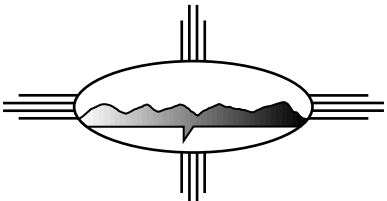

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September 1998

Evaluation of Sediment Contamination in Lower Los Alamos Canyon

Reaches LA-4 and LA-5

Environmental Restoration Project
A Department of Energy Environmental Cleanup Program

Los Alamos
NATIONAL LABORATORY
Los Alamos, NM 87545

Produced by the Canyons Focus Area

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EXECUTIVE SUMMARY

This interim report presents the results of investigations on contaminated sediments in lower 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 lower Los Alamos Canyon, evaluating potential human health and ecological risk related to these contaminants, and evaluating the processes that redistribute these contaminants and the future consequences of this redistribution. The risk assessments presented in this report are preliminary and are intended to identify the need, if any, for immediate remedial action or additional data collection. More comprehensive risk assessments will be presented in future reports on Los Alamos Canyon and Pueblo Canyon that will incorporate the results of ongoing groundwater investigations and additional sediment investigations.

Lower Los Alamos Canyon has received contaminants from multiple potential release sites (PRSs) within the watershed. The most significant contaminant sources were former Technical Area (TA) -45, where radioactive effluent was discharged between 1944 and 1964 into Acid Canyon, a tributary to Pueblo Canyon, and the 21-011(k) outfall at TA-21, where radioactive effluent was discharged between 1956 and 1985 into DP Canyon, a tributary to upper Los Alamos Canyon. Additional sources exist within the watershed that contributed smaller amounts of contaminants.

The technical approach followed in this investigation focused on detailed evaluation of contamination within two sections of lower Los Alamos Canyon, called “reaches.” These reaches were selected (1) to encompass the range of potential risk related to contaminated sediments within lower Los Alamos Canyon 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 chemicals of potential concern (COPCs) in the sediments of lower Los Alamos Canyon with regard to potential human health risk are cesium-137, which was released from the 21-011(k) outfall at TA-21, and plutonium-239,240, which was mostly released from TA-45. Both of these radionuclides have been carried by floods downstream to the Rio Grande, a distance of 14 to 19 km from their sources, and have been dispersed laterally away from the stream channel and deposited on floodplains. Concentrations of both radionuclides have decreased over time in lower Los Alamos Canyon, and, because the release of radioactive effluent in the watershed stopped more than 10 years ago, concentrations are expected to either remain constant or decline 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, radionuclide concentrations are highest in relatively old fine-grained sediments. The highest concentrations of cesium-137; plutonium-239,240; and associated radionuclides in lower Los Alamos Canyon are found to the west, closest to the confluence of Pueblo Canyon and Los Alamos Canyon, and concentrations are much lower near the Rio Grande. The largest inventory of each of the key radionuclide COPCs in the Los Alamos Canyon watershed is on Laboratory land, and relatively small inventories are present in lower Los Alamos Canyon.

Other COPCs identified in the sediments of lower Los Alamos Canyon include 4 additional radionuclides, 11 inorganic chemicals, and 2 organic chemicals. All these COPCs are either detected much less

frequently or detected less frequently above background values than cesium-137 and plutonium-239,240. Several COPCs (americium-241, copper, and lead) are generally collocated with cesium-137 and apparently have primary source areas in the upper Los Alamos Canyon watershed. Both the 21-011(k) outfall and TA-45 are apparently important sources for the plutonium-238 present in lower Los Alamos Canyon. Sources for the remaining COPCs have not been defined, and it is possible that none of these represent significant releases from the Laboratory.

The levels of contamination in lower Los Alamos Canyon sediments do not present a significant human health risk under the conditions of present-day land use, including scenarios for trail use, resource use, residential use, and construction work. Thus, no immediate remedial action is required with regard to potential human health risk. In addition, because concentrations of contaminants in sediments carried by floods are not increasing over time, no immediate remedial actions are required upstream in the context of the future remobilization of contaminated sediments. Possible decisions to implement any remedial action in the Los Alamos Canyon watershed 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 lower Los Alamos Canyon (Figures 1.1-1 and 1.1-2) 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 two 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 these reaches 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

The Los Alamos Canyon watershed heads in the Sierra de los Valles on Santa Fe National Forest land and extends eastward across the Pajarito Plateau to the Rio Grande. Elevations in the watershed range from 10,441 ft (3183 m) at the summit of Pajarito Mountain to 5490 ft (1674 m) at the Rio Grande. Lower Los Alamos Canyon, as referred to in this report, is the 7.6-km-long part of the canyon downstream from the confluence of Los Alamos Canyon and Pueblo Canyon and includes the confluence with the Rio Grande. The entire Los Alamos Canyon watershed has a drainage area of 152 km^2 and a basin length of approximately 27 km (as measured along the Los Alamos Canyon stream channel). The major subbasins that drain into lower Los Alamos Canyon are upper Los Alamos Canyon (28 km^2), Pueblo Canyon (22 km^2), Bayo Canyon (10 km^2), and Guaje Canyon (81 km^2); the latter includes the basins of Barrancas Canyon and Rendija Canyon (Figure 1.1-1).

Geologic units exposed within lower Los Alamos Canyon include Pliocene basaltic rocks of the Cerros del Rio volcanic field, Pliocene conglomerates of the Puye Formation, and Miocene sediments of the Santa Fe Group. Much of the watershed upstream from the confluence with Pueblo Canyon is underlain by the Pleistocene Bandelier Tuff, and the headwaters include Pliocene and Miocene dacites of the Tschicoma Formation (Griggs 1964, 8795; Smith et al. 1970, 9752).

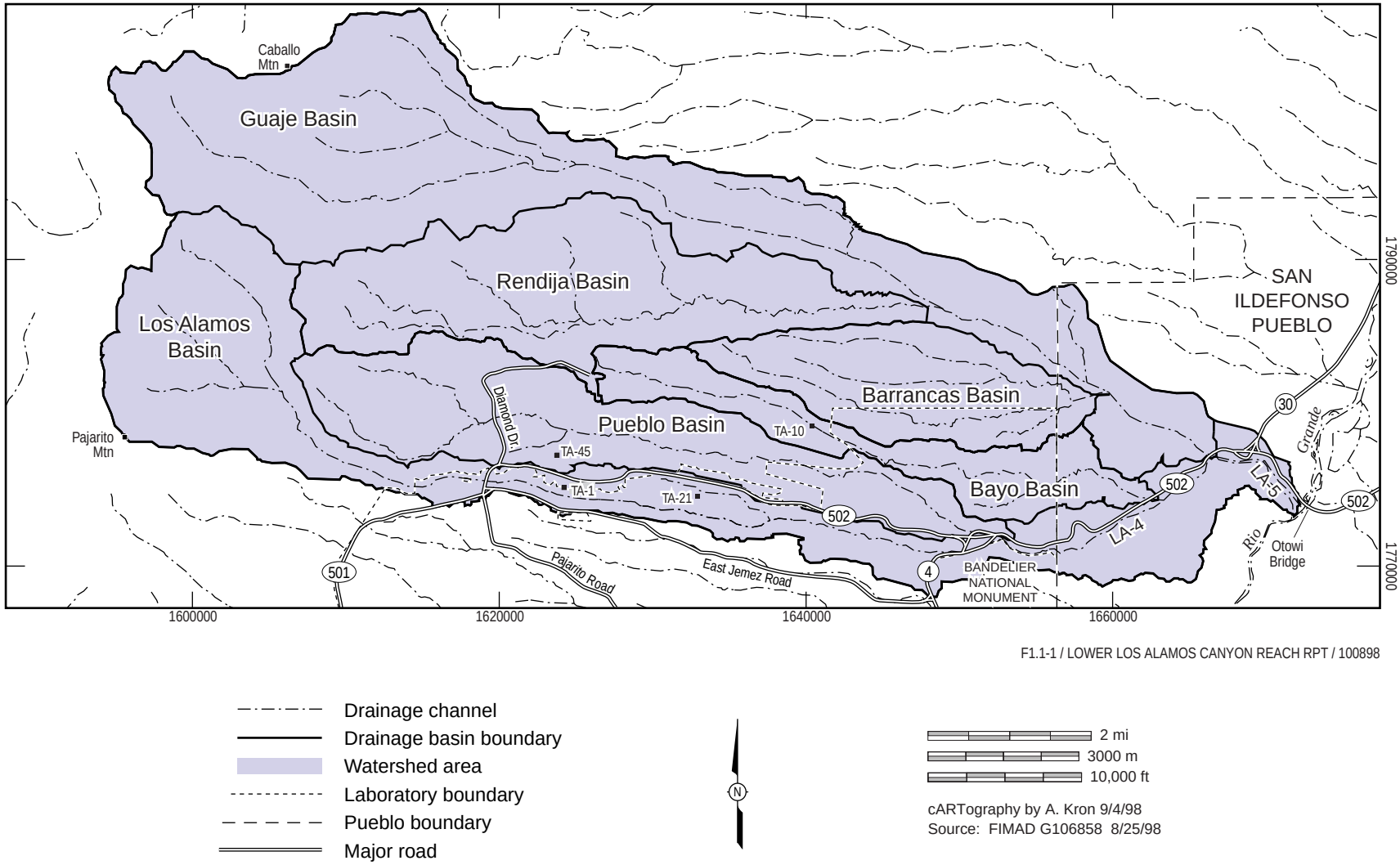

Figure 1.1-1. Map of the Los Alamos Canyon watershed showing major subbasins, key Laboratory technical areas, and sampling reaches in lower Los Alamos Canyon.

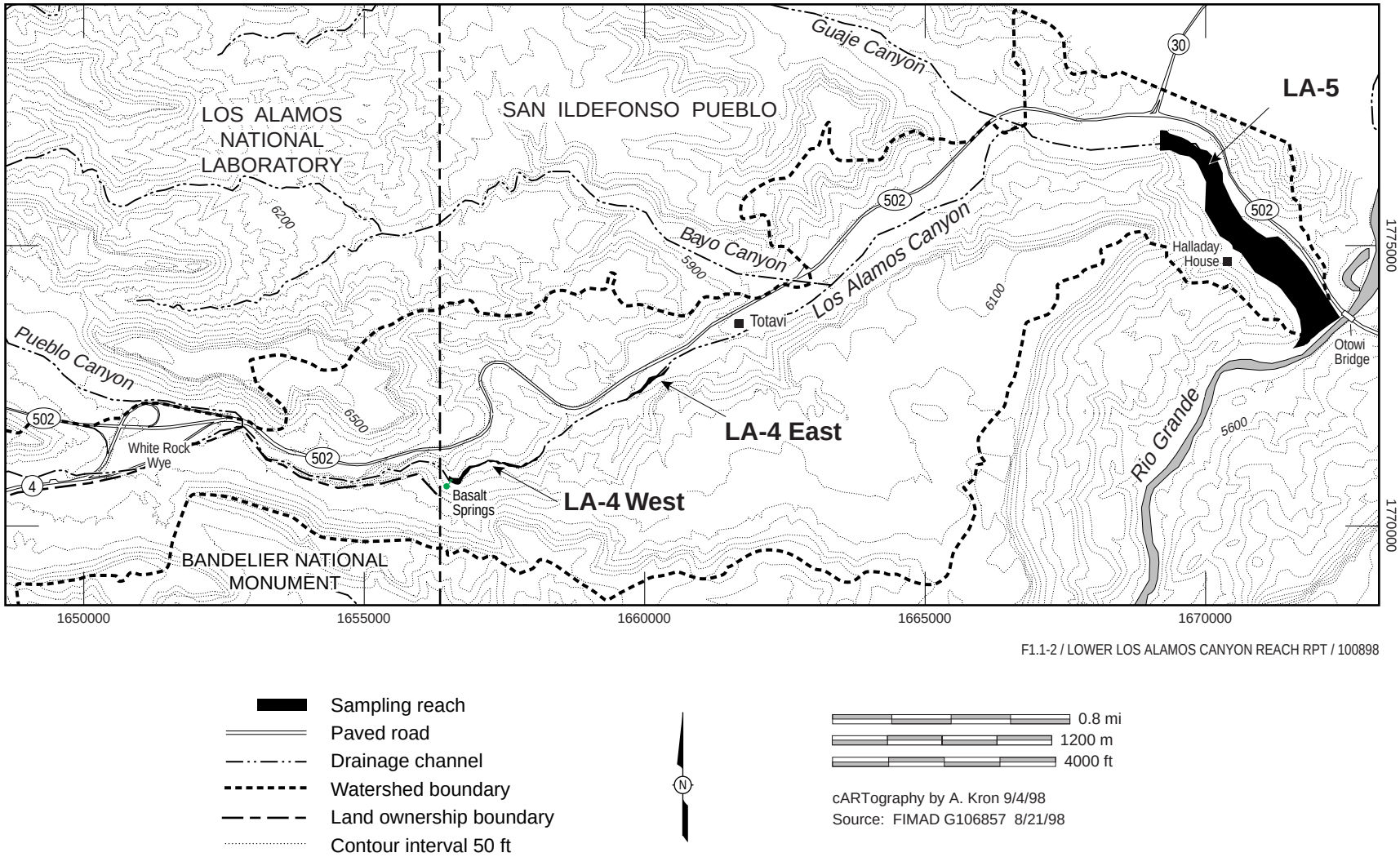

Figure 1.1-2. Topographic map of the lower Los Alamos Canyon watershed between Pueblo Canyon and the Rio Grande showing sampling reaches.

Stream flow in lower Los Alamos Canyon includes snow melt runoff originating in the Sierra de los Valles in the upper Los Alamos Canyon basin and runoff from rain storms within the different subbasins. In addition, lower Los Alamos Canyon includes a short perennial reach, which is fed by discharges from Basalt Springs. The chemistry of the water at Basalt Springs indicates that it is partially recharged by effluent released from the Bayo Canyon Wastewater Treatment Plant (WWTP) into Pueblo Canyon (LANL 1995, 50290).

1.3.2 Laboratory History and Operations

Several active and former Laboratory sites within the Los Alamos Canyon watershed have contributed or may have contributed contaminants that reached the main channels of either upper Los Alamos Canyon or Pueblo Canyon. These sites include some of the original Manhattan Project laboratories within the current Los Alamos townsite that date back to 1943. Technical areas (TAs) that have been identified as the primary sources for contaminants within sediments in the watershed include TA-1, TA-21, and TA-45 (Figure 1.1-1). Brief summaries of pertinent information on key sites in the Los Alamos Canyon watershed are presented below. Other sites in the upper Los Alamos Canyon and Pueblo Canyon subbasins are summarized in the work plan (LANL 1995, 50290) and in the reports on sediment investigations in Pueblo Canyon and upper Los Alamos Canyon (Reneau et al. 1998, 59159; Reneau et al. 1998, 59160).

TA-45 was the site of the first radioactive liquid waste treatment plant at the Laboratory, and radioactive effluent was discharged from TA-45 into Acid Canyon, a small tributary of Pueblo Canyon, between 1944 and 1964 (LANL 1981, 6059; LANL 1992, 7668). This effluent was untreated before 1951, when the first treatment plant became operational, and the highest concentrations of radionuclides were probably discharged before this time. TA-45 was the source for most of the plutonium-239,240 within the Los Alamos Canyon watershed and was also the source for other radionuclides present at much lower concentrations, including americium-241, cesium-137, plutonium-238, strontium-90, and tritium.

TA-21 was established in 1945 on DP Mesa and was the site of a plutonium processing plant and radionuclide research laboratories (LANL 1991, 7528). Treated radioactive liquid waste was discharged at the 21-011(k) outfall into DP Canyon, a small tributary of upper Los Alamos Canyon, between 1956 and 1985. The 21-011(k) outfall was the source for most of the americium-241, cesium-137, and strontium-90 within the Los Alamos Canyon watershed and was also the source for other radionuclides at much lower concentrations, including plutonium-238; plutonium-239,240; tritium; and several isotopes of uranium and thorium. Discharges of cesium-137 and strontium-90 from the 21-011(k) outfall were apparently highest before 1968, and discharges of americium-241 were apparently highest after 1978.

TA-1 was established in 1943 within the current Los Alamos townsite, and several outfalls discharged liquid wastes off the mesa into upper Los Alamos Canyon (LANL 1992, 43454). The most significant of these outfalls in terms of supplying contaminants to upper Los Alamos Canyon was apparently an outfall at Hillside 137 that received wastewater from former Building D-2, the first plutonium facility at the Laboratory. This outfall was active from the mid 1940s to the mid 1950s, and sediment data collected in this investigation indicate that it was the primary source for plutonium-239,240 in upper Los Alamos Canyon, although much more plutonium was released from TA-45.

In addition to potential release sites (PRSs) in the upper Los Alamos Canyon and Pueblo Canyon subbasins, PRSs also exist in Bayo Canyon, Rendija Canyon, and lower Los Alamos Canyon that could potentially contribute contaminants to sediments in lower Los Alamos Canyon, although such contributions are expected to be minor. Bayo Canyon includes former TA-10, which was used as a firing site from approximately 1944 to 1963 and included a radiochemistry laboratory, which was used to

facilitate preparation of the shots (LANL 1992, 7668). Contaminants identified at the surface in ER Project investigations include copper, mercury, thallium, zinc, strontium-90, uranium, and several organic compounds associated with high explosives (LANL 1995, 49974). Rendija Canyon includes several ordnance impact areas, and ER Project investigations indicated no evidence of contaminant transport from these areas by surface runoff (LANL 1994, 35219). Lower Los Alamos Canyon has two PRSs (0-029[a] and 0-029[b]) at the sites of former water production wells in reach LA-4 where polychlorinated biphenyl (PCB) leakage from transformers was documented, but only very low levels of PCBs were found in the soil (LANL 1993, 26972).

1.4 Current Land Use

Lower Los Alamos Canyon includes a narrow rock-bound portion to the west that constitutes the boundary between the Laboratory and the Tsankawi unit of Bandelier National Monument, and a longer more open section that is part of San Ildefonso Pueblo (Figure 1.1-2). The part of the canyon on Laboratory land, west of the sampling reaches, includes a popular rock climbing area (Jackson 1996, 59164). The part of the canyon on San Ildefonso Pueblo land is used for grazing, hunting, and other activities and includes residences in two areas. The residential areas include three houses at Totavi, located between reach LA-4 East and the confluence with Bayo Canyon, and one house (the Halladay House) adjacent to reach LA-5 between the junction of state roads NM 502 and NM 30 and the Rio Grande. The western part of lower Los Alamos Canyon near the confluence with Pueblo Canyon (within TA-72) 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 the Los Alamos Canyon watershed have been investigated in many studies since the initial contaminant releases from TA-1 and TA-45. The first sediment sampling, in 1946, indicated the presence of plutonium along the full length of Pueblo Canyon and upper Los Alamos Canyon downstream from Laboratory sources, documenting rapid transport along a distance of at least 11 km from the source (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, with stations in lower Los Alamos Canyon being sampled since 1977 (e.g., Environmental Surveillance and Compliance Programs 1997, 56684). Additional studies during the 1970s that included sample sites in lower Los Alamos Canyon as well as upstream within Pueblo Canyon and upper Los Alamos Canyon were conducted by the Laboratory Environmental Sciences Group (e.g., Hakonson and Bostick 1975, 29678; Nyhan et al. 1976, 11747; Nyhan et al. 1982, 7164) and as part of the Formerly Utilized Sites Remedial Action Program (FUSRAP) (LANL 1981, 6059). More recently, a study conducted out of Arizona State University combined existing data on plutonium in sediments with geomorphic mapping of Pueblo Canyon and Los Alamos Canyon to provide an improved estimate of the inventory of plutonium in these canyons (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 lower Los Alamos Canyon sediments before this investigation indicated that cesium-137; plutonium-239,240; and other radionuclides discharged into Acid Canyon from TA-45 and 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. Contaminants associated with sediments have been dispersed by floods from the original release sites downstream past the confluence of Pueblo Canyon and Los Alamos Canyon and 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 greatest portion of the total plutonium inventory in the Los Alamos Canyon watershed occurs in the lower several kilometers of Pueblo Canyon where large amounts of sediment have been deposited by floods since 1943 (LANL 1981, 6059; LANL 1995, 50290; Graf 1996, 55537).

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 lower 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 discussed briefly below.

During implementation of the work plan the technical team decided to modify the location of one of the sampling reaches in lower Los Alamos Canyon. Reach LA-4 was originally proposed to extend upstream from the confluence with Bayo Canyon past the residences at Totavi. However, a reconnaissance in 1997 before initial geomorphic mapping suggested that locations upstream would be preferable for investigation for two reasons. First, the area adjacent to Totavi has been disturbed, and the channel area is partly constricted; it was judged that a more representative sampling of sediments could be performed a short distance upstream. Second, it was decided that sampling should be undertaken in the area near Basalt Springs because this area has a perennial stream and is ecologically important. This area is the first major area of sediment deposition downstream from Pueblo Canyon; hence, it potentially contains the highest concentrations of contaminants in lower Los Alamos Canyon. Therefore, LA-4 includes two subreaches: LA-4 West, located downstream from Basalt Springs, and LA-4 East, located a short distance upstream from Totavi (Figure 1.1-2).

Radiological field surveys conducted in 1996 revealed that the concentrations of radionuclide contaminants were too low in reach LA-5 to allow the extent of contaminated sediments to be determined using field instruments but that cesium-137 concentrations were high enough in upper Los Alamos

Canyon near the confluence with Pueblo Canyon to allow use of gross gamma radiation measurements to identify the areas with the highest levels of contamination. Therefore, sample site selection in LA-5 in 1997 was based entirely on geomorphic criteria instead of relying on field radiological data as was proposed in the work plan. In addition, radiological surveys in LA-4 in 1997 were restricted to gross gamma radiation surveys instead of also using field measurements of alpha and beta radiation as specified in the work plan. In the first LA-4 sampling round, sample site selection was biased by the field measurements of gamma radiation, but analytical results indicated that the field instruments were largely or entirely recording variations in background radiation. Therefore, sample site selection in the second sampling round did not use the field measurements.

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 lower 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 lower 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 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 the Los Alamos Canyon watershed, 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 lower 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 Los Alamos Canyon and Pueblo 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 lower 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 lower Los Alamos Canyon reaches. Appendix B-1.0 discusses 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, including discussion of instrument calibration and use. Appendix B-5.0 presents the chronology of sediment sampling events in the lower 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 lower 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 QA samples and resampled layers for key radionuclides.

Appendix F-1.0 presents the ecological scoping checklist for the lower 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. The gross gamma radiation walkover survey was performed by the Environmental Restoration Group (ERG) (Dave Hunter, Darrio Rocha, and John Taylor), 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. Gerald Martinez and Louis Naranjo served as liaisons with San Ildefonso Pueblo. Felicia Aguilar, Candi Chroninger, and Robert Trujillo provided data management support. 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.

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2.0 FIELD INVESTIGATIONS

2.1 Introduction to Reaches

The initial locations of the lower 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 lower 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 in LA-4 to better define geographic variations in contamination. The locations of the reaches and the topography of lower Los Alamos Canyon are shown in Figures 1.1-2, 2.1-1, and 2.1-2. 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-4 is located between the confluences of Los Alamos Canyon with Pueblo Canyon and Bayo Canyon, and two subreaches were defined for geomorphic characterization and sediment sampling (Figures 1.1-2 and 2.1-1). Reach LA-4 West is located a short distance downstream from where Los Alamos Canyon emerges from a steep rocky area in basalt. This is the first area where significant sediment deposition can occur downstream from the confluence of Los Alamos Canyon and Pueblo Canyon, and it is immediately east of the boundary between the Laboratory and San Ildefonso Pueblo. Several springs occur in this subreach, particularly downstream from Basalt Springs, and LA-4 West has a perennial stream. Many boulders occur along the channel in this subreach. Reach LA-4 East is located upstream from the residences at Totavi and is drier than LA-4 West; the stream is ephemeral in this subreach. Both subreaches have fairly narrow floodplains below higher stream terraces or colluvial slopes. Puye Formation bedrock is exposed along the canyon walls in both subreaches.

Reach LA-5 is located between the confluence of Los Alamos Canyon and Guaje Canyon and the Rio Grande. The canyon floor is very wide in this area, including a very broad active channel and large areas of floodplains and post-1942 abandoned channels. The entire area downstream from Guaje Canyon was originally selected for geomorphic characterization and radiological field measurements, but sampling was later focused on the lower 1.4 km above the Rio Grande. The sampling area is designated reach LA-5 in this report, and the area upstream where no samples were collected is designated LA-5 West in the discussion of radiological field measurements in Appendix B-4.2. The stream is ephemeral in LA-5, and Santa Fe Group bedrock underlies the canyon walls.

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.

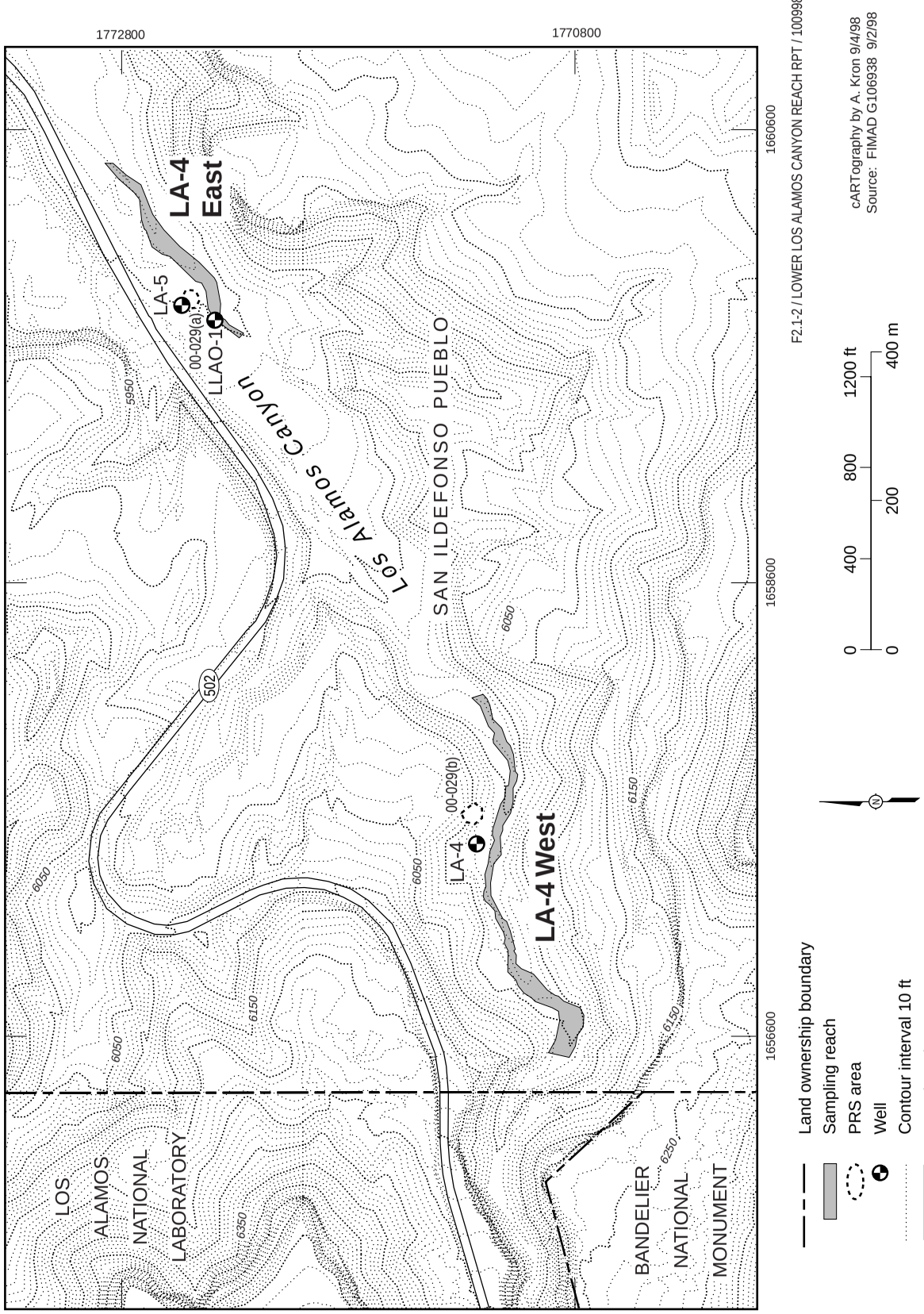


Figure 2.1-1. Topographic map of part of lower Los Alamos Canyon that includes reaches LA-4 West and LA-4 East.

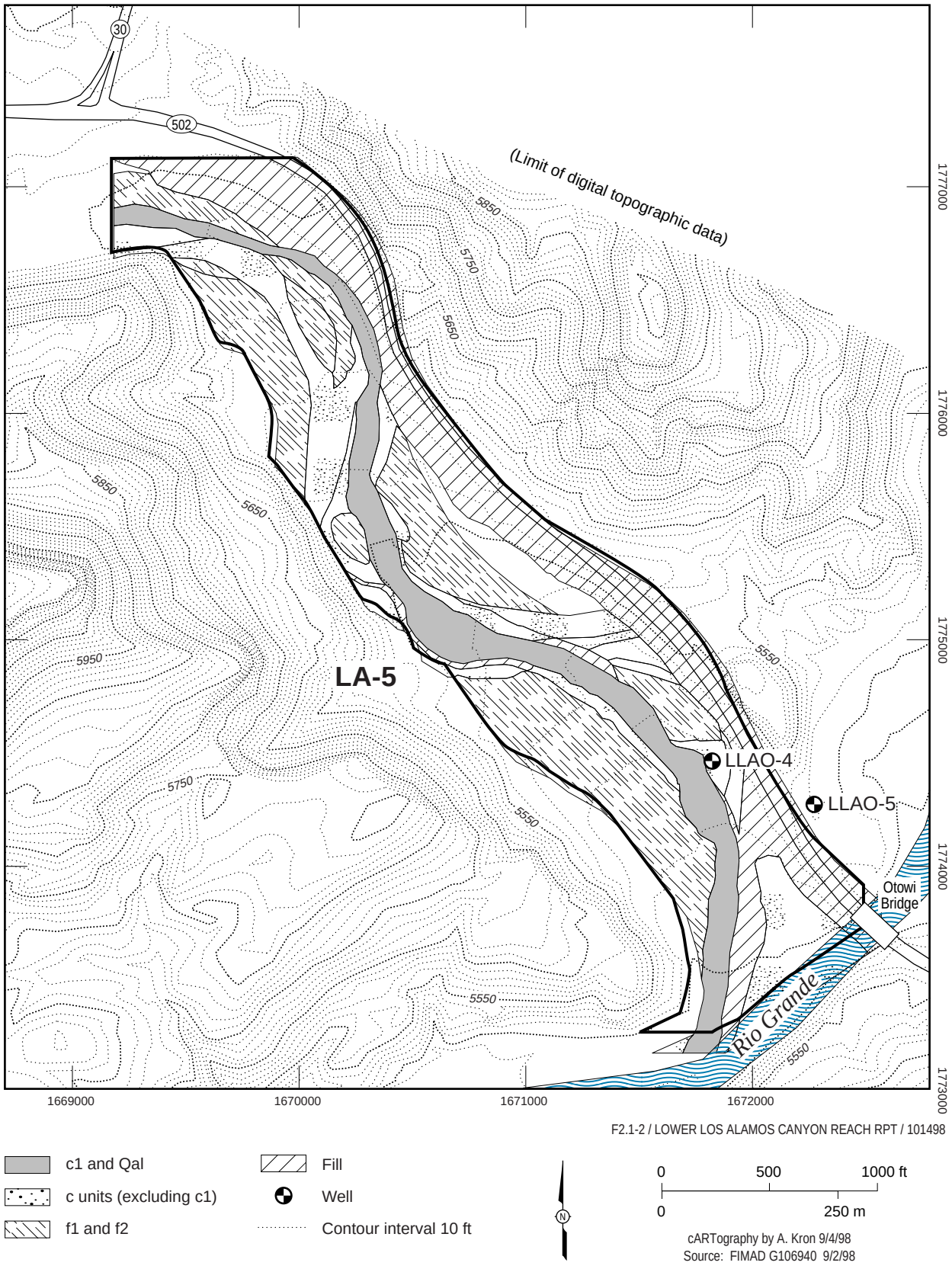


Figure 2.1-2. Topographic map of part of lower Los Alamos Canyon that includes reach LA-5.

Mapping in reach LA-5 was at a scale of 1:4800 and used high-resolution 1:4800 orthophotographs that were prepared from 1991 aerial photographs. Initial mapping in reach LA-4 also used these orthophotographs, but the geomorphic units in LA-4 are too narrow to allow adequate mapping using aerial photographs. Instead subsequent mapping in LA-4 was at a scale of 1:200 and involved measuring distances along the channel from reference points that could be recognized on the orthophotographs and frequently measuring unit width. Boundaries between geomorphic units were typically defined on the basis of topographic breaks, vegetation changes, and/or changes in surface sediments, although boundaries are more approximate in some areas with thick vegetation. Examination of sequential aerial photographs dating back to 1935 were used in reach LA-5 to determine which areas were occupied by the stream channel in the early post-1942 period. In reach LA-4 an attempt was made to partially subdivide geomorphic units on the basis of field measurements of gross gamma radiation, but it was found that concentrations of cesium-137 were too low, and these measurements were not reliable.

Geomorphic mapping was iterative, and the maps were revised after each phase of investigation in each reach. For example, in reach LA-4 West analytical results identified some floodplain areas away from the active channel as having concentrations of plutonium-239,240 that were higher than adjacent areas, and these areas were broken out as a separate geomorphic unit (unit f1b). In addition, geodetic surveying of sample locations after each sampling event often led to map revisions so that the surveyed sample locations were within the appropriate geomorphic unit (e.g., 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. 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, comparison of isotopic ratios in sediment samples from the c3 unit in LA-4 with samples of known age upstream in LA-2 East indicates that the c3 unit contains sediment that was largely deposited after 1968. In contrast, examination of aerial photographs indicates that the c3 unit in LA-5 may have been largely deposited during the 1950s or earlier.

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 by post-1942 floods, the thickness of post-1942 sediment would be small. The designation “f1b” is used for a floodplain area in LA-4 West with concentrations of plutonium-239,240 higher than adjacent areas.

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. “Qls” refers to large-scale landslides. Bedrock geologic units are also shown in some areas.

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. The determination of unit thicknesses used a variety of approaches, including identifying the depth at which the bases of trees are buried by sediment, recognizing buried soil horizons, and searching for the presence of man-made material that indicates a post-1942 age. 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. A few trees were cored for dendrochronologic analysis (tree-ring dating) 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 lower 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-5 in 1996 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. Extensive low-resolution gross gamma radiation walkover surveys were followed by higher resolution “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. These measurements were made during a pilot study phase of investigation when the utility of different field methods was being evaluated. Because of the relatively low concentrations of radiological contaminants in LA-5, these methods were not found to be useful in differentiating geomorphic units with different levels of contamination in that reach. During investigations in upper Los

Alamos Canyon in 1996 and 1997 (Reneau et al. 1998, 59160), gross gamma radiation measurements were found to be very useful in defining variations in the concentrations of cesium-137, and the initial field investigations in LA-4 in 1997 included extensive fixed-point gross gamma radiation measurements at 103 surface locations and in 48 depth profiles. However, subsequent laboratory analyses indicated that the concentrations of cesium-137 were too low in LA-4 to allow effective use of these methods, and the field measurements may have indicated only background variations in gamma radiation. Because of this, the field measurements are not 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 reach LA-5 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 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. Full-suite analyses were also obtained from sampling reaches in both Pueblo Canyon and Los Alamos Canyon upstream of the Laboratory boundary to determine which analytes were present above background values in these reaches and to help focus analyses in LA-4 (Reneau et al. 1998, 59159; Reneau et al. 1998, 59160).

Subsequent sampling phases in both reaches LA-4 and LA-5 were primarily focused on key contaminants that were used to define the horizontal and vertical variations in contaminant levels. Cesium-137 and plutonium-239,240 were selected as key contaminants for LA-4 because preliminary risk assessments using data from upstream reaches indicated that these radionuclides were the primary risk drivers in upper Los Alamos Canyon and Pueblo Canyon. Plutonium-239,240 was selected as a key contaminant in LA-5 because it was the only analyte in this reach that was found above background values in multiple samples in the full-suite analyses. 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 radionuclide inventory in reach LA-4, a stratified random sample allocation process was applied in the second sampling event (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. This process was not applied in LA-5 because the concentrations of all

contaminants were very low, instead it was decided to focus sampling on reducing uncertainties in the horizontal and vertical extent of contamination.

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 upstream reaches in lower Los Alamos Canyon and Pueblo Canyon. The limited suite included metals, polychlorinated biphenyls (PCBs) and pesticides, and select radionuclides; it 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. Sample collection for limited-suite analyses in LA-4 included sample intervals that had yielded the highest cesium or plutonium concentration in the initial sampling event 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-4

2.3.1.1 Physical Characteristics

Reach LA-4 is in a part of lower Los Alamos Canyon with a narrow, bouldery canyon floor. The area that has been impacted by post-1942 floods averages approximately 18 m wide in LA-4 West and 16 m wide in LA-4 East. The areal distribution of the geomorphic units is shown on Figures 2.1-1 and 2.1-2 and Figures 2.3-1 and 2.3-2, and topographic relations are illustrated in the cross sections of Figures 2.3-3 and 2.3-4. Physical characteristics of the geomorphic units in LA-4 are summarized in Table 2.3-1. Data on particle size and unit thickness are presented in Table B3-1, Table B3-3, and Figures B2-1 through B2-3.

The c1 unit averages 4.7 m wide in reach LA-4 West and 3.4 m wide in reach LA-4 East; it includes an active channel that is too narrow to map at a reasonable scale and adjacent low areas that are typically grassy and contain interstratified channel facies and overbank facies sediment. These adjacent low surfaces look like part of the active channel on the 1991 aerial photographs and are inferred to have been inundated during 1991 floods. The area comprising the active channel in 1997 averages only 0.8 m wide in both subreaches and has a bed composed of coarse sand and gravel. The adjacent low surfaces average 3.9 m wide in LA-4 West and 2.6 m in LA-4 East and have average heights of approximately 0.25 m (Table 2.3-1). The entire area of the c1 unit includes an average of 11 to 12 cm of relatively fine-grained overbank facies sediment dominated by fine sand, although approximately 30 to 35% of the total c1 area is composed of either the active channel or boulders.

The c1 unit is usually bordered by abandoned post-1942 channel units (c2, c3) that average approximately 5.5 to 7 m in combined width and have average heights of 0.6 to 1.0 m above the channel (Table 2.3-1). The c2 and c3 units are usually capped by an average of approximately 0.1 to 0.5 m of relatively fine-grained overbank sediments dominated by fine to very fine sand. In both reaches LA-4 West and LA-4 East the overbank facies sediment on the c3 unit is thicker than on the c2 unit.

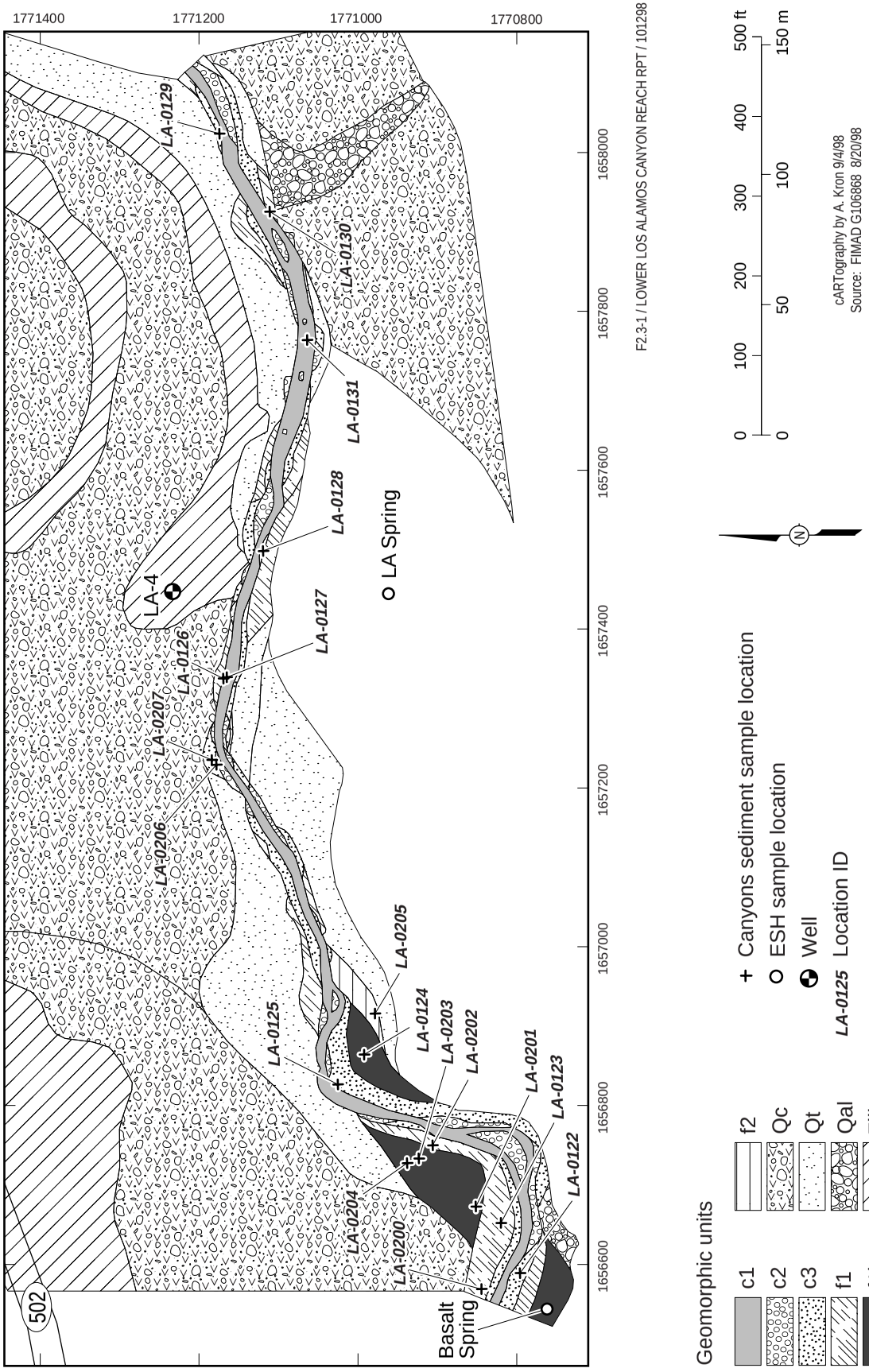


Figure 2.3-1. Geomorphic units and sample locations in reach LA-4 West.

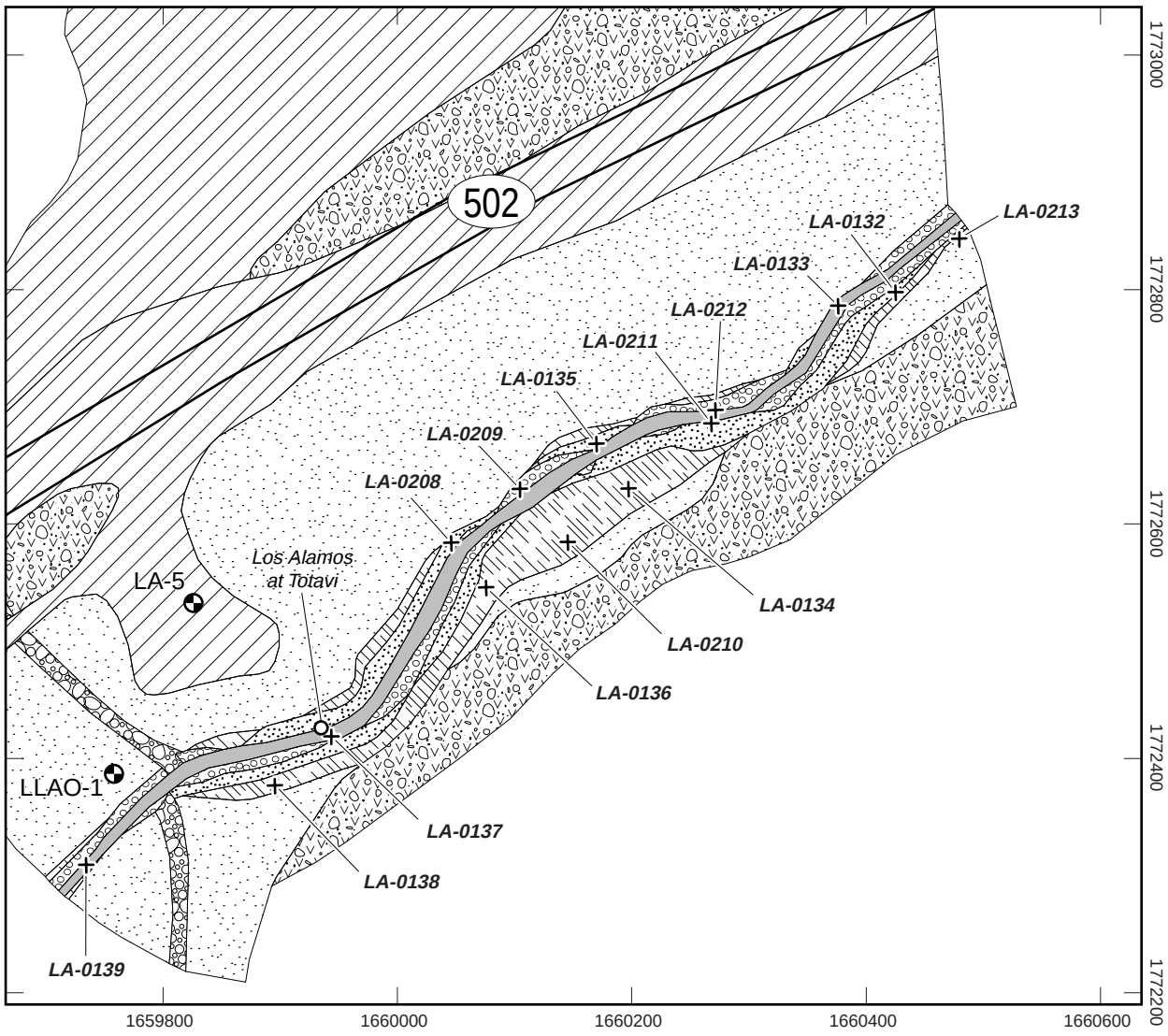


Figure 2.3-2. Geomorphic units and sample locations in reach LA-4 East.

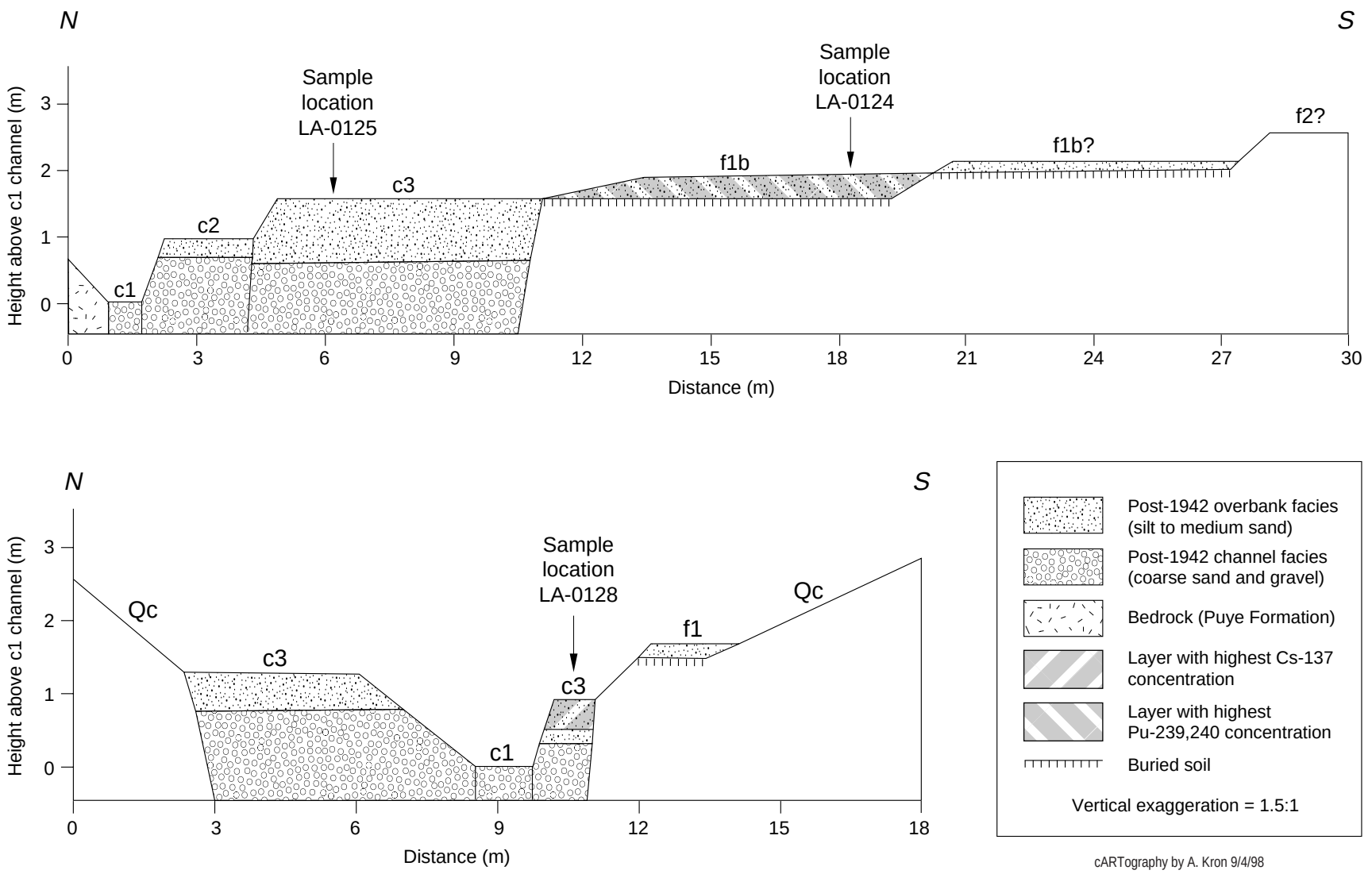


Figure 2.3-3. Schematic cross sections showing relations between geomorphic units in reach LA-4 West.

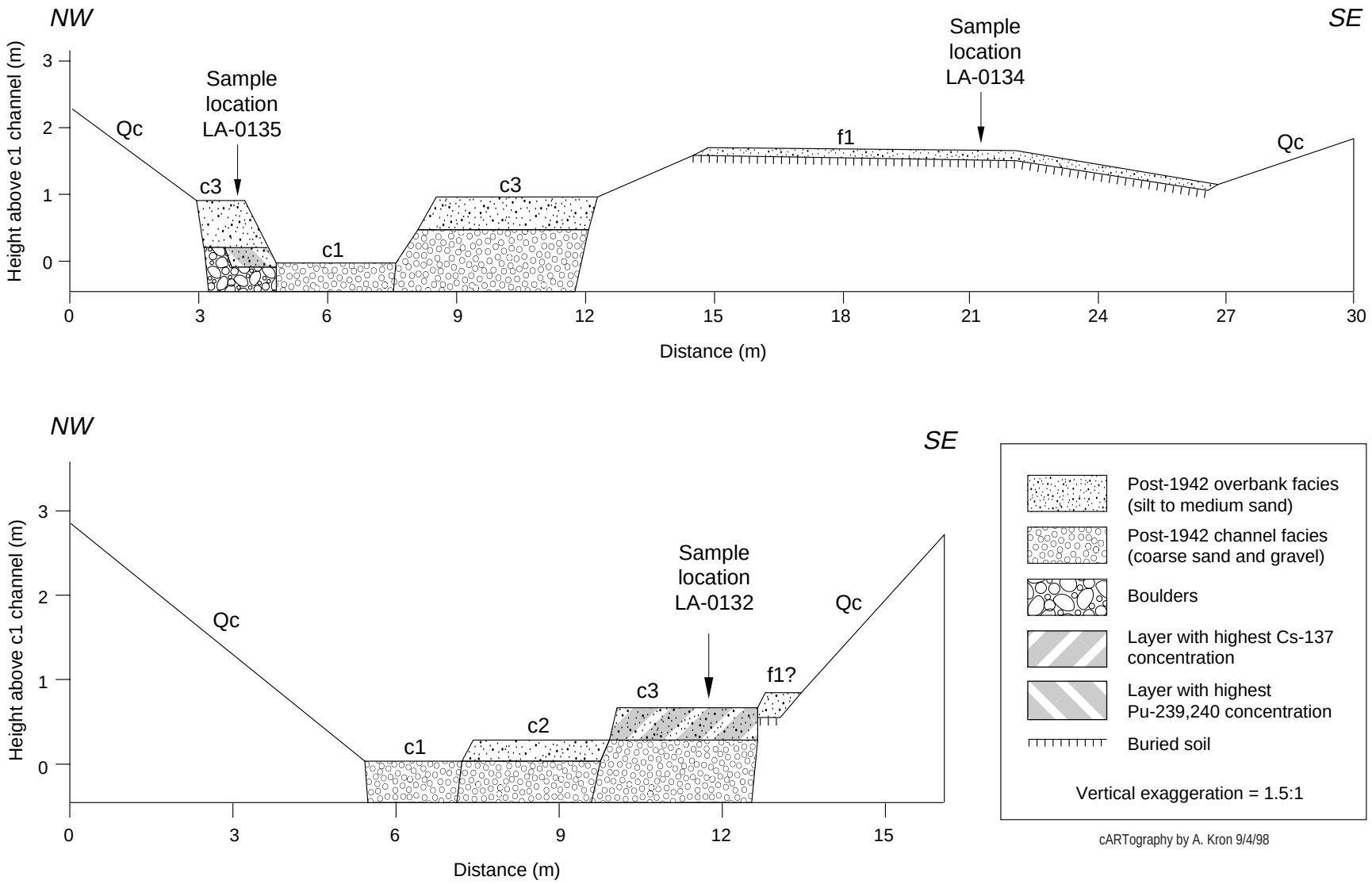


Figure 2.3-4. Schematic cross sections showing relations between geomorphic units in reach LA-4 East.

TABLE 2.3-1

GEOMORPHIC MAPPING UNITS IN REACH LA-4

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-4 West	c1	0.25	2467	3.9	Overbank	0.12 ± 0.10	Fine sand	Sandy loam	Active channel
		0		0.8	Channel	0.5	Coarse sand	Gravelly sand	
	c2	0.6	944	1.8	Overbank	0.24 ± 0.21	Very fine sand	Sandy loam	Younger abandoned post-1942 channel
					Channel	0.5	Coarse sand	Gravelly sand	
	c3	0.9	1961	3.8	Overbank	0.51 ± 0.26	Fine sand	Sandy loam	Older abandoned post-1942 channel
					Channel	0.5	Coarse sand	Gravelly sand	
	f1	1.1	2146	4.1	Overbank	0.29 ± 0.20	Fine sand	Sandy loam	Active floodplain
					Channel	0.05	Coarse sand	Gravelly sand	
	f1b	1.3	1624	3.1	Overbank	0.17 ± 0.14	Very fine sand	Sandy loam	Floodplain with highest plutonium concentrations
					Channel	0.05	Coarse sand	Gravelly sand	
	f2	1.6	244	0.5	Overbank	0.05	Coarse silt	Loam	Potentially active floodplain
LA-4 East	c1	0.25	988	2.6	Overbank	0.11 ± 0.10	Fine sand	Sandy loam	active channel
		0		0.8	Channel	0.5	Coarse sand	Gravelly sand	
	c2	0.6	856	3.0	Overbank	0.13 ± 0.12	Very fine sand	Sandy loam	Younger abandoned post-1942 channel
					Channel	0.5	Coarse sand	Gravelly sand	
	c3	1.0	1164	4.0	Overbank	0.48 ± 0.23	Fine sand	Sandy loam	Older abandoned post-1942 channel
					Channel	0.5	Coarse sand	Gravelly sand	
	f1	1.3	1701	5.9	Overbank	0.20 ± 0.13	Fine sand	Sandy loam	Active floodplain

* Average unit width uses lengths of 520 m for LA-4 West and 290 m for LA-4 East. The portion of the c1 unit that included the active channel in 1997 is based on direct field measurements and not on a mapped area.

Active post-1942 floodplains (f1 and f1b) average 7.2 m wide in reach LA-4 West and 5.9 m wide in reach LA-4 East. In LA-4 West the floodplain is subdivided using analytical data on plutonium concentrations into a typical f1 unit, which occurs close to the channel and has relatively low concentrations of plutonium, and an f1b unit, which occurs farther away from the channel and has higher concentrations of plutonium. The f1 unit in LA-4 West averages 1.1 m above the active channel and is capped by an average of 0.3 m of overbank sediments dominated by fine sand and 0.05 m of channel facies sediment dominated by coarse sand and gravel (Table 2.3-1). The f1b unit in LA-4 West is restricted to the western part of this subreach and averages approximately 1.3 m above the channel; it is capped by an average of 0.17 m of overbank facies sediment dominated by very fine sand and 0.05 m of channel facies sediment dominated by coarse sand and gravel. The f1 unit in LA-4 East has an average height of 1.3 m and is capped by an average of 0.2 m of overbank facies sediment dominated by fine sand. Areas mapped as potentially active floodplains (f2) occur only in LA-4 West and are small, with an average width of only 0.5 m. 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

Field measurements of gross gamma radiation in reach LA-4 initially suggested that there were variations in radiation that were related to levels of cesium-137 in post-1942 sediment deposits. However, analytical results from sediment samples collected in the first sampling event indicated that there was no relation between these field measurements and cesium-137 concentrations and that instead the variability in measured radiation was the result of background variability. Therefore, these measurements were not relied on for the geomorphic mapping or to help select sample sites in the second sampling event. A summary of the gross gamma radiation measurements and maps showing measurement locations are presented in Appendix B-4.0.

2.3.1.3 Geomorphic History

Geomorphic processes within reach LA-4 since 1942 have included the lateral migration of the active channel within an area that averages approximately 10 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 locally in LA-4, 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 layers of coarse sand and gravel on floodplains in the western part of LA-4 West that probably record local aggradation during multiple floods. This is in the area where the stream channel emerges from a steep and rocky reach incised into basalt and extends downstream from the confluence of Pueblo Canyon and Los Alamos Canyon; in this area the stream gradient decreases, and floods would have an opportunity to spread laterally. These geometric changes would result in a decrease in flood velocity and enhance the deposition of sediment, and the gravelly layers on the floodplains probably represent the local aggradation of the stream bed associated with the dissipation of energy by floods in this area.

The post-1942 overbank facies sediment and associated contaminants present within reach LA-4 are stored within both the c2 and c3 units relatively close to the active channel and the f1 and f1b units farther away from the channel. Most of the overbank sediment in both subreaches is contained within the c2 and c3 units where it is particularly susceptible to remobilization by lateral bank erosion during floods; 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 on evidence for sediment age provided by isotopic ratios in sediment

samples from the c2 and c3 units, as discussed further in Section 3.3. Specifically, the ratios of americium-241 to both cesium-137 and plutonium-239,240 in typical c2 and c3 overbank facies sediment indicate that these sediments were deposited after 1968 when the discharge of americium-241 from the 21-011(k) outfall at TA-21 into DP Canyon increased. The most important unit for the storage of overbank sediment in both subreaches is the c3 unit, which contains an estimated 40 to 50% of the volume of overbank sediment in the subreaches. It is notable that large basalt boulders are common in this unit, which should help impede lateral erosion during floods, and an unknown part of the overbank sediment deposited in the c3 unit may have residence times exceeding 50 years.

Approximately 30 to 35% of the overbank sediment in both reaches LA-4 West and LA-4 East is estimated to be 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. In particular, the highest concentrations of plutonium-239,240 in LA-4 are found in the f1b unit of LA-4 West, which is relatively far from the active channel where the potential for remobilization is relatively low (Figures 2.3-1 and 2.3-3). Comparison of the concentrations of plutonium-239,240 in the uppermost f1b sediments with dated sediment in lower Pueblo Canyon suggests that the last flood to overtop these surfaces occurred sometime between 1945 and 1965, as discussed in Section 3.3. The floodplain areas are most likely to be subjected to occasional overtopping during large floods, resulting in the deposition of additional fine-grained sediment, although floods of this size may be relatively infrequent.

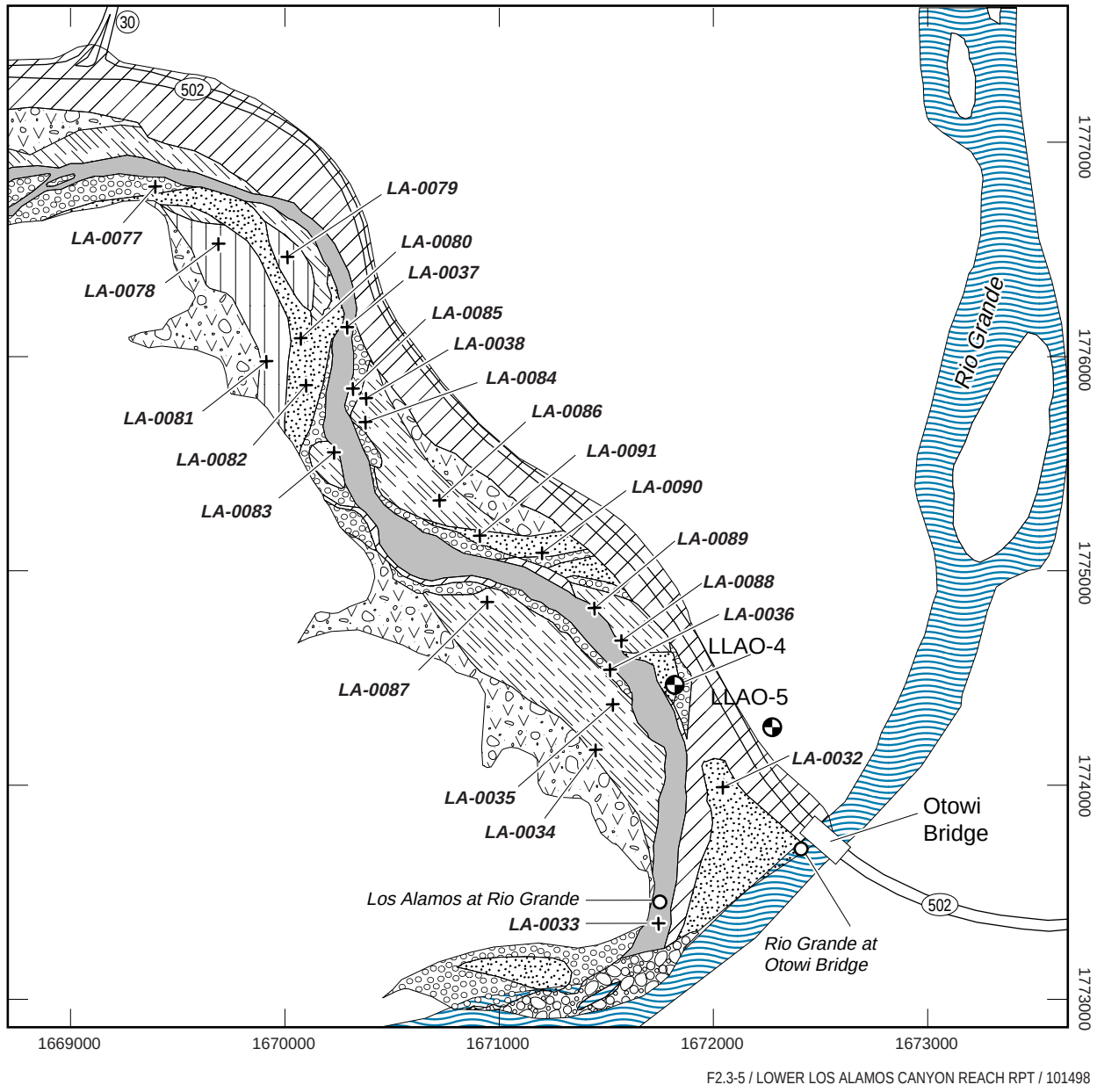
2.3.2 Reach LA-5

2.3.2.1 Physical Characteristics

Reach LA-5 is in a part of lower Los Alamos Canyon where the canyon floor is exceptionally broad, and the area that has been impacted by post-1942 floods has an average width of approximately 150 m. The areal distribution of the geomorphic units in the sampled reach is shown on Figures 2.1-2 and 2.3-5, and topographic relations are illustrated in the cross sections of Figure 2.3-6. Geomorphic units between the sampled reach and the confluence with Guaje Canyon are shown in Appendix B-4.0. Physical characteristics of the geomorphic units in LA-5 are summarized in Table 2.3-2. Data on particle size are presented in Tables B3-2 and B3-4.

The c1 unit in reach LA-5 averages 35 m wide and includes areas that apparently comprised the active channel in 1991, when the latest high-resolution aerial photographs were taken, although the stream channel during this investigation (1996 to 1998) occupies only part of this area. The remainder of the c1 unit generally includes sand or gravel bars that are within 0.5 m of the main channel and that have become partially vegetated since 1991. Sediment in the entire area of the c1 unit is dominated by coarse sand and gravel.

The c1 unit in reach LA-5 is usually bordered by large abandoned post-1942 channel units, c2 and c3, although these units also include areas separated from the active channel by floodplain units that formerly constituted part of a braided channel system. The younger c2 unit averages 16 m wide and has an average height of approximately 1.0 m above the channel (Table 2.3-2). The c2 unit is capped by an average of approximately 0.15 m of relatively fine-grained overbank sediment dominated by fine sand, which overlies coarse sand and gravel. The c3 unit averages 33 m wide and has an average height of approximately 1.3 m above the channel. The c3 unit is capped by an average of approximately 0.1 m of relatively fine-grained overbank sediment dominated by fine sand, which also overlies coarse sand and gravel. The c3 unit includes areas occupied by the active channel during the earliest part of Laboratory operations, as shown by examination of 1935 and 1954 aerial photographs.



F2.3-5 / LOWER LOS ALAMOS CANYON REACH RPT / 101498

Geomorphic units

- c1
- c2
- c3
- f1
- f2
- Qc + Qf
- Qal
- Fill

+ Canyons sediment sample location

○ ESH sample location

◔ Well

LA-0033 Location ID

N

0 500 1000 ft

0 250 m

cARTography by A. Kron 9/4/98
Source: FIMAD G106869 8/21/98

Figure 2.3-5 Geomorphic units and sample locations in reach LA-5.

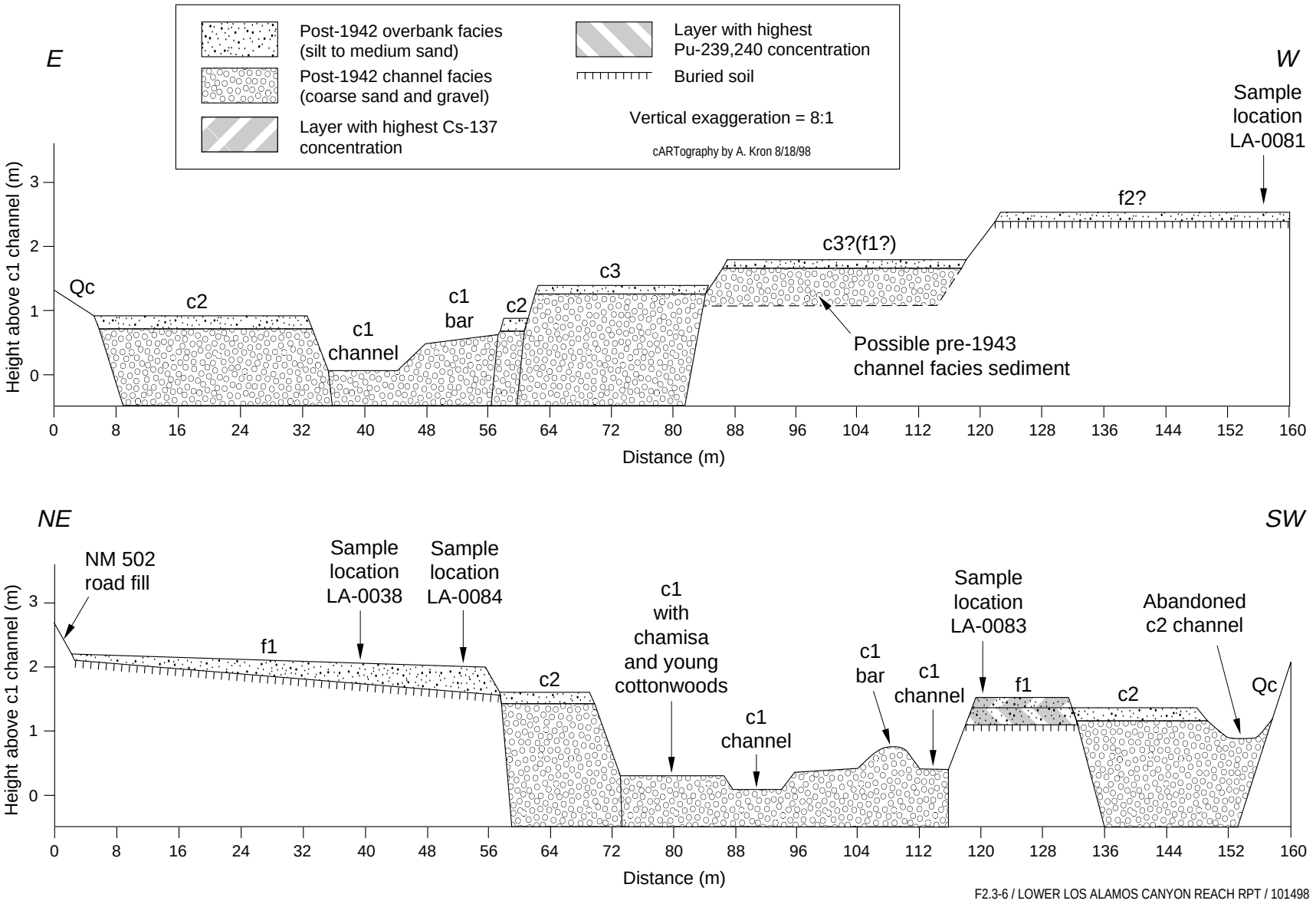


Figure 2.3-6. Schematic cross sections showing relations between geomorphic units in reach LA-5.

TABLE 2.3-2

GEOMORPHIC MAPPING UNITS IN REACH LA-5

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	48795	35	Channel	1.0	Coarse sand	Gravelly sand	Active channel and adjacent bars from 1990s
c2	1.0	22394	16	Overbank	0.15	Fine sand	Loamy sand	Younger abandoned post-1942 channel
				Channel	1.0	Coarse sand	Gravelly sand	
c3	1.3	46441	33	Overbank	0.1	Fine sand	Loamy sand	Older abandoned post-1942 channel
				Channel	0.5	Coarse sand	Gravelly sand	
f1	1.5	73888	52	Overbank	0.2	Very fine sand	Sandy loam	Active floodplain
f2	1.6	21800	15	Overbank	0.1	Very fine sand	Sandy loam	Potentially active floodplain

*Average unit width uses a length of 1.41 km for LA-5.

Active post-1942 floodplains (f1) average 52 m wide in reach LA-5, and potentially active floodplains (f2) average 15 m wide. The distinction between the f1 and the f2 units is made based on analytical data on plutonium concentrations, with the f1 unit containing plutonium-239,240 above the background value and the f2 unit containing plutonium that is close to the background value. The f1 unit in LA-5 averages approximately 1.5 m above the active channel and is capped by an average of 0.2 m or less of overbank sediments dominated by very fine sand. This average is based on measurements made at sample sites and, because sample site selection was generally biased to areas close to the channel where post-1942 sediment could be relatively thick, these measurements probably provide a conservative overestimate of average thickness. The f2 unit is slightly higher than f1 relative to the active channel, and is probably capped by 0.1 m or less of post-1942 overbank sediment.

2.3.2.2 Radiological Characteristics

Field measurements of gross alpha, beta, and gamma radiation in reach LA-5 indicated that levels of all radionuclides were not high enough to allow contaminated areas to be distinguished from background radiation; therefore, these measurements were not used in the geomorphic mapping or to help select sample sites after the first sampling event. A summary of the field radiation measurements and maps showing measurement locations are presented in Appendix B-4.0.

2.3.2.3 Geomorphic History

Since 1942 geomorphic processes within reach LA-5 have included significant changes in both the elevation of the stream bed and the horizontal position of the channel. Aerial photographs taken in 1935 and 1954 show that during that period the channel was braided in the west part of LA-5, represented by the c3 unit (Figure 2.3-5), and that subsequently one branch of the channel was abandoned. The c3 channel deposits in this area occur up to 1.5 m above the present channel (Figure 2.3-6), indicating channel incision since that time. The nature of these channel changes is similar to what is documented in lower Pueblo Canyon, where channel aggradation was followed by channel incision over a period of decades (Reneau et al. 1998, 59159). The channel changes in Pueblo Canyon are believed to have resulted from large variations in the supply of sediment from upstream reaches, and the channel changes in LA-5 may have similar causes.

The c2 unit in reach LA-5 also records channel incision and includes a braided channel that was abandoned in the central part of the reach (near sample location LA-0084; Figures 2.3-5 and 2.3-6). The c2 channel in this area was abandoned before 1969, and approximately 1 m of incision has occurred since that time.

Channel changes downstream closer to the Rio Grande have been strongly influenced by engineering activities that have diverted the channel. In the area near well LLA0-4 (Figure 2.3-5), the channel had been impinging on the highway at the outside of a bend, and a new channel was apparently excavated to the southwest through a former floodplain surface to protect the highway. Farther downstream a large berm was apparently constructed to prevent the channel from impinging on the supports for Otowi Bridge during floods, confining the channel and forcing it to enter the Rio Grande downstream (Figure 2.3-5).

These changes in channel location since 1942 have influenced the pattern of sediment deposition in reach LA-5. Floodplains near the abandoned c3 channels should have experienced the most significant deposition of relatively fine-grained overbank facies sediment when these channels were active, and deposition would probably decrease after channel incision because there would be less frequent overtopping of these surfaces during floods. Similarly floodplain areas near abandoned c2 channels would likely have experienced the most frequent inundation by floods with associated sediment deposition when these channels were active. The engineered channel diversions closer to the Rio Grande may also have helped keep floods confined and reduced the deposition of overbank sediment on adjacent surfaces in these areas.

3.0 ANALYTICAL RESULTS AND DATA REVIEW

3.1 Data Review

Sediment samples collected in the lower 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 seven samples in reach LA-5. The full-suite analytes included semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs) and pesticides, americium-241 by alpha spectroscopy, tritium, isotopic plutonium, cesium-137 and other radionuclides in the gamma spectroscopy suite, isotopic uranium, isotopic thorium, strontium-90, gross alpha/beta radiation, and gross gamma radiation. Plutonium-239,240 was chosen as a key contaminant in both reaches LA-4 and LA-5, and isotopic plutonium analyses were obtained from every sampled sediment layer (110 total analyses). Cesium-137 was chosen as a key contaminant in LA-4 and was part of the limited-suite in LA-5; americium-241, cesium-137, and other radionuclides in the gamma spectroscopy suite were obtained from all sampled layers in LA-4 and from a subset of the LA-5 layers (87 total analyses). The following analytes were included in both limited-suite and full-suite analyses: strontium-90 (28 total analyses), inorganic chemicals that are on the TAL (19 total analyses), and PCBs and pesticides (14 total analyses).

TABLE 3.1-1

NUMBER OF SAMPLES ANALYZED BY SUITE

Analytical Suite	Reach		
	LA-4	LA-5	Total
Pesticides and PCBs	7	7	14
SVOCs	0	7	7
Inorganic chemicals (TAL)	12	7	19
Boron, total cyanide, titanium	0	7	7
Uranium, total uranium	0	7	7
Americium-241 (by alpha spectroscopy)	0	7	7
Gross alpha and beta radiation	0	7	7
Gross gamma radiation	0	7	7
Gamma-spectroscopy radionuclides	77	10	87
Tritium	0	7	7
Isotopic plutonium	78	32	110
Isotopic thorium	0	7	7
Isotopic uranium	0	7	7
Strontium-90	21	7	28

The objective of this data review is to determine which analytes should be retained for further assessment or eliminated before calculating human health and ecological risk. Considerations in these assessments

include the magnitude of contaminant concentrations relative to background values (or detection limits for organic chemicals), the correlation of contaminant concentrations both 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 for in 19 sediment samples collected from both lower Los Alamos Canyon reaches. Analysis for four other inorganic chemicals was also requested in a subset of samples. Boron, total cyanide, titanium, uranium, and total uranium were requested for seven samples from reach LA-5. Inorganic chemical sample results were compared with the sediment background values that are presented in "Inorganic and Radionuclide Background Data for Soils, Canyons Sediments, and Bandelier Tuff at LANL" (Ryti et al. 1998, 58093).

As detailed in Appendix C, most of the QC problems associated with this data set were caused by the detection of inorganic chemicals in method blanks and high or low recoveries in the matrix spike samples. Other problems included finding unacceptably high or low laboratory duplicate results or large differences (>10%) between serial dilutions required for certain analytes analyzed by the inductively coupled plasma (ICP) technique. 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. 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 were interferences in the ICP technique, which can also cause problems with the reported recoveries.

Data qualifications due to blank contamination were noted for six inorganic chemicals in a subset of the samples: arsenic (seven samples), beryllium (two samples), chromium (two samples), nickel (one sample), selenium (four samples), and titanium (four samples). Matrix spike duplicate recovery problems were noted for arsenic (six samples) and selenium (seven samples). Exceptionally low matrix spike recoveries were noted for antimony in request number (RN) 2252 (seven samples); therefore, these data were rejected. This QC problem has eliminated all antimony results for reach LA-5. Appendix C also shows that some laboratory duplicate measurements are out of the ±35% control window for seven sample results of the following analytes: aluminum, chromium, lead, sodium, and titanium. These problems are not considered to be serious and probably reflect the heterogeneous nature of the sediment samples. Also, ICP serial dilution problems were associated with five sample results for potassium and sodium. In summary, most of the QC problems associated these data are not expected to impact the identification of chemicals of potential concern (COPCs) except for the rejected antimony sample results.

The analytical methods for the inorganic chemicals are comparable to those used to generate the Laboratory background data, except antimony. Some of the lower 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 lower 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 lower 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 sample collected from lower Los Alamos Canyon sediment. Antimony and thallium were not detected in any sample. The detection limit for most antimony sample results exceeded the background value. Two nondetected thallium sample results were greater than the background value. Detection limits for some of the cadmium and selenium analyses were also greater than the background values. Tables 3.1-2 and 3.1-3 present the concentration range and frequency of results above the background values for the 25 detected inorganic chemicals and the two nondetected inorganic chemicals for reaches LA-4 and LA-5, respectively.

