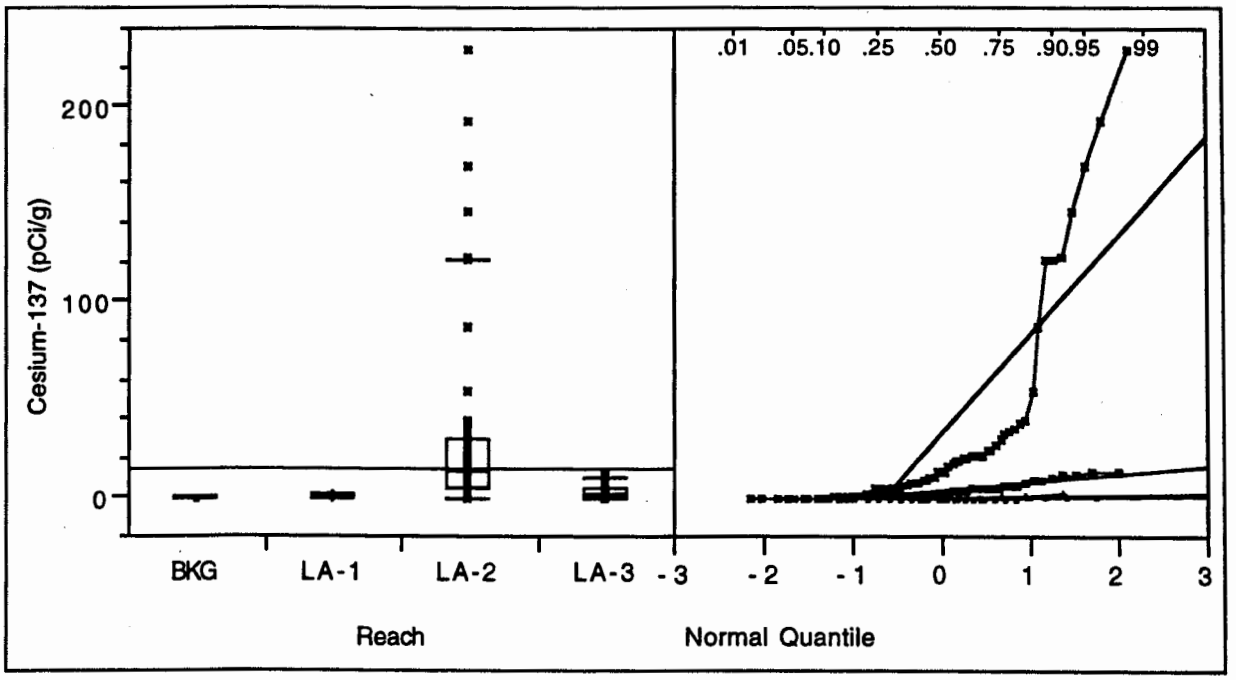

Figure E2-3. Box plot for cesium-137.

E-2.2.4 Cobalt-60

Cobalt-60 was detected in one sample collected from reach LA-2 and four samples collected from reach LA-3. Because cobalt-60 was not detected in the background samples, statistical testing is inappropriate. Figure E2-4 shows that reach LA-3 has three results that are marginally greater than the rest of the data, which appears to indicate a release of cobalt-60 into upper Los Alamos Canyon sediments. In addition, the magnitude of the cobalt-60 results in reaches LA-2 and LA-3 are greater than in reach LA-1. This difference could be due to the greater gamma activity from cesium-137 in samples collected from reaches LA-2 and LA-3, in addition to detection of cobalt-60 in reach LA-3 samples. The radionuclide evaluation method is to retain detected radionuclides as COPCs if there are no background data available for comparison. Thus, cobalt-60 is retained as a COPC.

E-2.2.5 Europium-152

Europium-152 was detected in one sample collected from reach LA-2 and two samples collected from reach LA-3. The detected results are within the range of nondetected europium-152 sample results. Because europium-152 was not detected in the background samples, statistical testing is inappropriate. Figure E2-5 shows that the magnitude of the europium-152 results in reaches LA-2 and LA-3 are greater than in reach LA-1. This difference could be due to the greater gamma activity from cesium-137 in samples collected from reach LA-2. The radionuclide evaluation method is to retain detected radionuclides as COPCs if there are no background data available for comparison. Thus, europium-152 is retained as a COPC.

E-2.2.6 Plutonium-238

Results of the statistical testing (Table E2-1) indicate there are significant differences between plutonium-238 data from all three reaches and background data. A review of the data plotted by reach (Figure E2-6) confirms these results. Thus, plutonium-238 is retained as a COPC.

E-2.2.7 Plutonium-239,240

Results of the statistical testing (Table E2-1) indicate there are significant differences between plutonium-239,240 data from all three reaches and background data. A review of the data plotted by reach (Figure E2-7) confirms these results. Thus, plutonium-239,240 is retained as a COPC.

E-2.2.8 Strontium-90

Results of the statistical testing (Table E2-1) indicate there are significant differences between some reach data for strontium-90 (LA-2 and LA-3) and background data. A review of the data plotted by reach (Figure E2-8) confirms these results. Thus, strontium-90 is retained as a COPC.

E-2.2.9 Thorium-228

Thorium-228 was determined in samples collected from reaches LA-2 and LA-3. The box plot (Figure E2-9) and results of the statistical testing (Table E2-1) suggest that results from both reaches LA-2 and LA-3 are elevated relative to background data. It is important to note that the reach LA-3 sample results are derived from a laboratory different than other thorium-228 sample results, and the highest result in LA-3 could result from a laboratory bias. However, the LA-2 data also suggest a difference from background. Because of the apparent differences between results from the reaches and background data, thorium-228 is retained as a COPC.

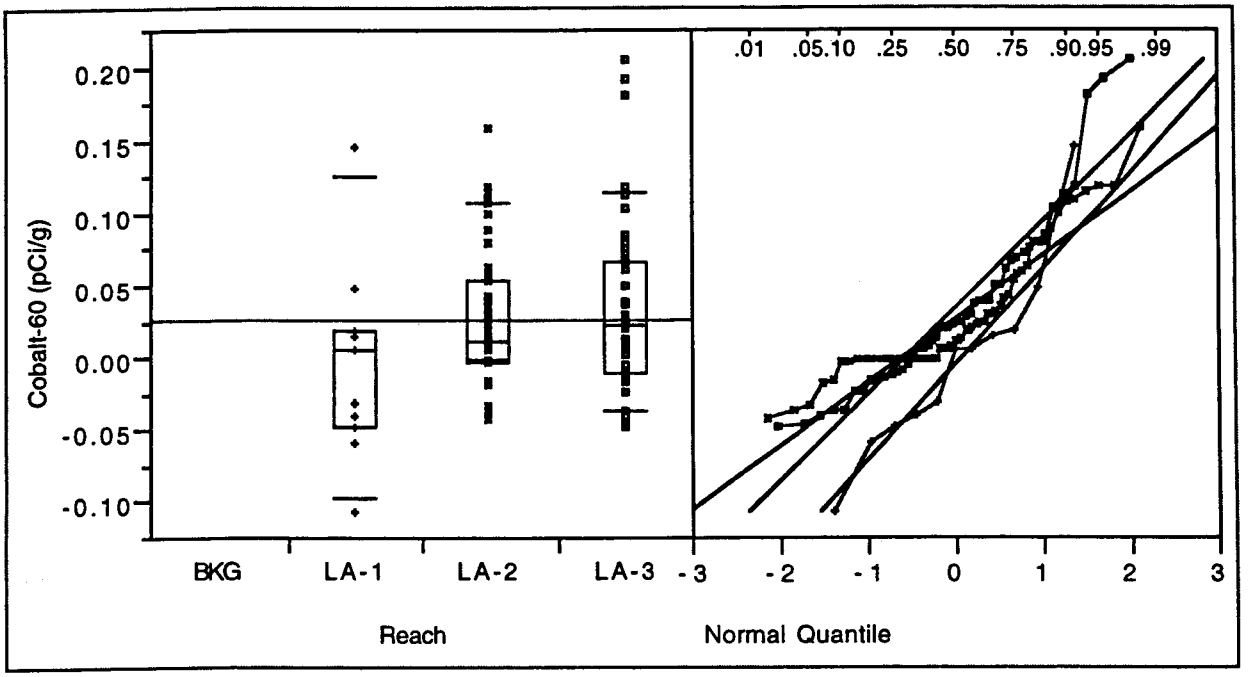

Figure E2-4. Box plot for cobalt-60.

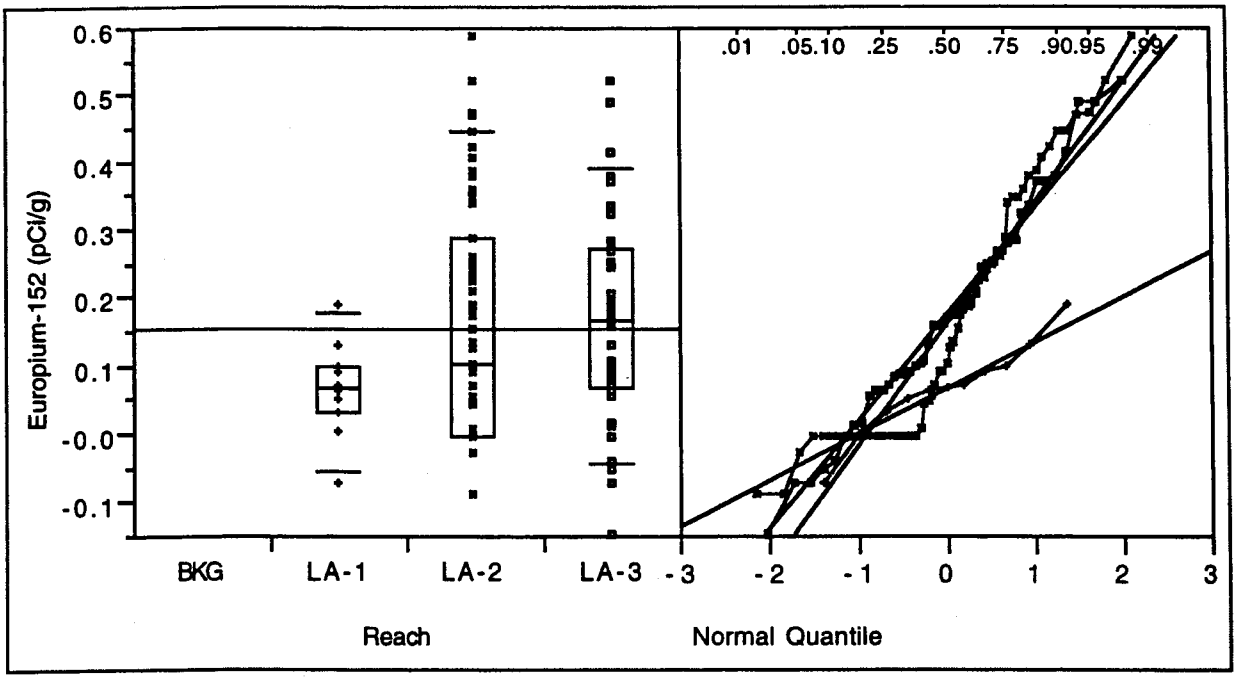

Figure E2-5. Box plot for europium-152.

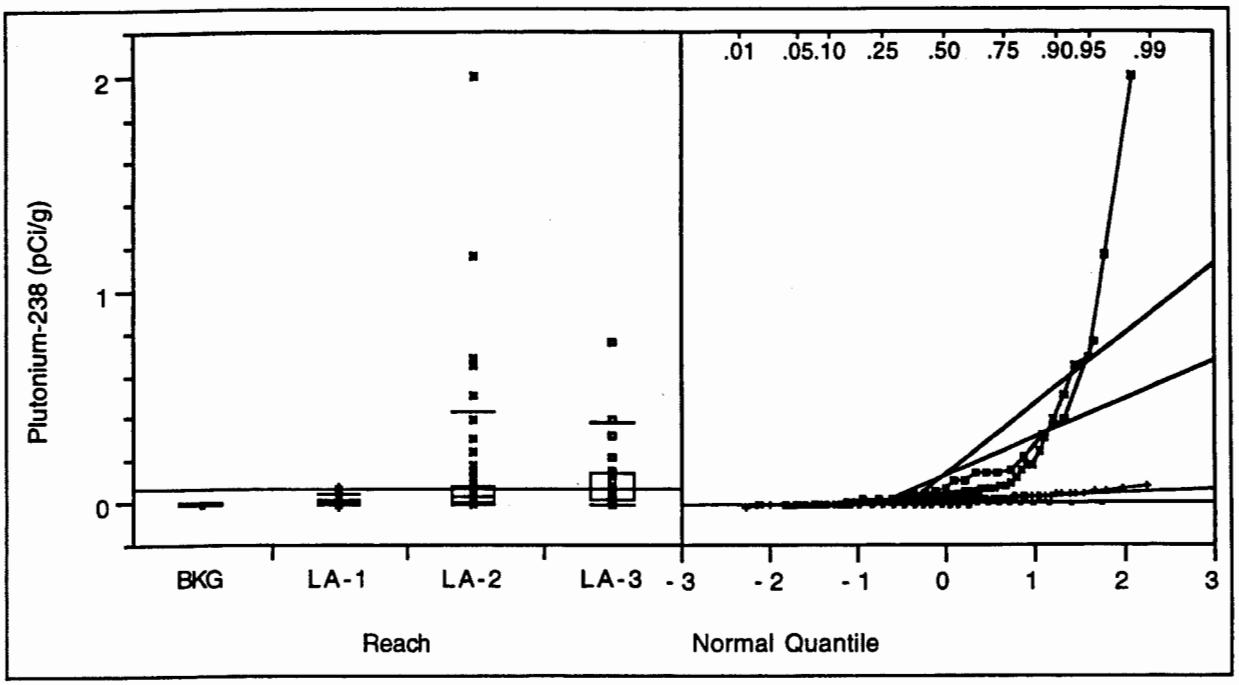

Figure E2-6. Box plot for plutonium-238.

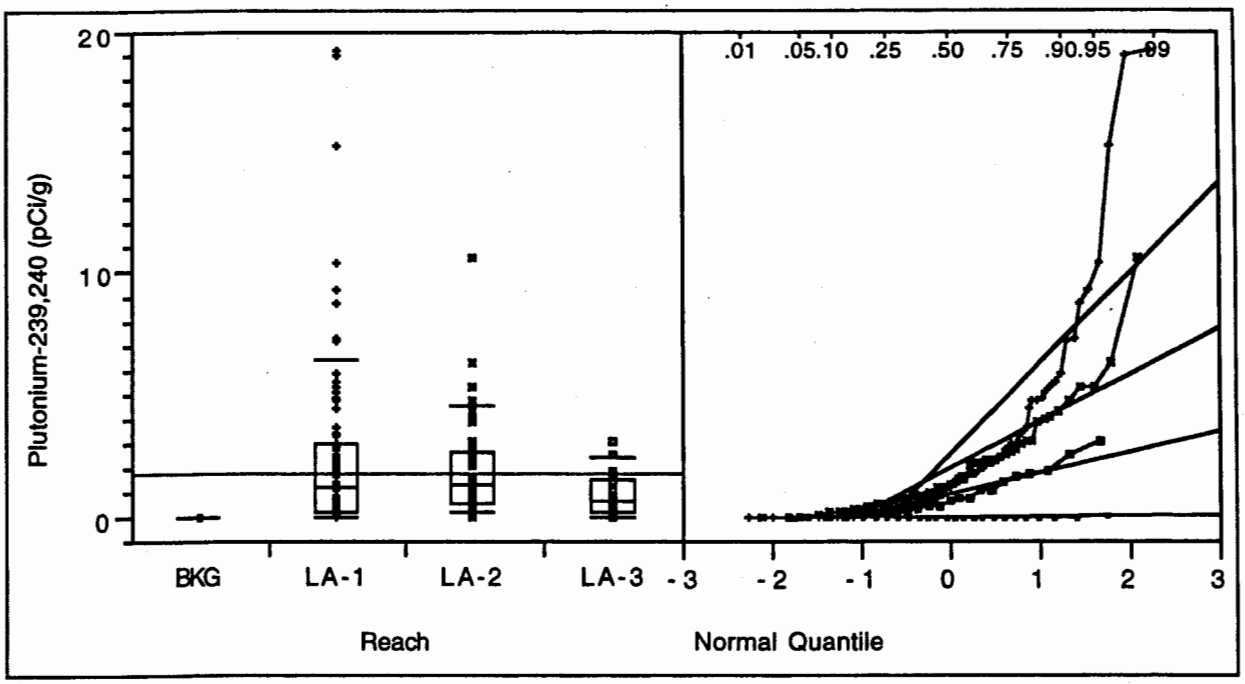

Figure E2-7. Box plot for plutonium-239,240.

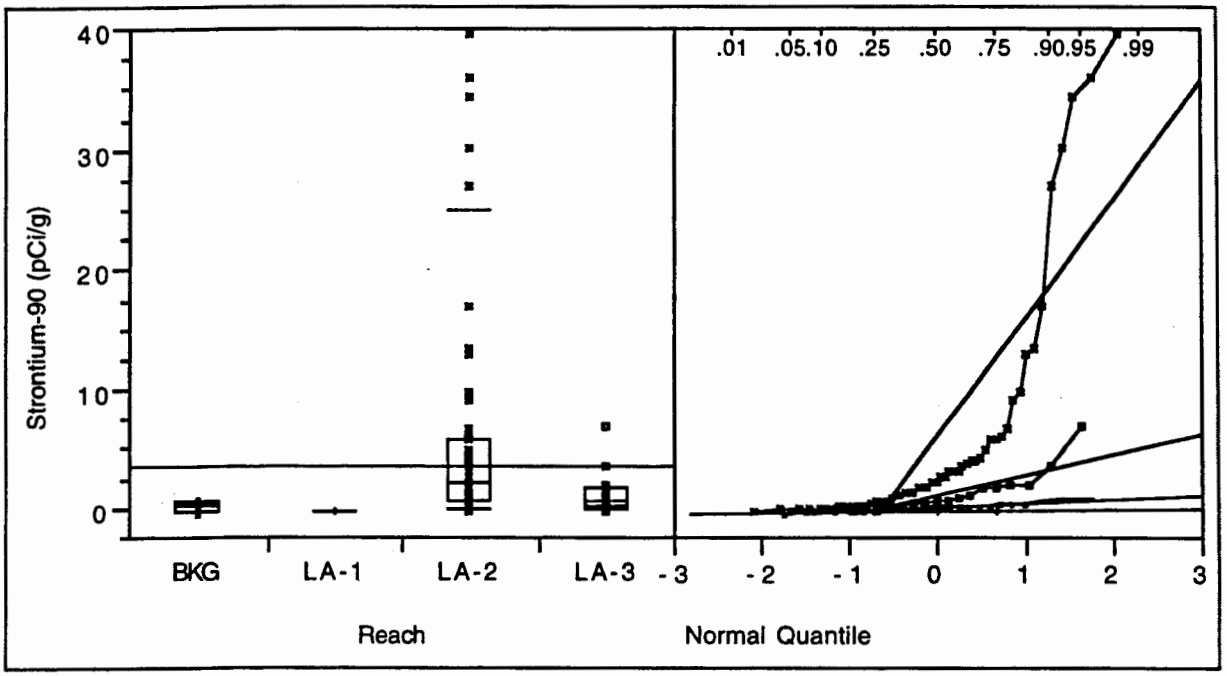

Figure E2-8. Box plot for strontium-90.

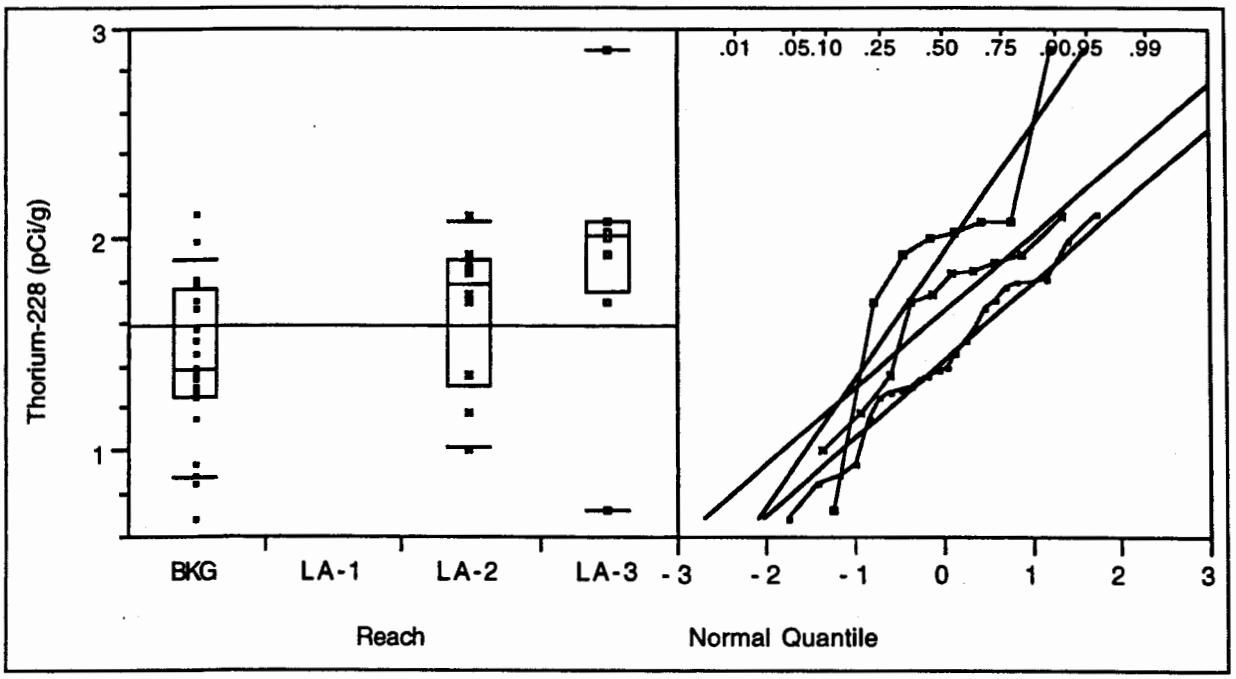

Figure E2-9. Box plot for thorium-228.

E-2.2.10 Thorium-230

Thorium-230 was determined in samples collected from reaches LA-2 and LA-3. The box plot (Figure E2-10) and results of the statistical testing (Table E2-1) suggest that results from both reaches LA-2 and LA-3 are elevated relative to background data. The observation that thorium-230 elevated relative to background data is not surprising because total uranium has been identified as a COPC, and thorium-230 is in the uranium decay chain. It is important to note that the reach LA-3 sample results are derived from a laboratory different than other thorium-230 sample results, which may suggest a possible laboratory bias for these data. However, because of the apparent differences between results from the reaches and background data, thorium-230 is retained as a COPC.

E-2.2.11 Thorium-232

Thorium-232 was determined in samples collected from reaches LA-2 and LA-3. The box plot (Figure E2-11) and results of the statistical testing (Table E2-1) suggest that results from reach LA-3 are elevated relative to background data. It is important to note that the reach LA-3 sample results are derived from a laboratory different than other thorium-232 sample results. However, because of the apparent differences between the LA-3 results and background data, thorium-232 is retained as a COPC.

E-2.2.12 Tritium

Tritium was determined in samples collected from reaches LA-2 and LA-3. The box plot (Figure E2-12) and results of the statistical testing (Table E2-1) suggest there are significant differences between one reach (LA-2) and background data. It is important to note that the two highest sample results for reach LA-2 are nondetected values. However, even when those values are excluded, there is a small but statistically significant increase in concentration relative to background data for reach LA-2 samples. In addition, the maximum detected tritium result is collocated with the maximum cesium-137 result, supporting the inference that tritium is present as a contaminant. Thus, tritium is retained as a COPC.

E-2.2.13 Uranium-234

Results of the statistical testing (Table E2-1) suggest there are significant differences between some reach data for uranium-234 (LA-2) and background data. A review of the data plotted by reach (Figure E2-13) confirms these results. Thus, uranium-234 is retained as a COPC.

E-2.2.14 Uranium-235

Results of the statistical testing (Table E2-1) suggest there are significant differences between some reach data for uranium-235 (LA-2) and background data. A review of the data plotted by reach (Figure E2-14) confirms these results. Although no uranium-235 sample results are greater than the background value, uranium-235 is retained as a COPC because of the results of statistical testing and visual inspection of the box plot.

E-2.2.15 Uranium-238

Results of the statistical testing (Table E2-1) suggest there are significant differences between some reach data for uranium-238 (LA-2) and background data. A review of the data plotted by reach (Figure E2-15) confirms these results. Thus, uranium-238 is retained as a COPC.

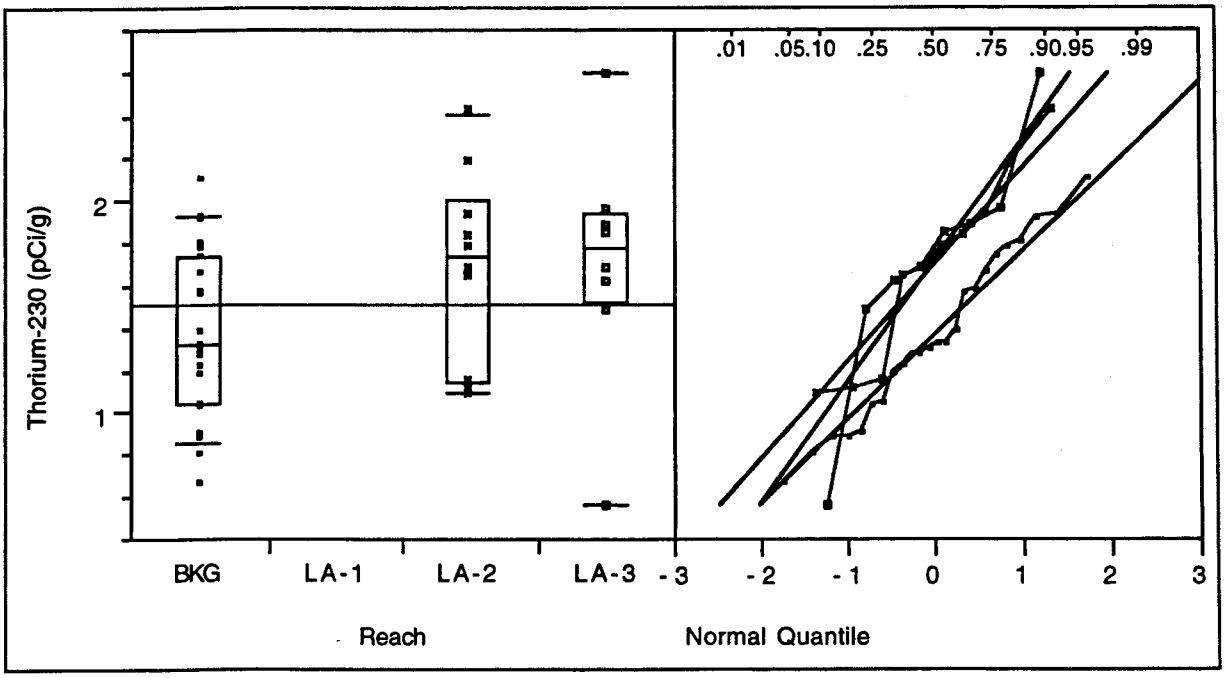

Figure E2-10. Box plot for thorium-230.

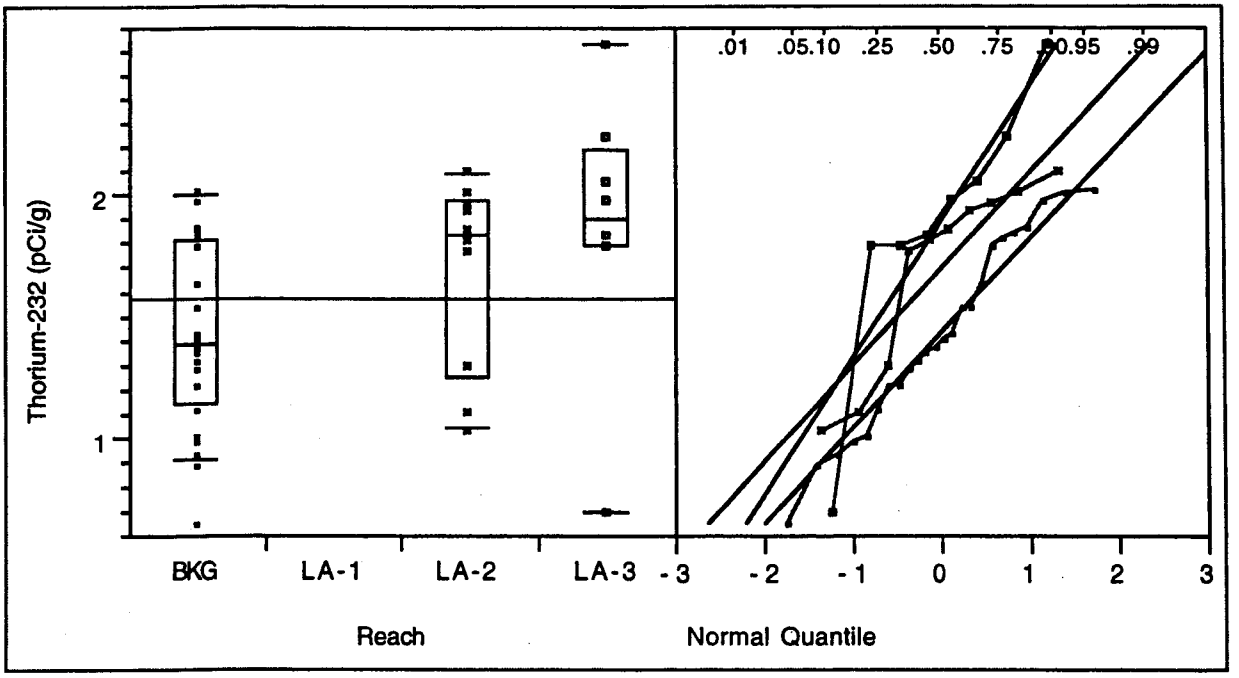

Figure E2-11. Box plot for thorium-232.