TABLE 3.1-2

FREQUENCY OF DETECTED INORGANIC CHEMICALS IN REACH LA-4

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	12	12	999 to 5480	5480	15400	0/12
Antimony	12	0	[0.7] to [5.3]	ND[c]	0.83	9/12 DL[d]>BV[e]
Arsenic	12	12	0.5 to 2.9	2.9	3.98	0/12
Barium	12	12	14 to 104	104	127	0/12
Beryllium	12	5	[0.39] to [1.3]	0.6	1.31	0/5, 0/7 DL>BV
Cadmium	12	1	[0.04] to [0.53]	0.07	0.4	0/1, 7/11 DL>BV
Calcium	12	12	597 to 7410	7410	4420	2/12
Chromium, total	12	10	[1.7] to 5.3	5.3	10.5	0/10, 0/2 DL>BV
Cobalt	12	12	0.96 to 4.4	4.4	4.73	0/12
Copper	12	12	2.5 to 10.8	10.8	11.2	0/12
Iron	12	12	3030 to 7530	7530	13800	0/12
Lead	12	12	4.2 to 31.6	31.6	19.7	2/12
Magnesium	12	12	316 to 1940	1940	2370	0/12
Manganese	12	12	129 to 364	364	543	0/12
Mercury	12	7	[0.011] to 0.04	0.04	0.1	0/7, 0/5 DL>BV
Nickel	12	11	[1.6] to 7.1	7.1	9.38	0/11, 0/1 DL>BV
Potassium	12	12	256 to 1860	1860	2690	0/12
Selenium	12	0	[0.18] to [0.83]	ND	0.3	5/12 DL>BV
Silver	12	1	[0.14] to 0.64	0.64	1	0/1, 0/11 DL>BV
Sodium	12	12	57.1 to 777	777	1470	0/12
Thallium	12	0	[0.18] to [0.88]	ND	0.73	2/12 DL>BV
Vanadium	12	11	3.5 to 13.1	13.1	19.7	0/11, 0/1 DL>BV
Zinc	12	12	14.1 to 35.6	35.6	60.2	0/12

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-5

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	7	7	1510 to 7590	7590	15400	0/7
Arsenic	7	0	[0.92] to [1.8]	ND[c]	3.98	0/7 DL[d]>BV[e]
Barium	7	7	35.2 to 102	102	127	0/7
Beryllium	7	7	0.15 to 0.54	0.54	1.31	0/7
Boron	7	5	[1.2] to 6.8	6.8	3.9	1/5, 0/2 DL>BV
Cadmium	7	0	[0.2] to [0.2]	ND	0.4	0/7 DL>BV
Calcium	7	7	1320 to 4910	4910	4420	1/7
Chromium, total	7	7	2.7 to 9.4	9.4	10.5	0/7
Cobalt	7	7	0.52 to 3.4	3.4	4.73	0/7
Copper	7	7	2.2 to 5.9	5.9	11.2	0/7
Cyanide, total	7	2	0.15 to 0.3	0.3	0.82	0/2, 0/5 DL>BV
Iron	7	7	3500 to 10200	10200	13800	0/7
Lead	7	7	4 to 26.2	26.2	19.7	1/7
Magnesium	7	7	600 to 1780	1780	2370	0/7
Manganese	7	7	116 to 256	256	543	0/7
Mercury	7	0	[0.02] to [0.02]	ND	0.1	0/7 DL>BV
Nickel	7	7	2.9 to 7	7	9.38	0/7
Potassium	7	7	556 to 2880	2880	2690	1/7
Selenium	7	2	[0.3] to [0.74]	0.4	0.3	2/2, 4/5 DL>BV
Silver	7	0	[0.1] to [0.1]	ND	1	0/7 DL>BV
Sodium	7	7	497 to 1530	1530	1470	1/7
Thallium	7	0	[0.4] to [0.4]	ND	0.73	0/7 DL>BV
Titanium	7	7	133 to 394	394	439	0/7
Uranium	7	7	0.1 to 0.51	0.51	2.22	0/7
Uranium, total	7	7	1.9 to 5.4	5.4	6.99	0/7
Vanadium	7	7	6.5 to 20.6	20.6	19.7	1/7
Zinc	7	7	14.6 to 38.4	38.4	60.2	0/7

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

Fifteen inorganic chemicals (aluminum, arsenic, barium, beryllium, total chromium, cobalt, total cyanide, iron, manganese, mercury, nickel, silver, titanium, uranium [both as uranium and total uranium], and zinc) were measured above the detection limits and below the background values. The only QC problem of note for these chemicals was the possible low bias for arsenic indicated by low spike recoveries in six samples from reach LA-5 (see Appendix C). All arsenic sample results were qualified as UJ, and the maximum detection limit was less than 50% of the background value, which suggests that any correction

for possible low bias would not change the conclusion of the arsenic background comparisons. Thus, these 15 inorganic chemicals (including both uranium and total uranium) are not retained for further assessment in this report because concentrations in the samples collected from the lower Los Alamos Canyon sediment do not differ from concentrations in background samples. Additional discussion and graphical data presentations for these chemicals can be found in Appendix E.

Thallium was not detected in any sample, and two detection limit values were marginally greater than the background value (0.83[U] and 0.88[U] mg/kg versus a background value of 0.73 mg/kg). Thallium is not retained as a COPC in lower Los Alamos Canyon because the detection limit range is within the detection limit range of the Laboratory background data for this chemical (a detection limit of up to 1 mg/kg for soil, which provides the basis for the thallium background value of 0.73 mg/kg). In addition, thallium was not identified as a COPC in any upstream reaches in upper Los Alamos Canyon or Pueblo Canyon. Additional discussion and graphical data presentations for thallium can be found in Appendix E.
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. It is important to note that antimony was not detected in any upstream reach in upper Los Alamos Canyon or Pueblo Canyon.

Cadmium was detected in only one lower Los Alamos Canyon sample, and this detected cadmium result is less than the background value. However, cadmium is retained as a COPC because 7 of 18 detection limits were greater than the background values. Cadmium was also identified as a COPC in some upstream reaches in both upper Los Alamos Canyon and Pueblo Canyon.

Nine other inorganic chemicals are 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 boron, calcium, copper, lead, magnesium, potassium, selenium, sodium, and vanadium. It is worth noting that selenium had QC indicators of positive bias, which suggests that selenium may have been erroneously identified as a COPC. However, all sample results are used as reported without any adjustment for possible bias; therefore, selenium will be retained for further assessment.

In summary, the inorganic chemical data review yielded eleven analytes to be carried forward as COPCs (see Table 3.1-4). 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 Los Alamos Canyon watershed. The concentrations of the chemicals eliminated as COPCs were well within the background concentration range, except for the two thallium detection limits greater than the background value for samples from reach LA-4; therefore, these chemicals are justifiably excluded from further assessment.

3.1.2 Radionuclide Comparison with Background/Fallout Radionuclide Concentrations

A total of 117 samples were analyzed for radionuclides in the lower 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, Canyons Sediments, and Bandelier Tuff at LANL” (Ryti et al. 1998, 58093). The analytical methods used for the lower Los Alamos Canyon radionuclide analyses are comparable to those used for the Laboratory background data.

TABLE 3.1-4

RESULTS OF INORGANIC DATA REVIEW

Analyte	Result	Rationale
Aluminum	Eliminated as a COPC	No values exceeded the background value
Antimony	Retained as a COPC	Detection limits in reach LA-4 exceeded the background value (note that the reach LA-5 results were rejected)
Arsenic	Eliminated as a COPC	No values exceeded the background value
Barium	Eliminated as a COPC	No values exceeded the background value
Beryllium	Eliminated as a COPC	No values exceeded the background value
Boron	Retained as a COPC	Detected value above the background value in reach LA-5
Cadmium	Retained as a COPC	Detection limits above the background value in reach LA-4
Calcium	Retained as a COPC	Detected values above the background value in reaches LA-4 and LA-5
Chromium, total	Eliminated as a COPC	No values exceeded the background value
Cobalt	Eliminated as a COPC	No values exceeded the background value
Copper	Retained as a COPC	Statistical and graphical data analyses presented in Appendix E indicate reach LA-4 results are greater than background values
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-4 and LA-5
Magnesium	Retained as a COPC	Statistical and graphical analysis presented in Appendix E
Manganese	Eliminated as a COPC	No values exceeded the background value
Mercury	Eliminated as a COPC	No values exceeded the background value
Nickel	Eliminated as a COPC	No values exceeded the background value
Potassium	Retained as a COPC	Detected values above the background value in reach LA-5
Selenium	Retained as a COPC	Detected values above the background value in reach LA-5 and detection limits above the background value in reaches LA-4 and LA-5
Silver	Eliminated as a COPC	No values exceeded the background value
Sodium	Retained as a COPC	Detected values above the background value in reach LA-5
Thallium	Eliminated as a COPC	No detected values exceeded the background value, and the two detection limits above the background value were within the range of detection limits observed in the background data
Titanium	Eliminated as a COPC	No values exceeded the background value
Uranium	Eliminated as a COPC	No values exceeded the background value
Uranium, total	Eliminated as a COPC	No values exceeded the background value
Vanadium	Retained as a COPC	Detected value above the background value in reach LA-5
Zinc	Eliminated as a COPC	No values exceeded the background value

The detected radionuclides include isotopes associated with worldwide fallout. For these radionuclides (americium-241; cesium-137; plutonium-238; plutonium-239,240; and tritium) 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 three-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 gas proportional counting. 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 includes actinium-228, americium-241, bismuth-211, bismuth-212, bismuth-214, cadmium-109, cerium-139, cerium-144, cesium-134, cesium-137, cobalt-57, europium-152, lanthanum-140, lead-211, lead-212, lead-214, manganese-54, potassium-40, protactinium-231, protactinium-233, protactinium-234M, radium-224, radium-226, radon-219, selenium-75, thallium-208, thorium-234, tin-113, yttrium-88, 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.

1. 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-211 [half-life = 36 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 = 1600 years], radon-219 [half-life = 4 seconds], thallium-208 [half-life = 3.1 minutes], and thorium-234 [half-life = 24 days]). 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.

2. 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.

3. The third category consists of cerium-144 (half-life = 280 days), cobalt-57 (half-life = 270 days), lanthanum-140 (half-life = 1.7 days), manganese-54 (half-life = 310 days), protactinium-233 (half-life = 27 days), selenium-75 (half-life = 120 days), and zinc-65 (half-life = 240 days), which are nuclear reactor activation or fission products with half-lives of less than one year. The detected concentrations of these radionuclides are either within the range of nondetected results or are marginally greater than the nondetected results (see Appendix D, Table D3-2). Because of the short half-lives and the low concentrations measured, these radionuclides are excluded from further evaluation.

4. The fourth group consists of cadmium-109 (half-life = 460 days), cerium-139 (half-life = 140 days), tin-113 (half-life = 120 days), and yttrium-88 (half-life = 107 days), which are used as analytical laboratory control standards and do not warrant further evaluation in this report.

5. The last group consists of plutonium chemistry or nuclear reactor activation or fission products with half-lives of greater than one year, which includes americium-241 (half-life = 430 years),

cesium-134 (half-life = 2.1 years), cesium-137 (half-life = 30 years), and europium-152 (half-life = 14 years). Because these radionuclides were identified as COPCs in upper Los Alamos Canyon, all will be carried forward to the background comparison. Americium-241 was also measured by alpha spectroscopy, and 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, and europium-152 are the only gamma-spectroscopy radionuclides carried forward to the background comparison. Twenty-six 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. Detection limits were somewhat elevated for one americium-241 sample result and five plutonium-239,240 sample results. The overall quality and comparability of the radionuclide data are also evident through the detailed statistical analyses presented in Appendix E.

One important measure of data quality was addressed through quality assurance (QA) duplicate and resamples. This evaluation is presented in Appendix E-4, but one pair of resample values has bearing on data review for strontium-90. Sample 04LA-97-0222 was collected during the first reach LA-4 sampling event from the c3 unit in LA-4 West. The strontium-90 result for this sample was 12.8 pCi/g. This sediment layer was resampled for strontium-90 in the second LA-4 sampling event along with seven other sediment layers. The resample value for 04LA-97-0222 was 0.74(U) (undetected, sample 04LA-97-0554). Because of the large difference between these sample results and the lack of any other detected strontium-90 values for LA-4, the strontium-90 result for sample 04LA-97-0222 is considered to be invalid. Therefore, strontium-90 in LA-4 is considered to be not detected. No detects were observed for strontium-90 in reach LA-5. Thus, strontium-90 is not retained as a COPC for lower Los Alamos Canyon.

Tables 3.1-5 and 3.1-6 present the concentration range and frequency of results above the background value for the 12 detected radionuclides for reaches LA-4 and LA-5, respectively. A complete presentation of the data for these radionuclides is in Appendix D.

TABLE 3.1-5

FREQUENCY OF DETECTED RADIONUCLIDES IN REACH LA-4

Analyte	Number of Analyses	Number of Detects	Concentration Range (pCi/g)[a]	Maximum Detect (pCi/g)	Background Value/ Fallout Value (pCi/g)[b]	Frequency of Detects above Background Value/Fallout Value
Americium-241[c]	77	21	[-0.515] to 4.64	4.64	DL[d]	21/21
Cesium-137	77	54	[-0.045] to 4.65	4.65	0.9	20/54
Europium-152	75	3	[-0.734] to [0.467]	0.408	DL	3/3
Plutonium-238	78	28	[-0.01] to 0.227	0.227	0.006	28/28
Plutonium-239,240	78	74	[0.002] to 13.8	13.8	0.068	71/74

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 = sample-specific detection limit (see Appendix D, Table D3-2 for nondetect concentration range)

TABLE 3.1-6

FREQUENCY OF DETECTED RADIONUCLIDES IN REACH LA-5

Analyte	Number of Analyses	Number of Detects	Concentration Range (pCi/g)[a]	Maximum Detect (pCi/g)	Background Value/ Fallout Value (pCi/g)[b]	Frequency of Detects above Background Value/Fallout Value
Americium-241	7	2	[0.023] to 0.065	0.065	0.04	2/2
Cesium-134	10	1	[0.0088] to 0.24	0.24	DL[c]	1/1
Cesium-137	10	5	[-0.029] to 1.073	1.073	0.9	1/5
Tritium	7	6	[0.002] to 0.012	0.012	0.093	0/6
Plutonium-239,240	32	19	[-0.0066] to 2.524	2.524	0.068	19/19
Thorium-228	7	7	0.67 to 1.88	1.88	2.28	0/7
Thorium-230	7	7	0.69 to 1.99	1.99	2.29	0/7
Thorium-232	7	7	0.63 to 1.77	1.77	2.33	0/7
Uranium-234	7	7	0.63 to 2	2	2.59	0/7
Uranium-238	7	7	0.63 to 1.8	1.8	2.29	0/7

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. DL = sample-specific detection limit (see Appendix D, Table D3-2 for nondetect concentration range)

Two detected radionuclides, cesium-134 and europium-152, have no background data. The radionuclide evaluation method is to retain such analytes for further evaluation. Thus, cesium-134 and europium-152 are retained as COPCs. Six radionuclides (thorium-228, thorium-230, thorium-232, tritium, uranium-234, and uranium-238) were eliminated as COPCs because their concentrations were not different from background values. Appendix E provides the statistical and graphical evidence used to eliminate these radionuclides as COPCs. Four radionuclides (americium-241; cesium-137; plutonium-238; and plutonium-239,240) were retained as COPCs because concentrations were greater than background values. A complete presentation of the sample results for radionuclide COPCs is provided in Section 3.3 and Appendix D.

In summary, the radionuclide data review yielded six analytes to be carried forward as COPCs (see Table 3.1-7) based on comparison of sample results to background values and the statistical and graphical data evaluations presented in Appendix E.

3.1.3 Evaluation of Organic Chemicals

Fourteen sediment samples were analyzed for PCBs and pesticides and seven samples were analyzed for SVOCs. Two organic chemicals were detected in these samples: aldrin and dichloro diphenyl trichloroethane (DDT).

As presented in Appendix C, QC problems associated with the organic chemical analyses are limited to a select number of analytes and samples. One SVOC that is commonly found as a laboratory contaminant (bis[2-ethylhexyl]phthalate) was classified as nondetected in seven samples because of contamination of that chemical in the blank. Spike results for N-nitroso-di-n-propylamine exceeded the acceptable recovery range, but this compound was not detected in any sample; no data qualification was required for this problem. In summary, only minor QC problems were noted that should not impact the identification of detected organic chemicals.

TABLE 3.1-7

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-4 and LA-5.
Cesium-134	Retained as a COPC	Radionuclide was detected in reach LA-5, and it has no background value.
Cesium-137	Retained as a COPC	Detected sample results were greater than the background value in reaches LA-4 and LA-5.
Europium-152	Retained as a COPC	Radionuclide was detected in reach LA-4, and it has no background value.
Plutonium-238	Retained as a COPC	Detected sample results were greater than the background value in reach LA-4.
Plutonium-239,240	Retained as a COPC	Detected sample results were greater than the background value in reaches LA-4 and LA-5.
Thorium-228	Eliminated as a COPC	No detected sample results were greater than the background value in reach LA-5. This radionuclide was not determined in samples collected in reach LA-4.
Thorium-230	Eliminated as a COPC	No detected sample results were greater than the background value in reach LA-5. This radionuclide was not determined in samples collected in reach LA-4.
Thorium-232	Eliminated as a COPC	No detected sample results were greater than the background value in reach LA-5. This radionuclide was not determined in samples collected in reach LA-4.
Uranium-234	Eliminated as a COPC	No detected sample results were greater than the background value in reach LA-5. This radionuclide was not determined in samples collected in reach LA-4.
Uranium-238	Eliminated as a COPC	No detected sample results were greater than the background value in reach LA-5. This radionuclide was not determined in samples collected in reach LA-4.
Tritium	Eliminated as a COPC	No detected sample results were greater than the background value in reach LA-5. This radionuclide was not determined in samples collected in reach LA-4.

Tables 3.1-8 and 3.1-9 present the concentration range and frequency of detects for these analytes in reaches LA-4 and LA-5, respectively. A complete presentation of the sample results for these detected organic chemicals is provided in Appendix D.

In summary, two organic chemicals were retained as COPCs because they were positively detected in one sample each, as presented in Table 3.1-10.

TABLE 3.1-8

FREQUENCY OF DETECTED ORGANIC CHEMICALS IN REACH LA-4

Analyte	Number of Analyses	Number of Detects	EQL[a] (mg/kg)	Range of Concentrations (mg/kg)[b]	Maximum Detect (mg/kg)	Frequency of Detects
4,4'-DDT	7	1	0.0033	[0.0034] to 0.0051	0.0051	1/7

a. EQL = estimated quantitation limit

b. Values in square brackets indicate nondetected results.

TABLE 3.1-9

FREQUENCY OF DETECTED ORGANIC CHEMICALS IN REACH LA-5

Analyte	Number of Analyses	Number of Detects	EQL (mg/kg)	Range of Concentrations (mg/kg)*	Maximum Detect (mg/kg)	Frequency of Detects
Aldrin	7	1	0.00165	[0.00067] to 0.00117	0.00117	1/7
*Values in square brackets indicate nondetected results.						

TABLE 3.1-10

RESULTS OF ORGANIC DATA REVIEW

Analyte	Result	Rationale
Aldrin	Retained as a COPC	Detected in one reach LA-5 sample
4,4'-DDT	Retained as a COPC	Detected in one reach LA-4 sample

3.2 Nature and Sources of Contamination

Contamination in lower 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 6 radionuclides, 11 inorganic chemicals, and 2 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. The primary sources of contaminants in the sediments of lower Los Alamos Canyon are believed to be potential release sites (PRSs) within the upper Los Alamos Canyon and Pueblo Canyon subbasins, although PRSs in the Los Alamos Canyon watershed also exist in Bayo Canyon, Rendija Canyon (which drains into Guaje Canyon), and on the canyon floor in reach LA-4 (Section 1.3.2). The evaluation of sample data presented in this section is used to test this component of the conceptual model. Specifically, plutonium-239,240 is a good indicator of contamination from Pueblo Canyon, and cesium-137 is a good indicator of contamination associated with upper Los Alamos Canyon; the relations of other COPCs to these key radionuclides can indicate whether they have similar sources. Additional details on all COPCs are presented in Appendix E, and detailed discussions of americium-241; cesium-137; and plutonium-239,240 are presented in Section 3.3.

Two graphics are used in this section to visually present variations in the COPCs within reaches and between reaches. For inorganic and radionuclide COPCs, summary figures are presented that show the normalized maximum value of COPCs relative to background values; 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 (inorganic chemicals and radionuclides) from highest to lowest for reach LA-4. Thus, the normalized values for reach LA-4 follow a decreasing trend by chemical. Where values for reach LA-5 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. For inorganic chemicals, a second summary figure show

only values reported as above detection limits because these results may more accurately portray the actual levels of contamination.

The other graphics used to present data on COPCs in sediment samples in the Los Alamos Canyon watershed are plots of analyte concentration versus distance upstream from the Rio Grande 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. These plots include data from all the reaches in upper and lower Los Alamos Canyon and Pueblo Canyon to allow comparison of possible contributions from the two upper subbasins and better identification of possible sources.

3.2.1 Inorganic COPCs

In Section 3.1, 11 inorganic chemicals were identified as COPCs: antimony, boron, cadmium, calcium, copper, lead, magnesium, potassium, selenium, sodium, and vanadium. 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 for an analyte (whether it is a detected sample result or a detection limit). Antimony has the highest normalized value, 6.4, which is based on the ratio of its maximum detection limit to the antimony background value. Figure 3.2-1b uses only the maximum detected sample results, and all the maximum detected values for inorganic COPCs are within a factor of two of the background value (normalized values of less than 2). Three inorganic COPCs (antimony, cadmium, and selenium) were not detected with sufficient frequency to draw conclusions about potential contaminant sources, if any, in the Los Alamos Canyon watershed. Antimony was not detected in any sediment sample, and some detection limits were greater than the background value for reach LA-4. Note that antimony sample results for reach LA-5 were rejected and cannot be used to evaluate concentration trends (Section 3.1.1). Antimony was also not detected in any sediment sample collected upstream in either upper Los Alamos Canyon or Pueblo Canyon. Cadmium was not detected above the background value in any sample. Two detected selenium sample results from LA-5 were greater than the background value. The nondetected sample results for cadmium and selenium are less than three times the background value, providing an upper limit for any possible cadmium or selenium contamination in lower Los Alamos Canyon sediments.

Table 3.2-1 summarizes the inorganic COPCs identified in the lower Los Alamos Canyon reaches and in the reaches directly upstream in upper Los Alamos Canyon (reach LA-3) and Pueblo Canyon (reach P-4) (LA-3 and P-4 data are presented in Reneau et al. 1998, 59160, and Reneau et al. 1998, 59159). The rank of the inorganic COPCs in Table 3.2-1 uses their order in Figure 3.2-1b. Lead is a common analyte in both of the potential source reaches (P-4 and LA-3) and the lower Los Alamos Canyon reaches. Copper was identified as a COPC in both LA-3 and LA-4, which may indicate an upper Los Alamos Canyon source for this analyte. Cadmium was identified as a COPC in reach P-4 and was detected only at a small fraction of the background value in reach LA-4. Mercury was identified as a COPC in both LA-3 and P-4 but was not identified as a COPC in lower Los Alamos Canyon.

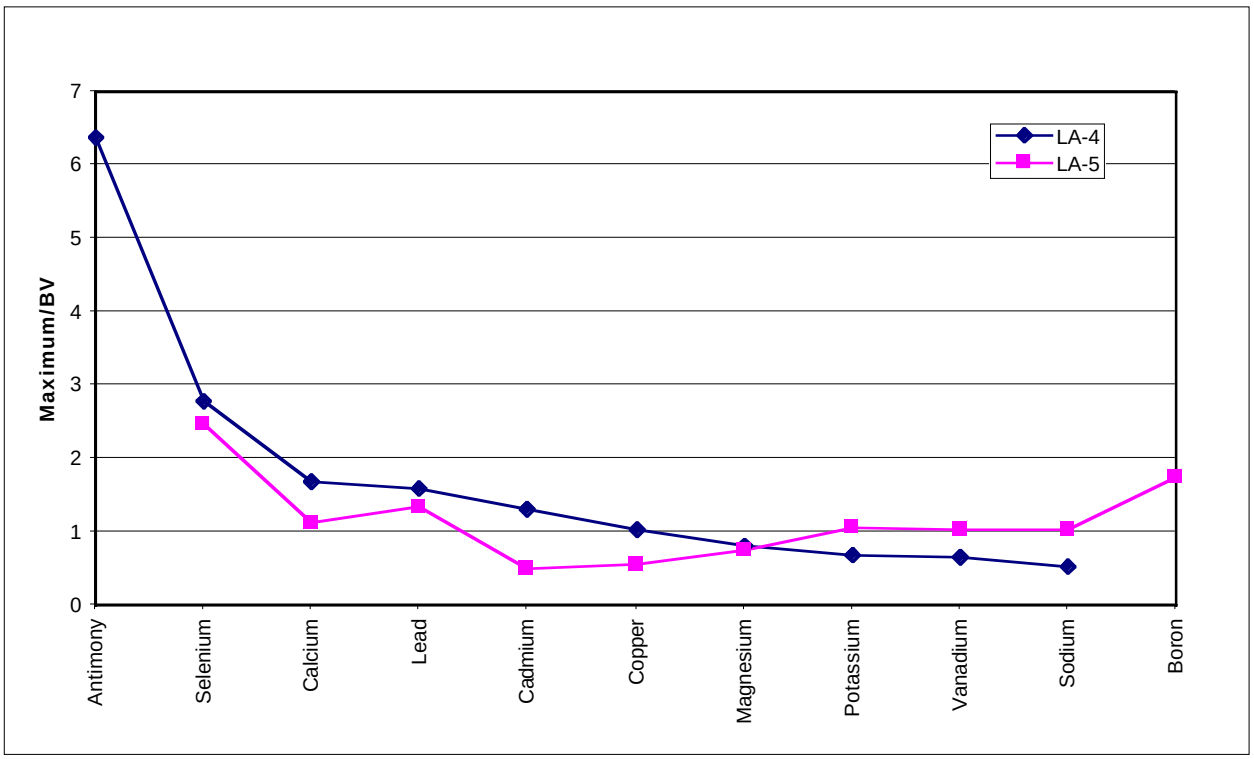


Figure 3.2-1a. Maximum inorganic chemical results for lower Los Alamos Canyon sediment samples, using either detected or nondetected values, normalized by background values.

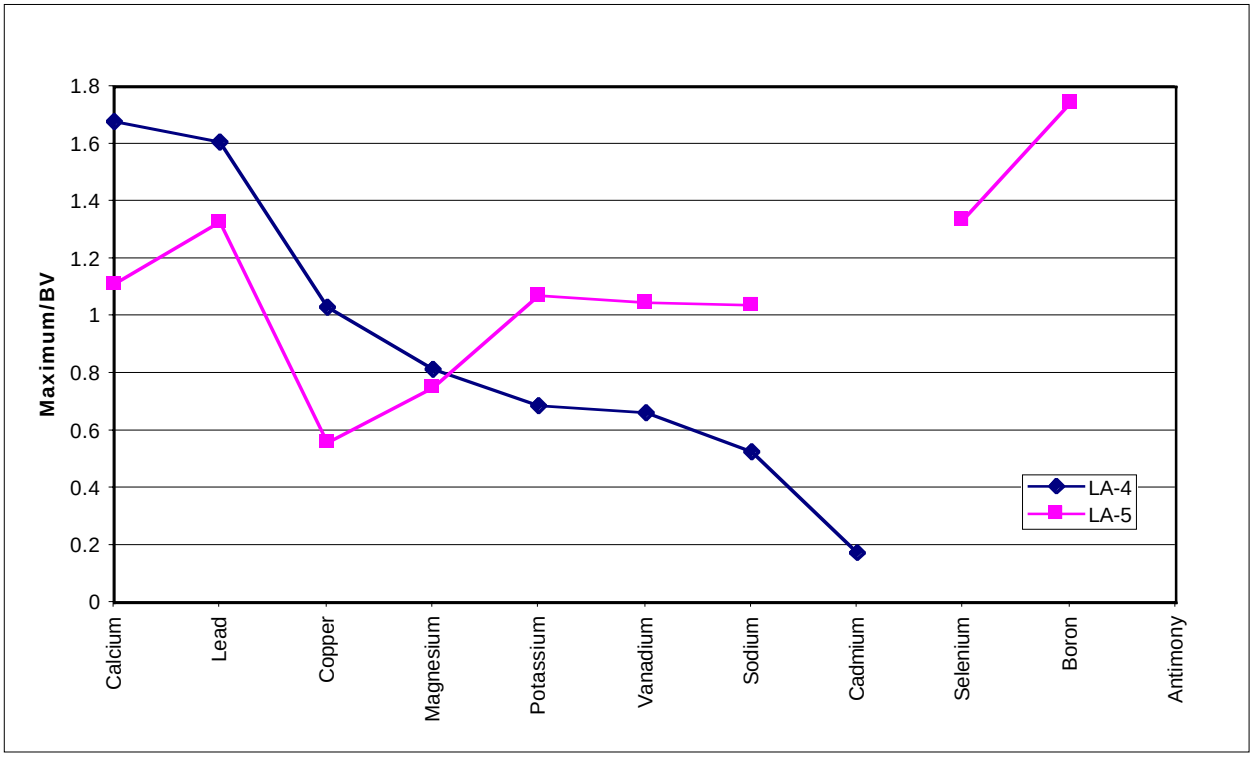


Figure 3.2-1b. Maximum detected inorganic chemical results for lower Los Alamos Canyon sediment samples, normalized by background values.

TABLE 3.2-1

SUMMARY OF INORGANIC COPCs IN LOWER LOS ALAMOS CANYON AND UPSTREAM REACHES

Analyte	Reach			
	P-4	LA-3	LA-4	LA-5
Antimony	Not detected[a]	Not detected	Not detected	Not detected
Boron	Not a COPC	Not a COPC	NA[b]	*COPC rank 1*[c]
Cadmium	**COPC rank 2**[d]	Not detected	**COPC rank 4**	Not a COPC
Calcium	Not a COPC	Not a COPC	*COPC rank 1*	*COPC rank 4*
Copper	Not a COPC	**COPC rank 2**	**COPC rank 3**	Not a COPC
Lead	**COPC rank 1**	**COPC rank 1**	**COPC rank 2**	**COPC rank 3**
Magnesium	Not a COPC	Not a COPC	Not a COPC	*COPC rank 8*
Mercury	**COPC rank 3**	**COPC rank 3**	Not a COPC	Not a COPC
Potassium	Not a COPC	Not a COPC	Not a COPC	*COPC rank 7*
Selenium	Not detected	Not a COPC	Not detected	*COPC rank 2*
Sodium	Not a COPC	Not a COPC	Not a COPC	*COPC rank 6*
Vanadium	Not a COPC	Not a COPC	Not a COPC	*COPC rank 5*

a. Not detected = analyte not detected but detection limit is greater than background value

b. NA = not analyzed

c. Italicized cells show COPCs that were not identified in the upstream reaches (P-4 and/or LA-3)

d. Bolded cells show COPCs that were identified in the upstream reaches (P-4 and/or LA-3)

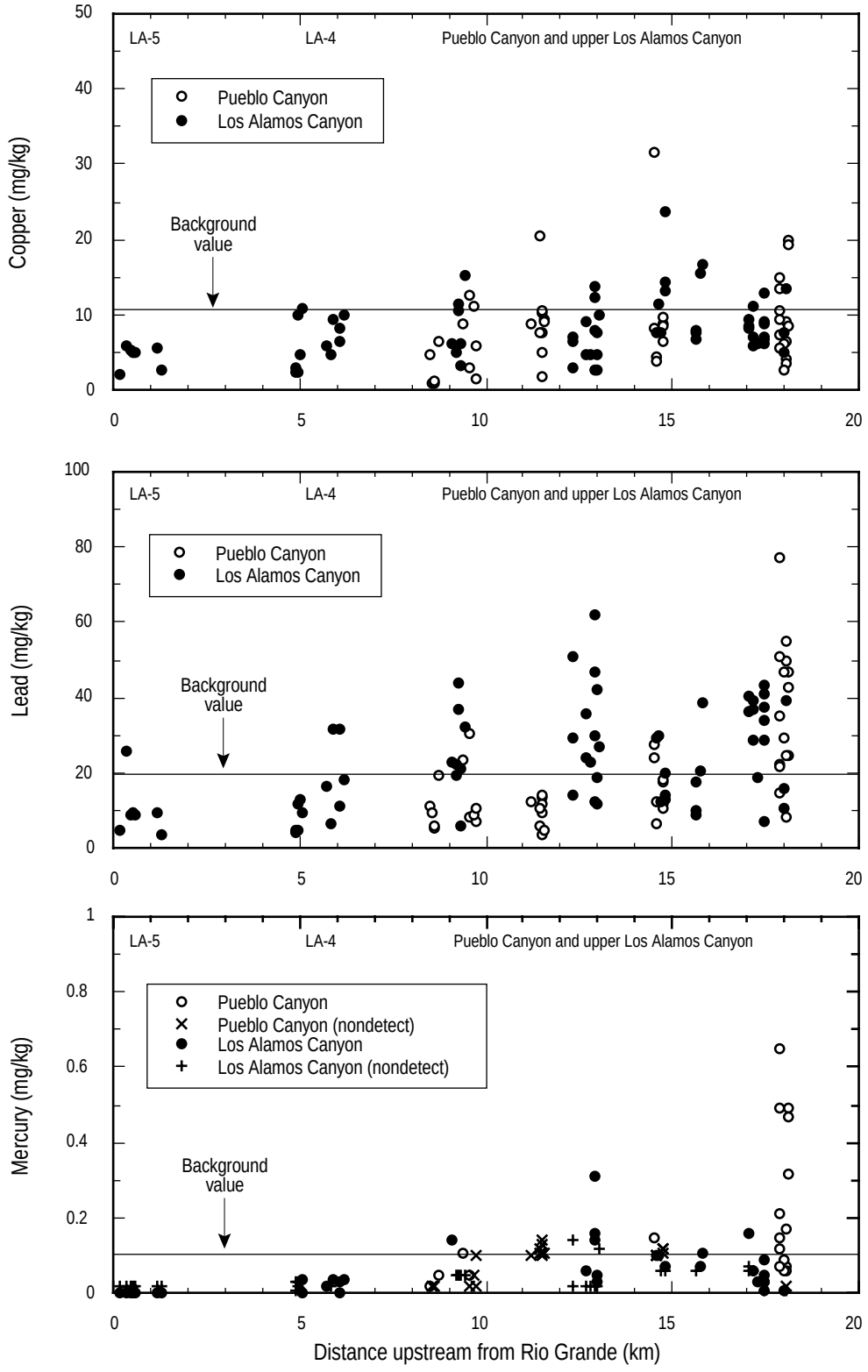
Six inorganic COPCs were identified in lower Los Alamos Canyon that were not identified as COPCs in either reaches LA-3 or P-4: boron, calcium, magnesium, selenium, sodium, and vanadium (Table 3.2-1). Only calcium was identified as a COPC in both reaches LA-4 and LA-5. The other five inorganic chemicals were identified as COPCs based only on samples collected from LA-5. The occurrence of these inorganic chemicals above background values in reach LA-5 may be due to a partial source for sediments in a geologic unit (e.g., the Santa Fe Group) that is geochemically different from units upstream of the background sediment sample sites. An alternative possibility is that these analyses record some additional but unknown source of contamination, although this possibility is considered to be small. Given that the differences between concentrations of these detected inorganic COPCs and background is small (the maximum detected values are less than twice the background values), it is probably not important to determine the source of these additional inorganic COPCs identified in LA-4 and LA-5.

A few sample locations in each subreach in lower Los Alamos Canyon contain most of the elevated inorganic COPC results. Samples 04LA-97-0552 and 04LA-97-0223 were collected from relatively old, fine-grained overbank sediments in the f1b and c3 units of reach LA-4 West. These samples have two of the four highest copper results, the two highest lead results, and one of the three highest calcium results for reach LA-4. Notably, sample 04LA-97-0552 was a resample of the 04LA-97-0172 layer, which provided the highest plutonium-239,240 result in lower Los Alamos Canyon, and sample 04LA-97-0223 provided the highest results for americium-241, cesium-137, and plutonium-238. This apparent

collocation of inorganic and radionuclide COPCs suggests common sources in the upstream subbasins and/or similar times of release. Samples 04LA-97-0228 and 04LA-97-0526 were collected from fine-grained overbank sediments in the relatively young c1 and c2 units of LA-4 East. These samples have two of the four highest copper results and two of the three highest calcium results for LA-4. In contrast to the two LA-4 West samples discussed previously, these LA-4 East samples have relatively low cesium-137 and plutonium-239,240 concentrations, and the lack of collocation with the key radionuclides suggests different sources and/or different release histories. Samples 04LA-96-0177 and 04LA-96-0181 were collected from fine-grained overbank sediments in the f1 unit of reach LA-5 and have the highest sample results for boron, magnesium, potassium, sodium, and vanadium. Sample 04LA-96-0175, collected from fine-grained sediments in the c3 unit of LA-5, has the highest copper and lead concentrations for this reach. It is worth noting that sample 04LA-96-0175 was collected from a site (location LA-0032) close to state road NM 502, and it is possible that some contaminants could have been derived from local road runoff.

Concentrations of copper and lead exhibit statistically significant positive correlations with cesium-137 concentration. This correlation suggests sources for both copper and lead in upper Los Alamos Canyon. A review of the scatter plots presented in Appendix E shows that the relationship of these metals with cesium-137 has a lot of variability, which could suggest multiple contaminant sources and/or variations in their release history. The collocation of the highest plutonium-239,240 result in lower Los Alamos Canyon and one of the highest copper results, discussed previously, suggests at least a partial source for copper in the Pueblo Canyon basin, although no correlation between copper and plutonium-239,240, was seen in the Pueblo Canyon samples. Potassium and vanadium exhibit negative correlations with plutonium-239,240, which is based on measuring higher concentrations of these inorganic chemicals in reach LA-5. None of the other frequently detected inorganic COPCs have notable correlations with the indicator COPCs.

The geographic context of sample results for key inorganic COPCs in the Los Alamos Canyon watershed is shown in Figure 3.2-2, indicating both the general source areas for these COPCs and changes in concentration between Laboratory sites and the Rio Grande. Figure 3.2-2 shows results for copper and lead, which are identified as COPCs in lower Los Alamos Canyon, and also for mercury, which is a potentially significant inorganic COPC upstream in both upper Los Alamos Canyon and Pueblo Canyon but not in lower Los Alamos Canyon. All three of these inorganic COPCs have their highest values and the highest frequency of results above the background value in upstream reaches and show general decreases in concentration downstream. Both lead and mercury have their highest values in the Los Alamos Canyon watershed in Pueblo Canyon near the confluence with Acid Canyon (reach P-1), indicating an upstream source or sources. Lead and mercury in upper Los Alamos Canyon have their highest values near the confluence with DP Canyon, suggesting a source at TA-21, although results above the background value have also been obtained farther upstream in Los Alamos Canyon and indicate multiple sources for each COPC. The geographic distribution of copper in both subbasins is less clear, and the scattered nature of relatively high values suggests multiple sources for copper. The highest frequency of copper results above the background value, and the second highest result in the watershed is from reach LA-1 East downstream from a former laundry at TA-21. The LA-1 East results suggest that either TA-21, or perhaps TA-2 or TA-41 a short distance upstream, constitute the most important source for copper in the watershed.



F3.2-2 / LOWER LOS ALAMOS REACH RPT / 091498

Figure 3.2-2. Concentration of copper, lead, and mercury in Los Alamos Canyon and Pueblo Canyon sediment samples versus the distance upstream from the Rio Grande.

3.2.2 Radionuclide COPCs

In Section 3.1 six radionuclides were identified as COPCs: americium-241; cesium-134; cesium-137; europium-152; plutonium-238; and plutonium-239,240. All of these radionuclides have been identified as COPCs in upper Los Alamos Canyon, and some of these radionuclides were identified as COPCs in Pueblo Canyon.

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 where both a sample result and a minimum detectable activity were reported). For americium-241, the gamma spectroscopy results were used in this plot. Figure 3.2-3 shows that only americium-241; plutonium-238; and plutonium-239,240 were detected at concentrations far above the background value (more than 10 times the background value). In addition to americium-241 and the plutonium isotopes, cesium-137 concentrations provide information on the potential sources for radionuclide contaminants present in lower Los Alamos Canyon. The remaining two radionuclides, cesium-134 and europium-152, were measured at maximum concentrations less than twice the typical detection limits (note that these radionuclides have no background values).

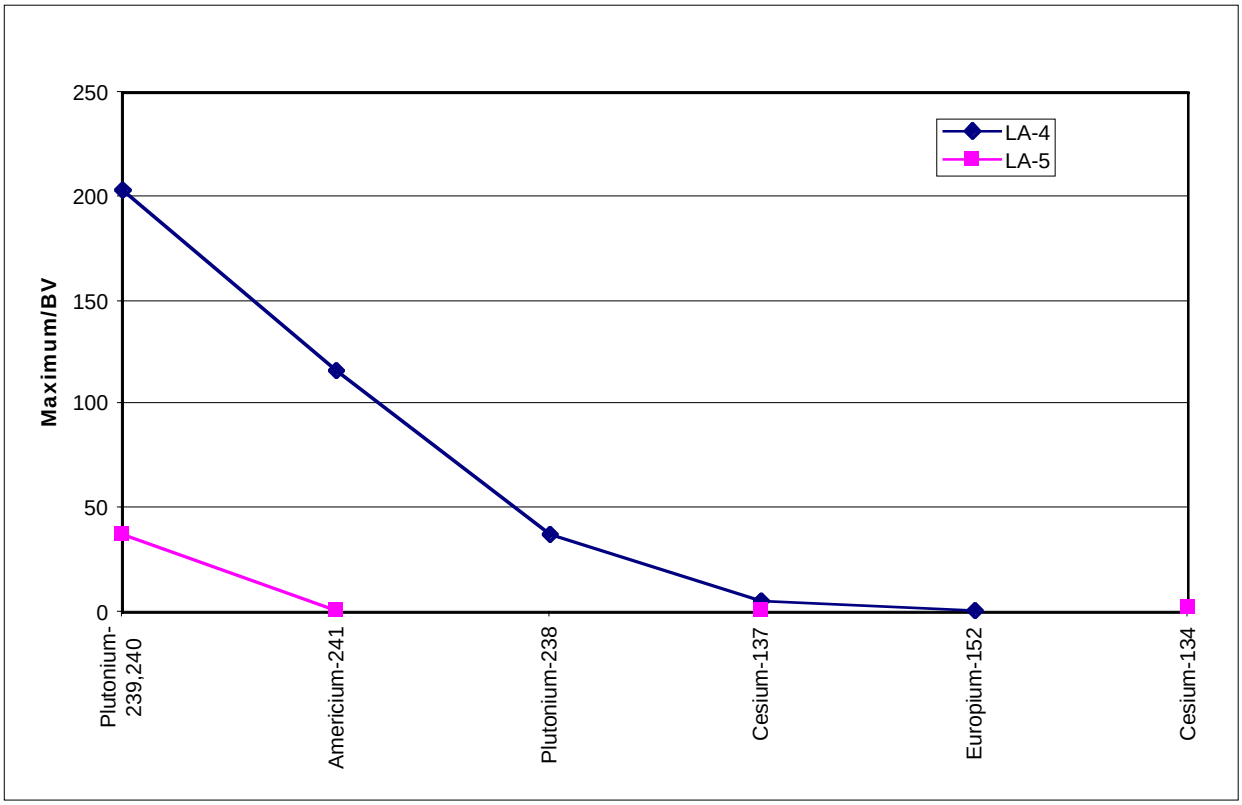


Figure 3.2-3. Maximum radionuclide results for lower Los Alamos Canyon sediment samples, normalized by the background value.

Table 3.2-2 summarizes the radionuclide COPCs identified in the lower Los Alamos Canyon reaches and the reaches directly upstream in upper Los Alamos Canyon (reach LA-3) and Pueblo Canyon (reach P-4) (LA-3 and P-4 data are presented in Reneau et al. 1998, 59160, and Reneau et al. 1998, 59159). The rank

of the detected radionuclide COPCs in Table 3.2-2 uses their order in Figure 3.2-3. This table shows that the sediments in reach LA-4 reflect a mixture of upper Los Alamos Canyon and Pueblo Canyon sources. Plutonium-239,240 ranks first in reaches P-4, LA-4, and LA-5, reflecting the relative importance of this radionuclide in these three reaches, although plutonium-239,240 is also a COPC in LA-3. Americium-241 and plutonium-238 are also primary COPCs in both LA-3 and P-4 as well as in lower Los Alamos Canyon. Cesium-137 is a COPC in LA-3, LA-4, and LA-5 but not in P-4, consistent with the known source for cesium-137 at the 21-011(k) outfall in upper Los Alamos Canyon. Strontium-90 is a COPC in LA-3 but is not a COPC in lower Los Alamos Canyon. The other two radionuclide COPCs in upstream reaches, cesium-134 and europium-152, have been identified in both LA-3 and either LA-4 or LA-5.

TABLE 3.2-2

SUMMARY OF RADIONUCLIDE COPCs IN LOWER LOS ALAMOS CANYON AND UPSTREAM REACHES

Analyte	Reach			
	P-4	LA-3	LA-4	LA-5
Americium-241	**COPC rank 3**[a]	**COPC rank 1**	**COPC rank 2**	**COPC rank 3**
Cesium-134	Not a COPC	Not a COPC	Not a COPC	*COPC rank 2*[b]
Cesium-137	Not a COPC	**COPC rank 4**	**COPC rank 4**	**COPC rank 4**
Cobalt-60	Not a COPC	COPC rank 6	Not a COPC	Not a COPC
Europium-152	Not a COPC	**COPC rank 10**	**COPC rank 5**	Not a COPC
Plutonium-238	**COPC rank 2**	**COPC rank 2**	**COPC rank 3**	Not a COPC
Plutonium-239,240	**COPC rank 1**	**COPC rank 3**	**COPC rank 1**	**COPC rank 1**
Strontium-90	Not a COPC	COPC rank 5	Not a COPC	Not a COPC
Thorium-228	Not a COPC	COPC rank 7	NA[c]	Not a COPC
Thorium-230	Not a COPC	COPC rank 9	NA	Not a COPC
Thorium-232	Not a COPC	COPC rank 8	NA	Not a COPC

a. Bolded cells show COPCs that were identified in the upstream reaches (P-4 and/or LA-3)

b. Italicized cell shows COPC that was not identified in the upstream reaches (P-4 and/or LA-3)

c. NA = not analyzed

The possible collocation of radionuclide COPCs was evaluated through the statistical correlation analysis of radionuclide COPCs presented in Appendix E. There are statistically significant correlations of both indicator radionuclides with americium-241 (by gamma spectroscopy), although the correlation is stronger between cesium-137 and americium-241. This result is consistent with cesium-137 and americium-241 in lower Los Alamos Canyon being associated with an upper Los Alamos Canyon source, specifically the 21-011(k) outfall at TA-21. The statistical correlation analysis does not lead to clear interpretation of a primary source for plutonium-238, which suggests more equal contributions of plutonium-238 from upper Los Alamos Canyon and Pueblo Canyon, consistent with the widespread occurrence of plutonium-238 above the background value in both subbasins. The key radionuclides in lower Los Alamos Canyon are discussed in more detail in Section 3.3, and their geographic distribution within the Los Alamos Canyon watershed is discussed further in Section 4.

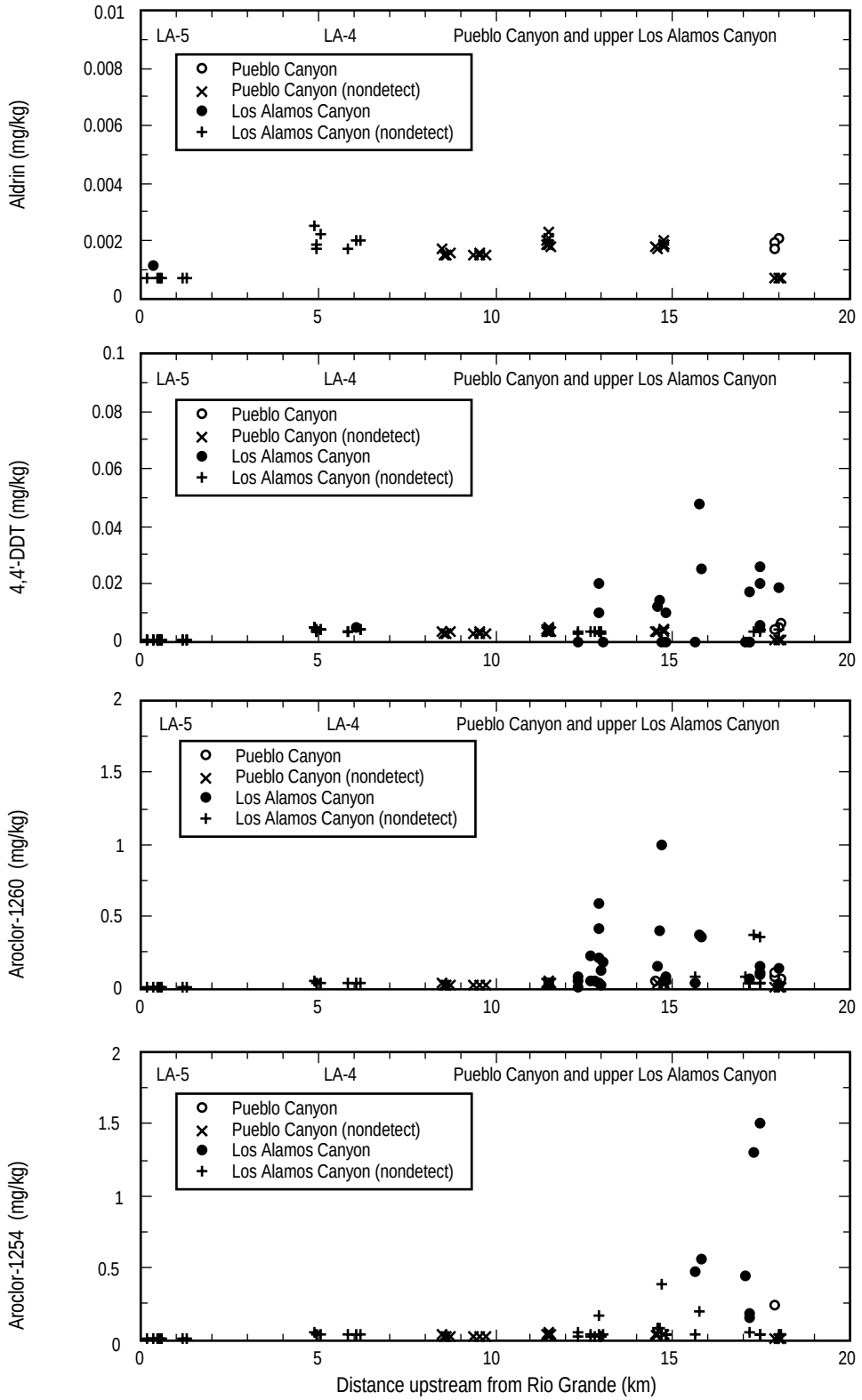
The radionuclides present at relatively low levels above the background value include isotopes that may be associated with plutonium chemistry and nuclear reactor fission or activation products. Cesium-134, with a radiological half-life of 2.1 years, was identified as a COPC because of a single detection out of 44 sample results in sample 04LA-96-0176, collected from coarse sands in the active stream channel in reach LA-5 (c1 unit). The detected cesium-134 result was approximately 70% greater than the maximum nondetected 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 (May 1996) and the present (September 1998). Thus, cesium-134 warrants no further discussion of potential sources given its infrequent detection at low concentrations and its relatively short radiological half-life. Europium-152 was detected in 3 out of 85 samples, for a detection frequency of 4%. The "detected" europium-152 sample results fall within the range of nondetected sample results, and there are no available data from Laboratory sites that suggest releases of europium-152 in the Los Alamos Canyon watershed. Because of its infrequent detection at low concentrations, europium-152 also warrants no further discussion of possible contaminant sources and distribution.

3.2.3 Organic COPCs

Two organic chemicals were detected at low concentrations in the lower Los Alamos Canyon sediment samples and identified as COPCs: DDT and aldrin, as discussed in Section 3.1. Both of the organic COPCs are pesticides and were detected once each in two separate samples from two different reaches. No PCBs or SVOCs were detected in lower Los Alamos Canyon samples, although some of these chemicals were detected in reach P-4 and in upper Los Alamos Canyon reaches. However, note that all organic chemical results were rejected in reach LA-3 in upper Los Alamos Canyon and that no SVOC analyses were obtained in reach LA-4, limiting interpretations about the sources and distributions of organic COPCs in the Los Alamos Canyon watershed.

Because of the infrequent detection of the organic COPCs (1 of 14 samples) at concentrations within the range of nondetected sample results, little can be inferred regarding possible collocation with other COPCs. Both DDT and aldrin were detected in upstream reaches, so a Laboratory source and/or other sources in the Los Alamos Canyon watershed, such as the Los Alamos townsite, are possible. DDT was detected in one sample from reach LA-4, and was also detected in reaches LA-1, LA-2, and P-1. Aldrin was detected in reach LA-5, and the only other detected results for aldrin were from P-1.

The geographic context of sample results for key organic COPCs in the Los Alamos Canyon watershed is shown in Figure 3.2-4, indicating both the general source areas for these COPCs and changes in concentration between Laboratory sites and the Rio Grande. Figure 3.2-4 shows results for aldrin and DDT, which are identified as COPCs in lower Los Alamos Canyon, and also for the PCBs Aroclor-1254 and Aroclor-1260, which are potentially significant organic COPCs upstream in both upper Los Alamos Canyon and Pueblo Canyon but were not detected in reaches LA-4 or LA-5. DDT and the PCBs have their highest values and the highest frequency of detected results in upper Los Alamos Canyon in reaches LA-1 or LA-2, indicating one or more sources in the upper watershed, although these organic COPCs have not yet been traced to specific sources. In contrast, aldrin was detected in only 4 of 80 sediment samples and only in reaches P-1 and LA-5. All of the aldrin detects are within the range of nondetected values, and there is no evidence for significant releases of aldrin in the Los Alamos Canyon watershed.



F3.2-4 / LOWER LOS ALAMOS REACH RPT / 110498

Figure 3.2-4. Concentration of aldrin; Aroclor-1254; Aroclor-1260; and 4,4'-DDT in Los Alamos Canyon and Pueblo Canyon sediment samples versus distance upstream from the Rio Grande.

3.3 Key Contaminant Analyses

The radionuclides cesium-137 and plutonium-239,240 were selected as key contaminants for reach LA-4, and plutonium-239,240 was selected as a key contaminant for reach LA-5 based on the results of the full-suite analyses from upper Los Alamos Canyon, Pueblo Canyon, and LA-5. Preliminary human health screening assessments had indicated that cesium-137 was the most significant COPC in upper Los Alamos Canyon and that plutonium-239,240 was the most significant COPC in Pueblo Canyon (Reneau et al. 1998, 59159; Reneau et al. 1998, 59160); therefore, all sediment samples from reach LA-4 were analyzed for these two radionuclides. Data on additional COPCs, americium-241 and plutonium-238, were obtained during the gamma spectroscopy analyses for cesium-137 and the isotopic plutonium analyses, and are also available for all samples from LA-4. The full-suite analyses in LA-5 identified plutonium-239,240 as being the only COPC frequently above background values; therefore, all samples from LA-5 were analyzed for isotopic plutonium. Analyses from upper Los Alamos Canyon had also identified strontium-90 as being an important contributor to potential human health risk associated with contaminants in sediments; therefore, analyses for strontium-90 were also obtained from many samples in LA-4 to evaluate its concentration and distribution.

In this section the data are presented on americium-241; cesium-137; plutonium-238; plutonium-239,240; and strontium-90 for each reach. The discussion is focused on examining variations in the concentrations of the 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 lower 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 can vary greatly within the sediments of lower 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 was 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. 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 plutonium-239,240 than texturally similar c2 sediment in older, abandoned channel units), but these subsets were combined where no such trends were apparent in the data. Final binning of data used the plutonium-239,240 analyses because of the higher frequency of analyses above background values for plutonium-239,240 relative to cesium-137.

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 lower 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 for upper Los Alamos Canyon and Pueblo Canyon are presented in Appendix B-4.0 of Reneau et al. (1998, 59159), and the same densities are assumed to occur in the lower Los Alamos Canyon sediments. 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 lower Los Alamos Canyon sediment samples (Sections 3.3.2.2 and 3.3.3.2). 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. 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 LA-4, 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 reach LA-5, 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 50 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 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 used primarily weapons-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.

In this report the ratios of various radionuclides were calculated from the analytical data for each reach LA-4 sample and for averages in each LA-4 bin. The actual ratios of individual samples are sometimes used to constrain the age of specific sediment layers. Isotopic ratios were not used for reach LA-5 samples because radionuclide concentrations were too low to allow usable isotopic ratios to be calculated. Note that all the LA-4 isotopic 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 the effects of 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 Key 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 lower Los Alamos Canyon data set. First are field splits of the same sample material, which are called QA duplicate analyses. QA duplicates were collected in a random manner and included 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 Los Alamos Canyon. Figure E4-1 in Appendix E shows the relationship between 17 pairs of QA duplicate results and 3 pairs of resample results for these key radionuclides. The QA duplicates show less variability than the resamples, but interpretation of differences between these collocated sample types is limited by the small number of resamples in lower Los Alamos Canyon. As noted in Sections 3.1.2 and 3.3.2.1, the single strontium-90 resample apparently records an anomalous initial sample result. The remainder of the collocated sample results show good agreement between the initial result and the second result, including resampling of the layer in reach LA-4 West that has the highest plutonium-239,240 value in lower 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-4

3.3.2.1 Contaminant Concentrations

Most sediment samples from the c1, c2, c3, f1, and f1b units in reach LA-4 contain plutonium-239,240 concentrations above the background value of 0.068 pCi/g (Table 3.3-1), providing a clear signature of sediments supplied from Pueblo Canyon. In contrast, cesium-137 is above the background value of 0.9 pCi/g for less than one-third of the samples from each unit, indicating either dilution of the cesium-137 supplied from upper Los Alamos Canyon and/or the absence of post-1956 sediment supplied from upper Los Alamos Canyon in many layers. The highest frequency of cesium-137 analyses above the background value occurs in samples from the c3 and f1 units, including 31 to 32% of the analyses from these units. Cesium-137 was found above the background value for only 13 to 20% of the samples from the c1, c2, and f1b units. Variations in the concentrations of the key radionuclides with depth at individual sample locations in LA-4 are shown in Figures 3.3-1 through 3.3-4.

The concentrations of both cesium-137 and plutonium-239,240 within reach LA-4 are highest in fine-grained overbank facies sediment deposits, although the maximum values for the different radionuclides occur within different geomorphic units. The highest plutonium-239,240 values occur within overbank sediments in the f1b unit of reach LA-4 West, with a maximum value of 13.8 pCi/g and an average of 9.8 pCi/g (Table 3.3-2; Figure 3.3-4); all samples containing more than 10 pCi/g were obtained from the f1b unit. The highest cesium-137 values occur within overbank sediments in the c3 unit (Figure 3.3-2), with a maximum value of 4.65 pCi/g and an average of 1.3 pCi/g; c3 is the only geomorphic unit where the average cesium-137 concentration is greater than the background value.

TABLE 3.3-1

RADIONUCLIDE ANALYSES FROM REACH LA-4

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Cs-137 (pCi/g)	Am-241 (gamma spec) (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-4 West														
c1	LA-0127	0–4.5	0–11	Overbank	1	04LA-97-0179	0.723	0.184	-0.002 (U)[c]	0.645	NA[d]	fs	sl	
c1	LA-0131	0-9	0–23	Overbank	1	04LA-97-0190	0.979	-0.044 (U)	0.044	0.86	NA	fs	sl	
c2	LA-0206	1.5–5	4–13	Overbank	2	04LA-97-0535	0.474	0.019 (U)	0.0259 (U)	0.443	NA	csi	l	
		5–9	13–23	Overbank	2	04LA-97-0536	1.19	0.752 (U)	0.0325	0.794	NA	fs	sl	
		9–19.5	23–50	Channel	2	04LA-97-0537	0.198	0.112 (U)	0.029 (U)	0.275	NA	cs	s	
c3	LA-0122	0–5	0–13	Overbank	1	04LA-97-0165	0.753	0.253 (U)	-0.001 (U)	1.12	NA	ms	ls	
		5–12	13–30	Overbank	1	04LA-97-0166	1.1	0.29	-0.001 (U)	2.06	NA	fs	ls	
		14–17.5	35–45	Overbank	1	04LA-97-0221	1.41	0.194	0.025 (U)	1.83	-0.59 (U)	fs	sl	Limited-suite sample
		17.5–27	45–68	Overbank	1	04LA-97-0168	0.679	0.63	0.017 (U)	5.78	NA	vfs	sl	
		27–35.5	68–90	Channel	1	04LA-97-0169	-0.003 (U)	0.063 (U)	0.031	9.05	NA	cs	gs	
c3	LA-0125	0–5	0–13	Overbank	1	04LA-97-0173	0.394	0.495 (U)	-0.01 (U)	0.796	NA	ms	s	
		0–5	0–13	Overbank	2	04LA-97-0556	NA	NA	NA	NA	0.19 (U)	NA	NA	Resampled layer for strontium-90
		6.5–14	17–35	Overbank	1	04LA-97-0174	0.663	0.153	0.003 (U)	0.478	NA	fs	ls	
		6.5–14	17–35	Overbank	2	04LA-97-0557	NA	NA	NA	NA	0.81 (U)	NA	NA	Resampled layer for strontium-90
		14–27.5	35–70	Overbank	1	04LA-97-0175	1.74	0.868	0.071	1.34	NA	vfs	sl	
		14–27.5	35–70	Overbank	2	04LA-97-0558	NA	NA	NA	NA	0.3 (U)	NA	NA	Resampled layer for strontium-90
		14–27.5	35–70	Overbank	2	04LA-97-0559	NA	NA	NA	NA	0.31 (U)	NA	NA	QA duplicate
		27.5–36	70–92	Overbank	1	04LA-97-0222	2.82	2.07	0.215	1.3	12.8	fs	sl	Limited-suite sample

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, 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

TABLE 3.3-1 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-4

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Cs-137 (pCi/g)	Am-241 (gamma spec) (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-4 West														
c3	LA-0125	27.5–36	70–92	Overbank	2	04LA-97-0554	NA[c]	NA	NA	NA	0.74 (U)[d]	NA	NA	Resampled layer for strontium-90 and PCBs
		36–43.5	92–110	Channel	1	04LA-97-0177	0.676	-0.395 (U)	0.02	1.36	NA	cs	gs	
		36–43.5	92–110	Channel	2	04LA-97-0555	NA	NA	NA	NA	-0.08 (U)	NA	NA	Resampled layer for strontium-90
c3	LA-0128	0–8	0–20	Overbank	1	04LA-97-0180	3.45	2.57	0.161	1.15	NA	vfs	sl	
		8–12	20–30	Overbank	1	04LA-97-0223	4.65	4.64	0.227	1.91	-0.17 (U)	fs	sl	Limited-suite sample
		18.5–23	47–59	Overbank	1	04LA-97-0182	0.812	0.239 (U)	0.012 (U)	0.546	NA	vfs	sl	
c3	LA-0129	0–8	0–20	Overbank	1	04LA-97-0183	0.605	0.235	0.017 (U)	1.58	NA	fs	ls	
		8–15.5	20–40	Overbank	1	04LA-97-0224	1.27	0.106 (U)	0.041	0.968	-0.07 (U)	fs	sl	Limited-suite sample
		20–31.5	50–80	Channel	1	04LA-97-0185	0.134	0.117 (U)	0.006 (U)	2.13	NA	cs	gs	
		20–31.5	50–80	Channel	1	04LA-97-0186	0.174	0.011 (U)	0.011 (U)	2.98	NA	NA	NA	QA duplicate
c3	LA-0207	35.5–51	90–130	Channel	2	04LA-97-0539	0.589	0.04 (U)	0.0102 (U)	0.996	NA	cs	gs	
f1	LA-0123	0–10	0–26	Overbank	1	04LA-97-0171	0.093 (U)	0.02 (U)	0.024	3.32	NA	ms	s	
		11–17	28–43	Overbank	2	04LA-97-0520	0 (U)	0.044	0.0149 (U)	2.81	NA	fs	ls	
f1	LA-0126	0–14	0–35	Overbank	1	04LA-97-0178	0.954	0.196 (U)	0.02 (U)	1.92	NA	fs	sl	
f1	LA-0200	0–5	0–13	Overbank	2	04LA-97-0515	0.796	0.63	0.028	4.09	NA	fs	ls	
		5–14	13–36	Channel	2	04LA-97-0516	0.049 (U)	-0.05 (U)	0.0149 (U)	1.156	NA	cs	s	
		14–21.5	36–55	Overbank	2	04LA-97-0517	0.013 (U)	-0.149 (U)	0.023 (U)	0.176	NA	ms	ls	
		21.5–27.5	55–70	Channel	2	04LA-97-0518	0.015 (U)	-0.037 (U)	0.0055 (U)	0.0194 (U)	NA	ms	gls	Background
		27.5–41	70–104	Overbank	2	04LA-97-0519	0.041 (U)	-0.365 (U)	0.04 (U)	0.0193 (U)	NA	vfs	sl	Background

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.

TABLE 3.3-1 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-4

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Cs-137 (pCi/g)	Am-241 (gamma spec) (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-4 West														
f1	LA-0202	0-3	0–8	Overbank	2	04LA-97-0530	1.55 (U)[c]	-0.233 (U)	0.037	2.96	NA[d]	vfs	sl	
		3–8.5	8–22	Overbank	2	04LA-97-0531	2.38	0.185 (U)	0.084	2.39	NA	vfs	sl	
f1? (c3?)	LA-0130	0–6.5	0–16	Overbank	1	04LA-97-0187	1.04	0.307	0.003 (U)	2.1	NA	fs	ls	
		6.5–18	16-46	Overbank	1	04LA-97-0188	2.03	0.289 (U)	0.044	7.46	NA	vfs	sl	
		27.5–39.5	70–100	Channel	1	04LA-97-0189	0.017 (U)	0.073 (U)	-0.001 (U)	0.135	NA	cs	gs	Near background?
f1b	LA-0124	0–6	0–15	Overbank	1	04LA-97-0172	0.749	0.316 (U)	0.041	13.8	NA	vfs	sl	
		0–6	0–15	Overbank	2	04LA-97-0552	NA	NA	0.042	12.91	0.56 (U)	NA	NA	Resampled layer for limited suite
		6–11	15–28	Overbank	2	04LA-97-0524	0.104 (U)	0.136 (U)	0.057	13.04	NA	vfs	sl	
		11–16	28–41	Overbank	2	04LA-97-0525	0.01 (U)	-0.515 (U)	0 (U)	0.327	NA	csi	sil	
f1b	LA-0201	0–3	0–7	Overbank	2	04LA-97-0521	0.635	0.246 (U)	0.047	10.07	NA	csi	sil	
		0–3	0–7	Overbank	2	04LA-97-0522	0.4	-0.016 (U)	0.037	9.31	NA	NA	NA	QA duplicate
		4.5–10	11–26	Channel	2	04LA-97-0523	0.053 (U)	0.296 (U)	0.07	2.07	NA	cs	s	
		10–17.5	26–44	Overbank	2	04LA-97-0528	-0.045 (U)	0.101 (U)	-0.003 (U)	0.113	NA	ms	s	Near background?
		17.5–25.5	44–65	Overbank	2	04LA-97-0529	-0.022 (U)	0.016 (U)	0.0101 (U)	0.082 (U)	NA	fs	sl	Background?
f1b	LA-0204	0–3.5	0–9	Overbank	2	04LA-97-0534	1.33	-0.008 (U)	0.042	10.03	NA	fs	sl	
f1b	LA-0203	0–3	0–7	Overbank	2	04LA-97-0532	0.331	-0.245 (U)	0.075	11.68	NA	vfs	sl	
		0–3	0–7	Overbank	2	04LA-97-0533	0.488	-0.314 (U)	0.0265	5.18	NA	NA	NA	QA duplicate
f2?	LA-0205	0–3	0–7	Overbank	2	04LA-97-0527	0.358	-0.131 (U)	0.0034 (U)	0.082	NA	csi	l	Background?

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. 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

TABLE 3.3-1 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-4

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Cs-137 (pCi/g)	Am-241 (gamma spec) (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-4 East														
c1	LA-0133	0–2	0–5	Channel	1	04LA-97-0195	0.033 (U)[c]	0.01 (U)	-0.003 (U)	0.042	NA[d]	cs	gs	
		0–2	0–5	Channel	2	04LA-97-0553	NA	NA	NA	NA	0.09 (U)	NA	NA	Resampled layer for limited suite
c1	LA-0137	0–4	0–10	Overbank	1	04LA-97-0228	0.444	0.031 (U)	0.011 (U)	0.314	-0.68 (U)	vfs	sl	Limited-suite sample
		0–4	0–10	Overbank	2	04LA-97-0560	NA	NA	NA	NA	NA	NA	NA	Resampled layer for PCBs
c1	LA-0139	0–2	0–5	Channel	1	04LA-97-0205	0.062 (U)	-0.004 (U)	0.005 (U)	0.081	NA	cs	gs	
c2	LA-0209	0–3.5	0–9	Overbank	2	04LA-97-0543	0.109 (U)	-0.357 (U)	0.0177 (U)	0.059	NA	fs	ls	
		3.5–6.5	9–17	Overbank	2	04LA-97-0542	0.548	-0.062 (U)	0.0197 (U)	0.272	NA	fs	sl	
		8.5–17.5	21–45	Channel	2	04LA-97-0541	0.231	-0.009 (U)	0.125 (U)	0.478	NA	cs	gs	
c2	LA-0212	0–6.5	0–16	Overbank	2	04LA-97-0526	0.308	0.348 (U)	0.0162 (U)	0.214	0.18 (U)	vfs	sl	Limited-suite sample
		6.5–23.5	16–60	Channel	2	04LA-97-0538	0.335	0.043 (U)	0.024	0.498	0.51 (U)	cs	gs	Limited-suite sample
c3	LA-0132	0–14	0–36	Overbank	1	04LA-97-0191	1.81	0.228	0.005 (U)	2.87	NA	fs	sl	
		14–23.5	36–60	Channel	1	04LA-97-0192	0.047 (U)	0.052 (U)	0 (U)	0.189	NA	cs	gs	
		23.5–28.5	60–72	Channel	1	04LA-97-0225	0.027 (U)	0.044 (U)	-0.005 (U)	0.034	-0.33 (U)	ms	s	Limited-suite sample
		28.5–33.5	72–85	Channel	1	04LA-97-0194	0.049 (U)	0.023 (U)	0 (U)	0.2	NA	cs	gs	
c3	LA-0208	0–9	0–23	Overbank	2	04LA-97-0549	0.5	-0.062 (U)	0.0163 (U)	0.639	0.57 (U)	fs	sl	
		9–15	23–38	Overbank	2	04LA-97-0561	0.803	0.307	0.0341	1.007	0.47 (U)	fs	ls	
		15–19.5	38–49	Overbank	2	04LA-97-0562	0.716	-0.085 (U)	0.0154 (U)	1.034	-0.19 (U)	fs	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

TABLE 3.3-1 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-4

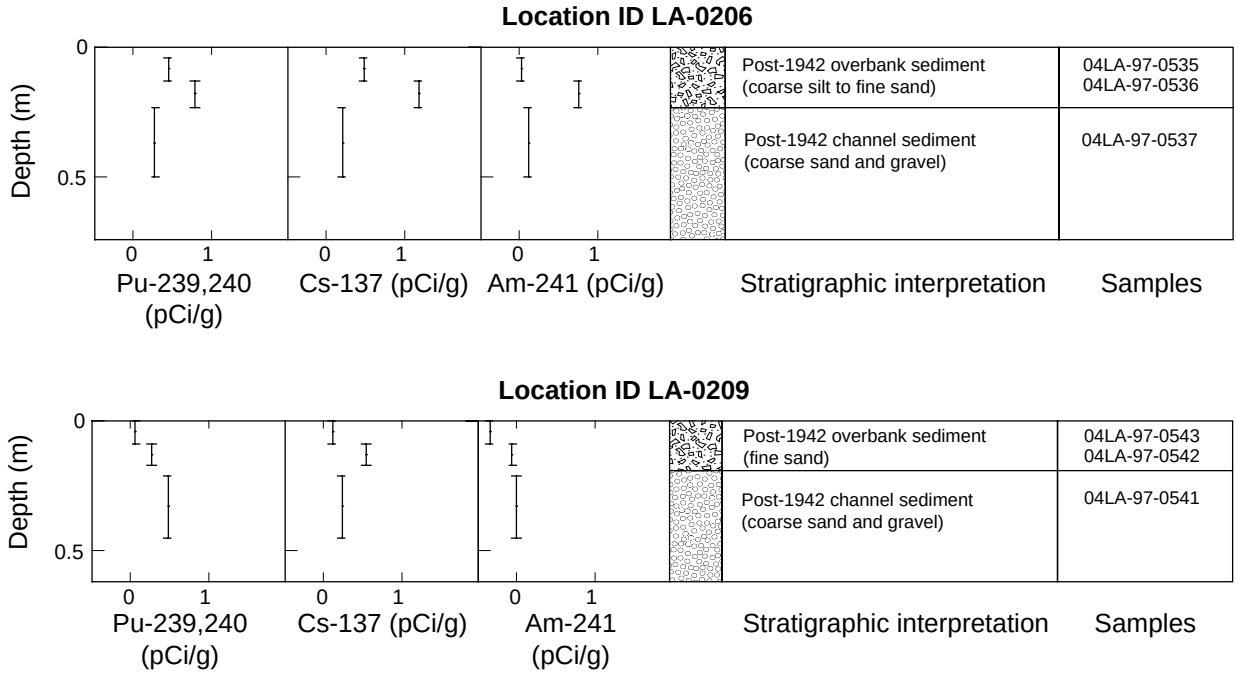
Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Cs-137 (pCi/g)	Am-241 (gamma spec) (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
LA-4 East														
c3	LA-0208	25.5–35.5	65–90	Channel	2	04LA-97-0514	0.2	0.011 (U)[c]	0.028 (U)	3.52	0.3 (U)	cs	gs	Limited-suite sample
c3	LA-0211	27.5–38.5	70–98	Channel	2	04LA-97-0545	0.07 (U)	-0.143 (U)	0.022 (U)	1.76	NA[d]	cs	gs	
		38.5–48	98–122	Channel	2	04LA-97-0546	0.184 (U)	-0.179 (U)	0.027 (U)	2.1	NA	cs	gs	
c3 (f1?)	LA-0135	0–6	0–15	Overbank	1	04LA-97-0197	0.462	0.23 (U)	0.008 (U)	0.579	NA	fs	ls	
		9–20	23–50	Overbank	1	04LA-97-0227	0.774	0.148	0.037	0.727	-0.38 (U)	fs	ls	Limited-suite sample
		20–28.5	50–72	Overbank	1	04LA-97-0199	1.42	0.602	0.051	1.13	NA	vfs	sl	
		28.5–37.5	72–95	Overbank	1	04LA-97-0200	1.07	0.307	0.049	6.02	NA	vfs	gsl	
f1	LA-0134	0–6	0–15	Overbank	1	04LA-97-0196	1.11	-0.088 (U)	-0.002 (U)	0.443	NA	vfs	sl	
f1	LA-0136	0–7	0–18	Overbank	1	04LA-97-0201	0.407	0.289 (U)	0.015	3.41	NA	vfs	sl	
		15.5–23.5	40–60	Channel	1	04LA-97-0202	0 (U)	-0.018 (U)	0.001 (U)	0.095	NA	cs	gs	Background?
f1	LA-0138	0–15.5	0–40	Overbank	1	04LA-97-0204	0.106	-0.002 (U)	-0.005 (U)	1.74	NA	fs	ls	
		17.5–25.5	45–65	Channel	2	04LA-97-0540	0.038 (U)	0.214 (U)	0.0071 (U)	0.002 (U)	NA	ms	s	Background?
f1	LA-0210	0-–3.5	0–9	Overbank	2	04LA-97-0544	0.627	0.125 (U)	0.0095 (U)	0.51	NA	csi	l	
Qt	LA-0213	0–1	0–3	Overbank	2	04LA-97-0547	0.652	-0.214 (U)	0.032	0.111	NA	fs	ls	Background?

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, 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



F3.3-1 / LOWER LOS ALAMOS REACH RPT / 110498

Figure 3.3-1. Depth variations in americium-241; cesium-137; and plutonium-239,240 concentration at sample sites in the c2 unit in reach LA-4.

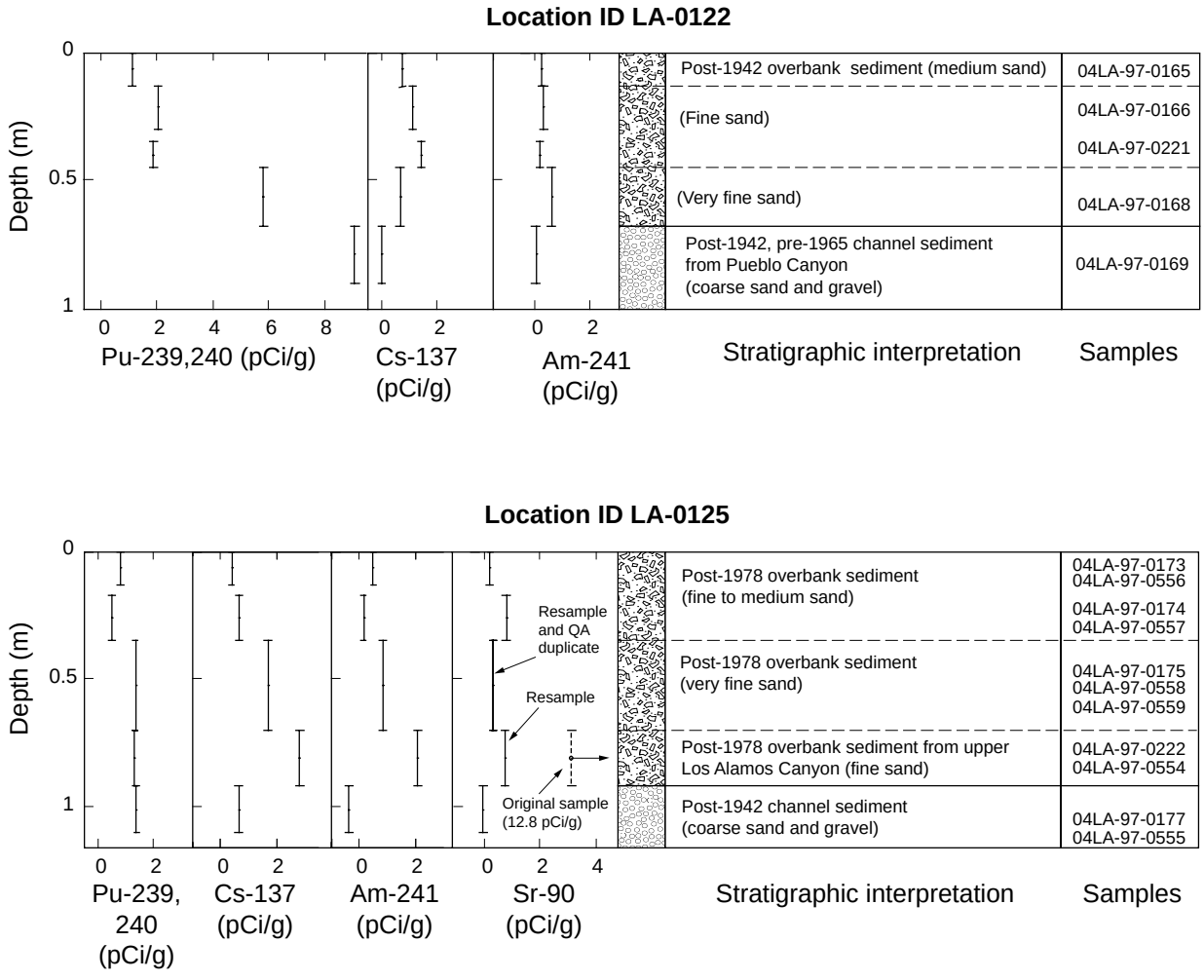


Figure 3.3-2a. Depth variations in americium-241; cesium-137; plutonium-239,240; and strontium-90 concentration at sample sites in the c3 unit in reach LA-4.