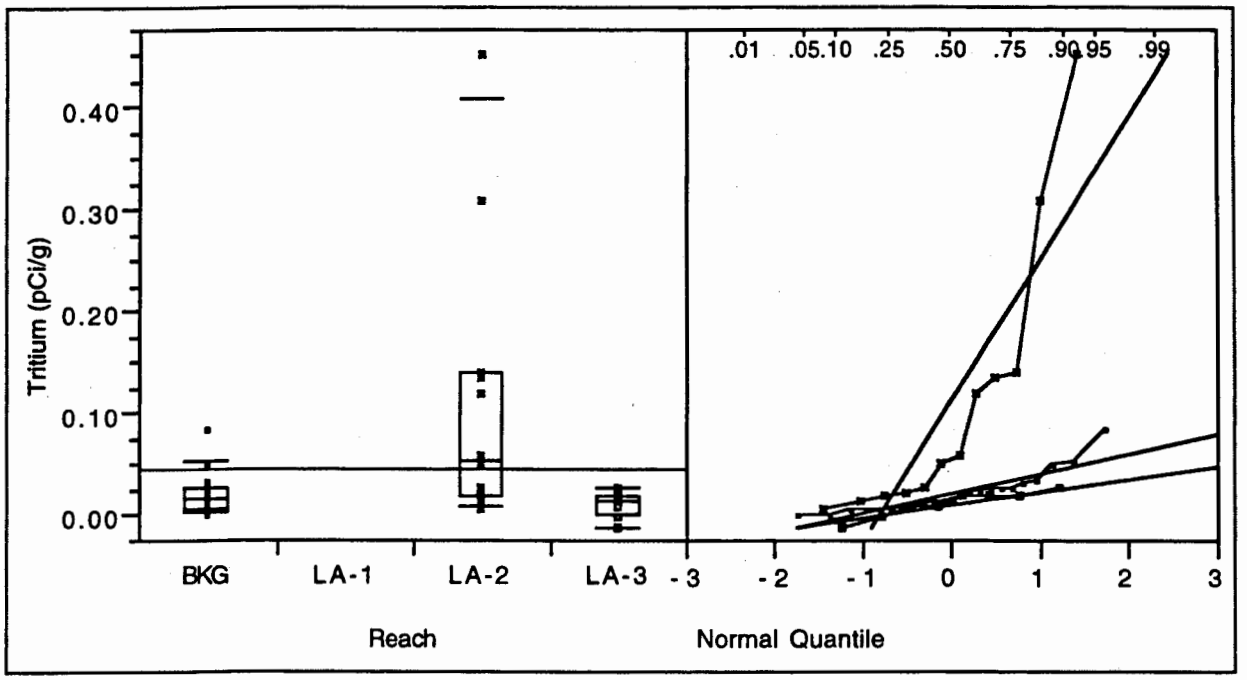

Figure E2-12. Box plot for tritium.

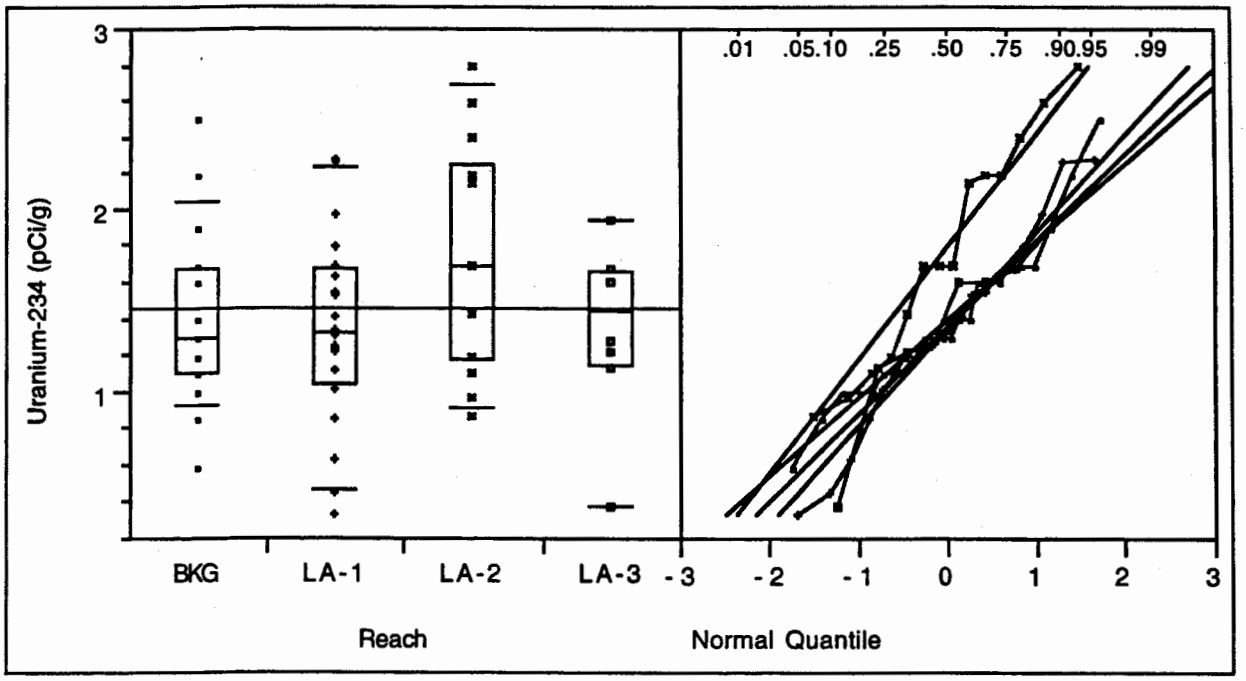

Figure E2-13. Box plot for uranium-234.

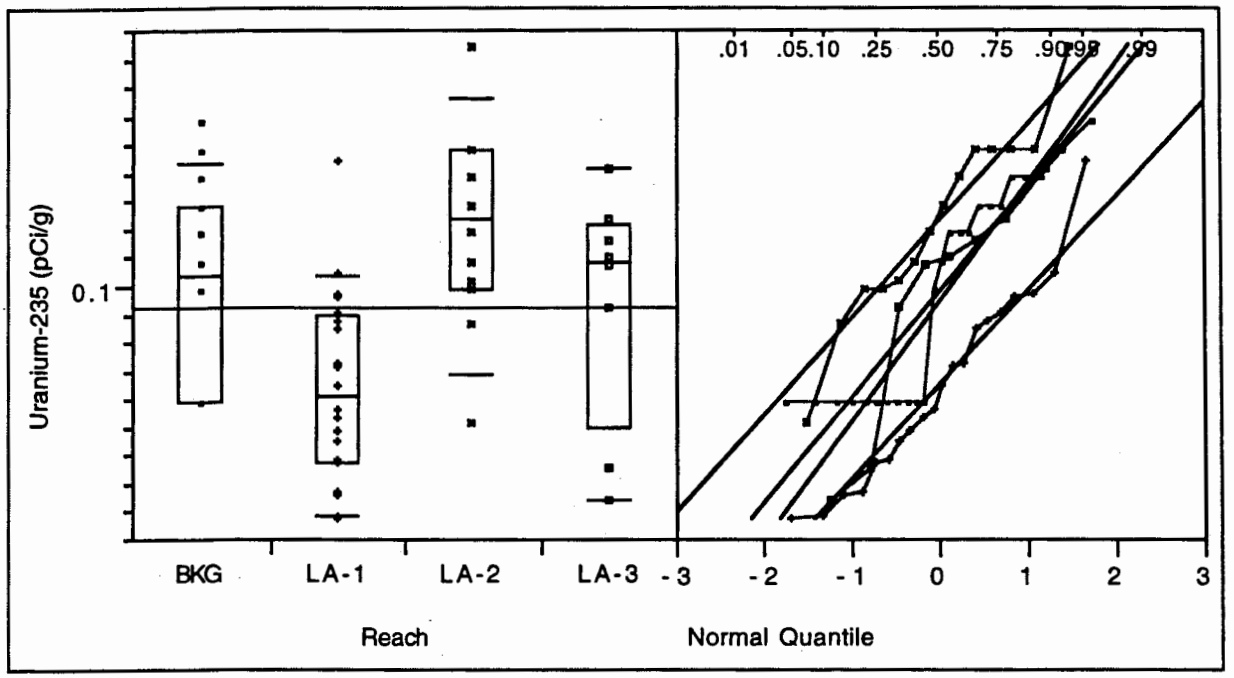

Figure E2-14. Box plot for uranium-235.

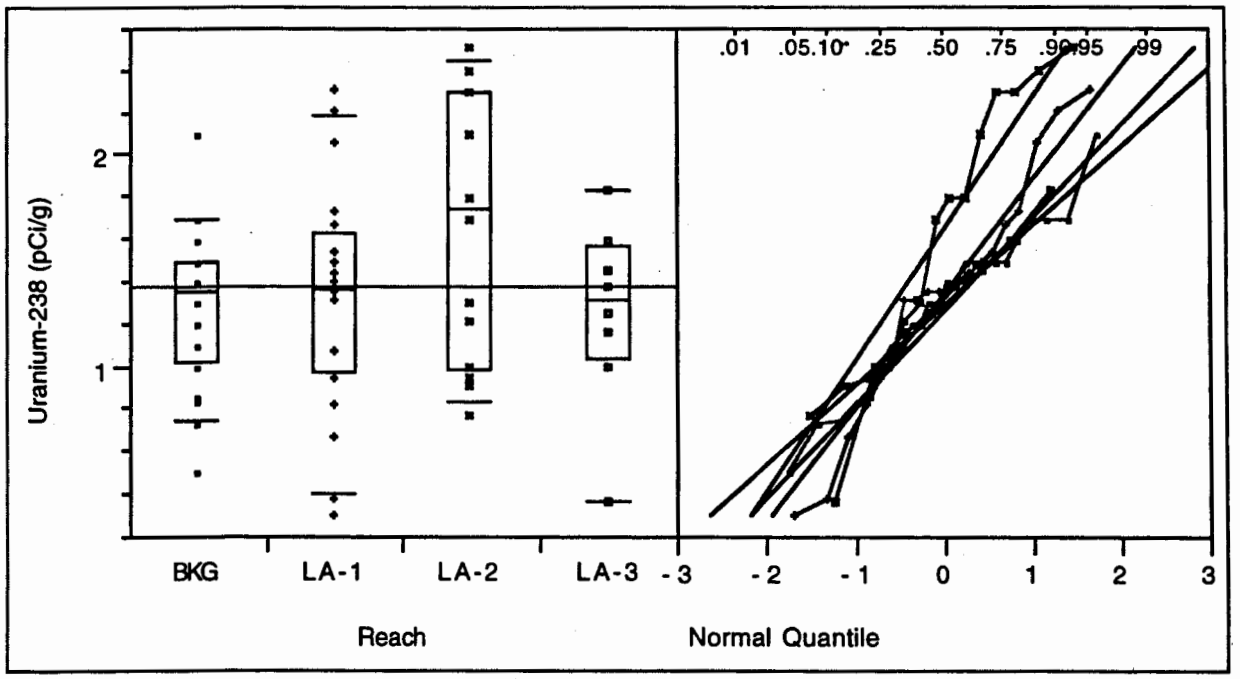

Figure E2-15. Box plot for uranium-238.

E-3.0 COLLOCATION OF COPCs

The collocation, or correlation of concentrations, of COPCs was evaluated through a series of figures. Five radionuclides (americium-241; cesium-137; plutonium-238; plutonium-239,240; and strontium-90) were selected as key radionuclides because of their abundance in upper Los Alamos Canyon sediments. Contaminant sources can be linked to two of these fives radionuclides. Cesium-137 can be used an indicator of releases from Technical Area (TA) -21 into DP Canyon. Plutonium-239,240 can be used as an indicator of releases from TA-1 and TA-21 outfalls that drain into Los Alamos Canyon. Thus, the concentration of other COPCs are evaluated against cesium-137 and plutonium-239,240 as indicator COPCs.

E-3.1 Methods

To evaluate the collocation of COPCs, scatter plots were developed for each COPC versus cesium-137 and plutonium-239,240. In these scatter plots the logarithm of the cesium-137 and plutonium-239,240 data (log[Cs-137] and log[Pu-239,240]) are displayed as the x-axis values. The values on the x-axis are log-transformed so that the reader can better determine if the COPC concentrations displayed on the y-axis exhibit correlation over the entire range of cesium-137 and plutonium-239,240 concentrations. These plots contain two types of symbols: the "x" symbols represent nondetected sample results, and the solid squares represent detected sample results. For radionuclides and inorganic COPCs the plots also show background results with the same symbols. Cesium-137 values less than log(Cs-137) of 0 represent background concentrations, and most log(Cs-137) <0 data presented on the scatter plots are either background samples or reach LA-1 samples. Plutonium-239,240 values less than log(Pu-239,240) of -1 represent background values on the scatter plots, and almost none of the upper Los Alamos Canyon sediment samples are less than log(Pu-239,240) of -1. Collocation is suggested by observing an increasing trend in the COPC concentration values for increasing values of cesium-137 or plutonium-239,240 (especially for log[Cs-137]>0, or log[Pu-239,240] > -1). A lack of collocation is suggested by observing elevated COPC values associated with low cesium-137 (or -1 < log[Cs-137] < 0) or plutonium-239,240 values (or -1 < log[Pu-239,240] < +1).

To support the graphical analysis provided by the scatter plot matrix, both parametric and nonparametric correlations were calculated. The parametric, or Pearson's correlation coefficient, was calculated from the logarithm-transformed cesium-137 or plutonium-239,240 sample results. Pearson's correlation analysis yields a correlation coefficient and an associated measure of statistical significance (or p-value). The Spearman rank correlation analysis also provides a nonparametric correlation coefficient and an associated measure of statistical significance (or p-value). The correlation coefficients can potentially range between -1 and +1. A correlation coefficient of zero suggests no correlation between the two measurements. A correlation coefficient of +1 suggests a perfect positive relationship between the measurements. A correlation coefficient of -1 suggests a perfect negative relationship between the measurements.

E-3.2 Results

Table E3-1 provides the results of the correlation analysis between the log(Cs-137) or log(Pu-239,240) with the other COPCs. There are many statistically significant correlations between inorganic and radionuclides COPCs with either cesium-137 and plutonium-239,240. Correlations of most organic chemicals in the polychlorinated biphenyl (PCB)/pesticide group with cesium-137 are negative. Semivolatile organic compounds (SVOCs) do not exhibit significant correlations with either cesium-137 or plutonium-239,240. Typically, significant correlations are observed either with both indicator COPCs or with neither indicator COPC because there is a statistically significant correlation between log(Cs-137) and log(Pu-239,240) as shown in Table E3-1. The scatter plots that relate cesium-137 and plutonium-239,240 results to results from the other COPCs present more information and help interpret the practical importance of these correlations.

TABLE E3-1
PEARSON AND SPEARMAN RANK CORRELATION VALUES[a]

Analyte	log(Cs-137)					log(Pu-239,240)				
	Count	Pearson Correlation	Signif. Prob. (p)	Spearman Rank Corr.	Signif. Prob. (p)	Count	Pearson Correlation	Signif. Prob. (p)	Spearman Rank Corr.	Signif. Prob. (p)
Antimony	27	**0.610**	**0.001**	**0.713**	**<.0001**	61	0.153	0.239	0.245	0.058
Cadmium	37	**0.452**	**0.005**	**0.634**	**<.0001**	71	0.439	0.000	0.299	0.011
Chromium, total	37	**0.455**	**0.005**	**0.307**	**0.064**	71	0.197	0.099	0.028	0.817
Copper	37	-0.006	0.973	-0.006	0.974	71	**0.548**	**0.000**	**0.623**	**<.0001**
Lead	37	0.406	0.013	0.252	0.133	71	**0.692**	**0.000**	**0.728**	**<.0001**
Mercury	37	0.061	0.721	0.213	0.205	71	**0.583**	**0.000**	**0.782**	**<.0001**
Selenium	37	-0.176	0.299	-0.150	0.375	71	**0.524**	**0.000**	**0.677**	**<.0001**
Silver	37	-0.038	0.824	**0.478**	**0.003**	65	**0.293**	**0.018**	0.356	0.004
Uranium	17	0.411	0.101	0.423	0.090	34	**0.448**	**0.008**	**0.339**	**0.050**
Uranium, total	17	**0.466**	**0.059**	**0.679**	**0.003**	34	0.392	0.022	0.391	0.022
Zinc	37	**0.486**	**0.002**	**0.458**	**0.004**	71	0.445	0.000	0.437	0.000
Americium-241[b]	107	**0.349**	**0.000**	**0.603**	**<.0001**	67	0.258	0.035	0.416	0.001
Americium-241	35	**0.761**	**0.000**	**0.757**	**<.0001**	53	0.483	0.000	0.755	<.0001
Cesium-134	41	0.256	0.107	0.182	0.254	30	-0.022	0.907	-0.082	0.668
Cesium-137	N/A[c]	N/A	N/A	N/A	N/A	91	0.317	0.002	0.710	<.0001
Cobalt-60	114	0.002	0.983	-0.027	0.779	91	**-0.349**	**0.001**	**-0.402**	**<.0001**
Europium-152	107	**0.206**	**0.033**	0.110	0.260	67	-0.021	0.867	-0.023	0.854
Plutonium-238	73	**0.349**	**0.003**	**0.654**	**<.0001**	177	0.237	0.002	0.629	<.0001
Plutonium-239,240	73	0.035	0.768	0.484	<.0001	N/A	N/A	N/A	N/A	N/A
Strontium-90	63	**0.612**	**0.000**	**0.731**	**<.0001**	79	0.333	0.003	0.549	<.0001
Thorium-228	23	**0.469**	**0.024**	**0.618**	**0.002**	40	0.366	0.020	0.388	0.013
Thorium-230	23	**0.567**	**0.005**	**0.625**	**0.001**	40	0.345	0.029	0.294	0.065
Thorium-232	23	**0.526**	**0.010**	**0.608**	**0.002**	40	0.358	0.023	0.325	0.041
Tritium	25	0.228	0.273	0.338	0.098	41	**0.470**	**0.002**	**0.420**	**0.006**
Uranium-234	37	**0.469**	**0.003**	**0.404**	**0.013**	64	0.409	0.001	0.387	0.002
Uranium-235[b]	41	**0.518**	**0.001**	**0.309**	**0.049**	30	0.265	0.157	0.336	0.070
Uranium-235	37	**0.655**	**0.000**	**0.659**	**<.0001**	64	0.149	0.239	0.092	0.471
Uranium-238	37	0.381	0.020	0.334	0.044	64	**0.427**	**0.000**	**0.367**	**0.003**
Aroclor-1254	23	-0.286	0.186	**-0.556**	**0.006**	38	0.046	0.786	0.210	0.205
Aroclor-1260	23	-0.169	0.441	-0.153	0.485	38	0.095	0.570	0.014	0.932
α-Chlordane	21	-0.314	0.166	**-0.596**	**0.004**	27	0.192	0.336	0.167	0.405
γ-Chlordane	21	-0.324	0.152	**-0.596**	**0.004**	27	0.191	0.341	0.167	0.405
4,4'-DDE	21	0.401	0.072	-0.354	0.115	27	0.195	0.331	0.111	0.581
4,4'-DDT	21	-0.408	0.067	**-0.601**	**0.004**	27	0.064	0.750	-0.013	0.948
Acenaphthene	11	-0.206	0.544	0.233	0.491	11	-0.433	0.183	-0.132	0.698
Anthracene	11	-0.047	0.891	0.109	0.750	11	-0.046	0.894	0.018	0.958
Benz(a)anthracene	11	0.081	0.812	0.064	0.853	11	-0.242	0.474	-0.182	0.593
Benzo(a)pyrene	11	0.196	0.563	0.109	0.750	11	-0.039	0.909	-0.127	0.709
Benzo(b)fluoranthene	11	0.204	0.547	0.273	0.417	11	-0.131	0.701	-0.118	0.729
Benzo(g,h,i)perylene	11	-0.104	0.760	-0.205	0.545	11	0.248	0.463	0.319	0.339
Benzo(k)fluoranthene	11	0.294	0.380	0.498	0.119	11	-0.261	0.439	0.069	0.841
Chrysene	11	0.117	0.731	0.118	0.729	11	-0.182	0.593	-0.155	0.650
Di-n-butylphthalate	9	-0.244	0.526	0.193	0.620	9	-0.560	0.117	-0.243	0.529
Dibenz(a,h)anthracene	11	-0.206	0.543	-0.005	0.989	11	-0.337	0.312	0.069	0.841
Dibenzofuran	9	-0.396	0.291	0.210	0.587	9	-0.429	0.249	0.084	0.830
Fluoranthene	11	0.319	0.339	0.409	0.212	11	-0.126	0.713	-0.200	0.555
Fluorene	11	0.045	0.897	0.343	0.303	11	-0.453	0.162	-0.087	0.800
Indeno(1,2,3-cd)pyrene	11	0.091	0.791	0.087	0.800	11	-0.127	0.711	0.073	0.831
Naphthalene	11	-0.175	0.608	0.178	0.600	11	-0.522	0.100	-0.160	0.639
Phenanthrene	11	0.529	0.094	0.538	0.088	11	0.103	0.764	-0.041	0.905
Pyrene	11	0.275	0.414	0.382	0.247	11	-0.085	0.805	-0.127	0.709

a. Bolded values indicate the most significant correlations for a COPC (between log[Cs-137] and log[Pu-239,240]).
b. Analyzed by gamma spectroscopy
c. N/A = not applicable (correlation analysis is not appropriate to the same analyte)

Figures E3-1 through E3-15 show the relationships of cesium-137 or plutonium-239,240 with the other radionuclides identified as COPCs. Recall that "x" symbols shown on these plots represent nondetected values. Americium-241, plutonium-238, strontium-90, tritium (if two high nondetect values are eliminated), thorium-228, thorium-230, thorium-232, and uranium-235 tend to have better correlations with cesium-137 than with plutonium-239,240. Uranium-238 is the only radionuclide that tends to have a better correlation with plutonium-239,240 than with cesium-137. Interpretation of isotopic thorium correlations with cesium-137 or plutonium-239,240 is limited by the relatively small difference of isotopic thorium data from background data and the possible laboratory bias in the reach LA-3 isotopic thorium sample results. Likewise, the isotopic uranium sample results are only slightly different from background data, which makes the observation and interpretation of correlations more difficult. In general, the radionuclide scatter plots may show the variation in release history and presence of multiple contaminant sources for many of these radionuclides by not exhibiting strictly linear trends between the indicator COPCs and other radionuclide COPCs. The high frequency of results below background values for some radionuclides also affects the ability to identify correlations

Figures E3-16 through E3-26 show the relationships of plutonium-239,240 with the inorganic COPCs. Recall that "x" symbols shown on some of these plots represent nondetected values. Antimony, cadmium, and selenium are not detected with sufficient frequency to draw conclusions regarding possible collocation. Total chromium and total uranium tend to exhibit a better correlation with cesium-137 than with plutonium-239,240. Copper, lead, mercury, silver and zinc tend to have a better correlations with plutonium-239,240 than with cesium-137. Interpretation of the correlations for most inorganic chemicals is limited by the small differences observed from background concentrations. An improvement to the inorganic COPC correlation analysis may be to evaluate the correlation of residuals from an aluminum or iron regression analysis, which could enhance deviations from the background data set.

Figures E3-27 through E3-49 show the relationships of plutonium-239,240 with the organic COPCs. Recall that "x" symbols shown on these plots represent nondetected values. No organic chemicals exhibit positive correlations with cesium-137 or plutonium-239,240. The relationships of the two detected PCBs (Aroclor-1254 and Aroclor-1260) with cesium-137 or plutonium-239,240 are provided in Figures E3-27 and E3-28. Aroclor-1254 is negatively correlated to cesium-137, which suggests a different contaminant source. The relationships of the four detected pesticides with cesium-137 or plutonium-239,240 are provided in Figures E3-29 to E3-32, which also show negative correlations to cesium-137 (the correlation of 4,4'-DDE to cesium-137 is negative but not significant). The relationships of the 17 detected SVOCs (mostly polycyclic aromatic hydrocarbons [PAHs]) with cesium-137 or plutonium-239,240 are provided in Figures E3-33 to E3-49. None of the SVOCs are detected with sufficient frequency or concentration relative to detection limits to provide much meaningful information on possible collocation. In summary, the infrequent detection of SVOCs suggests that this chemical group is not a significant component of the COPCs observed in the upper Los Alamos Canyon sediments. No organic COPCs are clearly collocated with either cesium-137 or plutonium-239,240.

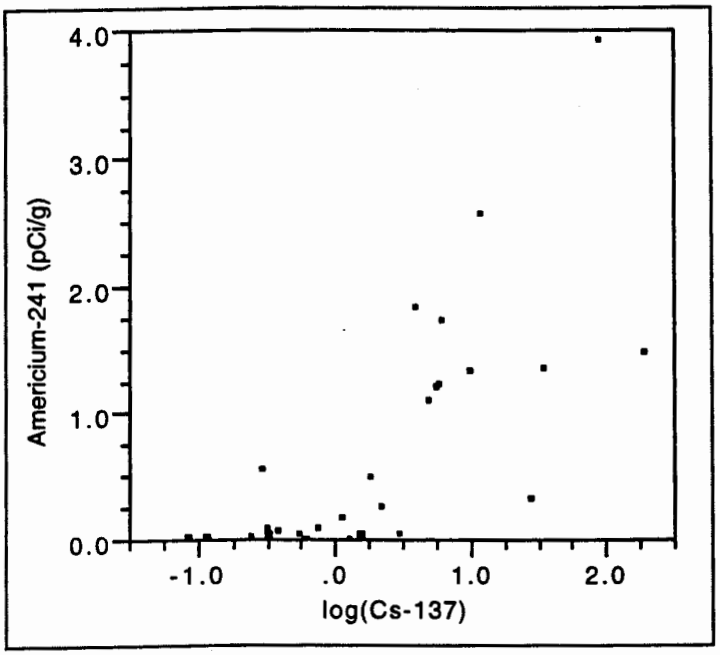

Figure E3-1a. Scatter plot for americium-241 (alpha spectroscopy) versus log(Cs-137).

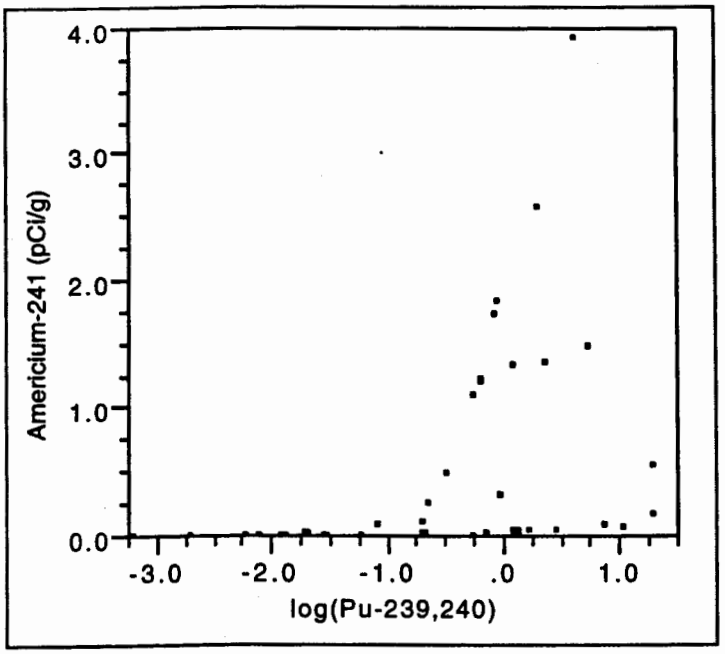

Figure E3-1b. Scatter plot for americium-241 (alpha spectroscopy) versus log(Pu-239,240).

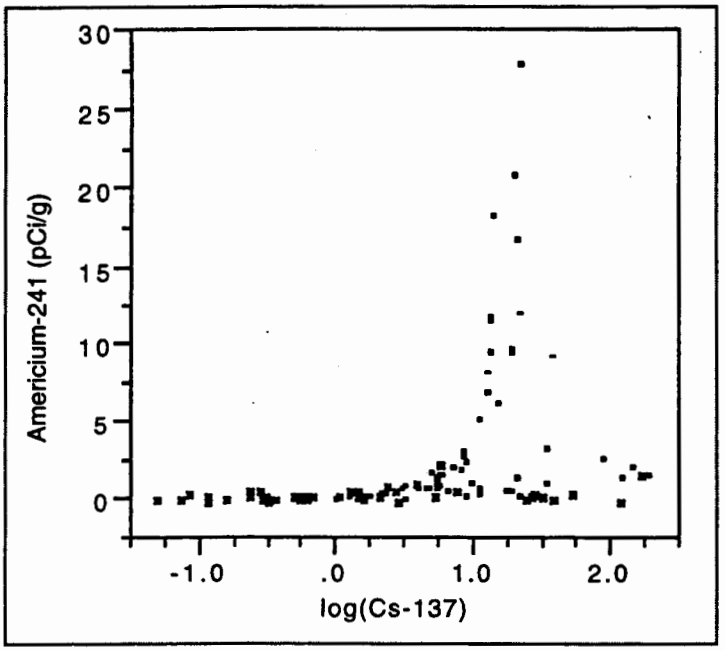

Figure E3-2a. Scatter plot for americium-241 (gamma spectroscopy) versus log(Cs-137).

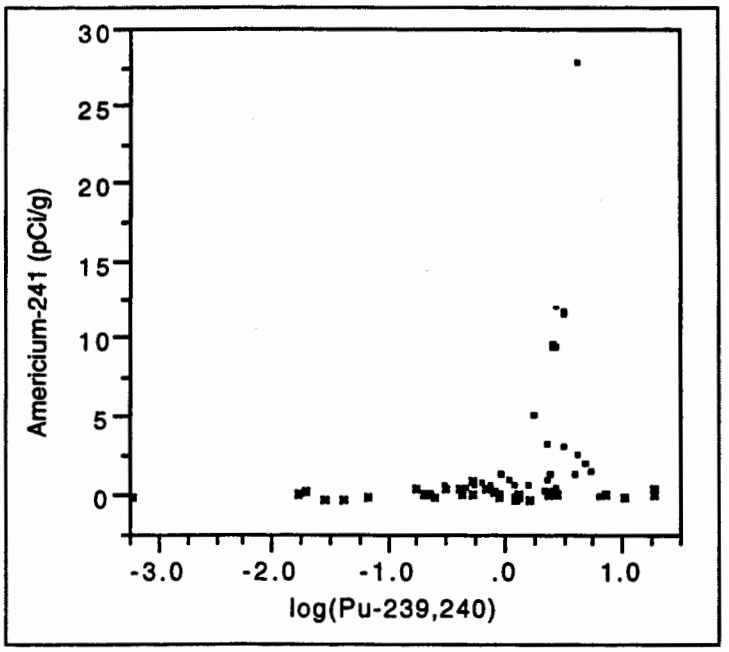

Figure E3-2b. Scatter plot for amercium-241 (gamma spectroscopy) versus log(Pu-239,240).

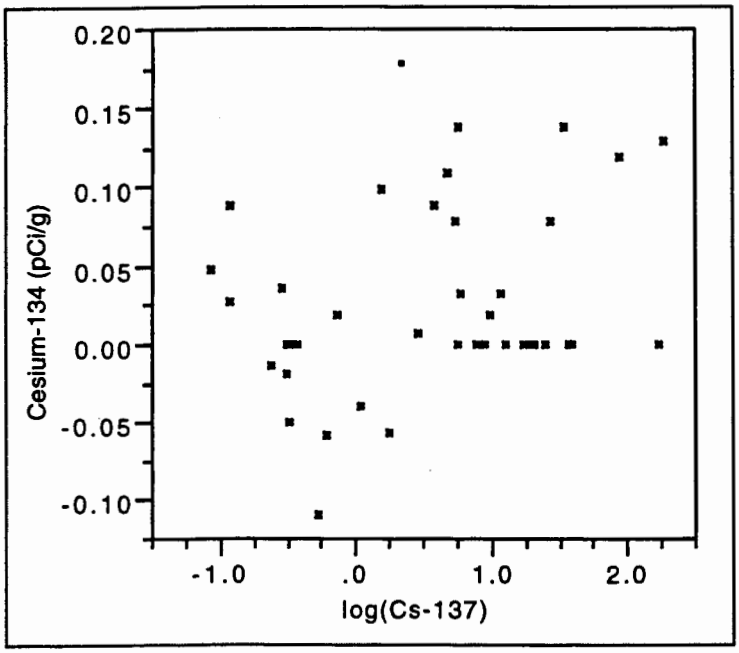

Figure E3-3a. Scatter plot for cesium-134 versus log(Cs-137).

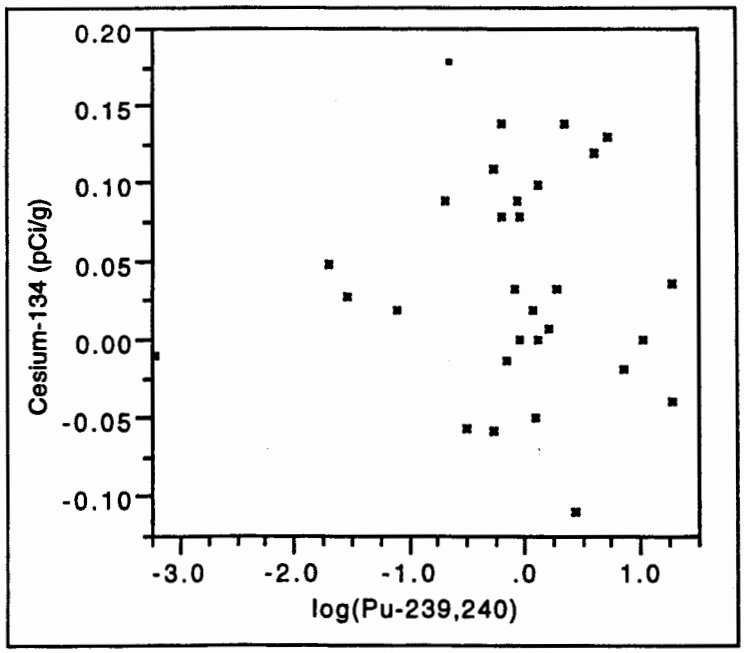

Figure E3-3b. Scatter plot for cesium-134 versus log(Pu-239,240).

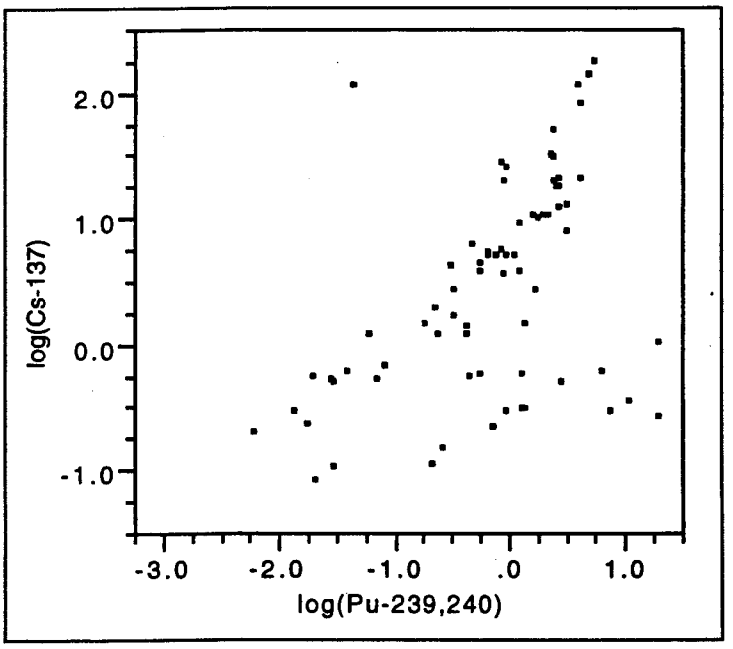

Figure E3-4. Scatter plot for log(Cs-137) versus log(Pu-239,240).

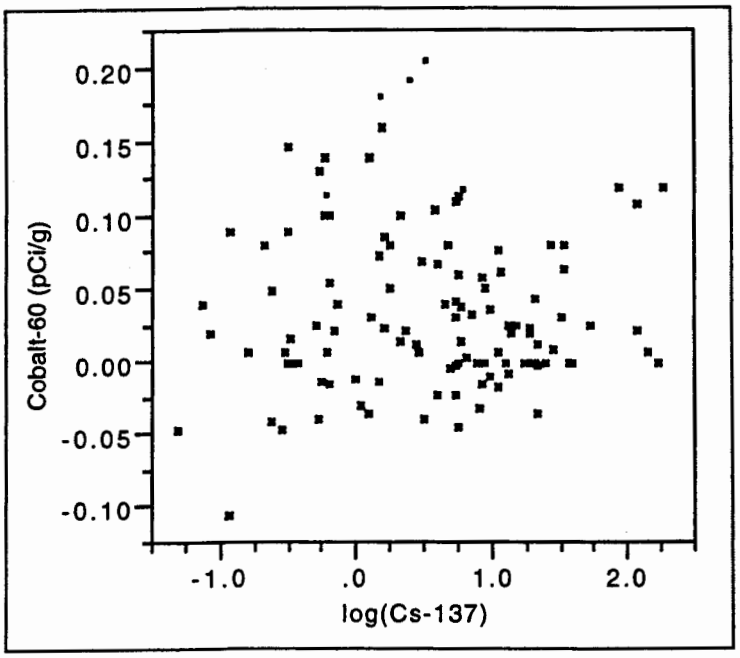

Figure E3-5a. Scatter plot for cobalt-60 versus log(Cs-137).

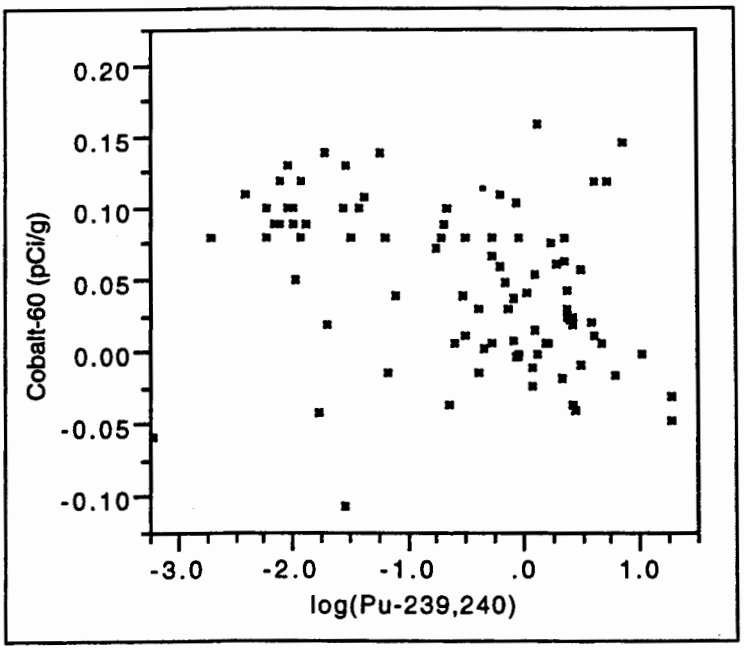

Figure E3-5b. Scatter plot for cobalt-60 versus log(Pu-239,240).

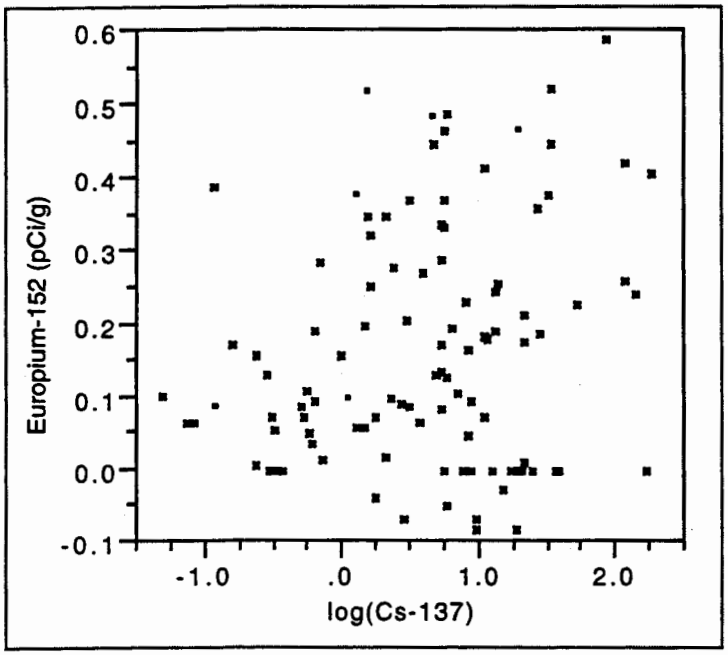

Figure E3-6a. Scatter plot for europium-152 versus log(Cs-137).

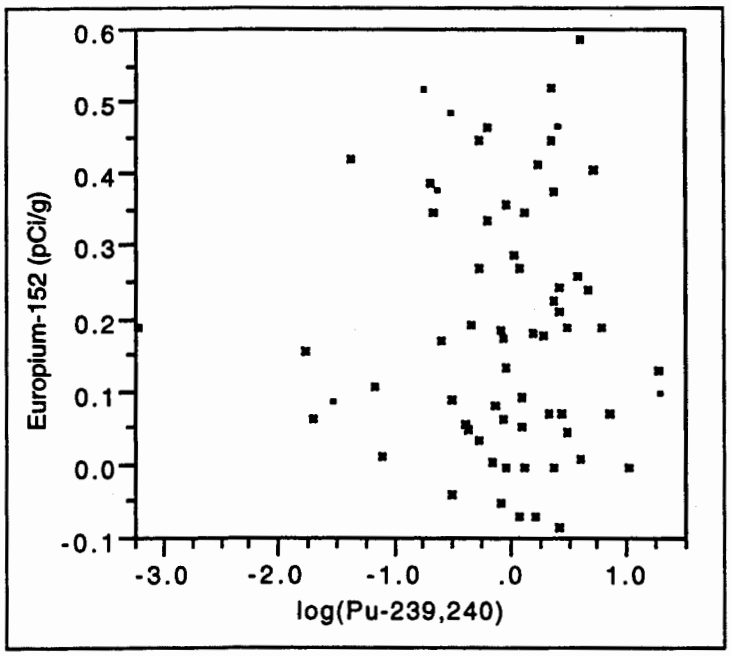

Figure E3-6b. Scatter plot for europium-152 versus log(Pu-239,240).

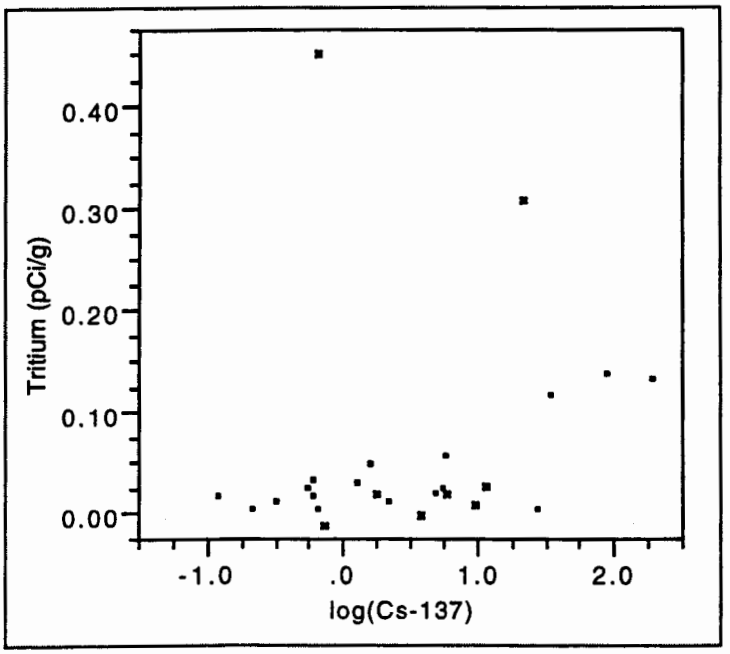

Figure E3-7a. Scatter plot for tritium versus log(Cs-137).

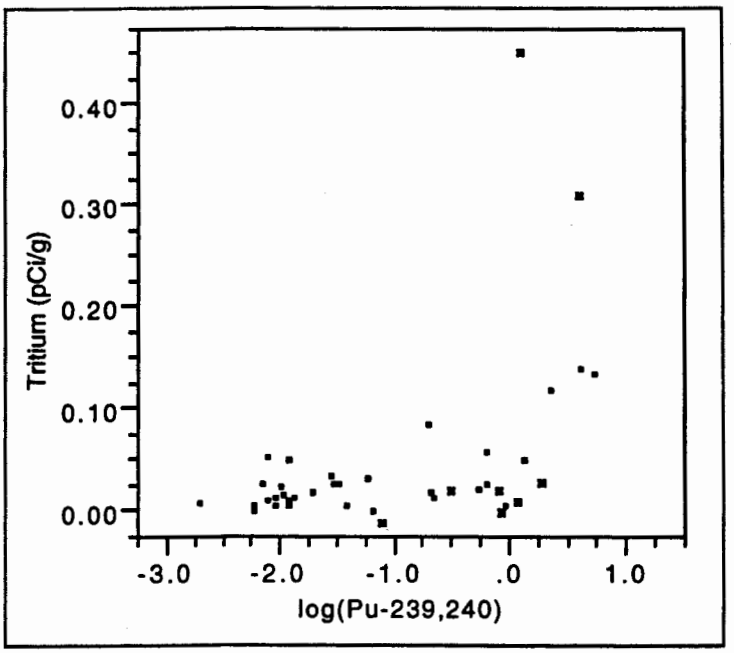

Figure E3-7b. Scatter plot for tritium versus log(Pu-239,240).

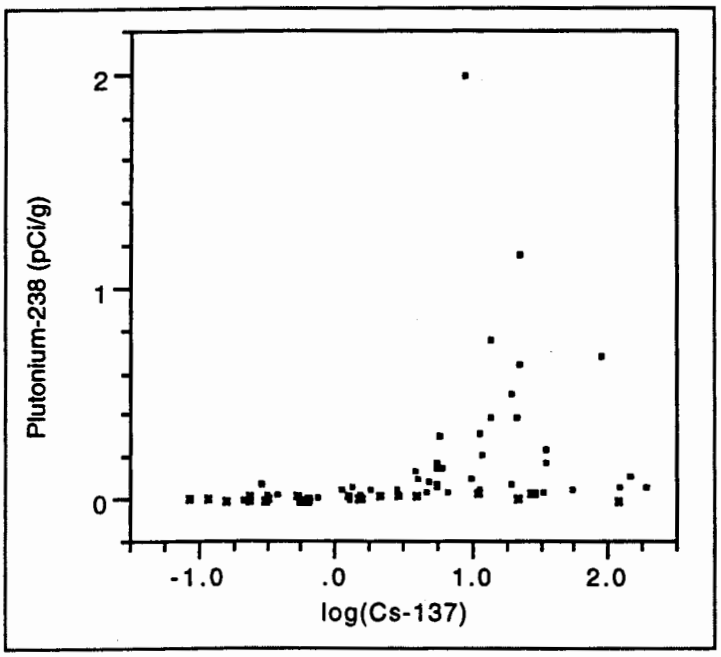

Figure E3-8a. Scatter plot for plutonium-238 versus log(Cs-137).

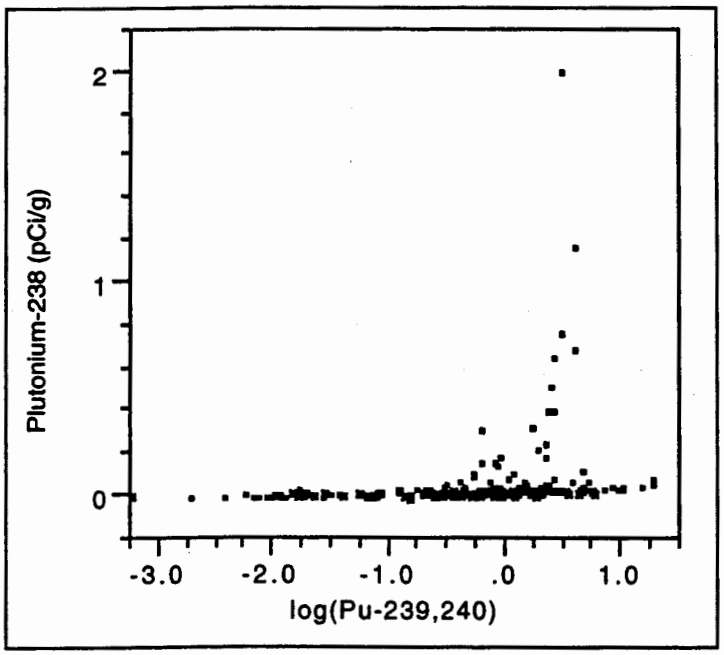

Figure E3-8b. Scatter plot for plutonium-238 versus log(Pu-239,240).

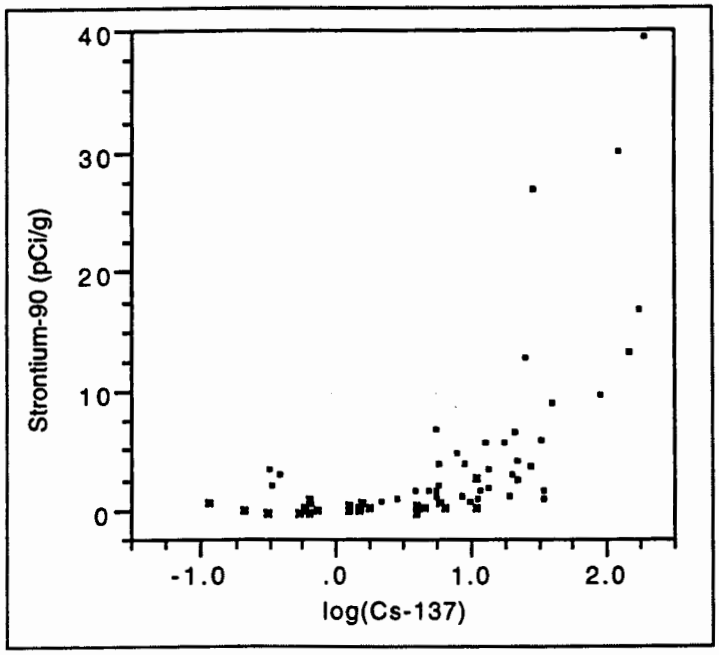

Figure E3-9a. Scatter plot for strontium-90 versus log(Cs-137).

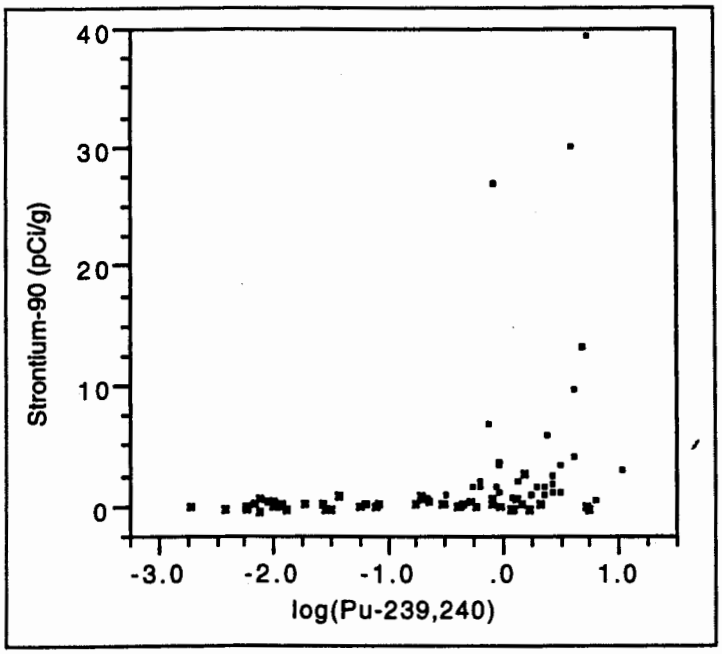

Figure E3-9b. Scatter plot for strontium-90 versus log(Pu-239,240).

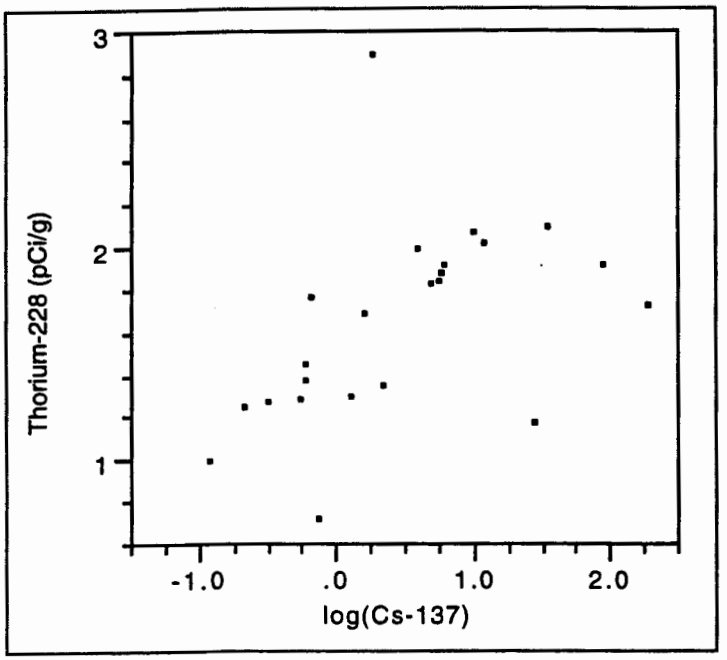

Figure E3-10a. Scatter plot for thorium-228 versus log(Cs-137).

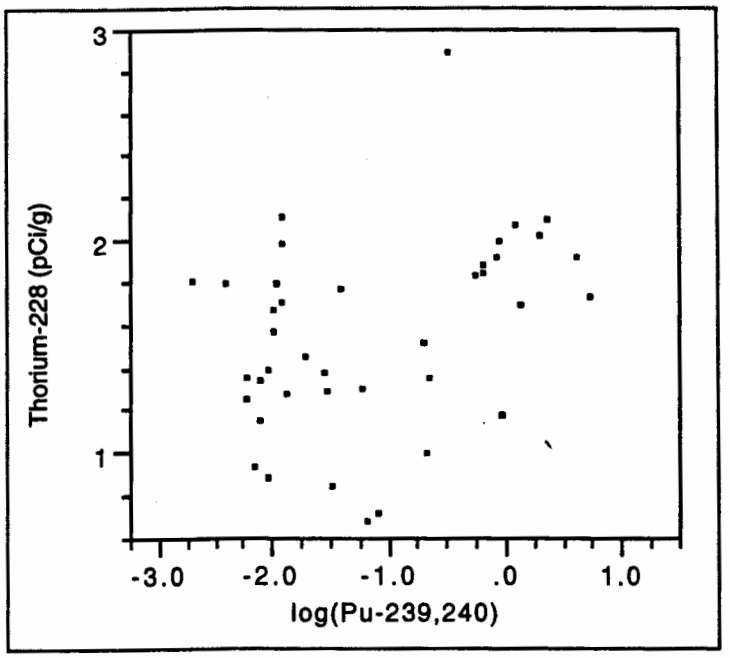

Figure E3-10b. Scatter plot for thorium-228 versus log(Pu-239,240).

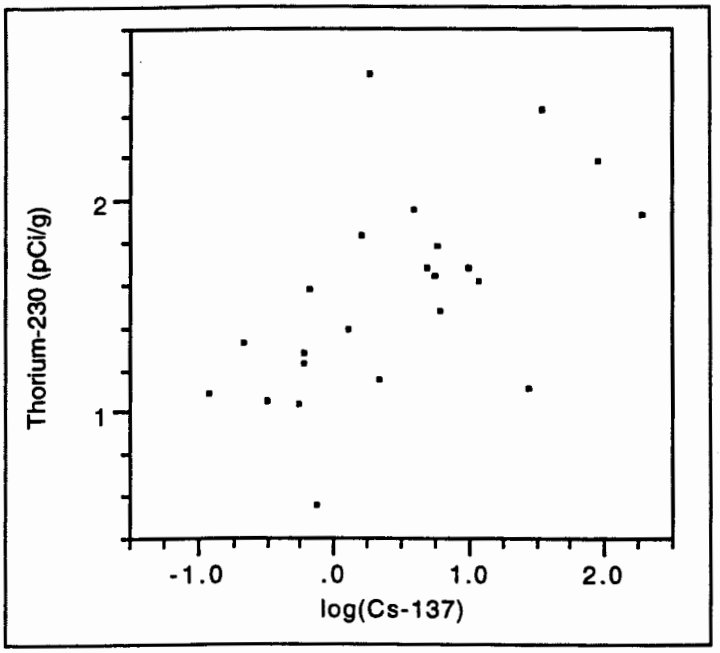

Figure E3-11a. Scatter plot for thorium-230 versus log(Cs-137).

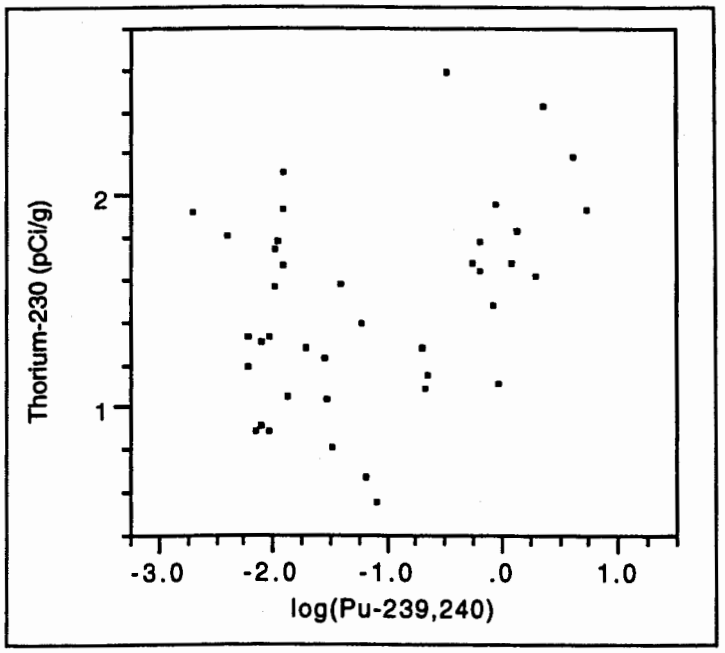

Figure E3-11b. Scatter plot for thorium-230 versus log(Pu-239,240).