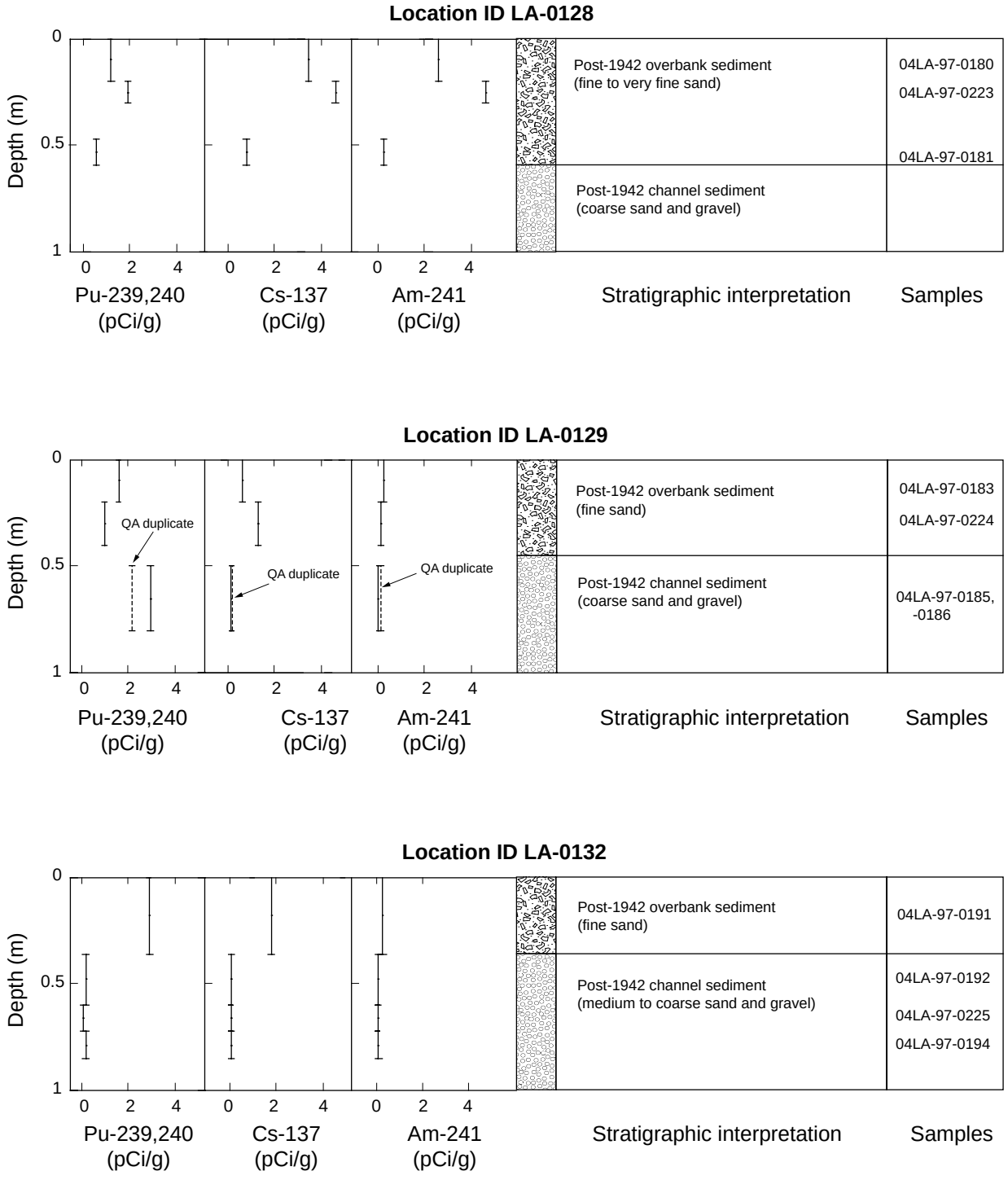
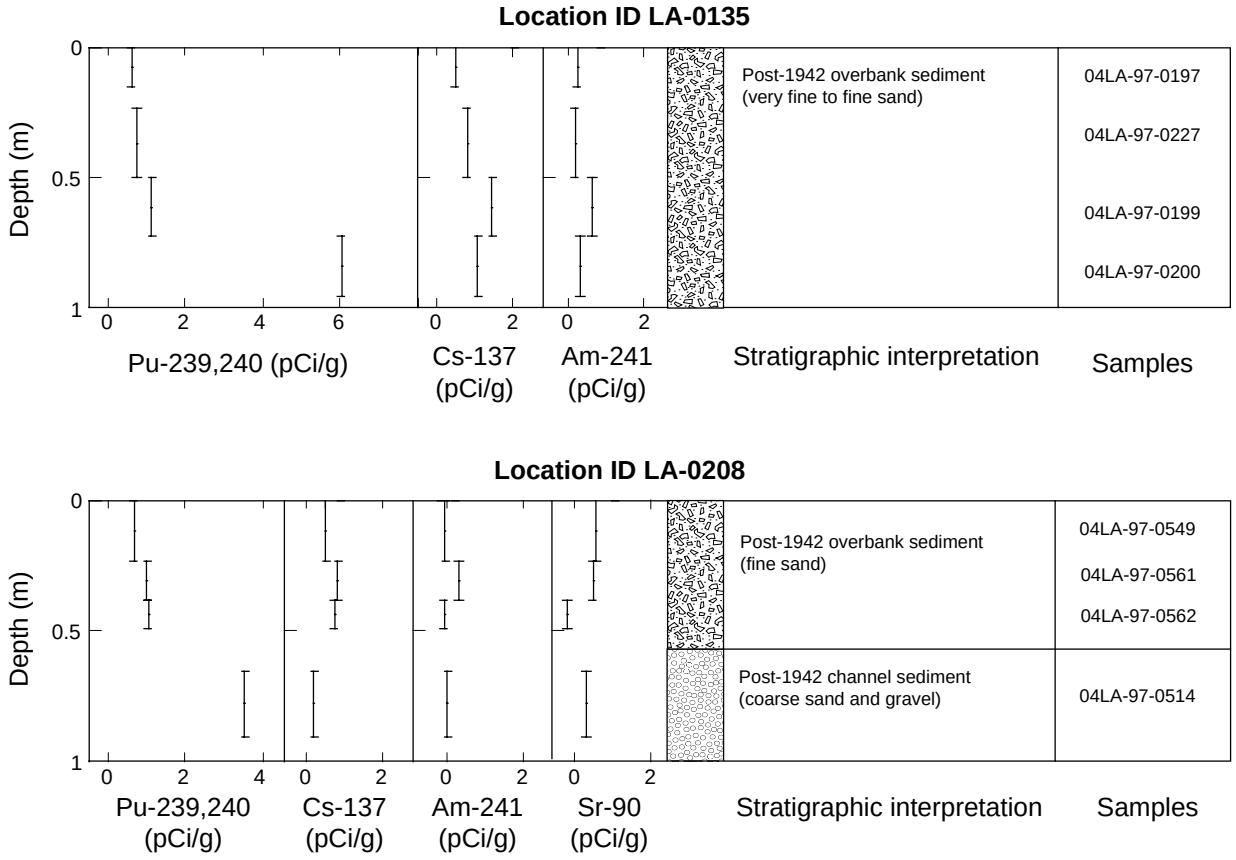


Figure 3.3-2b. Depth variations in americium-241; cesium-137; and plutonium-239,240 concentration at sample sites in the c3 unit in reach LA-4.



F3.3-2c / LOWER LOS ALAMOS REACH RPT / 110598

Figure 3.3-2c. Depth variations in americium-241; cesium-137; plutonium-239,240; and strontium-90 concentration at sample sites in the c3 unit in reach LA-4.

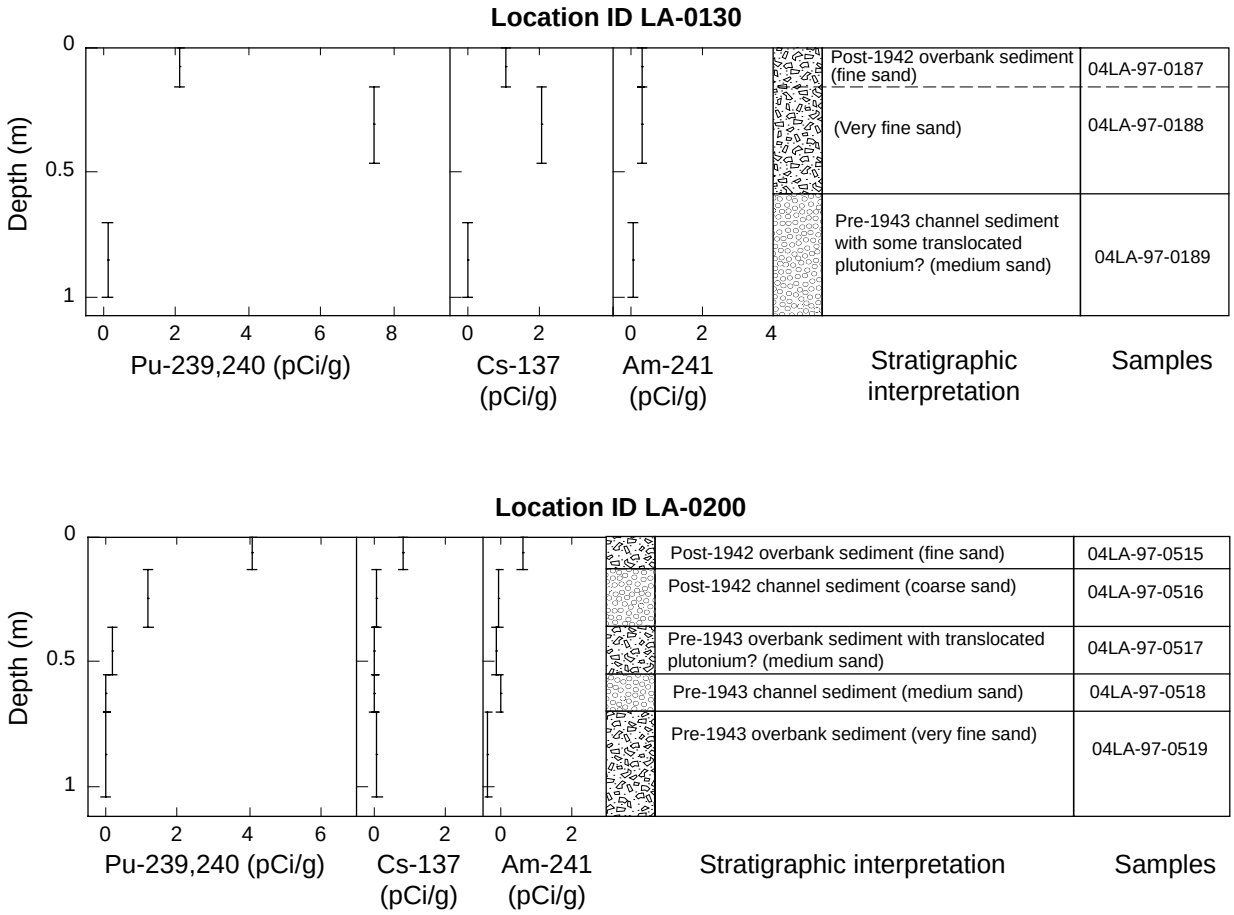


Figure 3.3-3. Depth variations in americium-241; cesium-137; and plutonium-239,240 concentration at sample sites in the f1 unit in reach LA-4.

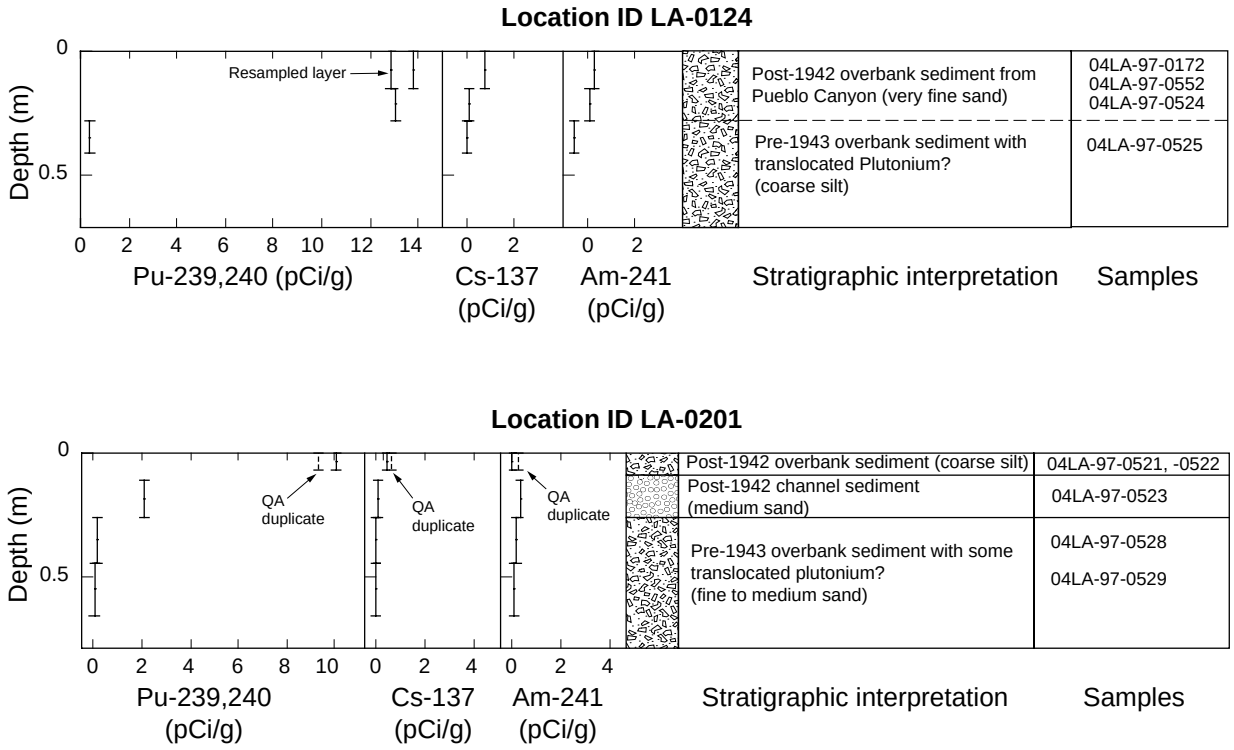


Figure 3.3-4. Depth variations in americium-241; cesium-137; and plutonium-239,240 concentration at sample sites in the f1b unit in reach LA-4.

TABLE 3.3-2

SUMMARY OF BINNED ANALYSES IN REACH LA-4

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)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]	Pu-239/238 Ratio	Am-241/ Pu-239 Ratio	Cs-137/ Am-241 Ratio
c1 and c2 overbank	average	0.109	0.597	0.021	0.450	vfs	0.112	sl	22	0.24	5
	std. dev.	0.330	0.354	0.014	0.289						
	maximum	0.752	1.190	0.044	0.860						
	minimum	-0.357	0.109	-0.002	0.059						
	median	0.025	0.511	0.019	0.379						
	n	8	8	8	8						
c1 channel	average	0.003	0.048	0.001	0.062	cs	0.799	gs	62	0.05	16
	std. dev.	0.010	0.021	0.006	0.028						
	maximum	0.010	0.062	0.005	0.081						
	minimum	-0.004	0.033	-0.003	0.042						
	median	0.003	0.048	0.001	0.062						
	n	2	2	2	2						
c2 channel	average	0.049	0.255	0.059	0.417	cs	0.680	gs	7	0.12	5
	std. dev.	0.061	0.072	0.057	0.123						
	maximum	0.112	0.335	0.125	0.498						
	minimum	-0.009	0.198	0.024	0.275						
	median	0.043	0.231	0.029	0.478						
	n	3	3	3	3						
c3 overbank	average	0.687	1.329	0.047	1.660	fs	0.161	sl	35	0.41	2
	std. dev.	1.117	1.085	0.068	1.525						
	maximum	4.640	4.650	0.227	6.020						
	minimum	-0.085	0.394	-0.010	0.478						
	median	0.253	0.812	0.017	1.130						
	n	21	21	21	21						
c3 channel	average	-0.037	0.197	0.014	2.134	cs	0.680	gs	153	N/A[c]	N/A
	std. dev.	0.156	0.240	0.013	2.661						
	maximum	0.117	0.676	0.031	9.050						
	minimum	-0.395	-0.003	-0.005	0.034						
	median	0.032	0.102	0.015	1.560						
	n	10	10	10	10						

a. 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-4

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)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]	Pu-239/238 Ratio	Am-241/ Pu-239 Ratio	Cs-137/ Am-241 Ratio
f1 overbank	average	0.124	0.854	0.023	2.564	fs	0.148	sl	113	0.05	7
	std. dev.	0.230	0.771	0.023	1.905						
	maximum	0.630	2.380	0.084	7.460						
	minimum	-0.233	0.000	-0.005	0.176						
	median	0.125	0.796	0.020	2.390						
	n	13	13	13	13						
f1 channel	average	-0.05	0.05	0.01	1.16	cs	0.630	s	78	N/A[c]	N/A
	n	1	1	1	1						
f1b overbank	average	-0.012	0.527	0.044	9.825	vfs	0.064	sl	225	N/A	N/A
	std. dev.	0.317	0.488	0.025	4.897						
	maximum	0.316	1.330	0.075	13.800						
	minimum	-0.515	0.010	0.000	0.327						
	median	0.064	0.483	0.045	10.875						
	n	6	6	6	6						
f1b channel	average	0.296	0.053	0.070	2.070	cs	0.645	s	30	0.14	0.2
	n	1	1	1	1						
f2? overbank	average	-0.131	0.358	0.003	0.082	csi	0.028	l	24	N/A	N/A
	n	1	1	1	1						
background or near background[d]	average	-0.040	0.117	0.011	0.073	ms	0.341	ls	7	N/A	N/A
	std. dev.	0.175	0.233	0.015	0.048						
	maximum	0.214	0.652	0.040	0.135						
	minimum	-0.365	-0.045	-0.003	0.002						
	median	-0.018	0.017	0.006	0.082						
	n	9	9	9	9						

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

c. N/A = not applicable

d. Samples inferred to represent background or be very close to background have ≤0.14 pCi/g Pu-239,240 (2× background value) and are from the f1, f1b, f2, and Qt units.

The concentrations of the key radionuclides within the coarse-grained channel facies sediment in each geomorphic unit are typically less than in related fine-grained sediment. The only exception is plutonium-239,240 in the c3 unit, where the average concentration in channel facies sediment, 2.2 pCi/g, exceeds that in overbank facies sediment, 1.7 pCi/g (Table 3.3-2); maximum and median values are also higher in the channel facies sediment of c3. Plutonium-239,240 concentrations are less in channel facies sediment of the younger c2 and c1 units, averaging 0.4 and 0.06 pCi/g, respectively. Cesium-137 concentrations in all channel facies sediment samples are below the background value.

Americium-241 concentrations in reach LA-4 are closely related to cesium-137 concentrations. The maximum americium-241 value, 4.64 pCi/g, was obtained from the same sample that had the highest cesium-137 concentration, sample 04LA-97-0223 from fine-grained overbank facies sediment in the c3 unit of reach LA-4 West (sample location LA-0128, Figures 2.3-3 and 3.3-2). Average and median americium-241 concentrations are also highest in c3 overbank sediments, 0.69 and 0.25 pCi/g, respectively (Table 3.3-2). Overbank sediments from the c1, c2, and f1 units average 0.11 to 0.12 pCi/g americium-241, and the coarser-grained channel facies sediment from the c1, c2, and c3 units average 0.0 to 0.05 pCi/g.

Plutonium-238 concentrations in reach LA-4 are related to americium-241 and cesium-137 concentrations, and the maximum concentration of plutonium-238, 0.23 pCi/g, was from the same sample that yielded the highest concentrations of the other radionuclides. However, conclusions concerning plutonium-238 distribution are limited by the high frequency of results below the detection limit.

Strontium-90 was reported above the background value of 1.04 pCi/g in only a single sample, at 12.8 pCi/g in a fine-grained overbank facies sediment layer in the c3 unit of reach LA-4 West (sample 04LA-97-0222, Table 3.3-1). This result was one of seven strontium-90 analyses obtained in the first sampling event in reach LA-4 and was unexpected for two reasons. First, it was higher than in any sample upstream in reach LA-3 (Reneau et al. 1998, 59160), conflicting with the expectation that strontium-90 concentrations would be decreasing downstream. Second, cesium-137 and strontium-90 concentrations are well correlated in samples from upper Los Alamos Canyon, with cesium-137 concentrations typically being approximately five times higher, but strontium-90 in this sample was reported at 4.5 times higher than cesium-137. Because of the uncertainties about strontium-90 in LA-4 related to this high sample result, the second sampling round in LA-4 included 13 additional strontium-90 analyses, including resampling of the 04LA-97-0222 layer and all other layers at this sample site (location LA-0125, Figure 3.3-2). All of these results were below the background value, providing evidence to reject the 12.8 pCi/g result and indicating that strontium-90 is not present above the background value in LA-4 sediments. Note that the absence of strontium-90 above the background value is consistent with the concentrations of cesium-137 in LA-4 and the cesium/strontium ratios obtained in upstream reaches; using a cesium/strontium ratio of 5 and a maximum cesium-137 concentration of 4.65 pCi/g, a maximum strontium-90 value of <1 pCi/g would be expected.

3.3.2.2 Age and Particle Size Relations

Evidence for time-dependent variations in radionuclide concentrations in the sediments of reach LA-4 is provided by comparing results from sediments with different age but similar particle size characteristics. Approximate ages for some sediment layers are provided by comparing isotopic ratios within the LA-4 sediments to isotopic ratios in sediment in upstream reaches where approximate ages have been determined, as discussed in Section 3.3.1.5. Use of these ratios is limited in most LA-4 samples by the mixing of sediment derived from upper Los Alamos Canyon and Pueblo Canyon and by the relatively low radionuclide concentrations, resulting in relatively high uncertainty in the isotopic ratios, although some

samples can be clearly identified as containing post-1968 sediment derived from upper Los Alamos Canyon.

Decreases in the concentration of plutonium-239,240 in overbank facies sediment over time are shown by comparing results from the f1b unit, representing the oldest overbank sediment in reach LA-4 that is clearly younger than 1942, with results from the younger c3 unit and the still younger c1 and c2 units. The f1b sediments have very low cesium-137 concentrations and may predate the initial releases of cesium-137 from the 21-011(k) outfall at TA-21 in 1956, although it is also possible that these sediments were entirely derived from Pueblo Canyon and post-date 1956. Regardless, the f1b sediments are older than the typical c3 overbank sediments closer to the channel which, based on the ratios between cesium-137 and americium-241, were deposited after 1968 and may have been deposited after 1978. The c1 and c2 overbank facies sediments include flood deposits from the 1990s but cannot otherwise be distinguished from c3 sediments based on isotopic ratios. Estimated average plutonium-239,240 concentrations decrease from 9.8 pCi/g in the f1b unit to 1.7 pCi/g in the c3 unit and 0.5 pCi/g in the c1 and c2 sediments (Table 3.3-2), clearly showing decreases over time.

Evidence for decreases in plutonium-239,240 concentration over time are also provided by the progressive decreases in concentration between the channel facies sediment underlying the c3 and c2 units and the active c1 channel. Average plutonium-239,240 concentration in these coarser sediments decreases from 2.1 pCi/g in the oldest c3 sediment to 0.4 pCi/g in the younger c2 sediment to 0.06 pCi/g in the active channel (Table 3.3-2).

Both cesium-137 and americium-241 show similar decreases in concentration between the older overbank facies sediments of the c3 unit and the younger sediments of the c1 and c2 units. Cesium-137 decreases in average concentration from 1.3 to 0.6 pCi/g and americium-241 decreases from 0.7 to 0.1 pCi/g in the overbank sediments of these units (Table 3.3-2).

Additional data on possible changes in radionuclide concentrations over time are available from active channel sediment samples from the environmental surveillance sampling station at Totavi within reach LA-4 East that date back to 1977 (e.g., Environmental Surveillance and Compliance Programs 1997, 56684) (Figure 3.3-5). These data show relatively low concentrations of cesium-137 since 1986 and concentrations of plutonium-239,240 since 1989 that are very similar to analyses obtained in this investigation. Higher values were reported for both radionuclides in the early part of the sampling period that could indicate decreases in concentrations since the mid 1980s, although there is much scatter in these data and systematic trends are not apparent. No particle size data are available for these samples, and the possible influences of variations in silt and clay content on the radionuclide concentrations cannot be evaluated. However, these data provide support for the inference that radionuclide concentrations are not increasing over time, and instead may have been relatively stable during the last decade.

General relations between radionuclide concentration and particle size are shown by the differences between the relatively fine-grained overbank facies sediment, with median particle sizes of fine to very fine sand, and the coarser channel facies sediment, with a median particle size of coarse sand (Table 3.3-2). Relations between particle size and radionuclide concentration in reach LA-4 are complicated by the presence of sediment with varying age combined with the mixing of sediment from upper Los Alamos Canyon with sediment from Pueblo Canyon. Consequently, plots showing radionuclide concentrations against particle size for all samples from LA-4 do not display strong relations (Figures B3-1 through B3-3). However, smaller subsets of these data that do indicate general increases in radionuclide concentration with decreasing particle size.

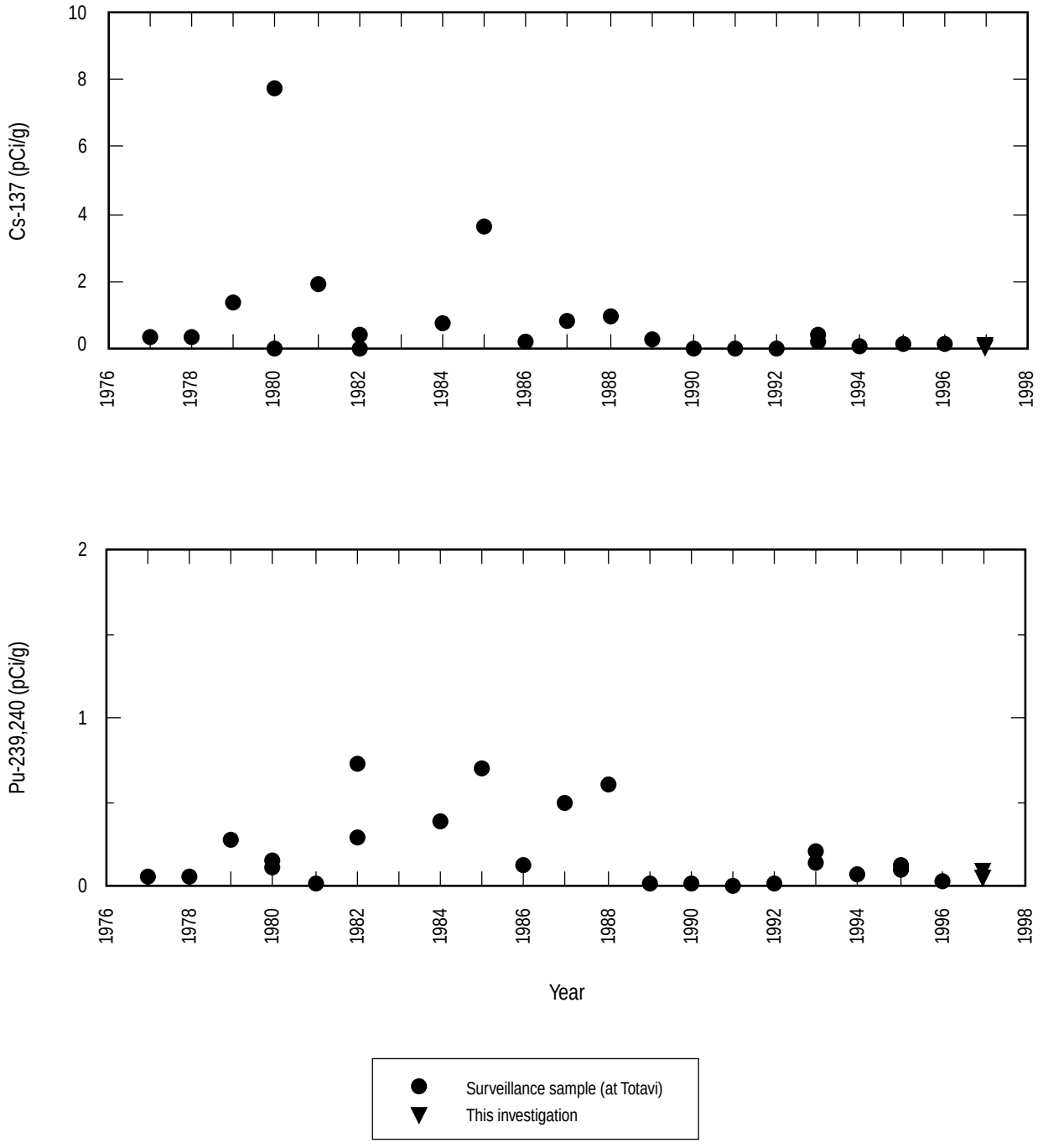


Figure 3.3-5. Relation of cesium-137 and plutonium-239,240 concentration to age from active channel sediment samples collected in reach LA-4 East.

Figure 3.3-6 shows the relation of the concentrations of the key radionuclides to the percentages of silt and clay in each sample for all overbank facies samples from the c3 unit and all channel facies samples from the c2 and c3 units. The c3 overbank samples were chosen for this figure because of the relatively large number of samples from this unit, and channel samples from both the c2 and c3 units are shown because of their likely overlap in age with the c3 overbank samples. Specifically, it is expected that the same floods may have deposited channel sediments that are present in the c2 unit and overbank sediments that are present in the adjacent c3 units, whereas some of the c3 channel sediments may be significantly older than overlying overbank sediments.

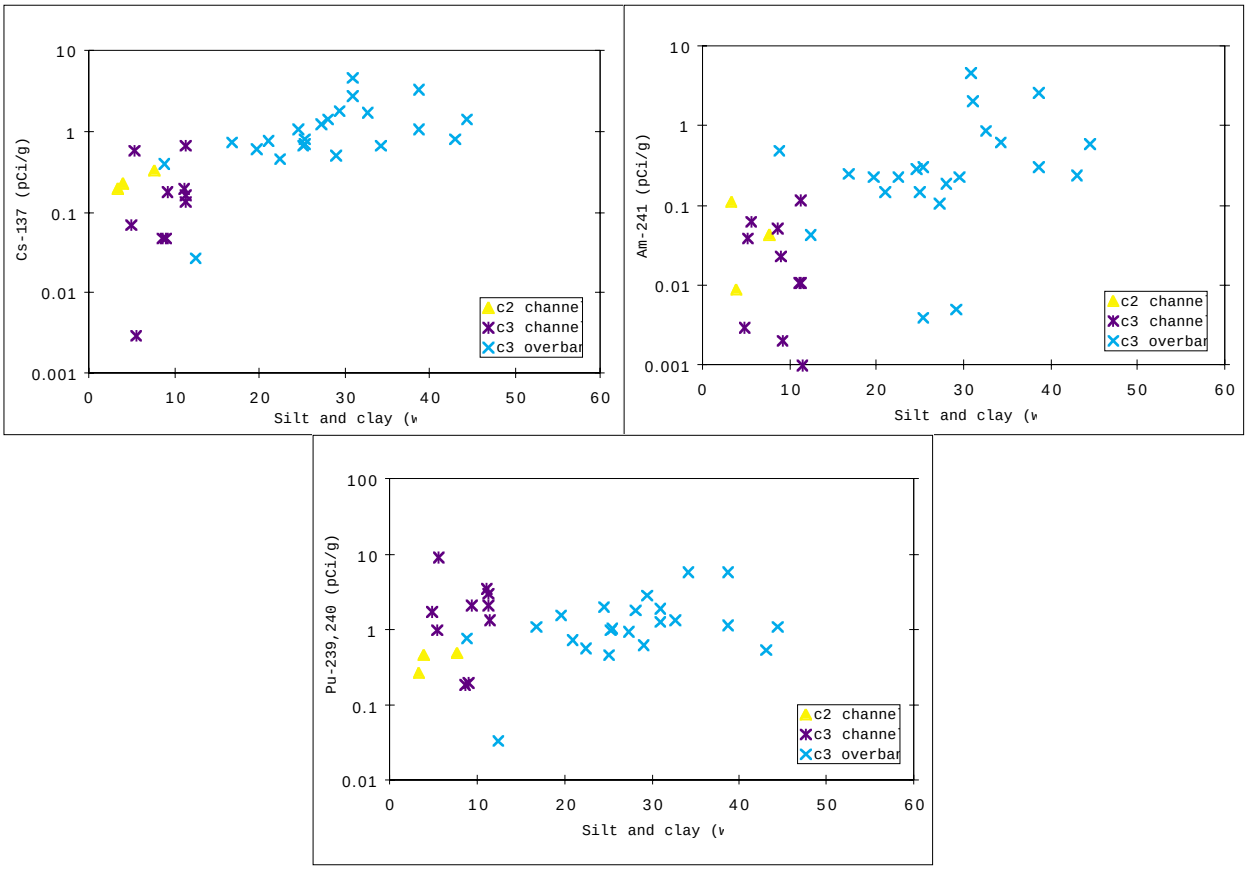


Figure 3.3-6. Scatter plots of americium-241; cesium-137; and plutonium-239,240 concentration against silt and clay content for samples from the c2 and c3 units in reach LA-4.

In this data set, both americium-241 and cesium-137 show overall increases in concentration with increases in silt and clay content (Figure 3.3-6). The plot for plutonium-239,240 is less clear, and in particular the plutonium-239,240 concentrations in the c3 channel sediments seem exceptionally high for the low silt and clay content. However, plutonium 239/238 ratios in the c3 channel sediments indicate either a predominant source in Pueblo Canyon for these sediments or a pre-1968 age, before increased releases of plutonium-238 from the 21-011(k) outfall at TA-21. If the c3 channel sediments are ignored, then a better relation of plutonium-239,240 to particle size is apparent in Figure 3.3-6.

3.3.2.3 Contaminant Inventory

The estimated plutonium-239,240 inventory in reach LA-4 West is 13.9 mCi/km and the estimated inventory in LA-4 East is 9.3 mCi/km. These estimates are both much less than present upstream in

Pueblo Canyon, where the estimated inventory ranges from 37 to 305 mCi/km in the different reaches (Reneau et al. 1998, 59159). Most of the estimated inventory is contained within the relatively fine-grained overbank facies sediment deposits, including 76% of the total in reach LA-4 West and 67% in reach LA-4 East (Table 3.3-3). The most important geomorphic unit in terms of plutonium-239,240 inventory in both subreaches is c3, which contains an estimated 39% of the inventory in LA-4 West and 60% of the inventory in LA-4 East. The floodplain units also contain significant parts of the total plutonium-239,240 inventory. In LA-4 West, the f1b unit contains 38% and the f1 unit contains 17% of the estimated inventory. In LA-4 East, the f1 unit contains 31% of the estimated inventory. The c1 and c2 units are relatively unimportant as deposition areas for plutonium-239,240, together containing only 6 to 9% of the estimated inventory in the different subreaches.

The estimated cesium-137 inventories in reach LA-4 West and reach LA-4 East are virtually identical at 4.3 to 4.4 mCi/km. These estimated inventories are less than those present upstream in upper Los Alamos Canyon, where the estimated inventory ranges from 14 to 66 mCi/km between reaches LA-3 and LA-2 East (Reneau et al. 1998, 59160). Most of the estimated inventory is contained within the relatively fine-grained overbank facies sediment deposits, including 88 to 89% in LA-4 West and LA-4 East (Table 3.3-3). The most important geomorphic unit in terms of cesium-137 inventory in both subreaches is c3, which contains an estimated 60 to 61% of the inventory in each subreach. The f1 unit contains the next largest part of the estimated cesium-137 inventory, including 17% of the total in LA-4 West and 22% in LA-4 East. Similar to plutonium-239,240, the c1 and c2 units are relatively unimportant as deposition areas for cesium-137, together containing an estimated 16% of the total inventory in LA-4 West and 10% in LA-4 East.

The estimated americium-241 inventory varies from that for plutonium-239,240 and cesium-137 in that an even larger part is contained within the relatively fine-grained overbank facies sediment, 93% in reach LA-4 West and 97% in reach LA-4 East (Table 3.3-3). The c3 unit is again the most important deposition area in LA-4, including 80 to 82% of the estimated total in LA-4 West and LA-4 East. The estimated total americium-241 inventory in both LA-4 subreaches is 1.5 mCi/km, much less than upstream in reach LA-2 East (19 mCi/km) or reach LA-3 (4.3 mCi/km) (Reneau et al. 1998, 59160).

Most of the estimated inventories for the key radionuclides in reach LA-4 are in geomorphic units that are judged to be susceptible to remobilization in floods during the next 50 years, although the percentage of the inventory that is most easily remobilized varies among the different radionuclides. For americium-241, 94 to 95% of the total estimated inventory is considered to be susceptible to remobilization in the two subreaches. For cesium-137, 83 to 84% is considered to be susceptible to remobilization. For plutonium-239,240, 63% is judged to be susceptible to remobilization in LA-4 West and 78% in LA-4 East. The difference between LA-4 West and LA-4 East results from the presence of the f1b unit in only LA-4 West, which contains a significant part of the total plutonium-239,240 inventory in that subreach and is located relatively far from the active channel.

3.3.3 Reach LA-5

3.3.3.1 Contaminant Concentrations

Approximately 60% of the sediment samples from reach LA-5 contain plutonium-239,240 concentrations above the background value of 0.068 pCi/g, including samples from each geomorphic unit (Table 3.3-4), which is a much lower frequency than upstream in reach LA-4 where more than 90% of the analyses were above the background value. Concentrations are also much lower in LA-5 than in LA-4, and the maximum concentration of plutonium-239,240 from LA-5 is only 2.52 pCi/g (sample 04LA-97-0041 at location LA-0083; Figures 2.3-6 and 3.3-7).

TABLE 3.3-3

ESTIMATED CESIUM, AMERICIUM, AND PLUTONIUM INVENTORY IN REACH LA-4

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 Radionuclide 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-4 West Cesium-137													
Channel	c1	Lower	2467	0.5	1234	0.5	1.23	0.05	0.04	2%	100%	0.04	2%
Channel	c2	Lower	944	0.5	472	0.5	1.23	0.26	0.08	3%	100%	0.08	3%
Channel	c3	Lower	1961	0.5	981	0.5	1.23	0.2	0.12	5%	100%	0.12	6%
Channel	f1	Lower	2146	0.05	107	0.7	1.23	0.05	0.00	0%	100%	0.00	0%
Channel	f1b	Lower	1624	0.05	81	0.9	1.23	0.05	0.00	0%	100%	0.00	0%
Subtotal			**9142**		**2875**				**0.24**	**11%**		**0.24**	**11%**
Overbank	c1	Upper	2467	0.12	296	0.88	1.04	0.60	0.16	7%	100%	0.16	7%
Overbank	c2	Upper	944	0.24	227	0.93	1.04	0.60	0.13	6%	100%	0.13	6%
Overbank	c3	Upper	1961	0.51	1000	0.89	1.04	1.33	1.23	54%	100%	1.23	54%
Overbank	f1	Upper	2146	0.29	471	0.93	1.04	0.85	0.39	17%	30%	0.12	5%
Overbank	f1b	Upper	1624	0.17	276	0.91	1.04	0.53	0.14	6%	10%	0.01	1%
Overbank	f2	Upper	244	0.05	12	0.9	1.04	0.36	0.00	0%	0%	0.00	0%
Subtotal					**2282**				**2.05**	**89%**		**1.66**	**72%**
Total									**2.30**	**100%**			**83%**
LA-4 East Cesium-137													
Channel	c1	Lower	988	0.5	494	0.5	1.23	0.05	0.02	1%	100%	0.02	1%
Channel	c2	Lower	856	0.5	428	0.5	1.23	0.26	0.07	5%	100%	0.07	5%
Channel	c3	Lower	1164	0.5	582	0.5	1.23	0.2	0.07	6%	100%	0.07	6%
Subtotal			**3008**		**1504**				**0.16**	**12%**		**0.16**	**12%**
Overbank	c1	Upper	988	0.11	109	0.88	1.04	0.60	0.06	5%	100%	0.06	5%
Overbank	c2	Upper	856	0.13	111	0.93	1.04	0.60	0.06	5%	100%	0.06	5%
Overbank	c3	Upper	1164	0.48	559	0.89	1.04	1.33	0.69	55%	100%	0.69	55%
Overbank	f1	Upper	1701	0.20	340	0.93	1.04	0.85	0.28	22%	30%	0.08	7%
Subtotal					**1119**				**1.09**	**88%**		**0.90**	**72%**
Total									**1.25**	**100%**			**84%**

TABLE 3.3-3 (continued)

ESTIMATED CESIUM, AMERICIUM, AND PLUTONIUM INVENTORY IN REACH LA-4

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 Radionuclide 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-4 West Americium-241													
Channel	c1	Lower	2467	0.5	1234	0.5	1.23	0.003	0.00	0%	100%	0.00	0%
Channel	c2	Lower	944	0.5	472	0.5	1.23	0.049	0.01	2%	100%	0.01	2%
Channel	c3	Lower	1961	0.5	981	0.5	1.23	0	0.00	0%	100%	0.00	0%
Channel	f1	Lower	2146	0.05	107	0.7	1.23	0.124	0.01	1%	100%	0.01	2%
Channel	f1b	Lower	1624	0.05	81	0.9	1.23	0.3	0.03	3%	100%	0.03	3%
Subtotal			**9142**		**2875**				**0.05**	**7%**		**0.05**	**7%**
Overbank	c1	Upper	2467	0.12	296	0.88	1.04	0.11	0.03	4%	100%	0.03	4%
Overbank	c2	Upper	944	0.24	227	0.93	1.04	0.11	0.02	3%	100%	0.02	3%
Overbank	c3	Upper	1961	0.51	1000	0.89	1.04	0.69	0.64	80%	100%	0.64	80%
Overbank	f1	Upper	2146	0.29	471	0.93	1.04	0.12	0.05	7%	30%	0.02	2%
Overbank	f1b	Upper	1624	0.17	276	0.91	1.04	0.00	0.00	0%	10%	0.00	0%
Overbank	f2	Upper	244	0.05	12	0.9	1.04	0.00	0.00	0%	0%	0.00	0%
Subtotal					**2282**				**0.75**	**93%**		**0.71**	**88%**
Total									**0.80**	**100%**			**95%**
LA-4 East Americium-241													
Channel	c1	Lower	988	0.5	494	0.5	1.23	0.003	0.00	0%	100%	0.00	0%
Channel	c2	Lower	856	0.5	428	0.5	1.23	0.049	0.01	3%	100%	0.01	3%
Channel	c3	Lower	1164	0.5	582	0.5	1.23	0	0.00	0%	100%	0.00	0%
Subtotal			**3008**		**1504**				**0.01**	**3%**		**0.01**	**3%**
Overbank	c1	Upper	988	0.11	109	0.88	1.04	0.11	0.01	3%	100%	0.01	3%
Overbank	c2	Upper	856	0.13	111	0.93	1.04	0.11	0.01	3%	100%	0.01	3%
Overbank	c3	Upper	1164	0.48	559	0.89	1.04	0.69	0.36	82%	100%	0.36	82%
Overbank	f1	Upper	1701	0.20	340	0.93	1.04	0.12	0.04	9%	30%	0.01	3%
Subtotal					**1119**				**0.42**	**97%**		**0.39**	**90%**
Total									**0.43**	**100%**			**94%**

TABLE 3.3-3 (continued)

ESTIMATED CESIUM, AMERICIUM, AND PLUTONIUM INVENTORY IN REACH LA-4

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 Radionuclide 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-4 West Plutonium-239,240													
Channel	c1	Lower	2467	0.5	1234	0.5	1.23	0.06	0.05	1%	100%	0.05	1%
Channel	c2	Lower	944	0.5	472	0.5	1.23	0.42	0.12	2%	100%	0.12	2%
Channel	c3	Lower	1961	0.5	981	0.5	1.23	2.13	1.28	18%	100%	1.28	23%
Channel	f1	Lower	2146	0.05	107	0.7	1.23	1.16	0.11	1%	100%	0.11	2%
Channel	f1b	Lower	1624	0.05	81	0.9	1.23	2.07	0.19	3%	100%	0.19	3%
Subtotal			**9142**		**2875**				**1.75**	**24%**		**1.75**	**30%**
Overbank	c1	Upper	2467	0.12	296	0.88	1.04	0.45	0.12	2%	100%	0.12	2%
Overbank	c2	Upper	944	0.24	227	0.93	1.04	0.45	0.10	1%	100%	0.10	1%
Overbank	c3	Upper	1961	0.51	1000	0.89	1.04	1.66	1.54	21%	100%	1.54	21%
Overbank	f1	Upper	2146	0.29	471	0.93	1.04	2.56	1.17	16%	30%	0.35	5%
Overbank	f1b	Upper	1624	0.17	276	0.91	1.04	9.82	2.57	35%	10%	0.26	4%
Overbank	f2	Upper	244	0.05	12	0.9	1.04	0.08	0.00	0%	0%	0.00	0%
Subtotal					**2282**				**5.49**	**76%**		**2.36**	**33%**
Total									**7.24**	**100%**			**63%**
LA-4 East Plutonium-239,240													
Channel	c1	Lower	988	0.5	494	0.5	1.23	0.06	0.02	1%	100%	0.02	1%
Channel	c2	Lower	856	0.5	428	0.5	1.23	0.42	0.11	4%	100%	0.11	4%
Channel	c3	Lower	1164	0.5	582	0.5	1.23	2.13	0.76	28%	100%	0.76	28%
Subtotal			**3008**		**1504**				**0.89**	**33%**		**0.89**	**33%**
Overbank	c1	Upper	988	0.11	109	0.88	1.04	0.45	0.04	2%	100%	0.04	2%
Overbank	c2	Upper	856	0.13	111	0.93	1.04	0.45	0.05	2%	100%	0.05	2%
Overbank	c3	Upper	1164	0.48	559	0.89	1.04	1.66	0.86	32%	100%	0.86	32%
Overbank	f1	Upper	1701	0.20	340	0.93	1.04	2.56	0.84	31%	30%	0.25	9%
Subtotal					**1119**				**1.79**	**67%**		**1.20**	**45%**
Total									**2.69**	**100%**			**78%**

TABLE 3.3-4

RADIONUCLIDE ANALYSES FROM REACH LA-5

Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Cs-137 (pCi/g)	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (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-0033	0–4	0–10	Channel	1	04LA-96-0176	0.08 (U)[c]	0.023 (U)	0.2 (U)	-0.001 (U)	0.124	0.59 (U)	cs	gs	
c1	LA-0037	0–3	0–8	Channel	1	04LA-96-0180	0.12 (U)	0.032 (U)	0.3 (U)	0.004 (U)	0.161	0.24 (U)	cs	gs	
c2	LA-0036	0–3	0–8	Overbank	1	04LA-96-0179	0.11	0.052	0.25 (U)	0.005 (U)	1.379	0.43 (U)	fs	ls	
c2	LA-0077	0–3	0–7	Channel	2	04LA-97-0011	NA[d]	NA	NA	-0.011 (U)	0.04 (U)	NA	cs	s	
c2	LA-0085	0–5	0–13	Overbank	2	04LA-97-0021	NA	NA	NA	-0.009 (U)	0.053 (U)	NA	fs	ls	
c2	LA-0085	5–13	13–32	Channel	2	04LA-97-0022	NA	NA	NA	0.004 (U)	0.151 (U)	NA	cs	gs	
c3	LA-0080	0–4	0–10	Channel	2	04LA-97-0014	NA	NA	NA	0.002 (U)	0.018 (U)	NA	ms	ls	
c3	LA-0082	0–4	0–10	Overbank	2	04LA-97-0016	NA	NA	NA	-0.013 (U)	0.02 (U)	NA	fs	ls	
c3	LA-0082	5–9	12–22	Channel	2	04LA-97-0017	NA	NA	NA	-0.013 (U)	-0.007 (U)	NA	ms	s	
c3	LA-0090	0–12	0–30	Channel	2	04LA-97-0029	NA	NA	NA	-0.022 (U)	0.06 (U)	NA	ms	s	
c3	LA-0090	12–14	30–35	Overbank	2	04LA-97-0030	NA	NA	NA	-0.002 (U)	0.393	NA	fs	ls	
c3	LA-0090	14–26	35–65	Channel	2	04LA-97-0031	NA	NA	NA	0.002 (U)	-0.002 (U)	NA	ms	s	
c3	LA-0032	0–3	0–8	Overbank	1	04LA-96-0175	0.43	0.025 (U)	0.26 (U)	0.003 (U)	0.098	0.42 (U)	vfs	ls	
c3	LA-0091	0–5	0–13	Overbank	2	04LA-97-0032	NA	NA	NA	-0.018 (U)	0.038 (U)	NA	ms	s	
f1? (c3?)	LA-0088	2–5	6–12	Overbank	2	04LA-97-0025	NA	NA	NA	-0.007 (U)	0.601	NA	fs	sl	
f1? (c3?)	LA-0089	0–11	0–28	Channel	2	04LA-97-0026	NA	NA	NA	0.002 (U)	0.053 (U)	NA	cs	s	
f1? (c3?)	LA-0089	11–13	28–32	Overbank	2	04LA-97-0027	NA	NA	NA	0.002 (U)	0.105	NA	fs	ls	
f1? (c3?)	LA-0089	11–13	28–32	Overbank	2	04LA-97-0028	NA	NA	NA	-0.009 (U)	0.007 (U)	NA	NA	NA	QA duplicate
f1	LA-0034	0–4	0–10	Overbank	1	04LA-96-0177	0.39	0.026 (U)	0.26 (U)	0 (U)	0.18	0.55 (U)	fs	ls	
f1	LA-0035	0–4	0–10	Overbank	1	04LA-96-0178	0.79	0.065	0.28 (U)	0.005 (U)	0.189	0.72 (U)	fs	sl	
f1	LA-0038	0–2	0–5	Overbank	1	04LA-96-0181	0.45	0.023 (U)	0.32 (U)	-0.002 (U)	0.436	0.56 (U)	fs	ls	

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

TABLE 3.3-4 (continued)

RADIONUCLIDE ANALYSES FROM REACH LA-5

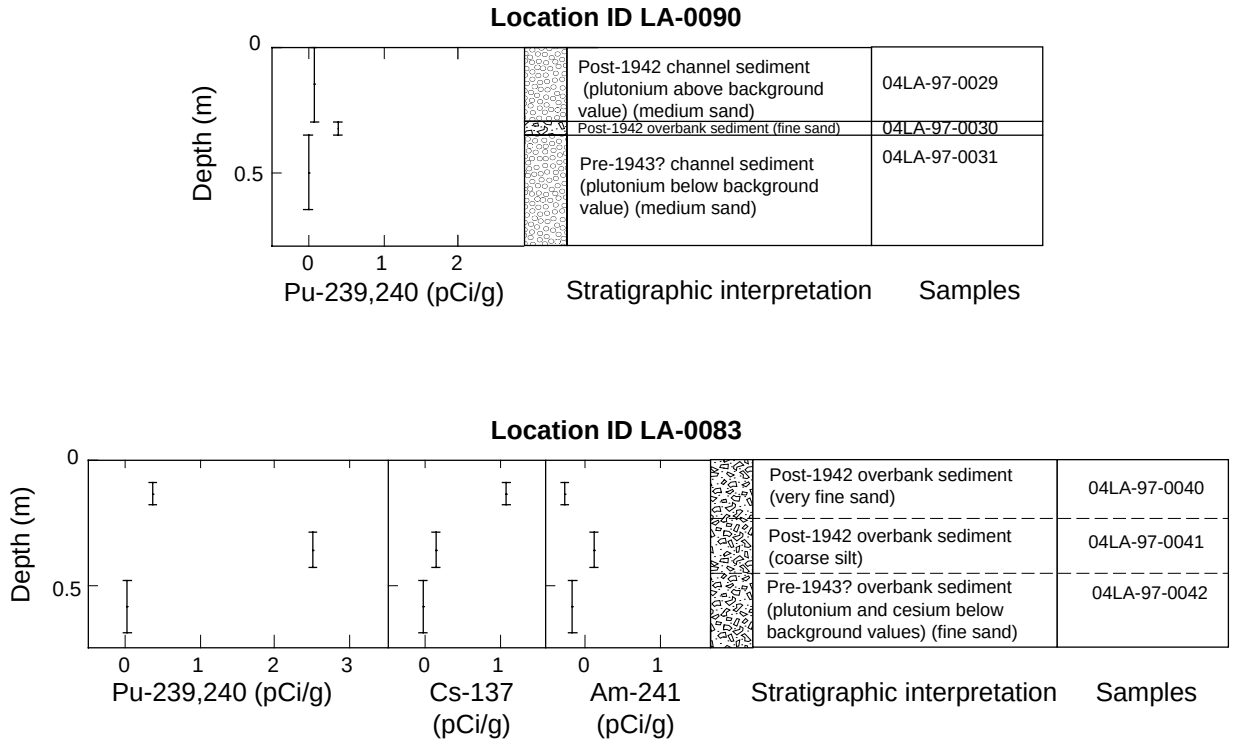
Geomorphic Unit	Location ID	Depth (in.)	Depth (cm)	Sediment Facies	Sampling Event	Sample ID	Cs-137 (pCi/g)	Am-241 (alpha spec) (pCi/g)	Am-241 (gamma spec) (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Sr-90 (pCi/g)	Median Particle Size Class[a]	Soil Texture[b]	Notes
f1	LA-0038	4–8	10–20	Overbank	2	04LA-97-0020	NA[c]	NA	NA	-0.009 (U)[d]	1.463	NA	fs	ls	
f1	LA-0083	3–7	7–18	Overbank	2	04LA-97-0040	1.070	NA	-0.279 (U)	-0.004 (U)	0.366	NA	vfs	sl	
f1	LA-0083	11–17	29–43	Overbank	2	04LA-97-0041	0.148 (U)	NA	0.12 (U)	0.009 (U)	2.524	NA	csi	l	
f1	LA-0083	19–27	48–69	Overbank	2	04LA-97-0042	-0.029 (U)	NA	-0.191 (U)	-0.014 (U)	0.009 (U)	NA	fs	ls	Background; pre-1943?
f1	LA-0084	0–5	0–13	Overbank	2	04LA-97-0018	NA	NA	NA	0.002 (U)	0.169	NA	fs	s	
f1	LA-0084	5–15	13–38	Overbank	2	04LA-97-0019	NA	NA	NA	0.004 (U)	1.569	NA	vfs	gsl	
f1	LA-0086	0–6	0–15	Overbank	2	04LA-97-0023	NA	NA	NA	0.008 (U)	0.149	NA	vfs	sl	
f1	LA-0087	0–3	0–5	Overbank	2	04LA-97-0024	NA	NA	NA	0.002 (U)	0.141	NA	fs	ls	
f2	LA-0078	0–2	0–4	Overbank	2	04LA-97-0012	NA	NA	NA	-0.009 (U)	0.064 (U)	NA	vfs	sl	
f2	LA-0079	0–2	0–4	Overbank	2	04LA-97-0013	NA	NA	NA	-0.002 (U)	0.038 (U)	NA	vfs	gsl	
f2	LA-0081	0–4	0–10	Overbank	2	04LA-97-0015	NA	NA	NA	-0.019 (U)	0.081 (U)	NA	csi	l	

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

b. l = loam, 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.



F3.3-7 / LOWER LOS ALAMOS REACH RPT / 110598

Figure 3.3-7. Depth variations in americium-241; cesium-137; and plutonium-239,240 concentration at sample sites in the c3 and f1 units in reach LA-5.

The highest concentrations of plutonium-239,240 in reach LA-5 are found in relatively fine-grained overbank facies sediment deposits on the c2 and f1 units, although samples from these units also provide results below the background value. Overbank sediments from the c2 and f1 units have an average concentration of 0.67 pCi/g and a median concentration of 0.28 pCi/g (Table 3.3-5). In contrast, overbank sediments on the c3 unit have a maximum concentration of 0.39 pCi/g and an average concentration of 0.14 pCi/g. Sampled overbank sediments on the f2 unit yielded no plutonium-239,240 results above detection limits, but because of relatively high detection limits in these samples, the possibility exists that plutonium-239,240 is elevated relative to background data.

Plutonium-239,240 concentrations in the coarse-grained channel facies sediment are lower than in related fine-grained sediment and are close to or below the background value. The maximum concentration obtained from channel facies sediment was 0.161 pCi/g from coarse sand in the active channel (c1 unit). The average concentration in the relatively young channel sediments of the c1 and c2 units is 0.12 pCi/g, and the median concentration is 0.14 pCi/g (Table 3.3-5). In contrast, plutonium-239,240 concentration in all channel facies samples from the c3 unit are below detection limits and below the background value.

No cesium-137 results were above the background value in the full-suite analyses in reach LA-5; therefore, few cesium-137 analyses were obtained in the second sampling round. Cesium-137 analyses in the second sampling round were obtained on three overbank facies sediment samples from an f1 sample site where geomorphic evidence (the burial of the base of cottonwood trees) indicated the

presence of a relatively thick section of post-1942 overbank sediment. The uppermost sample at this location provided the only result above the background value of 0.9 pCi/g, 1.07 pCi/g in sample 04LA-97-0040 (Table 3.3-4; Figures 2.3-7 and 3.3-7). Notably, this sample directly overlays the sample with the highest plutonium-239,240 concentration, but cesium-137 was below the detection limit in that lower sample (04LA-97-0041).

TABLE 3.3-5

SUMMARY OF BINNED ANALYSES IN REACH LA-5

Geomorphic Unit and Sediment Facies	Summary Statistic	Cs-137 (pCi/g)	Pu-238 (pCi/g)	Pu-239,240 (pCi/g)	Median Particle Size Class[a]	Median Particle Size (mm)	Soil Texture[b]
c1 and c2 channel	average	0.100	-0.001	0.119	cs	0.709	gs
	std. dev.	0.028	0.007	0.055			
	maximum	0.120	0.004	0.161			
	minimum	0.080	-0.011	0.040			
	median	0.100	0.002	0.138			
	n	2	4	4			
c2 and f1 overbank	average	0.493	0.000	0.666	fs	0.128	sl
	std. dev.	0.374	0.006	0.760			
	maximum	1.070	0.009	2.524			
	minimum	0.110	-0.009	0.053			
	median	0.420	0.002	0.278			
	n	6	14	14			
c3 overbank	average	0.430	-0.008	0.137	fs	0.179	ls
	std. dev.	N/A[c]	0.010	0.174			
	maximum	N/A	0.003	0.393			
	minimum	N/A	-0.018	0.020			
	median	N/A	-0.008	0.068			
	n	1	4	4			
c3 + f1? channel	average	NA[d]	-0.006	0.024	ms	0.396	s
	std. dev.	NA	0.011	0.031			
	maximum	NA	0.002	0.060			
	minimum	NA	-0.022	-0.007			
	median	NA	0.002	0.018			
	n	NA	5	5			
f2 overbank	average	NA	-0.010	0.061	vfs	0.079	sl
	std. dev.	NA	0.009	0.022			
	maximum	NA	-0.002	0.081			
	minimum	NA	-0.019	0.038			
	median	NA	-0.009	0.064			
	n	NA	3	3			
background?[e]	average	-0.029	-0.014	0.009	fs	0.125	ls
	n	1	1	0			

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. N/A = not applicable

d. NA = not analyzed

e. Sample inferred to represent background is from a subsurface layer in the f1 unit. Other samples are within background range but are from probable post-1942 sediment deposits.

Analytical results by alpha spectroscopy from the seven full-suite samples indicated that americium-241 was slightly above the background value of 0.04 pCi/g in two samples, with a maximum of only 0.065 pCi/g (sample 04LA-6-0178; Table 3.3-4). Both of these samples were from fine-grained overbank facies sediment. Because of these low values, no more americium-241 analyses were obtained in the second sampling round except for the lower precision analyses by gamma spectroscopy. No strontium-90 analyses in the full-suite samples were above the background value, and strontium-90 analyses were not obtained in the second sampling event. Plutonium-238 was reported as being below the detection limit in all samples from reach LA-5 (Table 3.3-4).

3.3.3.2 Age and Particle Size Relations

Little evidence for time-dependent variations in radionuclide concentrations is available in reach LA-5 in part because of the limited age control for sediment deposits. The ability to detect any changes in concentration over time are also limited by the low radionuclide concentrations and the mixing of sediment from multiple sources, including sediment supplied downstream from reach LA-4 by Bayo Canyon and Guaje Canyon.

Examination of aerial photographs from 1935 and 1954 identified that during the early period of Laboratory operations the active channel included at least part of the area mapped as c3, although part may have already been abandoned before 1942. Sediment deposits of this age yielded the highest plutonium-239,240 concentrations in lower Pueblo Canyon (Reneau et al. 1998, 59159), yet sampling of the c3 unit in reach LA-5 at five different locations provided a maximum concentration of only 0.39 pCi/g from an overbank sediment layer (sample location LA-0090; Figure 3.3-7). This unexpected result may have been caused by these sediments having been deposited before significant amounts of plutonium-239,240 had been transported this far downstream from the source at TA-45 (a distance of 17 km) or by these deposits having been dominated by sediment from Bayo Canyon or Guaje Canyon.

Vertical variations in radionuclide concentrations at one f1 sample site (location LA-0083; Figure 3.3-7) suggest general changes over time that are consistent with changes seen upstream, although precise age control is not available. These sediments bury the base of a cottonwood tree that was cored for dendrochronological analysis, but it was not possible to reliably identify annual growth rings in this tree, and its age is unknown. The uppermost sampled layer had the highest cesium-137 result in reach LA-5, the only result above the background value, but relatively low plutonium-239,240 (0.37 pCi/g), and the underlying layer had the highest plutonium-239,240 concentration in LA-5 (2.52 pCi/g). These vertical relations suggest a decrease in plutonium-239,240 over time, although the possible influence of variable sediment sources cannot be ruled out.

Additional data on possible changes in radionuclide concentrations over time are available from active channel sediment samples from the environmental surveillance sampling station in lower Los Alamos Canyon at Otowi, just upstream from the Rio Grande, that date back to 1977 (e.g., Environmental Surveillance and Compliance Programs 1997, 56684) (Figure 3.3-8). These data indicate no significant changes in plutonium-239,240 concentration during this 20-year period and, except for relatively high values in 1983 and 1988 (0.3 to 0.5 pCi/g), all analyses are similar to those obtained in 1996 during this investigation. Cesium-137 analyses reported from this sampling station show much more variability, and interpretation of this data set is less clear. In particular, although most results are below the background value and similar to analyses obtained in this investigation, several results exceed the background value, including analyses in 1996. Notably, these 1996 surveillance sample results are also higher than any samples from the young c1 and c2 units of reach LA-4 in this investigation and are not consistent with other evidence for cesium-137 concentrations in lower Los Alamos Canyon.

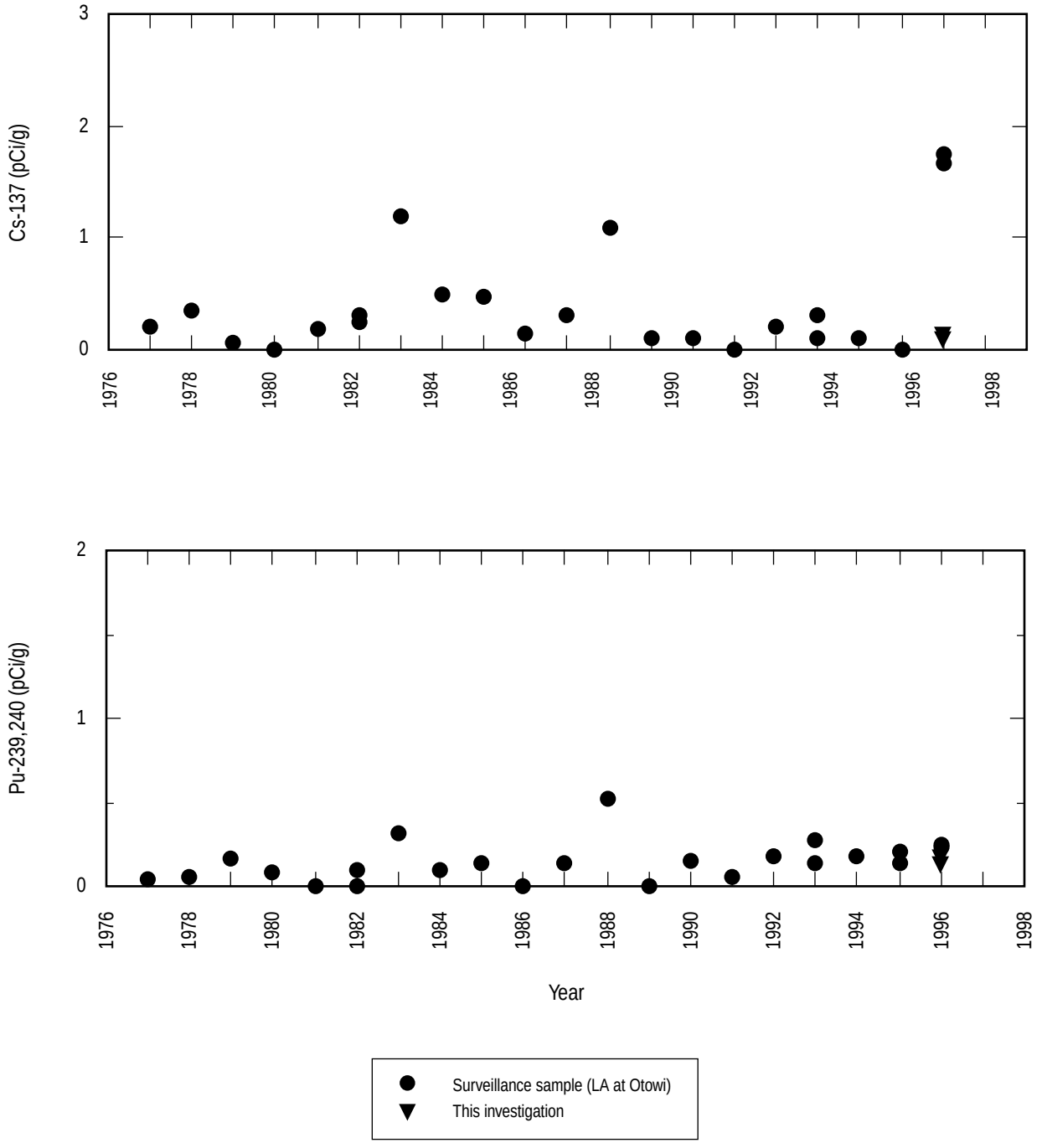


Figure 3.3-8. Relation of cesium-137 and plutonium-239,240 concentration to age from active channel sediment samples collected in reach LA-5.

General relations between radionuclide concentration and particle size in reach LA-5 are shown by the differences between the relatively fine-grained overbank facies sediment, with a median particle size of fine sand, and the coarser channel facies sediment, with a median particle size of coarse sand (Table 3.3-5) as was also discussed for reach LA-4 (Section 3.3.2.2). Scatter plots presented in Appendix B (Figures B3-4 and B3-5) also suggest increases in radionuclide concentration with decreasing particle size, particularly with silt and clay content, but these relations are undoubtedly complicated by the influence of variable sediment age and variable sources discussed previously.

3.3.3.3 Contaminant Inventory

The estimated plutonium-239,240 inventory in reach LA-5 is 12.6 mCi/km, which is similar to that estimated for the two LA-4 subreaches. Most of the estimated inventory, 69%, is within the relatively fine-grained overbank facies sediment (Table 3.3-6), which is also similar to that estimated upstream in reach LA-4 (Section 3.3.2.3). The most important unit in terms of plutonium-239,240 inventory is f1, which contains 52% of the estimated total. The c1 and c2 units contain 20 and 22% of the total, respectively, and the c3 unit only 6% of the total. Fifty-eight percent of the total inventory is estimated to be located in areas most susceptible to remobilization in floods during the next 50 years, and the remainder is in more stable geomorphic settings.

It is notable that much of the estimated plutonium-239,240 inventory in reach LA-5 is related to the exceptionally large areas of the post-1942 geomorphic units and the resultant large estimates of sediment volume, although the estimated average concentrations are relatively low. If this entire volume of sediment had plutonium-239,240 at the background value of 0.068 pCi/g, the inventory would be 4.0 mCi/km, or approximately one-third of the estimate based on the values in Table 3.3-6. Using the average plutonium-239,240 value of 0.025 pCi/g from the background sediment data set (McDonald et al. 1996, 55532) yields a more realistic estimate of the “background inventory” of 1.5 mCi/km for LA-5, or approximately one-tenth of the total estimated LA-5 inventory.

It should be stressed that these estimates of plutonium-239,240 inventory are considered to be much less reliable than the estimates made in upstream reaches for several reasons. The most significant uncertainties are in the average thickness of sediment post-dating 1942 in the different geomorphic units. No data are available on the actual thickness of coarse-grained post-1942 channel facies sediment below the c1, c2, or c3 units, and the estimates used in Table 3.3-6 could be either too high or too low. The average thickness of fine-grained post-1942 overbank facies sediment on the different units is also poorly constrained, but the estimates used in Table 3.3-6 were biased to sites where field evidence suggested thicknesses higher than in nearby sites on the same units and are intended to provide conservative overestimates of contaminant inventory. Uncertainties in the average plutonium-239,240 concentration in the different units may also be relatively high because of the smaller number of samples analyzed in reach LA-5 relative to upstream reaches. However, sample site selection was biased to sites where plutonium-239,240 were expected to be highest based on the geomorphic mapping and on the results of the full-suite samples, and the averages are also most likely biased on the high side.

TABLE 3.3-6

ESTIMATED CESIUM AND PLUTONIUM INVENTORY IN REACH LA-5

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 Radionuclide 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
Cesium-137													
Channel	c1	Lower	48795	1.0	48795	0.5	1.23	0.10	3.0	18%	100%	3.0	18%
Channel	c2	Lower	22393	1.0	22393	0.5	1.23	0.10	1.4	8%	100%	1.4	8%
Channel	c3	Lower	46441	0.5	23221	0.5	1.23	0.10	1.4	8%	50%	0.7	4%
Subtotal			**117629**		**94409**				**5.8**	**34%**		**5.1**	**30%**
Overbank	c2	Upper	22393	0.15	3359	0.95	1.04	0.49	1.6	10%	100%	1.6	10%
Overbank	c3	Upper	46441	0.1	4644	0.94	1.04	0.43	2.0	11%	50%	1.0	6%
Overbank	f1	Upper	73888	0.2	14778	0.9	1.04	0.49	6.8	40%	25%	1.7	10%
Overbank	f2	Upper	21800	0.1	2180	0.85	1.04	0.49	0.9	6%	0%	0.0	0%
Subtotal					**24961**				**11.3**	**66%**		**4.3**	**25%**
Total									**17.1**	**100%**			**55%**
Plutonium-239,240													
Channel	c1	Lower	48795	1.0	48795	0.5	1.23	0.12	3.6	20%	100%	3.6	20%
Channel	c2	Lower	22393	1.0	22393	0.5	1.23	0.12	1.7	9%	100%	1.7	9%
Channel	c3	Lower	46441	0.5	23221	0.5	1.23	0.02	0.3	2%	50%	0.1	1%
Subtotal			**117629**		**94409**				**5.5**	**31%**		**5.4**	**30%**
Overbank	c2	Upper	22393	0.15	3359	0.95	1.04	0.67	2.2	13%	100%	2.2	13%
Overbank	c3	Upper	46441	0.1	4644	0.94	1.04	0.14	0.6	4%	50%	0.3	2%
Overbank	f1	Upper	73888	0.2	14778	0.9	1.04	0.67	9.3	52%	25%	2.3	13%
Overbank	f2	Upper	21800	0.1	2180	0.85	1.04	0.06	0.1	1%	0%	0.0	0%
Subtotal					**24961**				**12.2**	**69%**		**4.9**	**27%**
Total									**17.8**	**100%**			**58%**

The estimated cesium-137 inventory in reach LA-5 is 12.1 mCi/km, which is approximately three times the estimated inventory in each of the two LA-4 subreaches and is very similar to the estimated 14 mCi/km in reach LA-3 upstream from Pueblo Canyon (Reneau et al. 1998, 59160). The percentages of the estimated cesium-137 inventory among the different geomorphic units and sediment facies are similar to that estimated for plutonium-239,240 (Table 3.3-6). However, these estimates are all based on average cesium-137 concentrations that are below the background value of 0.9 pCi/g, and most of the cesium-137 inventory in LA-5 may be derived from worldwide fallout. Using the average cesium-137 value of 0.211 pCi/g from the background sediment data set (McDonald et al. 1996, 55532) and the volumes of sediment estimated in Table 3.3-6 yields an estimate of the background cesium-137 inventory of 12.2 mCi/km for LA-5. This is indistinguishable from the amount of cesium-137 estimated in Table 3.3-6. Although there are uncertainties in the average cesium-137 concentration in both LA-5 sediment and in background sediment, available data indicate that the cesium-137 inventory in LA-5 is not significantly different from what would be expected in background areas.

4.0 REVISED CONCEPTUAL MODEL

A key part of the technical approach for the evaluation of contamination in lower 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 lower 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 lower 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-4 and LA-5 as discussed in Sections 2 and 3 of this report. This section also incorporates information on contaminants in both upper Los Alamos Canyon (Reneau et al. 1998, 59160) and Pueblo Canyon (Reneau et al. 1998, 59159) that are relevant for understanding the relation of contaminants in LA-4 and LA-5 to those present upstream on Department of Energy (DOE) land and Los Alamos County land. 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

Nineteen analytes are present within the sediments in lower 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 either former Technical Area (TA) -45 into Acid Canyon, within the Pueblo Canyon watershed, or from the 21-011(k) outfall at TA-21 into DP Canyon, within the upper Los Alamos Canyon watershed. Americium-241; cesium-137; plutonium-238; and plutonium-239,240 were all identified as COPCs in this investigation and can be directly related to releases at these Laboratory sites. Investigations upstream indicate that most of the plutonium-239,240 present in lower Los Alamos Canyon originated from TA-45 and that most of the other radionuclide COPCs originated primarily at TA-21. Strontium-90, which is associated with releases from TA-21, was also tentatively identified as a COPC in reach LA-4 after the first sampling round. However, strontium-90 was reported as detected in only one sample, and this result could not be replicated upon resampling, leading to the elimination of strontium-90 as a COPC. The absence of strontium-90 above the background value is consistent with cesium/strontium ratios obtained in upstream reaches and the concentration of cesium-137 in lower Los Alamos Canyon, as discussed in Section 3.3.2.1.

TABLE 4.1-1

SUMMARY OF LOWER LOS ALAMOS CANYON COPCs[a]

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	4.64	LA-4 West	c3, overbank	21-011(k)
Cesium-134	0.14	0.24	LA-5	c1, channel	Unknown, possibly background
Cesium-137	0.90	4.65	LA-4 West	c3, overbank	21-011(k)
Europium-152	0.59	0.408 [0.467]	LA-4 West	c1, overbank	Unknown, possibly background
Plutonium-238	0.006	0.227	LA-4 West	c3, overbank	21-011(k), TA-45
Plutonium-239,240	0.068	13.8	LA-4 West	f1b, overbank	TA-45
Inorganic Chemicals (mg/kg)					
Antimony	0.83	[5.3]	[LA-4 West]	[c3, overbank]	Possibly background
Boron		6.8	LA-5	f1, overbank	Probably background
Cadmium	0.4	0.07 [0.53]	[LA-4 West]	[c3, overbank]	Possibly background
Calcium	4420	7410	LA-4 West	f1b, overbank	Probably background
Copper	11.2	10.8	LA-4 East	c1, overbank	TA-1, TA-21, and other sources?
Lead	19.7	31.6	LA-4 West	c3, overbank	TA-1, TA-21, and other sources?
Magnesium	2370	1940	LA-4 East	c2, overbank	Probably background
Potassium	2690	2880	LA-5	f1, overbank	Probably background
Selenium	0.3	0.4 [0.83]	LA-5 [LA-4 East]	c3, overbank [c1 channel]	Possibly background
Sodium	1470	1530	LA-5	f1, overbank	Probably background
Vanadium	19.7	20.6	LA-5	f1, overbank	Probably background
Organic Chemicals (mg/kg)					
Aldrin	0.033	0.00117	LA-5	c3, overbank	Unknown (multiple sources? nps[b]?)
4,4'-DDT	0.033	0.0051	LA-4 West	c3, overbank	Unknown (multiple sources? nps?)

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

b. nps = nonpoint sources

Two other radionuclide COPCs, cesium-134 and europium-152, were identified as COPCs because of their detection in samples from either reach LA-4 or reach LA-5. Because these radionuclides were not detected in background samples, the detection limits are used as surrogate background levels. The detected results for these radionuclides may represent false positive analytical detections caused by spectral interferences in the gamma spectroscopy analytical method. Cesium-134 was detected in only one sample in LA-5, at slightly above the detection limit, and the absence of any detects in LA-4 indicates that cesium-134 is not present as a contaminant in lower Los Alamos Canyon. All three detected europium-152 results are within the range of nondetected results, and these data are not conclusive as to whether they represent releases in the Los Alamos Canyon watershed. The same uncertainty existed for europium-152 upstream in upper Los Alamos Canyon.

Inorganic chemicals identified as COPCs in this investigation include antimony, boron, cadmium, calcium, copper, lead, magnesium, potassium, selenium, sodium, and vanadium (Table 4.1-1). Two of the inorganic COPCs (copper and lead) were identified as COPCs in upstream reaches and appear to be collocated with one of the key radionuclides. A possible positive correlation between these inorganic COPCs and cesium-137 suggests a primary source for copper and lead in the upper Los Alamos Canyon watershed. Three other inorganic COPCs (antimony, cadmium, and selenium) were also identified as COPCs in upper Los Alamos Canyon and Pueblo Canyon but have a very low frequency of detects both in lower Los Alamos Canyon and in upstream reaches, and no conclusions can be drawn about possible sources. The remaining inorganic COPCs (boron, calcium, magnesium, potassium, sodium, and vanadium) were not identified as COPCs in upstream reaches and also generally show negative correlations with the key radionuclides, indicating that the apparent elevation of concentrations of these analytes is probably due to a different geochemical background in lower Los Alamos Canyon than upstream at the background sample sites. There is also a possibility that these COPCs in part represent releases into either the Bayo Canyon or Rendija Canyon subbasins upstream from reach LA-5, although releases of these chemicals from potential release sites have not been identified in either subbasin.

Two organic chemicals were identified as COPCs in this investigation because they were detected in single samples in lower Los Alamos Canyon: the pesticides aldrin and dichloro diphenyl trichloroethane (DDT) (Table 4.1-1). Aldrin was also identified as a COPC in Pueblo Canyon because of three detects in reach P-1, but the four detected aldrin results are all within the range of nondetected results (Figure 3.2-4), and there is no evidence of significant releases of this pesticide in the watershed. DDT was detected in both Pueblo Canyon and upper Los Alamos Canyon, with higher results and a higher frequency of detects in upper Los Alamos Canyon in reaches LA-1 and LA-2 (Figure 3.2-4). The geographic distribution of DDT suggests a primary source in the upper Los Alamos Canyon watershed, although this pesticide has not been traced to any specific Laboratory source; a source in the Los Alamos townsite is possible. Note that there are significant gaps in data coverage for organic chemicals in Los Alamos Canyon, including the lack of analyses for semivolatile organic compounds in reach LA-4 and the lack of any organic chemical analyses in reach LA-3 in upper Los Alamos Canyon. Revisions to this part of the conceptual model may be necessary following additional analyses for organic chemicals.

4.1.2 Horizontal and Vertical Extent

The horizontal and vertical extent of contaminated sediments in lower Los Alamos Canyon have been defined using a combination of geomorphic mapping and analytical results from sediment sampling in reaches LA-4 and LA-5. In particular, plutonium-239,240 analyses from sediment samples helped guide the geomorphic characterization both by demonstrating a wider horizontal distribution of post-1942 sediment than was originally mapped and by indicating the thickness of post-1942 overbank sediments on the floodplains. Plutonium-239,240 originating at TA-45 has been dispersed by floods along the full

length of lower Los Alamos Canyon between Pueblo Canyon and the Rio Grande, a distance of more than 18 km from the source. Floods have also distributed contaminants laterally across the canyon floor in a belt that varies in width from an average of 16 to 18 m in LA-4 to 150 m in LA-5 (Section 2.3).

The vertical extent of contamination in lower Los Alamos Canyon sediments ranges from depths of less than 5 cm to at least 1.0 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, are 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. Contaminants could be present through the full thickness of the alluvium below the active and abandoned channels associated with the translocation of contaminants adsorbed to sediment particles or organic colloids, as inferred for plutonium in Pueblo Canyon (Reneau et al. 1998, 59159). The thickness of alluvium in lower Los Alamos Canyon has been reported at approximately 8 to 24 m at water supply wells (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.