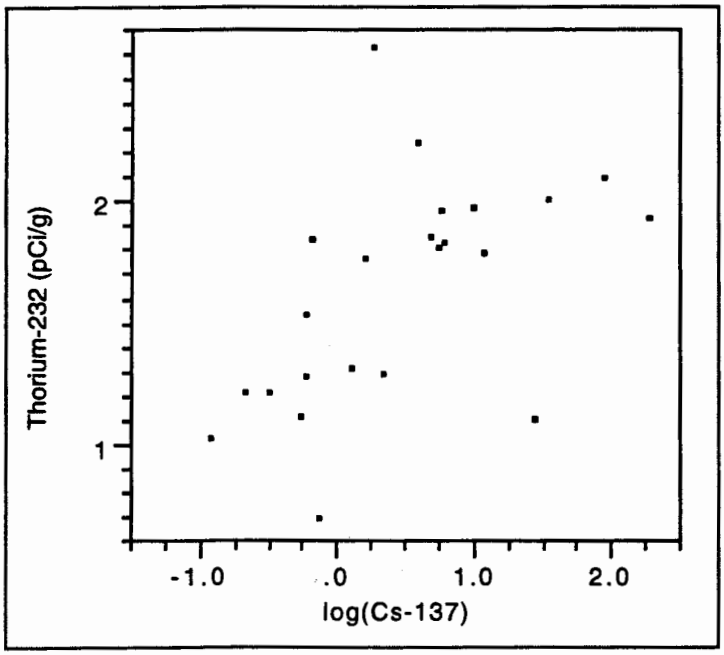

Figure E3-12a. Scatter plot for thorium-232 versus log(Cs-137).

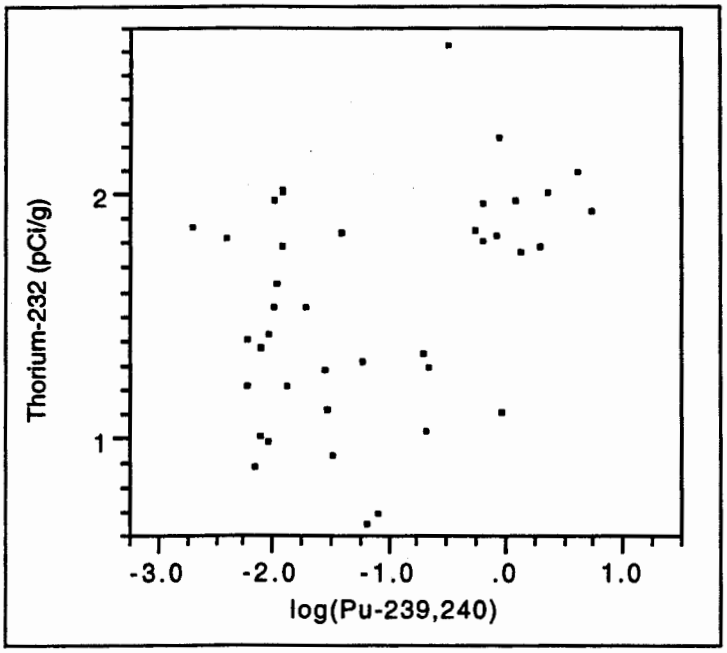

Figure E3-12b. Scatter plot for thorium-232 versus log(Pu-239,240).

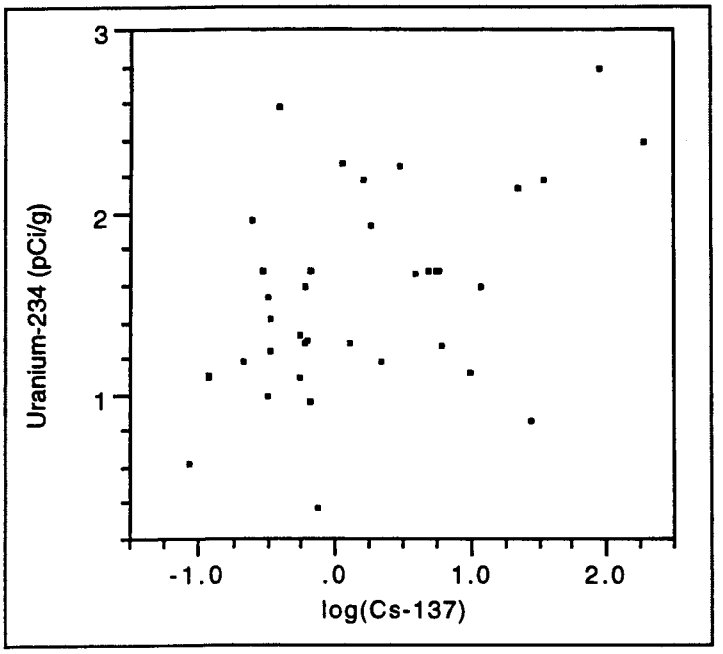

Figure E3-13a. Scatter plot for uranium-234 versus log(Cs-137).

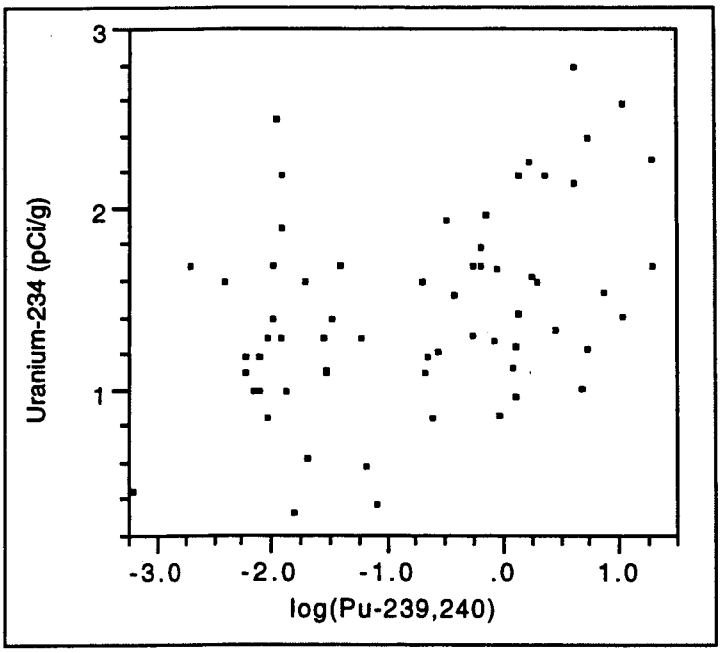

Figure E3-13b. Scatter plot for uranium-234 versus log(Pu-239,240).

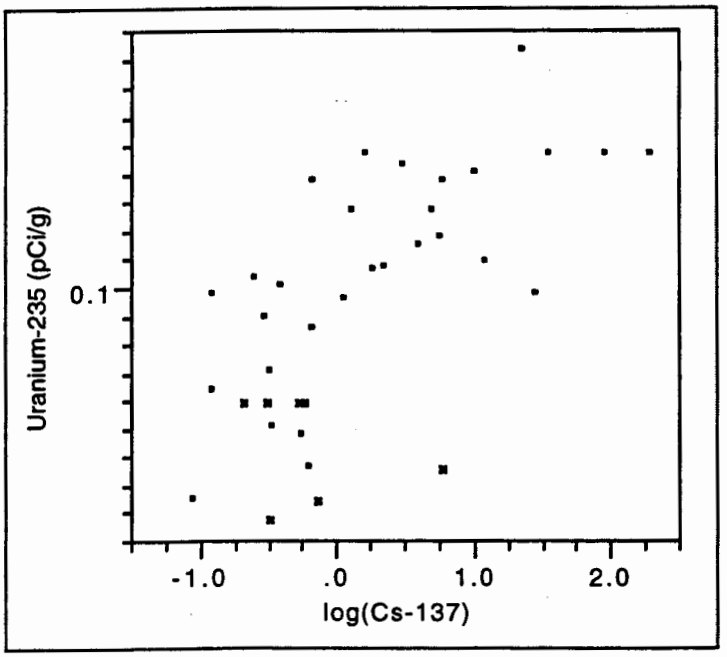

Figure E3-14a. Scatter plot for uranium-235 versus log(Cs-137).

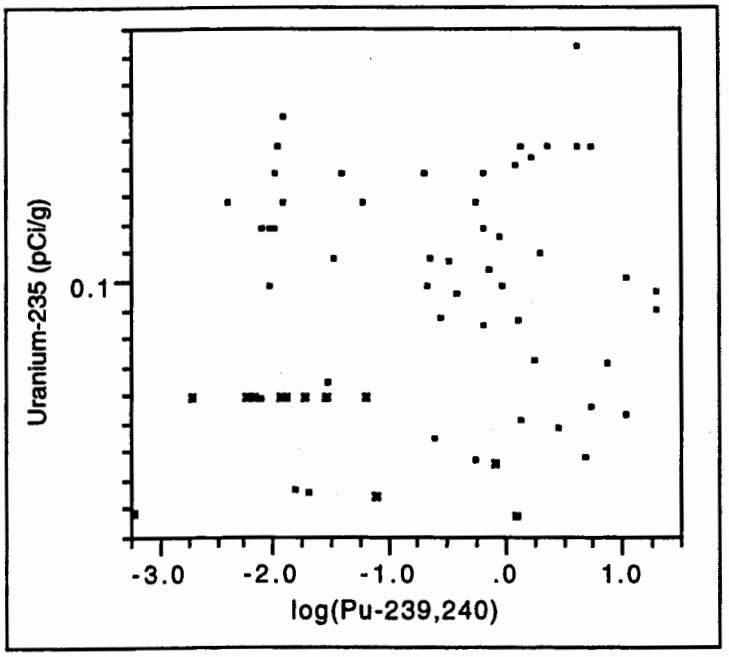

Figure E3-14b. Scatter plot for uranium-235 versus log(Pu-239,240).

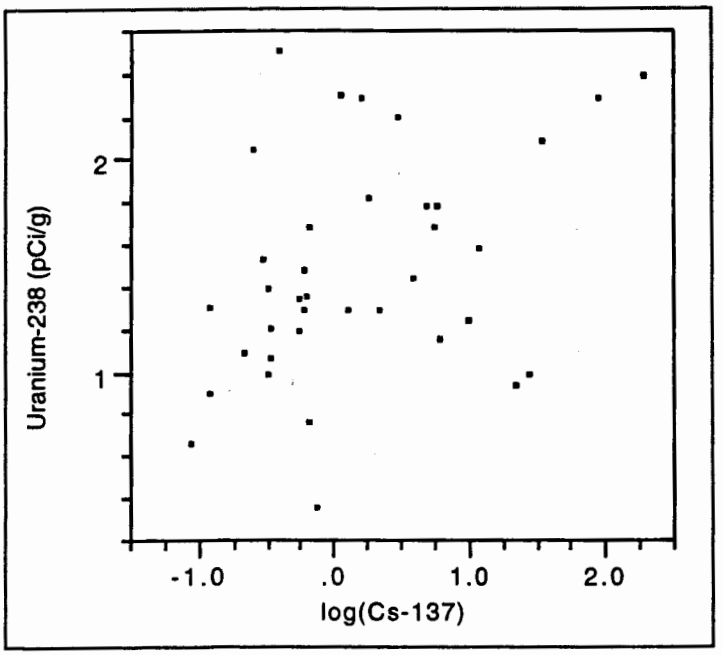

Figure E3-15a. Scatter plot for uranium-238 versus log(Cs-137).

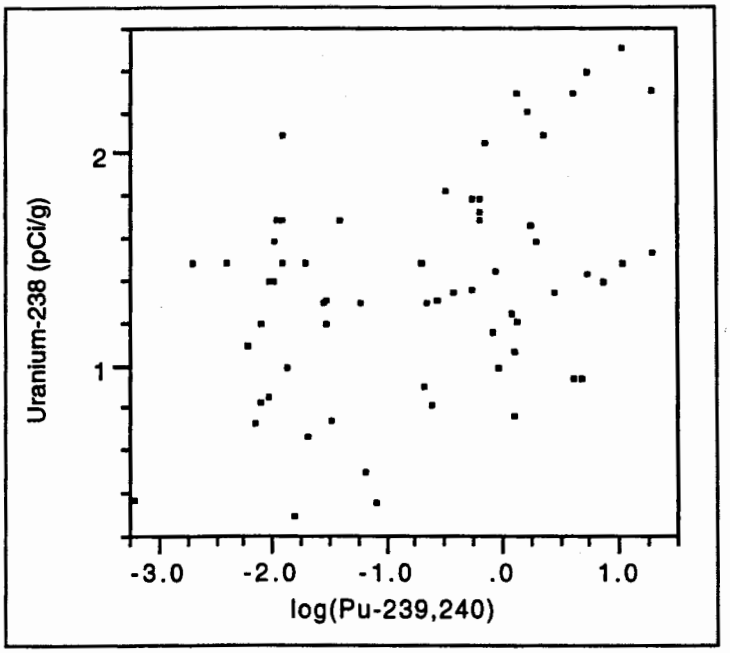

Figure E3-15b. Scatter plot for uranium-238 versus log(Pu-239,240).

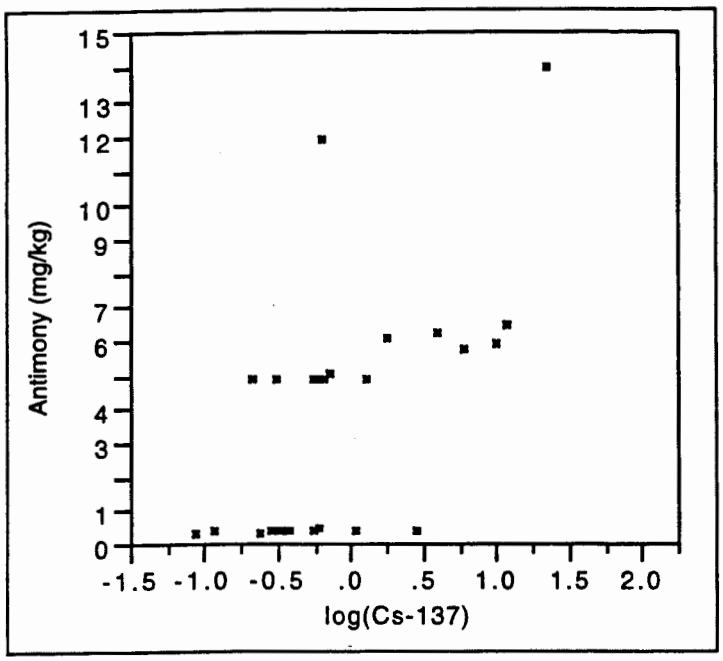

Figure E3-16a. Scatter plot for antimony versus log(Cs-137).

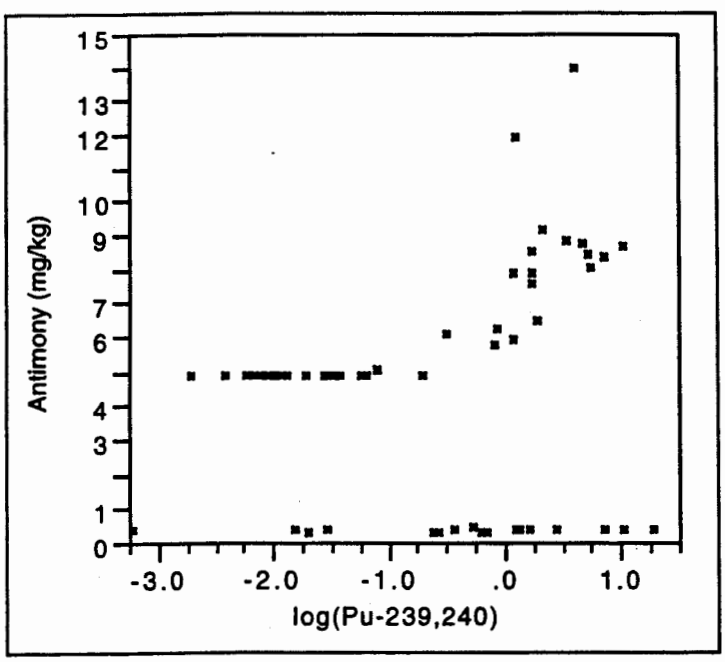

Figure E3-16b. Scatter plot for antimony versus log(Pu-239,240).

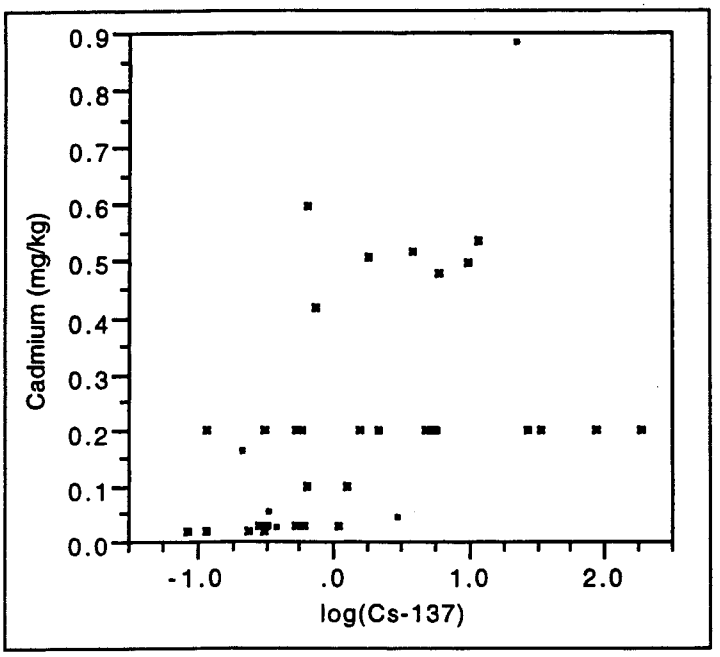

Figure E3-17a. Scatter plot for cadmium versus log(Cs-137).

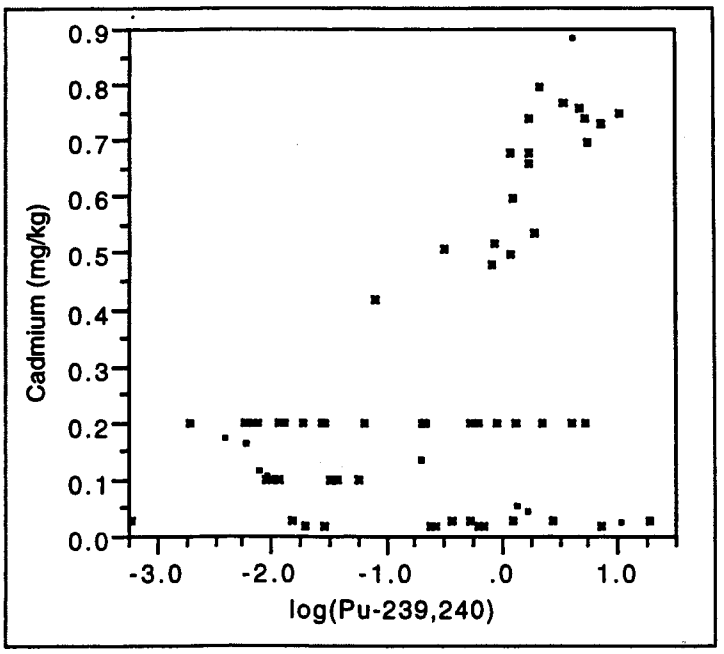

Figure E3-17b. Scatter plot for cadmium versus log(Pu-239,240).

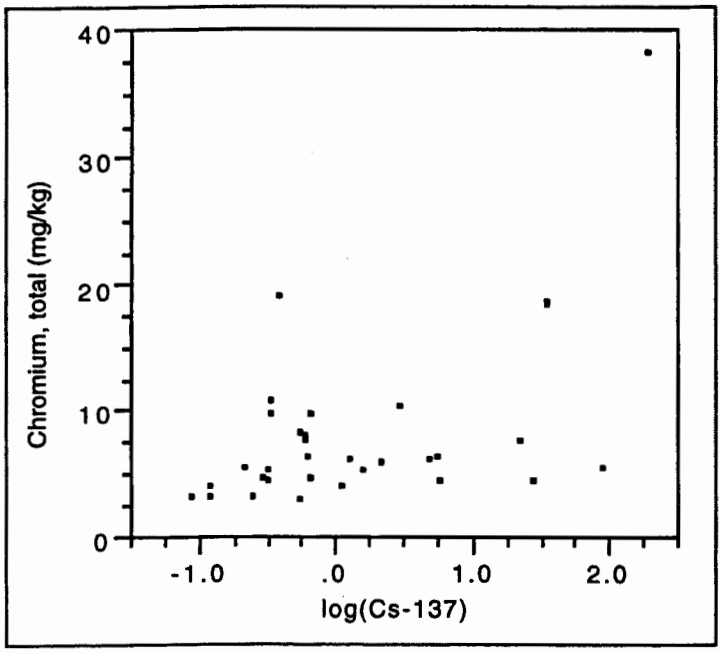

Figure E3-18a. Scatter plot for total chromium versus log(Cs-137).

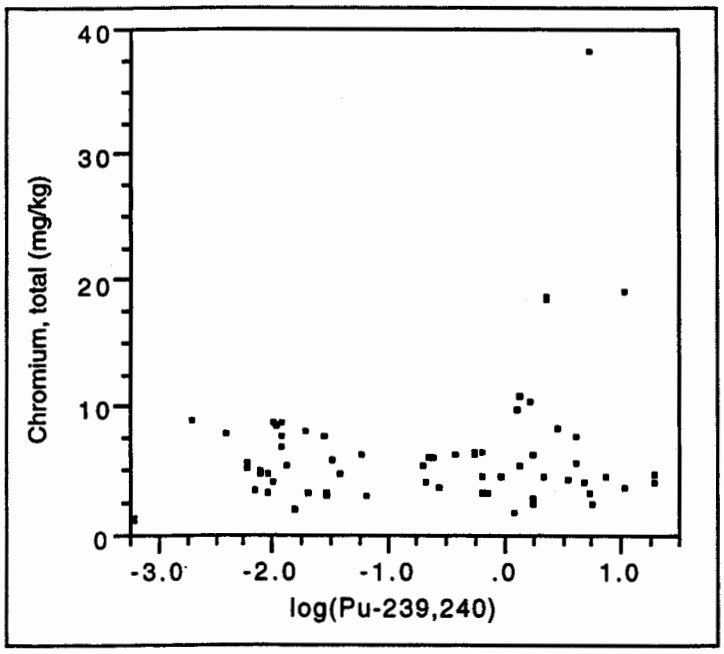

Figure E3-18a. Scatter plot for total chromium versus log(Pu-239,240).

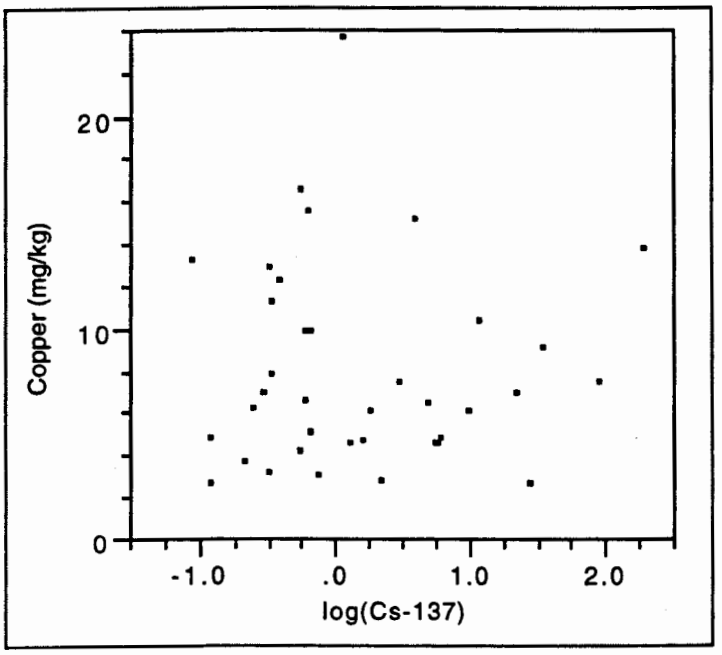

Figure E3-19a. Scatter plot for copper versus log(Cs-137).

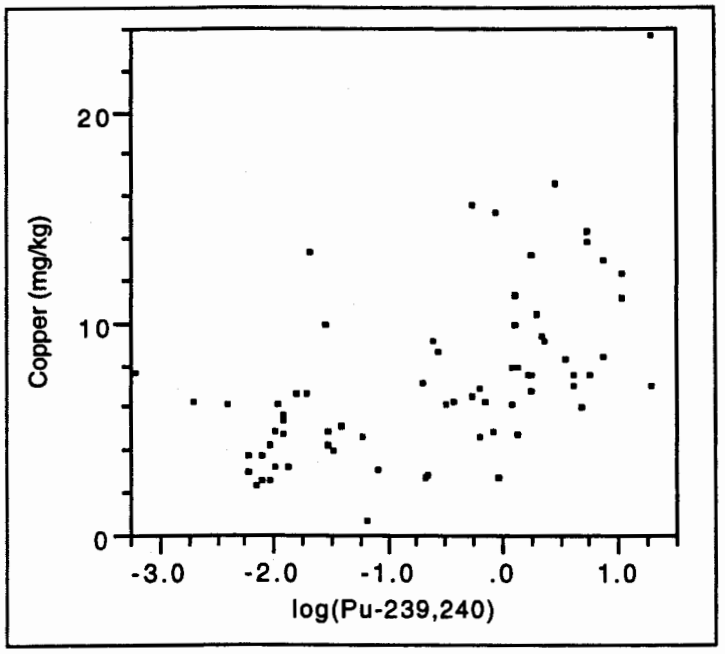

Figure E3-19b. Scatter plot for copper versus log(Pu-239,240).

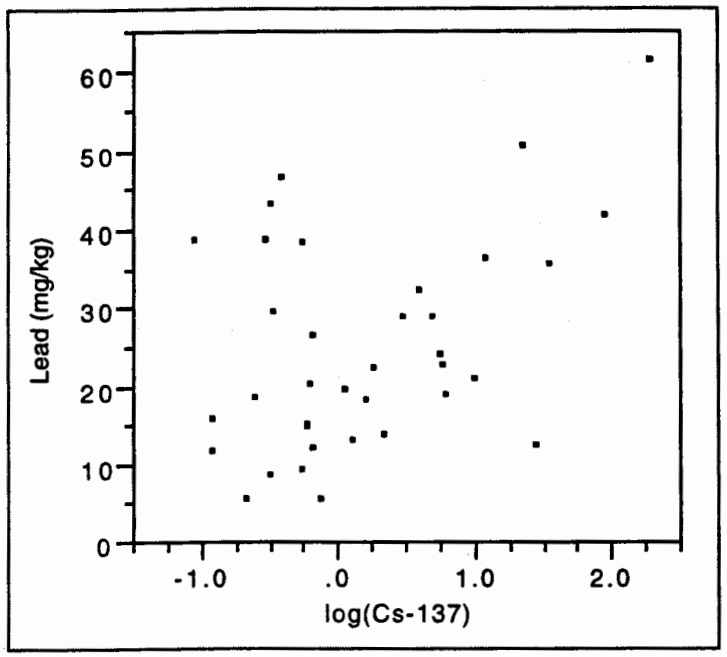

Figure E3-20a. Scatter plot for lead versus log(Cs-137).

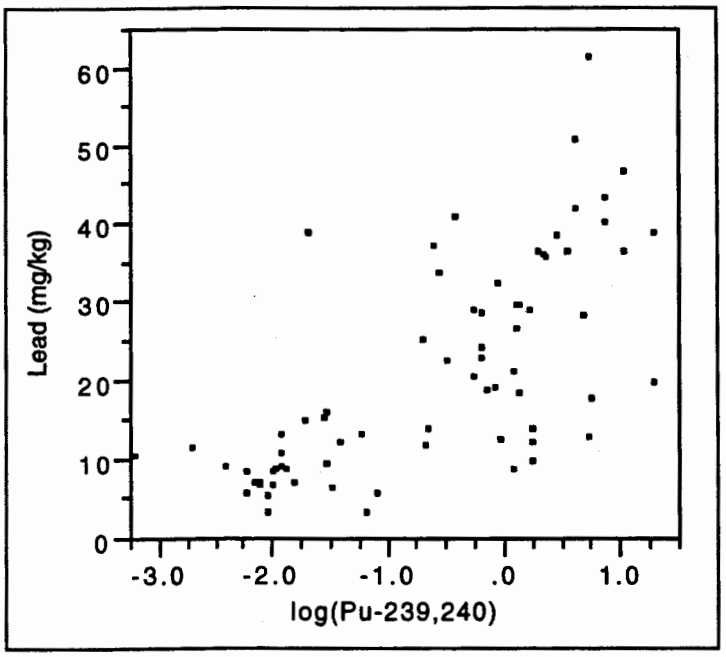

Figure E3-20b. Scatter plot for lead versus log(Pu-239,240).