4.2 Variations in Contamination

The present distribution of most COPCs and variations in contaminant concentration in lower 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 Laboratory boundary (reach LA-4), in relatively fine-grained sediment deposits, and in relatively old sediments. The relatively small inventory of plutonium in lower Los Alamos Canyon as compared with that present in Pueblo Canyon that was proposed by Graf (1995, 48851; 1996, 55537) was also confirmed in this investigation.

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 lower 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. 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 obtained in this investigation indicates clear decreases in the concentrations of key radionuclides over time in reach LA-4. Evidence is inconclusive in reach LA-5, but because the general tends in LA-4 are consistent with those seen upstream in Pueblo Canyon and upper Los Alamos Canyon (Reneau et al. 1998, 59159; Reneau et al. 1998, 59160), it is probable that similar trends have occurred in LA-5 as well.

Figure 4.2-1 shows the average concentration of key radionuclides in overbank facies sediment from reach LA-4 West as a function of approximate sediment age. Based on isotopic ratios and the release history of the 21-011(k) outfall at TA-21, in combination with evidence for variations in plutonium-239,240 concentration over time in lower Pueblo Canyon, the following age estimates are used for the f1b, c3, and c1 plus c2 overbank sediments in LA-4 West. The f1b sediments are assumed to predate major releases of cesium-137 from the 21-011(k) outfall; possible correlative sediment deposits in lower Pueblo Canyon are related to the c5 unit of reach P-4 West, which likely dates to the early 1950s. The typical c3 deposits are inferred to have been deposited after discharges of americium-241 and plutonium-238 increased from the 21-011(k) outfall in 1968, and the typical c1 and c2 deposits are assumed to be younger, deposited in part during floods in 1991 that left deposits which are evident on 1991 aerial photographs.

As shown in Figure 4.2-1, average plutonium-239,240 concentrations in reach LA-4 West decreased by an order of magnitude between the pre-1956 f1b sediments and the c1 and c2 sediments that are inferred to include deposits from the 1990s. Cesium-137 concentrations are below the background value in the f1b sediments and are highest in the c3 sediments in LA-4 West, subsequently decreasing. Note that on Figure 4.2-1 cesium-137 concentrations are inferred to have been highest during the period between 1956 and 1968 when discharges of cesium-137 from the 21-011(k) outfall were probably greatest, although sediments of this age have not been clearly identified either in LA-4 or upstream in reach LA-3. Similar to cesium-137, americium-241 concentrations were low during the early post-1942 period (represented by the f1b sediments), reached a peak later (represented by the c3 sediments), and subsequently declined. Based on evidence in upper Los Alamos Canyon, americium-241 reached its highest concentrations after 1978 associated with increased discharges of this radionuclide from the 21-011(k) outfall.

Data collected since 1977 from active channel sediments at the environmental surveillance station in lower Los Alamos Canyon at Totavi provide supporting evidence that radionuclide concentrations have been stable or have declined during the past 10 to 20 years, as discussed in Section 3.3.2.2. Because effluent releases stopped more than 10 years ago at the 21-011(k) outfall and more than 30 years ago at TA-45 and because concentrations in sediments in upper Los Alamos Canyon and Pueblo Canyon closer to the contaminant sources have also generally been decreasing over time (Reneau et al. 1998, 59159; Reneau et al. 1998, 59160), there is no reason to expect concentrations in lower Los Alamos Canyon to increase in the future.

TABLE 4.2-1

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

Part 1

Reach	Approx. Stream Elevation Upstream End (ft)	Approx. Distance above Rio Grande 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[b] (mCi)	Estimated Total Inventory Unsampled Reaches (mCi)
Cesium-137								
Pueblo to LA-4	6262			1.27				
LA-4 West	6004	6.30	0.52		5529	4388	2.3	5.6
LA-4 unsampled	5925	5.78		0.61				
LA-4 East	5850	5.17	0.29	0.29	5186	3859	1.3	2.7
LA-4 to Bayo	5815	4.88		0.95				
Bayo to Guaje	5753	3.93		1.55				4.1
Guaje to LA-5	5645	2.38		0.80				12.7
LA-5	5595	1.58	1.41		66957	17703	17.1	9.7
LA-5 to Rio	5498	0.17		0.17				
Subtotal			**2.22**	**5.64**			**20.6**	2.1
Total						**57.5**		**36.8**
Plutonium-239,240								
Pueblo to LA-4	6262	7.57		1.27				
LA-4 West	6004	6.30	0.52		5529	4388	7.2	
LA-4 unsampled	5925	5.78		0.61				17.7
LA-4 East	5850	5.17	0.29	0.29	5186	3859	2.7	
LA-4 to Bayo	5815	4.88		0.95				7.1
Bayo to Guaje	5753	3.93		1.55				
Guaje to LA-5	5645	2.38		0.80				8.8
LA-5	5595	1.58	1.41		66957	17703	17.7	16.9
LA-5 to Rio	5498	0.17		0.17				10.0
Subtotal			**2.22**	**5.64**			**27.6**	
Total		**7.86**				**90.2**		2.1

a. Approximate distances from Rio Grande measured along the stream channel as depicted on 1:4800 scale FIMAD maps with 10-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 LOWER LOS ALAMOS CANYON REACHES

Part 2								
Reach	Estimated Total Inventory, Channel Facies Sampled Reaches (mCi/km)	Estimated Total Cs-137 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								
Pueblo to LA-4							4.6	
LA-4 West	0.5	3.9	4.4	0.1	0.9	1.9		3.7
LA-4 unsampled							2.2	
LA-4 East	0.6	3.8	4.3	0.2	1.0	1.1		3.7
LA-4 to Bayo							3.5	
Bayo to Guaje							3.4	
Guaje to LA-5							0.6	
LA-5	4.1	8.0	12.1	0.1	0.5	1.1		0.8
LA-5 to Rio							0.1	
Subtotal						**4.0**	**14.5**	
Total					**18.5**			
Plutonium-239,240								
Pueblo to LA-4							10.0	
LA-4 West	3.4	10.6	13.9	0.9	2.5	4.1		7.9
LA-4 unsampled							4.6	
LA-4 East	3.1	6.2	9.2	0.9	1.7	2.1		7.2
LA-4 to Bayo							6.8	
Bayo to Guaje							11.2	
Guaje to LA-5							5.8	
LA-5	3.9	8.7	12.6	0.1	0.5	10.3		7.3
LA-5 to Rio							1.2	
Subtotal						**16.5**	**39.8**	
Total					**56.2**			

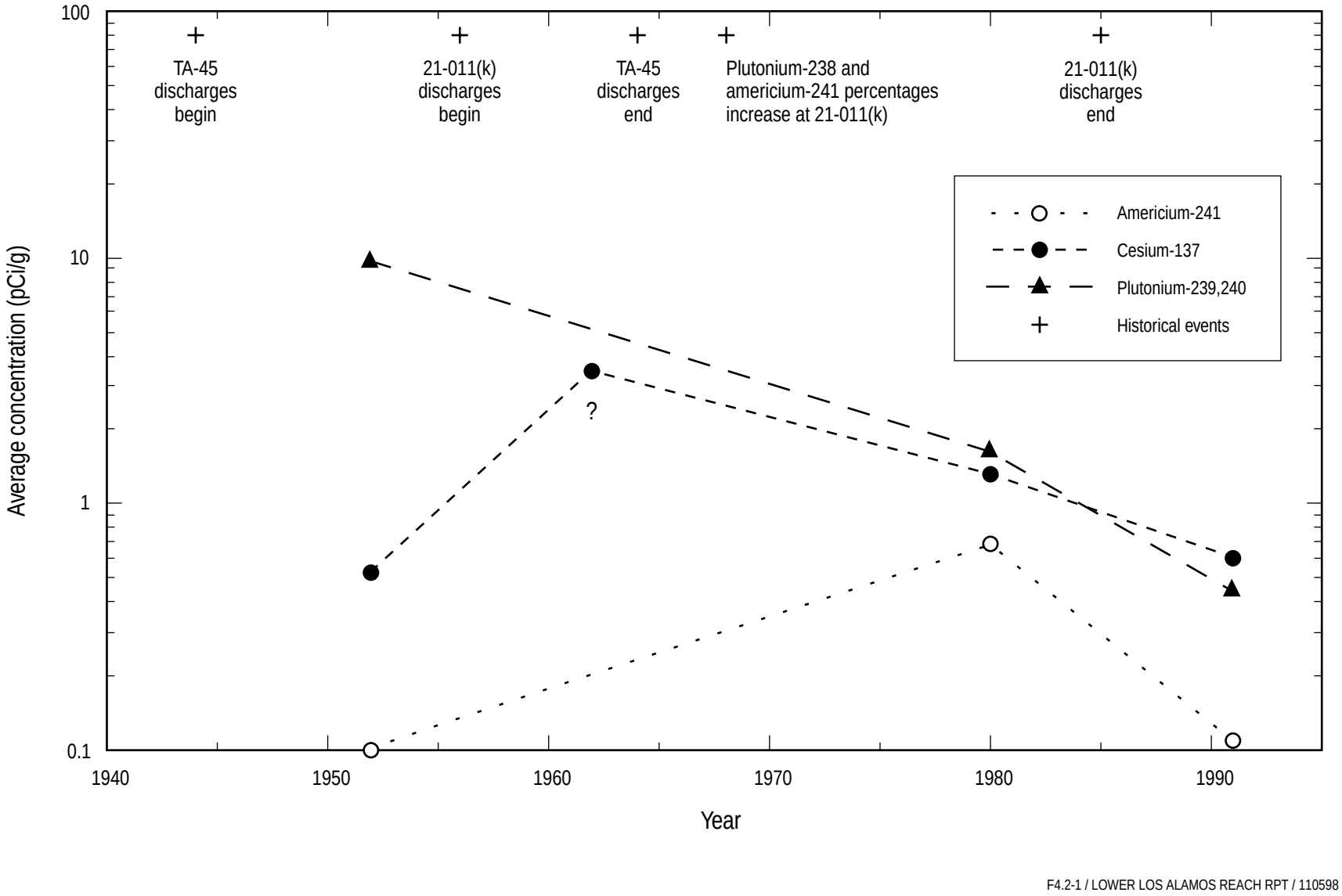


Figure 4.2-1. Estimated variations over time of average radionuclide concentration in overbank sediments in reach LA-4 West.

4.2.3 Spatial Trends

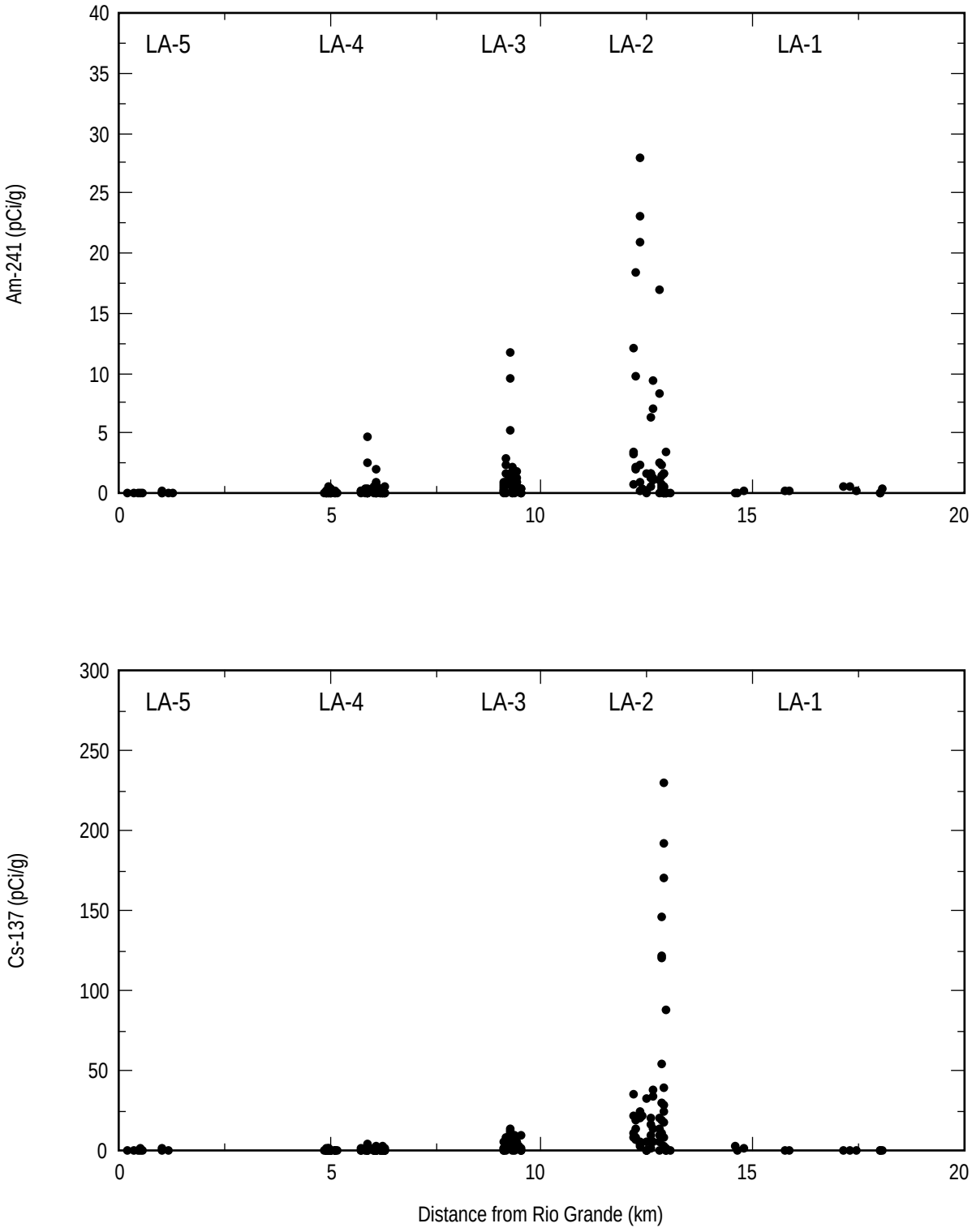
Two key spatial trends in contamination of sediments in the Los Alamos Canyon watershed are an integral part of the conceptual model describing contaminants in these sediments: spatial trends in contaminant concentration and spatial trends in contaminant inventory. Based on the results of prior investigations (e.g., Nyhan et al. 1975, 11746; LANL 1981, 6059; Graf 1996, 55537), it was expected that contaminant concentrations would tend to decrease downstream from the sources (LANL 1995, 50290). This component of the preliminary conceptual model was confirmed in this investigation, as discussed in Section 4.2.3.1, although some revision of the conceptual model was necessary in Pueblo Canyon in this regard because of the occurrence of elevated concentrations of plutonium-239,240 in the lower canyon many kilometers from the source (Reneau et al. 1998, 59159). Previous investigations had also proposed that the largest part of the total plutonium-239,240 inventory in the Los Alamos Canyon watershed was contained within lower Pueblo Canyon (Graf 1996, 55537), and this component of the conceptual model was also confirmed in this investigation. Estimates of the geographic variations in inventories of the other key radionuclides in the Los Alamos Canyon watershed had not been made before this investigation, and the conceptual model has been expanded to include the inventories of americium-241, cesium-137, and strontium-90.

4.2.3.1 Spatial Trends in Radionuclide Concentration

Data collected in this investigation demonstrate clear decreases in the concentrations of key radionuclides in the Los Alamos Canyon watershed with progressive distance from the contaminant sources. Figure 4.2-2 shows all analyses for americium-241, cesium-137, and strontium-90 in the Los Alamos Canyon reaches and all analyses for plutonium-239,240 in the lower Los Alamos Canyon and Pueblo Canyon reaches.

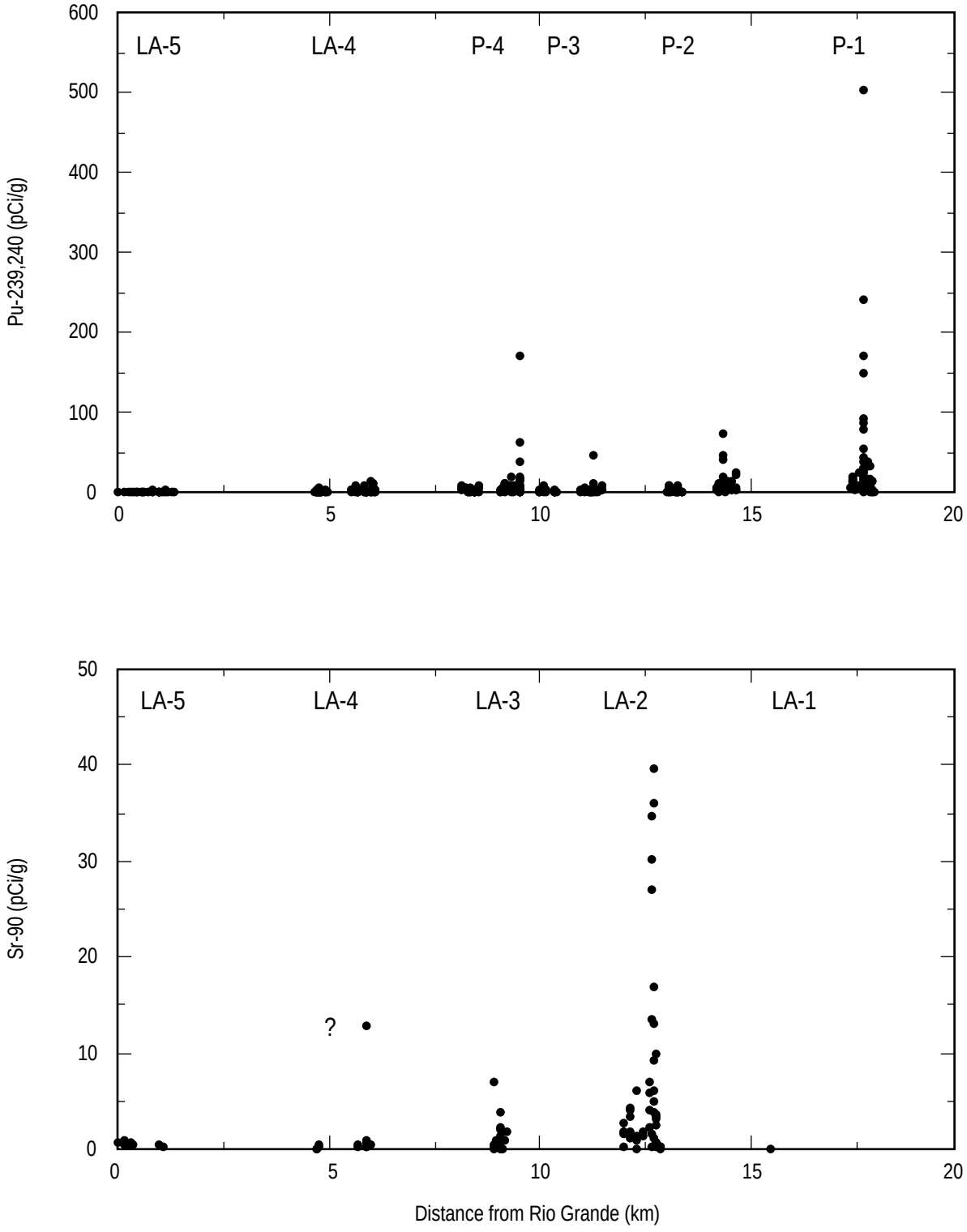
Concentrations of americium-241, cesium-137, and strontium-90 are highest in reach LA-2 East immediately downstream from the confluence of DP Canyon and Los Alamos Canyon, and all decrease to near or below background values in reach LA-5 near the Rio Grande (Figure 4.2-2). The one anomalous strontium-90 analysis from reach LA-4 West, discussed previously, is shown as questioned on Figure 4.2-2b. Concentrations of plutonium-239,240 are highest in reach P-1 East immediately downstream from the confluence with Acid Canyon and decrease to low levels near the Rio Grande. The irregular variation in maximum plutonium-239,240 concentrations in the Pueblo Canyon reaches is due to the irregular geographic distribution of sediment deposits dating to the early post-1942 period, and one unusually high value in reach P-4 is from a very fine-grained sediment layer that probably dates to the early 1950s (Reneau et al. 1998, 59159).

The data shown in Figure 4.2-2 have been used to calculate average concentrations of the key radionuclides within the different sediment facies in each reach to better show spatial trends, as shown in Figure 4.2-3. The average concentrations for lower Los Alamos Canyon are derived from the average values presented in Tables 3.3-3 and 3.3-6 and are weighted by the estimated volume of sediment in each geomorphic unit. The average concentrations in upper Los Alamos Canyon and Pueblo Canyon were derived using the same method (Reneau et al. 1998, 59159; Reneau et al. 1998, 59160).



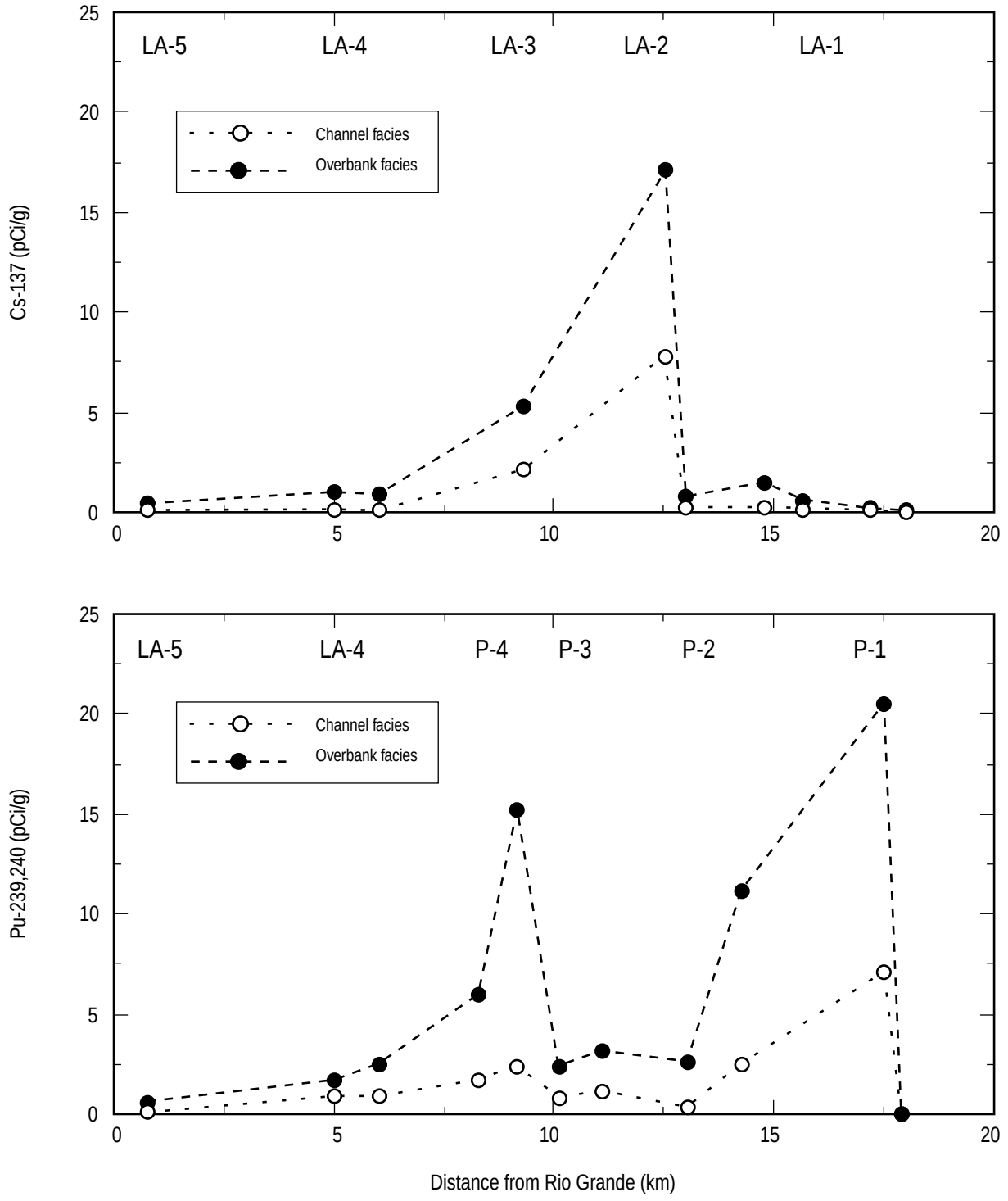
F4.2-2a / LOWER LOS ALAMOS REACH RPT / 101598

Figure 4.2-2a. Concentrations of americium-241 and cesium-137 in sediment samples from the Los Alamos Canyon watershed.



F4.2-2b / LOWER LOS ALAMOS REACH RPT / 101598

Figure 4.2-2b. Concentrations of plutonium -239,240 and strontium-90 in sediment samples from the Los Alamos Canyon watershed.



F4.2-3 / LOWER LOS ALAMOS REACH RPT / 101598

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

Average cesium-137 concentrations are highest in the part of Los Alamos Canyon closest to DP Canyon and the 21-011(k) outfall at TA-21 (reach LA-2 East) and progressively decrease downstream (Figure 4.2-3). Average concentrations are below the background value in both reaches LA-4 and LA-5; in LA-5 the average concentrations are close to the average cesium-137 concentration of 0.21 pCi/g in the background sediment data set (McDonald et al. 1996, 55532). Average americium-241 and strontium-90 concentrations (not shown) follow the same trend as cesium-137. Average plutonium-239,240 concentrations are highest in the part of Pueblo Canyon closest to Acid Canyon and the TA-45 discharge site (reach P-1 East) and generally decrease downstream, although the increase in reach P-4 that is related to relatively old post-1942 sediment deposits is again apparent (Figure 4.2-3).

4.2.3.2 Spatial Trends in Radionuclide Inventory

Data collected in this investigation indicate significant geographic variations in the inventories of the key radionuclides within the Los Alamos Canyon watershed and the relative importance of the different sediment facies as deposition areas for cesium-137 and plutonium-239,240, as indicated in Figure 4.2-4. Cesium-137 and related radionuclides (americium-241 and strontium-90, not shown) have their highest inventories in the part of upper Los Alamos Canyon closest to their source area at TA-21 and lower inventories in downstream reaches. In all reaches the relatively fine-grained overbank facies sediment deposits contain most of the cesium-137. In contrast, plutonium-239,240 has its highest inventory in the lower part of Pueblo Canyon, and most of its inventory in that area is in the relatively coarse-grained channel facies sediment deposits. Upstream in Pueblo Canyon, closer to the source, and also downstream in lower Los Alamos Canyon, most of the estimated plutonium-239,240 inventory is contained within the overbank facies sediments (Figure 4.2-4).

Approximate estimates of the total amount of cesium-137 contained within post-1942 sediment between the westernmost part of former TA-1 and the Rio Grande were made by direct extrapolation between the sampled reaches, assuming either average inventories (in units of mCi/km) of the two bounding reaches or the same concentration in areas close to major confluences (e.g., inventories in reach LA-4 West were assumed to be applicable to the area between LA-4 West and Pueblo Canyon). It should be stressed that these estimates have large but undefined uncertainties related to both the inventories within each sampled reach and extrapolation through the intervening unsampled reaches, but the general geographic variations in inventory are considered to be accurate. The estimated total inventory in lower Los Alamos Canyon is presented in Table 4.2-1, and the estimated inventory in upper Los Alamos Canyon is presented in Section 4 of Reneau et al. (1998, 59160). These estimates are summarized in Table 4.2-2. Of the total estimated cesium-137 inventory of approximately 250 mCi, 72% is within the 5.3 km of Los Alamos Canyon between DP Canyon and Pueblo Canyon, 24% is within the 7.6 km between Pueblo Canyon and the Rio Grande, and the remaining 4% is within the 4.5 km between former TA-1 and DP Canyon.

Note that no estimate of the cesium-137 inventory in DP Canyon is available; therefore, cesium-137 was not included in these estimates, although DP Canyon could contain a significant amount of this radionuclide (in addition to other radionuclides). Incorporation of DP Canyon would increase the percentage of the total cesium-137 inventory within the portion of the Los Alamos Canyon watershed that is on Laboratory land. The cesium-137 inventory in Pueblo Canyon was also not calculated because it is not certain that cesium-137 is significantly elevated above the background value in Pueblo Canyon.

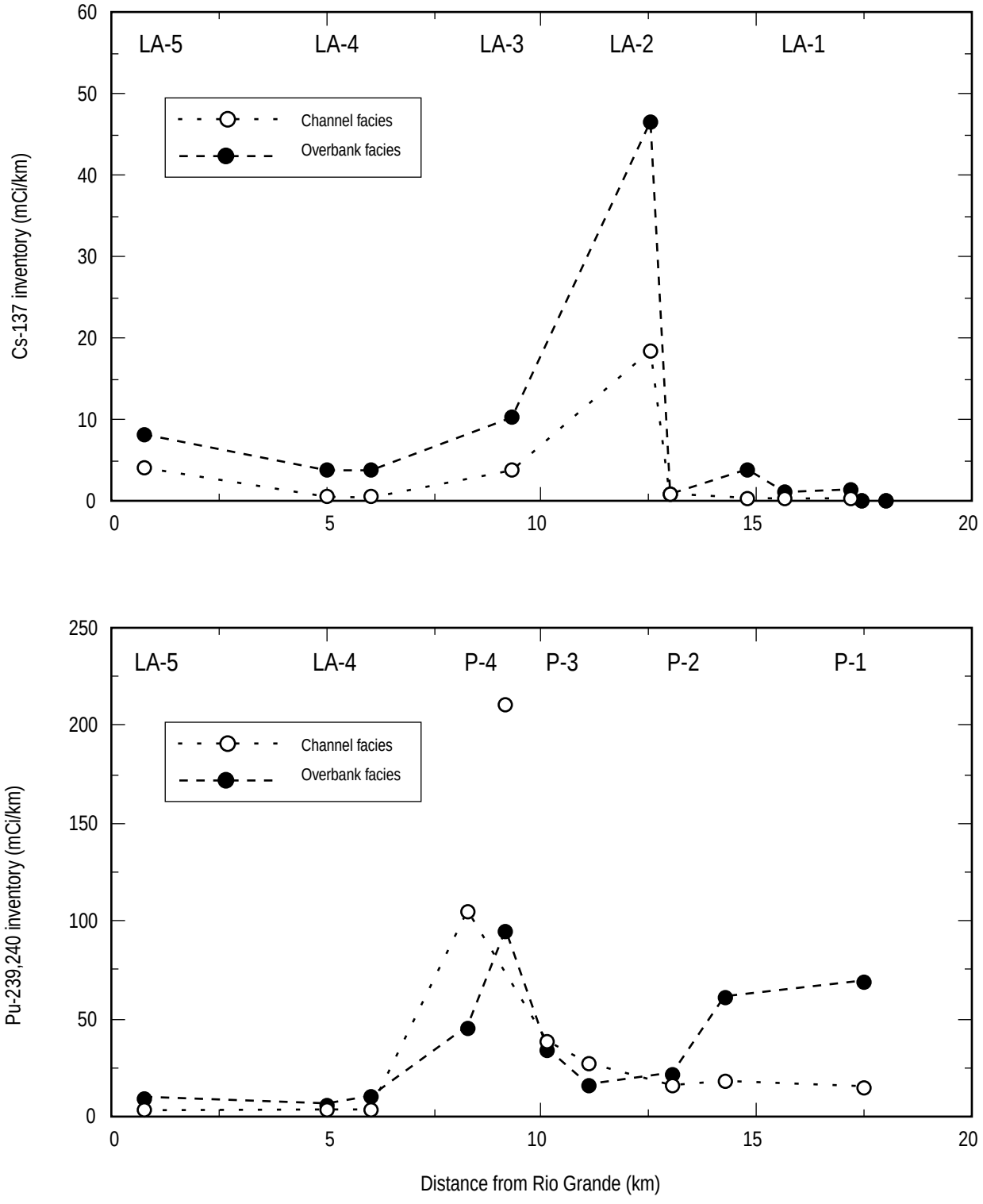


Figure 4.2-4. Variations in the estimated cesium-137 and plutonium-239,240 inventories in post-1942 channel and overbank facies sediment in the Los Alamos Canyon watershed.

TABLE 4.2-2

SUMMARY OF THE CESIUM-137 AND PLUTONIUM-239,240 INVENTORY IN THE LOS ALAMOS CANYON WATERSHED

Area	Estimated Cesium-137 Inventory (mCi)	Percent of Total Cesium-137 Inventory	Estimated Cesium-137 Inventory Susceptible to Remobilization (mCi)	Percent of Total Cesium-137 Inventory Susceptible to Remobilization	Estimated Plutonium-239,240 Inventory (mCi)	Percent of Total Plutonium-239,240 Inventory	Estimated Plutonium-239,240 Inventory Susceptible to Remobilization (mCi)	Percent of Total Plutonium-239,240 Inventory Susceptible to Remobilization
Pueblo Canyon downstream from Acid Canyon	(not calculated)	N/A*	N/A	N/A	1030.7	86%	394.2	33%
Upper Los Alamos Canyon between TA-1 Hillside 137 and DP Canyon	9.8	4%	6.2	3%	47.4	4%	27.5	2%
Upper Los Alamos Canyon between DP Canyon and Pueblo Canyon	176.2	72%	165.6	68%	23.5	2%	22.6	2%
Lower Los Alamos Canyon	57.5	24%	18.5	8%	90.2	8%	56.2	5%
Total	**243.5**	**100%**	**190.3**	**71%**	**1191.8**	**100%**	**500.5**	**42%**

*N/A = not applicable

The relatively large percentage of cesium-137 estimated to be stored in lower Los Alamos Canyon is related to the large volumes of post-1942 sediment in the lower canyon, particularly in reach LA-5, although the average cesium-137 concentration in these sediments is below the background value of 0.9 pCi/g. Using the average cesium-137 concentration from the background sediment data set provides an estimate of the "background cesium-137 inventory" in LA-5 that is indistinguishable from the amount estimated in this investigation (Section 3.3.3.3). Therefore, available data suggest that most of the cesium-137 present in LA-5 is derived from worldwide fallout and not Laboratory discharges.

Approximate estimates of the total amount of plutonium-239,240 within the Los Alamos Canyon watershed downstream from Laboratory sources were made following the same procedure as used for cesium-137. These calculations incorporate the plutonium-239,240 contained within both Pueblo Canyon and upper Los Alamos Canyon because there are sources for this radionuclide in both subbasins, but the calculations do not include plutonium stored within Acid Canyon, DP Canyon, or on the canyon walls between TA-1 outfalls and the stream channel in upper Los Alamos Canyon. The estimated total inventory in lower Los Alamos Canyon is presented in Table 4.2-1, and the estimated inventories in upper Los Alamos Canyon and Pueblo Canyon are presented in Section 4 of the reports on the reaches in these subbasins (Reneau et al. 1998, 59160; Reneau et al. 1998, 59159). Of the total estimated inventory of approximately 1.2 Ci, 86% is within the 10.2 km of Pueblo Canyon downstream from Acid Canyon, 8% is within the 7.6 km of Los Alamos Canyon between Pueblo Canyon and the Rio Grande, and the remaining 6% is within the 9.8 km of Los Alamos Canyon between former TA-1 and Pueblo Canyon (Table 4.2-2).

The estimates of the total plutonium-239,240 inventory in the Los Alamos Canyon watershed calculated in this investigation agree well with those made by Graf (1995, 48851; 1996, 55537), and the total of 1.0 Ci estimated by Graf is very similar to the 1.2 Ci estimated in this investigation using a completely different data set and new mapping. Thus, despite the large uncertainties inherent in such calculations, the total plutonium inventory is reasonably well constrained. One revision that has been made to the previous inventory estimates is in the amount of plutonium contained within sediment in lower Los Alamos Canyon. Graf had estimated that 18% of the total plutonium inventory, or approximately 180 mCi, was within lower Los Alamos Canyon, whereas the data collected in this investigation suggest that only 8% of the total inventory, or approximately 90 mCi, is between Pueblo Canyon and the Rio Grande.

4.3 Fate and Transport of Contaminants

The fate and transport of COPCs in sediments in the Los Alamos Canyon watershed depend on sediment transport processes that will continue to redistribute these COPCs and, for certain radionuclides, on radioactive decay. Plutonium-239,240 and americium-241 both have very long half-lives of 24,000 and 422 years, respectively, and significant decreases in concentration because of radioactive decay will not occur over time scales that are relevant for evaluating risk. Therefore, under natural conditions, sediment transport processes will be the dominant control on the fate of these radionuclides. In contrast, 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 when cesium concentrations were highest have 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.

The following sections discuss important transport processes occurring in the Los Alamos Canyon watershed and the likely effects of these processes on future levels of sediment contamination in lower Los Alamos Canyon. Under natural conditions, future changes in contaminant levels from those documented in this investigation will be primarily 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, relatively soluble contaminants such as strontium-90 will also be transported as part of the dissolved load of surface water and groundwater.

4.3.1 Original Effluent Releases and Resultant Contaminant Distribution

Radionuclide contaminants in sediments in the Los Alamos Canyon watershed were originally supplied largely by effluent releases from two main sources: former TA-45 on the rim of Acid Canyon and the 21-011(k) outfall at TA-21 on the rim of DP Canyon. Discharges from TA-45 directly entered stream channels in the Acid Canyon basin and flowed down the main channel of Acid Canyon into Pueblo Canyon, infiltrating into the stream beds in both basins. Discharges from 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).

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 beds in Acid Canyon, DP Canyon, or Pueblo Canyon would have encountered mainly coarse-grained sediment, and adsorption 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 21-011(k) slope and in the channels. The part of the inventory in the main channels might have been readily remobilized during floods, but the inventory on the 21-011(k) slope might have been more stable initially. However, development of a gully on this slope both caused erosion of some of the contaminated soil and allowed easier transport of effluent from the top of the slope into the DP Canyon channel.

Recent estimates of the plutonium inventory in the Acid Canyon basin suggest it contains only 4% of the total plutonium inventory in the Pueblo Canyon watershed, indicating that most of the plutonium discharged from TA-45 between 1945 and 1964 has been transported into Pueblo Canyon (Graf 1995, 48851; Graf 1996, 55537). Similar estimates have not been made for DP Canyon, and it is uncertain how much of the cesium-137 and associated radionuclides that were discharged from the 21-011(k) outfall between 1956 and 1985 remain either on the colluvial slope below the 21-011(k) outfall or within sediments in DP Canyon close to the outfall.

4.3.2 Effects of Floods

Floods constitute the primary transport process for sediment and associated contaminants in the Los Alamos Canyon watershed, 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. Therefore, floods have strongly affected any human and ecological risk that may be associated with contaminated sediments. Importantly, the present variations in radionuclide concentration in sediments in Los Alamos Canyon and Pueblo Canyon, 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 the 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 includes major tributaries such as Bayo Canyon and Guaje Canyon as well as rills and other small channels on canyon walls.

A large part of the radionuclide inventory transported by floods during the time of the effluent releases from the TA-21 and TA-45 outfalls may have been derived from scouring of the active stream bed in DP Canyon, Acid Canyon, and Pueblo Canyon, although radionuclides would have become depleted from the active stream channels following termination of the effluent releases. After effluent releases ceased, other sediment deposits in the watersheds likely became more important as sources of radionuclides carried by the stream.

The other primary deposition areas for radionuclides that are accessible for transport are sediments in abandoned channel and floodplain units that continuously line the main stream channel in Los Alamos Canyon and Pueblo Canyon downstream from Laboratory release sites. 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 contaminant concentrations. For example, contaminant concentrations in a flood in reach LA-5 would be much lower if the flood waters were derived from the Guaje Canyon basin as opposed to either the upper Los Alamos Canyon basin or the Pueblo Canyon basin.

Since the peak releases of plutonium-239,240 from TA-45 before 1951 and of cesium-137 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 Acid Canyon and DP Canyon from those before 1968 (Section 4.2.2), and future decreases in the concentrations of these radionuclides can be expected. Data from reach LA-4 supports evidence from upstream reaches (Reneau et al. 1998, 59159; Reneau et al. 1998, 59160) in showing decreases in the concentrations of key radionuclides in both relatively coarse-grained channel facies sediment and relatively fine-grained overbank facies sediment.

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 toward or into 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 abandoned channel units along the active channel of Los Alamos Canyon and Pueblo Canyon downstream from the contaminant sources have variable residence times. Based on isotopic ratios in the sediments, sediments in the c2 and c3 units of reach LA-4 have estimated residence times of less than 30 years, which is also inferred for most of the abandoned channel units in upper Los Alamos Canyon and many similar units in Pueblo Canyon. In contrast, the large abandoned channel units in reach LA-5 may have average sediment residence times of greater than 50 years, including the c3 unit, which might have been largely abandoned in the 1950s or earlier. Similar long residence times are inferred for large abandoned channel units in lower Pueblo Canyon that contain the largest part of the total plutonium-239,240 inventory in the Los Alamos Canyon watershed.

4.3.3 Local Redistribution of Contaminants

Local redistribution of contaminants that have been deposited by floods in lower Los Alamos Canyon occurs by several processes. One process that is important in many areas is the mixing of soil by burrowing mammals, which affects contaminant levels over a range of time frames and spatial scales. This burrowing 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, burrowing mammals 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 of contamination that resulted from original deposition of sediment layers with varying radionuclide levels, producing more homogeneous contaminant concentrations in sediments. Where burrowing 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 burrowing 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 burrowing 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, animal burrowing 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.

Wind may have provided a mechanism for at least local redistribution of contaminants within upper Los Alamos Canyon, in addition to being an important part of the exposure pathways included in the risk assessments in Section 5.1. Recently deposited, unvegetated, fine-grained overbank sediment may provide a source for wind-transported sediment with contaminants above background values, as has been documented in other regions (e.g., Lechler et al. 1997, 58475). However, 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 lower Los Alamos Canyon.

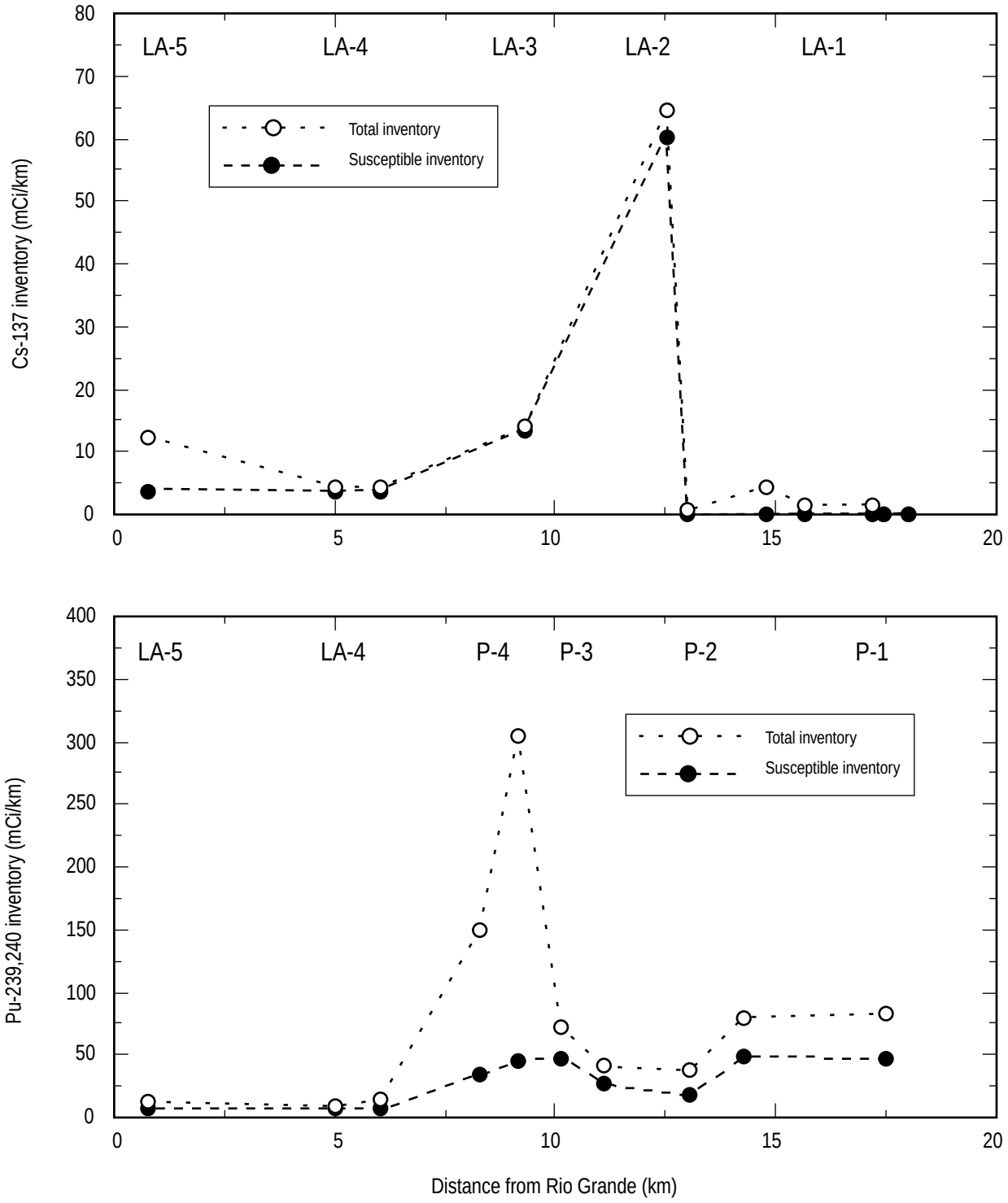
Local redistribution of contaminants deposited by floods may also occur by alluvial groundwater in lower Los Alamos Canyon. Although there are no data from lower Los Alamos Canyon in this regard, evidence for the translocation of plutonium-239,240 from post-1942 sediments into deeper pre-1943 sediment below the stream channel has been found in Pueblo Canyon (Reneau et al. 1998, 59159), and the same process likely occurs in lower Los Alamos Canyon. Plutonium-239,240 and other radionuclides that have adsorbed onto sediment particles or organic colloids could be translocated into deeper alluvium by infiltrating water and then be transported by alluvial groundwater. However, the data from Pueblo Canyon indicate that resulting concentrations at depth are much less than in the surface sediments, and radionuclide concentrations in pre-1943 sediment in lower Los Alamos Canyon are probably very low. The desorption of more soluble contaminants such as strontium-90 can also occur from post-1942 sediments, followed by subsurface transport dissolved within alluvial groundwater, but this process is not expected to be significant in lower Los Alamos Canyon because concentrations of strontium-90 are so low.

4.3.4 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 the Los Alamos Canyon watershed over this temporal scale.

Under natural conditions, future floods will continue to redistribute radionuclides within the Los Alamos Canyon watershed and to transport some of these radionuclides from Laboratory land into lower Los Alamos Canyon and into the Rio Grande. 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 reach LA-4. In these areas average sediment residence times are generally less than 30 years, and remobilization of most of this sediment is considered to be very likely during the next 50 years. Radionuclides stored in other areas such as the large abandoned channel units in reach LA-5 and floodplains are less susceptible to remobilization, and most of the radionuclides in these areas may be stored for periods of 50 to 100 years or longer.

Preliminary evaluations of the susceptibility to remobilization of post-1942 sediment deposits in the Los Alamos Canyon watershed downstream from Laboratory sources (Reneau et al. 1998, 59159; Reneau et al. 1998, 59160; Tables 3.3-3 and 3.3-6 of this report) suggest that approximately 78% of the cesium-137 and 42% of the plutonium-239,240 is susceptible to remobilization during the next 50 years (Tables 4.2-1 and 4.2-2; Figure 4.3-1). The percentages for americium-241 and strontium-90 are similar to those for cesium-137. Cesium-137 and plutonium-239,240 have much different geographic patterns in their inferred susceptibility to remobilization. Most of the cesium-137 is located in geomorphic units close to the active channel where average sediment residence times may be less than 30 years; approximately 90% of the cesium-137 in upper Los Alamos Canyon is in such locations. In contrast, the areas with the largest plutonium-239,240 inventories in Pueblo Canyon are at sites removed from the active channel where average sediment residence times are inferred to exceed 50 years, including both pre-1942 floodplains and large areas of post-1942 channels that were abandoned 30 to 50 years ago and have experienced little erosion since that time.



F4.3-1 / LOWER LOS ALAMOS REACH RPT / 101598

Figure 4.3-1. Variations in the total 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 Los Alamos Canyon watershed.

Although most of the cesium-137 inventory is in geomorphic units very susceptible to remobilization during floods during the next 30 years, the cesium-137 inventory will be naturally reduced by half during this period due to radioactive decay. This reduction in inventory due to radioactive decay applies to strontium-90 as well. Thus, any decision concerning possible remedial actions to reduce the transport of radionuclides should consider the time scales of remobilization and the natural process of radioactive decay in addition to the susceptibility to remobilization and the downstream consequences of this remobilization.

There are significant remaining uncertainties concerning the remobilization of contaminated sediments in the Los Alamos Canyon watershed that prevent a complete assessment of the future impacts on either San Ildefonso Pueblo land or the Rio Grande.

First, the rate that sediment and associated contaminants are transported from either upper Los Alamos Canyon or Pueblo Canyon into lower Los Alamos Canyon is unknown, limiting the ability to make predictions about the redistribution of the radionuclide inventory within the watershed. Specifically, some fraction of the contaminated sediment remobilized in the upper basins in each flood will be redeposited upstream of the confluence of Los Alamos Canyon and Pueblo Canyon, and the average transport distance of specific sediment particles in any flood and the total mass transported past the confluence in any flood are unknown.

Second, the relative rates that sediment and associated contaminants are being supplied to lower Los Alamos Canyon from the upper basins versus the rate that contaminants are being transported from lower Los Alamos Canyon into the Rio Grande are also unknown. Therefore, changes in the contaminant inventory in lower Los Alamos Canyon cannot be quantified. The contrast between the relatively large inventories of plutonium-239,240 in Pueblo Canyon and of cesium-137 in upper Los Alamos Canyon and the much smaller inventories in lower Los Alamos Canyon suggests two hypotheses.

One hypothesis is that the inventory in lower Alamos Canyon is small because most of the radionuclides discharged into the upper basins have remained in storage upstream from the confluence of Pueblo Canyon and Los Alamos Canyon. If correct, then significant increases could occur in the radionuclide inventory of lower Los Alamos Canyon as the upstream inventory is reduced by future remobilization and transport. A second hypothesis is that only a small fraction of the sediments and associated contaminants that are carried into lower Los Alamos Canyon from the upper basins in a typical flood are stored within lower Los Alamos Canyon, with floods in lower Los Alamos Canyon being capable of transporting most sediment directly to the Rio Grande. If this hypothesis is correct, then the radionuclide inventory in lower Los Alamos Canyon may be decreasing because of the remobilization of previously stored contaminants, which are being replaced by sediment with lower radionuclide concentrations.

Neither of these hypotheses can be fully tested at present because there are no reliable estimates of the total amounts of radionuclides originally discharged from the key Laboratory sites or of the radionuclide inventory along the Rio Grande downstream from Los Alamos Canyon. Sediment transport modeling has been used to estimate that an average of approximately 5 mCi/yr of plutonium was transported from Los Alamos Canyon into the Rio Grande between 1948 and 1985 (Lane et al. 1985, 6604; Graf 1994, 55536, p. 149), which, if extrapolated to present, would total approximately 250 mCi or less than 25% of the present plutonium inventory in the Los Alamos Canyon watershed. Although this estimate suggests that most of the plutonium released into the watershed remains upstream of the confluence of Pueblo Canyon and Los Alamos Canyon, the uncertainties in this estimate are not known. Therefore, it is not certain if most of radionuclides released from Laboratory sites remain in the upper basins or have already reached the Rio Grande. In addition, both hypotheses may be correct and help account for the low inventory in

lower Los Alamos Canyon: most of the radionuclides could be stored upstream from the confluence of Pueblo Canyon and Los Alamos Canyon, and most of those transported into lower Los Alamos Canyon could be transported to the Rio Grande.

Although it cannot be proven at present, several lines of evidence support the possibilities that sediment can be efficiently transported through lower Los Alamos Canyon to the Rio Grande and that the radionuclide inventory is not increasing in lower Los Alamos Canyon and may actually be decreasing. The stream channel in reach LA-4 is steeper than in either Los Alamos Canyon or Pueblo Canyon upstream from their confluence (~4% gradient in LA-4 and ~2% gradient in reaches LA-3 and P-4), and, because sediment transport capacity increases with increasing gradient, floods originating in the upper basins may be able to effectively transport sediment through LA-4 and into downstream reaches. The evidence for relatively short residence times for most sediment in LA-4 (<30 years) discussed previously is consistent with the progressive replacement of older sediments having higher radionuclide concentrations with younger sediments having lower concentrations, hence reducing the total inventory in LA-4. A relatively steep gradient (~2%) is also maintained through lower Los Alamos Canyon between Bayo Canyon and the Rio Grande despite the much larger drainage area and the resultant potential for much larger floods than upstream. Coarse dacite gravel derived from erosion of the Puye Formation is common in lower Los Alamos Canyon, and the stream must maintain a relatively steep gradient to transport this coarse sediment, which in turn decreases the opportunity for finer sediment particles to be deposited.

In summary, although the rate that sediment and associated contaminants are being supplied from the upper basins to lower Los Alamos Canyon and the rate that they are being transported into the Rio Grande are unknown, available geomorphic evidence suggests that the radionuclide inventory in lower Los Alamos Canyon is not increasing significantly over time and may actually be decreasing. In addition, evidence discussed earlier also indicates that radionuclide concentrations in sediment carried by floods has been either stable or declining during the past decades and that concentrations will not increase in the future because of the remobilization and transport of sediment from upstream.

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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 lower 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), a construction worker, and a resident. These scenarios are considered to be inclusive of realistic present-day potential exposure activities in lower Los Alamos Canyon. The bases of primary and secondary exposures are the concentrations of contaminants in sediments.

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 can be achieved by combining the results for the residential scenario with the resource user scenario.

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. The residential scenario would be expected to concentrate in an area smaller than a reach. The impacts of smaller areas associated with the residential scenario are considered further in Section 5.1.8. 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 lower Los Alamos Canyon is 13.8 pCi/g. Therefore, the PRG is more than 30 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, which in turn are used to support 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 PRG fractions 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 lower Los Alamos Canyon sediment samples and a selection of the COPCs that warrant further consideration in site management decisions. There are 2 organic chemicals, 11 inorganic chemicals, and 6 radionuclides recommended for further evaluation (Table 5.1-1). A primary focus of the investigation in lower 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 the full-suite analyses obtained during this investigation in reach LA-5 and sediment investigations upstream in upper Los Alamos Canyon and Pueblo Canyon. Additional limited-suite 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
LOWER LOS ALAMOS CANYON MAXIMUM CONTAMINANT VALUES
AND EXPOSURE SCENARIO PRGs

COPC	Lower Los Alamos Canyon Maximum Value[a]	Trail User PRG	Resource User PRG	Construction Worker PRG	Residential PRG
Organic Chemicals					
Aldrin	0.00117	0.074	0.074	0.42	0.01
4,4'-DDT	0.0051	3.7	3.7	21	0.52
Inorganic Chemicals					
Antimony	ND[b][5.3][c]	890	48	77	6.3
Boron	6.8	190000	330	17000	37
Cadmium	ND[0.53][c]	520	6.6	180	0.68
Calcium	7410	d	d	d	d
Copper	10.8	87000	250	7700	62
Lead	31.6	400	400	400	400
Magnesium	1940	d	d	d	d
Potassium	2880	d	d	d	d
Selenium	[0.83][c]	11000	6.7	960	10
Sodium	1530	d	d	d	d
Vanadium	20.6	16000	810	1300	170
Radionuclides					
Americium-241	4.64	420	160	23	14
Cesium-134	0.24	180	43	6.9	2.0
Cesium-137	4.65	510	71	19	5.4
Europium-152	0.408	250	250	9.4	2.9
Plutonium-238	0.227	480	170	26	17
Plutonium-239,240[e]	13.8	440	150	24	15

a. Values for organic and inorganic chemicals are expressed in mg/kg; values for radionuclides are expressed in pCi/g.
b. ND = not detected
c. Maximum nondetected value
d. Essential macronutrient with no PRG
e. PRGs for plutonium-239,240 are calculated using the toxicity value for plutonium-239.

A screening assessment of the 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. None of the COPCs carried forward from Section 3.1 plot to the left of the lines of equality. The residential scenario plot has four points that are close to the line of equality, and the construction scenario plot has one. Two of those points on the residential plot are the maximum nondetected values for antimony and cadmium. Antimony was not detected in any of the lower Los Alamos Canyon samples. Cadmium was detected once in 19 samples at 0.07 mg/kg, which is 10% of the residential PRG. Because of the low frequency of detects and the absence of any detects above background values, these two COPCs are not considered further. The other two points near the line of equality for the residential plot are the maximum values for plutonium-239,240 and cesium-137. The point near the line of equality in the construction scenario plot is due to plutonium-239,240. Cesium-137 was detected in 59 of 87 samples, and plutonium-239,240 was detected in 104 of 110 samples in lower Los Alamos Canyon. These COPCs are assessed further in Section 5.1.6 and 5.1.7.

F5.1-1 / LOWER LOS ALAMOS CANYON REACH RPT / 091498

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

Four inorganic chemicals identified as COPCs in Section 3.1 and shown in Table 5.1-1 are essential macronutrients and are major ions present in blood plasma and intracellular fluid. They are calcium, magnesium, potassium, and sodium. The first three are routinely added to agricultural land to increase crop yields. These elements are dropped as COPCs and will not be considered further in this screening assessment. The macronutrients are not plotted in Figure 5.1-1 because PRG values have not been estimated for them.

None of the COPCs carried forward from the data review in Section 3.1 exceed PRGs. Three radionuclides were pervasively detected in reach LA-4: plutonium-239,240; cesium-137; and americium-241. Two of these radionuclides, plutonium-239,240 and cesium-137, were also widely detected in reach LA-5. An assessment is presented in Sections 5.1.6, 5.1.7, and 5.1.8 for LA-4 and LA-5 to confirm that the summed PRGs for the pervasive radionuclides result in a dose below the limit of 15 mrem/yr across all four exposure scenarios. The information is presented to support comparisons with the assessment results for upper Los Alamos Canyon and Pueblo Canyon (Reneau et al. 1998, 59159; Reneau et al. 1998, 59160).

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. The child and adult exposure durations of 6 and 24 years for the residential scenario were taken from RAGS (EPA 1991, 58234). 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 and represents the reasonable worst-case consumption of homegrown beef.

Professional judgement was used to specify the following parameters:

- 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 for trail use and resource use (10%);
- the proportion of fruits and vegetables from a reach for a resident (100%);
- constant contaminant concentrations over the rooting depth of plants;
- the proportion of meat from a reach for a resident (0%); and
- the average construction time (one year, with eight-hour work days).

The intent of changing the parameters among the scenarios is to provide intrinsic differences in the potential exposures for different land uses. For example, the resource user may either hunt game or graze domestic stock to produce 75% of the meat consumed in this scenario and collect wild fruits and vegetables that make up 10% of the vegetable and fruit component of the diet. In contrast, the resident is assumed to cultivate a garden and fruit trees that provide all of the vegetables and fruit but not graze livestock or hunt game. These differences in the scenarios have the effect of changing the relative contributions of the pathways within each scenario. The resource user scenario is sensitive to the transfer

of contaminants from sediments to plants and from plants to meat animals. The residential scenario is sensitive to plant uptake of contaminants and also to direct ingestion and inhalation of sediments because of the exposure duration and frequency. Building differences into the scenarios in this manner is important for developing a full range of situations under which contaminant concentrations may become a concern.

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 (EPA 1990, 58694). The resource users are assumed to obtain 10% of their fruits and vegetables (5.1 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 lower 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.

5.1.4.4 Residential Scenario

The residential scenario includes exposure factors suggested by EPA (1991, 58234; 1990, 58694). For chemical carcinogens, there is a combination exposure duration of 6 years for child exposure and 24 years for adult exposure. The child and adult ingestion rates for soil are 200 and 100 mg/day, respectively. Both components of the scenario assume an exposure frequency of 350 days per year. The assumptions for noncarcinogens and radionuclides are 24-year exposure times without a separate child component. The resident is assumed to get 100% of fruits (51 kg/yr) and vegetables (73 kg/yr) from plants growing in the contaminated sediments. The exposure times for the child and adult are 24 hours per day. Professional judgment was used to partition the external exposure from radionuclides into 18-hour indoor exposure and 6-hour outdoor exposure. The scenario is considered conservative because

of the consumption of all fruits and vegetables grown on contaminated sediments and the exposure durations and times of 24 years, 24 hours per day. Large parts of the canyon floor are uncontaminated, and it is likely that activities would not be restricted to only the active floodplain areas. In addition, it is likely that some percentage of fruits and vegetables consumed would be obtained elsewhere. 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, and plutonium-239 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 Department of Energy (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”), but these standards are not applicable here because most of lower Los Alamos Canyon is part of San Ildefonso Pueblo, and only a small part is owned by DOE. The PRGs for americium-241; cesium-137; and plutonium-239,240 that result in an exposure 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 four 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. The residential scenario is dependent upon the volume-weighted averages because of the fruit and vegetable pathways. 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 lower Los Alamos Canyon, suggesting that the trail user will be potentially exposed to the volume-weighted concentrations sometime in the future. The results for reaches LA-4 East and LA-4 West show that americium-241; cesium-137; and plutonium-239,240 are present above background values. Cesium-137 and plutonium-239,240 are present above their background values in LA-5. The assessments presented below sum the PRG fractions 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 5.1-4. Each table consists of four 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 is a table of the summed PRGs for each exposure scenario by sediment package. The sediment packages in Part 2 correspond to the sediment packages in the cross section. The third part is a table of surface-weighted and volume-weighted average contaminant concentrations for each of the radionuclides. The fourth 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. For example, the surface-weighted average for Table 5.1-2 consists of the average of the contaminant concentrations for the "c1 ob," "c2 ob," "c3 ob," "f1 ob," "f1b ob," and "f2 ob" sediment packages. These are the surface packages in the cross section. Each package contributes to the weighted sum an amount that is the proportion of the individual package area to the sum of all the package areas. The volume-weighted sum consists of all 11 sediment packages in Table 5.1-2 Part 1, with each package contributing an amount that is the proportion of the individual package volume to the total volume of all the packages. The PRG fractions include the average concentrations for plutonium-239,240 divided by the PRG for plutonium-239 only.

The key information on potential human health risk in each reach is presented in the fourth 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-4 West (Table 5.1-2); none of these values exceed 1.0. The maximum value for the trail user scenario is a surface PRG sum of 0.01, or only 1% of 15 mrem/yr, and the maximum value for a resource user is a surface PRG sum of 0.03. The highest potential risk from contaminants in the sediments of lower Los Alamos Canyon is associated with the residential scenario. The surface PRG sum is 0.36, and the volume PRG sum is 0.21. Because of the conservative assumptions built into this scenario, the actual risk to a resident would likely be less.

The residential scenario is usually applied to smaller areas than the full extent of any of the sampling reaches, and an assessment of a smaller area centered on geomorphic units with the highest contaminant concentrations would indicate a higher potential risk than that calculated from the reach-wide averages. The potential residential exposures at smaller spatial scales were assessed by calculating surface PRG sums for americium-241; cesium-137; and plutonium-239,240 for each of the overbank sediment packages in reach LA-4 West. The smallest sediment package (f2) is 3% of the area containing post-1942 sediment in the sampled reach. The other sediment packages range from 10 to 26% of the sampling area.

TABLE 5.1-2

DOSE CALCULATION RESULTS FOR REACH LA-4 WEST

Part 1. Schematic Cross Section

			f1 ob	f1b ob	f2 ob
c1 ob	c2 ob	c3 ob	f1 ch	f1b ch	
c1 ch	c2 ch	c3 ch			

ch = channel facies
ob = overbank facies

Part 2. Summed PRG Fractions for Plutonium 239, Cesium-137, and Americium-241 by Sediment Unit and Exposure Scenario

Sediment Unit	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)	Resident (fraction)
c1 ch	0.00	0.00	0.00	0.01
c2 ch	0.00	0.00	0.03	0.08
c3 ch	0.00	0.01	0.10	0.18
f1 ch	0.00	0.01	0.06	0.10
f1b ch	0.00	0.01	0.10	0.17
c1 ob	0.00	0.01	0.05	0.15
c2 ob	0.00	0.01	0.05	0.15
c3 ob	0.00	0.03	0.17	0.41
f1 ob	0.01	0.03	0.16	0.34
f1b ob	0.02	0.08	0.44	0.75
f2 ob	0.00	0.01	0.02	0.08

Part 3. Average Reach Concentrations Weighted by Surface Area and Volume of Sediment Units

Reach	Pu-239,240 (pCi/g)	Cs-137 (pCi/g)	Am-241 (pCi/g)
LA-4 West surface aggregate	2.8	0.79	0.21
LA-4 West volume aggregate	1.6	0.50	0.17

Part 4. Summed PRG Fractions Based Upon Surface and Volume Aggregate Concentrations

Reach	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)	Residential (fraction)
LA-4 West surface aggregate	0.01	0.03	0.17	0.36
LA-4 West volume aggregate	<0.00	0.02	0.11	0.21

TABLE 5.1-3

DOSE CALCULATION RESULTS FOR REACH LA-4 EAST

Part 1. Schematic Cross Section

			f1 ob
c1 ob	c2 ob	c3 ob	
c1 ch	c2 ch	c3 ch	

ch = channel facies
ob = overbank facies

Part 2. Summed PRG Fractions for Plutonium 239, Cesium-137, and Americium-241 by Sediment Unit and Exposure Scenario

Sediment Unit	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)	Resident (fraction)
c1 ch	0.00	0.00	0.00	0.01
c2 ch	0.00	0.00	0.03	0.08
c3 ch	0.00	0.01	0.10	0.18
c1 ob	0.00	0.01	0.05	0.15
c2 ob	0.00	0.01	0.05	0.15
c3 ob	0.00	0.03	0.17	0.41
f1 ob	0.01	0.03	0.16	0.34

Part 3. Average Reach Concentrations Weighted by Surface Area and Volume of Sediment Units

Reach	Pu-239,240 (pCi/g)	Cs-137 (pCi/g)	Am-241 (pCi/g)
LA-4 East surface aggregate	1.5	0.87	0.26
LA-4 East volume aggregate	1.3	0.54	0.18

Part 4. Summed PRG Fractions Based Upon Surface and Volume Aggregate Concentrations

Reach	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)	Residential (fraction)
LA-4 East surface aggregate	<0.00	0.02	0.12	0.28
LA-4 East volume aggregate	<0.00	0.02	0.09	0.20

TABLE 5.1-4

DOSE CALCULATION RESULTS FOR REACH LA-5

Part 1. Schematic Cross Section

			f1 ob	f2 ob
	c2 ob	c3 ob		
c1 ch	c2 ch	c3 ch		

ch = channel facies
ob = overbank facies

Part 2. Summed PRG Fractions for Plutonium 239 and Cesium-137 by Sediment Unit and Exposure Scenario

Sediment Unit	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)	Resident (fraction)
c1 ch	0.00	0.00	0.01	0.03
c2 ch	0.00	0.00	0.01	0.03
c3 ch	0.00	0.00	0.01	0.02
c2 ob	0.00	0.01	0.06	0.13
c3 ob	0.00	0.01	0.03	0.09
f1 ob	0.00	0.01	0.06	0.13
f2 ob	0.00	0.01	0.03	0.09

Part 3. Average Reach Concentrations Weighted by Surface Area and Volume of Sediment Units

Reach	Pu-239,240 (pCi/g)	Cs-137 (pCi/g)
LA-5 surface aggregate	0.44	0.47
LA-5 volume aggregate	0.18	0.18

Part 4. Summed PRG Fractions Based Upon Surface and Volume Aggregate Concentrations

Reach	Trail User (fraction)	Resource User (fraction)	Construction Worker (fraction)	Residential (fraction)
LA-5 surface aggregate	<0.00	0.01	0.04	0.12
LA-5 volume aggregate	<0.00	<0.00	0.02	0.04

The results for the residential scenario for reach LA-4 West are presented in Part 2 of Table 5.1-2. The overbank units have surface PRG sum fractions of 0.15 for c1 and c2, 0.41 for c3, 0.34 for f1, 0.75 for f1b, and 0.08 for f2. These PRG sums indicate that potential residential exposures would be highest for the f1b unit where the highest plutonium-239,240 concentrations are found. Potential residential exposures are lower in the c3 unit (0.41) where the highest cesium-137 concentrations are found. The highest PRG sum for a sediment package in reach LA-4 East is 0.41 for c3, which is 25% of the reach area. The reach LA-5 sediment package with the highest PRG sum is 0.13 for c2, which is 14% of that reach's area. Results for all the sediment packages in LA-4 East and LA-5 are located in Part 2 of Tables 5.1-3 and 5.1-4. All of the surface PRG sum fractions for the sediment packages in LA-4 East, LA-4 West, and LA-5 are less than one and therefore below the EPA dose limit of 15 mrem/yr.

In summary, these calculations indicate that the levels of contaminants in the sediments of lower 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.

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 lower 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 lower Los Alamos Canyon, using cesium-137 and plutonium-239,240 results to guide sediment sampling for other COPCs in lower Los Alamos Canyon, estimating area and volume for the sediment packages, and using reach-averaged contaminant concentrations for the residential exposure scenario. However, all of these uncertainties are considered minor and unlikely to affect the conclusion that there is no immediate need for remedial action in regard to contaminated sediment in lower Los Alamos Canyon. 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 interim 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 lower Los Alamos Canyon. Within the sampled reaches, which represent 29% of the total length of lower Los Alamos Canyon downstream from the confluence with Pueblo Canyon, it is considered unlikely that contaminant concentrations in any area greatly exceed those measured at sample sites. In the phased sampling approach used in this investigation, sample site selection in the second sampling event in each reach was guided by the results of the first sampling event and also by results from sediment sampling upstream in upper Los Alamos Canyon and Pueblo Canyon. Sampling density was highest in those areas most likely to have the highest contaminant concentrations (i.e., relatively old post-1942 sediments and fine-grained sediments), and the results of the second sampling event in both reaches confirmed that the primary variations in contaminant concentration between geomorphic units had been identified during the first sampling event. The horizontal and vertical extent of layers with the highest plutonium-239,240 concentration, in the f1b unit of reach LA-4 West, were defined with extensive sampling during the second sampling event. The absence of areas with cesium-137 concentrations significantly higher than that measured is shown by the absence of areas with high gross gamma radiation as measured with field instruments, particularly in reach LA-4 where cesium-137 concentrations are highest. 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 radionuclide concentrations in the unsampled reaches, although these uncertainties are also considered to be minor. The highest concentrations of all radionuclides in lower Los Alamos Canyon were found in reach LA-4 West, and both maximum and average concentrations decrease downstream. This spatial trend was expected from the conceptual model. The existence of higher radionuclide concentrations in small areas in the 0.6 km of canyon between reaches LA-4 West and LA-4 East is possible, but the consistency in analytical data between the two LA-4 subreaches indicates that average concentrations in the sediments upstream from Bayo Canyon are well constrained. It is notable that a nearly continuous gross gamma radiation walkover survey in 1996 along the active channel and adjacent overbank deposits between Basalt Springs in LA-4 West and the Rio Grande failed to locate any areas of elevated radioactivity that would indicate high levels of cesium-137 (Appendix B-4.0). Therefore, available data suggest that there are not areas of elevated radiation between reaches LA-4 and LA-3 with sufficient radionuclide concentration, area, and/or volume to cause exceedances of PRGs.

Uncertainties concerning the use of cesium-137 and plutonium-239,240 analyses to identify sites containing other COPCs are considered minor. The extensive characterization in upper Los Alamos Canyon reaches indicated that the other key radionuclides, americium-241 and strontium-90, were collocated with cesium-137, and analytical results from lower Los Alamos Canyon supported the collocation of cesium-137 and americium-241 and failed to identify strontium-90 as a COPC. The main inorganic COPCs in lower Los Alamos Canyon, copper and lead, are also apparently collocated with cesium-137; therefore, their concentrations are well constrained by the cesium-137 analyses.

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.

An additional uncertainty in this assessment applies to the use of area-weighted concentrations averaged over an entire reach for the residential use scenario. The residential scenario is usually applied to smaller areas than the full extent of any of the sampling reaches, and an assessment of a smaller area centered on geomorphic units with the highest contaminant concentrations would indicate a higher potential risk than that calculated from the reach-wide averages. If the maximum values for the pervasive radionuclides were collocated, their summed PRGs would exceed one, although summing these PRGs is not appropriate because the key radionuclides are not collocated. The averages for the radionuclides in each of the overbank sediment packages were used to assess the PRG sums at a smaller scale. All the

sediment package PRG sums were 0.75 or less, indicating that analyzing the data at a smaller scale, and summing across radionuclides, still supports the conclusion that immediate action is not warranted in lower Los Alamos Canyon. This assessment is conservative for the reasons discussed in Section 5.1.4, including the assumption in the plant ingestion pathway that contaminant concentrations are constant for the full depth of rooting, although plants can root to 1 m or more, and the highest concentrations are always found in layers less than 1 m thick. Consequently, the residential scenario is sufficiently conservative that, based on the data in this report, immediate action to mitigate human health risk in lower Los Alamos Canyon is not warranted.

5.2 Ecological Screening Assessment

The ecological screening assessment as presented in Kelly et al. (1998, 57916) and followed in this report has two phases: 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 lower 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 interim 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 lower 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 lower 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 lower 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 uncertainty associated with the sediment sample data is the lack of semivolatile organic compound (SVOC) analyses from reach LA-4.

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 lower Los Alamos Canyon, where the dominant plants include piñon pine, juniper, chamisa, apache plume, forbs, and grasses. Some areas of lower Los Alamos Canyon also have riparian plants (e.g., cottonwood). Many areas, especially noted in parts of reach LA-5, 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-4 is the only area included in this report that has perennial surface water flow and aquatic ecological receptors. The surface water in LA-4 originates primarily from springs (notably Basalt Spring). Snow melt runoff and storm water runoff are other sources of ephemeral water in lower Los Alamos Canyon. Physical disturbance is minimal throughout most of lower Los Alamos Canyon except along roads such as state road NM 502 and in areas near the Rio Grande where the channel has been confined within engineered levees. Some physical disturbance from cattle grazing is apparent in parts of LA-4 and LA-5. The localized disturbed areas were noted to have early successional plant species (grasses and forbs).

Threatened and endangered (T&E) species are potential receptors for contaminants in lower Los Alamos Canyon sediments. Specifically, the Mexican spotted owl, the peregrine falcon, and the bald eagle may forage in lower Los Alamos Canyon (Koch 1998, 59114). 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 lower Los Alamos Canyon sediments and to represent west-to-east geographic variations in the size of contaminated geomorphic units. For this preliminary ecological risk assessment, maximum COPC values from both reaches and all geomorphic units are compared with terrestrial ecological screening levels (ESLs). Future screening-level ecological risk assessments will evaluate sediment sample data in relation to exposure to appropriate receptors, which will include both aquatic and terrestrial species.

Historical contaminants from the Laboratory that have affected the sediments in lower Los Alamos Canyon are mainly derived from various sources in either upper Los Alamos Canyon or Pueblo Canyon. There are also sources of contamination in Bayo Canyon and Rendija Canyon. Rendija Canyon drains

into Guaje Canyon, which then flows into lower Los Alamos Canyon. Both Bayo Canyon and Guaje Canyon enter lower Los Alamos Canyon between reaches LA-4 and LA-5 (Figure 1.1-2).

For the lower Los Alamos Canyon investigation, the primary impacted media are (1) surface soil in the canyon floodplain (f1, f1b, and f2 geomorphic units); (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.

The most important transport mechanism for contaminants in channel and floodplain units is lateral and vertical erosion of post-1942 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 and incidental ingestion of contaminated sediment/water. However, the importance of the sediment/water pathways is questionable because of the limited extent of active channel sediments and surface water along the entire length of lower Los Alamos Canyon. Exposure to vapors is not a complete pathway because of the lack of volatile contaminants. External gamma radiation exposure to either soil, sediment, or surface water is expected to be a minor pathway because of the relatively low concentrations of gamma-emitting radionuclides (primarily cesium-137, which is present at up to five times the background value in reach LA-4 West). 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 is the dominant contaminant (e.g., c3 geomorphic unit in LA-4) compared with areas where plutonium-239,240 is the dominant contaminant (e.g., f1b unit in LA-4 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).

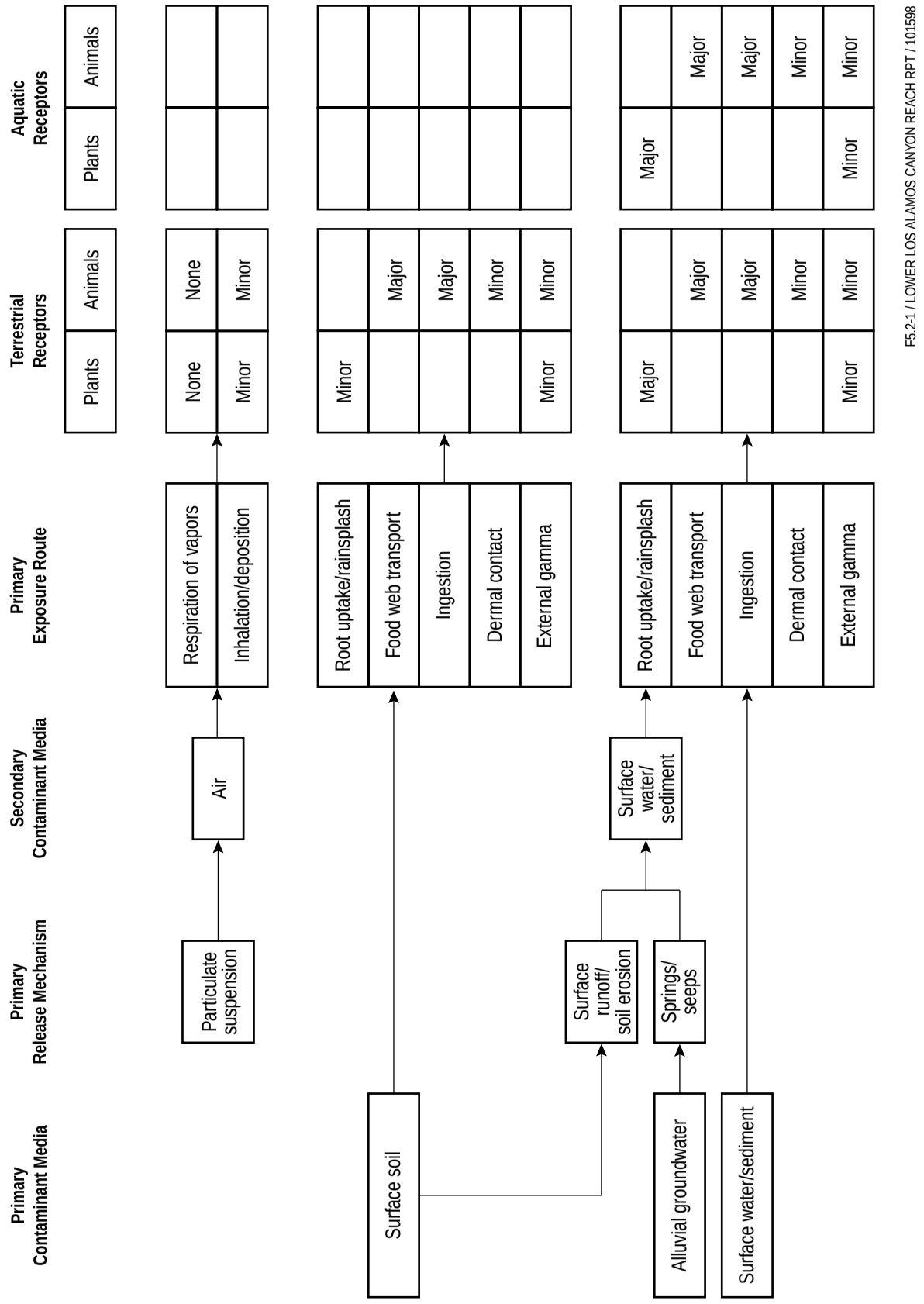

Figure 5.2-1. Conceptual site model of ecological receptors.

5.2.1.3 Bioaccumulator Evaluation

Several analytes detected above background values in the lower 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.

TABLE 5.2-1

COPCs FOR THE ECOLOGICAL SCREENING EVALUATION

Analyte Group	Analytes
Inorganic chemicals	Antimony, boron, cadmium*, calcium, copper*, lead*, magnesium, potassium, selenium*, sodium, vanadium
Radionuclides	Americium-241*; cesium-134; cesium-137*; europium-152; plutonium-238*; plutonium-239,240*
Pesticides	Aldrin, 4,4'-DDT*
*Potential persistent bioaccumulator as defined by the New Mexico Environment Department	

5.2.2 Screening Evaluation

The formal, quantitative screening evaluation will be made after 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 ecological risk uncertainties.

As discussed in Section 5.2.1.2, the kestrel, with a flesh diet, is used as a surrogate for the avian T&E species. Because the kestrel does not have the lowest ESL for any of these COPCs, no clear potential risk to avian T&E species is identified.

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 lower Los Alamos Canyon COPC and the corresponding minimum terrestrial ESL. Five inorganic COPCs have no terrestrial ESLs: boron, calcium, magnesium, potassium, and sodium. Calcium, magnesium, and potassium are essential macronutrients and are routinely added to agricultural land to increase crop yield. Thus, the lack of ESLs for calcium, magnesium, and potassium is not viewed to impact this preliminary assessment. However, further ecological screening assessments should determine if any ecotoxicological data exist for boron and sodium, and ESLs should be calculated for these COPCs if such data are identified. The data in Table 5.2-2 are presented graphically in Figure 5.2-2, where the x-axis plots the maximum value for each COPC in lower Los Alamos Canyon and the y-axis plots the minimum terrestrial ESL[1]. The y-axis

[1] This 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).

represents a conservative estimate of the exposure point concentrations for ecological receptors, and 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 lower Los Alamos Canyon. The three COPECs that represent the highest potential risk to terrestrial ecological receptors, listed in order of HQ, are vanadium, antimony, and dichloro diphenyl trichloroethane (DDT). The qualitative uncertainty analysis and interpretation sections of the screening-level ecological risk assessment will focus on these three COPECs.

TABLE 5.2-2

LIST OF MAXIMUM DETECTED COPC CONCENTRATIONS AND ECOLOGICAL SCREENING LEVELS

Analyte	Maximum Detected Sample Result (mg/kg)	Minimum ESL (mg/kg)	Screening Receptor with Minimum ESL[a]
Inorganic Chemicals			
Antimony	5.3[b]	1.0	Mouse
Boron	6.8	N.A.[c]	N.A.
Cadmium	0.07	3.0	Plant
Calcium	7410	N.A.	N.A.
Copper	10.8	50	Invert
Lead	31.6	50	Plant
Magnesium	1940	N.A.	N.A.
Potassium	2880	N.A.	N.A.
Selenium	0.4	0.85	Robin
Sodium	1530	N.A.	N.A.
Vanadium	20.6	1.9	Shrew
Organic Chemicals			
Aldrin	0.00117	0.14	Robin
4,4'-DDT	0.0051	0.0021	Robin
Radionuclides[d]			
Americium-241	4.62	47	Robin
Cesium-134	0.24	16	Robin
Cesium-137	4.65	42	Robin
Europium-152	0.408	3.5	Robin
Plutonium-238	0.227	31	Robin
Plutonium-239	13.8	33	Robin

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

b. Antimony result is *not* a detect.

c. N.A. = not available

d. Radionuclides have units of pCi/g.

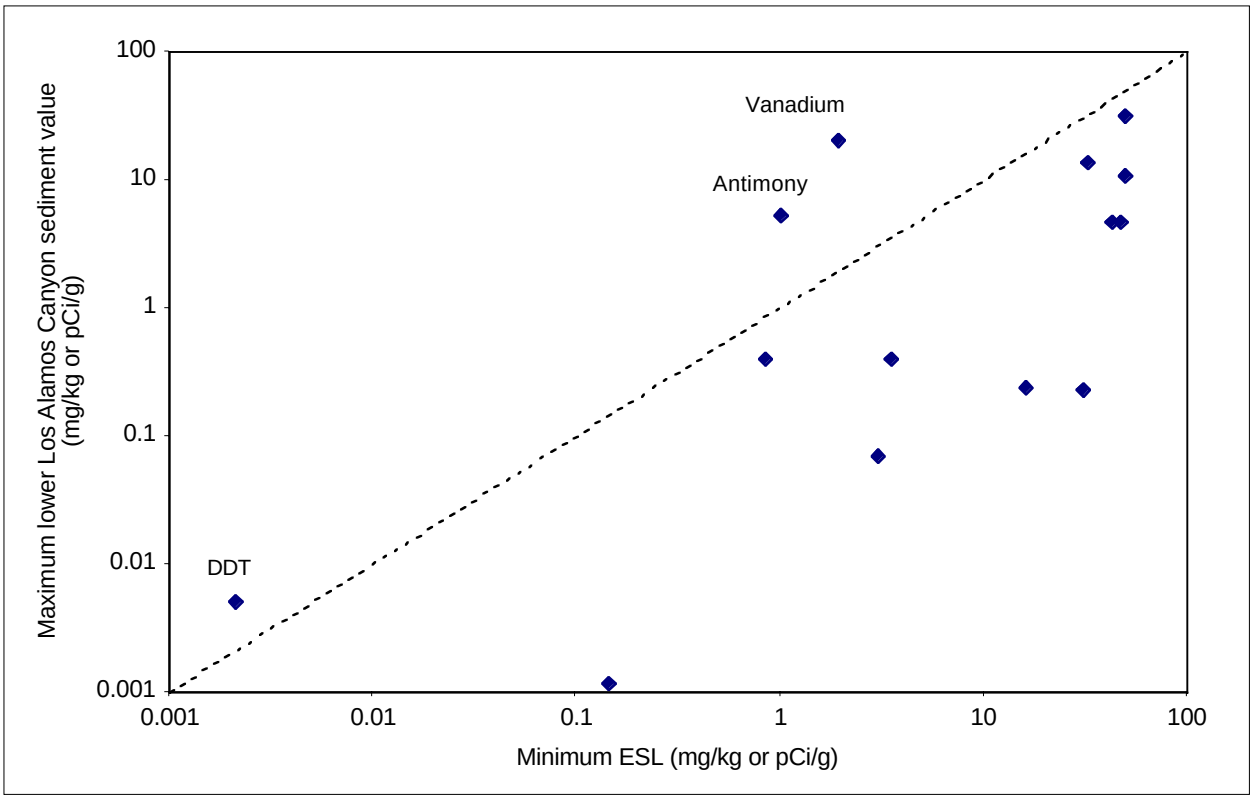

Figure 5.2-2. Preliminary comparison of the relative hazard posed by lower Los Alamos Canyon COPCs to terrestrial ecological receptors.

5.2.2.1 Uncertainty Analysis

This qualitative uncertainty analysis will consider the three COPECs identified in the qualitative screening evaluation section. These COPECs include two inorganic chemicals and one organic chemical. One of these chemicals is also considered a potentially persistent bioaccumulator. Each of these COPECs is briefly discussed below.

Antimony. Antimony was not detected in the lower Los Alamos Canyon sediment samples, and it is retained for data assessment only because some detection limits were greater than the background value. Note that antimony sample results for reach LA-5 were rejected because of a serious quality control (QC) deficiency (Section 3.1). However, detection limits were not elevated in 5 of 12 antimony analyses from reach LA-4, and antimony is below the background value in these samples. Antimony was also not detected in any sediment sample collected in the upper Los Alamos Canyon or Pueblo Canyon reaches. Antimony was also not reported as a COPC in investigations in either Bayo Canyon or Rendija Canyon upstream from LA-5. This evidence indicates 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 should be adequate for evaluating potential for exposure for ecological receptors.

Vanadium. Vanadium was greater than the background value in one sample collected in reach LA-5, but the maximum vanadium sample result is only 5% greater than the background value. The small difference of vanadium sample results from background suggests either small releases or no release of vanadium

into the Los Alamos Canyon watershed. The high HQ for vanadium is inferred for two reasons. First, the ESL for vanadium is based on the more soluble and more bioavailable form of vanadium, vanadyl sulfate. However, vanadyl sulfate is not likely to be present in this environment because vanadium is more likely to occur as an oxide. Second, the level with no observed adverse effects on avian receptors is inferred from the highest dose administered in a toxicity experiment. Thus, even higher doses of this vanadyl sulfate could also be associated with no ecological effects. This information suggests that vanadium is not likely to be associated with ecological risk at the concentrations measured in lower Los Alamos Canyon, and no additional data should be needed for this COPEC.

DDT. DDT was detected in 1 of 14 samples collected in lower Los Alamos Canyon, in reach LA-4. DDT concentrations do not exhibit positive correlations with either plutonium-239,240 or cesium-137, and the source for the DDT is unknown. DDT has known ecological effects (especially for birds) and is a potentially persistent bioaccumulator. Because lower Los Alamos Canyon is potential foraging habitat for avian T&E species (medium probability for the peregrine falcon and low foraging likelihood for the bald eagle and the Mexican spotted owl [Koch 1998, 59114]), uncertainties in the contaminant source and exposure concentration should be reduced. The amount of bioaccumulation of DDT could be addressed through literature searches of existing data sources. Because the detected DDT sample result is within the range of nondetected sample results, it would not appear that additional sediment sample collection would help address uncertainty in exposure to avian T&E species.

5.2.2.2 Interpretation

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

Uncertainties in potential ecological risk should be addressed through literature searches of existing data sources to help estimate bioaccumulation of DDT in the lower Los Alamos Canyon food web. Additional data collection may be needed for DDT if a significant potential for risk is indicated by further assessments that address risk to aquatic and terrestrial receptors from all relevant pathways. There is some uncertainty in the maximum value and representative concentrations of SVOCs because no SVOC analyses were obtained from reach LA-4. There is also some uncertainty regarding antimony concentrations because of the lack of antimony data from reach LA-5. However, neither of these last two uncertainties would drive additional data collection.

Another obvious data gap in lower Los Alamos Canyon is analytical results on surface water in reach LA-4. Surface water data would be useful for developing a comprehensive ecological risk assessment of lower Los Alamos Canyon. A screening-level ecological risk assessment should be completed after this data gap is 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 lower 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 risk. These preliminary assessments consider only present-day land use scenarios and the potential risk presented by contaminated sediments. More comprehensive risk assessments will be presented in one or more future reports on Los Alamos Canyon and Pueblo 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 lower Los Alamos Canyon are radionuclides that were mainly discharged either from the 21-011(k) outfall at Technical Area (TA) -21 into DP Canyon, a tributary of upper Los Alamos Canyon, or from former TA-45 into Acid Canyon, a tributary of Pueblo Canyon. Radioactive effluent was discharged from TA-45 between 1944 and 1964 and from the 21-011(k) outfall between 1956 and 1985. The most significant radionuclides in terms of potential human health risk are cesium-137, originating at the 21-011(k) outfall, and plutonium-239,240, mostly originating at TA-45. Two other radionuclides, americium-241 and plutonium-238, are also detected above background values in lower Los Alamos Canyon and in both upper Los Alamos Canyon and Pueblo Canyon. The 21-011(k) outfall was the primary source for americium-241 in the Los Alamos Canyon watershed, and both the 21-011(k) outfall and TA-45 were apparently important sources for plutonium-238. The remaining two radionuclide COPCs in lower Los Alamos Canyon, cesium-134 and europium-152, have been detected only at low levels and may not represent Laboratory releases.

Eleven inorganic chemicals were identified as COPCs in lower Los Alamos Canyon during this investigation, but only two (copper and lead) can be clearly associated with contaminants in upstream reaches. Both copper and lead are apparently collocated with cesium-137, suggesting a primary source in the upper Los Alamos Canyon watershed, although specific sources in the watershed are not clearly identified. Three inorganic COPCs (antimony, cadmium, and selenium) were also identified as COPCs in upstream reaches but have very low detection frequencies. The remaining six inorganic COPCs (boron, calcium, magnesium, potassium, sodium, and vanadium) were not identified as COPCs in upstream reaches, and the elevated results in lower Los Alamos Canyon probably represent natural background levels associated with geologic units that are not present upstream.

Two organic chemicals (aldrin and dichloro diphenyl trichloroethane [DDT]) were identified as COPCs in this investigation based on their detection at low levels in single sediment samples from lower Los Alamos Canyon. Aldrin was also identified as a COPC in Pueblo Canyon based on three detects, although there is no evidence of significant releases of aldrin from Laboratory activities. DDT was identified as a COPC in both Pueblo Canyon and upper Los Alamos Canyon, with the highest values and the highest frequency of detects in upper Los Alamos Canyon, but DDT has not been traced to specific Laboratory sites in the Los Alamos Canyon watershed.

6.2 Present Distribution of Contaminants

Radionuclide COPCs and other contaminants within lower 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 lower Los Alamos Canyon, a distance of more than 18 km from the original source areas. The part of the canyon floor containing radionuclides above background values ranges in width from an average of 16 to 18 m in reach LA-4 to 150 m in reach LA-5 near the Rio Grande. The maximum horizontal extent of contaminated sediments is well defined in the reaches selected for investigation, although radionuclides are close to background values over much of this area in LA-5. The vertical extent of the relatively fine-grained overbank sediments with the highest concentrations of radionuclides is also generally well constrained, ranging in thickness from less than 5 cm to approximately 1 m. If required, the extent of contaminated sediments in unsampled reaches in lower Los Alamos Canyon could be estimated by extending the geomorphic mapping units between the sampled reaches.

Concentrations of the primary radionuclide COPCs in post-1942 sediment deposits show substantial variability both within reaches and between reaches, having a range of up to two orders of magnitude in reach LA-4 for plutonium-239,240. The highest concentrations of americium-241; cesium-137; and plutonium-239,240 were found in relatively old fine-grained sediments in reach LA-4 West, and lower concentrations occur in younger sediments, coarser-grained sediments, and sediments farther downstream.

Two inorganic COPCs (copper and lead) are apparently collocated with cesium-137, and their distribution can be estimated using data on cesium-137. The other inorganic and organic COPCs are not collocated with the key radionuclides; thus, their distributions are uncertain. However, these analytes either have a very low frequency of detection or are probably present only at background levels, and understanding their distribution is not needed for evaluating present-day risk.

6.3 Potential Human Health Risk

The preliminary human health risk assessment presented in Section 5.1 evaluated the radiation dose that could be received by trail users, resource users, construction workers, and residents in lower Los Alamos Canyon under present-day conditions of contamination and land use. The combined doses derived from americium-241; cesium-137; and plutonium-239,240 in sediments were evaluated in this report. These COPCs were chosen because they are widely distributed in the sediments of lower Los Alamos Canyon at levels above background values and were shown to be the main contributors to potential human health risk upstream in either Pueblo Canyon or upper Los Alamos Canyon. The assessment indicated that nowhere in the lower 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. In addition, a screening assessment using maximum values for each COPC, including organic and inorganic chemicals as well as radionuclides, also showed that no COPC exceeded its PRG for any land use scenario (Table 5.1-1). Therefore, the results of this investigation indicate no immediate risk to human health resulting from the levels of contamination in lower Los Alamos Canyon sediments and no need for immediate remedial action in the context of human health risk.

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 lower Los

Alamos Canyon by the Environmental Restoration Project for use in these future assessments. It is also planned that future risk assessments will incorporate an American Indian land use scenario after exposure parameters for this scenario become available.

6.4 Potential Ecological Risk

Potential ecological risk is incompletely defined in lower 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 lower 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 lower Los Alamos Canyon and made no attempt to estimate average concentrations or to evaluate risk on a reach basis or a watershed basis. 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 lower 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 three COPECs within the sediments of lower Los Alamos Canyon: antimony, vanadium, and DDT. None of these COPECs has been traced to specific Laboratory sources, although one, DDT, was commonly detected in sediments in upper Los Alamos Canyon. Because DDT has known effects on birds and because threatened and endangered raptor species may forage within lower Los Alamos Canyon, DDT is considered to be an important COPEC as identified in this preliminary ecological risk assessment. Further assessment of the ecological risk posed by DDT in the Los Alamos Canyon watershed is warranted because of its frequent detection in sediment samples. The highest potential risk is associated with vanadium, although the screening assessment assumed that all the vanadium is in its most toxic form (vanadyl sulfate). More realistic assessment of the ecological risk posed by vanadium would require data on its actual chemical form. However, because vanadium was not identified as a COPEC in upstream reaches, it is unlikely that it has a source at Laboratory sites in either upper Los Alamos Canyon or Pueblo Canyon. In addition, the maximum vanadium detect is only 5% greater than the background value. The remaining COPEC, antimony, was not detected in any sediment sample in the Los Alamos Canyon watershed, and there is no evidence that it was released from any Laboratory site.

The main data need identified by the terrestrial ecological risk assessment is collection of data from surface water to evaluate this potentially important exposure pathway. Another data need is information on the potential toxicity and bioaccumulation for the COPECs identified by the screening assessment, which can be pursued through additional literature reviews. Finally, analyses of sediment samples in reach LA-4 for semivolatile organic compounds (SVOCs) may be needed for future ecological risk assessments in lower Los Alamos Canyon.

6.5 Future Remobilization and Transport of Contaminated Sediments

Floods constitute the primary transport mechanism for contaminants in the Los Alamos Canyon watershed 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 all radionuclide COPCs transported by floods over time. In Pueblo Canyon, plutonium-239,240 concentrations in sediment transported during floods were highest during the period of releases of radioactive effluent from TA-45, between 1945 and 1964. In upper Los Alamos Canyon, cesium-137 concentrations were highest during the early period of releases from the 21-011(k) outfall at TA-21, between 1956 and 1968. Radionuclide concentrations in sediment carried by floods in both canyons dropped rapidly after these periods, and sediment analyses from reach LA-4 also indicate a decrease in radionuclide concentrations over time. Therefore, concentrations can be expected to remain stable or to decline during the next several decades. Remedial actions upstream to reduce radionuclide concentrations in sediment transported during floods will be necessary only if it is determined that present-day concentrations pose a significant human health or ecological risk or are otherwise unacceptable.

Most of the radionuclide inventory in sediments in the Los Alamos Canyon watershed is in Pueblo Canyon and upper Los Alamos Canyon, and a relatively small percent of the inventory is in lower Los Alamos Canyon. The potential for remobilization of the radionuclide COPCs upstream from lower Los Alamos Canyon varies between the two major subbasins. In Pueblo Canyon, most of the plutonium-239,240 is located within geomorphic units that are presently isolated from the active channel and that are not considered to be susceptible to remobilization by vertical channel incision or lateral bank erosion during the next 50 years. In addition, it is expected that some of the remobilized plutonium will be redeposited in relatively stable geomorphic settings within Pueblo Canyon and thus will not reach Los Alamos Canyon or the Rio Grande during the next 50 years. In contrast, in upper Los Alamos Canyon most of the radionuclide COPCs are located in geomorphic units that are adjacent to the active channel and are considered very susceptible to remobilization by lateral bank erosion during the next 30 to 50 years. Therefore, a larger part of the radionuclide inventory in upper Los Alamos Canyon can be expected to be transported into lower Los Alamos Canyon during this time period. However, it is significant that the main radionuclide COPC in upper Los Alamos Canyon, cesium-137, has a relatively short half-life of 30 years, and significant reductions in inventory will occur by radioactive decay during this time frame.

The size of the radionuclide inventory in lower Los Alamos Canyon depends both on sediment transport rates from the upstream subbasins and on transport rates into the Rio Grande, and this inventory can change over time because of erosion and deposition of sediment during floods. Although sediment transport rates in the Los Alamos Canyon watershed are poorly understood, available evidence on post-1942 sediment deposits in lower Los Alamos Canyon suggests that radionuclide inventories are not increasing significantly over time and may instead be decreasing. This inference is based on the evidence discussed previously that radionuclide concentrations have been decreasing over time and that sediment residence times are relatively short (<30 years) in many geomorphic units, particularly in reach LA-4 where radionuclide concentrations are highest. One main effect of floods is to remobilize some of the older sediments along the stream channel and to deposit younger sediments that have lower radionuclide concentrations. Because there is no evidence that the stream in lower Los Alamos Canyon is currently aggrading through net sediment deposition, it is inferred that sediment transport rates into each reach are no greater than sediment transport rates out of the reach, hence preventing significant increases in the volume of post-1942 sediment. Therefore, remedial actions upstream are not required at present to prevent an increase in the inventory of radionuclides in lower Los Alamos Canyon.

The largest uncertainty concerning the transport of contaminated sediments in the Los Alamos Canyon watershed is the actual sediment transport rate, both the transport rate into lower Los Alamos Canyon

from upstream subbasins and the transport rate into the Rio Grande. Therefore, it is not possible at present to reliably quantify the rate that the radionuclide inventory in Pueblo Canyon and upper Los Alamos Canyon has been or will be carried into the Rio Grande. Specifically, it is not certain if most of the radionuclides released by the Laboratory since 1943 remain within the Los Alamos Canyon watershed or have already reached the Rio Grande. If it is foreseen that decisions on future remedial actions will be based in part on rates of sediment transport, then collection of data on sediment transport rates during floods should be pursued. Ideally, such data should be used to validate a model of sediment transport that could both quantify the redistribution of contaminated sediments within the watershed and evaluate the effects of a range of possible remedial actions.

6.6 Summary of Recommendations

The assessments of potential human health and ecological risk presented in this report indicate that levels of contamination in the sediments of lower 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 either in lower Los Alamos Canyon or in upstream areas, 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 some additional sampling and analysis will be required to support these assessments. In particular, water quality data will be required for both human health and ecological risk assessments, and continued collection of sufficient data to perform risk assessments is considered a priority. Collection of additional sediment samples in lower Los Alamos Canyon may also be needed to evaluate the concentrations of SVOCs because there is currently a gap in data coverage, and potential contributions from upper Los Alamos Canyon are not understood.

Decision points concerning the transport of contaminants from upper Los Alamos Canyon and Pueblo Canyon into lower Los Alamos Canyon and the Rio Grande are not yet 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. Decisions concerning the possible need for remedial action in this context will depend on the development of specific decision criteria. If it is necessary to make reliable quantitative predictions concerning transport rates into lower Los Alamos Canyon and the Rio Grande, data on transport rates during floods should be collected and used to validate a sediment transport model that could also evaluate the effects of a variety of possible remedial actions.

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APPENDIX A LIST OF ACRONYMS AND UNIT CONVERSIONS

A-1.0 LIST OF ACRONYMS

ASTM	American Society for Testing and Materials
BKG	background data
BV	background value
CCV	continuous calibration verification
CMS	corrective measures study
COPC	chemical of potential concern
COPEC	contaminant of potential ecological concern
CVAA	cold vapor atomic absorption
DDT	dichloro diphenyl trichloroethane
DOE	Department of Energy
EC	expedited cleanup
EDL	estimated detection limit
EFH	Exposure Factors Handbook
EPA	Environmental Protection Agency
EQL	estimated quantitation limit
ER	Environmental Restoration
ERG	Environmental Restoration Group
ESL	ecological screening level
FIA	flame ionization analysis
FIMAD	Facility for Information Management, Analysis, and Display
GFAA	graphite furnace atomic absorption
GIS	geographic information system
GPC	gel permeation chromatography
GPS	global positioning system
HI	hazard index
HQ	hazard quotient
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
MDL	minimum detection limit
MF	moisture fraction
N/A	not applicable
NFA	no further action
NFG	national functional guidelines
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
SCM	site conceptual model
SOW	statement of work
SVOC	semivolatile organic compound
TA	Technical Area
TAL	target analyte list
T&E	threatened and endangered
TPU	total propagated uncertainty
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.
USGS	United States Geological Survey
VCA	voluntary corrective action
VCM	voluntary corrective measure
WRS	Wilcoxon Rank System
WWTP	wastewater treatment plant

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

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

B-1.0 DENDROCHRONOLOGICAL ANALYSES

Several trees were cored in reach LA-5 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. Details of the tree-ring dating method as used in this study are discussed in the reports for upper Los Alamos Canyon and Pueblo Canyon reaches (Reneau et al. 1998, 59159; Reneau et al. 1998, 59160). The utility of this technique was limited in lower Los Alamos Canyon because of the scarcity of trees suitable for such dating. Cottonwoods are the most common tree growing near the channel, and several cottonwoods were cored in an attempt to constrain the ages of sediment burying these trees. However, identification and counting of annual growth rings is very difficult in cottonwoods, and these trees commonly have rotten centers. Attempts at dating cottonwoods in LA-5 were not successful. The only tree successfully dated in LA-5 was a ponderosa pine tree growing on a c3 surface near sample location LA-0080 (tree LLA-001). The innermost ring of this pine tree has an estimated date of 1945 or 1946, which is consistent with evidence from aerial photographs that the channel was active in this area during the period between 1935 and 1954 (Section 2.3.1.3). This tree is growing on a locally high area within the c3 unit that represents an old sand bar, and the base of the tree is not buried by sediment. Therefore, parts of the c3 surface had been abandoned before 1946, and much of the channel facies sediment in these areas may predate initial activities at the Laboratory in 1943.

B-2.0 THICKNESS OF POST-1942 SEDIMENT DEPOSITS

The thickness of post-1942 sediment was measured in each of the lower 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 reaches LA-4 West and LA-4 East are presented in Figures B2-1 and B2-2, respectively. Few measurements were made in units that had small areas, and these are not presented in the figures in this appendix. In addition, measurements in reach LA-5 were made only at sample locations because laboratory results from the first round of sediment samples indicated that radionuclide concentrations were very low in this area and that the associated radionuclide inventory was also low. Because sample locations were biased to the parts of surfaces where post-1942 overbank sediment appeared thickest, these thickness measurements should provide a conservative overestimate of the average thickness of overbank sediment in these geomorphic units. Estimated thicknesses for all geomorphic units and all sediment facies in LA-4 and LA-5 are presented in Tables 2.3-1, 2.3-2, 3.3-3, and 3.3-6.

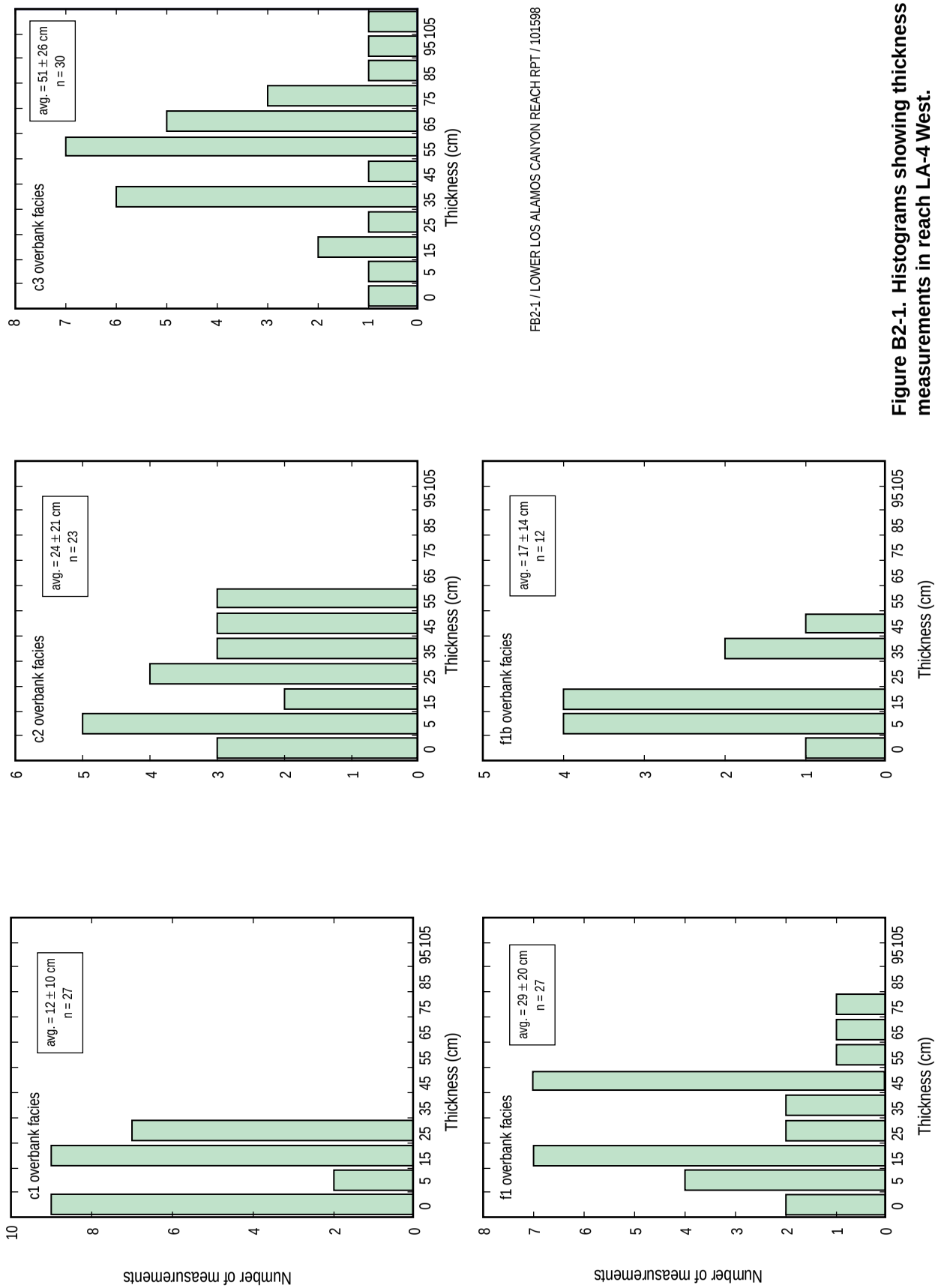


Figure B2-1. Histograms showing thickness measurements in reach LA-4 West.

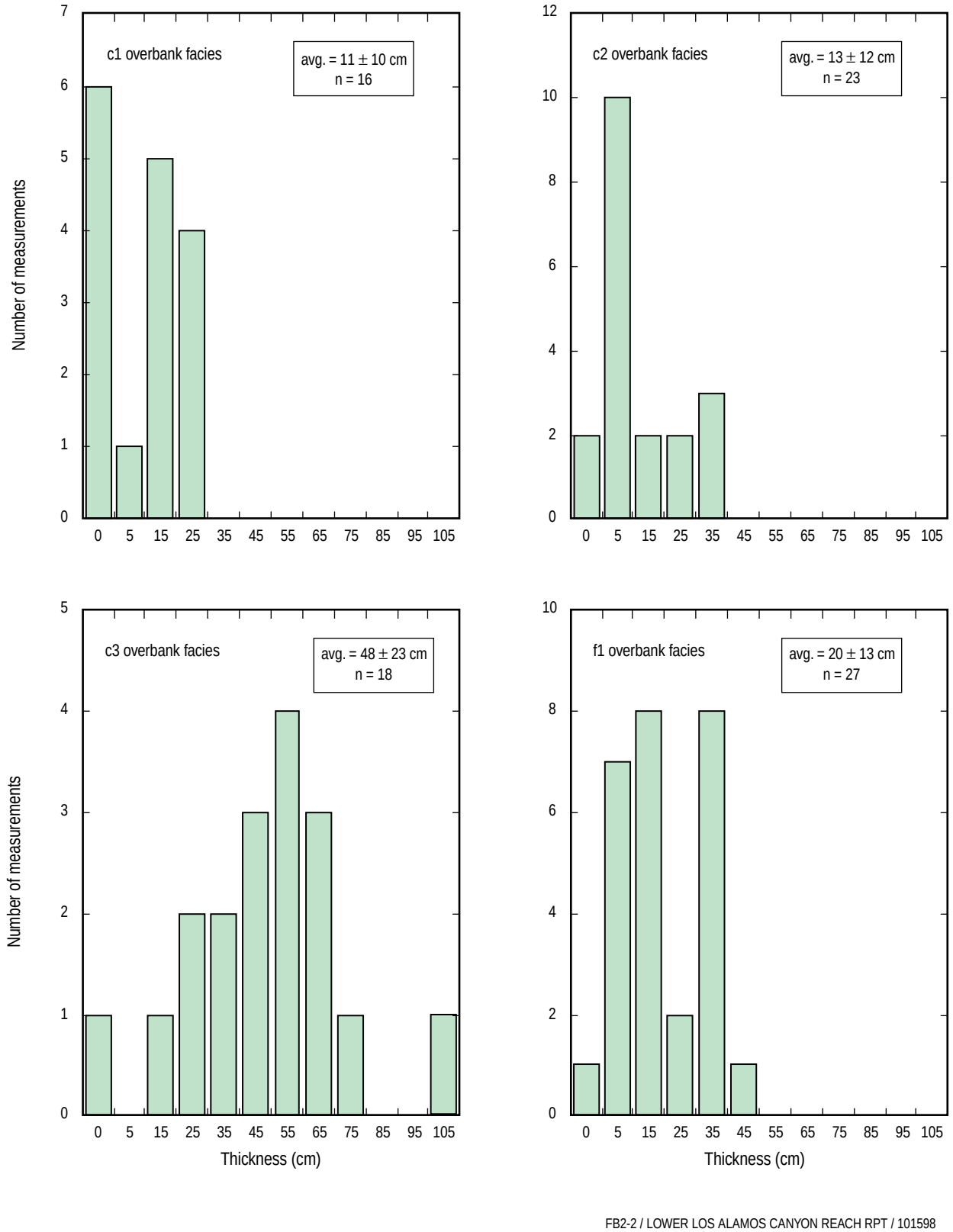


Figure B2-2. Histograms showing thickness measurements in reach LA-4 East.

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 laboratory of Rust Geotech 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 all 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 lower Los Alamos Canyon sediment samples are shown in Tables B3-1 and B3-2. Summaries of the particle size and organic matter data for each geomorphic unit are shown in Tables B3-3 and B3-4. 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). Thus, average gravel percentages for the coarse channel facies deposits are 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 B3-5.

Positive correlations between radionuclide concentration and organic matter content were also seen in some subsets of the lower Los Alamos Canyon data, and these plots are also 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.

TABLE B3-1

REACH LA-4 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-97-0165	7.6	10.5	23.6	26.5	14.6	8.2	10.1	3.8	2.5	2.5	ms	0.330	ls
04LA-97-0166	7.9	6.6	16.4	23.3	17.2	12.2	14.5	5.4	3.3	2.8	fs	0.215	ls
04LA-97-0168	2.6	2.9	5.6	13.9	22.2	21.3	24.9	5.9	3.3	2.0	vfs	0.105	sl
04LA-97-0169	26.4	39.3	39.5	11.4	2.9	1.4	2.2	1.4	1.0	1.0	cs	0.829	gs
04LA-97-0171	1.5	10.0	35.5	31.1	10.7	3.9	4.7	1.8	2.1	1.2	ms	0.453	s
04LA-97-0172	5.6	4.8	4.4	13.4	19.9	16.3	26.9	9.0	5.2	7.1	vfs	0.091	sl
04LA-97-0173	5.5	7.4	20.9	38.6	19.1	5.3	4.9	2.0	1.7	1.4	ms	0.338	s
04LA-97-0174	10.6	5.4	9.8	20.1	23.7	16.1	16.3	5.1	3.2	2.6	fs	0.162	ls
04LA-97-0175	11.0	3.2	4.5	16.9	24.1	18.7	19.6	7.9	4.9	3.9	vfs	0.119	sl
04LA-97-0177	33.1	19.0	35.5	21.6	8.1	4.5	5.1	2.4	3.2	1.2	cs	0.546	gs
04LA-97-0178	8.0	5.4	14.2	20.3	19.1	14.8	16.3	5.7	4.1	2.8	fs	0.174	sl
04LA-97-0179	13.4	9.6	19.0	19.0	14.0	11.2	14.7	6.9	4.6	2.8	fs	0.221	sl
04LA-97-0180	10.6	3.9	8.6	14.8	17.6	16.5	24.9	6.9	6.8	3.1	vfs	0.101	sl
04LA-97-0182	14.5	6.1	9.8	9.1	11.6	20.5	29.8	8.7	4.4	3.7	vfs	0.079	sl
04LA-97-0183	11.7	4.7	12.1	26.2	24.8	12.7	12.0	3.9	3.7	2.8	fs	0.205	ls
04LA-97-0185	58.5	28.0	35.0	16.4	6.1	3.3	4.6	2.8	3.8	1.3	cs	0.646	gs
04LA-97-0187	6.8	3.5	8.7	20.3	24.2	18.7	16.2	4.4	4.2	2.7	fs	0.151	ls
04LA-97-0188	7.7	0.2	4.0	13.9	25.5	22.5	18.5	7.1	6.4	3.2	vfs	0.103	sl
04LA-97-0189	55.0	45.8	32.9	11.3	3.3	1.3	1.5	1.8	2.2	1.0	cs	0.915	gs
04LA-97-0190	11.8	10.0	13.7	19.8	17.0	11.9	16.7	6.3	4.5	2.7	fs	0.192	sl
04LA-97-0191	10.1	9.0	14.3	15.7	17.4	14.2	17.0	6.6	5.9	3.1	fs	0.161	sl
04LA-97-0192	50.8	25.6	36.0	18.9	7.3	3.7	4.9	1.5	2.1	0.7	cs	0.625	gs
04LA-97-0194	44.6	27.1	39.2	17.0	5.6	2.3	3.2	1.8	3.8	1.0	cs	0.667	gs
04LA-97-0195	52.4	30.9	29.1	24.4	10.1	1.8	1.1	1.3	1.5	3.4	cs	0.635	gs
04LA-97-0196	7.4	6.0	6.2	6.6	11.7	21.9	33.0	7.8	6.9	2.7	vfs	0.067	sl
04LA-97-0197	10.9	5.7	12.5	22.1	23.0	14.3	13.0	4.3	5.3	2.9	fs	0.187	ls

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 B3-1 (continued)

REACH LA-4 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-97-0199	15.8	3.0	3.2	12.5	19.9	17.1	21.9	11.5	11.0	4.9	vfs	0.079	sl
04LA-97-0200	42.5	10.2	12.2	12.6	13.7	12.7	17.1	9.2	12.2	3.3	vfs	0.116	gsl
04LA-97-0201	1.8	1.8	5.7	15.4	22.8	22.1	24.2	3.9	3.9	1.8	vfs	0.109	sl
04LA-97-0202	56.5	29.7	31.2	20.0	8.0	3.3	3.7	1.9	2.2	0.8	cs	0.637	gs
04LA-97-0204	1.9	3.7	12.7	28.8	23.8	13.0	10.0	3.8	4.0	1.7	fs	0.217	ls
04LA-97-0205	62.8	49.7	30.7	12.3	3.4	0.6	1.6	0.7	1.0	0.5	cs	0.993	gs
04LA-97-0221	7.4	5.8	18.3	22.8	15.3	9.8	16.1	7.2	4.9	1.8	fs	0.217	sl
04LA-97-0222	16.2	10.8	16.3	14.6	13.9	13.5	16.9	7.2	6.7	2.4	fs	0.165	sl
04LA-97-0223	13.2	10.1	17.8	17.9	13.9	9.5	14.9	8.9	7.1	3.2	fs	0.203	sl
04LA-97-0224	6.6	4.5	8.0	14.4	25.0	20.9	16.8	5.2	5.1	2.4	fs	0.132	sl
04LA-97-0225	5.0	11.8	31.0	26.7	12.0	6.1	4.9	2.9	4.5	1.1	ms	0.415	s
04LA-97-0227	15.8	4.2	9.4	25.3	25.7	14.4	10.6	4.4	5.9	2.2	fs	0.186	ls
04LA-97-0228	11.0	2.3	2.8	8.9	27.3	23.3	22.1	6.6	6.7	2.7	vfs	0.096	sl
04LA-97-0514	58.6	37.0	30.6	14.9	4.8	1.7	2.5	2.3	6.2	1.2	gs	0.745	cs
04LA-97-0515	8.1	8.3	14.9	23.1	19.6	10.2	14.0	4.7	4.9	2.5	ls	0.220	fs
04LA-97-0516	3.2	20.2	44.7	19.4	5.8	2.7	3.2	1.0	3.0	0.6	cs	0.630	s
04LA-97-0517	18.0	17.3	23.6	17.2	10.7	7.3	12.8	5.7	5.2	2.0	ms	0.347	ls
04LA-97-0518	25.3	18.1	27.8	20.1	11.4	6.6	8.3	3.6	4.0	1.5	ms	0.434	gls
04LA-97-0519	9.2	6.3	9.6	11.0	12.3	13.5	29.1	10.8	7.2	2.3	vfs	0.072	sl
04LA-97-0520	1.4	3.8	11.2	22.4	24.0	15.4	15.8	2.2	5.0	1.4	fs	0.174	ls
04LA-97-0521	6.2	1.9	2.4	4.5	8.3	12.8	49.1	13.9	6.7	6.2	csi	0.034	sil
04LA-97-0526	13.3	5.3	4.8	7.6	17.5	23.0	28.0	7.8	6.3	3.8	vfs	0.080	sl
04LA-97-0527	9.8	6.6	7.7	6.2	8.3	9.7	21.4	17.5	22.4	6.7	csi	0.028	l
04LA-97-0528	3.6	8.9	29.6	30.9	13.7	6.0	6.1	2.6	2.1	1.1	ms	0.387	s
04LA-97-0529	3.9	6.4	15.3	23.9	16.6	10.4	16.3	7.2	3.5	3.6	fs	0.208	sl
04LA-97-0530	10.1	7.3	5.2	12.6	21.1	15.5	22.2	11.1	4.8	7.0	vfs	0.105	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, g = ≥20% gravel, sil = silt loam

TABLE B3-1 (continued)

REACH LA-4 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-97-0531	7.8	3.8	4.8	11.8	20.2	18.2	26.4	9.9	4.6	4.4	vfs	0.087	sl
04LA-97-0523	3.6	24.5	40.3	15.4	5.3	3.4	6.0	2.6	2.5	0.7	cs	0.645	s
04LA-97-0524	0.9	3.0	9.7	15.5	14.6	14.1	28.1	7.9	6.8	2.2	vfs	0.088	sl
04LA-97-0525	19.1	1.5	2.7	6.3	12.3	17.7	38.6	15.2	5.4	3.8	csi	0.044	sil
04LA-97-0532	19.4	9.7	9.0	9.8	11.4	12.2	29.5	12.5	5.7	8.6	vfs	0.070	sl
04LA-97-0534	12.3	17.4	16.0	13.5	10.5	7.6	19.9	8.5	6.4	8.7	fs	0.203	sl
04LA-97-0535	8.0	3.6	7.7	9.4	13.0	12.4	22.9	14.5	16.5	3.4	csi	0.049	l
04LA-97-0536	9.3	8.3	11.2	13.7	17.3	15.2	22.0	6.4	5.6	2.6	fs	0.128	sl
04LA-97-0537	12.1	0.0	75.0	15.5	4.9	1.4	1.7	0.5	1.1	0.6	cs	0.630	s
04LA-97-0538	34.8	37.1	35.9	12.4	4.8	2.3	7.4	2.2	1.6	1.2	cs	0.780	gs
04LA-97-0539	28.4	37.7	37.0	14.4	4.1	1.6	2.7	1.5	1.0	0.8	cs	0.794	gs
04LA-97-0540	0.3	7.2	41.5	32.1	9.7	3.4	3.4	1.6	1.1	0.5	ms	0.487	s
04LA-97-0541	25.2	28.6	40.7	20.2	5.3	1.4	2.5	0.9	0.5	1.4	cs	0.694	gs
04LA-97-0542	1.7	1.1	1.8	4.6	18.5	29.9	18.9	6.6	18.3	3.0	fs	0.051	sl
04LA-97-0543	4.0	6.7	14.8	23.7	24.2	12.1	10.8	4.7	2.7	2.7	fs	0.218	ls
04LA-97-0544	1.2	2.3	7.2	14.0	12.6	12.4	32.8	10.5	8.0	3.5	csi	0.059	l
04LA-97-0545	37.0	42.5	36.3	11.7	3.4	1.3	2.3	1.0	1.6	0.7	cs	0.866	gs
04LA-97-0546	34.8	36.1	31.9	15.1	6.0	1.7	2.6	2.3	4.4	1.2	cs	0.739	gs
04LA-97-0547	5.3	11.9	18.1	17.1	15.3	12.2	16.0	5.8	3.5	4.5	fs	0.219	ls
04LA-97-0549	7.6	5.2	9.0	18.4	21.8	16.7	17.0	5.3	6.5	2.6	fs	0.143	sl
04LA-97-0561	2.9	3.5	8.9	21.3	25.2	16.0	15.5	4.2	4.5	2.2	fs	0.159	ls
04LA-97-0562	3.4	5.5	12.7	18.8	20.9	16.7	12.2	4.5	8.7	1.8	fs	0.163	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, g = ≥20% gravel, sil = silt loam

TABLE B3-2

REACH LA-5 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-96-0175	5.3	5.6	9.8	11.0	23.0	27.7	16.8	3.6	2.5	0.3	vfs	0.123	ls
04LA-96-0176	20.4	30.5	43.6	18.4	5.4	0.3	1.6	0.1	0.2	0.1	cs	0.734	gs
04LA-96-0177	2.8	2.7	5.9	13.7	30.0	27.5	14.2	3.6	2.5	0.3	fs	0.132	ls
04LA-96-0178	9.9	7.3	12.2	16.3	20.8	11.3	24.8	5.3	2.1	0.3	fs	0.155	sl
04LA-96-0179	7.5	4.7	10.6	16.3	24.8	22.3	15.5	3.9	1.9	0.3	fs	0.150	ls
04LA-96-0180	28.2	47.6	33.5	11.0	4.7	0.4	2.5	0.1	0.2	0.1	cs	0.952	gs
04LA-96-0181	2.7	1.3	6.5	20.0	33.3	23.9	11.2	2.4	1.4	1.2	fs	0.158	ls
04LA-97-0011	13.7	27.5	38.6	19.6	6.6	2.5	2.8	1.0	1.4	0.9	cs	0.668	s
04LA-97-0012	5.9	4.4	5.7	9.6	25.9	26.1	19.5	4.4	4.2	3.1	vfs	0.111	sl
04LA-97-0013	34.0	1.8	3.4	7.9	18.4	26.1	29.8	7.9	4.4	4.9	vfs	0.077	gsl
04LA-97-0014	4.2	5.6	16.1	28.9	22.9	11.8	9.5	2.3	3.0	1.3	ms	0.253	ls
04LA-97-0015	4.7	5.7	5.1	7.0	11.1	14.7	26.6	14.9	14.5	3.9	csi	0.044	l
04LA-97-0016	15.9	7.1	13.8	21.6	22.1	14.8	16.2	2.3	2.0	1.7	fs	0.197	ls
04LA-97-0017	19.3	13.5	28.9	29.4	14.3	5.8	4.5	1.6	2.0	0.9	ms	0.418	s
04LA-97-0018	9.8	2.7	10.4	31.0	30.6	13.2	6.6	2.5	2.9	2.2	fs	0.219	s
04LA-97-0019	34.4	1.4	3.2	9.0	23.3	29.3	25.9	4.0	4.0	1.9	vfs	0.092	gsl
04LA-97-0020	16.1	1.7	3.6	17.5	31.3	21.4	16.9	4.1	3.5	2.2	fs	0.137	ls
04LA-97-0021	2.6	1.1	5.0	20.6	32.1	22.6	13.0	2.4	3.0	1.7	fs	0.151	ls
04LA-97-0022	28.6	18.6	37.0	26.9	10.3	3.0	1.8	0.8	1.6	0.7	cs	0.556	gs
04LA-97-0023	18.7	3.1	5.4	12.4	22.2	23.2	23.2	5.0	5.8	2.9	vfs	0.102	sl
04LA-97-0024	2.1	2.3	3.5	16.6	28.7	22.6	18.8	4.1	3.2	3.4	fs	0.128	ls
04LA-97-0026	11.9	22.6	35.2	22.4	9.5	4.0	3.1	1.3	1.9	0.9	cs	0.583	s
04LA-97-0025	9.7	4.2	5.7	17.1	24.4	18.5	19.8	5.4	4.9	2.7	fs	0.130	sl
04LA-97-0027	2.5	2.9	5.2	10.7	31.3	27.4	15.9	3.0	3.5	1.8	fs	0.125	ls
04LA-97-0029	18.2	11.2	29.9	31.6	14.5	5.9	2.5	2.1	2.5	0.7	ms	0.410	s
04LA-97-0030	0.8	1.5	3.8	13.7	36.2	25.0	15.0	1.3	3.4	1.1	fs	0.138	ls
04LA-97-0031	12.4	8.6	26.9	41.2	14.9	3.8	0.4	1.7	2.5	0.7	ms	0.392	s
04LA-97-0032	2.6	9.1	24.9	29.9	18.3	7.7	7.1	1.2	1.8	1.5	ms	0.345	s
04LA-97-0040	13.4	2.5	4.7	10.3	19.1	26.3	31.3	2.4	3.2	2.4	vfs	0.088	sl
04LA-97-0041	1.3	1.2	2.5	8.4	15.7	19.6	42.5	4.8	5.1	2.6	csi	0.057	sl
04LA-97-0042	1.8	1.9	3.3	7.9	36.8	30.4	2.5	11.9	5.1	1.6	fs	0.125	ls

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, g = ≥20% gravel

TABLE B3-3

REACH LA-4 PARTICLE SIZE SUMMARY

Geomorphic Unit	Sediment Facies	Summary Statistic	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1mm) (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]
c1	Overbank	average	12.1	7.3	11.8	15.9	19.4	15.5	17.8	6.6	5.3	2.7	fs	0.146	sl
		std. dev.	1.3	4.4	8.3	6.1	7.0	6.8	3.8	0.3	1.2	0.1			
		n	3	3	3	3	3	3	3	3	3	3			
c1	Channel	average	57.6	40.3	29.9	18.3	6.7	1.2	1.3	1.0	1.2	1.9	cs	0.799	gs
		std. dev.	7.3	13.3	1.1	8.6	4.7	0.9	0.4	0.4	0.3	2.0			
		n	2	2	2	2	2	2	2	2	2	2			
c2	Overbank	average	7.3	5.0	8.0	11.8	18.1	18.5	20.5	8.0	9.9	3.1	vfs	0.096	sl
		std. dev.	4.6	2.8	5.1	7.4	4.0	7.7	6.3	3.8	7.0	0.5			
		n	5	5	5	5	5	5	5	5	5	5			
c2	Channel	average	24.0	21.9	50.5	16.0	5.0	1.7	3.8	1.2	1.0	1.0	cs	0.680	gs
		std. dev.	11.4	19.4	21.3	3.9	0.3	0.5	3.1	0.9	0.6	0.4			
		n	3	3	3	3	3	3	3	3	3	3			
c3	Overbank	average	11.2	6.1	12.1	19.3	19.5	14.6	16.5	6.1	5.6	2.7	fs	0.161	sl
		std. dev.	8.3	2.6	5.3	6.6	4.5	4.2	5.6	2.3	2.6	0.8			
		n	21	21	21	21	21	21	21	21	21	21			
c3	Channel	average	37.7	30.4	35.2	16.8	6.0	2.8	3.5	2.0	3.2	1.0	cs	0.680	gs
		std. dev.	16.4	9.8	3.1	4.6	2.7	1.6	1.2	0.6	1.7	0.2			
		n	10	10	10	10	10	10	10	10	10	10			
f1	Overbank	average	6.5	5.7	11.7	17.7	18.4	15.0	19.7	6.4	5.1	2.8	fs	0.143	sl
		std. dev.	4.7	4.3	8.7	7.0	5.6	5.5	8.5	3.2	1.6	1.5			
		n	14	14	14	14	14	14	14	14	14	14			
f1	Channel	average	28.1	24.2	35.6	20.6	7.6	3.5	4.0	2.0	2.5	0.9	cs	0.605	gs
		std. dev.	27.0	14.5	7.2	7.5	3.2	1.9	2.5	1.0	1.1	0.4			
		n	5	5	5	5	5	5	5	5	5	5			
f1b	Overbank	average	8.9	6.7	11.2	14.7	13.4	12.1	26.8	9.6	5.2	5.2	vfs	0.099	sl
		std. dev.	7.2	5.3	9.1	8.9	3.7	4.0	13.3	4.1	1.7	2.9			
		n	8	8	8	8	8	8	8	8	8	8			
f1b	Channel	average	3.6	24.5	40.3	15.4	5.3	3.4	6.0	2.6	2.5	0.7	cs	0.645	s
		n	1	1	1	1	1	1	1	1	1	1			
f2?	Overbank	average	9.8	6.6	7.7	6.2	8.3	9.7	21.4	17.5	22.4	6.7	csi	0.028	l
		n	1	1	1	1	1	1	1	1	1	1			
Qt	Overbank	average	5.3	11.9	18.1	17.1	15.3	12.2	16.0	5.8	3.5	4.5	fs	0.219	ls
		n	1	1	1	1	1	1	1	1	1	1			

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, g = ≥20% gravel

TABLE B3-4

REACH LA-5 PARTICLE SIZE SUMMARY

Geomorphic Unit	Sediment Facies	Summary Statistic	Gravel (>2 mm) (wt %)	Very Coarse Sand (2–1mm) (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]
c1	Channel	average	24.3	39.1	38.6	14.7	5.0	0.4	2.0	0.1	0.2	0.1	cs	0.821	gs
		std. dev.	5.5	12.1	7.2	5.2	0.5	0.0	0.6	0.0	0.0	0.0			
		n	2	2	2	2	2	2	2	2	2	2			
c2	Overbank	average	5.0	2.9	7.8	18.4	28.5	22.4	14.3	3.2	2.5	1.0	fs	0.151	ls
		std. dev.	3.5	2.5	3.9	3.0	5.2	0.2	1.8	1.0	0.8	1.0			
		n	2	2	2	2	2	2	2	2	2	2			
c2	Channel	average	21.1	23.1	37.8	23.2	8.4	2.7	2.3	0.9	1.5	0.8	cs	0.611	gs
		std. dev.	10.5	6.3	1.1	5.1	2.6	0.3	0.6	0.2	0.1	0.1			
		n	2	2	2	2	2	2	2	2	2	2			
c3	Overbank	average	6.2	5.8	13.1	19.1	24.9	18.8	13.8	2.1	2.4	1.2	fs	0.179	ls
		std. dev.	6.8	3.2	8.9	8.5	7.8	9.3	4.5	1.1	0.7	0.6			
		n	4	4	4	4	4	4	4	4	4	4			
c3	Channel	average	13.5	9.7	25.5	32.7	16.6	6.8	4.2	1.9	2.5	0.9	ms	0.365	s
		std. dev.	6.9	3.4	6.3	5.7	4.2	3.5	3.9	0.3	0.4	0.3			
		n	4	4	4	4	4	4	4	4	4	4			
f1	Overbank	average	9.7	2.7	5.6	14.7	26.7	22.7	19.5	4.5	3.6	2.0	vfs	0.124	sl
		std. dev.	9.5	1.6	2.9	6.3	6.3	5.8	10.5	2.5	1.3	0.9			
		n	13	13	13	13	13	13	13	13	13	13			
f1	Channel	average	11.9	22.6	35.2	22.4	9.5	4.0	3.1	1.3	1.9	0.9	cs	0.583	s
		n	1	1	1	1	1	1	1	1	1	1			
f2	Overbank	average	14.8	3.9	4.7	8.2	18.5	22.3	25.3	9.1	7.7	4.0	vfs	0.079	sl
		std. dev.	16.6	2.0	1.2	1.3	7.4	6.6	5.3	5.3	5.9	0.9			
		n	3	3	3	3	3	3	3	3	3	3			

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

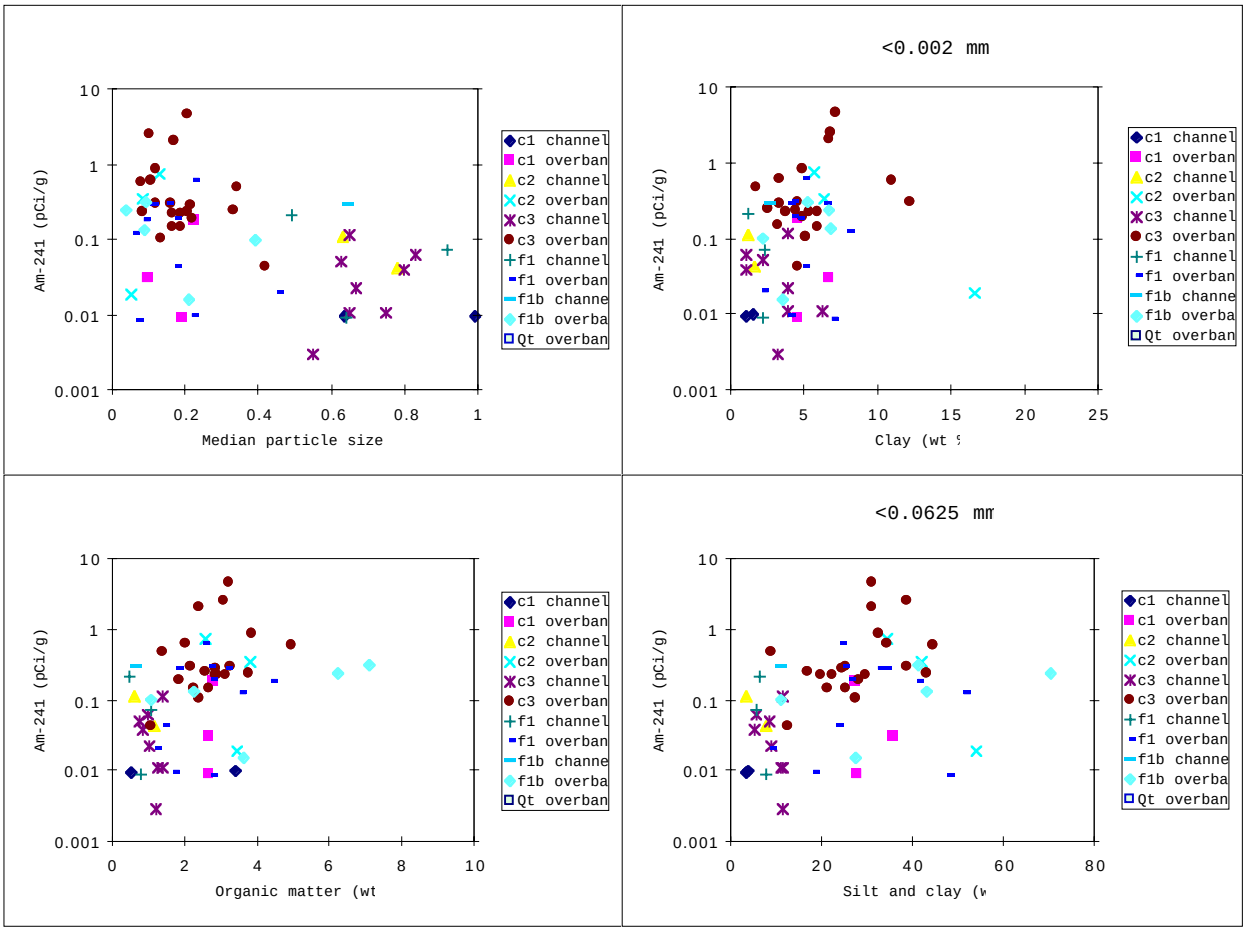


Figure B3-1. Scatter plots showing relations of americium-241 concentration to median particle size, silt and clay content, and organic matter content in reach LA-4.

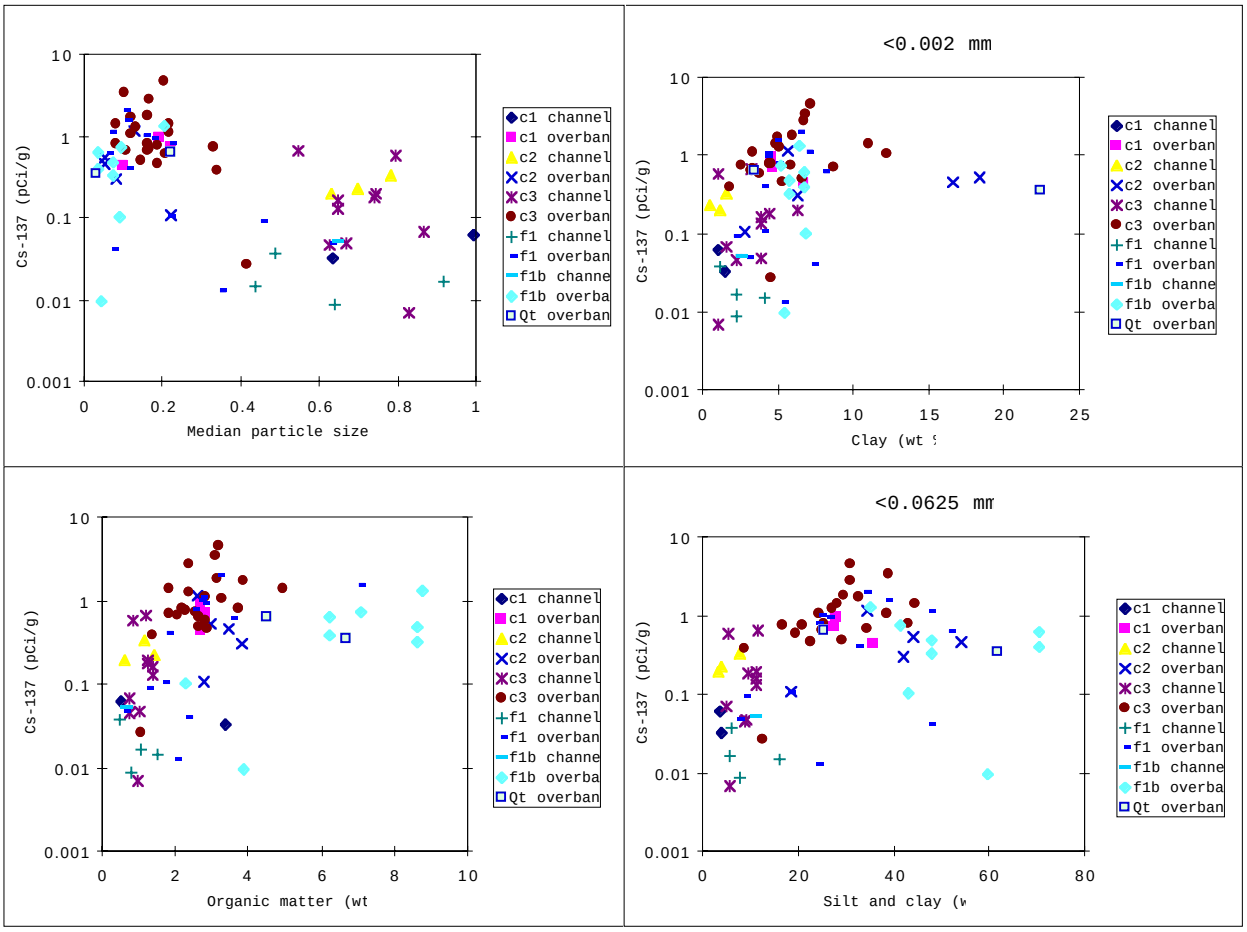


Figure B.3-2. Scatter plots showing relations of cesium-137 concentration to median particle size, silt and clay content, and organic matter content in reach LA-4.

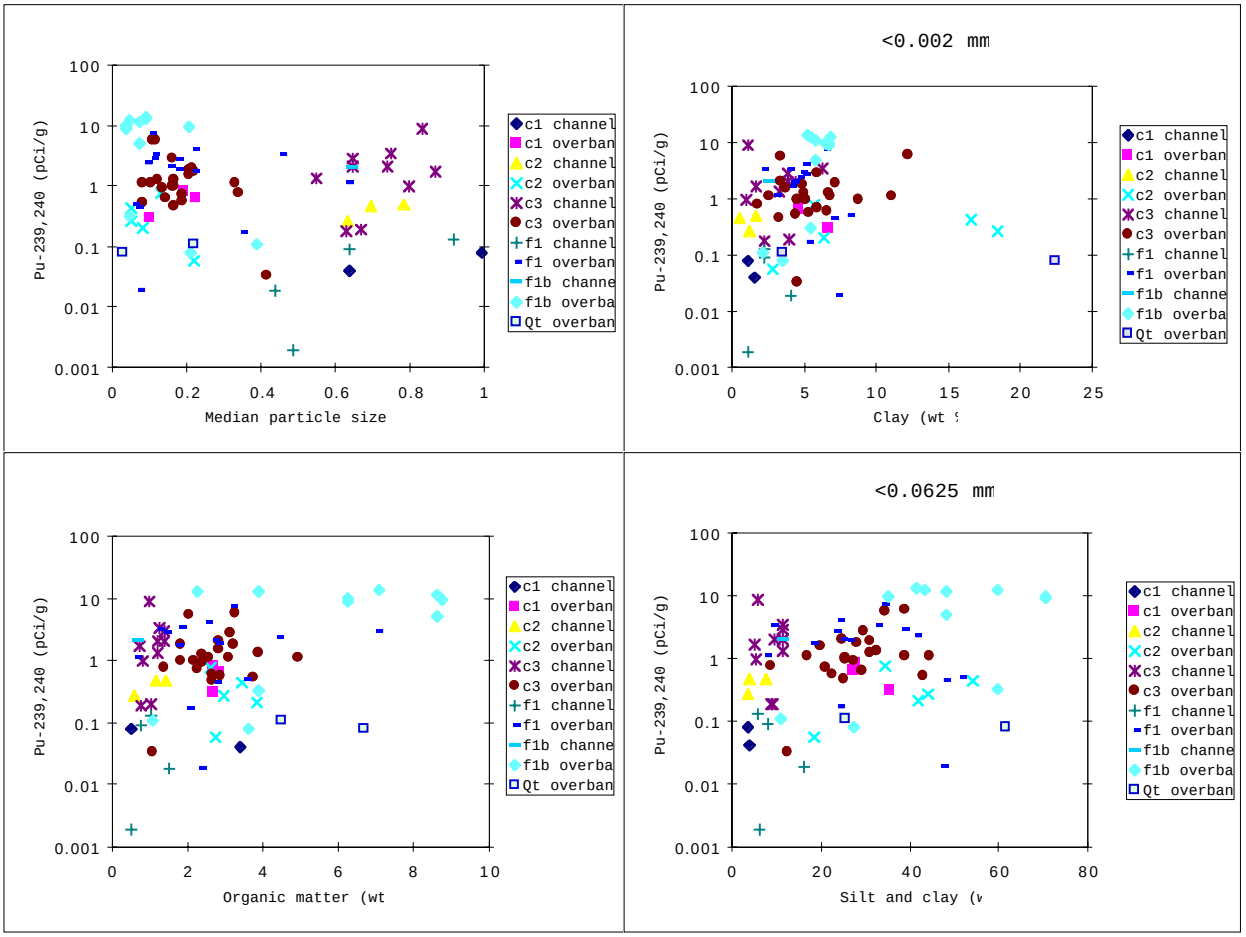


Figure B3-3. Scatter plots showing relations of plutonium-239,240 concentration to median particle size, silt and clay content, and organic matter content in reach LA-4.

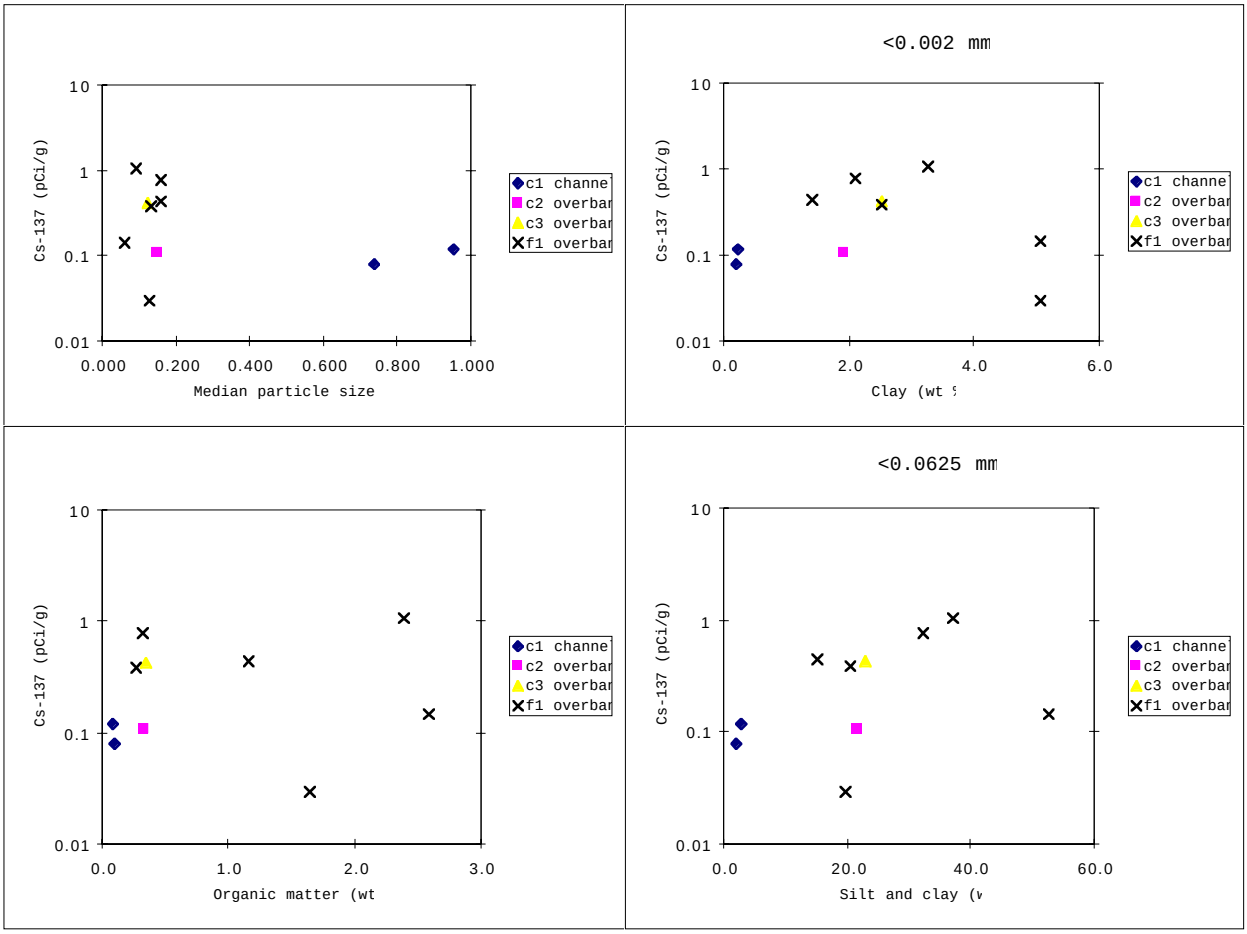


Figure B3-4. Scatter plots showing relations of cesium-137 concentration to median particle size, silt and clay content, and organic matter content in reach LA-5.

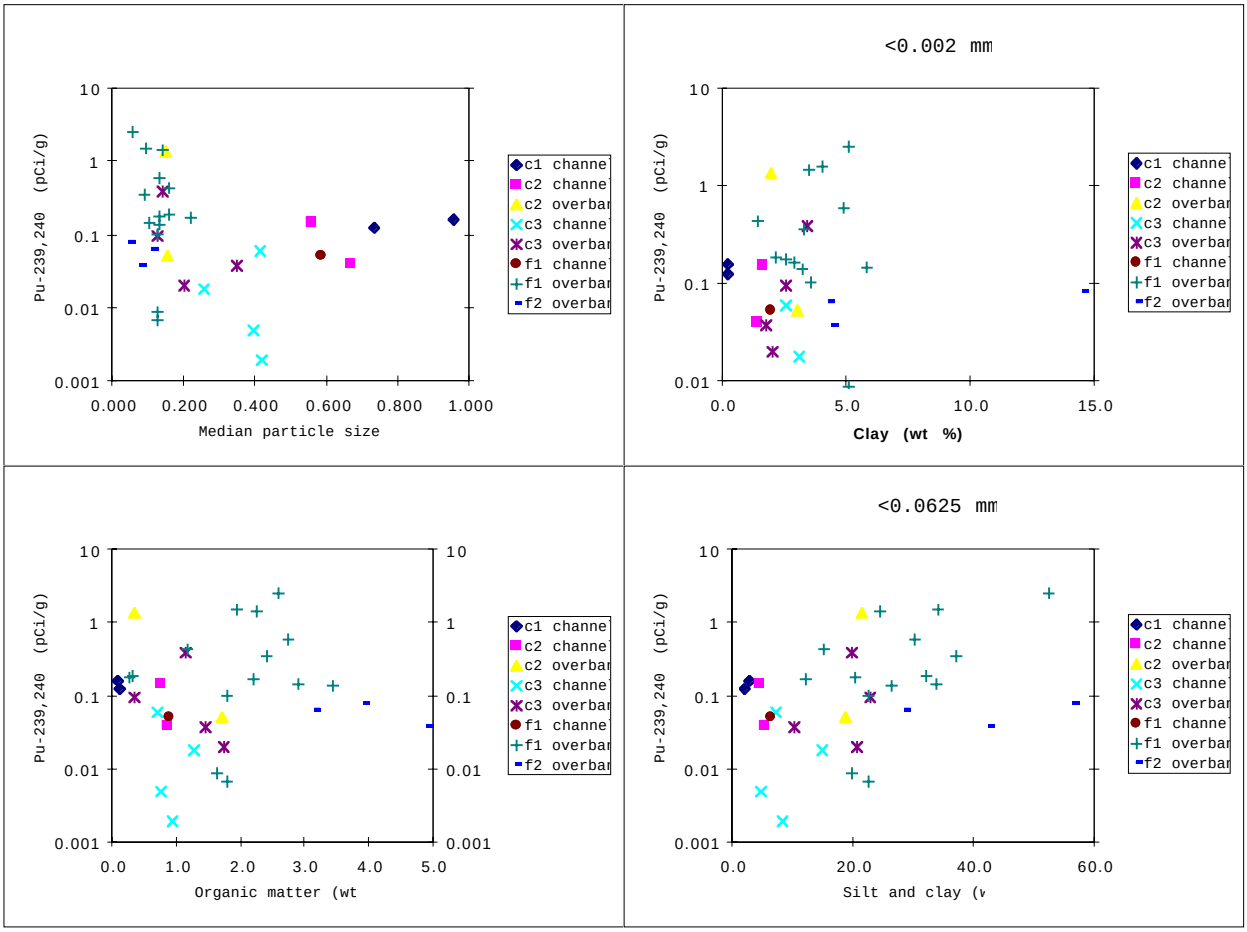


Figure B3-5. Scatter plots showing relations of plutonium-239,240 concentration to median particle size, silt and clay content, and organic matter content in reach LA-5.

B-4.0 RADIOLOGICAL FIELD MEASUREMENTS

B-4.1 Instrument Calibration and Use

B-4.1.1 Gross Gamma Radiation Walkover Surveys

The gross gamma radiation walkover survey in reach LA-5 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). 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 were also checked twice daily.

The survey was conducted by walking slowly with the probe face held approximately 1 ft from the ground surface. 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 restricted to parts of reach LA-5 that had low tree density.

Modifications were made to the gross gamma walkover survey procedure after it was realized during investigations in reach LA-2 in upper Los Alamos Canyon 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 that there were several limitations to the use of this method in both upper and lower Los Alamos Canyon. One limitation involved the small size of most individual geomorphic units in many reaches 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 the GPS method was often slowed down considerably because of tree cover. In the modifications to the walkover methodology in lower Los Alamos Canyon, the ERG instruments were used, but no attempt was made to obtain continuous GPS measurements. The operator walked a set distance within a specific geomorphic unit collecting measurements every 2 seconds, and the ends of these measured transects in addition to some of the points along the transect were located with the GPS. 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, which is 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 Basalt Springs to the Rio Grande, which supplemented similar measurements obtained upstream in upper Los Alamos Canyon. 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 units in some reaches, particularly in reach LA-4, although the units are wide enough downstream from Bayo Canyon to prevent this potential problem. 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 Fixed-Point Alpha, Beta, and Gamma Radiation Surveys

Alpha, beta, and gamma radiation were measured at fixed locations in reach LA-5 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-4 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-4 and LA-5 and specific sites of relatively high gross gamma radiation in LA-5 as identified in the gamma walkover survey. In addition, measurements of different stratigraphic layers exposed in stream banks were made at selected locations to evaluate depth variations. Beta and gamma measurements in LA-5 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). Because of the decision to focus all fixed-point measurements in LA-4 on gamma radiation, 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 in LA-4 were made at the surface and at 10-cm intervals. For the alpha measurements in LA-5, 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 radiation measurements used 5-min count times.

B-4.1.3 *In Situ* Gamma Spectroscopy Survey

Gamma radiation was measured at selected fixed-point locations in reach LA-5 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 some 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-4

B-4.2.1.1 Fixed-Point Gamma Radiation Survey

A total of 419 fixed-point gross gamma radiation measurements were made at 103 sites in reach LA-4 (Figures B4-1 and B4-2; Table B4-1). These sites included 48 vertical sections through stream banks or hand-dug pits in the c1, c2, c3, f1, f1b, and Qt units (Figure B4-3). Measurements ranged from 3351 to 9185 cpm and, because of differences in gamma radiation between different geomorphic units, appeared to record variability in the concentrations of cesium-137 as had been seen in upper Los Alamos Canyon. Figure B4-4 shows the average of all measurements from the sections within the different geomorphic units, illustrating the general occurrence of the highest gamma radiation in the c3 unit and the lowest gamma radiation in a pre-1943 stream terrace (Qt). Sediment sampling in the first sampling round was biased by these field gamma measurements, but there was no systematic relation between the field gamma radiation measurements and cesium-137 levels in the sediment samples. In addition, it is notable that most of these measurements are within the range of measurements with the same instrument for pre-1943 sediments upstream in reach LA-3, which reached 8100 cpm (Reneau et al. 1998, 59160). Therefore, these field radiation measurements were not considered reliable for identifying variations in contamination and were not used further in this investigation.

B-4.2.2 Reach LA-5

B-4.2.2.1 Gross Gamma Radiation Walkover Survey

A gross gamma radiation walkover survey was performed in reach LA-5 in March 1996, and gross gamma radiation data were obtained from 15,880 points using 2-second count times. Locations of the measurement points are shown on Figures B4-5 and B4-6, and the raw data are archived in the Facility for Information Management, Analysis, and Display (FIMAD). The survey included an area downstream from the confluence of Guaje Canyon and Los Alamos Canyon, extending to the junction of state roads NM 30 and NM 502, where no sediment samples were collected and where no investigations were conducted after March 1996. This unsampled area is referred to as reach LA-5 West (Figure B4-6), and the sampled reach is referred to as LA-5 (Figure B4-5). The highest gamma radiation value in the walkover survey, 25,262 cpm, was from the c3 unit near sample location LA-0032. The locations of several full-suite sediment samples in LA-5 were biased by these field measurements, but analytical results indicated that concentrations of gamma-emitting radionuclide contaminants such as cesium-137 were too low to allow effective use of this method. Therefore, these measurements were not used further in this investigation.