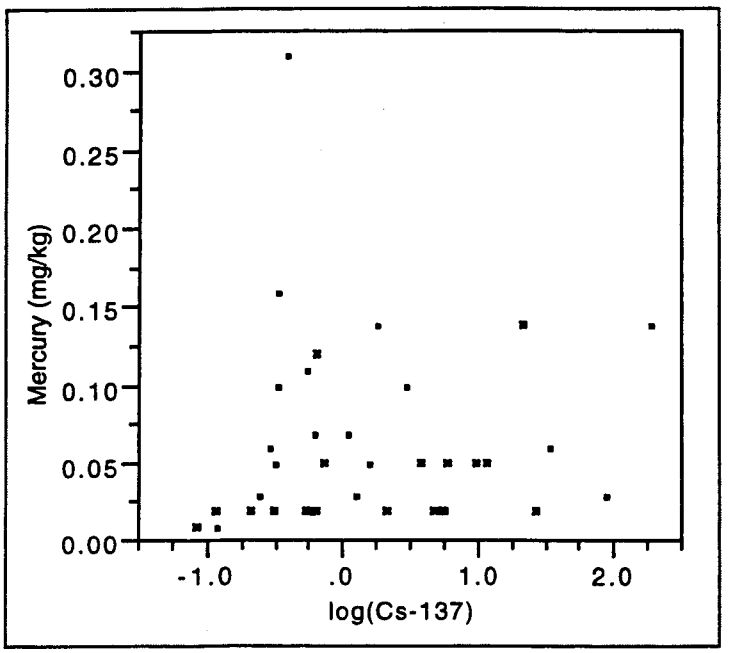

Figure E3-21a. Scatter plot for mercury versus log(Cs-137).

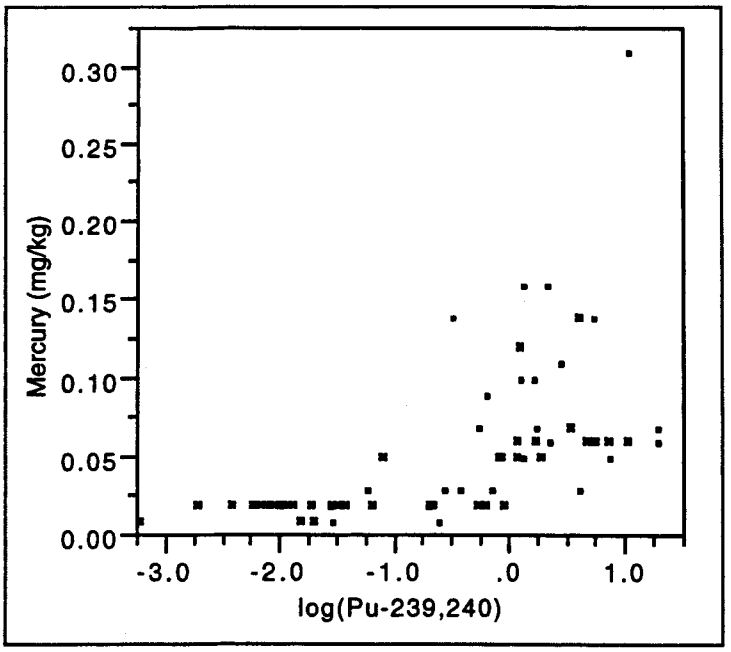

Figure E3-21b. Scatter plot for mercury versus log(Pu-239,240).

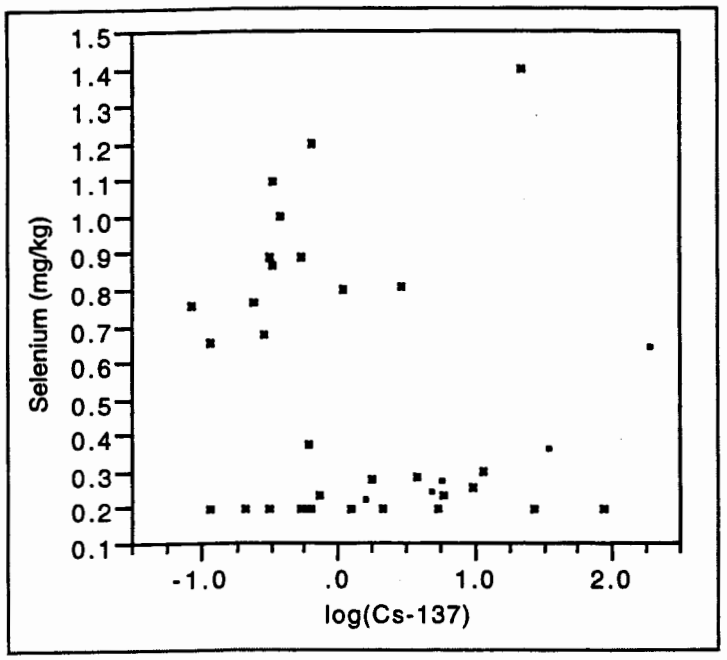

Figure E3-22a. Scatter plot for selenium versus log(Cs-137).

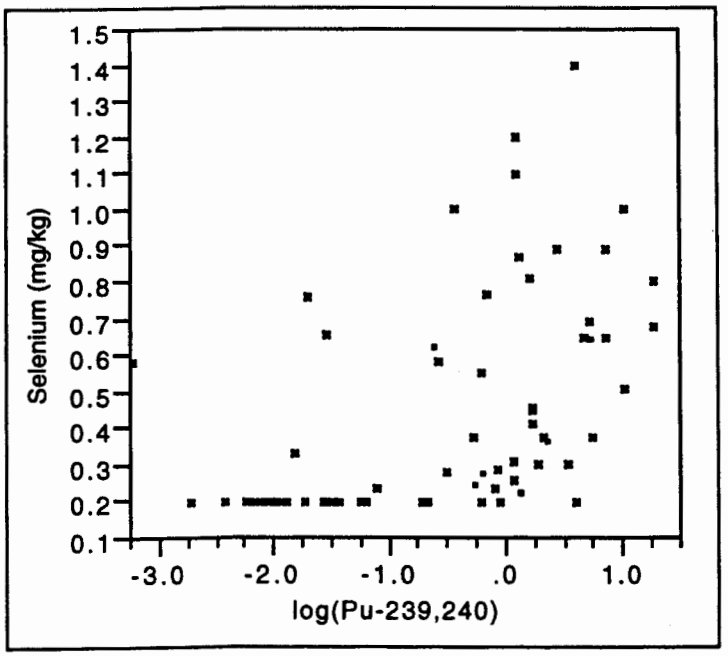

Figure E3-22b. Scatter plot for selenium versus log(Pu-239,240).

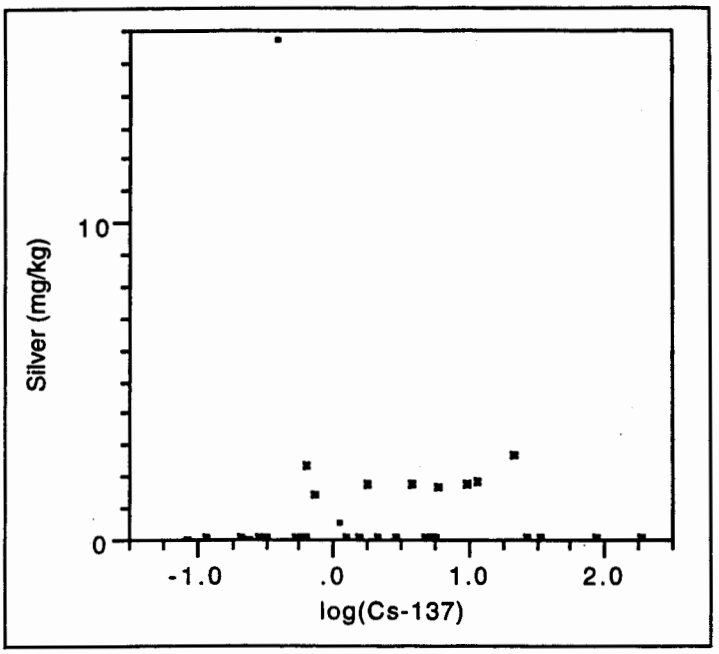

Figure E3-23a. Scatter plot for silver versus log(Cs-137).

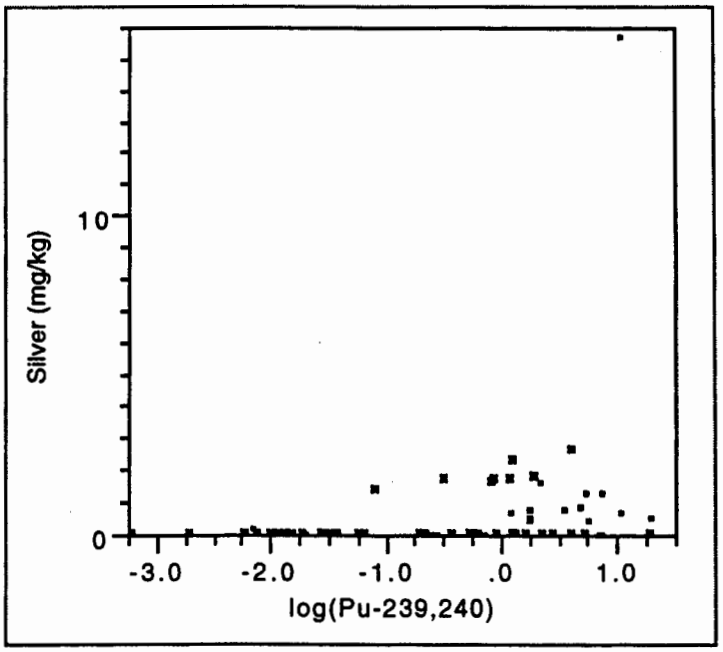

Figure E3-23b. Scatter plot for silver versus log(Pu-239,240).

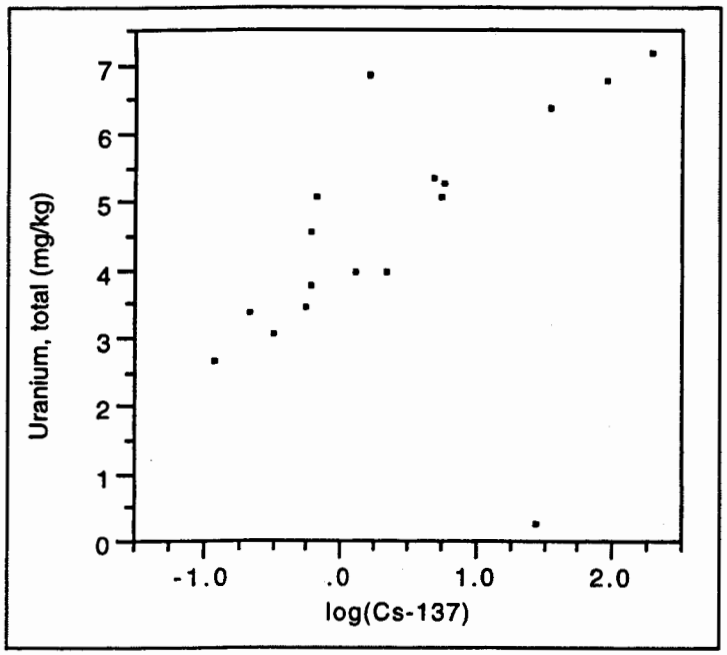

Figure E3-24a. Scatter plot for total uranium versus log(Cs-137).

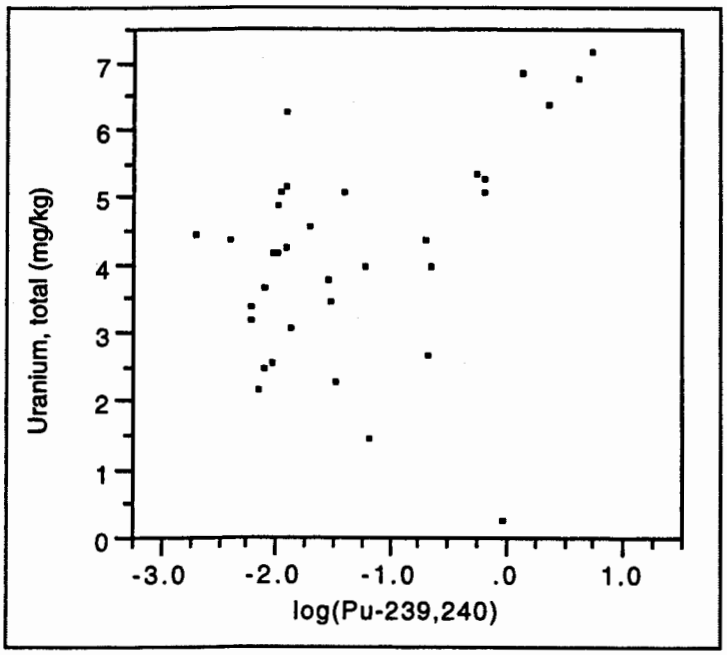

Figure E3-24b. Scatter plot for total uranium versus log(Pu-239,240).

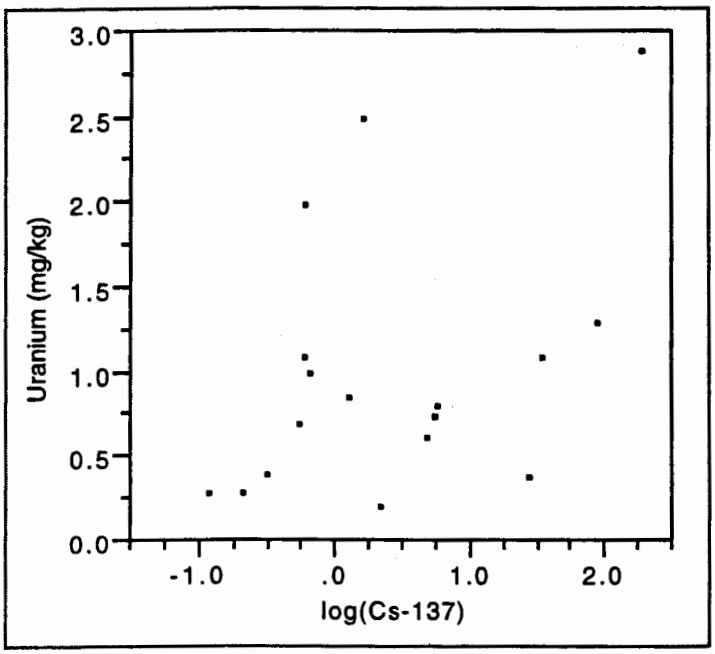

Figure E3-25a. Scatter plot for uranium versus log(Cs-137).

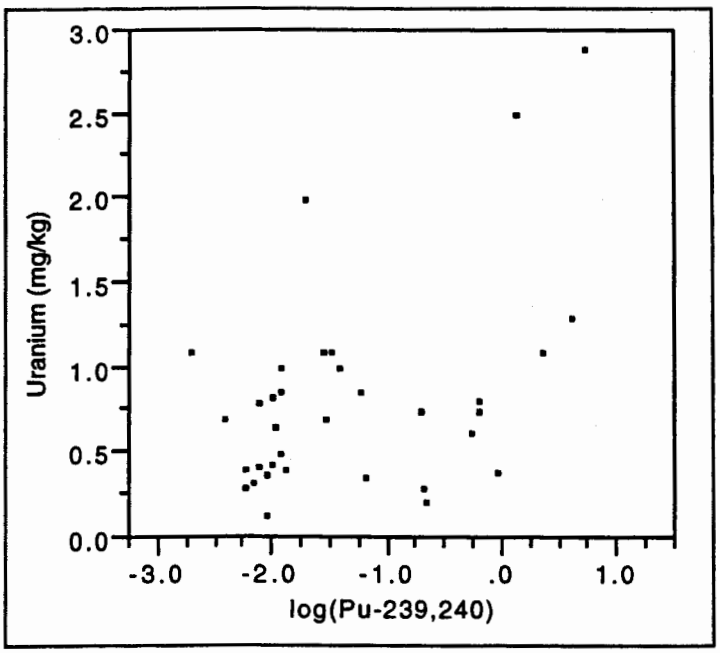

Figure E3-25b. Scatter plot for uranium versus log(Pu-239,240).

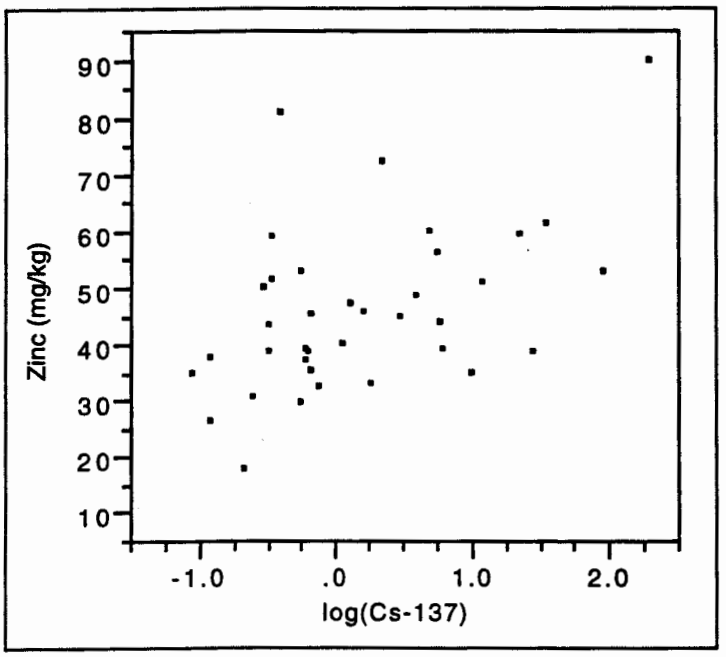

Figure E3-26a. Scatter plot for zinc versus log(Cs-137).

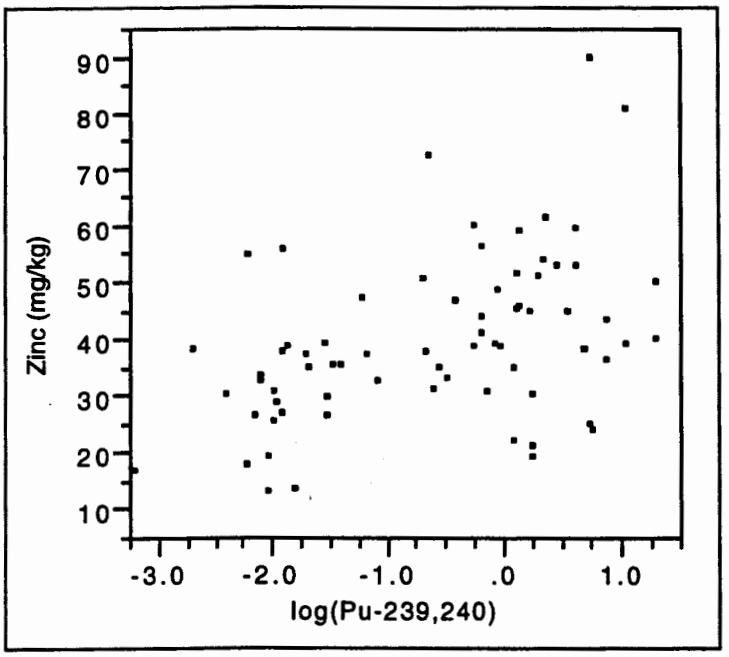

Figure E3-26b. Scatter plot for zinc versus log(Pu-239,240).

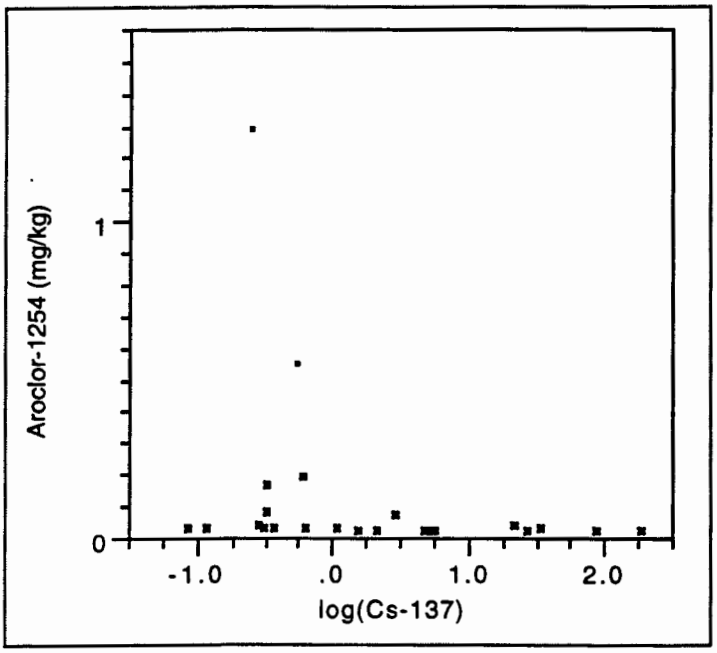

Figure E3-27a. Scatter plot for Aroclor-1254 versus log(Cs-137).

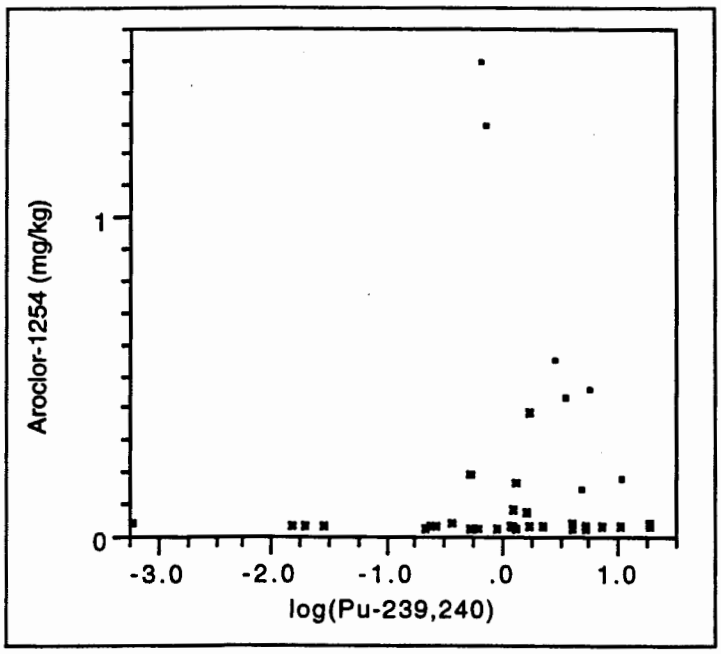

Figure E3-27b. Scatter plot for Aroclor-1254 versus log(Pu-239,240).

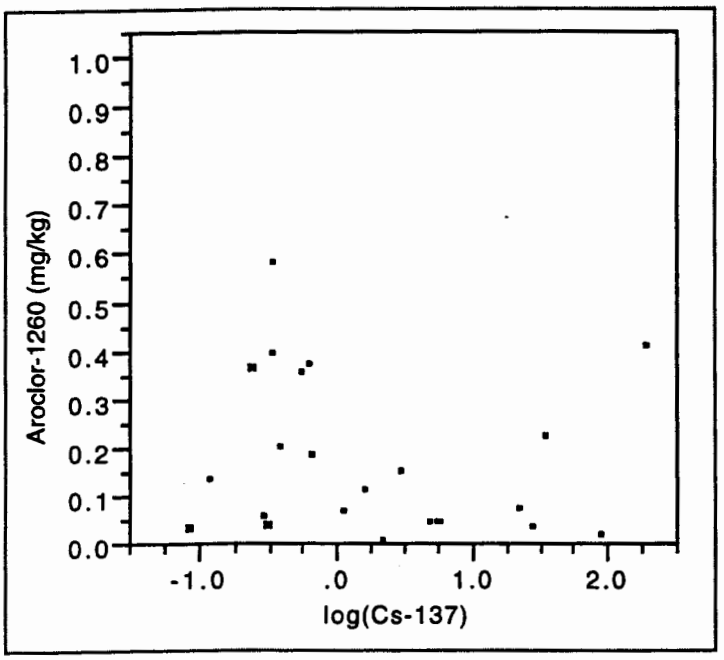

Figure E3-28a. Scatter plot for Aroclor-1260 versus log(Cs-137).

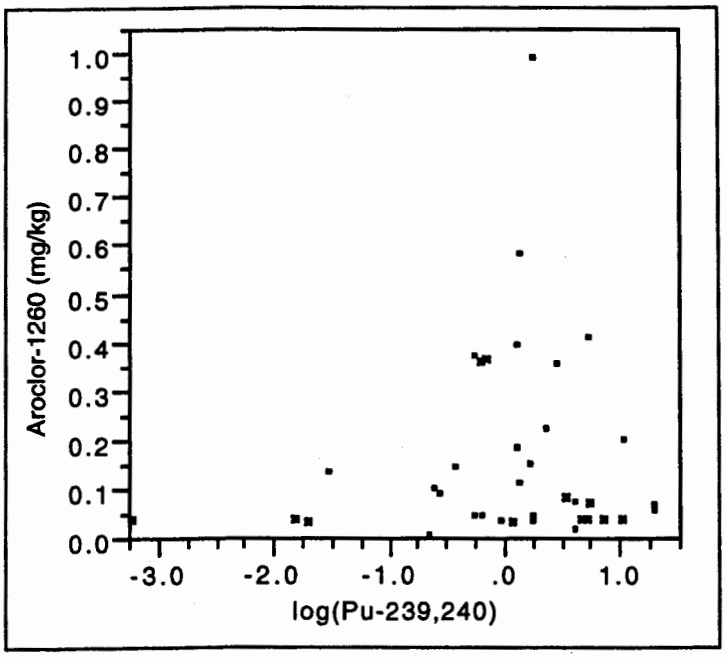

Figure E3-28b. Scatter plot for Aroclor-1260 versus log(Pu-239,240).

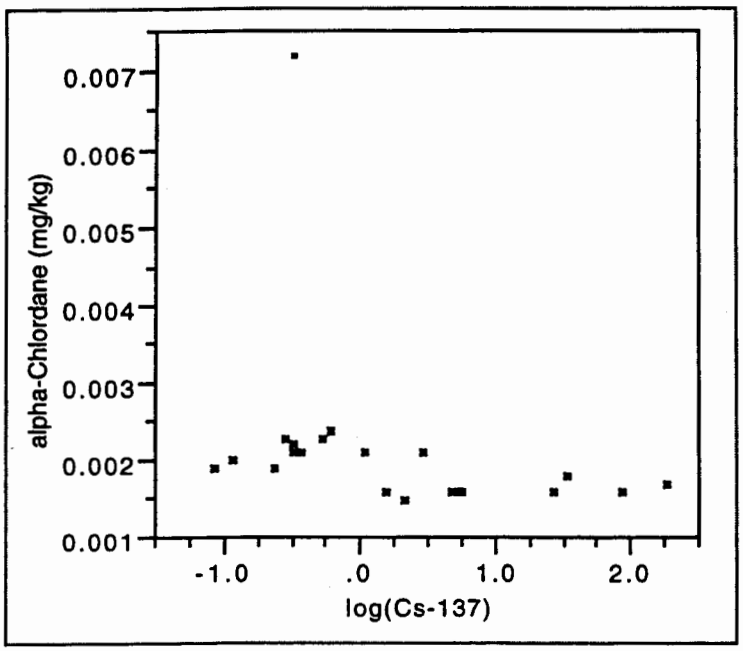

Figure E3-29a. Scatter plot for α-chlordane versus log(Cs-137).

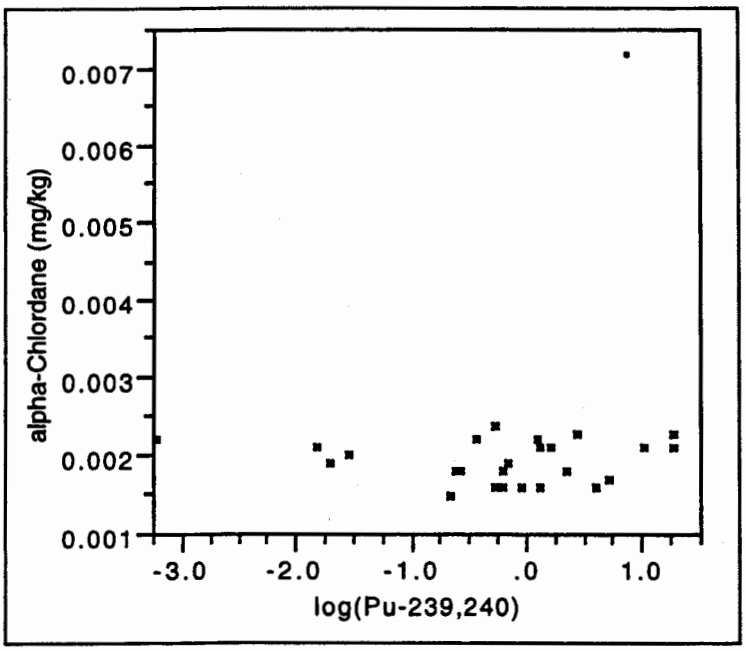

Figure E3-29b. Scatter plot for α-chlordane versus log(Pu-239,240).