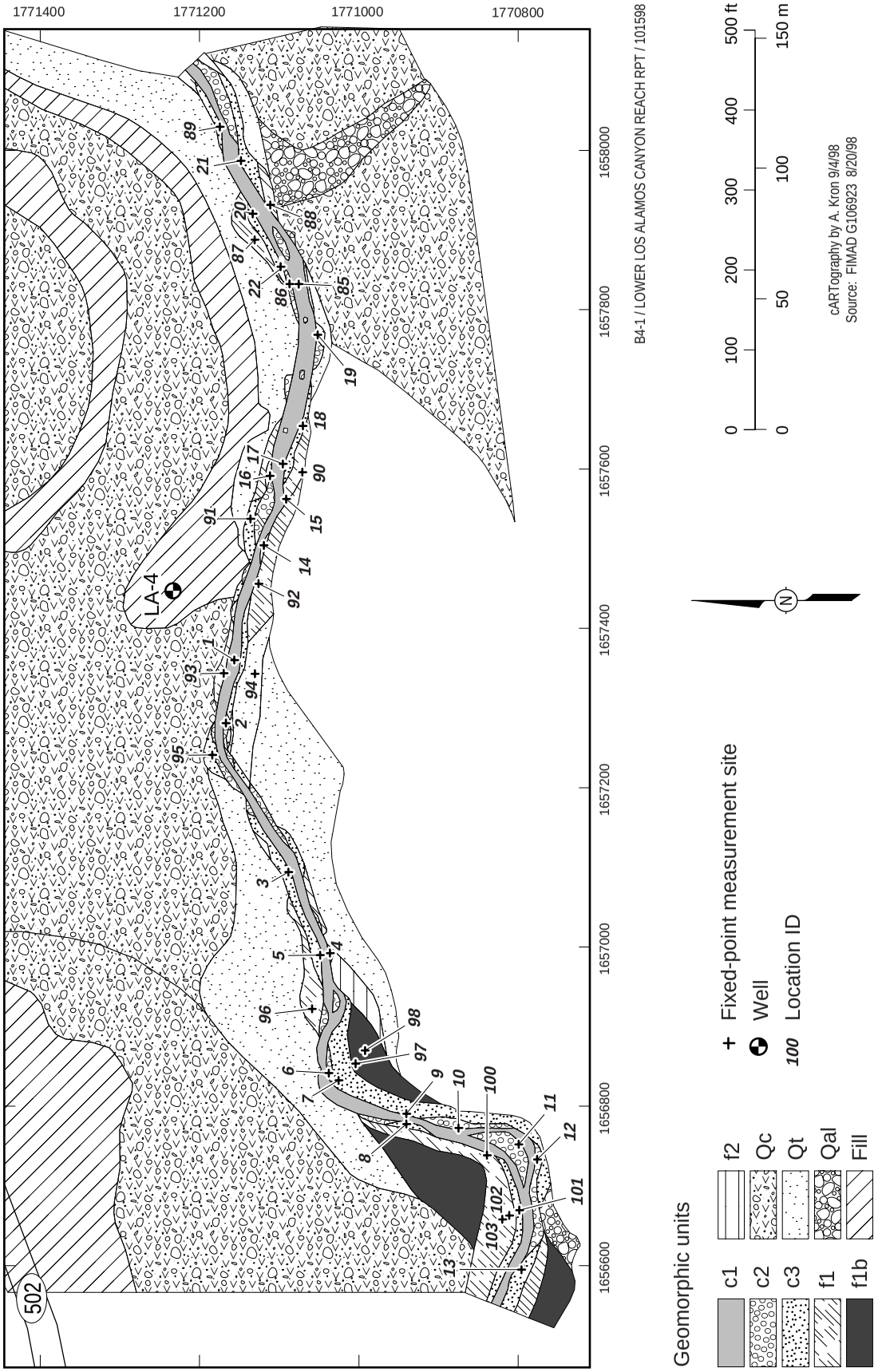


Figure B4-1. Map of reach LA-4 West showing fixed-point radiation measurement sites.

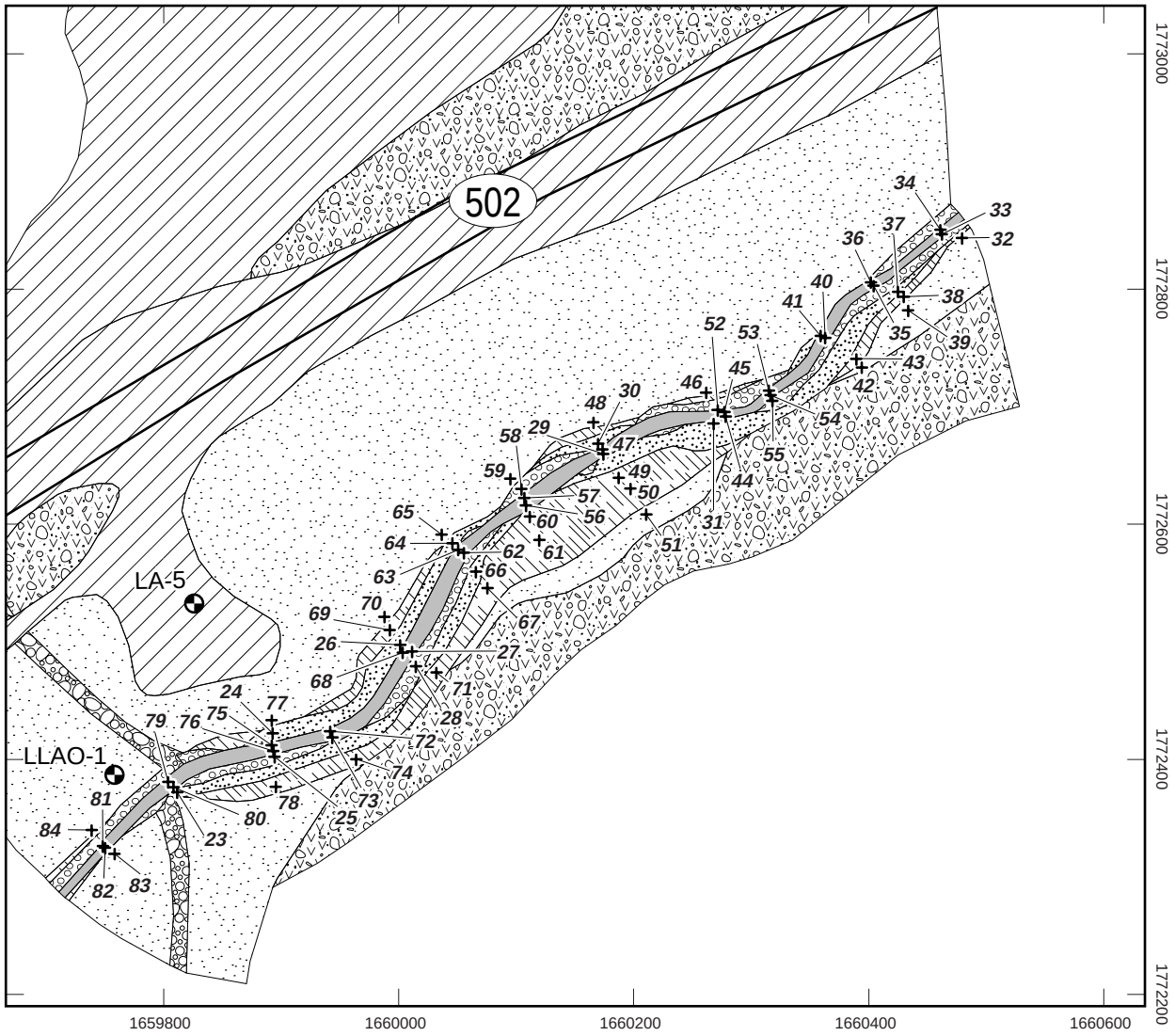


Figure B4-2. Map of reach LA-4 East showing fixed-point radiation measurement sites.

TABLE B4-1

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-4

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)
LA4-1	LA4-S1		LA-4 West	c1	0	5590
					10	4844
					20	4796
LA4-2	LA4-S2		LA-4 West	c2	0	6264
					10	5926
					20	6591
					30	6405
					40	6173
LA4-3	LA4-S3		LA-4 West	c3?	0	6610
					10	6582
					20	7541
					30	7662
					40	7912
					50	7939
					60	7402
					70	6851
LA4-4	LA4-S4		LA-4 West	c3	0	5975
					10	6335
					20	6192
					30	5722
					40	5502
LA4-5	LA4-S5		LA-4 West	c3?	0	6511
					10	5773
					20	6437
					30	6639
					40	6608
					50	6779
LA4-6	LA4-S6		LA-4 West	c2	0	5951
					10	5830
					20	6266
					30	6394
					40	6569
					50	6228
LA4-7	LA4-S7	LA-0125	LA-4 West	c3	0	6411
					10	6469
					20	7252
					30	7567
					40	8623
					50	8305
					60	8449
					70	9185
					80	9143
					90	8740
					100	7895
LA4-8	LA4-S8		LA-4 West	c3	0	5444
					10	5467
					20	5948

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-4

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)
LA4-8	LA4-S8		LA-4 West	c3	30	6044
					40	6487
					50	6514
					60	6452
					70	6169
LA4-9	LA4-S9		LA-4 West	c3	0	5767
					10	5824
					20	6233
					30	6288
					40	6293
					50	6086
LA4-10	LA4-S10		LA-4 West	c2	0	5202
					10	5533
					20	5631
					30	5337
					40	4941
					50	4871
					60	4781
					70	5310
					80	5112
					90	5249
LA4-11	LA4-S11		LA-4 West	c2	0	6475
					10	5889
					20	5767
					30	6233
					40	6310
					50	5790
					60	5954
					70	5520
LA4-12	LA4-S12		LA-4 West	c2	0	5832
					10	5270
					20	6262
					30	6074
					40	5882
					50	6210
					60	5928
					70	5801
LA4-13	LA4-S13	LA-0122	LA-4 West	c3	0	6205
					10	6213
					20	6729
					30	7055
					40	7033
					50	6770
					60	6697
					70	6247
LA4-14	LA4-S14	LA-0128	LA-4 West	c3	0	6288
					10	5666
					20	6060

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-4

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)
LA4-14	LA4-S14	LA-0128	LA-4 West	c3	30	6054
					40	6189
					50	5641
					60	5553
					70	5354
LA4-15	LA4-S15		LA-4 West	f1	0	4924
					10	4687
					20	4936
					30	5077
					40	5224
					50	5246
					60	5393
					70	5251
					80	5234
					90	5372
					100	5599
					110	5393
LA4-16	LA4-S16		LA-4 West	c3	0	6847
					10	6577
					20	7102
					30	7465
					40	7494
					50	7359
					60	7345
					70	6806
LA4-17	LA4-S17		LA-4 West	c1	0	5652
					10	4807
					20	4799
					30	4823
LA4-18	LA4-S18		LA-4 West	c3?	0	4470 ?
					10	5079
					20	4948
					30	4976
					40	4929
					50	4822
LA4-19	LA4-S19		LA-4 West	c3	0	5229
					10	5403
					20	5862
					30	5860
					40	5874
					50	5783
					60	5261
					70	5434
					80	5687
					90	5832
					100	6146
					110	6714
					120	6976

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-4

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)
LA4-20	LA4-S20		LA-4 West	c3	0	6087
					10	6409
					20	7140
					30	7621
					40	7805
					50	7879
					60	7747
					70	7757
					80	7766
LA4-21	LA4-S21		LA-4 West	c3	0	6514
					10	6485
					20	7235
					30	7514
					40	7750
					50	6855
LA4-22	LA4-S22		LA-4 West	c3	0	6153
					10	6364
					20	6777
					30	7335
					40	7898
					50	8177
					60	8310
					70	8220
					80	7716
					90	7962
					100	7631
					110	7632
LA4-23	LA4-S23		LA-4 East	c3	0	6004
					10	6155
					20	6537
					30	6647
					40	7030
					50	7313
					60	7054
					70	7066
LA4-24	LA4-S24		LA-4 East	c3	0	6399
					10	6161
					20	6516
					30	7019
					40	6927
					50	6967
					60	7125
					70	6378
					80	6825
					90	6634
					100	6611
					110	6693
LA4-25	LA4-S25		LA-4 East	c2	0	6533

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-4

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)
LA4-25	LA4-S25		LA-4 East	c2	10	6156
					20	6180
					30	6174
					40	6059
					50	5946
LA4-26	LA4-S26		LA-4 East	c3	0	6402
					10	6828
					20	6950
					30	7242
					40	7542
					50	7498
					60	7454
					70	6948
					80	6546
LA4-27	LA4-S27		LA-4 East	c1	0	5437
					10	4985
					20	4967
LA4-28	LA4-S28		LA-4 East	c2	0	6152
					10	6199
					20	6748
					30	6432
					40	6226
					50	5758
					60	5512
					70	5473
LA4-29	LA4-S29		LA-4 East	c1	0	5312
					10	5327
					20	5316
LA4-30	LA4-S30	LA-0135	LA-4 East	c3	0	6111
					10	5978
					20	7911
					30	8154
					40	8053
					50	8020
					60	6100
					70	5860
					80	5746
LA4-31	LA4-S31	LA-0211	LA-4 East	c3	0	6214
					10	5705
					20	6292
					30	6616
					40	6634
					50	6709
					60	6518
					70	6262
					80	6338
					90	6229
					100	6321

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-4

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)
LA4-31	LA4-S31	LA-0211	LA-4 East	c3	110	6253
LA4-32	LA4-S32	LA-0213	LA-4 East	Qt	0	5090
					10	4876
					20	5234
					30	5037
					40	5048
					50	4988
					60	4808
					70	4570
					80	4582
					90	4688
					100	4826
LA4-33			LA-4 East	c1	0	5042
LA4-34			LA-4 East	c1	0	5885
LA4-35			LA-4 East	c1	0	5614
LA4-36			LA-4 East	c1	0	5370
LA4-37	LA4-S33	LA-0132	LA-4 East	c3	0	5880
					10	6048
					20	6181
					30	6339
					40	6392
					50	6254
					60	6478
LA4-38			LA-4 East	f1	0	5249
LA4-39			LA-4 East	Qt	0	4893
LA4-40			LA-4 East	c1	0	4691
LA4-41			LA-4 East	c1	0	5433
LA4-42			LA-4 East	f1	0	6209
LA4-43			LA-4 East	Qt	0	5131
LA4-44			LA-4 East	c1	0	5154
LA4-45			LA-4 East	c1	0	6243
LA4-46			LA-4 East	Qt	0	4242
LA4-47			LA-4 East	c1	0	5043
LA4-48			LA-4 East	Qt	0	4511
LA4-49			LA-4 East	f1	0	4824
LA4-50		LA-0134	LA-4 East	f1	0	5014
LA4-51			LA-4 East	Qt	0	5272
LA4-52	LA4-S34	LA-0212	LA-4 East	c2	0	5158
					10	5306
					20	5486
					30	5185
					40	5277
LA4-53			LA-4 East	c1	0	4529
LA4-54			LA-4 East	c1	0	5336
LA4-55	LA4-S35		LA-4 East	c2	0	5059
					10	4684
					20	5192
					30	5235

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-4

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)
LA4-56			LA-4 East	c1	0	4493
LA4-57			LA-4 East	c1	0	5194
LA4-58		LA-0209	LA-4 East	c2	0	4488
LA4-59			LA-4 East	Qt	0	4802
LA4-60			LA-4 East	f1	0	5244
LA4-61			LA-4 East	f1	0	5276
LA4-62			LA-4 East	c1	0	4489
LA4-63			LA-4 East	c1	0	5243
LA4-64	LA4-S36	LA-0208	LA-4 East	c3	0	6282
					10	6226
					20	6329
					30	6539
					40	6854
					50	6702
					60	6442
					70	5877
LA4-65			LA-4 East	Qt	0	4890
LA4-66	LA4-S37		LA-4 East	c3	0	6319
					10	5835
					20	6266
					30	6370
					40	6035
					50	5867
					60	5714
LA4-67	LA4-S38	LA-0136	LA-4 East	f1	0	5529
					10	5734
					20	5956
					30	6122
					40	6141
LA4-68			LA-4 East	c1	0	4794
LA4-69			LA-4 East	f1	0	5522
LA4-70			LA-4 East	Qt	0	5212
LA4-71			LA-4 East	f1	0	4291
LA4-72			LA-4 East	c1	0	5012
LA4-73			LA-4 East	c1	0	5148
LA4-74			LA-4 East	f1	0	4841
LA4-75			LA-4 East	c1	0	5308
LA4-76			LA-4 East	c1	0	5665
LA4-77			LA-4 East	Qt	0	4043
LA4-78		LA-0138	LA-4 East	f1	0	6404
LA4-79			LA-4 East	c1	0	4928
LA4-80			LA-4 East	c1	0	5486
LA4-81			LA-4 East	c1	0	4983
LA4-82			LA-4 East	c1	0	5381
LA4-83			LA-4 East	Qt	0	5845
LA4-84			LA-4 East	Qt	0	4909
LA4-85			LA-4 West	c1	0	6064
LA4-86			LA-4 West	c2	0	6770

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-4

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)
LA4-87			LA-4 West	f1	0	5616
LA4-88	LA4-S39	LA-0130	LA-4 West	f1?	0	6211
					10	5928
					20	6650
					30	6528
					40	6455
					50	6127
					60	5782
					70	5798
					80	5742
					90	5595
LA4-89	LA4-S40	LA-0129	LA-4 West	c3	0	6101
					10	6489
					20	6952
					30	7253
					40	7476
					50	6961
					60	6049
LA4-90			LA-4 West	f1	0	5612
LA4-91	LA4-S41		LA-4 West	c3	0	6145
					10	6119
					20	6939
					30	7131
					40	7278
					50	7520
					60	7266
					70	7569
LA4-92	LA4-S42		LA-4 West	f1?	0	6556
					10	6294
					20	6510
					30	6285
					40	5952
					50	6006
					60	5713
					70	5755
LA4-93	LA4-S43	LA-0126	LA-4 West	f1	0	5071
					10	5097
					20	5295
					30	5428
					40	5287
					50	5759
LA4-94			LA-4 West	Qt	0	4783
LA4-95	LA4-S44	LA-0207	LA-4 West	c3	0	6430
					10	6671
					20	7219
					30	7332
					40	8066
					50	7935

TABLE B4-1 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-4

Fixed-Point Site	Section ID	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Gamma Radiation (cpm)
LA4-95	LA4-S44	LA-0207	LA-4 West	c3	60	7811
					70	7888
					80	8085
					90	7773
					100	7641
					110	7544
LA4-96	LA4-S45		LA-4 West	f1?	0	3508
					10	3708
					20	3727
					30	3399
					40	3351
LA4-97			LA-4 West	f1b	0	5266
LA4-98		LA-0124	LA-4 West	f1b	0	5682
LA4-99	LA4-S46		LA-4 West	f1	0	5708
					10	6097
					20	6402
					30	6398
					40	6225
LA4-100	LA4-S47		LA-4 West	f1	0	6480
					10	6442
					20	6803
					30	6859
					40	6836
					50	6549
					60	6499
LA4-101	LA4-S48		LA-4 West	c3	0	6460
					10	6888
					20	7741
					30	8448
					40	8866
					50	8496
					60	8680
					70	8587
					80	8268
					90	8232
LA4-102			LA-4 West	f1	0	4868
LA4-103		LA-0123	LA-4 West	f1	0	5478

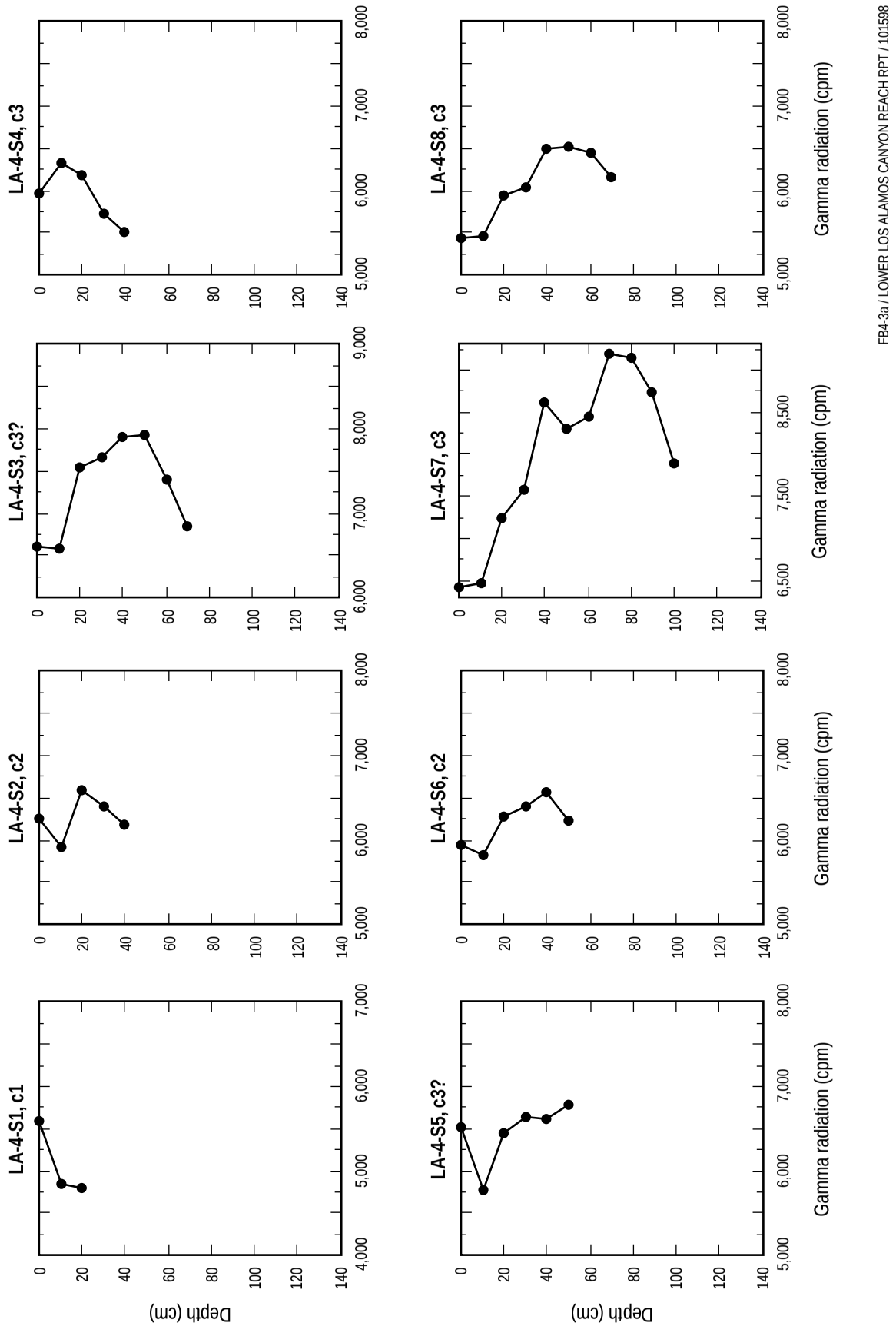


Figure B4-3a. Plots of gamma radiation against depth for the c1, c2, and c3 units in reach LA-4.

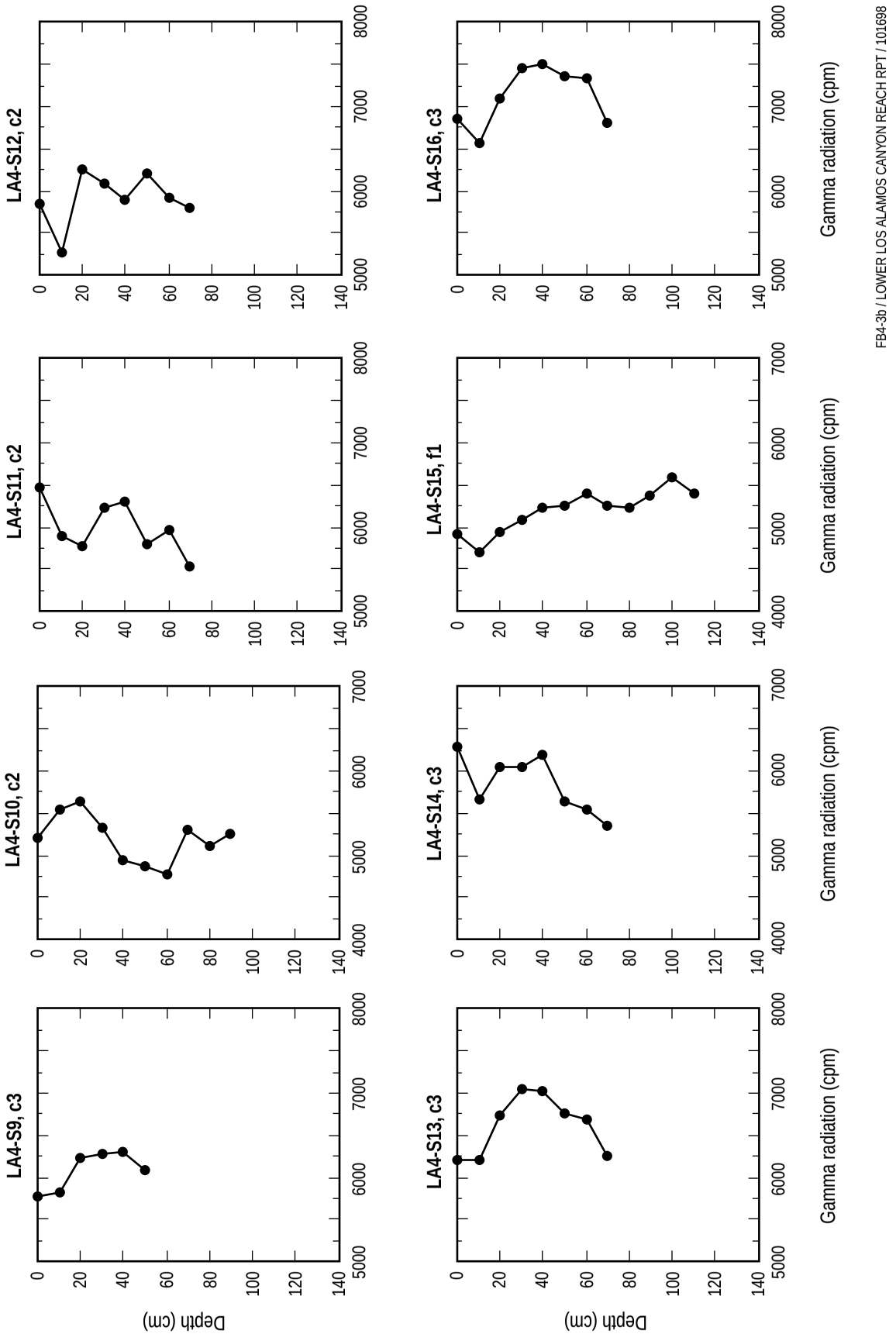


Figure B4-3b. Plots of gamma radiation against depth for the c2, c3, and f1 units in reach LA-4.

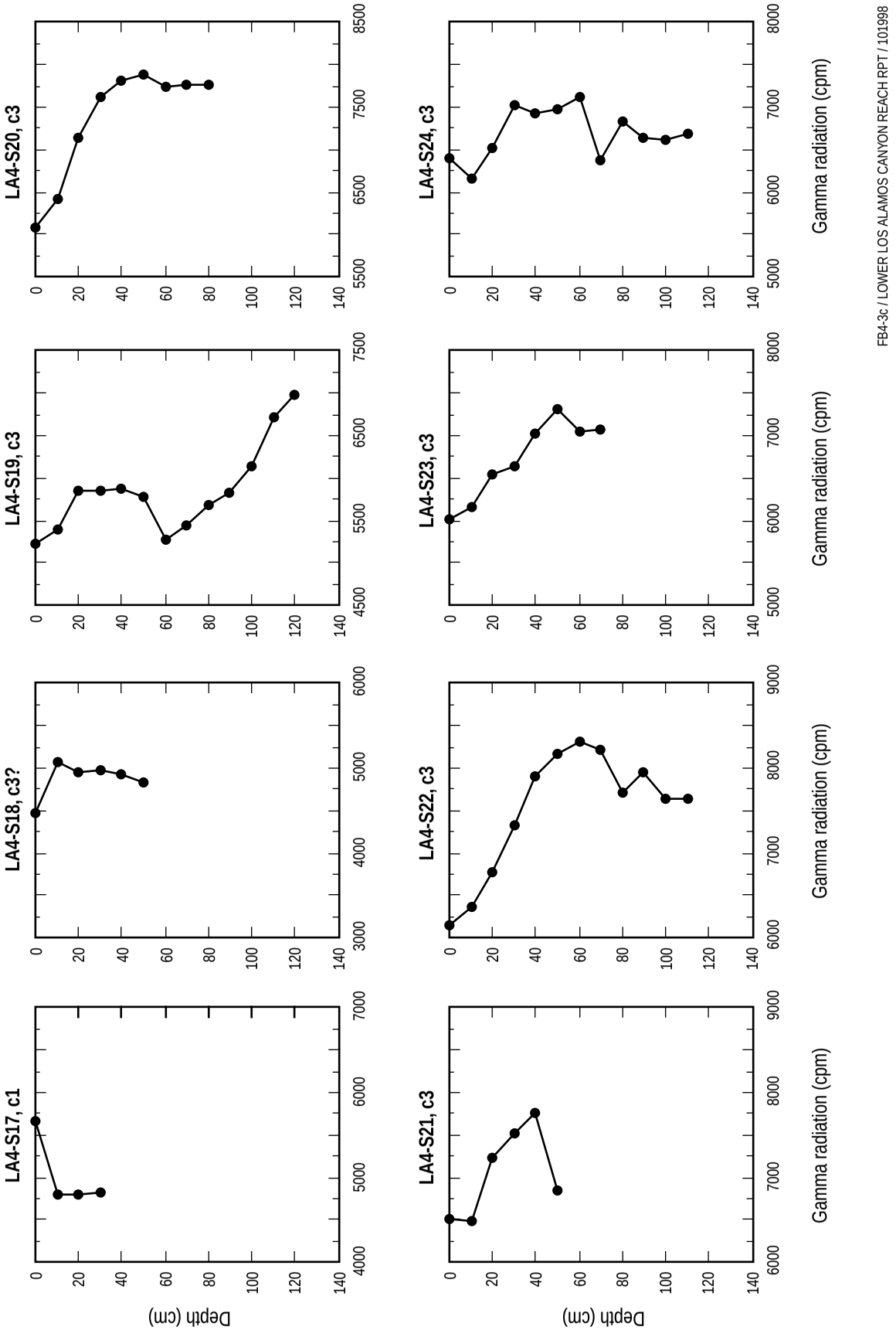


Figure B4-3c. Plots of gamma radiation against depth for the c1 and c3 units in reach LA-4.

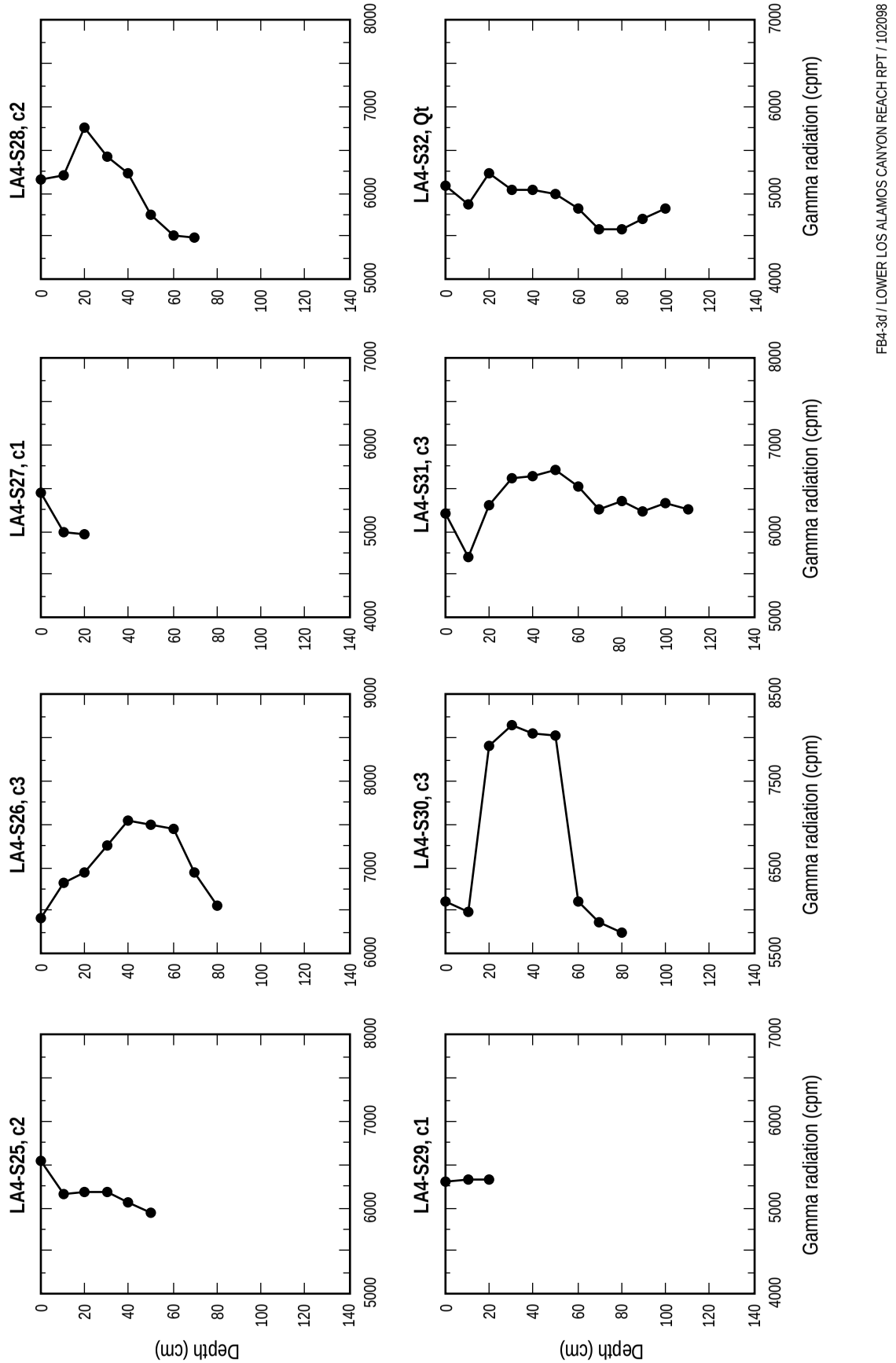


Figure B4-3d. Plots of gamma radiation against depth for the c1, c2, c3, and Qt units in reach LA-4.

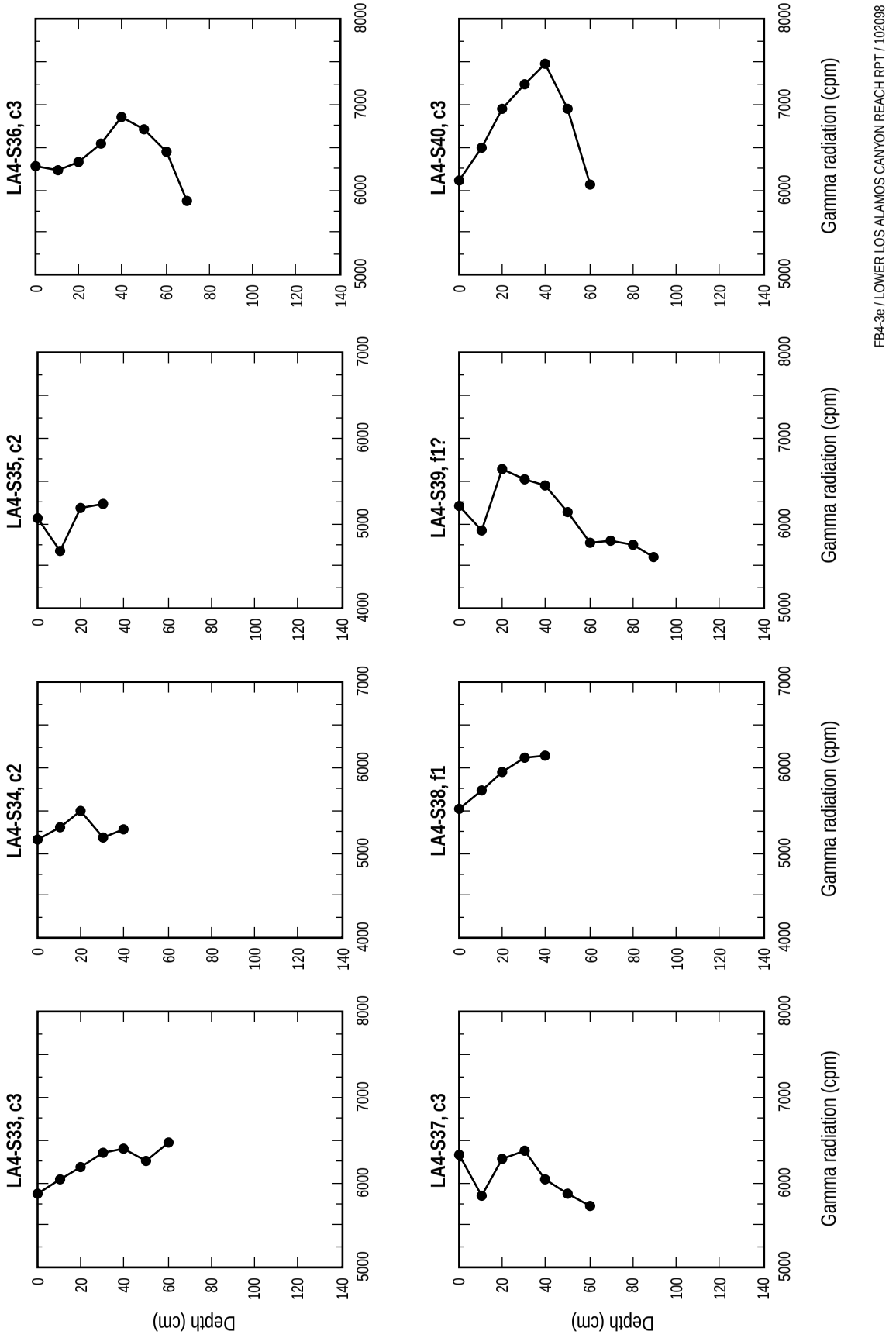


Figure B4-3e. Plots of gamma radiation against depth for the c2, c3, and f1 units in reach LA-4.

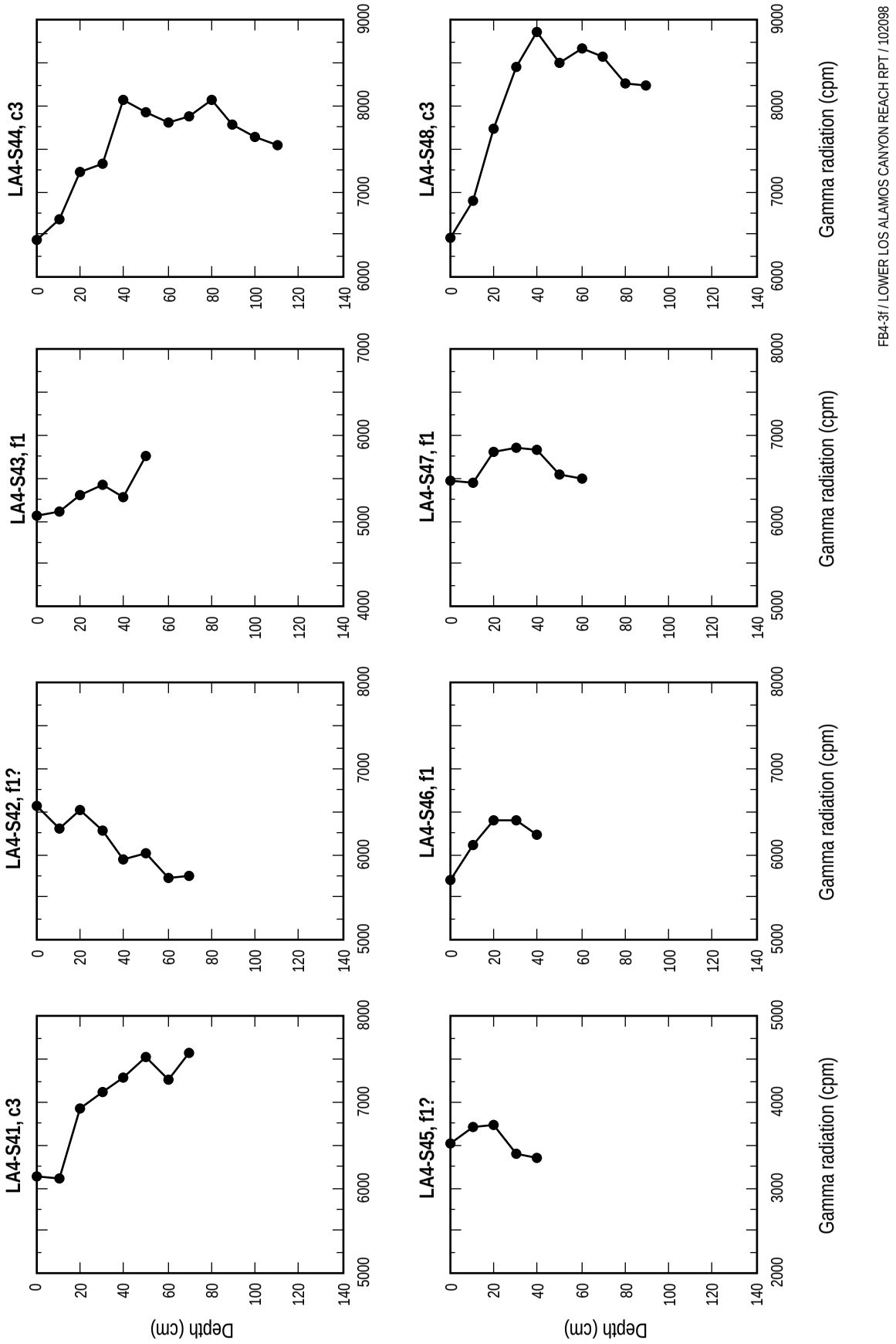
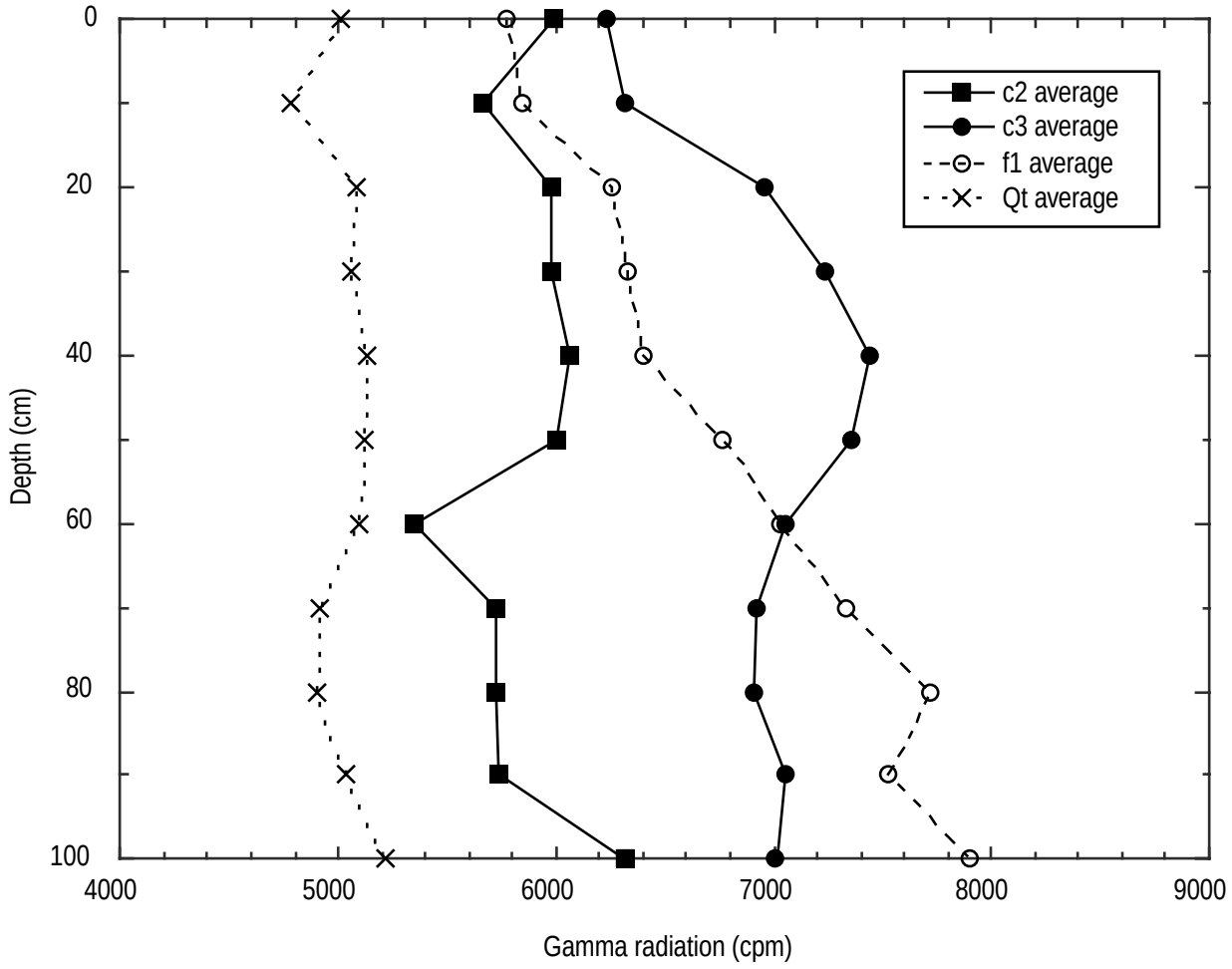
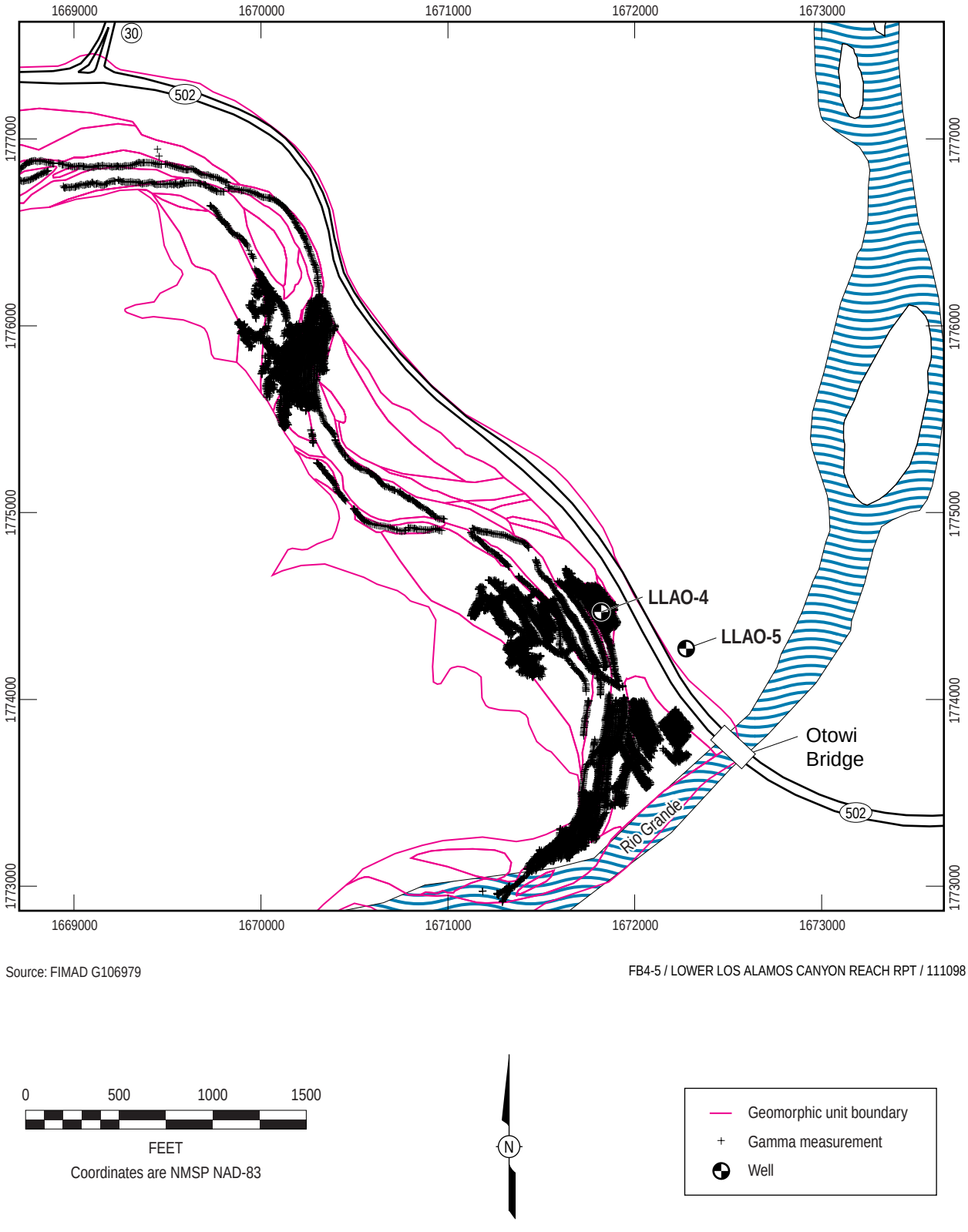


Figure B4-3f. Plots of gamma radiation against depth for the c3 and f1 units in reach LA-4.



FB4-4 / LOWER LOS ALAMOS CANYON REACH RPT / 091598

Figure B4-4. Average gamma radiation versus depth for geomorphic units in reach LA-4.



Source: FIMAD G106979

FB4-5 / LOWER LOS ALAMOS CANYON REACH RPT / 111098

Figure B4-5. Locations of gross gamma walkover radiation measurements in reach LA-5.

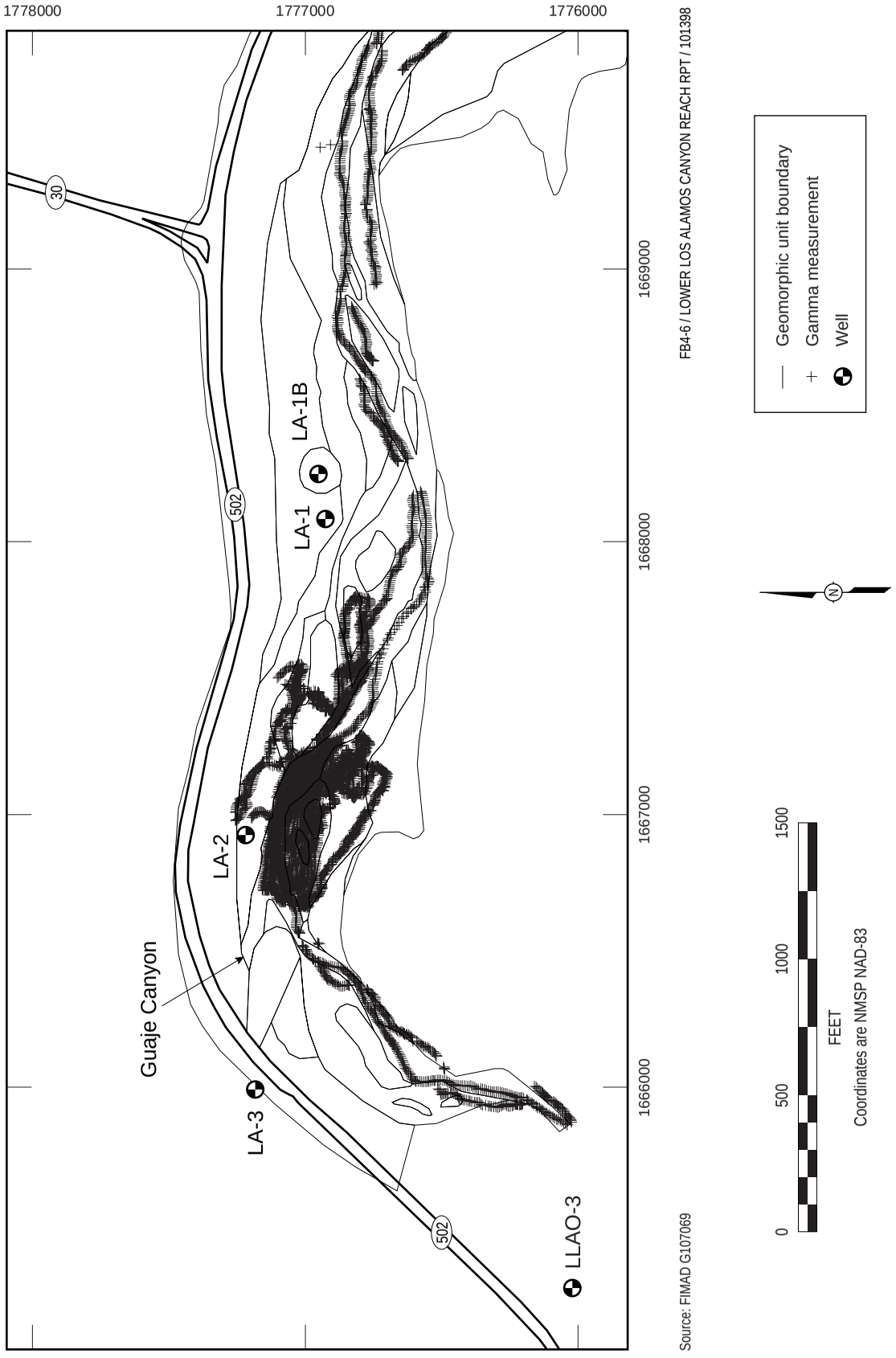


Figure B4-6. Map of reach LA-5 West showing locations of gross gamma walkover radiation measurements.

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

Fixed-point radiation data were obtained from 39 sites in reaches LA-5 and LA-5 West (Figures B4-7 and B4-8; Table B4-2). These data include 90 measurements of alpha radiation, 39 measurements of beta radiation, and 56 measurements of gamma radiation. Alpha radiation ranged from 0 to 14.4 cpm, beta radiation ranged from 281 to 423 cpm, and gamma radiation ranged from 4136 to 6404 cpm. The locations of full-suite sediment samples in LA-5 were in part biased by these measurements, but analytical results indicated that concentrations of all radionuclides were too low to allow effective use of these field instruments, and all of these measurements appear to represent background variations. Therefore, these measurements were not used further in this investigation.

B-4.2.2.3 In *Situ* Gamma Spectroscopy Survey

Five *in situ* gamma spectroscopy measurements were made in reach LA-5, in part to test the utility of this instrument in providing rapid estimates of the amount of gamma-emitting radionuclides present within the sediment. The only analyte identified in the gamma spectroscopy analyses that is a potential contaminant in lower Los Alamos Canyon is cesium-137. Cesium-137 was reported in four of the analyses at low levels of from 0.24 to 0.37 pCi/g, suggesting that the measured cesium-137 was derived from worldwide fallout. These results are consistent with measurements from fixed analytical laboratories (Table B4-3).

B-4.2.3 Supplemental Characterization between Reaches

After it was recognized in upper Los Alamos Canyon that gross gamma radiation walkover measurements provided a fast and efficient means to identify variations in gamma radiation, supplemental characterization between reaches was conducted in May 1996. This characterization involved the collection of gamma radiation measurements from a series of short (20 to 100 m long) sections of the active stream channel and adjacent post-1942 geomorphic units, extending a distance of more than 6 km from Basalt Springs to the Rio Grande. These measurements supplemented data obtained by the same method along 7 km of upper Los Alamos Canyon (Reneau et al. 1998, 59160).

Figure B4-9 summarizes the gamma walkover data obtained between Technical Area (TA) -2 in upper Los Alamos Canyon, within reach LA-1, and the Rio Grande. This figure shows average values from each measurement interval for both the active channel and the adjacent surfaces where fine-grained overbank facies sediment has been deposited (primarily c2 surfaces). Gamma radiation is relatively low between TA-2 and DP Canyon, approximately 25,000 cpm or less, which probably records background values in upper Los Alamos Canyon. Gamma radiation increases dramatically at DP Canyon in reach LA-2 and then progressively decreases to reach LA-3 near state road NM 4, although radiation at LA-3 is still elevated relative to radiation upstream from DP Canyon. A major drop in gamma radiation is apparent downstream from the confluence of Pueblo Canyon and Los Alamos Canyon, and average gamma radiation is typically less than 20,000 cpm in reach LA-4. A gradual decrease in gamma radiation is seen between LA-4 and the Rio Grande. Because of the relatively low levels of cesium-137 measured in lower Los Alamos Canyon, this downstream decrease in gamma radiation between Basalt Springs and the Rio Grande apparently records variations in background radiation associated with the different rock units exposed in lower Los Alamos Canyon. Therefore, these measurements are not useful in defining variations in cesium-137 concentration in lower Los Alamos Canyon.

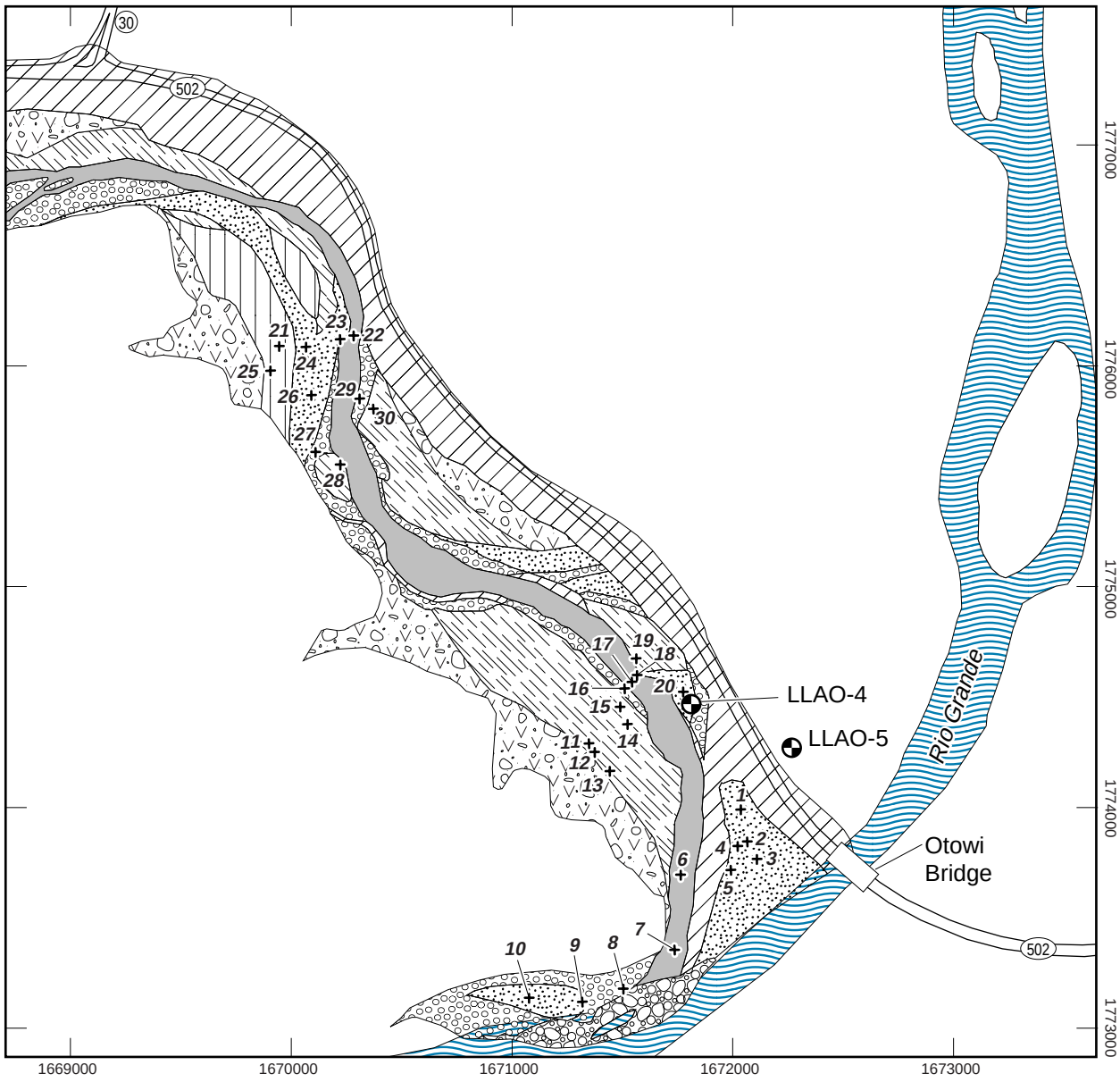


Figure B4-7. Fixed-point radiation measurement sites in reach LA-5.

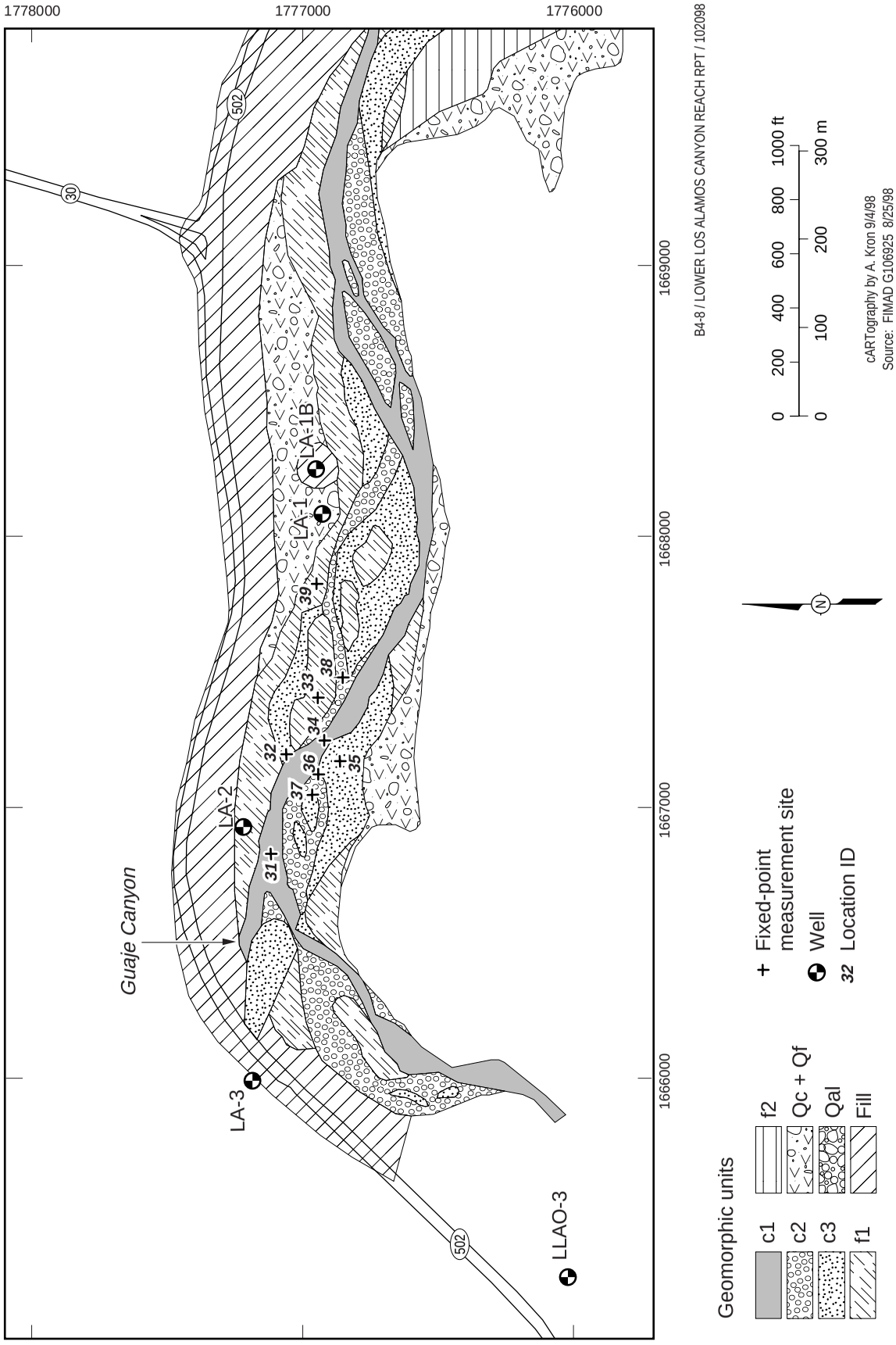


Figure B4-8. Fixed-point radiation measurement sites in reach LA-5 West.

TABLE B4-2

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-5

Fixed-Point Site	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Alpha Radiation (cpm)	Beta Radiation (cpm)	Gamma Radiation (cpm)
LA5-1	LA-0032	LA-5	c3	0	7.2	423	6252
				0	8		
LA5-2		LA-5	c3	0	5.2	417	5906
				0	9.4		
LA5-3		LA-5	c3	0	8.6	347	4762
				0	8		
LA5-4		LA-5	c3	0	5.2	356	4704
				0	6.4		
LA5-5		LA-5	c3	0	6	333	4824
				0	7.4		
LA5-6		LA-5	c1	0	4.2	310	4635
				0	7.2		
LA5-7	LA-0033	LA-5	c1	0	4.4	292	4136
				0	6.4		
LA5-8		LA-5	c2	0	5.4	311	4353
				0	7.4		
LA5-9		LA-5	c3	0	7	315	4593
				0	5.8		
LA5-10		LA-5	c3	0	5.4	313	5277
				0	7.6		
LA5-11		LA-5	f1	0	4.8	386	5357
				0	7.8		
LA5-12		LA-5	f1	0	9	378	5569
				0	5.2		
LA5-13	LA-0034	LA-5	f1	0	6.8	374	5976
				0	6.4		
LA5-14	LA-0035	LA-5	f1	0	6.8	377	5707
				0	14.4		
LA5-15		LA-5	f1	0	6.4	307	5243
				0	9.6		
LA5-16	LA-0036	LA-5	c2	0	7.6	316	5394
				0	7.2		
LA5-17		LA-5	c1	0	6.6	327	4944
				0	9.2		
LA5-18		LA-5	c1	0	4.6	296	4810
				0	5.4		
LA5-19	LA-0088	LA-5	c3	0	3	335	5642
				0	9		
				10			5161
				20	7.6		5242
				30	0		5879

TABLE B4-2 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-5

Fixed-Point Site	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Alpha Radiation (cpm)	Beta Radiation (cpm)	Gamma Radiation (cpm)
LA5-19	LA-0088	LA-5	c3	40	3.4		5954
				50			6404
				60	5.4		6246
				70			6162
				80	5		6248
				90	0		5832
				100	0		5449
LA5-20		LA-5	c3?	0	6.2	316	4978
				0	8		
LA5-21		LA-5	f2	0	10.4	350	5551
				0	6		
LA5-22	LA-0037	LA-5	c1	0	2.2	295	4560
				0	4.4		
LA5-23		LA-5	c3	0	3.6	315	4555
				0	7		
LA5-24	LA-0080	LA-5	c3	0	6.6	323	5155
				0	6.2		
LA5-25	LA-0081	LA-5	f2	0	8.4	343	5707
				0	9.4		
LA5-26	LA-0082	LA-5	c3	0	3.2	314	4948
				0	5.2		
LA5-27		LA-5	c2	0	7	315	4880
				0	4.4		
LA5-28	LA-0083	LA-5	f1	0	4	315	5248
				0	7.6		
				25	4.6		
				25	0		
				10			5030
				20			5341
				30			5459
				40			5581
				50			5436
				60			5442
				70	7.6		5668
LA5-29	LA-0085	LA-5	c2	0	5.6	322	5187
				0	8		
LA5-30	LA-0038	LA-5	f1	0	5.6	303	5185
				0	13.4		
				0	12.4		
				0	11		
LA5-31		LA-5 West	c1	0	4	281	4283
				0	4.8		

TABLE B4-2 (continued)

FIXED-POINT RADIATION MEASUREMENTS IN REACH LA-5

Fixed-Point Site	Sample Location ID	Subreach	Geomorphic Unit	Depth (cm)	Alpha Radiation (cpm)	Beta Radiation (cpm)	Gamma Radiation (cpm)
LA5-32		LA-5 West	c3	0	7	329	5726
				0	6.8		
LA5-33		LA-5 West	f1	0	7.2	353	5789
				0	8.4		
LA5-34		LA-5 West	c1	0	9.6	298	4273
				0	7		
LA5-35		LA-5 West	c3	0	4.6	308	4735
				0	7.8		
LA5-36		LA-5 West	c2	0	9	328	5147
				0	7		
LA5-37		LA-5 West	c3	0	4.8	310	5512
				0	6.2		
LA5-38		LA-5 West	c2	0	5.2	304	4694
				0	6.4		
LA5-39		LA-5 West	f1	0	5.2	306	5361
				0	7.8		

TABLE B4-3

***IN SITU* GAMMA SPECTROSCOPY MEASUREMENTS IN REACH LA-5**[a]

Fixed-Point Site	Sample Location ID[b]	Geomorphic Unit	Cs-137 (gamma spec)	Cs-137 (fixed lab)	Am-241 (gamma spec)	Am-241 (fixed lab, alpha spec)
LA5-1	LA-0032	c3	0.366	0.43	ND[c]	0.025
LA5-6	(LA-0033)	c1	ND	0.08 (U)[d]	ND	0.023 (U)
LA5-11	(LA-0034)	f1	0.242	0.39	ND	0.026 (U)
LA5-15	(LA-0035)	f1	0.247	0.79	ND	0.065
LA5-21	(LA-0037)	f2	0.290	NA[e]	ND	NA

a. pCi/g

b. Sample locations in parentheses indicate nearby sites in same geomorphic unit.

c. ND = not detected

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

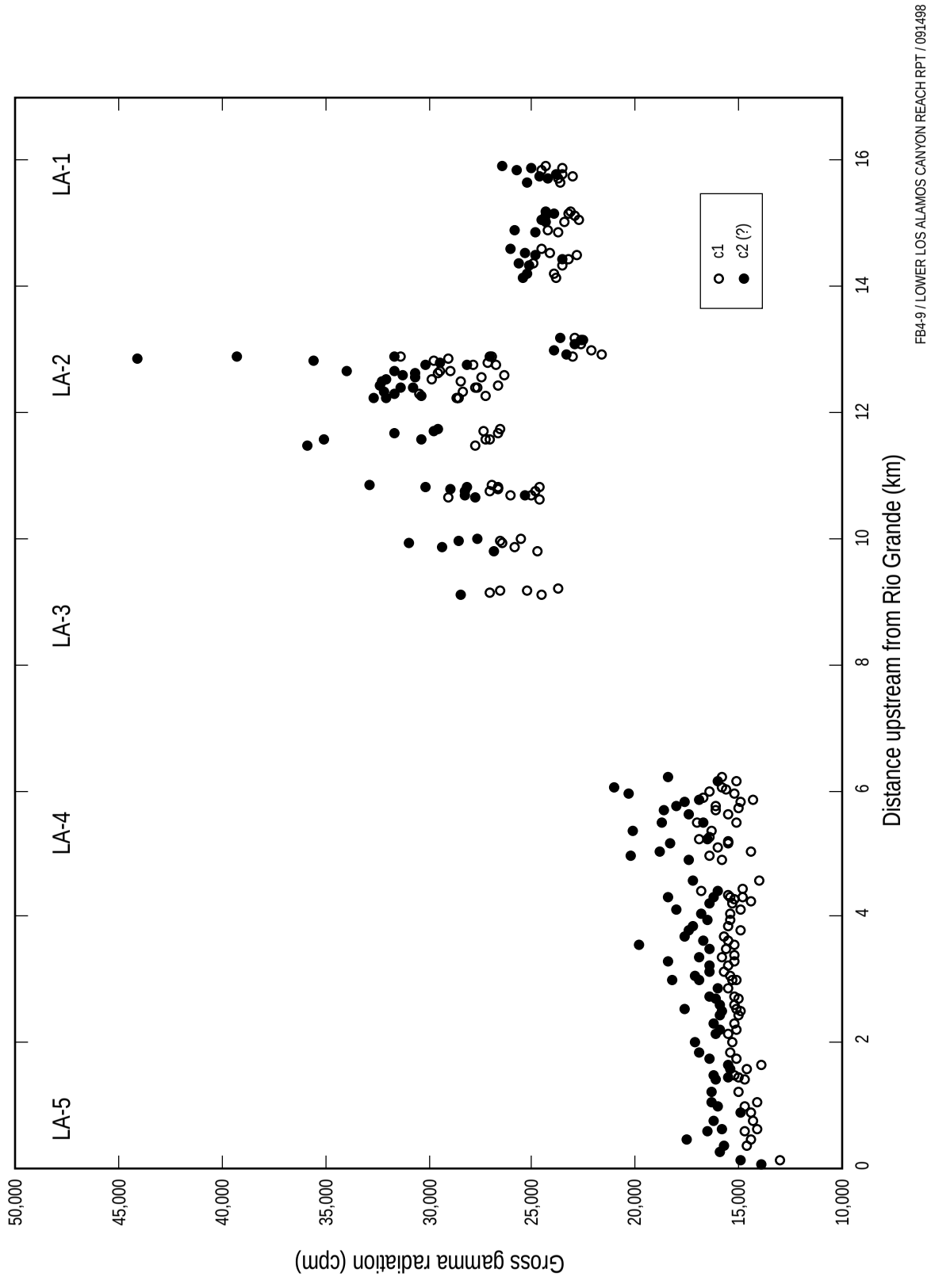


Figure B4-9. Average values of gross gamma radiation measured in short walkover surveys between TA-2 and the Rio Grande.

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 lower Los Alamos Canyon and the primary goals of each sampling event are summarized in Table B5-1.

TABLE B5-1

SUMMARY OF SEDIMENT SAMPLING EVENTS IN LOWER LOS ALAMOS CANYON

Reach	Sampling Event	Sampling Dates	Number of Samples Collected*	Type of Analyses and Primary Goals
LA-4	1	8/4/97–8/5/97	39	Cesium and plutonium analyses plus limited-suite analyses on seven samples; examine general variations in contaminants between geomorphic units and between subreaches; evaluate vertical variations in cesium and plutonium concentration; provide initial estimates of cesium and plutonium inventories; evaluate collocation of cesium and plutonium and presence of other analytes above background values
LA-4	2	10/28/97–10/29/97	43	Cesium and plutonium analyses on 35 samples plus limited-suite analyses on 14 samples; reduce uncertainty in cesium and plutonium inventories and in horizontal and vertical extent of contaminated sediments; evaluate reliability of highest plutonium-239,240 and strontium-90 results from first sampling event; evaluate concentrations of limited-suite analytes and possible collocation of contaminants
LA-5	1	5/30/96	7	Full-suite analyses; determine contaminants present above background values and primary risk drivers; examine general variations in contaminants between geomorphic units
LA-5	2	5/29/97	24	Plutonium analyses plus cesium-137 analyses on three samples; evaluate horizontal and vertical extent of contaminated sediments and variations in plutonium concentration between geomorphic units, between sediment facies, and with depth; provide estimate of plutonium inventory; examine fine-grained sediments for presence of cesium-137 above background values

*Number of samples does not include quality assurance duplicates.

APPENDIX C RESULTS OF QUALITY ASSURANCE/QUALITY CONTROL ACTIVITIES

C-1.0 SUMMARY OF QUALITY ASSURANCE/QUALITY CONTROL ACTIVITIES

The lower Los Alamos Canyon data set consists of analytical results from sediment samples collected from reaches LA-4 and LA-5 as described in the body of this report. Most of the data set for lower Los Alamos Canyon is composed of isotopic and gamma-emitting radionuclides. Selected samples were also analyzed for the full suite of analyses that also included 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 lower 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 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 [RNs]), 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 conducted 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 except for the rejection of antimony data from reach LA-5. 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 125 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-4	LA-5	
Pesticides and PCBs	7	7	14
SVOCs	0	7	7
Inorganic chemicals	12	7	19
Boron, total cyanide, titanium	0	7	7
Uranium, total uranium	0	7	7
Americium-241 (by alpha spectroscopy)	0	7	7
Gross alpha/beta radiation	0	7	7
Gross gamma radiation	0	7	7
Gamma-spectroscopy radionuclides	77	10	87
Tritium	0	7	7
Isotopic plutonium	78	32	110
Isotopic thorium	0	7	7
Isotopic uranium	0	7	7
Strontium-90	21	7	28

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 limits, also referred to as the maximum estimated quantitation limits (EQLs), 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 19 surface and subsurface sediment samples were collected in lower Los Alamos Canyon for inorganic chemical analyses. The total includes 12 samples from reach LA-4 and 7 samples from reach LA-5. 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, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, selenium, silver, sodium, 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, cadmium, and selenium analyses using ICPES. Most of the analyses for arsenic, antimony, selenium, and thallium were performed using the GFAA method and yielded detection limits below background values. Mercury was also analyzed using the CVAA method 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 and their corresponding analytes 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 3552R – LCS recoveries for aluminum and antimony were outside control limits (72 to 128%). No qualifiers were associated with these analytes because of adequate recoveries of matrix spikes and laboratory duplicates.

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 2252 – Sample results for analytes including arsenic and selenium were less than five times the amount reported in the associated preparation blank. These results were qualified as not detected.

- RN 3886R – Sample results for beryllium, chromium, nickel, and thallium 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 was 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 2185 – Spike results were outside the recovery range for arsenic, lead, and manganese. Manganese data were qualified as estimated with a potential for high bias (J+). Arsenic results were qualified as estimated (J), and lead did not require any special qualifiers.

- RN 2252 – Spike results were outside the recovery range for antimony (0%) and titanium (133%). Antimony data were qualified as rejected (R), and titanium data did not require any special qualifiers.

- RN 3522R – Spike results (analytical and matrix) were outside the acceptable recovery range for arsenic and selenium. Selenium data were qualified as not detected, but the associated value is an estimate (UJ). Arsenic data were qualified as estimated (J). All results should be regarded as estimated values.

- RN 3886R – Spike analysis was performed on a sample from a different request number. This analysis was determined to have no significant impact on data usability.

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 two reaches. The average relative percent difference (RPD) between the samples and the laboratory duplicate samples exceeded 35% for the following samples.

- RN 2185 – 35% RPD exceeded for lead. Sample results were J-qualified.

- RN 2252 – 35% RPD exceeded for aluminum, chromium, sodium, and titanium. Sample results were J-qualified.

- RN 3522R – 35% RPD 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 sample.

- RN 3886R – Percent difference was exceeded for potassium and sodium (25 and 36%). Sample results for these analytes were J-qualified.

The qualified results for the samples and analytes from the RN listed above are reported in Section C-5.0.

C-3.0 RADIOCHEMICAL ANALYSES

C-3.1 General

A total of 117 combined surface and subsurface sediment samples were collected in the lower Los Alamos Canyon reaches for radiochemical analyses, including a total of 85 and 32 samples for reaches LA-4 and LA-5, respectively. The samples were analyzed by one or more of the methods listed in Table C3-1.

TABLE C3-1

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 most 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. Maximum allowable estimated quantitation limits (EQLs) as defined by the ER Project analytical services SOW (LANL 1995, 49738) for radiochemicals are provided in Section D-1.0. 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 isotopic plutonium and americium-241 were less than or equal to 0.01 pCi/g, whereas the required EQL for these isotopes is 0.1 pCi/g. All MDAs for radiochemical analyses were equal to or less than the required EQL with the following exceptions.

- RN 2185 – Sample 04LA-96-0162 for americium-241 had an MDA of 0.16 pCi/g, which is slightly above the EQL of 0.1 pCi/g. The result was qualified as estimated and not detected (UJ-qualified).

- RN 3195R – Five samples for plutonium-239,240 had MDAs slightly above the EQL of 0.1 pCi/g. The MDAs ranged from 0.105 to 0.17 pCi/g. The results were qualified as estimated and not detected (UJ-qualified).

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. The analytical results for all individual spike samples were 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.

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 EQL. All method blanks met these criteria.

Laboratory duplicate analyses were evaluated to determine precision in the analyses. Results are evaluated based on a three-sigma TPU agreement between the field sample and the laboratory duplicate sample. All results reported for laboratory duplicate samples were within three-sigma TPU of the original sample.

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 that 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 were within these guidelines.

C-4.0 ORGANIC CHEMICAL ANALYSES

A total of 14 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).

C-4.1 Semivolatile Organic Chemical Analysis

Analyses for SVOCs were performed on seven samples at off-site fixed laboratories. Analyses were performed using EPA SW-846 Method 3540 to extract samples and EPA SW-846 Method 8270 for SVOC analyses. The SVOC analyte lists including their corresponding SOW-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 exception.

- RN 2184 – The analyte bis(2-ethylhexyl)phthalate was detected in the blank. Results were regarded as not detected because the sample was less than five times the concentration of the analyte in the blank.

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 exception.

- RN 2184 – Spike results exceeded the acceptable recovery range for n-nitroso-di-n-propylamine; however, this compound was not detected in any of the associated samples. Therefore, no data qualification was necessary for this compound.

C-4.2 Organochlorine Pesticides and Polychlorinated Biphenyl Chemical Analysis

Analyses for PESTPCB were performed on 14 samples at off-site fixed laboratories. Analyses were performed using EPA SW-846 Method 3540 to extract samples and EPA SW-846 Method 8081 for PESTPCB analysis. All holding times for extraction and analyses and all other QC criteria were met for the PESTPCB analyses.

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 and C5-3 list the qualifiers for reaches LA-4 and LA-5, respectively.

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 REACH LA-4 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3522R	04LA-97-0221 -0222 -0223 -0224 -0225 -0227 -0228	Lead	J	Metals	The results for lead should be regarded as estimated (J) because the duplicate RPD was exceeded.
3522R	04LA-97-0221 -0222 -0223 -0224 -0225 -0227 -0228	Selenium	UJ	Metals	The results for selenium should be regarded as nondetected and estimated (UJ) because the spike, and continuous calibration verification were outside of specified control limits.
3522R	04LA-97-0221 -0222 -0224 -0225 -0227 -0228	Arsenic	J	Metals	The results for arsenic should be regarded as positively identified and estimated (J) because the matrix and analytical spike were outside of specified control limits.
3522R	04LA-97-0221	Beryllium, cobalt, mercury, potassium, sodium, nickel	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the minimum detection limit (MDL) but above the instrument detection limit.
3522R	04LA-97-0222 -0223	Cobalt, nickel	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
3522R	04LA-97-0224	Beryllium, cobalt, mercury, nickel	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
3522R	04LA-97-0225	Cobalt, potassium, nickel	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
3522R	04LA-97-0227	Beryllium, mercury	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
3522R	04LA-97-0228	Cobalt	J	Metals	The results should be regarded as estimated (J) because this analyte was detected below the MDL but above the instrument detection limit.
3886R	04LA-97-0514	Beryllium, chromium, thallium	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.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR REACH LA-4 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3886R	04LA-97-0538	Beryllium, chromium, nickel	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.
3886R	04LA-97-0526 -0552 -0553	Beryllium	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.
3886R	04LA-97-0514	Barium, calcium, cobalt, magnesium, nickel, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
3886R	04LA-97-0526	Cobalt, nickel, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
3886R	04LA-97-0538	Arsenic, barium, calcium, cobalt, magnesium, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
3886R	04LA-97-0552	Silver, arsenic, cadmium, cobalt, mercury, nickel, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
3886R	04LA-97-0553	Arsenic, barium, cobalt, chromium, magnesium, nickel, vanadium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
3886R	04LA-97-0514 -0526 -0538 -0552 -0553	Potassium, sodium	J	Metals	The results should be regarded as estimated (J) because the percent difference for the soil inductively coupled plasma serial dilution was between 25 and 36% when a 10% value is required.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR REACH LA-4 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3521R	04LA-97-0165 -0166 -0168 -0173 -0174 -0178 -0179 -0182 -0183 -0185 -0186 -0187 -0189 -0191 -0192 -0194 -0195 -0196 -0197 -0202 -0204 -0205	Plutonium-238,	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3521R	04LA-97-0165	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.
3521R	04LA-97-0166 -0168	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.
3521R	04LA-97-0169 -0194 -0205	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.
3521R	04LA-97-0171	Americium-241, cerium-144, cobalt-57, cobalt-60, cesium-137, 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.
3521R	04LA-97-0171 -0173 -0188 -0189 -0204	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 TPU.
3521R	04LA-97-0172 -0177 -0182 -0185 -0186 -0190 -0196 -0201	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.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR REACH LA-4 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3521R	04LA-97-0173 -0188 -0204	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.
3521R	04LA-97-0174 -0178 -0183 -0187 -0191 -0199	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.
3521R	04LA-97-0175 -0180 -0200	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.
3521R	04LA-97-0179	Cerium-144, cobalt-57, cobalt-60, 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.
3521R	04LA-97-0189 -0195	Americium-241, cerium-144, cobalt-57, cobalt-60, cesium-137, 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.
3521R	04LA-97-0192 -0202	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.
3521R	04LA-97-0197	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.
3523R	04LA-97-0221 -0223 -0224 -0225 -0227 -0228	Strontium-90	U	Strontium-90	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3523R	04LA-97-0221 -0225 -0228	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3523R	04LA-97-0221 -0222 -0227	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.
3523R	04LA-97-0223	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.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR REACH LA-4 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3523R	04LA-97-0224 -0228	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.
3523R	04LA-97-0225	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.
3887R	04LA-97-0515	Bismuth-212, protactinium-233, lead-211, 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 TPU.
3887R	04LA-97-0533	Bismuth-212, protactinium-233, 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 TPU.
3887R	04LA-97-0515 -0523 -0526 -0536	Americium-241	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma TPU.
3887R	04LA-97-0543	Cobalt-60	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma TPU.
3887R	04LA-97-0531	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 TPU.
3887R	04LA-97-0517	Cesium-134	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma TPU.
3887R	04LA-97-0524 -0530 -0531 -0536 -0543 -0547 -0561	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 TPU.
3887R	04LA-97-0514	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cadmium-109, cesium-137, potassium-40, lanthanum-140, protactinium-231, protactinium-233, lead-212, lead-214, radium-224, radium-226, thallium-208, annihilation radiation)	U	Gamma spectroscopy	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 REACH LA-4 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3887R	04LA-97-0515	Gamma spectroscopy suite (except, americium-241, actinium-228, bismuth-212, bismuth-214, cadmium-109, cesium-137, potassium-40, lead-211, lead-212, lead-214, radium-224, radium-226)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0516	Gamma spectroscopy suite (except, actinium-228, barium-140, bismuth-214, cerium-139, potassium-40, lanthanum-140, protactinium-231, 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.
3887R	04LA-97-0517	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cadmium-109, potassium-40, lanthanum-140, lead-212, lead-214, radium-224, radium-226, thallium-208, annihilation radiation)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0518	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cadmium-109, potassium-40, lanthanum-140, lead-212, lead-214, radium-224, 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.
3887R	04LA-97-0519	Gamma spectroscopy suite (except, actinium-228, bismuth-214, potassium-40, lanthanum-140, neptunium-237, protactinium-231, lead-212, lead-214, radium-226, radon-219, tin-113, thallium-208, annihilation radiation)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0521	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cadmium-109, cesium-137, potassium-40, protactinium-231, lead-212, lead-214, radium-223, radium-224, selenium-75, thallium-208, annihilation radiation)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0522	Gamma spectroscopy suite (except, actinium-228, bismuth-211, bismuth-212, bismuth-214, cesium-137, potassium-40, lanthanum-140, protactinium-231, lead-211, lead-212, lead-214, radium-224, 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 C5-2 (continued)

DATA QUALIFIERS FOR REACH LA-4 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3887R	04LA-97-0523	Gamma spectroscopy suite (except, actinium-228, barium-140, bismuth-214, cobalt-57, potassium-40, lanthanum-140, lead-212, lead-214, radium-226, tin-113)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0524	Gamma spectroscopy suite (except, actinium-228, barium-140, bismuth-214, cadmium-109, potassium-40, protactinium-231, lead-212, lead-214, radium-224, radium-226, selenium-75, thallium-208, annihilation radiation)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0525	Gamma spectroscopy suite (except, actinium-228, barium-140, bismuth-214, cadmium-109, potassium-40, neptunium-237, protactinium-231, lead-212, lead-214, radium-224, radium-226, tin-113, thallium-208, annihilation radiation)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0526	Gamma spectroscopy suite (except, actinium-228, barium-140, bismuth-211, bismuth-214, cesium-137, potassium-40, lead-212, lead-214, radium-224, radium-226, radon-219, thallium-208, 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.
3887R	04LA-97-0527	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cesium-137, potassium-40, lanthanum-140, protactinium-231, protactinium-233, lead-212, lead-214, radium-224, radium-226, radon-219, thorium-234, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0528	Gamma spectroscopy suite (except, actinium-228, bismuth-211, bismuth-214, cadmium-109, potassium-40, lanthanum-140, protactinium-231, lead-212, lead-214, radium-224, radium-226, radon-219, tin-113, thallium-208, zinc-65)	U	Gamma spectroscopy	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 REACH LA-4 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3887R	04LA-97-0529	Gamma spectroscopy suite (except, actinium-228, cadmium-109, potassium-40, protactinium-231, lead-211, lead-212, lead-214, radium-224, radium-226, thallium-208, annihilation radiation)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0530	Gamma spectroscopy suite (except, actinium-228, bismuth-214, potassium-40, lanthanum-140, protactinium-231, lead-212, lead-214, radium-223, radium-226, radon-219, thallium-208, zinc-65)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0531	Gamma spectroscopy suite (except, actinium-228, bismuth-211, bismuth-214, cerium-144, cesium-137, potassium-40, neptunium-237, protactinium-233, lead-212, lead-214, radium-224, radium-226, tin-113, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0532	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cadmium-109, cesium-137, potassium-40, neptunium-237, protactinium-233, lead-212, lead-214, radium-224, radium-226, selenium-75, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0533	Gamma spectroscopy suite (except, actinium-228, bismuth-212, bismuth-214, cesium-137, potassium-40, protactinium-233, lead-212, lead-214, radium-223, radium-224, 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.
3887R	04LA-97-0534	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cadmium-109, cerium-144, cesium-137, potassium-40, protactinium-231, protactinium-233, lead-212, lead-214, 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.
3887R	04LA-97-0535	Gamma spectroscopy suite (except, actinium-228, barium-140, bismuth-214, cesium-137, potassium-40, lead-212, lead-214, radium-226, radon-219, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR REACH LA-4 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3887R	04LA-97-0536	Gamma spectroscopy suite (except, actinium-228, bismuth-211, bismuth-214, cadmium-109, cesium-137, potassium-40, lanthanum-140, lead-212, lead-214, radium-224, radium-226, tin-113, thallium-208, 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.
3887R	04LA-97-0537	Gamma spectroscopy suite (except, actinium-228, bismuth-211, bismuth-214, cesium-137, potassium-40, lead-212, lead-214, radium-224, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0538	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cerium-144, cesium-137, potassium-40, lanthanum-140, protactinium-231, lead-212, lead-214, radium-224, radium-226, radon-219, thallium-208, annihilation radiation)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0539	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cesium-137, potassium-40, lead-212, lead-214, 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.
3887R	04LA-97-0540	Gamma spectroscopy suite (except, actinium-228, bismuth-211, bismuth-214, potassium-40, lead-212, lead-214, radium-224, radium-226, tin-113, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0541	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cesium-137, potassium-40, protactinium-233, 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.
3887R	04LA-97-0542	Gamma spectroscopy suite (except, actinium-228, barium-140, bismuth-211, bismuth-214, cadmium-109, cerium-139, cesium-137, potassium-40, manganese-54, lead-212, lead-214, radium-224, radium-226, thallium-208, 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.

TABLE C5-2 (continued)

DATA QUALIFIERS FOR REACH LA-4 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3887R	04LA-97-0543	Gamma spectroscopy suite (except, actinium-228, bismuth-211, bismuth-214, cadmium-109, , potassium-40, lanthanum-140, protactinium-231, lead-212, lead-214, radium-224, radium-226, thallium-208, annihilation radiation)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0544	Gamma spectroscopy suite (except, actinium-228, bismuth-211, bismuth-214, cadmium-109, cesium-137, potassium-40, protactinium-231, lead-212, lead-214, radium-224, thallium-208, annihilation radiation)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0545	Gamma spectroscopy suite (except, actinium-228, barium-140, bismuth-214, potassium-40, lead-212, lead-214, radium-224, 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.
3887R	04LA-97-0546	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cadmium-109, cesium-137, potassium-40, lead-212, lead-214, radium-226, thallium-208, annihilation radiation)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0547	Gamma spectroscopy suite (except, actinium-228, bismuth-211, bismuth-214, cadmium-109, cerium-144, cesium-137, potassium-40, lead-212, lead-214, radium-224, radium-226, thallium-208, zinc-65)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0549	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cesium-137, potassium-40, protactinium-231, lead-211, lead-212, lead-214, 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.
3887R	04LA-97-0561	Gamma spectroscopy suite (except, actinium-228, americium-241, bismuth-214, cadmium-109, cesium-137, potassium-40, neptunium-237, lead-212, lead-214, radium-224, 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 C5-2 (continued)

DATA QUALIFIERS FOR REACH LA-4 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3887R	04LA-97-0562	Gamma spectroscopy suite (except, actinium-228, barium-140, bismuth-211, bismuth-214, cadmium-109, cesium-137, potassium-40, lanthanum-140, neptunium-237, protactinium-231, lead-212, lead-214, radium-224, 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.
3887R	04LA-97-0514 -0515 -0516 -0517 -0518 -0519 -0520 -0525 -0526 -0527 -0528 -0529 -0533 -0535 -0537 -0539 -0540 -0541 -0542 -0543 -0544 -0545 -0546 -0549	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3887R	04LA-97-0562	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 TPU.
3887R	04LA-97-0518 -0519 -0529 -0540	Plutonium-239,240	U	Isotopic plutonium	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
3887R	04LA-97-0514 -0526 -0538 -0549 -0552 -0553 -0544 -0555 -0556 -0557 -0558 -0559 -0561 -0562	Strontium-90	U	Strontium-90	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.

TABLE C5-3

DATA QUALIFIERS FOR REACH LA-5 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
2252	04LA-96-0175 -0176 -0177 -0178 -0179 -0180 -0181	Antimony	R	Metals	Sample results were rejected because of zero matrix spike recoveries.
2252	04LA-96-0175 -0176 -0177 -0178 -0179 -0180 -0181	Arsenic	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.
2252	04LA-96-0177 -0179 -0180 -0181	Selenium	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.
2252	04LA-96-0175 -0176 -0177 -0178 -0179 -0180 -0181	Aluminum, chromium, titanium, sodium	J	Metals	The duplicate result for aluminum, chromium, titanium and sodium were outside control limits. Sample results were qualified and estimated (J).
2252	04LA-96-0175	Boron, cobalt, selenium, uranium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
2252	04LA-96-0176	Beryllium, cobalt, copper, nickel, uranium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
2252	04LA-96-0177	Boron, cobalt	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
2252	04LA-96-0178	Cyanide (total), boron, beryllium, cobalt, selenium, uranium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
2252	04LA-96-0179	Cyanide (total), boron, beryllium, cobalt	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
2252	04LA-96-0180	Beryllium, cobalt, nickel	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
2252	04LA-96-0180	Uranium	U	Metals	The result should be regarded as nondetected (U) because this analyte was not detected above the reported MDL.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR REACH LA-5 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
2252	04LA-96-0181	Boron, beryllium, cobalt, uranium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
2185	04LA-96-0160 -0161 -0162 -0163 -0164 -0165 -0166	Manganese	J+	Metals	The results should be regarded as estimated high bias (J+) because the spike recovery exceeded the upper limit and the results exceed the EDL.
2185	04LA-96-0160 -0161 -0162 -0163 -0164 -0165 -0166	Lead	J	Metals	The duplicate result for lead was outside control limits. Sample results were qualified and estimated (J).
2185	04LA-96-0160	Arsenic, beryllium, cobalt, mercury, sodium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
2185	04LA-96-0161 -0165	Cobalt, copper, potassium, sodium, nickel, vanadium, arsenic	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
2185	04LA-96-0162 -0166	Arsenic, cobalt, sodium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
2185	04LA-96-0163	Arsenic, beryllium, cobalt, sodium	J	Metals	The results should be regarded as estimated (J) because these analytes were detected below the MDL but above the instrument detection limit.
2185	04LA-96-0164	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 instrument detection limit.
2184	04LA-96-0160 -0161 -0162 -0163 -0164 -0165 -0166	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 then five times the concentration of the analyte in the blank. Which indicates the detected result was indistinguishable from blank contamination and the detected result was changed to nondetected at the EQL.
3195R	04LA-97-0018 -0022 -0023 -0024 -0027	Plutonium-239,240	UJ	Isotopic plutonium	The results should be regarded as nondetected and estimated (UJ) because this analyte was based on elevated MDAs.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR REACH LA-5 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3195R	04LA-97-0011 -0012 -0013 -0014 -0015 -0016 -0017 -0018 -0019 -0020 -0021 -0022 -0023 -0024 -0025 -0026 -0027 -0028 -0029 -0030 -0031 -0032 -0040 -0041 -0042	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3195R	04LA-97-0015 -0017 -0028 -0031 -0042	Plutonium-239,240	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
3195R	04LA-97-0011 -0012 -0013 -0014 -0016 -0021 -0026 -0029 -0032	Plutonium-239,240	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma TPU.
3195R	04LA-97-0040	Gamma spectroscopy suite (except, actinium-228, bismuth-214, cadmium-109, cesium-137, potassium-40, lead-212, lead-214, radium-224, 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.
3195R	04LA-97-0040	Uranium-235, lanthanum-140	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma TPU.
3195R	04LA-97-0041	Gamma spectroscopy suite (except, actinium-228, bismuth-212, bismuth-214, 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 REACH LA-5 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
3195R	04LA-97-0041	Barium-140, cadmium-109, neptunium-237, 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 TPU.
3195R	04LA-97-0042	Gamma spectroscopy suite (except, actinium-228, bismuth-214, potassium-40, lead-212, lead-214, 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.
3195R	04LA-97-0042	Barium-140, cadmium-109, cerium-139, cerium-144, protactinium-231, 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 TPU.
2252	04LA-96-0175	Gamma spectroscopy suite (except, actinium-228, bismuth-211, 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.
2252	04LA-96-0176	Gamma spectroscopy suite (except, cesium-134, 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.
2252	04LA-96-0177	Gamma spectroscopy suite (except, bismuth-211, 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.
2252	04LA-96-0178	Gamma spectroscopy suite (except, bismuth-211, bismuth-214, cesium-137, potassium-40, lead-212, thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2252	04LA-96-0179	Gamma spectroscopy suite (except, actinium-228, bismuth-211, bismuth-214, 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.
2252	04LA-96-0180	Gamma spectroscopy suite (Except, Potassium-40, Protactinium-234m, Lead-212, Thallium-208)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2252	04LA-96-0181	Gamma spectroscopy suite (except, actinium-228, cesium-137, potassium-40, lead-212, lead-214)	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because these analytes were not detected above the reported MDA.
2252	04LA-96-0180	Tritium	U	Tritium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR REACH LA-5 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
2252	04LA-96-0175 -0176 -0177 -0178 -0179 -0180 -0181	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
2252	04LA-96-0175 -0176 -0177 -0178 -0179 -0180 -0181	Strontium-90	U	Strontium-90	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
2252	04LA-96-0175 -0176 -0177 -0178 -0179 -0180 -0181	Uranium-235	U	Isotopic uranium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
2252	04LA-96-0175 -0176 -0177 -0180 -0181	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 TPU.
2185	04LA-96-0160 -0161 -0162 -0163 -0164 -0165	Tritium	U	Tritium	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma TPU.
2185	04LA-96-0166	Tritium	U	Tritium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
2185	04LA-96-0160 -0161 -0163 -0164 -0165 -0166	Plutonium-238	U	Isotopic plutonium	The results should be regarded as nondetected (U) because this analyte was not detected above the reported MDA.
2185	04LA-96-0160 -0161 -0162 -0164 -0165 -0166	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 TPU.
2185	04LA-96-0162	Americium-241	UJ	Americium-241	The results should be regarded as nondetected and estimated (UJ) because this analyte was based on elevated MDAs.
2185	04LA-96-0160 -0161 -0162 -0166	Americium-241	U	Gamma spectroscopy	The results should be regarded as nondetected (U) because the result is less than three times the reported one-sigma TPU.

TABLE C5-3 (continued)

DATA QUALIFIERS FOR REACH LA-5 SAMPLES

Request No.	Sample ID	Analyte(s)	Qualifier	Analyte Suite	Comments
2185	04LA-96-0160 -0162 -0164 -0166	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.
2185	04LA-96-0161	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.
2185	04LA-96-0163 -0165	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.

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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 lower 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.

For the full-suite sampling event in reach LA-5, a shipping error resulted in all these samples having two different sample ID numbers and analyses from two different laboratories. The samples were intended to be analyzed for radionuclides and inorganic chemicals by Rust Geotech and for organic chemicals by QST Environmental, but the samples were mistakenly sent to the QST Environmental analytical laboratory for all analyses. After this mistake was realized, the samples were resubmitted to Rust Geotech with a different series of sample ID numbers. In this report sample ID numbers 04LA-96-0160 through 04LA-96-0166 are used for the organic chemical analyses, and 04LA-96-0175 through 04LA-96-0181 are used for the remaining analyses. The analytical data that were received for inorganic chemicals and radionuclides for sample ID numbers 04LA-96-0160 through 04LA-96-0166 were not evaluated in the data review in Section 3.1.

TABLE D2-1

LOWER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

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	Pesticides and PCBs	SVOCs	SR-90
04LA-96-0160	LA-0032	c3	Overbank	LA-5	1	2185	2185	2185	2185	2185	2185	2185	2185	2185	2184	2184	2185
04LA-96-0161	LA-0033	c1	Channel	LA-5	1	2185	2185	2185	2185	2185	2185	2185	2185	2185	2184	2184	2185
04LA-96-0162	LA-0034	f1	Overbank	LA-5	1	2185	2185	2185	2185	2185	2185	2185	2185	2185	2184	2184	2185
04LA-96-0163	LA-0035	f1	Overbank	LA-5	1	2185	2185	2185	2185	2185	2185	2185	2185	2185	2184	2184	2185
04LA-96-0164	LA-0036	c2	Overbank	LA-5	1	2185	2185	2185	2185	2185	2185	2185	2185	2185	2184	2184	2185
04LA-96-0165	LA-0037	c1	Channel	LA-5	1	2185	2185	2185	2185	2185	2185	2185	2185	2185	2184	2184	2185
04LA-96-0166	LA-0038	f1	Overbank	LA-5	1	2185	2185	2185	2185	2185	2185	2185	2185	2185	2184	2184	2185
04LA-96-0175	LA-0032	c3	Overbank	LA-5	1	2252	2252	2252	2252	2252	2252	2252	2252	2252			2252
04LA-96-0176	LA-0033	c1	Channel	LA-5	1	2252	2252	2252	2252	2252	2252	2252	2252	2252			2252
04LA-96-0177	LA-0034	f1	Overbank	LA-5	1	2252	2252	2252	2252	2252	2252	2252	2252	2252			2252
04LA-96-0178	LA-0035	f1	Overbank	LA-5	1	2252	2252	2252	2252	2252	2252	2252	2252	2252			2252
04LA-96-0179	LA-0036	c2	Overbank	LA-5	1	2252	2252	2252	2252	2252	2252	2252	2252	2252			2252
04LA-96-0180	LA-0037	c1	Channel	LA-5	1	2252	2252	2252	2252	2252	2252	2252	2252	2252			2252
04LA-96-0181	LA-0038	f1	Overbank	LA-5	1	2252	2252	2252	2252	2252	2252	2252	2252	2252			2252
04LA-97-0011	LA-0077	c2	Channel	LA-5	2						3195R						
04LA-97-0012	LA-0078	f2	Overbank	LA-5	2						3195R						
04LA-97-0013	LA-0079	f2	Overbank	LA-5	2						3195R						
04LA-97-0014	LA-0080	c3	Channel	LA-5	2						3195R						
04LA-97-0015	LA-0081	f2	Overbank	LA-5	2						3195R						
04LA-97-0016	LA-0082	c3	Overbank	LA-5	2						3195R						
04LA-97-0017	LA-0082	c3	Channel	LA-5	2						3195R						
04LA-97-0018	LA-0084	f1	Overbank	LA-5	2						3195R						
04LA-97-0019	LA-0084	f1	Overbank	LA-5	2						3195R						
04LA-97-0020	LA-0038	f1	Overbank	LA-5	2						3195R						
04LA-97-0021	LA-0085	c2	Overbank	LA-5	2						3195R						
04LA-97-0022	LA-0085	c2	Channel	LA-5	2						3195R						
04LA-97-0023	LA-0086	f1	Overbank	LA-5	2						3195R						
04LA-97-0024	LA-0087	f1	Overbank	LA-5	2						3195R						

TABLE D2-1 (continued)

LOWER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

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	Pesticides and PCBs	SVOCs	SR-90
04LA-97-0025	LA-0088	f1? (c3?)	Overbank	LA-5	2						3195R						
04LA-97-0026	LA-0089	f1? (c3?)	Channel	LA-5	2						3195R						
04LA-97-0027	LA-0089	f1? (c3?)	Overbank	LA-5	2						3195R						
04LA-97-0028	LA-0089	f1? (c3?)	Overbank	LA-5	2						3195R						
04LA-97-0029	LA-0090	c3	Channel	LA-5	2						3195R						
04LA-97-0030	LA-0090	c3	Overbank	LA-5	2						3195R						
04LA-97-0031	LA-0090	c3	Channel	LA-5	2						3195R						
04LA-97-0032	LA-0091	c3	Overbank	LA-5	2						3195R						
04LA-97-0040	LA-0083	f1	Overbank	LA-5	2				3195R		3195R						
04LA-97-0041	LA-0083	f1	Overbank	LA-5	2				3195R		3195R						
04LA-97-0042	LA-0083	f1	Overbank	LA-5	2				3195R		3195R						
04LA-97-0165	LA-0122	c3	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0166	LA-0122	c3	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0168	LA-0122	c3	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0169	LA-0122	c3	Channel	LA-4 West	1				3521R		3521R						
04LA-97-0171	LA-0123	f1	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0172	LA-0124	f1b	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0173	LA-0125	c3	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0174	LA-0125	c3	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0175	LA-0125	c3	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0177	LA-0125	c3	Channel	LA-4 West	1				3521R		3521R						
04LA-97-0178	LA-0126	f1	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0179	LA-0127	c1	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0180	LA-0128	c3	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0182	LA-0128	c3	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0183	LA-0129	c3	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0185	LA-0129	c3	Channel	LA-4 West	1				3521R		3521R						
04LA-97-0186	LA-0129	c3	Channel	LA-4 West	1				3521R		3521R						

TABLE D2-1 (continued)

LOWER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

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	Pesticides and PCBs	SVOCs	SR-90
04LA-97-0187	LA-0130	f1? (c3?)	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0188	LA-0130	f1? (c3?)	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0189	LA-0130	f1? (c3?)	Channel	LA-4 West	1				3521R		3521R						
04LA-97-0190	LA-0131	c1	Overbank	LA-4 West	1				3521R		3521R						
04LA-97-0191	LA-0132	c3	Overbank	LA-4 East	1				3521R		3521R						
04LA-97-0192	LA-0132	c3	Channel	LA-4 East	1				3521R		3521R						
04LA-97-0194	LA-0132	c3	Channel	LA-4 East	1				3521R		3521R						
04LA-97-0195	LA-0133	c1	Channel	LA-4 East	1				3521R		3521R						
04LA-97-0196	LA-0134	f1	Overbank	LA-4 East	1				3521R		3521R						
04LA-97-0197	LA-0135	c3 (f1?)	Overbank	LA-4 East	1				3521R		3521R						
04LA-97-0199	LA-0135	c3 (f1?)	Overbank	LA-4 East	1				3521R		3521R						
04LA-97-0200	LA-0135	c3 (f1?)	Overbank	LA-4 East	1				3521R		3521R						
04LA-97-0201	LA-0136	f1	Overbank	LA-4 East	1				3521R		3521R						
04LA-97-0202	LA-0136	f1	Channel	LA-4 East	1				3521R		3521R						
04LA-97-0204	LA-0138	f1	Overbank	LA-4 East	1				3521R		3521R						
04LA-97-0205	LA-0139	c1	Channel	LA-4 East	1				3521R		3521R						
04LA-97-0221	LA-0122	c3	Overbank	LA-4 West	1				3523R		3523R			3522R			3523R
04LA-97-0222	LA-0125	c3	Overbank	LA-4 West	1				3523R		3523R			3522R			3523R
04LA-97-0223	LA-0128	c3	Overbank	LA-4 West	1				3523R		3523R			3522R			3523R
04LA-97-0224	LA-0129	c3	Overbank	LA-4 West	1				3523R		3523R			3522R			3523R
04LA-97-0225	LA-0132	c3	Overbank	LA-4 East	1				3523R		3523R			3522R			3523R
04LA-97-0227	LA-0135	c3 (f1?)	Overbank	LA-4 East	1				3523R		3523R			3522R			3523R
04LA-97-0228	LA-0137	c1	Overbank	LA-4 East	1				3523R		3523R			3522R			3523R
04LA-97-0514	LA-0208	c3	Channel	LA-4 East	2				3887R		3887R			3886R	3885R		3887R
04LA-97-0515	LA-0200	f1	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0516	LA-0200	f1	Overbank (?)	LA-4 West	2				3887R		3887R						
04LA-97-0517	LA-0200	f1	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0518	LA-0200	f1	Channel	LA-4 West	2				3887R		3887R						

TABLE D2-1 (continued)

LOWER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

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	Pesticides and PCBs	SVOCs	SR-90
04LA-97-0519	LA-0200	f1	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0520	LA-0123	f1	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0521	LA-0201	f1b	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0522	LA-0201	f1b	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0523	LA-0201	f1b	Channel	LA-4 West	2				3887R		3887R						
04LA-97-0524	LA-0124	f1b	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0525	LA-0124	f1b	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0526	LA-0212	c2	Overbank	LA-4 East	2				3887R		3887R			3886R	3885R		3887R
04LA-97-0527	LA-0205	Qt	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0528	LA-0201	f1b	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0529	LA-0201	f1b	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0530	LA-0202	f1	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0531	LA-0202	f1	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0532	LA-0203	f1b?	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0533	LA-0203	f1b?	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0534	LA-0204	f1b	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0535	LA-0206	c2	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0536	LA-0206	c2	Overbank	LA-4 West	2				3887R		3887R						
04LA-97-0537	LA-0206	c2	Channel	LA-4 West	2				3887R		3887R						
04LA-97-0538	LA-0212	c2	Channel	LA-4 East	2				3887R		3887R			3886R	3885R		3887R
04LA-97-0539	LA-0207	c3	Channel	LA-4 West	2				3887R		3887R						
04LA-97-0540	LA-0138	f1	Channel	LA-4 East	2				3887R		3887R						
04LA-97-0541	LA-0209	c2	Channel	LA-4 East	2				3887R		3887R						
04LA-97-0542	LA-0209	c2	Overbank	LA-4 East	2				3887R		3887R						
04LA-97-0543	LA-0209	c2	Overbank	LA-4 East	2				3887R		3887R						
04LA-97-0544	LA-0210	f1	Overbank	LA-4 East	2				3887R		3887R						
04LA-97-0545	LA-0211	c3	Channel	LA-4 East	2				3887R		3887R						
04LA-97-0546	LA-0211	c3	Channel	LA-4 East	2				3887R		3887R						

TABLE D2-1 (continued)

LOWER LOS ALAMOS CANYON SAMPLES, ANALYTE SUITES, AND REQUEST NUMBERS

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	Pesticides and PCBs	SVOCs	SR-90
04LA-97-0547	LA-0213	Qt	Overbank	LA-4 East	2				3887R		3887R						
04LA-97-0549	LA-0208	c3	Overbank	LA-4 East	2				3887R		3887R						3887R
04LA-97-0552	LA-0124	f1b	Overbank	LA-4 West	2						3887R			3886R	3885R		3887R
04LA-97-0553	LA-0133	c1	Channel	LA-4 East	2									3886R	3885R		3887R
04LA-97-0554	LA-0125	c3	Overbank	LA-4 West	2										3885R		3887R
04LA-97-0555	LA-0125	c3	Channel	LA-4 West	2												3887R
04LA-97-0556	LA-0125	c3	Overbank	LA-4 West	2												3887R
04LA-97-0557	LA-0125	c3	Overbank	LA-4 West	2												3887R
04LA-97-0558	LA-0125	c3	Overbank	LA-4 West	2												3887R
04LA-97-0559	LA-0125	c3	Overbank	LA-4 West	2												3887R
04LA-97-0560	LA-0137	c1	Overbank	LA-4 East	2										3885R		
04LA-97-0561	LA-0208	c3	Overbank	LA-4 East	2				3887R		3887R						3887R
04LA-97-0562	LA-0208	c3	Overbank	LA-4 East	2				3887R		3887R						3887R

TABLE D2-2

LOWER LOS ALAMOS CANYON
REQUEST NUMBERS AND ANALYTICAL LABORATORIES

Request Number	Analytical Laboratory
2185	QST Environmental[a]
2252	Rust Geotech[b]
3195R	Thermo Nutech[c]
3521R	QST Environmental
3522R	Thermo Nutech
3523R	QST Environmental
3885R	Paragon Analytics, Inc.[d]
3886R	Paragon Analytics, Inc.
3887R	Paragon Analytics, Inc.

a. QST Environmental laboratory located in Gainesville, Florida; formerly Environmental Science and Engineering (ESE)
b. Rust Geotech laboratory located in Grand Junction, Colorado
c. Thermo Nutech laboratory located in Oak Ridge, Tennessee
d. Paragon Analytics, Inc., laboratory located in Fort Collins, Colorado; formerly ATI laboratory

D-3.0 SUMMARY OF LOWER 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 lower 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 LOWER 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	19	N/A*	N/A	N/A	19	999	7590
Antimony	12	12	0.7	5.3	N/A	N/A	N/A
Arsenic	19	7	0.92	1.8	12	0.5	2.9
Barium	19	N/A	N/A	N/A	19	14	104
Beryllium	19	7	0.39	1.3	12	0.15	0.6
Boron	7	2	1.2	1.2	5	2.2	6.8
Cadmium	19	18	0.04	0.53	1	0.07	0.07
Calcium	19	N/A	N/A	N/A	19	597	7410
Chromium, total	19	2	1.7	2.6	17	1.9	9.4
Cobalt	19	N/A	N/A	N/A	19	0.52	4.4
Copper	19	N/A	N/A	N/A	19	2.2	10.8
Cyanide, total	7	5	0.15	0.15	2	0.15	0.3
Iron	19	N/A	N/A	N/A	19	3030	10200
Lead	19	N/A	N/A	N/A	19	4	31.6
Magnesium	19	N/A	N/A	N/A	19	316	1940
Manganese	19	N/A	N/A	N/A	19	116	364
Mercury	19	12	0.011	0.03	7	0.014	0.04
Nickel	19	1	1.6	1.6	18	2.1	7.1
Potassium	19	N/A	N/A	N/A	19	256	2880
Selenium	19	17	0.18	0.83	2	0.37	0.4
Silver	19	18	0.1	0.53	1	0.64	0.64
Sodium	19	N/A	N/A	N/A	19	57.1	1530
Thallium	19	19	0.18	0.88	N/A	N/A	N/A
Titanium	7	N/A	N/A	N/A	7	133	394
Uranium	7	1	0.1	0.1	6	0.15	0.51
Uranium, total	7	N/A	N/A	N/A	7	1.9	5.4
Vanadium	19	1	7.01	7.01	18	3.5	20.6
Zinc	19	N/A	N/A	N/A	19	14.1	38.4

*N/A = not applicable

TABLE D3-2

SUMMARY OF RADIONUCLIDE ANALYSES FROM LOWER 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	7	5	0.023	0.032	2	0.052	0.065
GROSSAB	Gross alpha radiation	7	N/A*	N/A	N/A	7	18.75	55.83
GROSSAB	Gross beta radiation	7	N/A	N/A	N/A	7	24.45	40.07
GROSSG	Gross gamma radiation	7	N/A	N/A	N/A	7	N/A	N/A
GSCAN	Actinium-228	47	5	0.25	1.85	42	0.306	2.41
GSCAN	Americium-241	87	70	-0.515	0.752	17	0.148	4.64
GSCAN	Annihilation radiation	47	34	-0.199	0.2396	13	0.099	0.263
GSCAN	Barium-140	47	38	-2.04	1.546	9	0.325	3.42
GSCAN	Bismuth-211	47	30	0	2.2	17	0.4	2.34
GSCAN	Bismuth-212	47	46	-1.78	5.31	1	1.79	1.79
GSCAN	Bismuth-214	47	5	0.25	1.09	42	0.196	1.71
GSCAN	Cadmium-109	47	27	-0.618	3.93	20	1.64	5.07
GSCAN	Cerium-139	47	45	-0.063	0.09	2	0.042	0.058
GSCAN	Cerium-144	87	83	-5.79	1.53	4	0.252	0.404
GSCAN	Cesium-134	47	46	-0.194	0.12	1	0.24	0.24
GSCAN	Cesium-137	87	28	-0.045	1.55	59	0.106	4.65
GSCAN	Cobalt-57	87	86	-0.041	0.11	1	0.054	0.054
GSCAN	Cobalt-60	87	87	-0.175	0.16	N/A	N/A	N/A
GSCAN	Europium-152	87	84	-0.734	0.467	3	0.248	0.408
GSCAN	Iodine-129	23	23	-0.386	0.377	N/A	N/A	N/A
GSCAN	Lanthanum-140	47	33	-247	139	14	4.45	80.5
GSCAN	Lead-210	7	7	1.38	1.92	N/A	N/A	N/A
GSCAN	Lead-211	47	44	-1.48	2.72	3	0.657	1.86
GSCAN	Lead-212	47	1	1.31	1.31	46	0.53	2.07
GSCAN	Lead-214	47	3	0.24	1.22	44	0.3	1.76
GSCAN	Manganese-54	47	46	-0.096	0.08	1	0.134	0.134
GSCAN	Mercury-203	47	47	-0.174	0.11	N/A	N/A	N/A
GSCAN	Neptunium-237	87	81	-0.802	1.524	6	0.456	1.99
GSCAN	Potassium-40	87	1	26.7	26.7	86	17.5	33.9
GSCAN	Protactinium-231	47	30	-1.66	4.45	17	1.5	4.12
GSCAN	Protactinium-233	47	42	-0.095	0.19	5	0.02	0.217
GSCAN	Protactinium-234M	47	46	-18.1	17	1	32.04	32.04
GSCAN	Radium-223	47	45	-1.65	1.57	2	1.24	1.26
GSCAN	Radium-224	47	22	-12.7	2.99	25	0.792	4.22
GSCAN	Radium-226	47	15	0.426	3.53	32	0.891	5.35
GSCAN	Radon-219	47	40	-1.78	1.39	7	0.644	1.19
GSCAN	Ruthenium-106	87	87	-0.79	1.11	N/A	N/A	N/A
GSCAN	Selenium-75	47	44	-0.087	0.13	3	0.058	0.103

*N/A = not applicable

TABLE D3-2 (continued)

SUMMARY OF RADIONUCLIDE ANALYSES FROM LOWER 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	Sodium-22	87	87	-0.169	0.13	N/A*	N/A	N/A
GSCAN	Strontium-85	47	47	-0.305	0.12	N/A	N/A	N/A
GSCAN	Thallium-208	47	4	0.12	0.549	43	0.131	0.725
GSCAN	Thorium-227	47	47	-3.614	1.4	N/A	N/A	N/A
GSCAN	Thorium-234	47	46	-4.71	3.51	1	1.81	1.81
GSCAN	Tin-113	47	40	-0.155	0.12	7	0.052	0.091
GSCAN	Uranium-235	47	47	-0.0422	0.91	N/A	N/A	N/A
GSCAN	Yttrium-88	47	45	-0.1138	0.115	2	0.093	0.174
GSCAN	Zinc-65	47	43	-0.249	0.36	4	0.192	0.338
H3	Tritium	7	1	0.002	0.002	6	0.004	0.012
ISOPU	Plutonium-238	110	82	-0.09	0.04	28	0.015	0.227
ISOPU	Plutonium-239,240	110	6	-0.0066	0.082	104	0.0067	13.8
ISOTH	Thorium-228	7	N/A	N/A	N/A	7	0.67	1.88
ISOTH	Thorium-230	7	N/A	N/A	N/A	7	0.69	1.99
ISOTH	Thorium-232	7	N/A	N/A	N/A	7	0.63	1.77
ISOU	Uranium-234	7	N/A	N/A	N/A	7	0.63	2
ISOU	Uranium-235	7	7	0.04	0.04	N/A	N/A	N/A
ISOU	Uranium-238	7	N/A	N/A	N/A	7	0.63	1.8
SR90	Strontium-90	28	27	-0.68	0.81	1	12.8	12.8

*N/A = not applicable

TABLE D3-3

SUMMARY OF ORGANIC CHEMICAL ANALYSES FROM LOWER 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)
PESTPCB	Aldrin	14	13	0.00067	0.0025	1	0.00117	0.00117
PESTPCB	Aroclor-1016	14	14	0.0134	0.05	N/A*	N/A	N/A
PESTPCB	Aroclor-1221	14	14	0.0134	0.099	N/A	N/A	N/A
PESTPCB	Aroclor-1232	14	14	0.0134	0.05	N/A	N/A	N/A
PESTPCB	Aroclor-1242	14	14	0.0134	0.05	N/A	N/A	N/A
PESTPCB	Aroclor-1248	14	14	0.0134	0.05	N/A	N/A	N/A
PESTPCB	Aroclor-1254	14	14	0.0134	0.05	N/A	N/A	N/A
PESTPCB	Aroclor-1260	14	14	0.0134	0.05	N/A	N/A	N/A
PESTPCB	α-BHC	14	14	0.00067	0.0025	N/A	N/A	N/A
PESTPCB	β-BHC	14	14	0.00067	0.0025	N/A	N/A	N/A
PESTPCB	δ-BHC	14	14	0.00067	0.0025	N/A	N/A	N/A
PESTPCB	γ-BHC	14	14	0.00067	0.0025	N/A	N/A	N/A
PESTPCB	Chlordane (technical grade)	7	7	0.00335	0.00337	N/A	N/A	N/A
PESTPCB	α-Chlordane	14	14	0.00067	0.0025	N/A	N/A	N/A
PESTPCB	γ-Chlordane	14	14	0.00067	0.0025	N/A	N/A	N/A
PESTPCB	4,4'-DDD	14	14	0.00067	0.005	N/A	N/A	N/A
PESTPCB	4,4'-DDE	14	14	0.00067	0.005	N/A	N/A	N/A
PESTPCB	4,4'-DDT	14	13	0.00067	0.005	1	0.0051	0.0051
PESTPCB	Dieldrin	14	14	0.00067	0.005	N/A	N/A	N/A
PESTPCB	Endosulfan I	14	14	0.00067	0.0025	N/A	N/A	N/A
PESTPCB	Endosulfan II	14	14	0.00067	0.005	N/A	N/A	N/A
PESTPCB	Endosulfan sulfate	14	14	0.00067	0.005	N/A	N/A	N/A
PESTPCB	Endrin	14	14	0.00067	0.005	N/A	N/A	N/A
PESTPCB	Endrin aldehyde	14	14	0.00067	0.005	N/A	N/A	N/A
PESTPCB	Endrin ketone	7	7	0.0034	0.005	N/A	N/A	N/A
PESTPCB	Heptachlor	14	14	0.00067	0.0025	N/A	N/A	N/A
PESTPCB	Heptachlor epoxide	14	14	0.00067	0.0025	N/A	N/A	N/A
PESTPCB	4,4'-methoxychlor	14	14	0.00067	0.025	N/A	N/A	N/A
PESTPCB	Toxaphene (technical grade)	14	14	0.067	0.25	N/A	N/A	N/A
SEMI	Acenaphthene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Acenaphthylene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Aniline	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Anthracene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Azobenzene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Benz(a)anthracene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Benzo(a)pyrene	7	7	0.33	0.67	N/A	N/A	N/A

*N/A = not applicable

TABLE D3-3 (continued)

SUMMARY OF ORGANIC CHEMICAL ANALYSES FROM LOWER 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)
SEMI	Benzo(b)fluoranthene	7	7	0.33	0.67	N/A*	N/A	N/A
SEMI	Benzo(g,h,i)perylene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Benzo(k)fluoranthene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Benzoic acid	7	7	3.3	6.7	N/A	N/A	N/A
SEMI	Benzyl alcohol	7	7	1.3	2.6	N/A	N/A	N/A
SEMI	Bis(2-chloroethoxy)methane	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Bis(2-chloroethyl)ether	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Bis(2-ethylhexyl)phthalate	7	7	0.068	0.18	N/A	N/A	N/A
SEMI	4-Bromophenyl-phenylether	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Butylbenzylphthalate	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Carbazole	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	4-Chloro-3-methylphenol	7	7	0.66	1.3	N/A	N/A	N/A
SEMI	4-Chloroaniline	7	7	1.3	2.6	N/A	N/A	N/A
SEMI	2-Chloronaphthalene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	2-Chlorophenol	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	4-Chlorophenyl-phenyl ether	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Chrysene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Di-n-butylphthalate	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Di-n-octylphthalate	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Dibenz(a,h)anthracene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Dibenzofuran	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	1,2-Dichlorobenzene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	1,3-Dichlorobenzene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	1,4-Dichlorobenzene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	3,3'-Dichlorobenzidine	7	7	0.66	1.3	N/A	N/A	N/A
SEMI	2,4-Dichlorophenol	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Diethylphthalate	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Dimethyl Phthalate	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	2,4-Dimethylphenol	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	4,6-Dinitro-2-methylphenol	7	7	1.6	3.2	N/A	N/A	N/A
SEMI	2,4-Dinitrophenol	7	7	1.6	3.2	N/A	N/A	N/A
SEMI	2,4-Dinitrotoluene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	2,6-Dinitrotoluene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Fluoranthene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Fluorene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Hexachlorobenzene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Hexachlorobutadiene	7	7	0.33	0.67	N/A	N/A	N/A

*N/A = not applicable

TABLE D3-3 (continued)

SUMMARY OF ORGANIC CHEMICAL ANALYSES FROM LOWER 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)
SEMI	Hexachlorocyclopentadiene	7	7	0.33	0.67	N/A*	N/A	N/A
SEMI	Hexachloroethane	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Indeno(1,2,3-cd)pyrene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Isophorone	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	2-Methylnaphthalene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	2-Methylphenol	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	4-Methylphenol	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Naphthalene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	2-Nitroaniline	7	7	1.6	3.2	N/A	N/A	N/A
SEMI	3-Nitroaniline	7	7	1.6	3.2	N/A	N/A	N/A
SEMI	4-Nitroaniline	7	7	0.6	1.2	N/A	N/A	N/A
SEMI	Nitrobenzene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	2-Nitrophenol	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	4-Nitrophenol	7	7	1.6	3.2	N/A	N/A	N/A
SEMI	N-Nitroso-di-n-propylamine	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	N-Nitrosodimethylamine	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	N-Nitrosodiphenylamine	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	2,2'-Oxybis(1-chloropropane)	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Pentachlorophenol	7	7	1.6	3.2	N/A	N/A	N/A
SEMI	Phenanthrene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Phenol	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	Pyrene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	1,2,4-Trichlorobenzene	7	7	0.33	0.67	N/A	N/A	N/A
SEMI	2,4,5-Trichlorophenol	7	7	1.6	3.2	N/A	N/A	N/A
SEMI	2,4,6-Trichlorophenol	7	7	0.33	0.67	N/A	N/A	N/A
TOC	Carbon, total organic	7	N/A	N/A	N/A	7	787	11500

*N/A = not applicable

D-4.0 ANALYTICAL RESULTS FOR LOWER LOS ALAMOS CANYON COPCs

Tables D4-1 through D4-3 present analytical results for the analytes identified as chemicals of potential concern (COPCs) in the lower Los Alamos Canyon reaches, except for the key radionuclides, which are presented in Section 3.3. The data qualifiers are discussed in Appendix C.

TABLE D4-1

ANALYTICAL RESULTS FOR INORGANIC COPCS IN THE LOWER LOS ALAMOS CANYON REACHES[a]

Reach or Subreach	Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Depth (in.)	Antimony	Boron	Cadmium	Calcium	Copper	Lead	Magnesium	Potassium	Sodium	Selenium	Vanadium
LA-4 West	04LA-97-0221	LA-0122	c3	Overbank	14–17.5	5.3 (U)[b]	NA[c]	0.53 (U)	1830	6.5	11.1 (J)[d]	848	510	475	0.22 (UJ)[e]	5.4
LA-4 West	04LA-97-0222	LA-0125	c3	Overbank	27.5–36	4.9 (U)	NA	0.49 (U)	2220	8.4	31.6 (J)	896	620	777	0.27 (UJ)	6.2
LA-4 West	04LA-97-0223	LA-0128	c3	Overbank	8–12	4.7 (U)	NA	0.47 (U)	1380	9.5	31.6 (J)	567	504	543	0.26 (UJ)	8.6
LA-4 West	04LA-97-0224	LA-0129	c3	Overbank	8–15.5	5.0 (U)	NA	0.5 (U)	2250	5.9	16.5 (J)	872	771	538	0.24 (J)	6.3
LA-4 West	04LA-97-0552	LA-0124	f1b	Overbank	0–6	0.82 (U)	NA	0.07	7410	10	18.4	1580	1860 (J)	106 (J)	0.63 (U)	9.7
LA-4 East	04LA-97-0225	LA-0132	c3	Overbank	23.5–28.5	4.9 (U)	NA	0.49 (U)	1170	3.1	4.2 (J)	709	395	501	0.18 (UJ)	5.8
LA-4 East	04LA-97-0227	LA-0135	c3 (f1?)	Overbank	9–20	4.6 (U)	NA	0.46 (U)	2210	4.84	13.2 (J)	795	541	478	0.24 (UJ)	7.01 (U)
LA-4 East	04LA-97-0228	LA-0137	c1	Overbank	0–4	4.3 (U)	NA	0.43 (U)	3950	10.8	9.8 (J)	1380	806	572	0.22 (UJ)	10.1
LA-4 East	04LA-97-0514	LA-0208	c3	Channel	25.5–35.5	0.71 (U)	NA	0.04 (U)	770	4.9	6.5	547	399 (J)	80.6 (J)	0.54 (U)	6.3
LA-4 East	04LA-97-0526	LA-0212	c2	Overbank	0–6.5	0.9 (U)	NA	0.05 (U)	6980	10	11.9	1940	1530 (J)	309 (J)	0.69 (U)	13.1
LA-4 East	04LA-97-0538	LA-0212	c2	Channel	6.5–23.5	0.7 (U)	NA	0.04 (U)	597	2.6	5.1	316	256 (J)	57.1 (J)	0.53 (U)	3.5
LA-4 East	04LA-97-0553	LA-0133	c1	Channel	0–2	1.1 (U)	NA	0.06 (U)	2470	2.5	4.7	986	694 (J)	134 (J)	0.83 (U)	6.4
LA-5	04LA-96-0175	LA-0032	c3	Overbank	0–3	(R)[f]	3.3	0.2 (U)	3440	5.9	26.2	1580	2120	1430 (J)	0.4	13.9
LA-5	04LA-96-0176	LA-0033	c1	Channel	0–4	(R)	1.2 (U)	0.2 (U)	1320	2.2	5.1	600	556	497 (J)	0.3 (U)	6.5
LA-5	04LA-96-0177	LA-0034	f1	Overbank	0–4	(R)	2.5	0.2 (U)	3830	5.4	8.8	1780	2260	1530 (J)	0.7 (U)	18.8
LA-5	04LA-96-0178	LA-0035	f1	Overbank	0–4	(R)	2.4	0.2 (U)	3320	5	9.8	1560	2020	1360 (J)	0.37	16.4
LA-5	04LA-96-0179	LA-0036	c2	Overbank	0–3	(R)	2.2	0.2 (U)	3220	5.2	9	1480	1840	1180 (J)	0.67 (U)	18.8
LA-5	04LA-96-0180	LA-0037	c1	Channel	0–3	(R)	1.2 (U)	0.2 (U)	1380	2.8	4	658	1020	966 (J)	0.62 (U)	8.7
LA-5	04LA-96-0181	LA-0038	f1	Overbank	0–2	(R)	6.8	0.2 (U)	4910	5.8	9.5	1590	2880	875 (J)	0.74 (U)	20.6

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 associated numerical value is estimated to be more uncertain than would normally be expected for that analysis.
e. UJ = The analyte was analyzed for but not detected. Reported value is an estimate of the sample-specific quantitation limit or detection limit.
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 D4-2

ANALYTICAL RESULTS FOR RADIONUCLIDE COPCs IN THE LOWER LOS ALAMOS CANYON REACHES[a]

Reach or Subreach	Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Depth (in.)	Cesium-134[b] (pCi/g)	Europium-152[b] (pCi/g)
LA-4 West	04LA-97-0171	LA-0123	f1	Overbank	0–10	NA[c]	0.349
LA-4 West	04LA-97-0179	LA-0127	c1	Overbank	0–4.5	NA	0.408
LA-4 East	04LA-97-0195	LA-0133	c1	Channel	0–2	NA	0.248
LA-5	04LA-96-0176	LA-0033	c1	Channel	0–4	0.24	0.26 (U)[d]

a. Data for americium-241; cesium-137; plutonium-238; and plutonium-239,240 are in Section 3.3.

b. Results for cesium-134 and europium-152 are shown only for those samples with detects for one of these analytes.

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.

TABLE D4-3

ANALYTICAL RESULTS FOR ORGANIC COPCs IN THE LOWER LOS ALAMOS CANYON REACHES[a]

Reach or Subreach	Sample ID	Location ID	Geomorphic Unit	Sediment Facies	Depth (in.)	Aldrin	4,4´-DDT
LA-4 West	04LA-97-0552	LA-0124	f1b	Overbank	0–6	0.002 (U)[b]	0.004 (U)
LA-4 West	04LA-97-0554	LA-0125	c3	Overbank	27.5–36	0.002 (U)	0.0051
LA-4 East	04LA-97-0514	LA-0208	c3	Channel	25.5–35.5	0.0017 (U)	0.0035 (U)
LA-4 East	04LA-97-0526	LA-0212	c2	Overbank	0–6.5	0.0019 (U)	0.0039 (U)
LA-4 East	04LA-97-0538	LA-0212	c2	Channel	6.5–23.5	0.0017 (U)	0.0034 (U)
LA-4 East	04LA-97-0553	LA-0133	c1	Channel	0–2	0.0025 (U)	0.005 (U)
LA-4 East	04LA-97-0560	LA-0137	c1	Overbank	0–4	0.0022 (U)	0.0044 (U)
LA-5	04LA-96-0160	LA-0032	c3	Overbank	0–3	0.00117	0.000671 (U)
LA-5	04LA-96-0161	LA-0033	c1	Channel	0–4	0.00067 (U)	0.00067 (U)
LA-5	04LA-96-0162	LA-0034	f1	Overbank	0–4	0.000671 (U)	0.000671 (U)
LA-5	04LA-96-0163	LA-0035	f1	Overbank	0–4	0.000671 (U)	0.000671 (U)
LA-5	04LA-96-0164	LA-0036	c2	Overbank	0–3	0.00067 (U)	0.00067 (U)
LA-5	04LA-96-0165	LA-0037	c1	Channel	0–3	0.00067 (U)	0.00067 (U)
LA-5	04LA-96-0166	LA-0038	f1	Overbank	0–2	0.000673 (U)	0.000673 (U)

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.

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 lower 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 data 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 three 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-4 data by a plus symbol, and reach LA-5 data by an “x.”

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 three groups of data: the Laboratory sediment background data, reach LA-4 data, and reach LA-5 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 lower Los Alamos Canyon sediment 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).

E-1.2.2 Antimony

There are no antimony detects in reach LA-4; thus, statistical testing is not appropriate. 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). Note that antimony sample results for reach LA-5 were rejected because of a serious quality control deficiency (Appendix C-2.0), and thus are not shown on the

TABLE E1-1

SUMMARY OF THE P-VALUES FROM THE GEHAN STATISTICAL TESTING

Analyte	Reach LA-4	Reach LA-5
Aluminum	>0.999	0.5
Antimony	no background data	N.A.[a]
Arsenic	0.978	0.996
Barium	0.753	0.074
Beryllium	0.942	0.963
Boron	no reach data	**0.044**[b]
Cadmium	N/A[c]	N/A
Calcium	0.068	**0.007**
Chromium, total	>0.999	0.071
Cobalt	0.602	0.589
Copper	**0.042**	0.326
Cyanide, total	N.A.	0.996
Iron	>0.999	0.455
Lead	0.088	0.448
Magnesium	0.505	**0.045**
Manganese	0.996	0.965
Mercury	N/A	N/A
Nickel	0.995	0.261
Potassium	0.999	**0.047**
Selenium	N/A	N/A
Silver	N/A	N/A
Sodium	0.858	**0.001**
Thallium	no background data	no background data
Titanium	N.A.	0.078
Uranium, total	N.A.	0.389
Uranium	N.A.	0.970
Vanadium	0.997	**0.035**
Zinc	0.998	0.786

a. N.A. = not available (no data for this analyte in this reach)

b. Bolded values indicate that reach sample results are significantly greater than background values.

c. N/A = not applicable (statistical tests are not appropriate because of the high frequency of nondetected values)

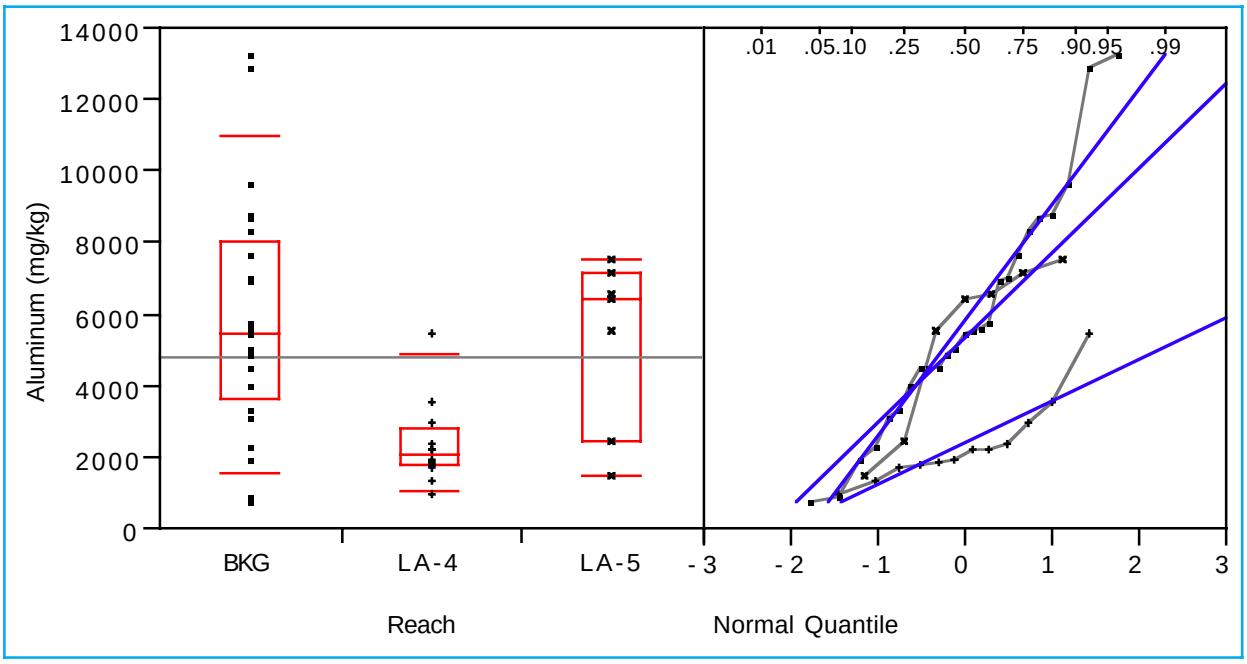

Figure E1-1. Box plot for aluminum.

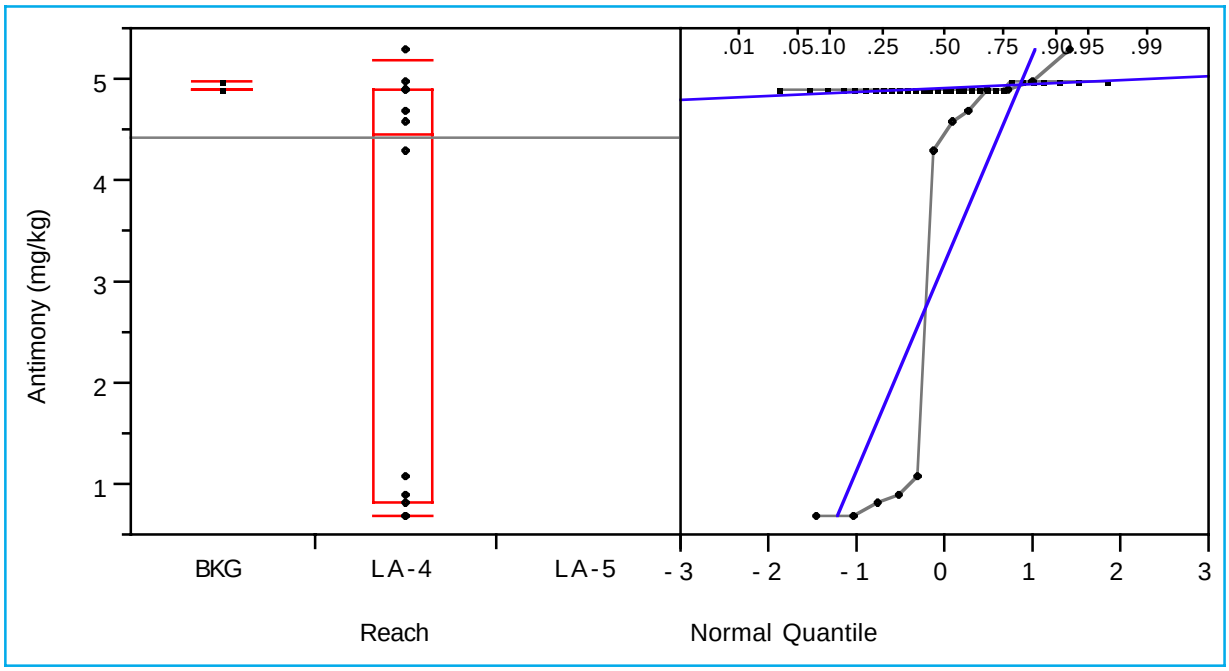

Figure E1-2a. Box plot for antimony.

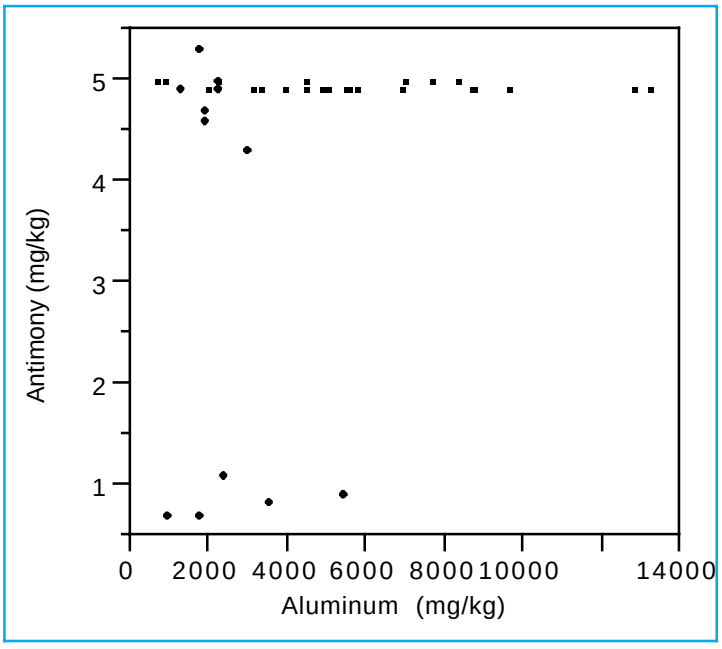

Figure E1-2b. Scatter plot for antimony versus aluminum.

box plots or scatter plot. Because some detection limits are greater than the antimony background value, antimony is retained as a COPC. There are some samples with detection limits less than the background value. Based on the lack of detected antimony sample results for any Los Alamos Canyon or Pueblo Canyon sediment sample, there is no evidence for significant releases of antimony into streams in the Los Alamos Canyon watershed.

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 significant 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 several samples in reaches LA-4 or LA-5 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 concentrations.

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 three samples in reach LA-4 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 concentrations.

E-1.2.6 Boron

Boron analytical results were obtained from samples collected in reach LA-5. Results of the statistical testing (Table E1-1) suggest that reach LA-5 sample results are elevated relative to background data. A review of the data plotted by reach (Figure E1-6a) and versus aluminum (Figure E1-6b) confirms these results. In addition, one boron result from LA-5 is more than 50% greater than the background value. Thus, boron is retained as a COPC.

E-1.2.7 Cadmium

Cadmium was not usually detected in the reach samples 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 mostly nondetected values to aluminum (Figure E1-7b). It is important to recognize that the apparently elevated sample results in reach LA-4 are all nondetected values. 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.

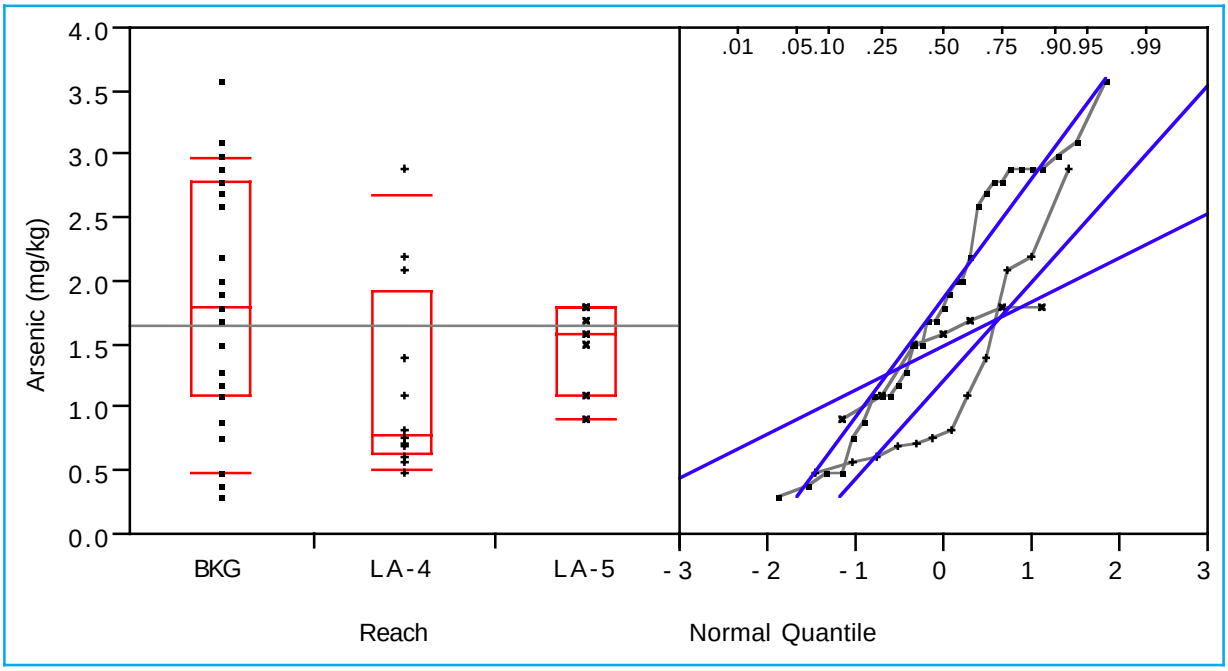

Figure E1-3a. Box plot for arsenic.

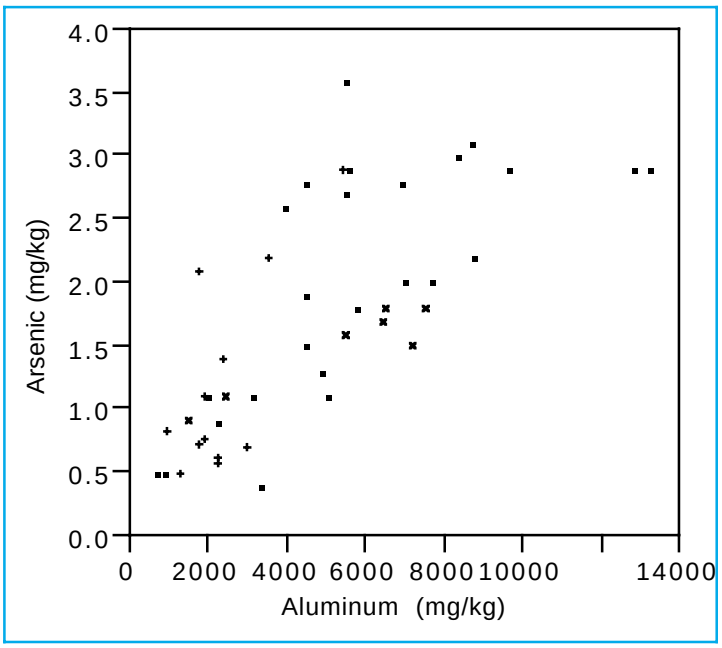

Figure E1-3b. Scatter plot for arsenic versus aluminum.

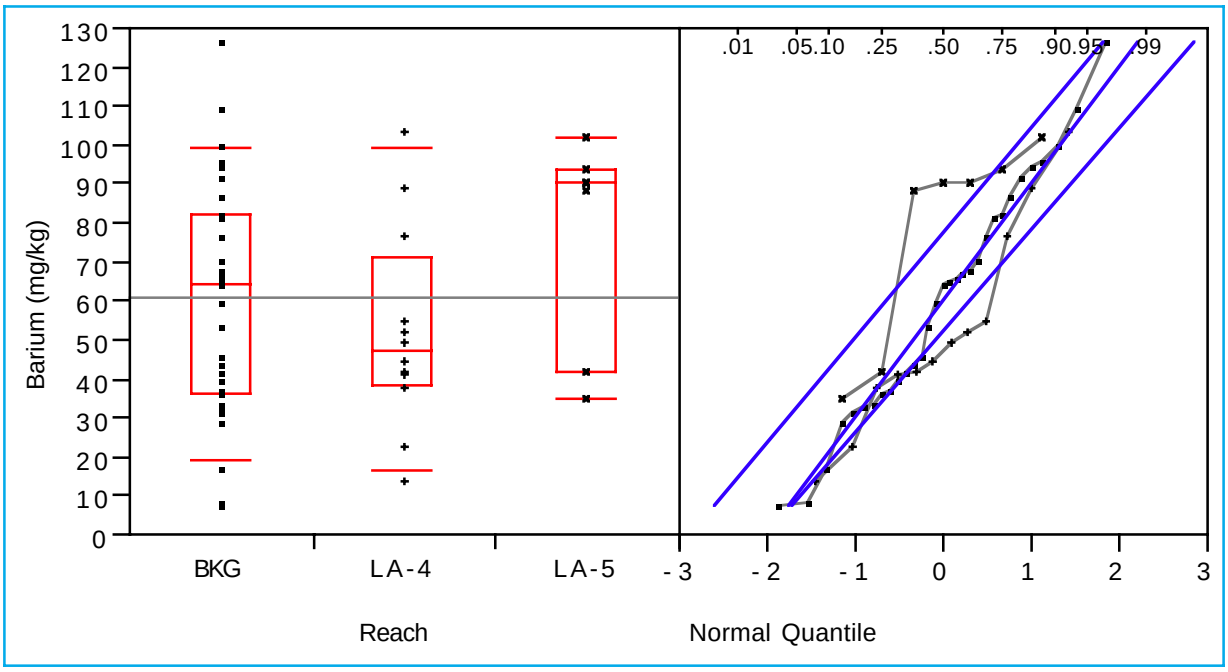

Figure E1-4a. Box plot for barium.

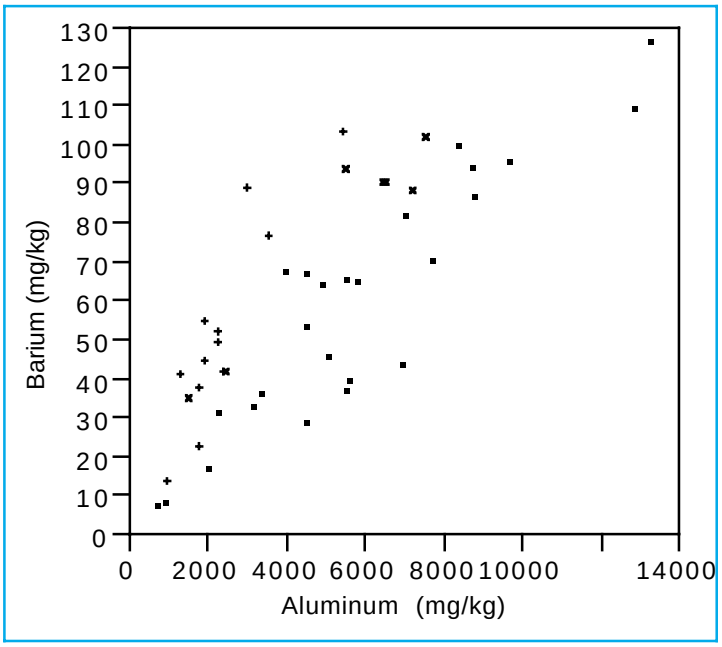

Figure E1-4b. Scatter plot for barium versus aluminum.

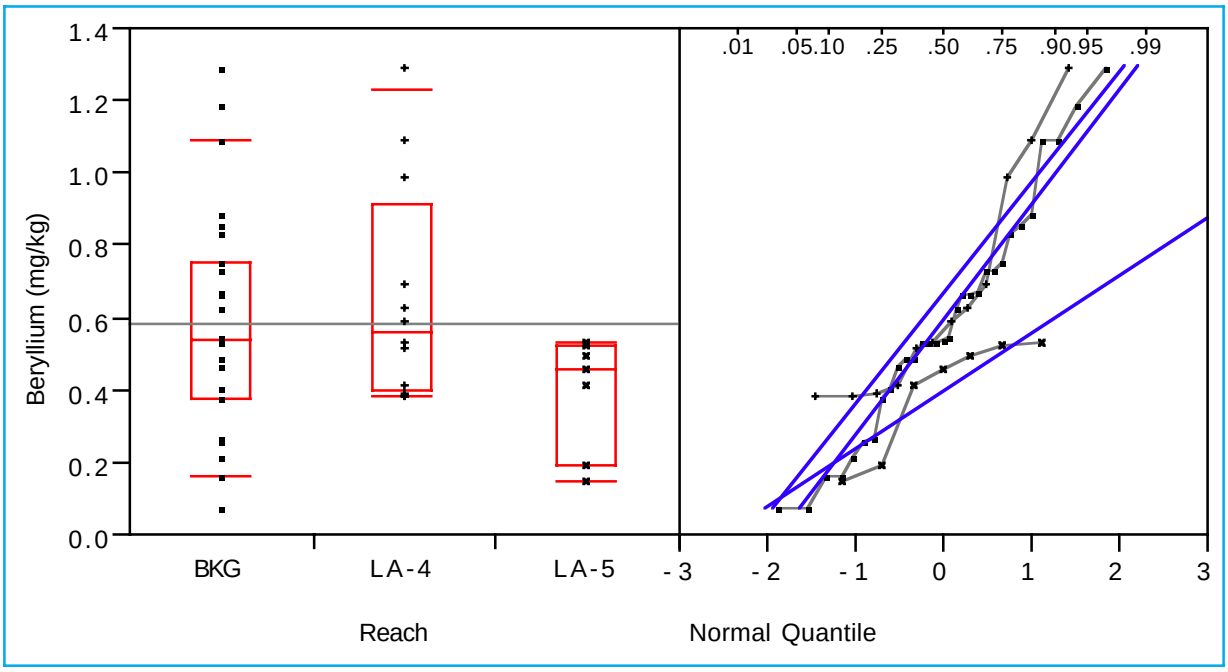

Figure E1-5a. Box plot for beryllium.

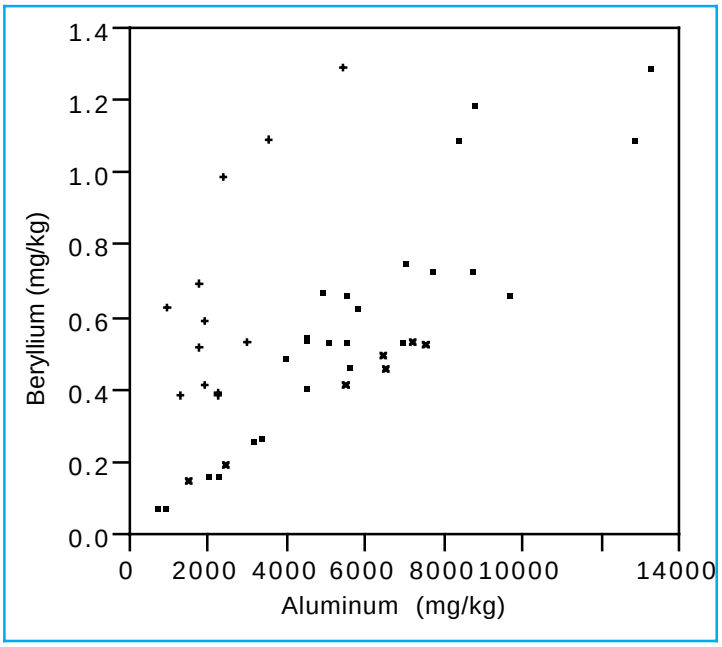

Figure E1-5b. Scatter plot for beryllium versus aluminum.

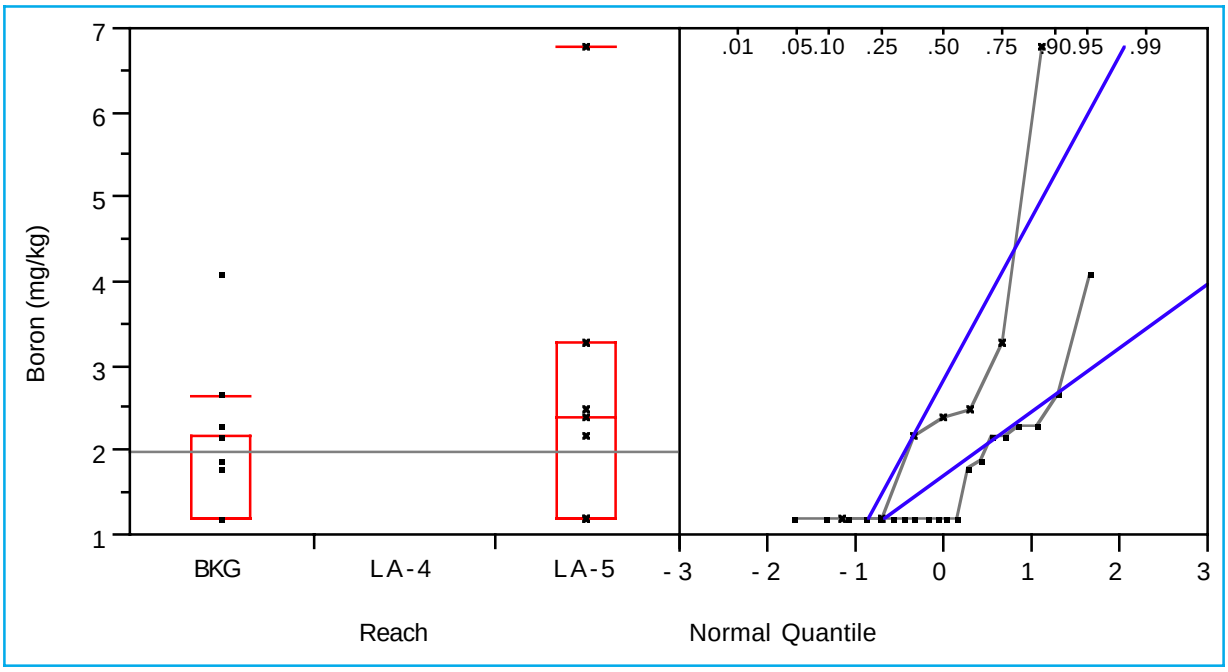

Figure E1-6a. Box plot for boron.

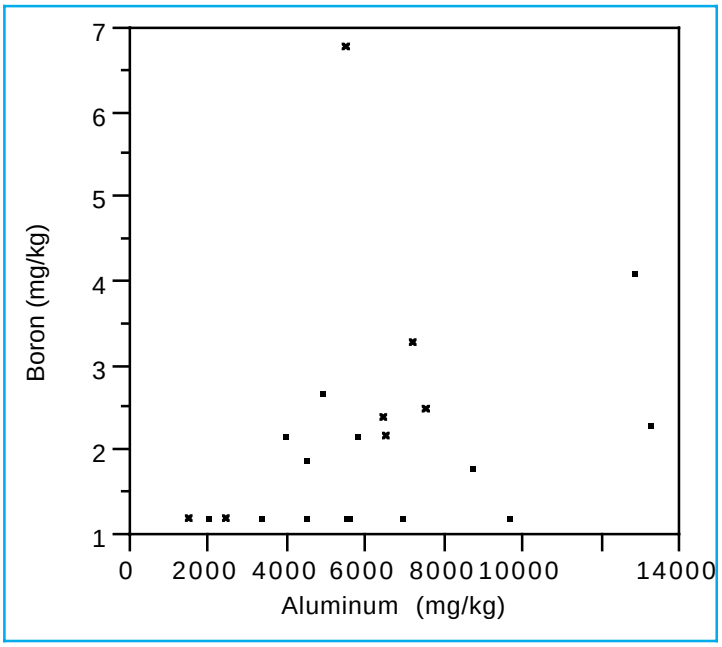

Figure E1-6b. Scatter plot for boron versus aluminum.