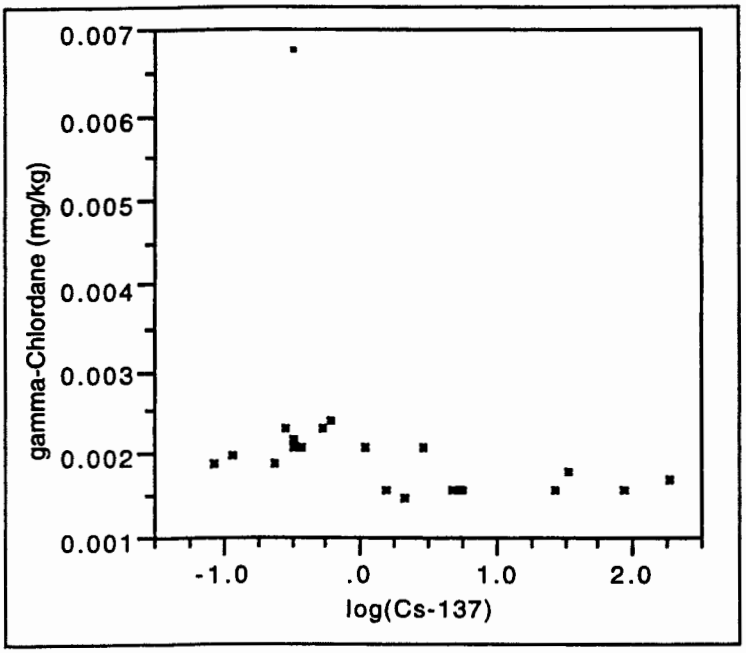

Figure E3-30a. Scatter plot for γ-chlordane versus log(Cs-137).

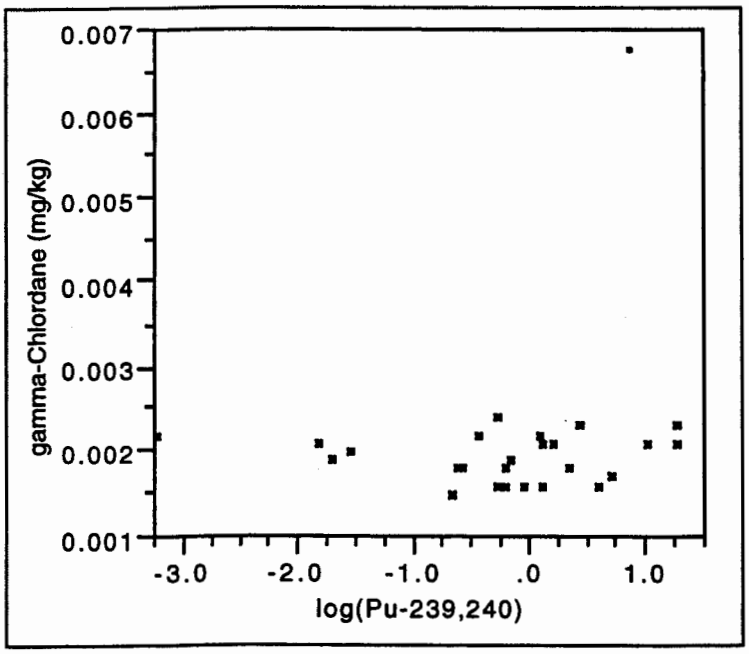

Figure E3-30b. Scatter plot for γ-chlordane versus log(Pu-239,240).

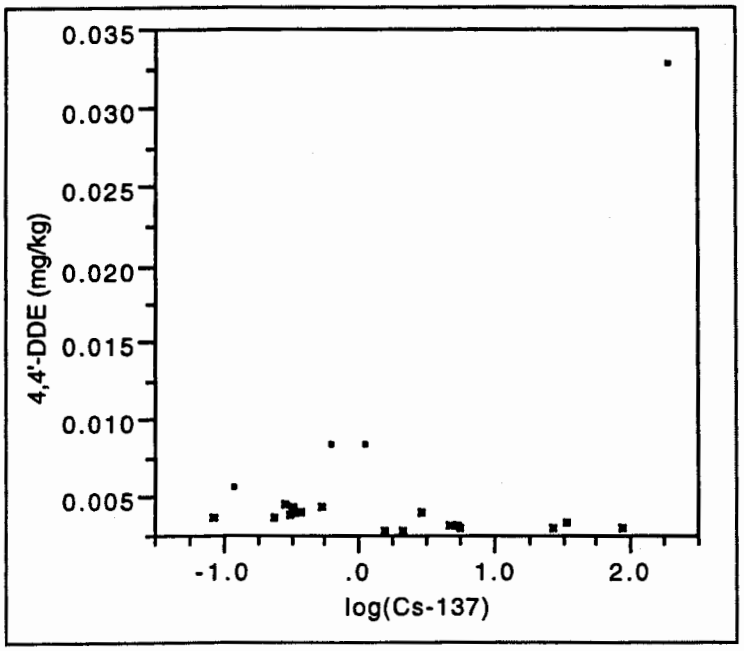

Figure E3-31a. Scatter plot for 4,4'-DDE versus log(Cs-137).

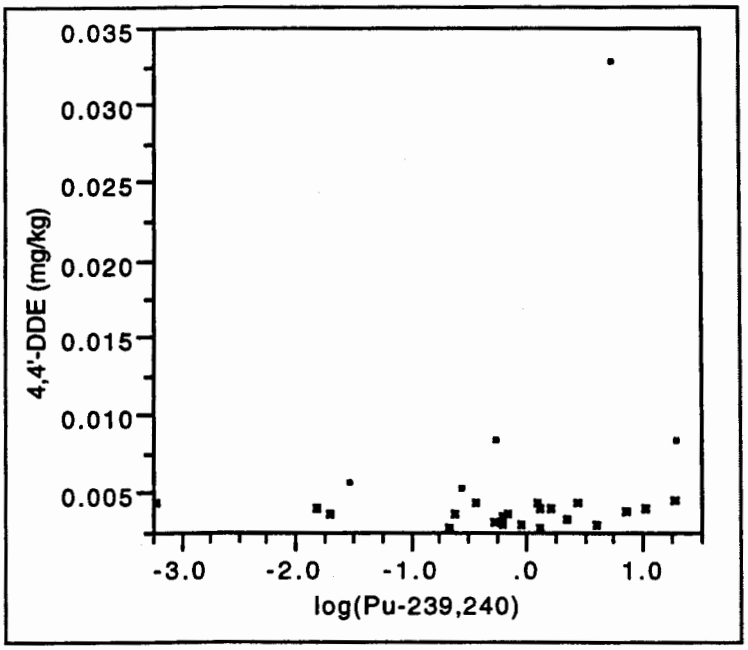

Figure E3-31b. Scatter plot for 4,4'-DDE versus log(Pu-239,240).

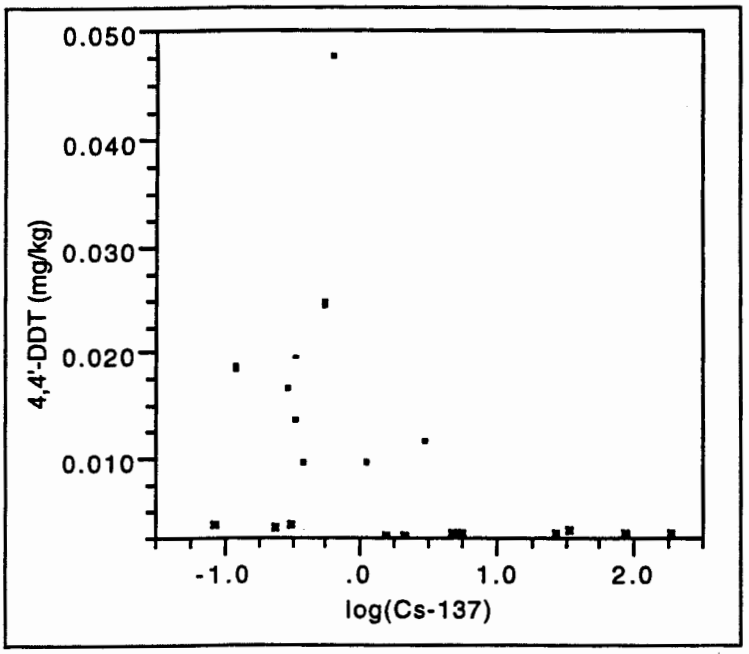

Figure E3-32a. Scatter plot for 4,4'-DDT versus log(Cs-137).

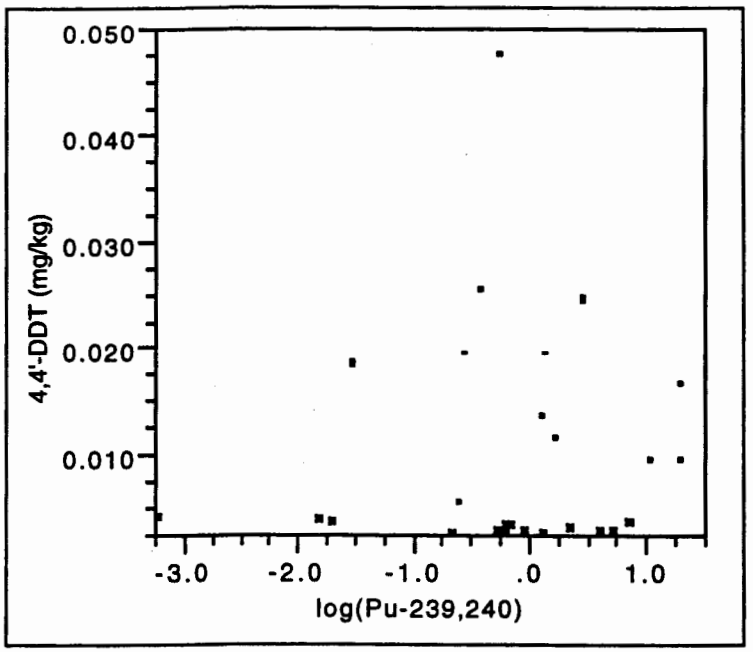

Figure E3-32b. Scatter plot for 4,4'-DDT versus log(Pu-239,240).

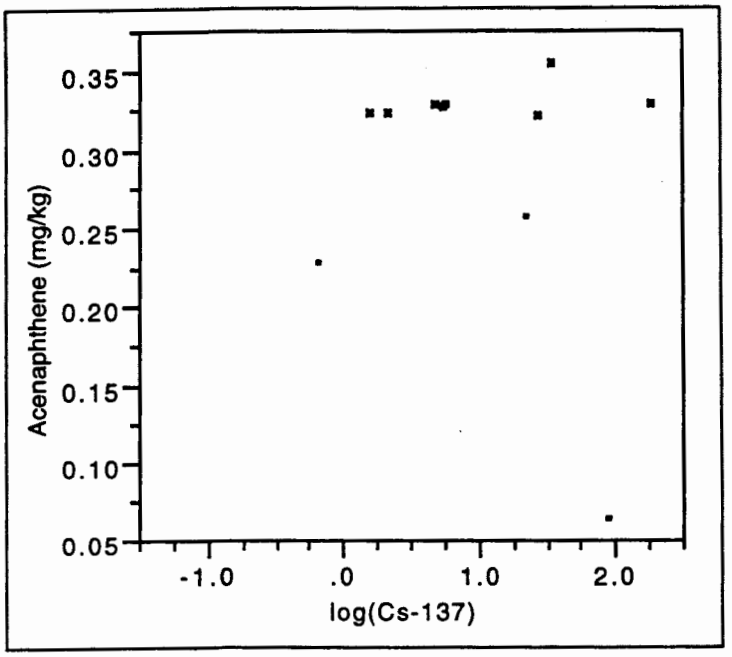

Figure E3-33a. Scatter plot for acenaphthene versus log(Cs-137).

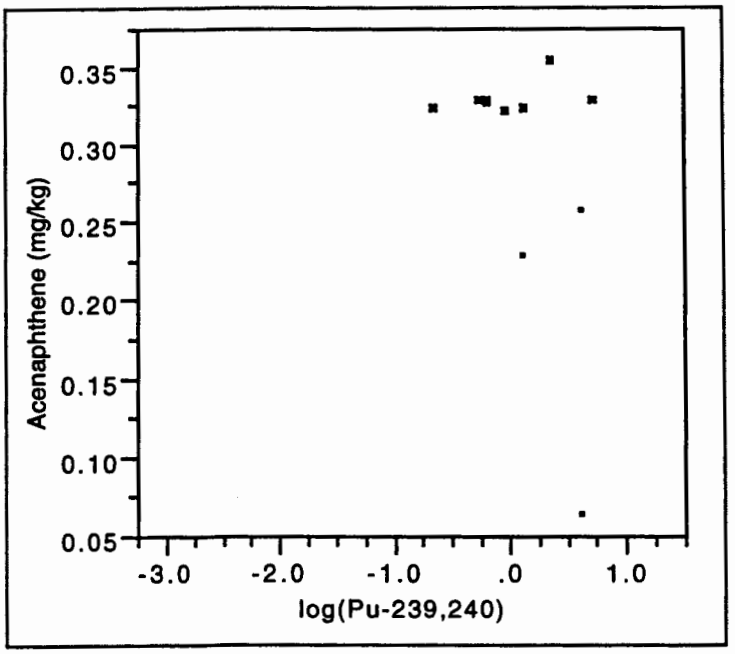

Figure E3-33b. Scatter plot for acenaphthene versus log(Pu-239,240).

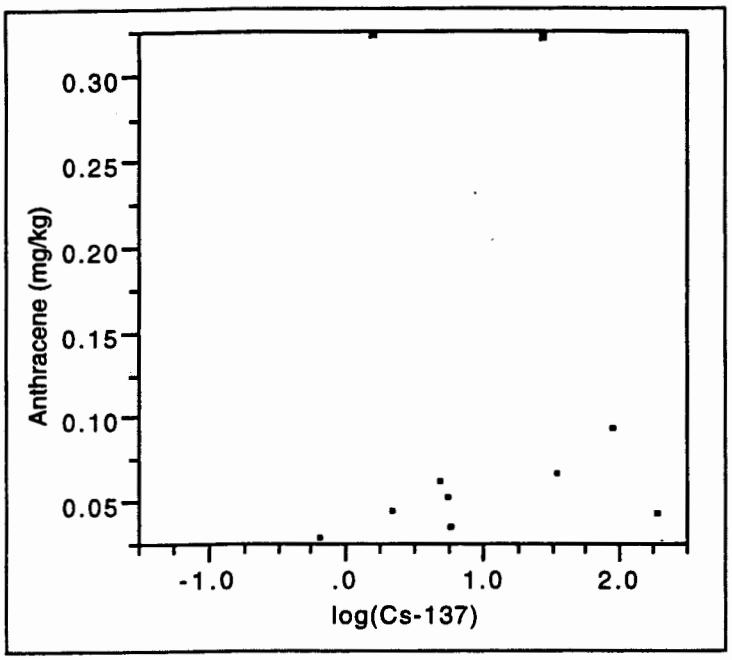

Figure E3-34a. Scatter plot for anthracene versus log(Cs-137).

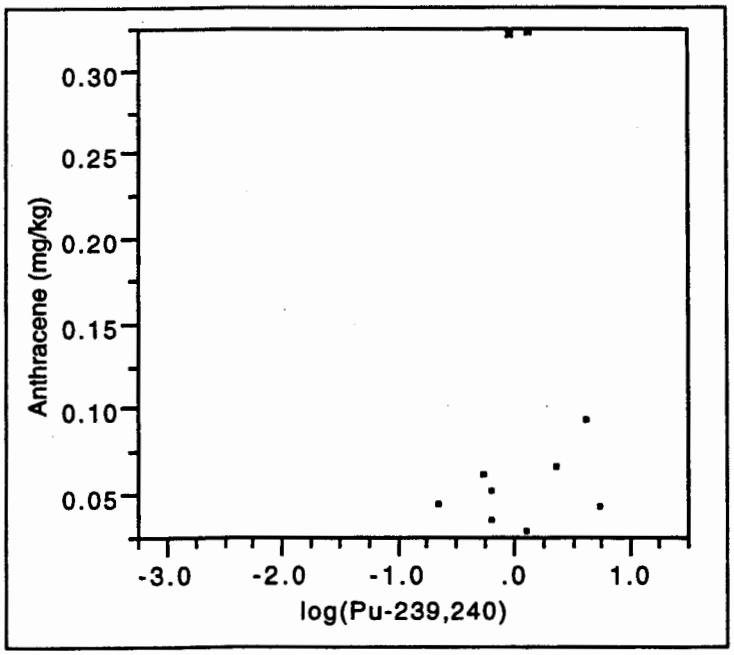

Figure E3-34b. Scatter plot for anthracene versus log(Pu-239,240).

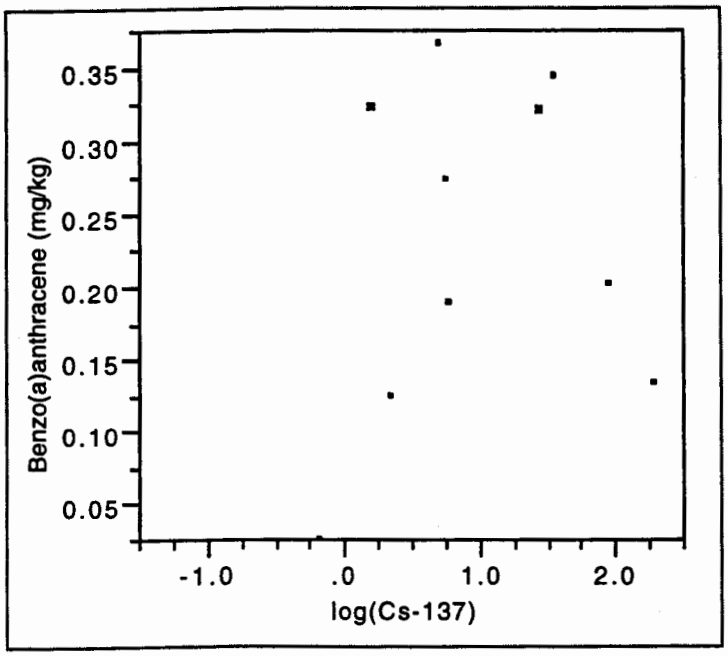

Figure E3-35a. Scatter plot for benz(a)anthracene versus log(Cs-137).

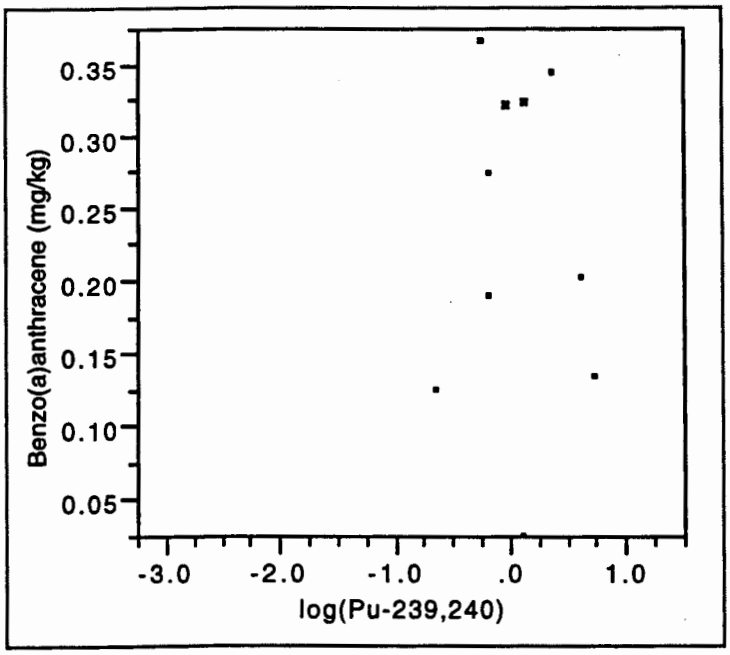

Figure E3-35b. Scatter plot for benz(a)anthracene versus log(Pu-239,240).

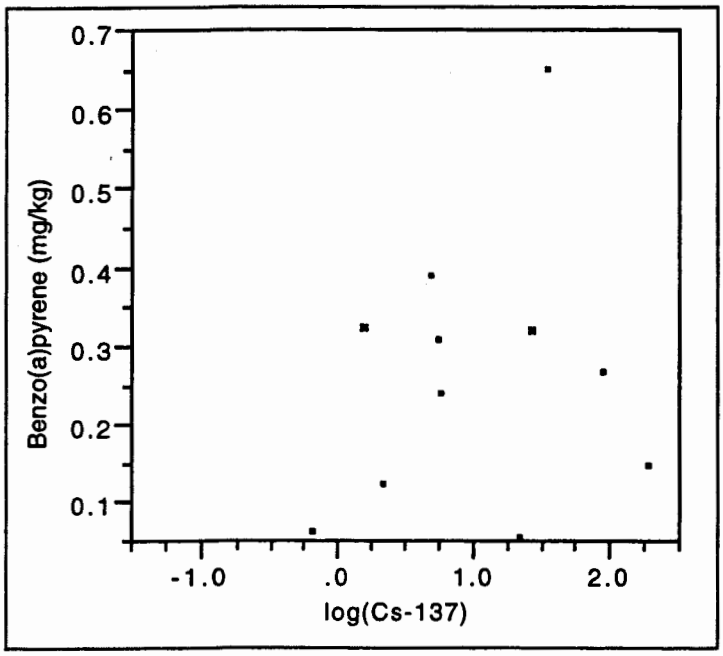

Figure E3-36a. Scatter plot for benzo(a)pyrene versus log(Cs-137).

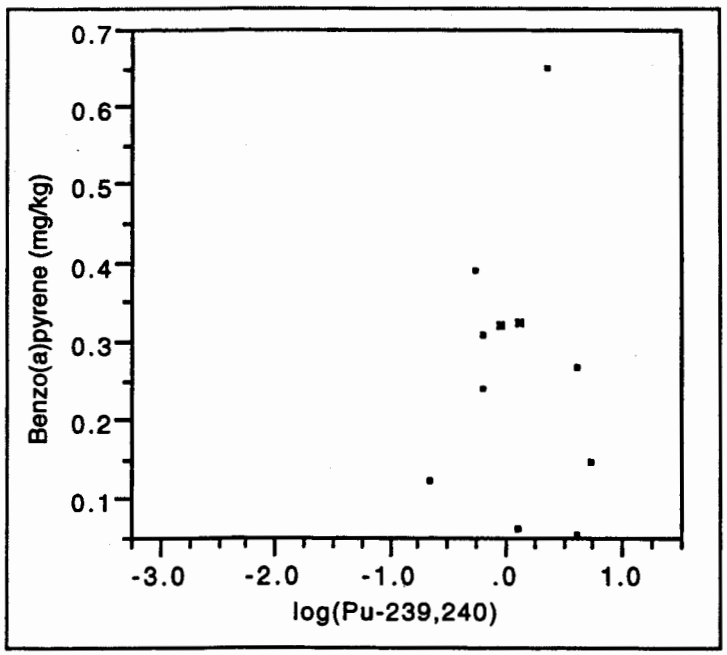

Figure E3-36b. Scatter plot for benzo(a)pyrene versus log(Pu-239,240).

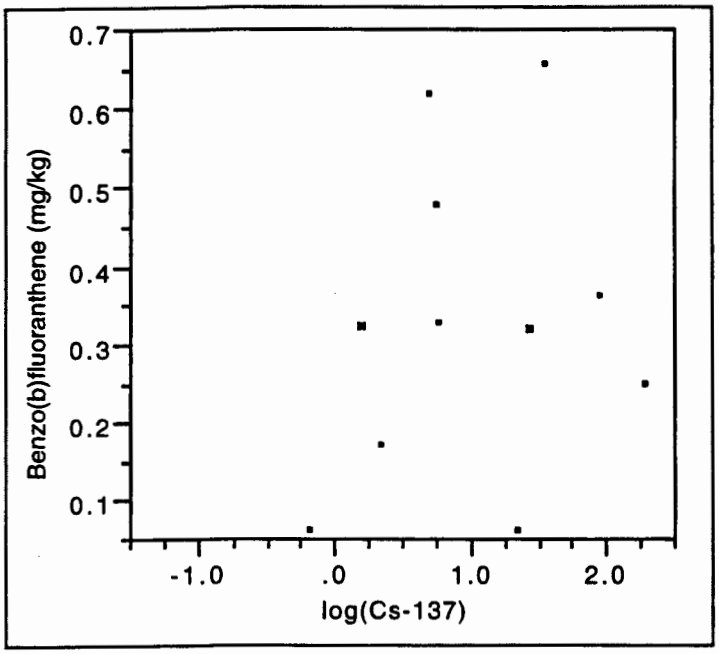

Figure E3-37a. Scatter plot for benzo(b)fluoranthene versus log(Cs-137).

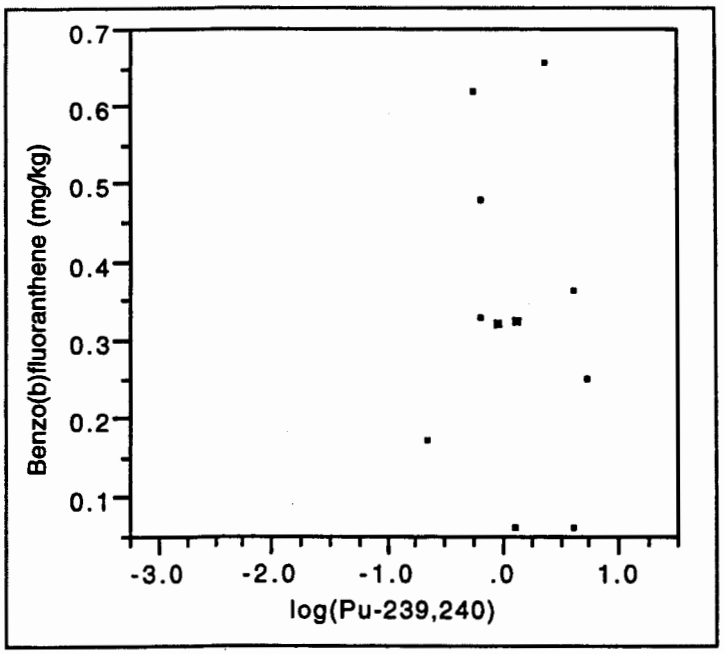

Figure E3-37b. Scatter plot for benzo(b)fluoranthene versus log(Pu-239,240).

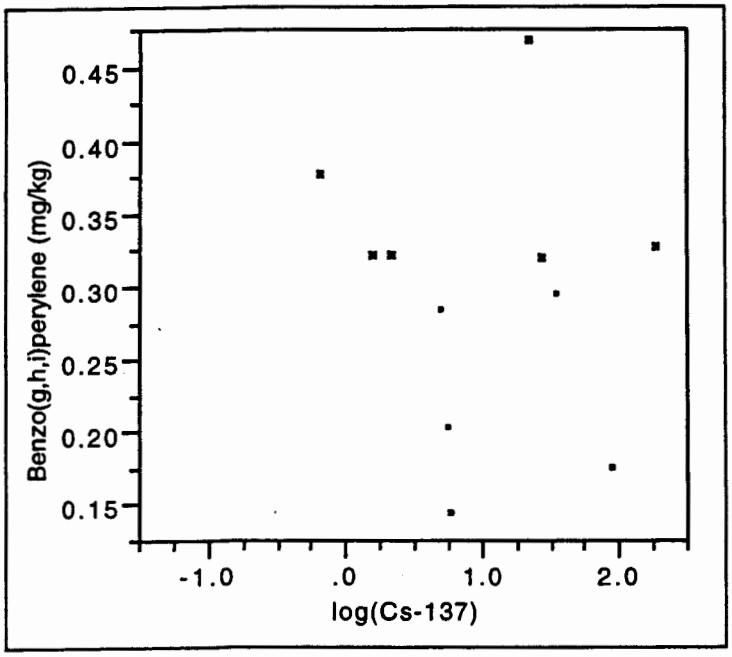

Figure E3-38a. Scatter plot for benzo(g,h,i)perylene versus log(Cs-137).

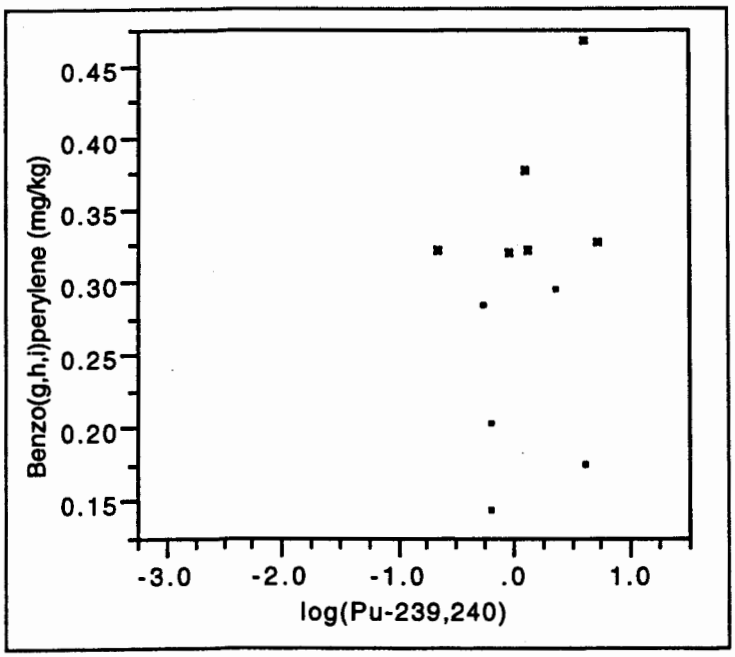

Figure E3-38b. Scatter plot for benzo(g,h,i)perylene versus log(Pu-239,240).

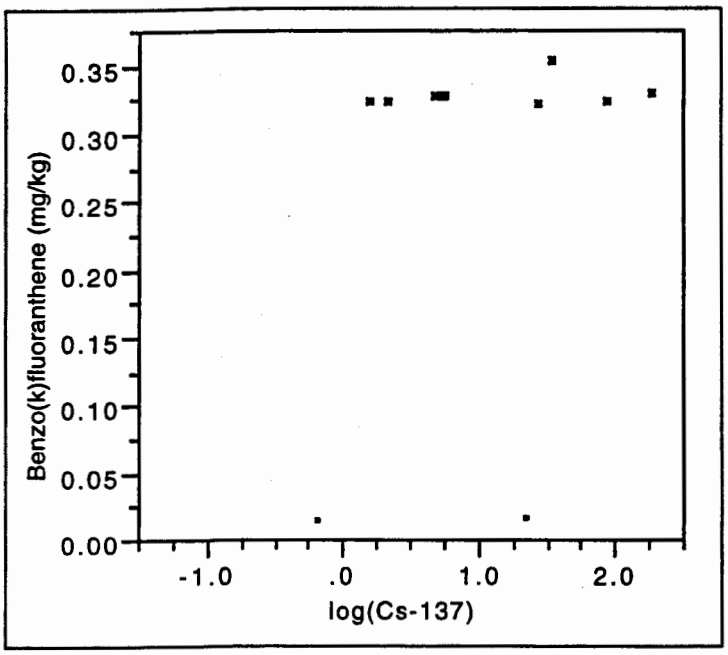

Figure E3-39a. Scatter plot for benzo(k)fluoranthene versus log(Cs-137).

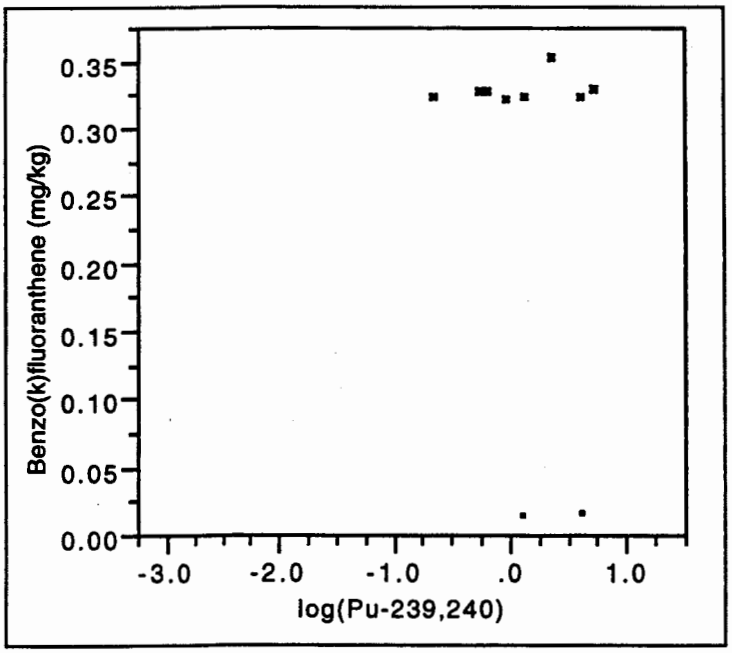

Figure E3-39b. Scatter plot for benzo(k)fluoranthene versus log(Pu-239,240).

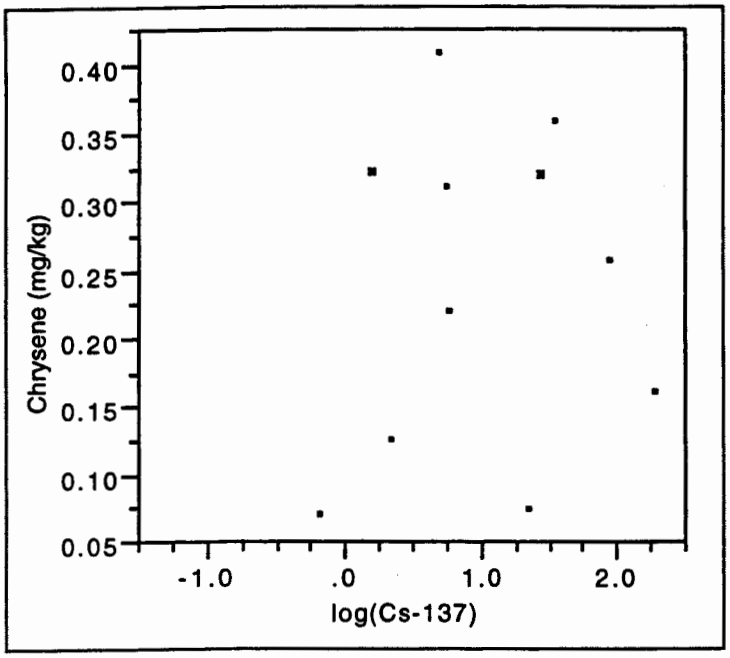

Figure E3-40a. Scatter plot for chrysene versus log(Cs-137).

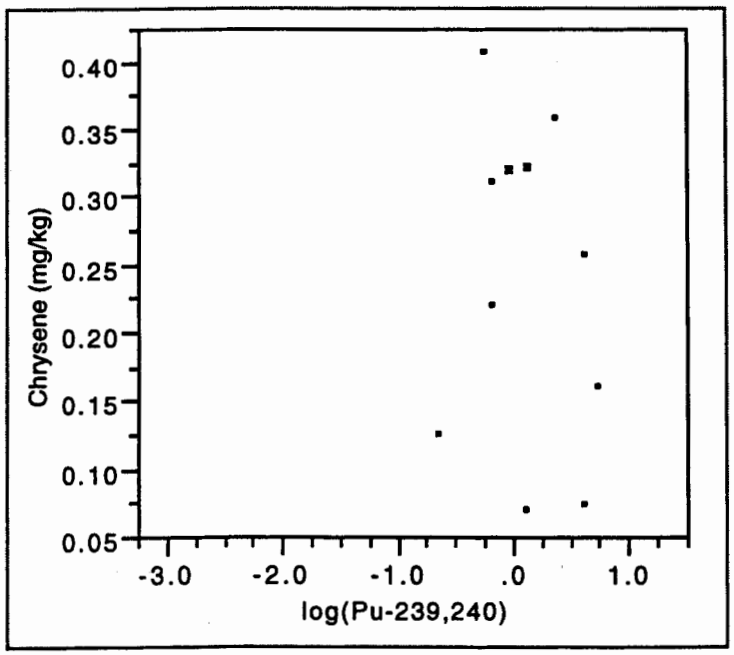

Figure E3-40b. Scatter plot for chrysene versus log(Pu-239,240).

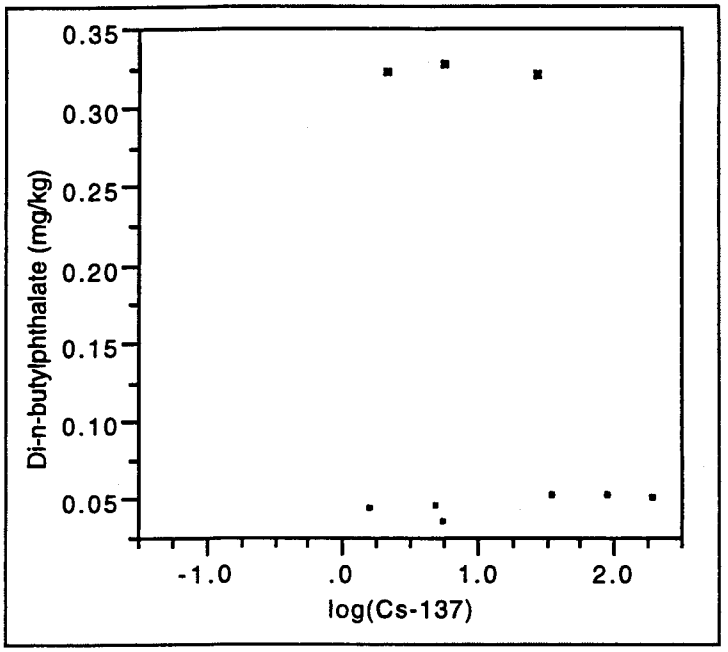

Figure E3-41a. Scatter plot for di-n-butylphthalate versus log(Cs-137).

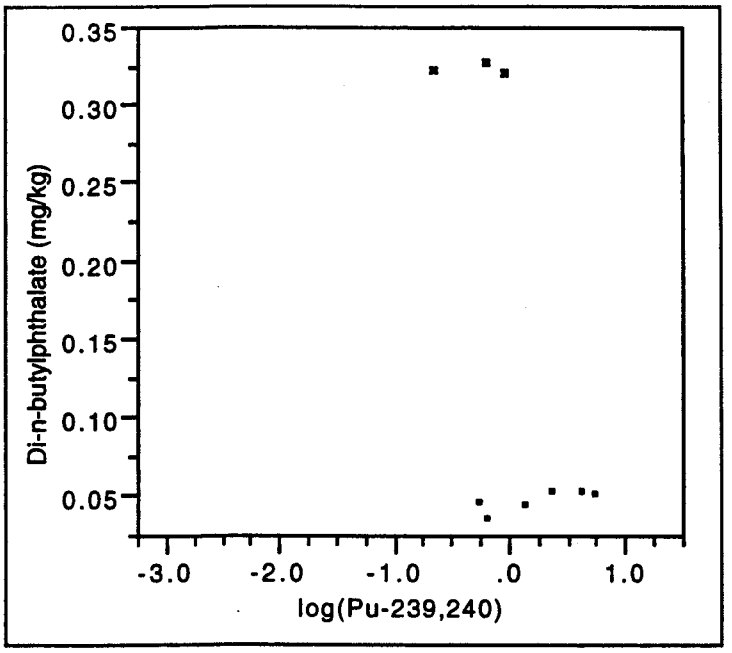

Figure E3-41b. Scatter plot for di-n-butylphthalate versus log(Pu-239,240).

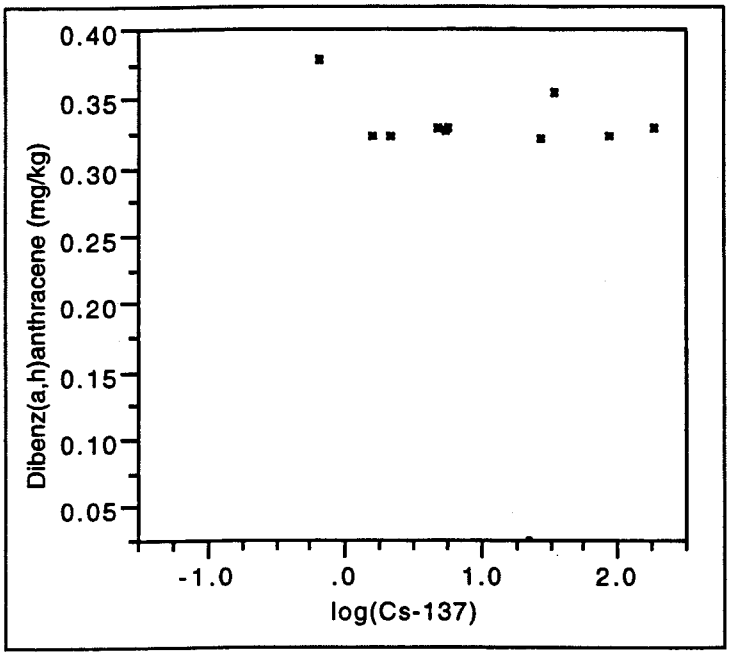

Figure E3-42a. Scatter plot for dibenz(a,h)anthracene versus log(Cs-137).

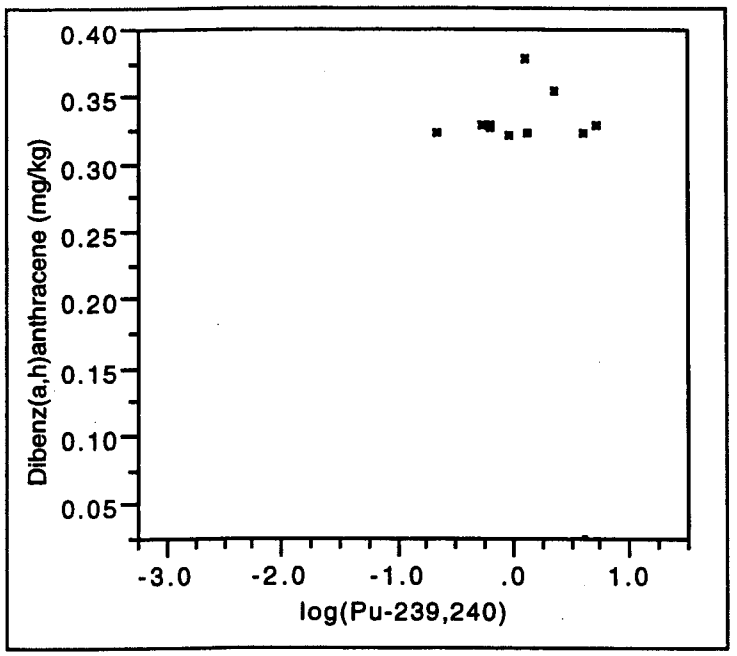

Figure E3-42b. Scatter plot for dibenz(a,h)anthracene versus log(Pu-239,240.

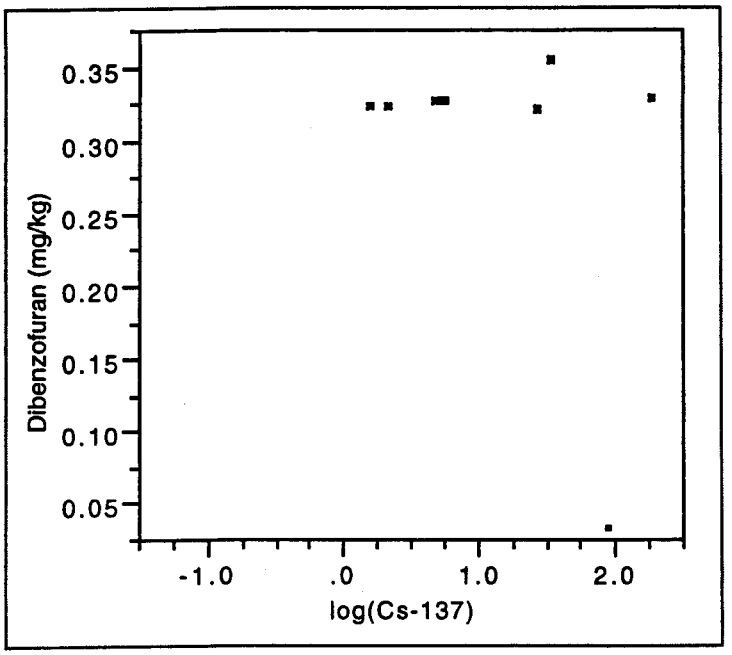

Figure E3-43a. Scatter plot for dibenzofuran versus log(Cs-137).

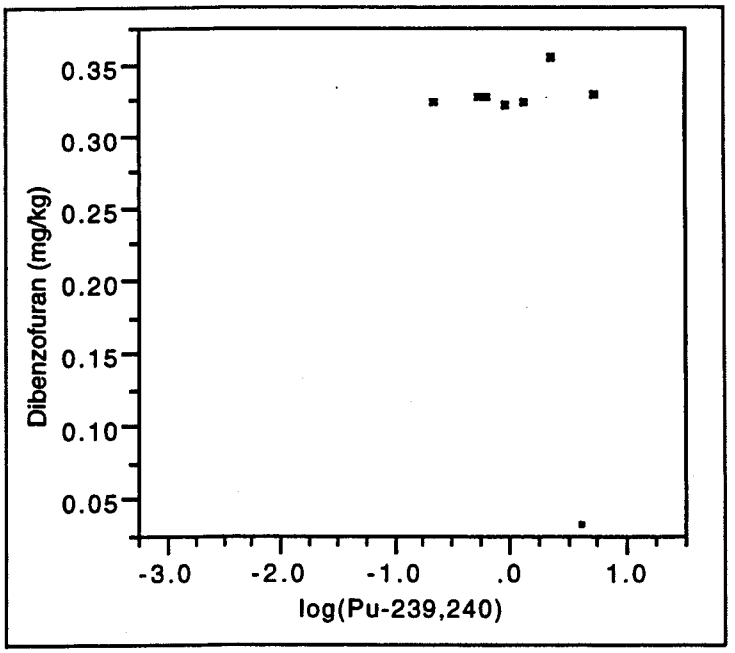

Figure E3-43b. Scatter plot for dibenzofuran versus log(Pu-239,240).

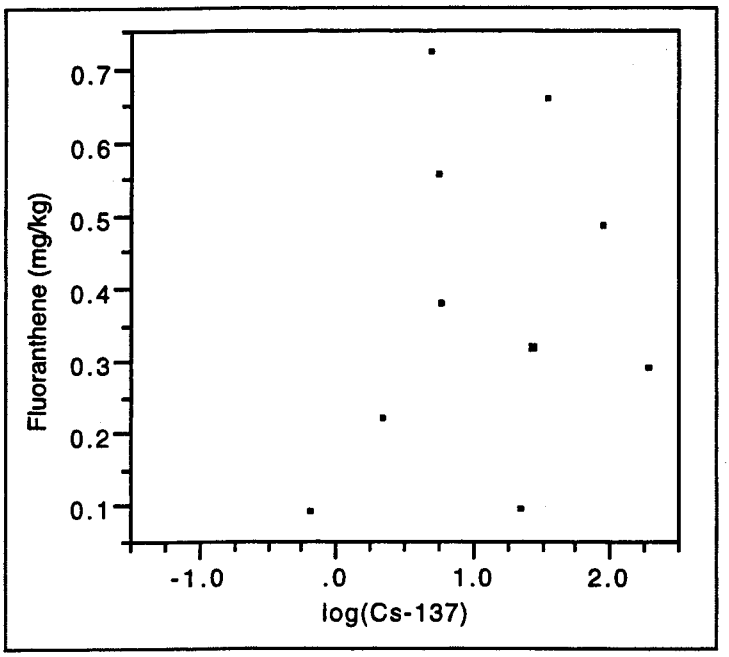

Figure E3-44a. Scatter plot for fluoranthene versus log(Cs-137).

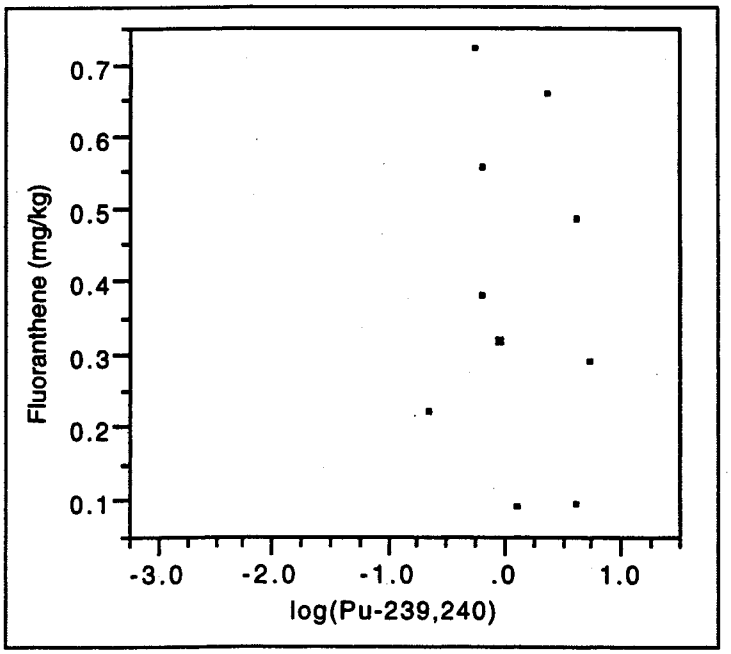

Figure E3-44b. Scatter plot for fluoranthene versus log(Pu-239,240).

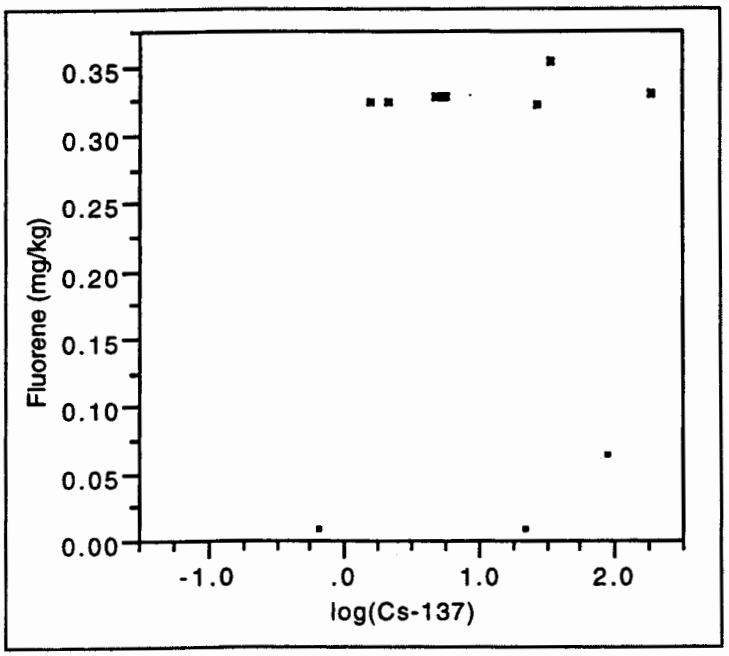

Figure E3-45a. Scatter plot for fluorene versus log(Cs-137).

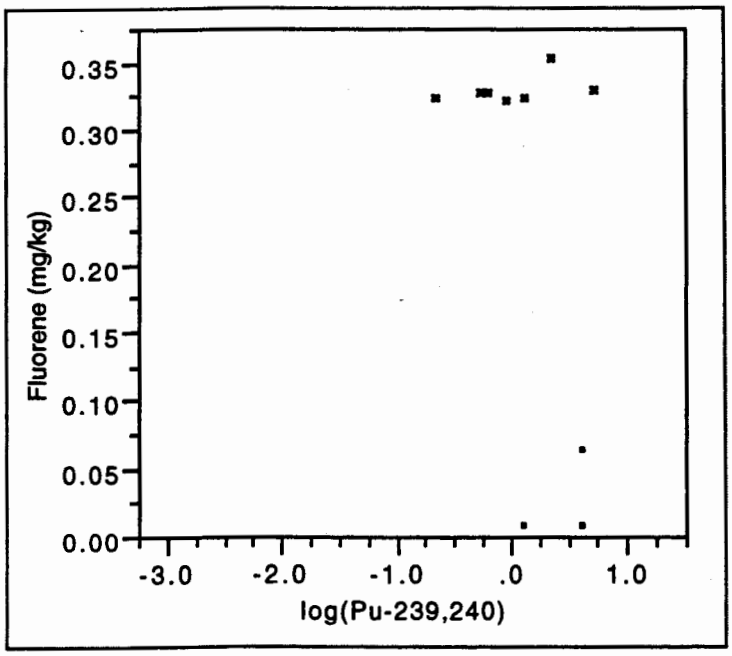

Figure E3-45b. Scatter plot for fluorene versus log(Pu-239,240).

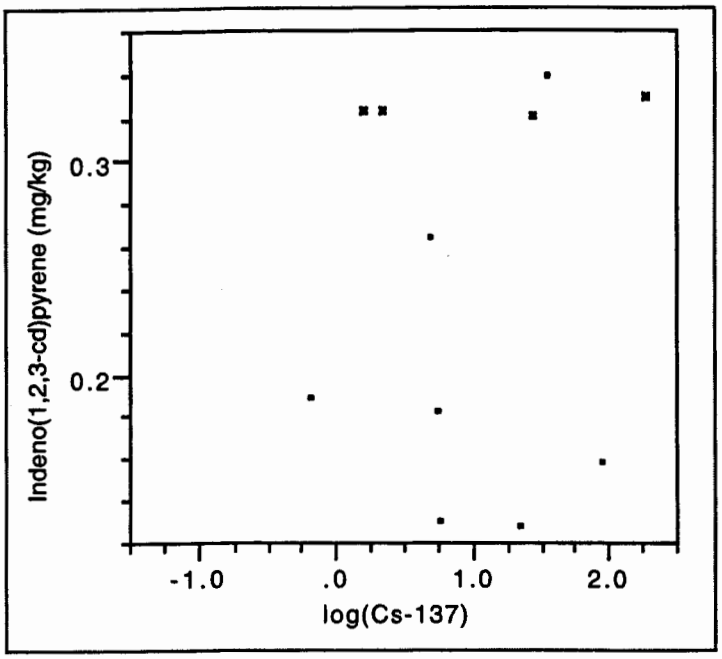

Figure E3-46a. Scatter plot for indeno(1,2,3-cd)pyrene versus log(Cs-137).

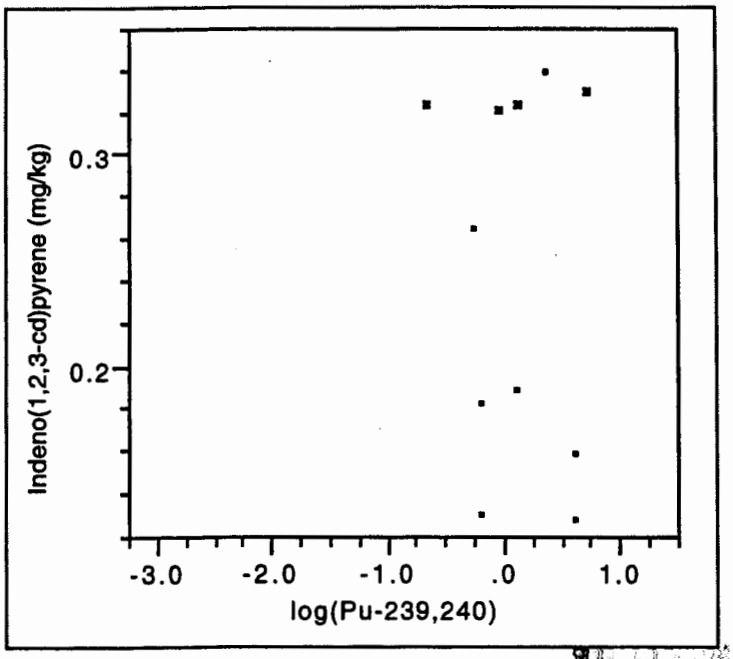

Figure E3-46b. Scatter plot for indeno(1,2,3-cd)pyrene versus log(Pu-239,240).

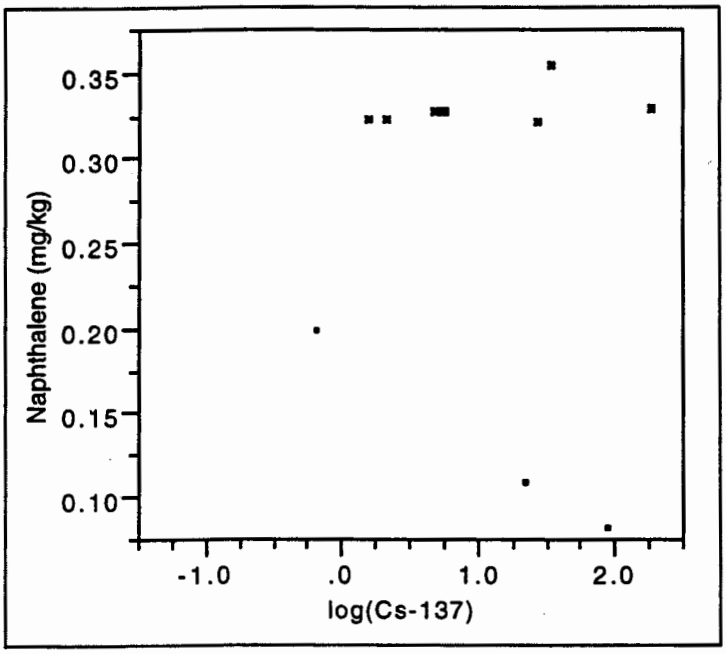

Figure E3-47a. Scatter plot for naphthalene versus log(Cs-137).

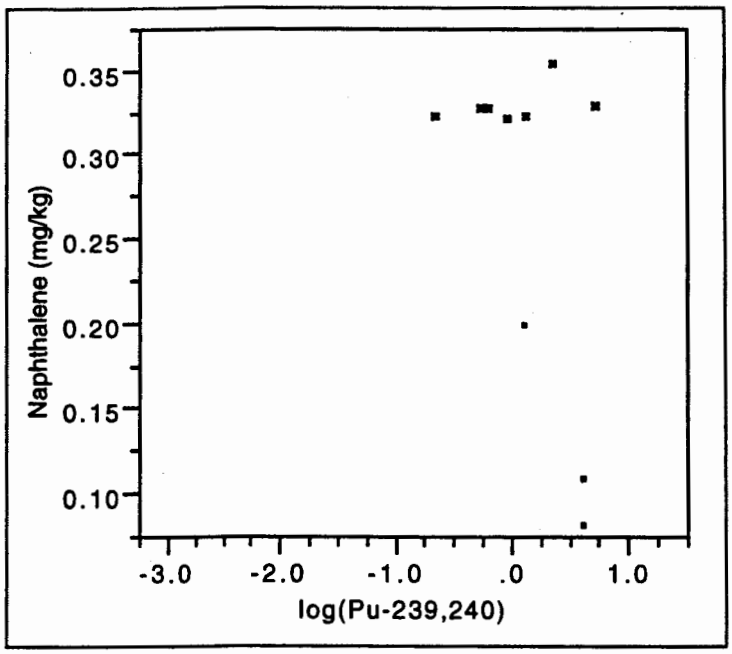

Figure E3-47b. Scatter plot for naphthalene versus log(Pu-239,240).

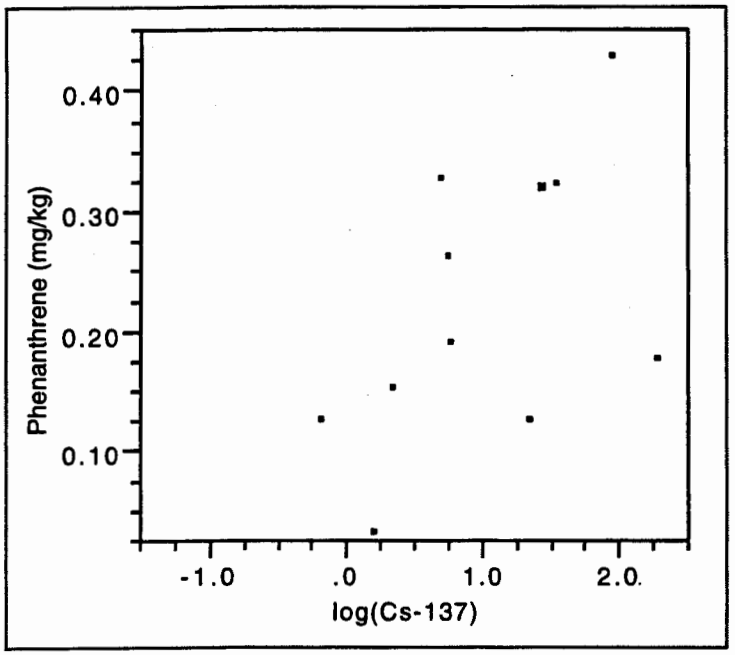

Figure E3-48a. Scatter plot for phenanthrene versus log(Cs-137).

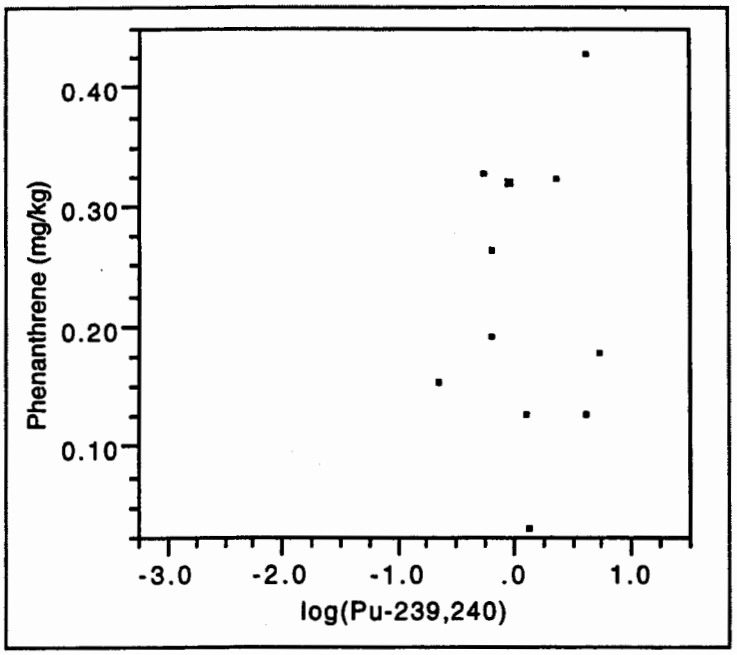

Figure E3-48b. Scatter plot for phenanthrene versus log(Pu-239,240).

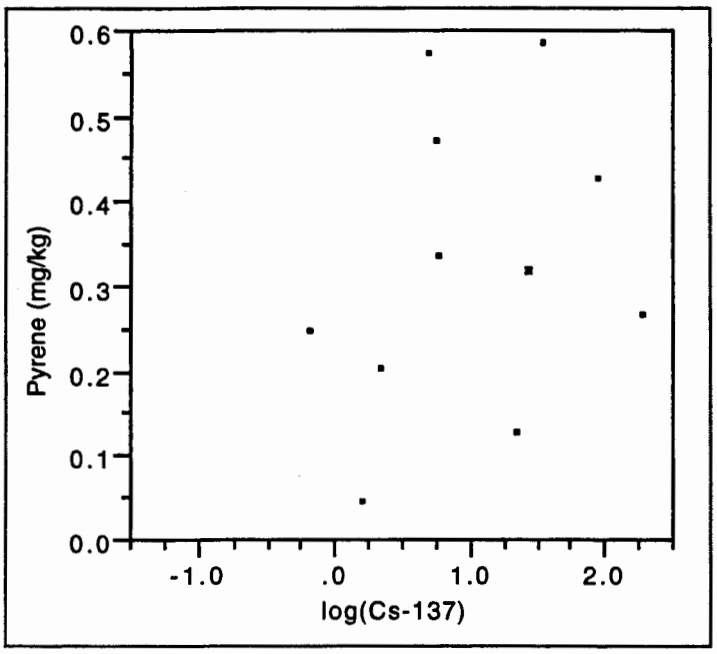

Figure E3-49a. Scatter plot for pyrene versus log(Cs-137).

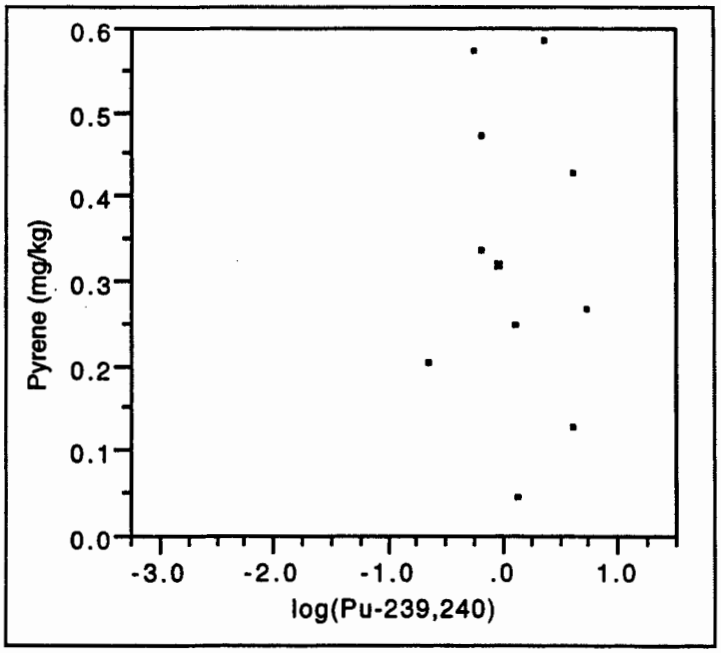

Figure E3-49b. Scatter plot for pyrene versus log(Pu-239,240).

E-4.0 ANALYSIS OF KEY RADIONUCLIDE FIELD QA SAMPLES AND RESAMPLES

An important aspect of the uncertainty associated with determining either the inventory or risk resulting from contaminants in upper Los Alamos Canyon sediments is the repeatability of collocated or replicated field samples. Because of the number of samples analyzed for the key radionuclides and their importance in human health risk calculations, this analysis of field quality assurance (QA) samples and resamples will be based only on data for the key radionuclides. Table E4-1 provides the results for two types of samples. QA duplicates are basically field splits of single field samples. Resamples are collocated field samples that are collected at key geomorphic sampling locations in later sampling events, such as layers with exceptionally high cesium-137 within a reach. Because of lateral variability in the thickness and particle size distribution of sediment layers, these resamples cannot replicate the original sampled sediment as well as the field QA samples, although they still provide useful information on radionuclide variability within geomorphic units. The graphical comparison of these types of QA samples and resamples is provided in Figure E4-1. This figure shows the first result for these samples plotted as the x-axis variable and the second result plotted as the y-axis variable. The line of equality (y = x) is also plotted as a point of reference. For concentrations of radionuclides greater than 0.1 pCi/g the QA duplicates show less variability than the resamples, and most of the variability in resamples is noted for two pairs of strontium-90 results. These two strontium-90 resamples are much lower than the originals and may record initial sample results that were biased high because of a laboratory measurement interference. The initial strontium-90 results for the resamples are from RN 2833, which was discussed in Appendix C as having possible high analytical laboratory bias. Based on the resamples, this bias appears to have added a nearly constant value increment to each sample result because the concentration difference between the two strontium-90 resamples is similar, even though the concentrations span an order of magnitude. The remainder of the collocated sample results show small differences between the initial sample result and the second sample result, including a resample of the layer with the highest cesium-137 and strontium-90 concentrations in upper Los Alamos Canyon. The americium-241 QA duplicates using the gamma spectroscopy method show more apparent variability than other analytes, but all these americium-241 values are low and are close to the detection limit. In contrast, the americium-241 QA duplicate results using the alpha spectroscopy method are within ±20% of the original values.

TABLE E4-1

SUMMARY OF KEY RADIONUCLIDE FIELD QA AND RESAMPLE RESULTS

Type	Original Sample ID[a]	Analyte	First Sample Result	Second Sample Result	RPD[b]
QA duplicate	04LA-97-0054	Am-241 (alpha spec)	1.46	1.5	2%
QA duplicate	04LA-97-0143	Am-241 (alpha spec)	2.59	2.22	-11%
QA duplicate	04LA-97-0145	Am-241 (alpha spec)	1.75	2.14	14%
QA duplicate	04LA-96-0217	Am-241 (gamma spec)	<0.24	<0.25	
QA duplicate	04LA-97-0122	Am-241 (gamma spec)	0.232	0.269	10%
QA duplicate	04LA-97-0127	Am-241 (gamma spec)	0.009	-0.23	153%
QA duplicate	04LA-97-0143	Am-241 (gamma spec)	1.54	1.67	6%
QA duplicate	04LA-97-0145	Am-241 (gamma spec)	2.34	0.918	-62%
QA duplicate	04LA-96-0217	Cs-137	0.32	0.28	-9%
QA duplicate	04LA-97-0054	Cs-137	121	122	1%
QA duplicate	04LA-97-0122	Cs-137	0.994	1.11	8%
QA duplicate	04LA-97-0127	Cs-137	0.075	0.067	-8%
QA duplicate	04LA-97-0143	Cs-137	11.7	12	2%
QA duplicate	04LA-97-0145	Cs-137	6.1	5.91	-2%
QA duplicate	04LA-97-0054	Pu-238	0.07	0.054	-18%
QA duplicate	04LA-97-0096	Pu-238	0.017	0.026	30%
QA duplicate	04LA-97-0143	Pu-238	0.219	0.142	-30%
QA duplicate	04LA-97-0145	Pu-238	0.154	0.146	-4%
QA duplicate	04LA-97-0247	Pu-238	0.0165	0.0098	-36%
QA duplicate	04LA-97-0259	Pu-238	0.0183	0.0127	-26%
QA duplicate	04LA-97-0616	Pu-238	0.021	0.043	49%
QA duplicate	04LA-97-0618	Pu-238	0.0006	0.0163	131%
QA duplicate	04LA-97-0054	Pu-239,240	3.89	4.39	9%
QA duplicate	04LA-97-0096	Pu-239,240	0.982	1.36	23%
QA duplicate	04LA-97-0143	Pu-239,240	1.95	1.82	-5%
QA duplicate	04LA-97-0145	Pu-239,240	0.852	1.45	37%
QA duplicate	04LA-97-0247	Pu-239,240	0.728	0.693	-3%
QA duplicate	04LA-97-0260	Pu-239,240	3.48	3.04	-10%
QA duplicate	04LA-97-0616	Pu-239,240	2.99	2.82	-4%
QA duplicate	04LA-97-0618	Pu-239,240	0.378	0.275	-22%
QA duplicate	04LA-96-0217	Sr-90	3.7	3.1	-12%
QA duplicate	04LA-97-0054	Sr-90	30.2	34.6	10%
QA duplicate	04LA-97-0096	Sr-90	0.08	0.01	-110%
QA duplicate	04LA-97-0143	Sr-90	1.93	2.08	5%
QA duplicate	04LA-97-0145	Sr-90	0.81	0.85	3%
Resample	04LA-96-0149	Am-241 (gamma spec)	1.59	<1.6	
Resample	04LA-96-0205	Am-241 (gamma spec)	28	23.1	-14%
Resample	04LA-96-0149	Cs-137	192.31	230	13%
Resample	04LA-96-0205	Cs-137	25	22.4	-8%
Resample	04LA-96-0149	Sr-90	39.56	36	-7%
Resample	04LA-96-0215	Sr-90	2.4	0.28	-112%
Resample	04LA-96-0216	Sr-90	3.3	0.45	-107%

a. See Tables 3.3-1, 3.3-4, 3.3-7, and D2-1 for the sample ID of the resample/QA duplicate

b. RPD = relative per cent difference between the two results

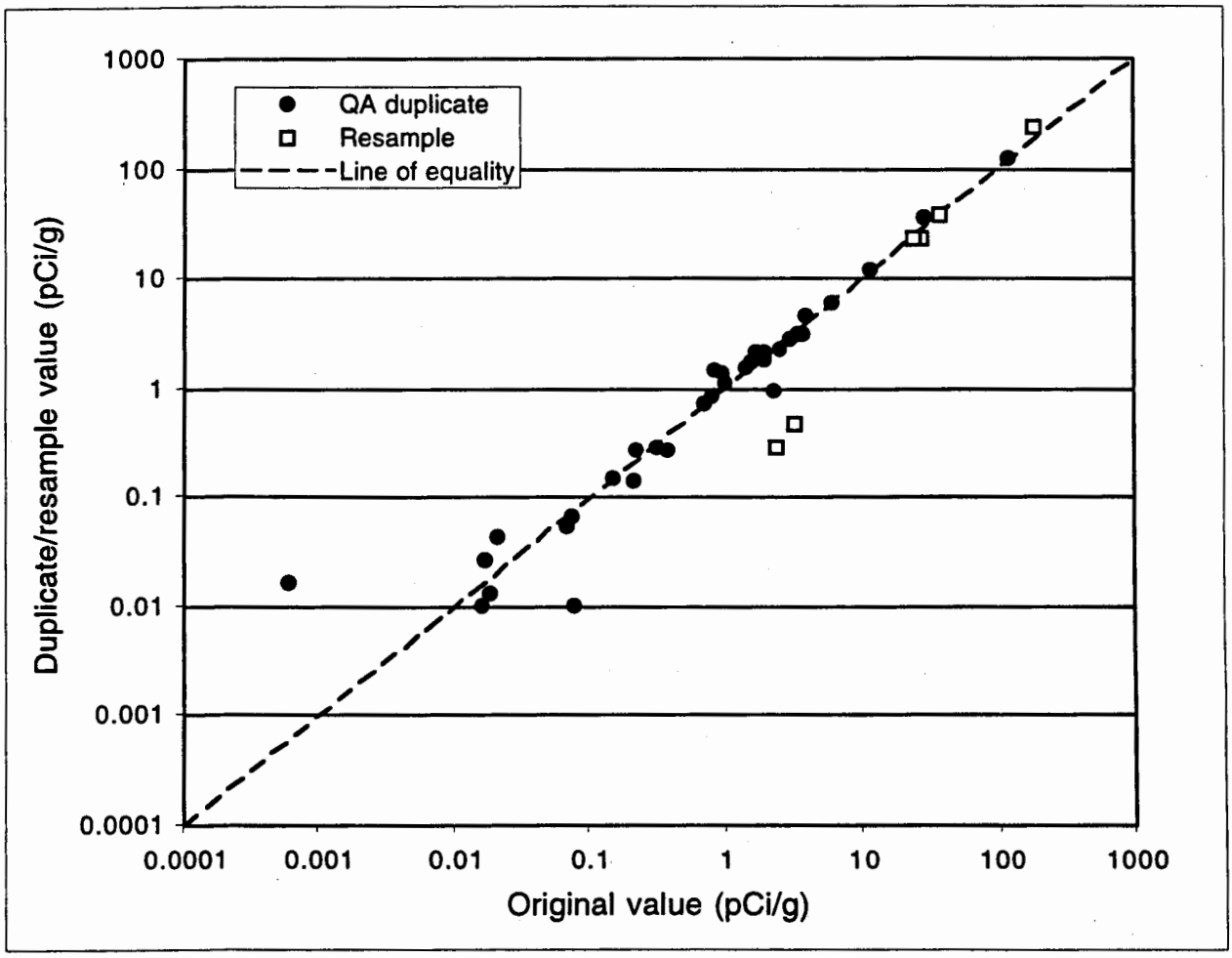

Figure E4-1. Evaluation of QA duplicate samples and resamples for upper Los Alamos Canyon.

Appendix F

Ecological Scoping Checklist

APPENDIX F ECOLOGICAL SCOPING CHECKLIST

F-1.0 PART A—SCOPING MEETING DOCUMENTATION

Site ID	Upper Los Alamos Canyon reaches
Nature of PRS releases **(indicate all that apply)**	**Solid** – Yes See the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* (LANL 1995, 50290) (e.g., Technical Area [TA] -45, TA-73, and the wastewater treatment plants [WWTPs]) **Liquid** – Yes See the *Task/Site Work Plan for Operable Unit 1049: Los Alamos Canyon and Pueblo Canyon* (LANL 1995, 50290) (e.g., TA-45, TA-73, and the WWTPs) **Gaseous** – No **Other, explain**
List of Primary Impacted Media **(indicate all that apply)**	**Surface soil** – Active channels, floodplains, and abandoned channels **Surface water/sediment** – Yes **Subsurface** – No **Groundwater** – Alluvial, perched, and main aquifer could all be impacted **Other, explain**
FIMAD vegetation class **(indicate all that apply)**	**Water** – No **Bare Ground/Unvegetated** – No **Spruce/fir/aspen/mixed conifer** – Yes **Ponderosa pine** – Yes **Piñon juniper/juniper savannah** – Yes **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. The bald eagle can be assumed to forage at low frequency, and is therefore not relevant to ecological risk scoping.
Provide list and description of Neighboring/ Contiguous/ Upgradient PRSs **(consider need to aggregate PRS for screening)**	Significant potential release sites (PRSs) include TA-1 hillsides TA-2 TA-21 21-011(k) outfall for impacts to DP Canyon, various outfalls on the south-facing slope of Los Alamos Canyon TA-53 lagoons
AP 4.5 Part B Information **Run-off score (out of 46)** **Terminal point of surface water transport**	This section does not apply because the site is not a PRS.
Other Scoping Meeting Notes	None

F-2.0 PART B—SITE VISIT DOCUMENTATION

F-2.1 Reach LA-1 West

Site ID	Reach LA-1 West (Did not visit LA-1 East and Central)
Date of Site Visit	7/24/98
Site Visit Conducted by	R. Ryti, G. McDermott, S. Reneau

Receptor Information:

Estimate cover	**% vegetated** = remainder **% wetland** = approximately 10% of the reach in the active channel **% structures/asphalt, etc.** = negligible
Field notes on the FIMAD vegetation class	Riparian shrubs are evident; some firs were noted
Field notes on T&E Habitat, if applicable	Potential spotted owl and falcon habitat; avian ecological screening levels (ESLs) (particularly for the kestrel flesh diet) are important in screening; lack of avian ESLs should be considered a valid reason for specifying an analyte to be a contaminant of potential concern(COPEC); the hazard quotient (HQ)/hazard index (HI) analysis should address potential bioaccumulative effects for raptors.
Are ecological receptors present at the PRS? **(yes/no/uncertain)** **Provide explanation**	Yes Aquatic and terrestrial receptors are present.

Contaminant Transport Information:

Surface water transport **Field notes on the terminal point of surface water transport (if applicable)**	This section does not apply because the site is not a PRS.
Are there any off-site transport pathways? **(yes/no/uncertain)** **Provide explanation**	Surface water/erosion is an obvious pathway, and transport to alluvial/perched aquifer may also be important.

Ecological Effects Information:

Physical Disturbance **(provide list of major types of disturbances)**	Minimal Some effects of road construction were noted.
Are there obvious ecological effects? **(yes/no/uncertain)** **Provide explanation**	No obvious effects of either physical disturbance or contaminants on vegetation

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)**	Yes, geomorphic sampling and field screening information should provide information on the nature/rate/extent of contamination for sediments. There is some question about the origin of elevated PCB levels in western-most sediments. No data for surface water, and lack of surface water contaminant data represents a data gap for the integrated Los Alamos Canyon report at the present time.
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)**	Known sources of contaminants from TA-1 hillsides, TA-2, and TA-41 These sources have been mostly detailed in the work plan.

Additional Field Notes:

Provide additional field notes on the site setting and potential ecological receptors. Noted cattails upstream of reach LA-1 west, which suggests perhaps a broader wetland habitat in this area. Noted little fossorial activity in the post-1942 sediment deposition area of the canyon floor. Strong contrast to some areas of Pueblo Canyon. Noted presence of riparian shrubs (water birch?) on the narrow canyon floor. The importance of the Los Alamos reservoir in regulating surface water flow must be noted. The reservoir probably dates back to the Manhattan Project era (need to check date of construction). Another important water contributor to this reach is storm water runoff from parts of the Los Alamos townsite. Took a photo at location LA-0175.

F-2.2 Reach LA-2

Site ID	Reach LA-2
Date of Site Visit	7/24/98
Site Visit Conducted by	R. Ryti, G. McDermott, S. Reneau

Receptor Information:

Estimate cover	**% vegetated** = 90% (some dense shrub thickets noted) **% wetland** = none **% structures/asphalt, etc.** = none
Field notes on the FIMAD vegetation class	Ponderosa pine is dominant.
Field notes on T&E Habitat, if applicable	Potential spotted owl and falcon habitat; avian ESLs (particularly for the kestrel flesh diet) are important in screening; lack of avian ESLs should be considered a valid reason for specifying an analyte to be a COPEC; the HQ/HI analysis should address potential bioaccumulative effects for raptors.
Are ecological receptors present at the PRS? **(yes/no/uncertain)** **Provide explanation**	Yes, terrestrial receptors are present.

Contaminant Transport Information:

Surface water transport **Field notes on the terminal point of surface water transport (if applicable)**	Not applicable
Are there any off-site transport pathways? **(yes/no/uncertain)** **Provide explanation**	Surface water/erosion is an obvious pathway. Alluvial/perched aquifer may also be important.

Ecological Effects Information:

Physical Disturbance **(provide list of major types of disturbances)**	Minimal Some effects of installation of Los Alamos County gas line were noted.
Are there obvious ecological effects? **(yes/no/uncertain)** **Provide explanation**	No obvious effects of either physical disturbance or contaminants on vegetation.

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)**	Yes, geomorphic sampling should provide information on the nature/rate/extent of contamination for sediments. Need to include data from fiscal year 97/98 DP Canyon investigation into this assessment (especially results from near the Los Alamos Canyon confluence). Radiological surveys were also instrumental in documenting the extent of cesium-137 and strontium-90 contamination. No data for surface water, and lack of surface water contaminant data represents a data gap for the integrated Los Alamos Canyon report at the present time.
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)**	Known sources of contaminants from TA-21 from the Los Alamos Canyon and DP Canyon sides. A dominant source in DP Canyon is PRS 21-011(k). See little contaminant influence from the TA-1 hillsides in reach LA-2 sediments.

Additional Field Notes:

Provide additional field notes on the site setting and potential ecological receptors. Typical ponderosa pine plant community was observed. Observed some harvester ants near the active channel and some fossorial mammal activity in the post-1942 sediments. The post-1942 sediments are typically constrained to a narrow portion of the canyon floor. Surface water flows during snow melt (most years) and during large storm events. Much of the Los Alamos townsite drains into DP Canyon, and the DP Canyon watershed includes paved areas (roadways and parking lots). The channel sands were moist from a recent summer rainstorm (likely during the night of 7/22/98). The installation of the Los Alamos County gas pipeline has created some disturbed areas with the post-1942 sediments, but of quite limited spatial extent.

F-2.3 Reach LA-3

Site ID	Reach LA-3
Date of Site Visit	7/24/98
Site Visit Conducted by	R. Ryti, G. McDermott, S. Reneau

Receptor Information:

Estimate cover	**% vegetated** = 70 to 90% (some dense shrub thickets noted) **% wetland** = none **% structures/asphalt, etc.** = none
Field notes on the FIMAD vegetation class	Mostly juniper with some piñon and other shrubs noted.
Field notes on T&E Habitat, if applicable	Would not expect to be high quality spotted owl or falcon nesting habitat, but would classify as potential foraging habitat for the falcon; the HQ/HI analysis should address potential bioaccumulative effects for raptors; the uncertainty analysis should consider the quality of foraging habitat present in reach LA-4 given the distance of this reach from potential nesting habitat in upper Los Alamos Canyon.
Are ecological receptors present at the PRS? **(yes/no/uncertain)** **Provide explanation**	Yes, terrestrial receptors are present.

Contaminant Transport Information:

Surface water transport **Field notes on the terminal point of surface water transport (if applicable)**	Not applicable
Are there any off-site transport pathways? **(yes/no/uncertain)** **Provide explanation**	Surface water/erosion is an obvious pathway. Alluvial/perched aquifer may also be important.

Ecological Effects Information:

Physical Disturbance **(provide list of major types of disturbances)**	Minimal Noted some old roads that may date back to homesteaders
Are there obvious ecological effects? **(yes/no/uncertain)** **Provide explanation**	No obvious effects of either physical disturbance or contaminants on vegetation.

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)**	Yes, geomorphic sampling should provide information on the nature/rate/extent of contamination for sediments. Radiological surveys were also instrumental in documenting the extent of cesium-137 and strontium-90 contamination. No data for surface water, and lack of surface water contaminant data represents a data gap for the integrated Los Alamos Canyon report at the present time.
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)**	Known sources of contaminants from TA-53, but it is suspected that reach LA-3 is too far downstream to pick up contaminants from the TA-53 lagoons. Still observe elevated radioactivity/cesium-137 from the 21-011(k) outfall in DP Canyon.

Additional Field Notes:

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

Some riparian shrubs are noted on the relatively more mesic north-facing slopes, but the vegetation is more typical of a xeric environment (much drier than reaches LA-1 and LA-2). Many dense shrub thickets are noted along the stream banks. Noted some fossorial mammal activity in the post-1942 sediments; harvester ants are also evident.

The post-1942 sediments are typically constrained to a narrow portion of the canyon floor. Surface water may flow during snow melt periods (some years, e.g., last year but not this year) and during very large storm events. Observed surface water in some portion of the active channel in this part of Los Alamos Canyon, likely from alluvial water being expressed at the surface.

Quite minimal disturbance of the sediments in this part of Los Alamos Canyon (current road crosses the active channel at one point and an old dirt road was noted near well R-9.

F-3.0 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 (Figure F3-1)

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 organic compounds are expected in active channel sediments, and there are no known solvent spills at TA-2 or TA-41.

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) Likely

Provide explanation:

Some areas of surficial contamination, so pathway is complete, but most contamination is subsurface.

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) Likely

Provide explanation:

The canyon has no AP 4.5 score, but sediment transport is an obvious pathway.

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) Likely

Provide explanation:

Alluvial aquifer is known to carry some contaminants from TA-2 (Omega West Reactor), and the alluival water would be commingled with surface water and sediments at certain points in Los Alamos 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) Likely

Provide explanation:

There are some subsurface contaminant sources in Los Alamos Canyon (TA-2 leach fields).

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:

Mass wasting is not applicable to a canyon floor physical setting, and erosion has previously been addressed.

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 = no pathway
Terrestrial Animals: 0 = no pathway

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 = minor pathway

Terrestrial Animals: 2 = minor pathway

Provide explanation:

Most contamination is expected to be subsurface, and vegetative cover is generally high throughout upper Los Alamos Canyon; thus, little contaminated dust is expected to be generated.

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 = minor pathway

Provide explanation:

Most contamination is subsurface, but alluvial water could be important for some plants.

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 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 = major pathway

Provide explanation:

Need to consider this a major pathway as some chemicals of potential concern (COPCs) are bioaccumulators in aquatic environments (which are present in some parts of Los Alamos Canyon).

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 = major pathway

Provide explanation:

This pathway could be a major pathway, but it is likely to be a minor pathway as most contamination is subsurface.

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 = minor pathway

Provide explanation:

This is a Minor pathway because of the type of COPCs present in Los Alamos Canyon (mostly not lipophilic) and because of the fact that most contamination is subsurface; should pay greater attention to this pathway for fossorial mammals.

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: 3 = major pathway
Terrestrial Animals: 3 = major pathway

Provide explanation:

This could be a major pathway because field screening can detect an elevated gamma field from reach LA-2 downstream to state road NM 4;the major gamma emitter is cesium-137.

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: 3 = major pathway
Aquatic Plants: 3 = major pathway

Provide explanation:

This could be a major pathway in reach LA-1;, expected to be a lessor pathway in reach LA-2 and least important in reach LA-3.

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 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 = major pathway
Aquatic Animals: 3 = major pathway

Provide explanation:

This could be a major pathway in reach LA-1; expected to be a lessor pathway in reach LA-2 and least important in reach LA-3 .

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: 3 = major pathway
Aquatic Animals: 3 = major pathway

Provide explanation:

This could be a major pathway in reach LA-1; expected to be a lessor pathway in reach LA-2 and least important in reach LA-3.

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: 2 = minor pathway
Aquatic Animals: 2 = minor pathway

Provide explanation:

Most COPCs are not likely to be lipophilic; concentrations of those that are potentially lipophilic are low (e.g., PCBs downstream of reach LA-1 are primarily nondetect sample results).

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:	3 = major pathway
Aquatic Plants:	2 = minor pathway
Terrestrial Animals:	3 = major pathway
Aquatic Animals:	2 = minor pathway

Provide explanation:

This could be a major pathway because cesium-137 is a key COPC; expect the pathway to be less important for aquatic receptors because of attenuation of gamma in the water column.

TABLE F3-1

BIOACCUMULATING CHEMICALS

Volatile Organic Compounds	**PCBs/Pesticides**
1,4-Dichlorobenzene	All aroclors
1,2,4-Trichlorobenzene	β-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

Figure F3-1. Conceptual exposure model for ecological pathways.

Signatures and certifications:

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

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

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