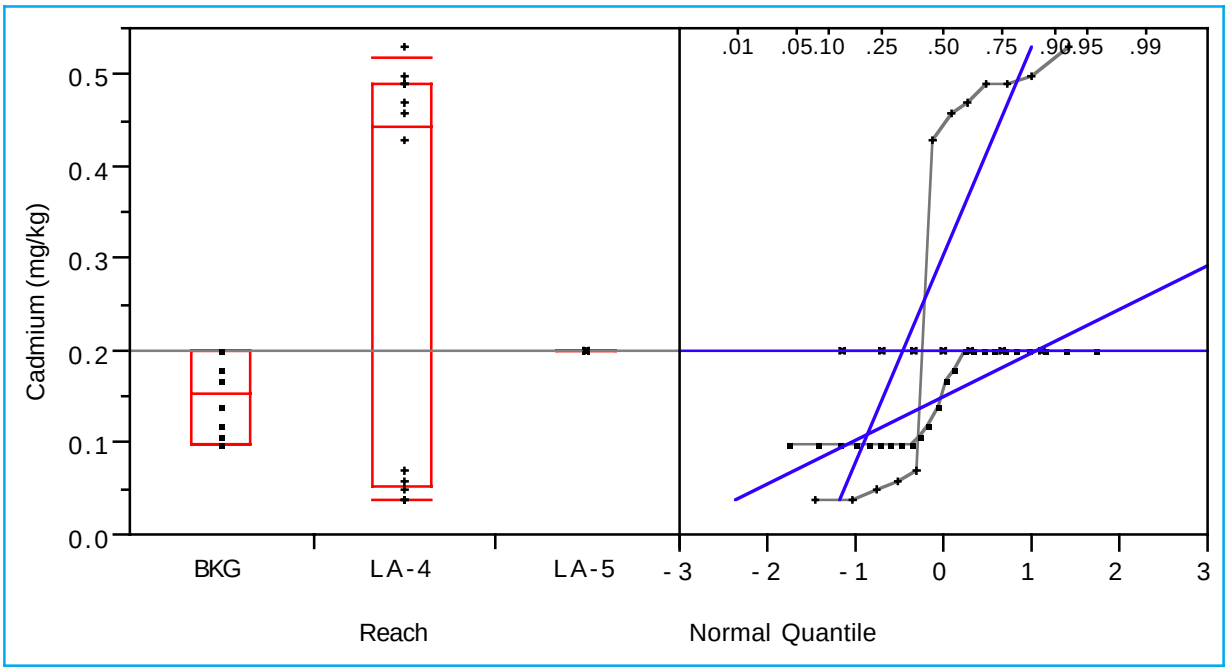

Figure E1-7a. Box plot for cadmium.

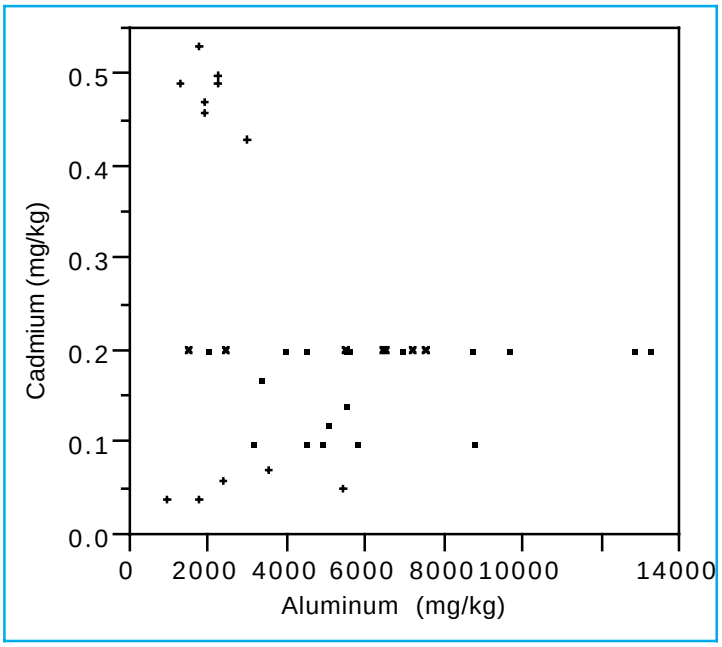

Figure E1-7b. Scatter plot for cadmium versus aluminum.

E-1.2.8 Calcium

Results of the statistical testing (Table E1-1) suggest that reach LA-5 results are elevated relative to background data. A review of the data plotted by reach (Figure E1-8a) and versus aluminum (Figure E1-8b) confirms these results and also suggests that two sample results for reach LA-4 are elevated relative to background data. Because of the statistical difference between LA-5 data and background data and the observation of two sample results above the background value in LA-4, calcium is retained as a COPC.

E-1.2.9 Chromium, Total

Results of the statistical testing (Table E1-1) suggest total chromium sample results are not different from background data. A review of the data plotted by reach (Figure E1-9a) confirms these results. The total chromium versus aluminum scatter plot (Figure E1-9b) suggests that three samples in reach LA-5 could have elevated total chromium given the aluminum concentration measured in these samples. However, chromium is not retained as a COPC because the box plots and statistical testing suggest that total chromium concentrations are not different from background concentrations.

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) suggest that one sample in reach LA-4 could have elevated cobalt given the aluminum concentration measured in this sample. However, cobalt is not retained as a COPC because the box plots and statistical testing suggest that cobalt concentrations are not different from background concentrations.

E-1.2.11 Copper

Results of the statistical testing (Table E1-1) suggest there are significant differences between reach LA-4 data 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. In addition, copper was identified as a COPC in both upper Los Alamos Canyon and Pueblo Canyon. Thus, copper is retained as a COPC.

E-1.2.12 Cyanide, Total

Total cyanide analytical results were obtained from samples collected from reach LA-5. 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 E1-12a) and versus aluminum (Figure E1-12b) confirms these results. Thus, total cyanide is not retained as a COPC.

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) and versus aluminum (Figure E1-13b) confirms these results. Because the box plots and statistical testing suggest that iron concentrations are not different from background concentrations, iron is not retained as a COPC.

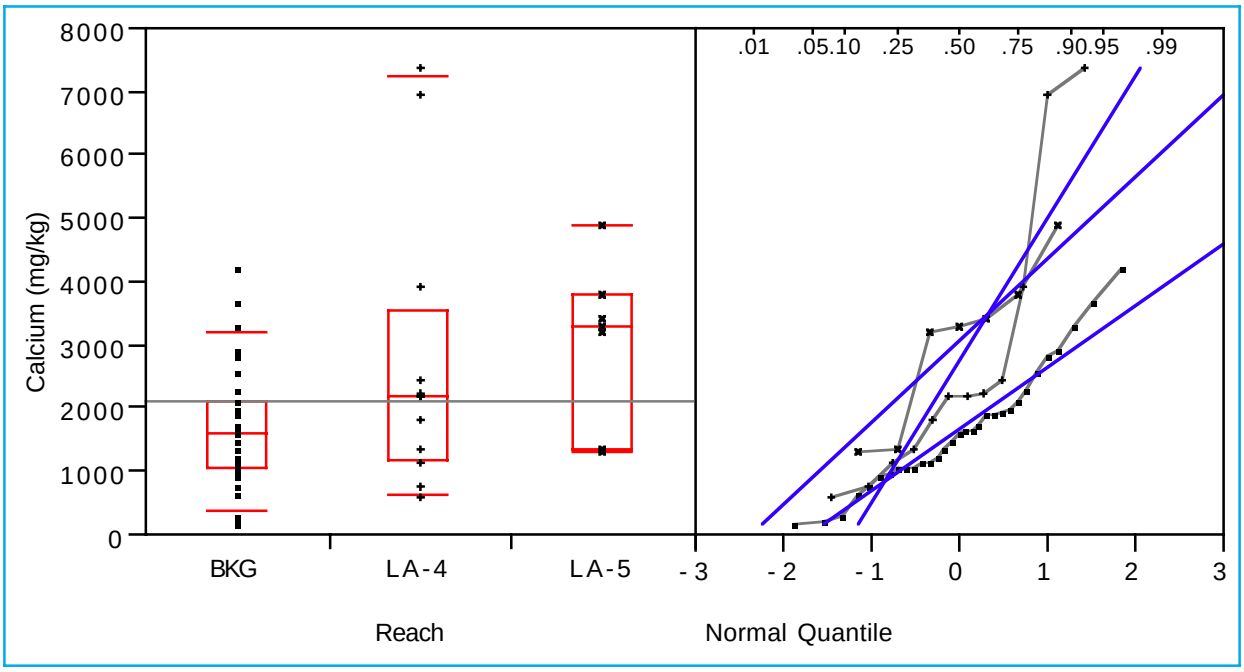

Figure E1-8a. Box plot for calcium.

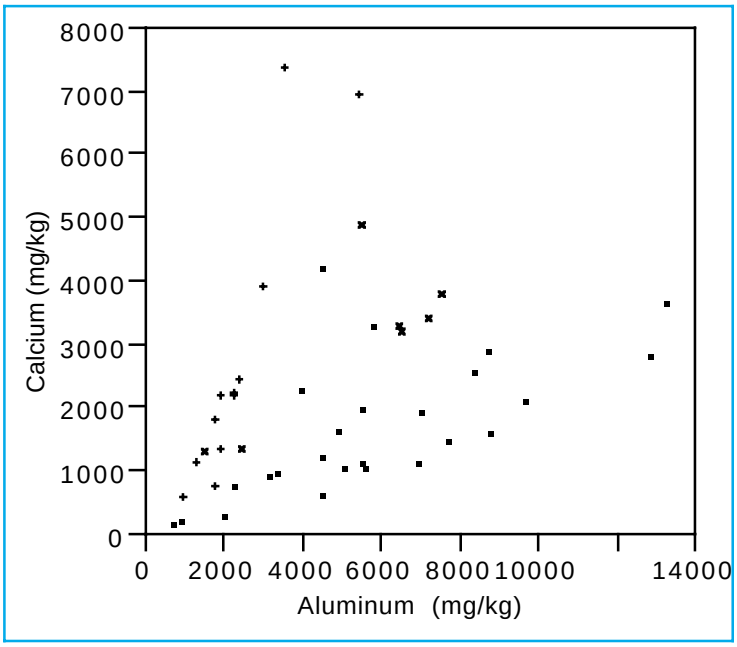

Figure E1-8b. Scatter plot for calcium versus aluminum.

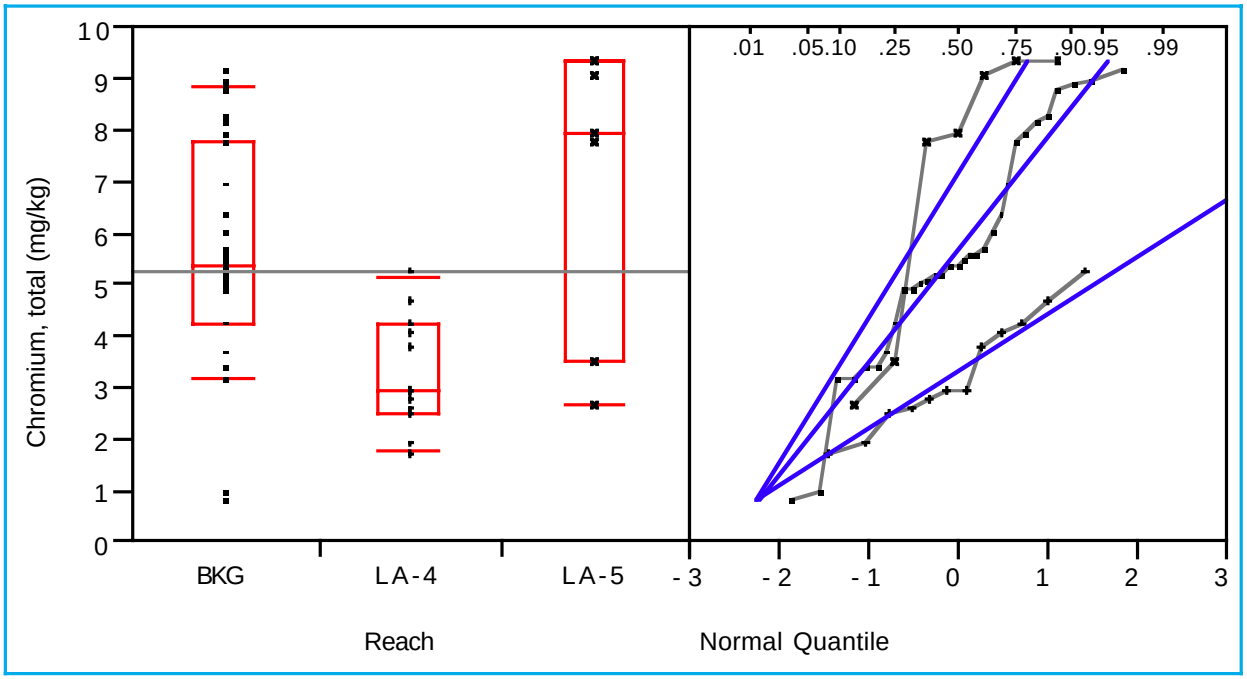

Figure E1-9a. Box plot for chromium.

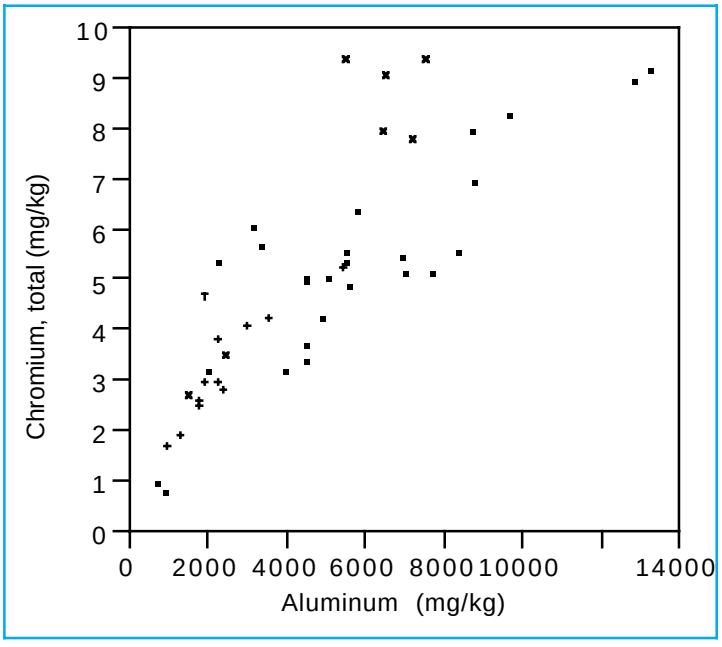

Figure E1-9b. Scatter plot for chromium versus aluminum.

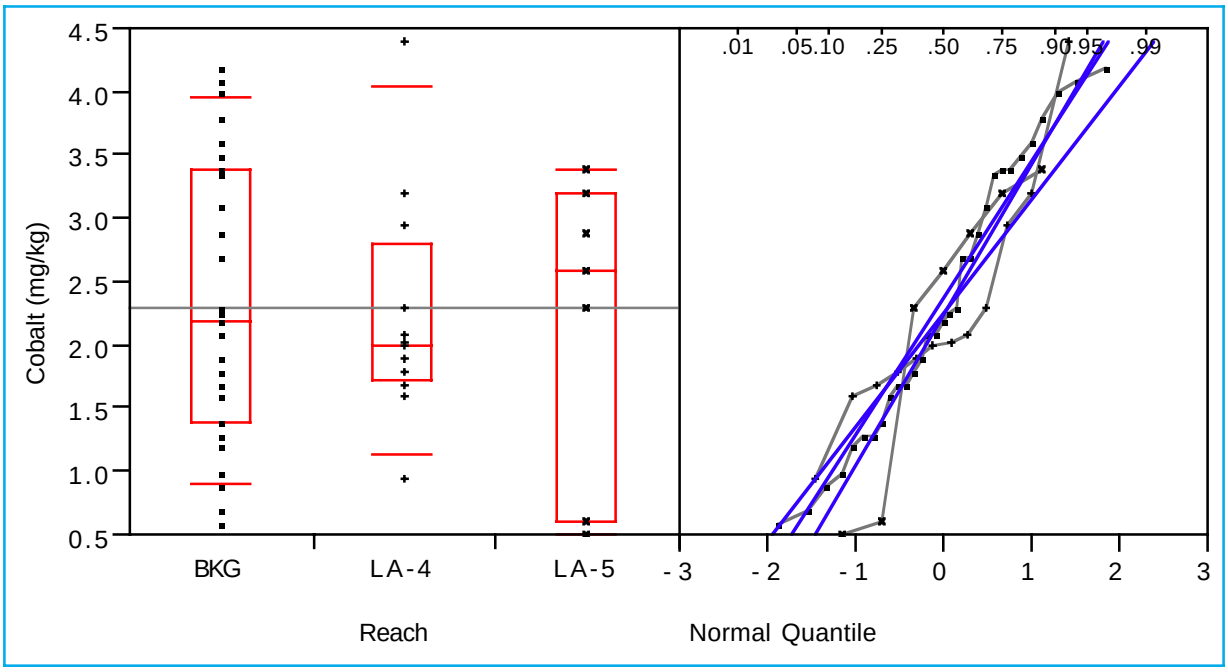

Figure E1-10a. Box plot for cobalt.

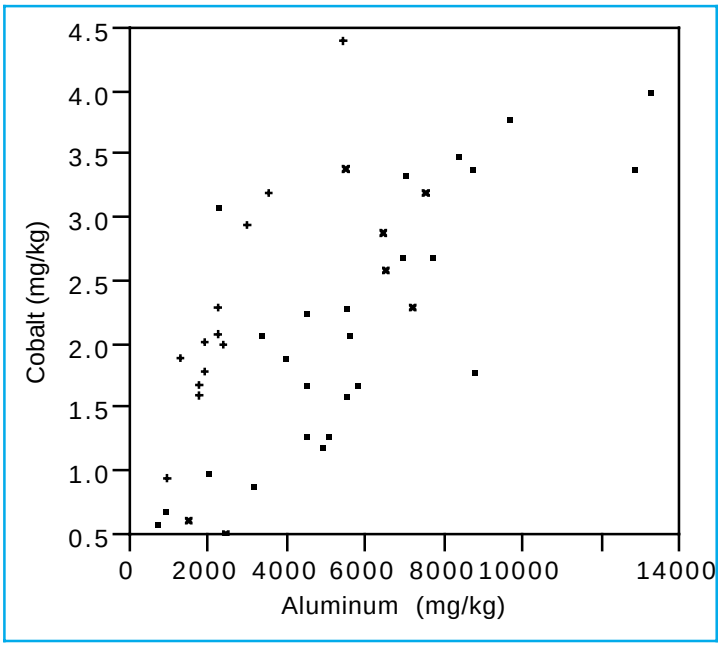

Figure E1-10b. Scatter plot for cobalt versus aluminum.

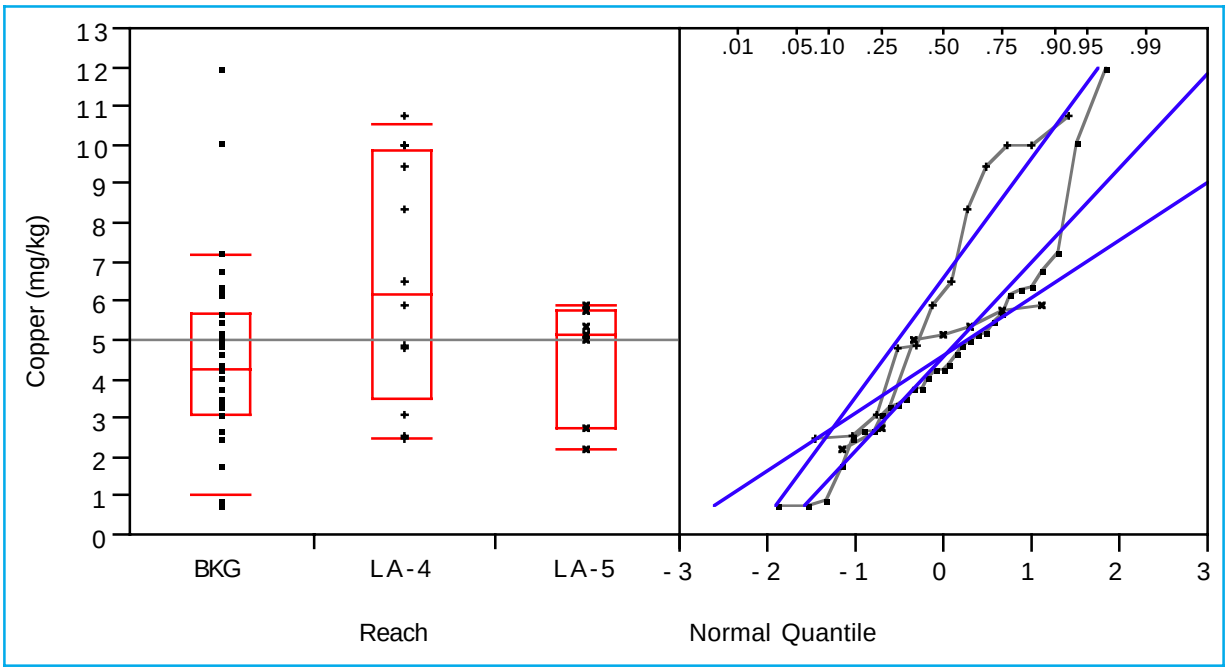

Figure E1-11a. Box plot for copper.

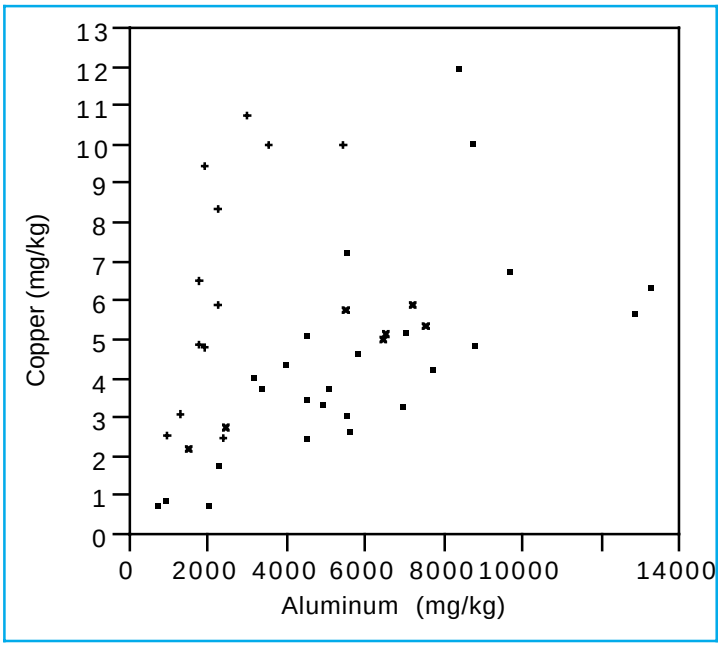

Figure E1-11b. Scatter plot for copper versus aluminum.

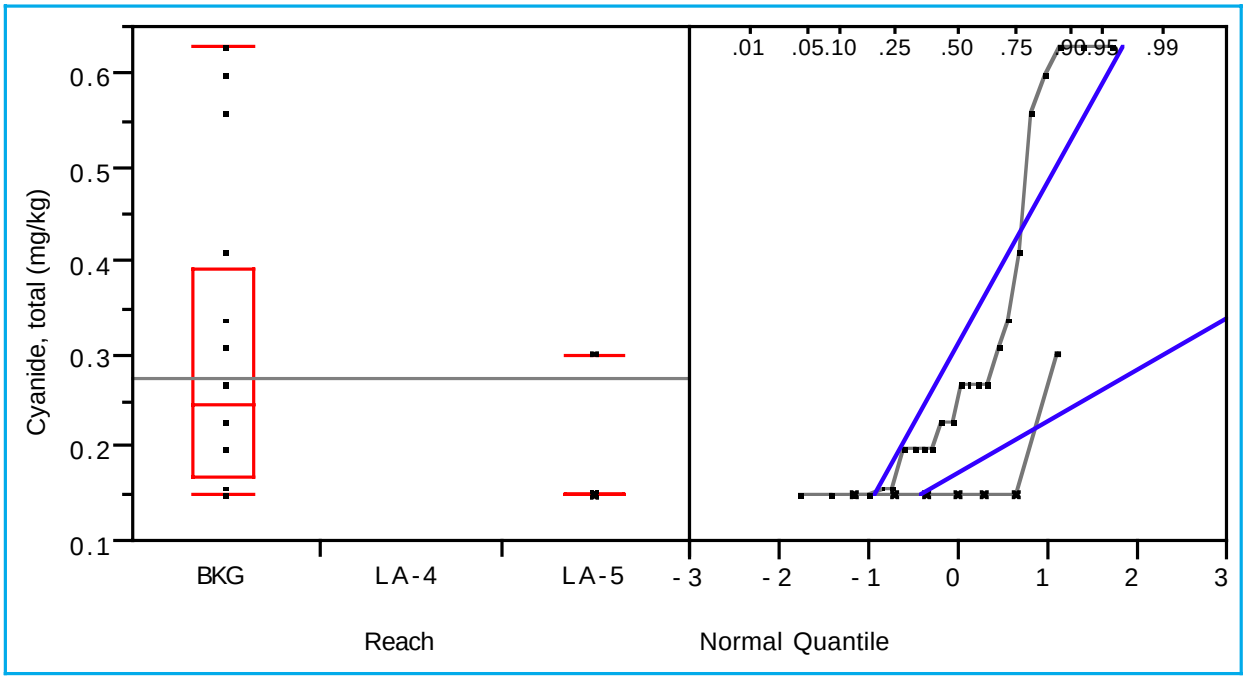

Figure E1-12a. Box plot for cyanide.

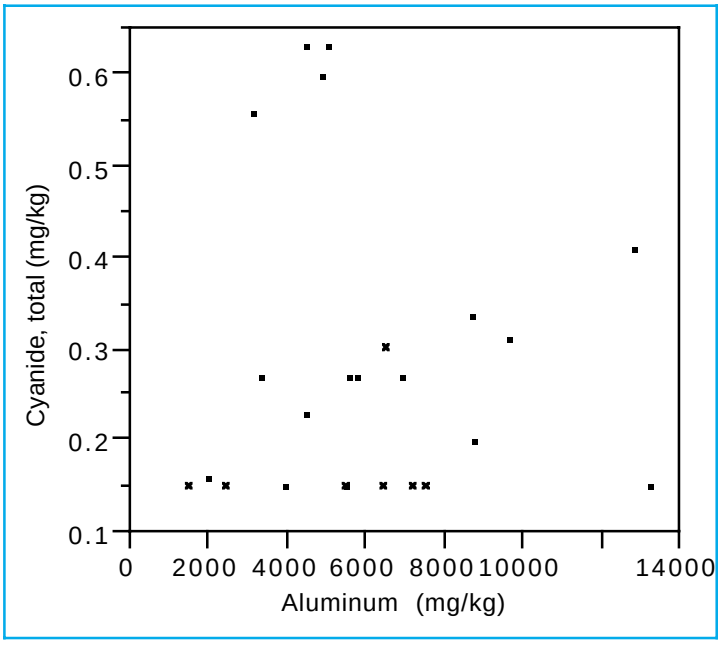

Figure E1-12b. Scatter plot for cyanide versus aluminum.

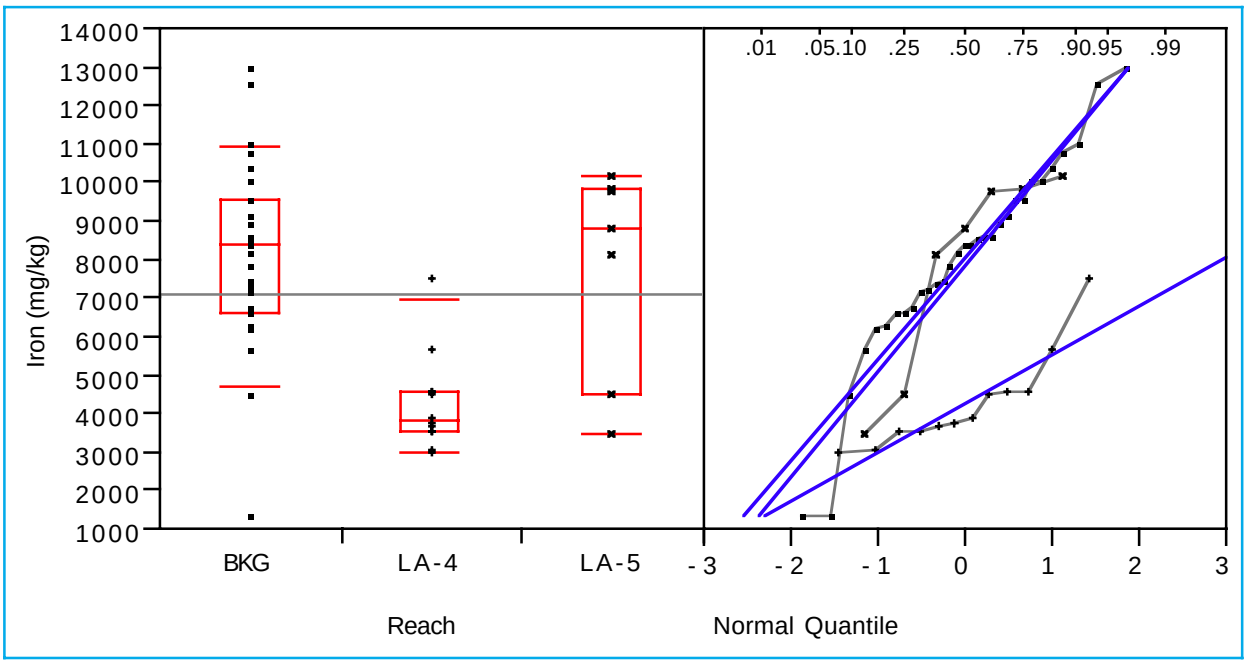

Figure E1-13a. Box plot for iron.

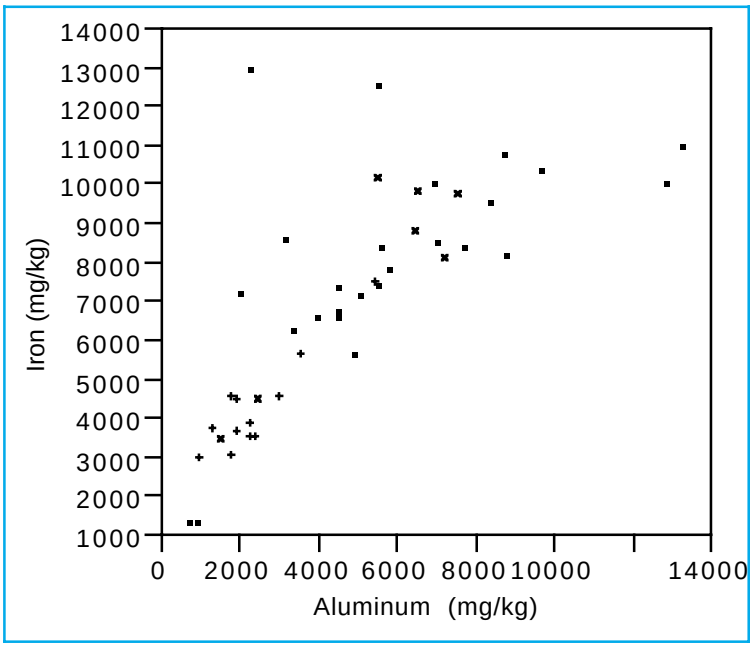

Figure E1-13b. Scatter plot for iron versus aluminum.

E-1.2.14 Lead

Results of the statistical testing (Table E1-1) suggest there are no significant differences between reach data and background data. A review of the data plotted by reach (Figure E1-14a) shows that two samples from reach LA-4 and a single sample from reach LA-5 could be viewed as outlier results, and one sample from each reach exceeds the background value. The lead versus aluminum scatter plot (Figure E1-14b) suggests that five samples from reach LA-4 and one sample from LA-5 could have elevated lead given the aluminum concentration measured in these samples. In addition, lead was identified as a COPC in both upper Los Alamos Canyon and Pueblo Canyon. Thus, lead is retained as a COPC.

E-1.2.15 Magnesium

Results of the statistical testing (Table E1-1) suggest that reach LA-5 results are elevated relative to background data. A review of the data plotted by reach (Figure E1-15a) and versus aluminum (Figure E1-15b) confirms these results and also seems to suggest that three sample results for reach LA-4 are also elevated relative to background data. Because of the statistical difference between LA-5 data and background data and the observation of three elevated LA-4 sample results, magnesium is 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 samples 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 no detected sample results or detection limits are greater than the mercury background value of 0.1 mg/kg, mercury is not 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 that reach LA-5 results are elevated relative to background data. A review of the data plotted by reach (Figure E1-19a) and versus aluminum (Figure E1-19b) confirms these results and also suggests that one sample result from reach LA-4 is elevated relative to background data. Because of the statistical difference between LA-5 data and background data and the observation of one elevated LA-4 sample result, potassium is retained as a COPC.

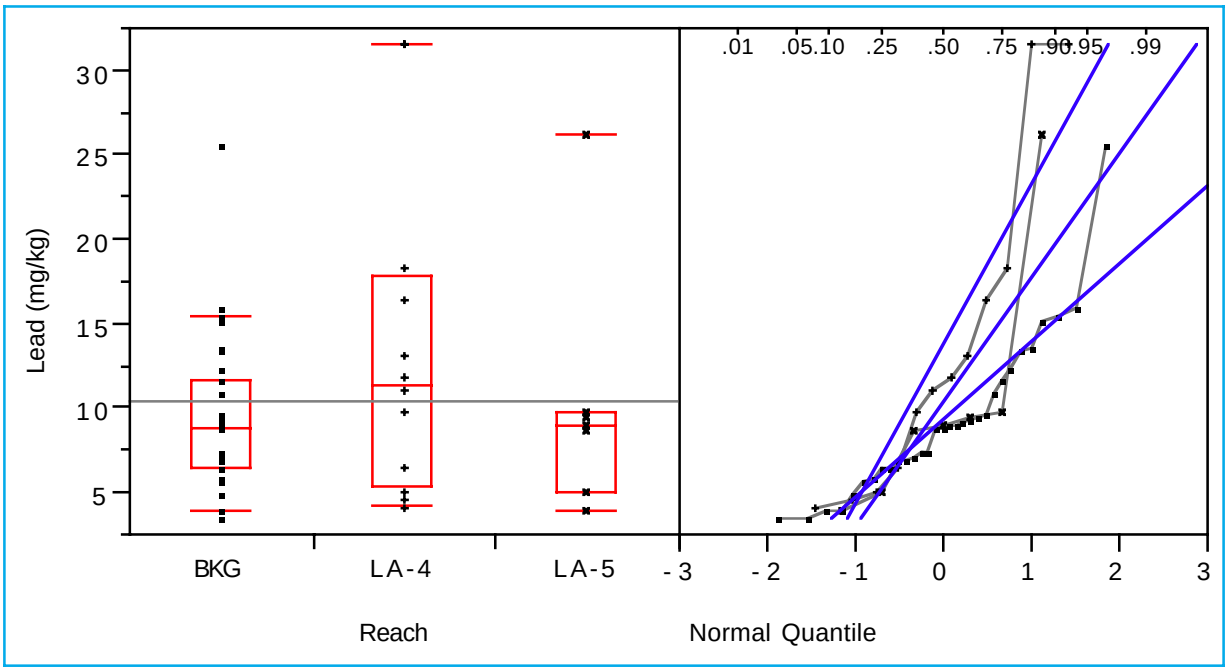

Figure E1-14a. Box plot for lead.

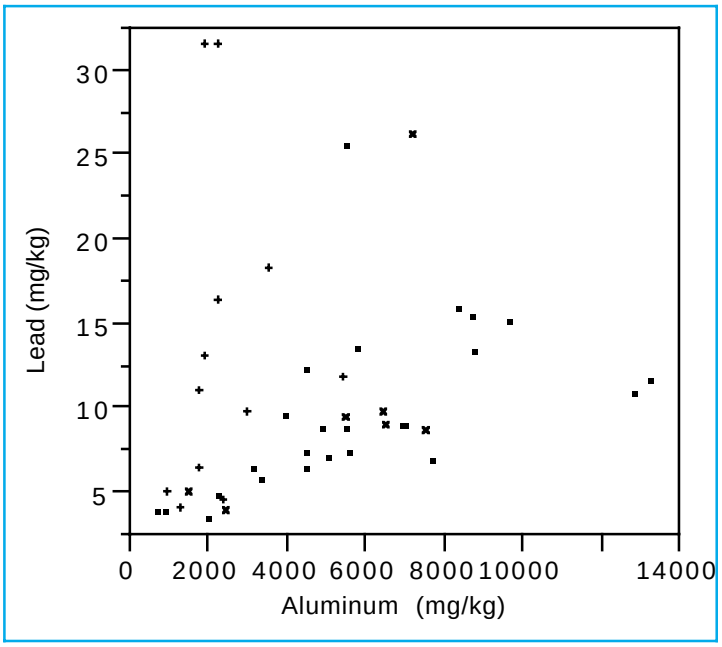

Figure E1-14b. Scatter plot for lead versus aluminum.

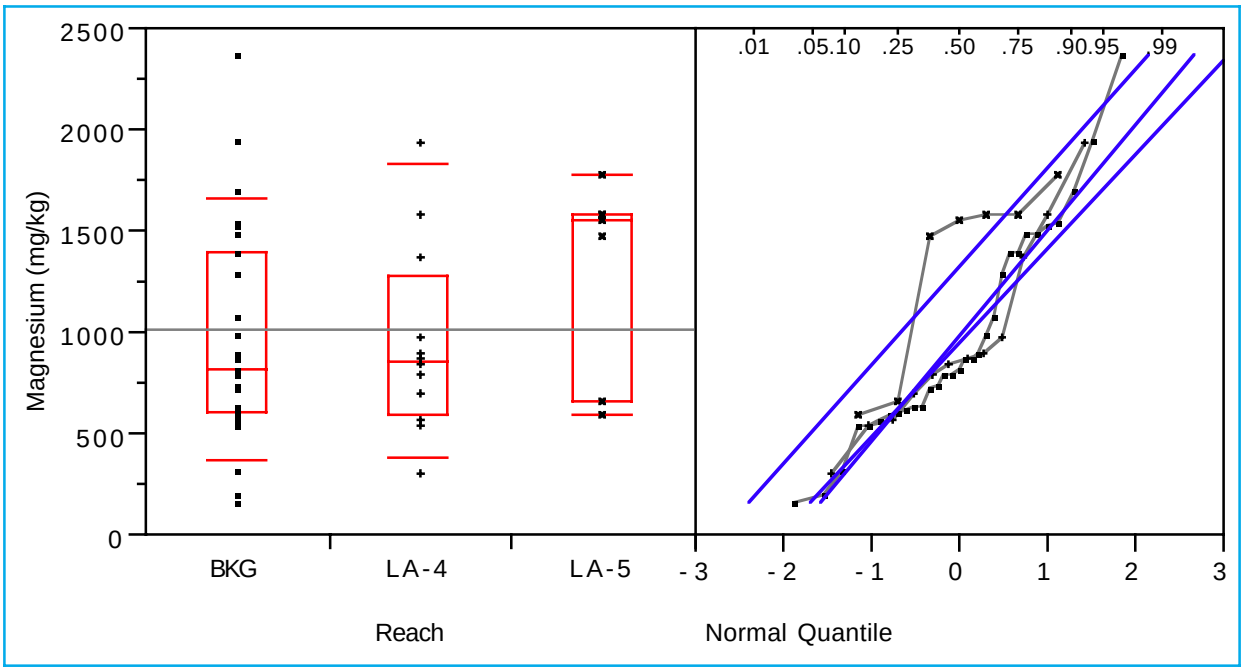

Figure E1-15a. Box plot for magnesium.

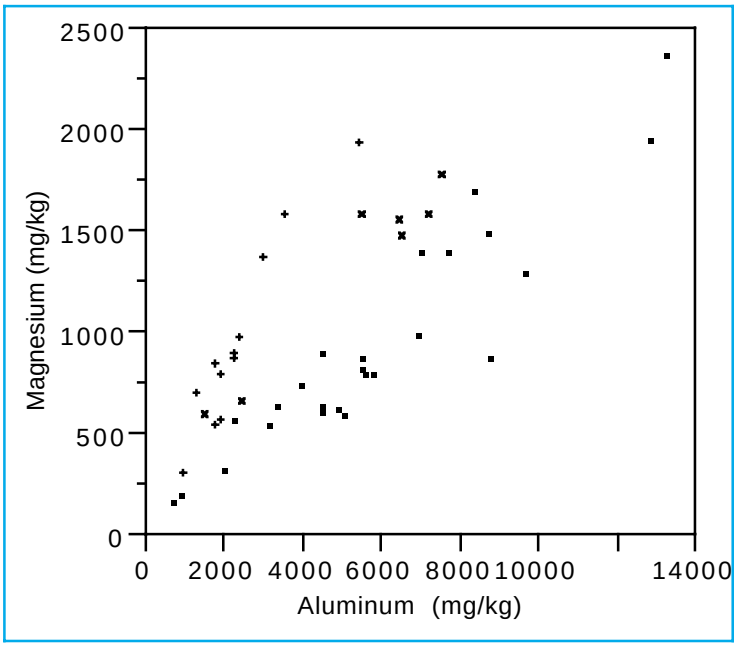

Figure E1-15b. Scatter plot for magnesium versus aluminum.

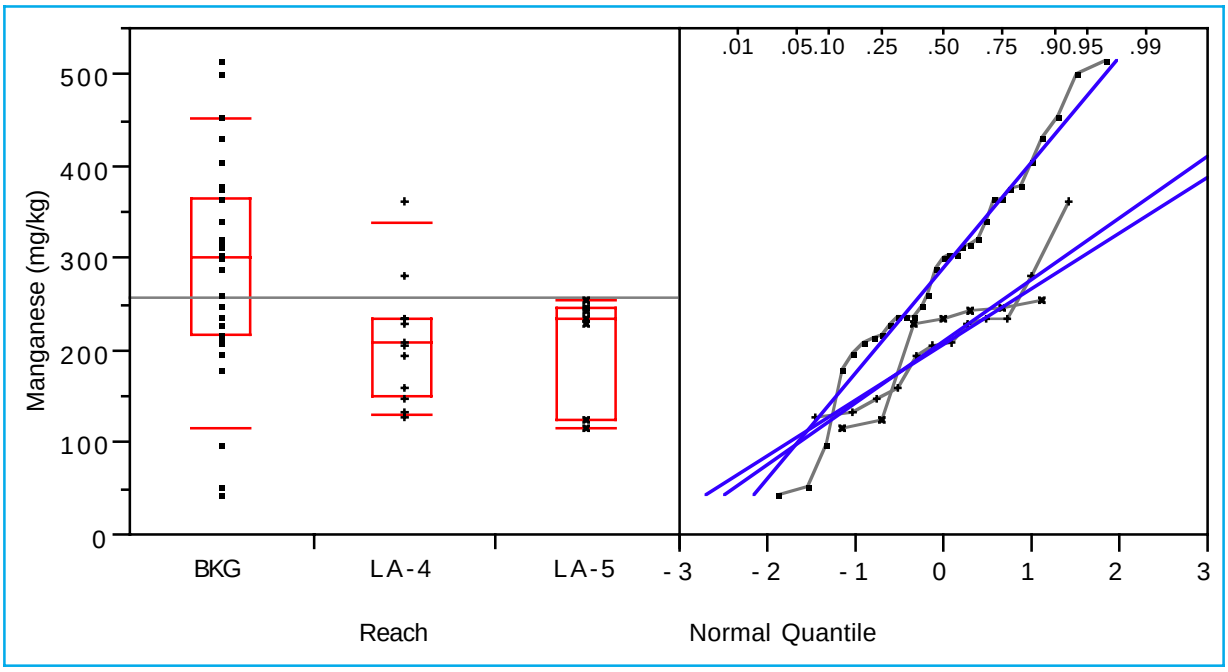

Figure E1-16a. Box plot for manganese.

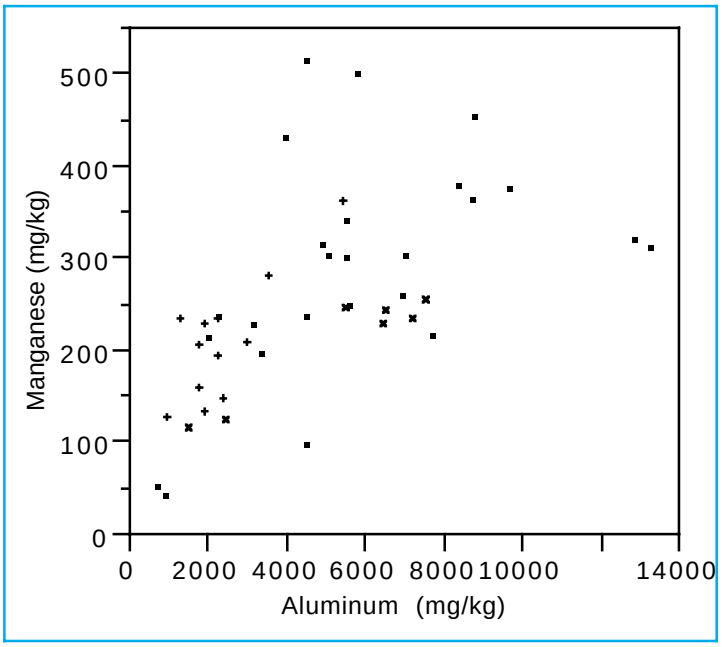

Figure E1-16b. Scatter plot for manganese versus aluminum.

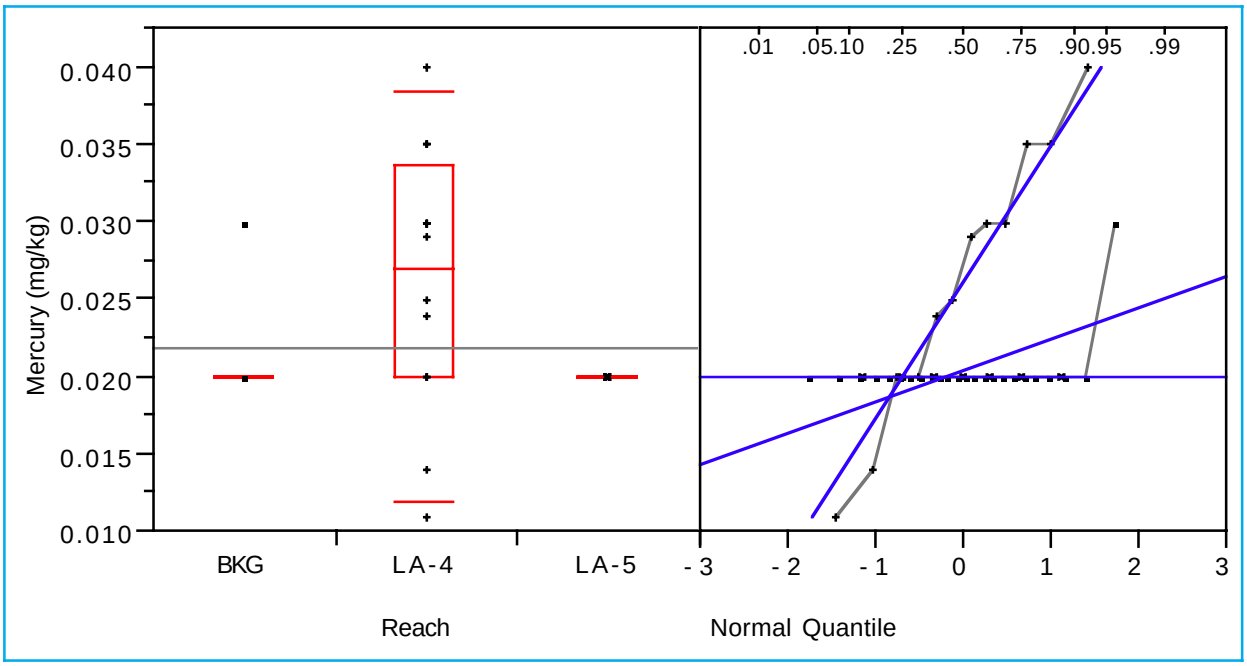

Figure E1-17a. Box plot for mercury.

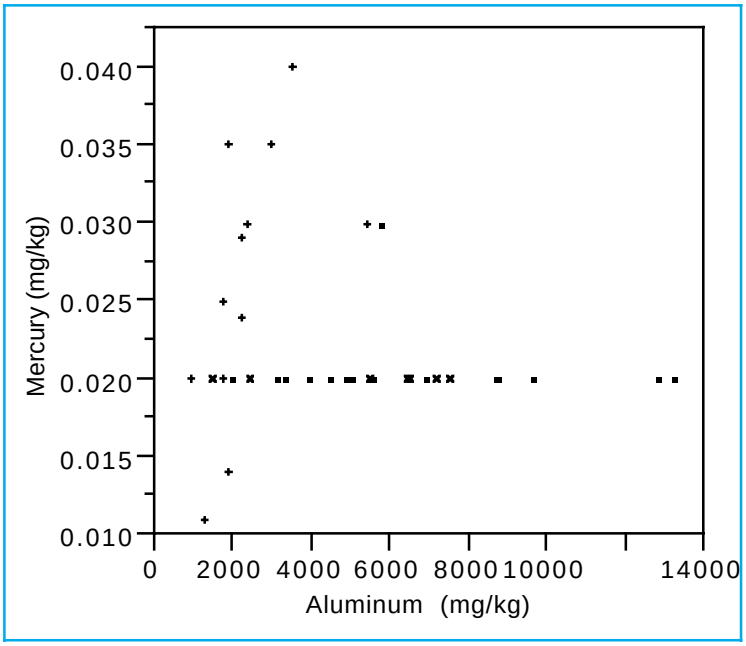

Figure E1-17b. Scatter plot for mercury versus aluminum.

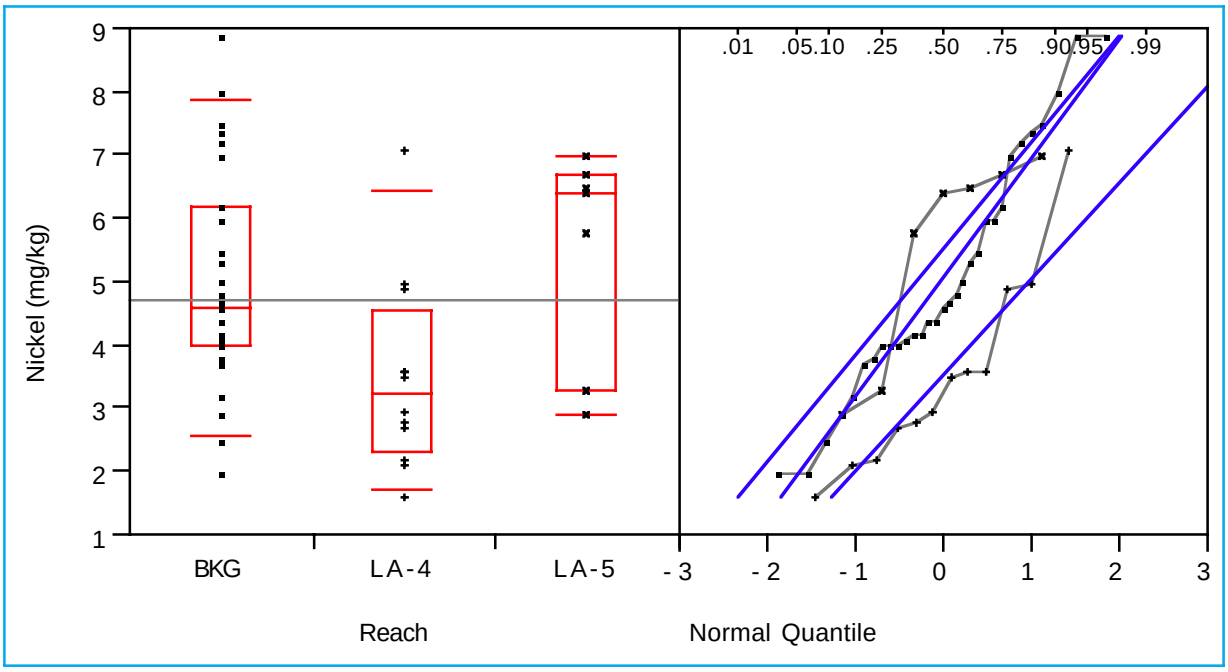

Figure E1-18a. Box plot for nickel.

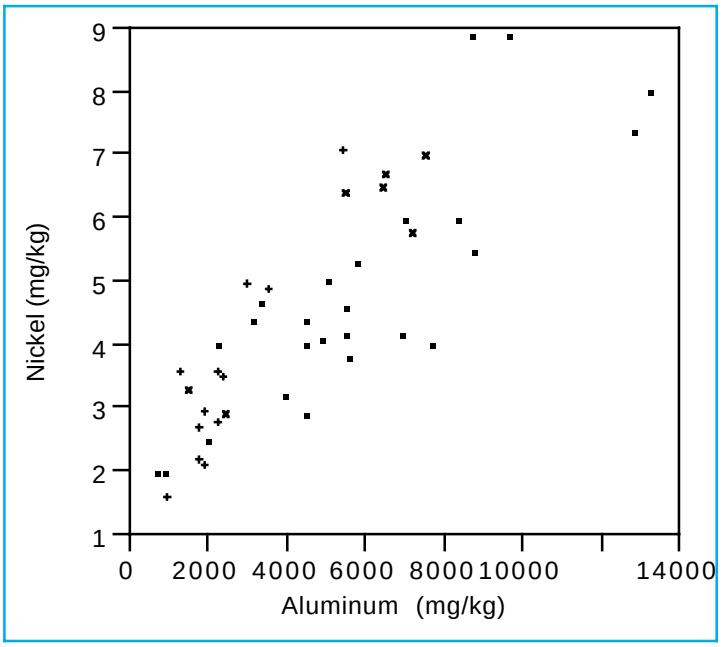

Figure E1-18b. Scatter plot for nickel versus aluminum.

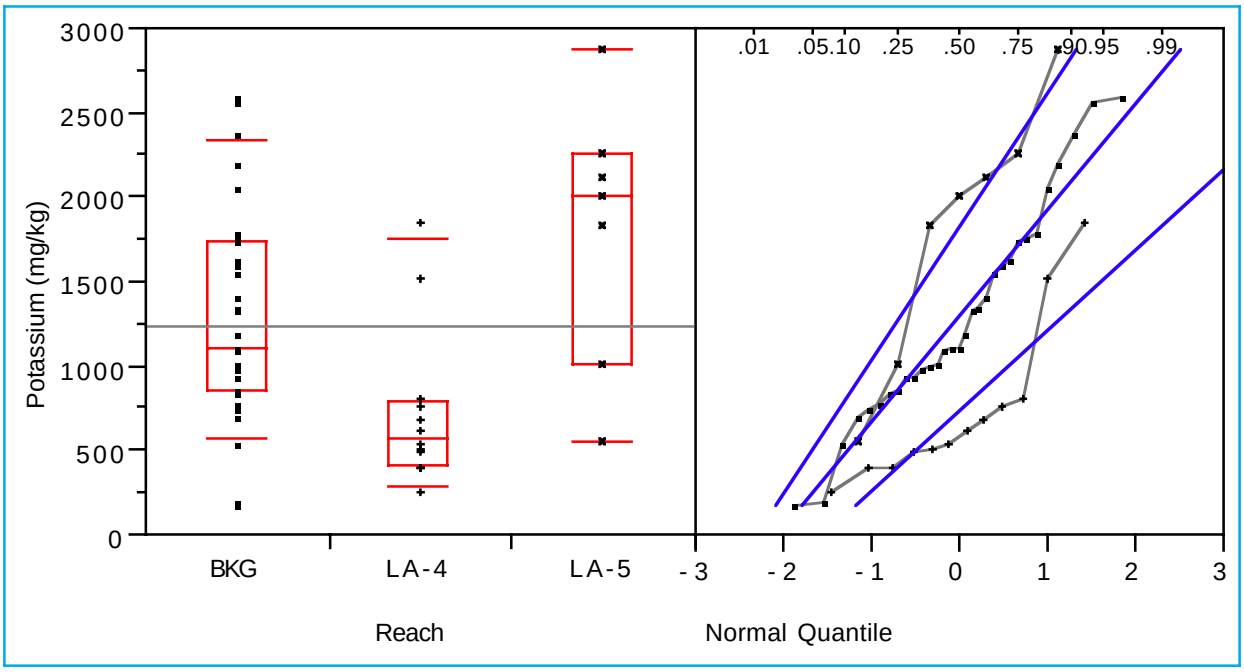

Figure E1-19a. Box plot for potassium.

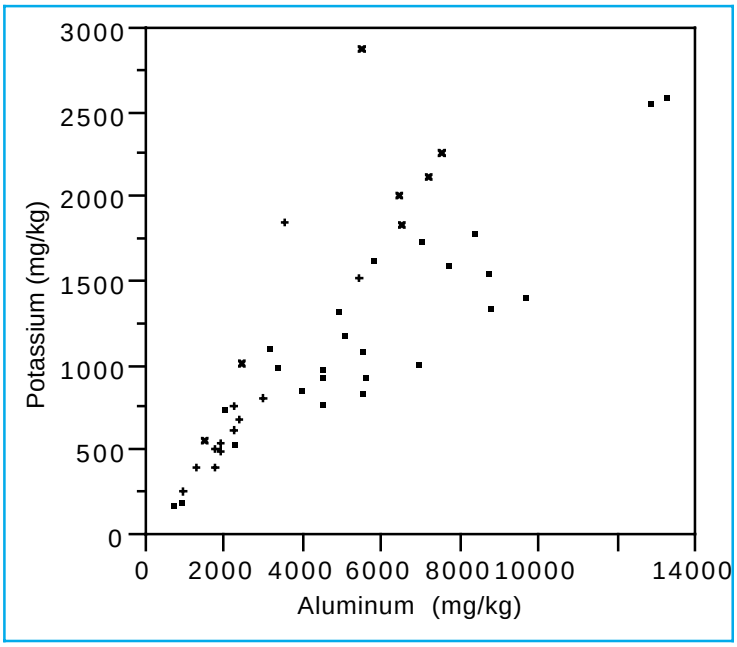

Figure E1-19b. Scatter plot for potassium versus aluminum.

E-1.2.20 Selenium

Selenium was not usually detected in the reach samples 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 background values in reaches LA-4 and LA-5 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 samples 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). Because no detected sample results or detection limits are greater than the silver background value of 1.0 mg/kg, silver is not retained as a COPC.

E-1.2.22 Sodium

Results of the statistical testing (Table E1-1) suggest that reach LA-5 results are elevated relative to background data. A review of the data plotted by reach (Figure E1-22a) and versus aluminum (Figure E1-22b) confirms these results. Because of the statistical difference between LA-5 data and background data, sodium is retained as a COPC.

E-1.2.23 Thallium

Thallium was not detected in any reach sample, and all but two nondetected sample results were less than the thallium background value of 0.73 mg/kg. Thallium data plotted by reach are shown in Figure E1-23a, and thallium data versus aluminum are shown in Figure E1-23b. Because thallium was not detected in any Los Alamos Canyon sediment samples and detection limits were less than the background value with the two exceptions noted above, thallium is not retained as a COPC.

E-1.2.24 Titanium

Titanium analytical results were obtained only from samples collected in reach LA-5. Results of the statistical testing (Table E1-1) suggest there are no significant differences between these LA-5 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.

E-1.2.25 Uranium

Uranium results were obtained by two analytical methods from samples collected in reach LA-5. 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 reach results and background data. A review of uranium data plotted by reach (Figure E1-25a) and versus aluminum (Figure E1-25b) confirms these results. Results of the statistical testing (Table E1-1) suggest that LA-5 total uranium results are not different from background data. Total uranium data plotted by reach (Figure E1-25c) and versus aluminum (Figure E1-25d) confirms these results. Thus, neither uranium nor total uranium are identified as COPCs.

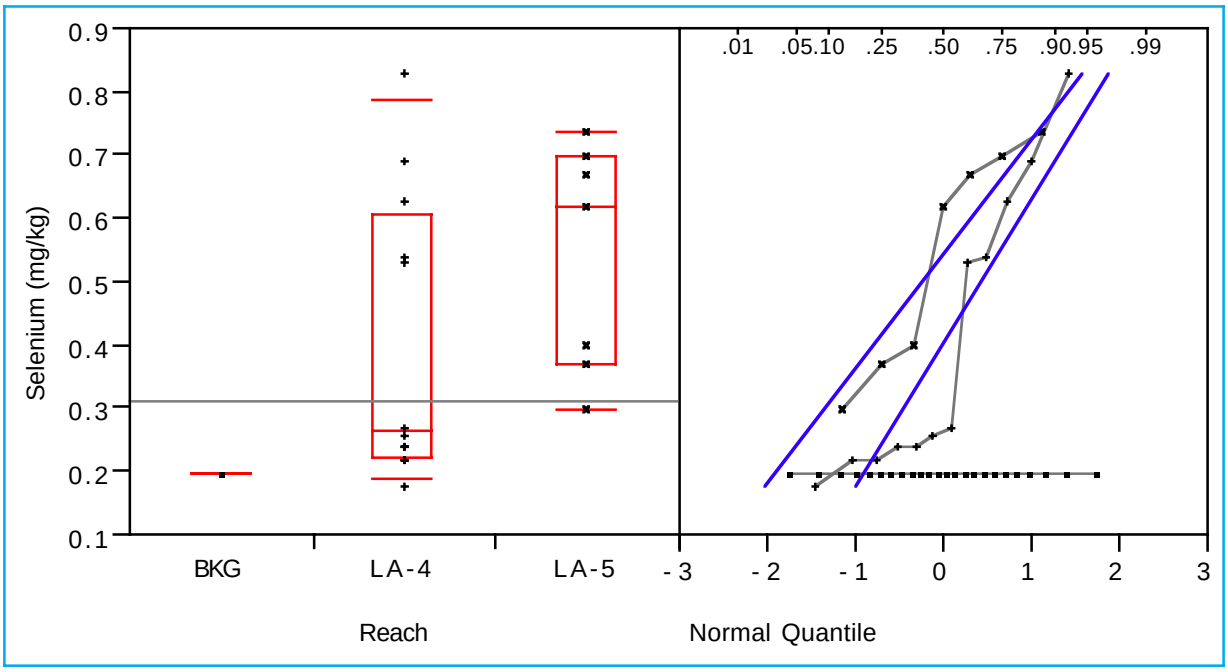

Figure E1-20a. Box plot for selenium.

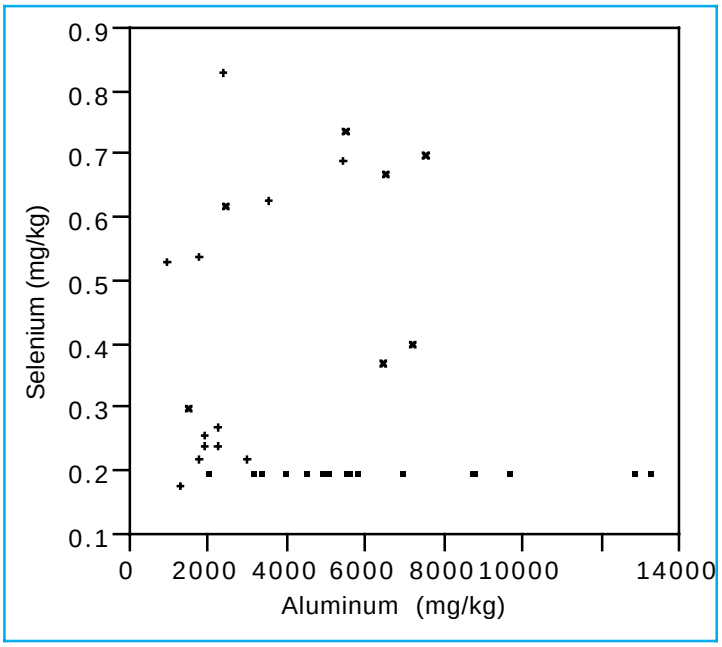

Figure E1-20b. Scatter plot for selenium versus aluminum.

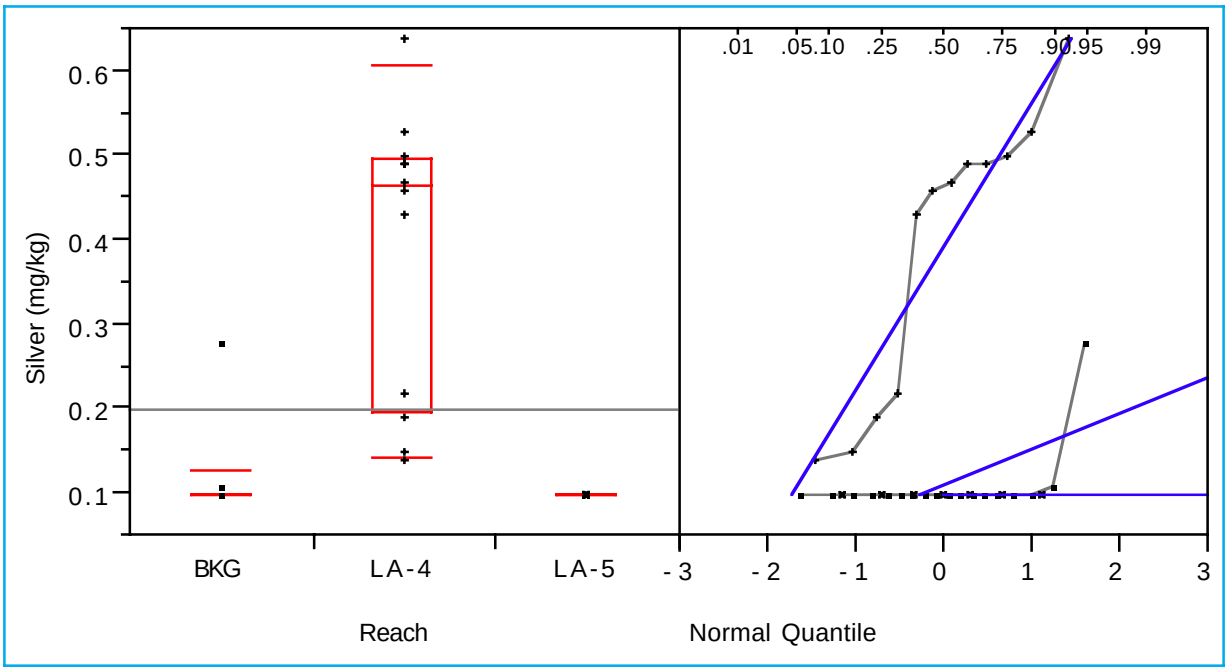

Figure E1-21a. Box plot for silver.

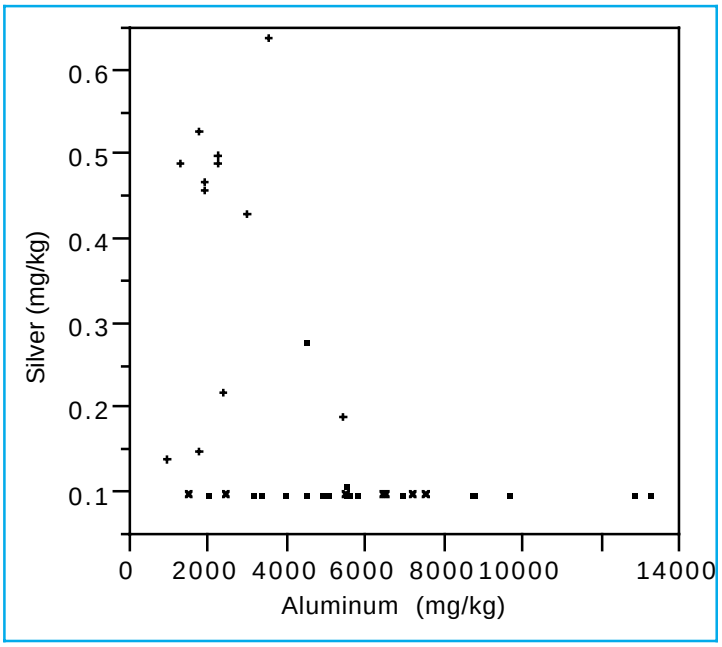

Figure E1-21b. Scatter plot for silver versus aluminum.

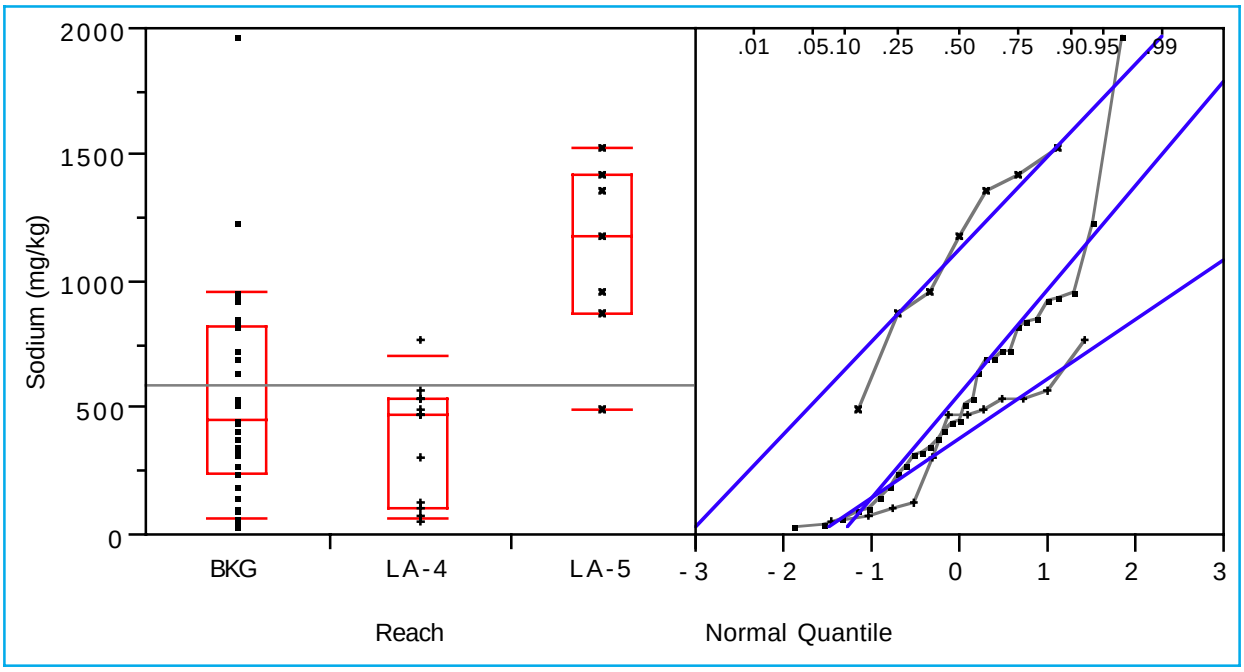

Figure E1-22a. Box plot for sodium.

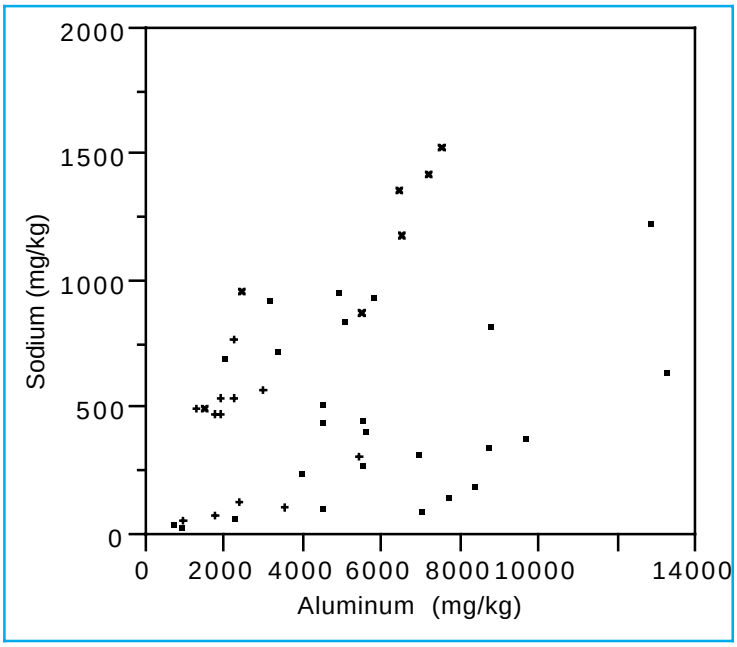

Figure E1-22b. Scatter plot for sodium versus aluminum.

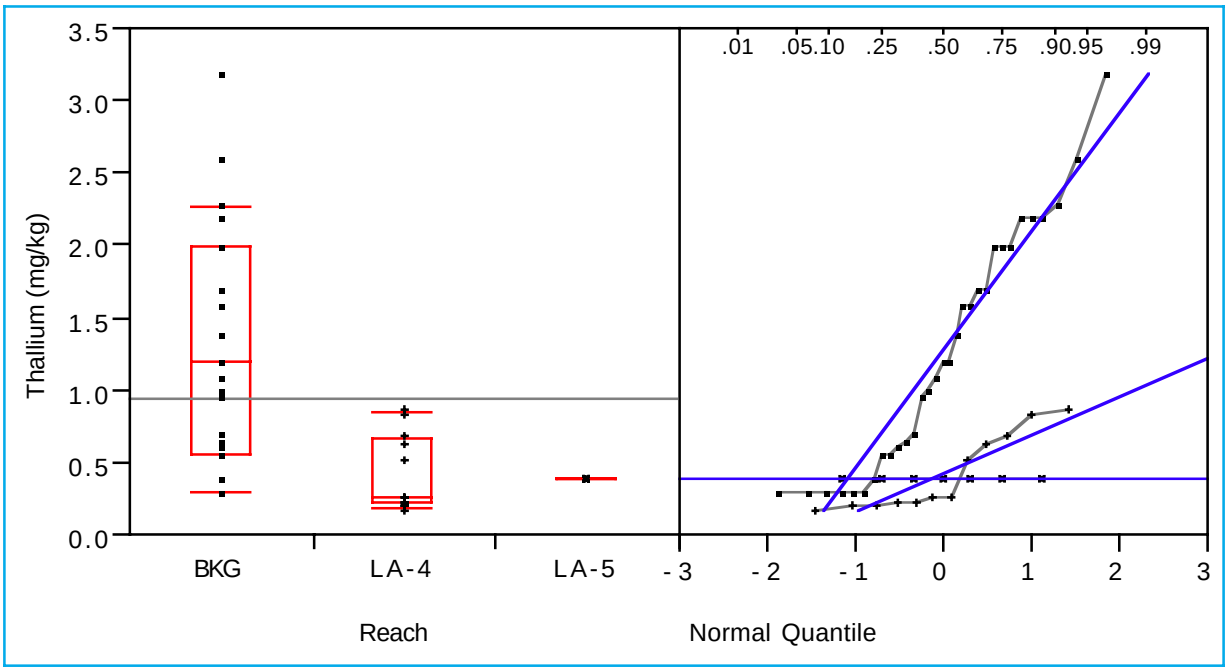

Figure E1-23a. Box plot for thallium.

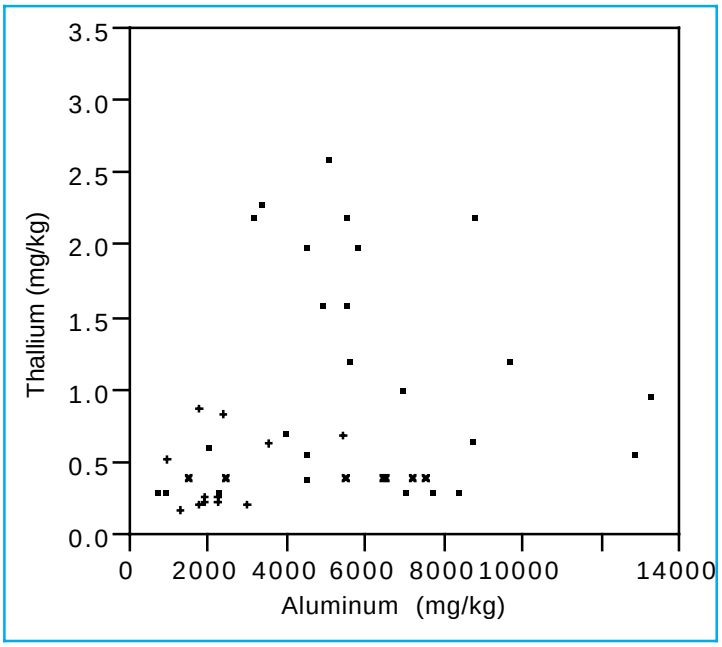

Figure E1-23b. Scatter plot for thallium versus aluminum.

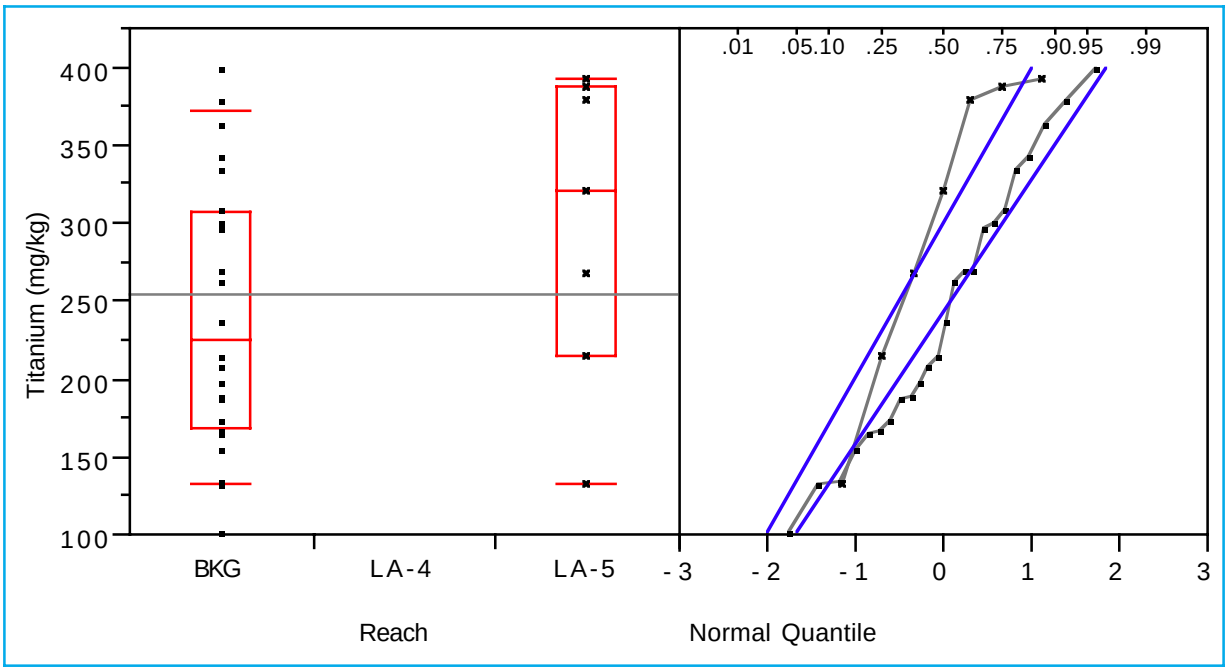

Figure E1-24a. Box plot for titanium.

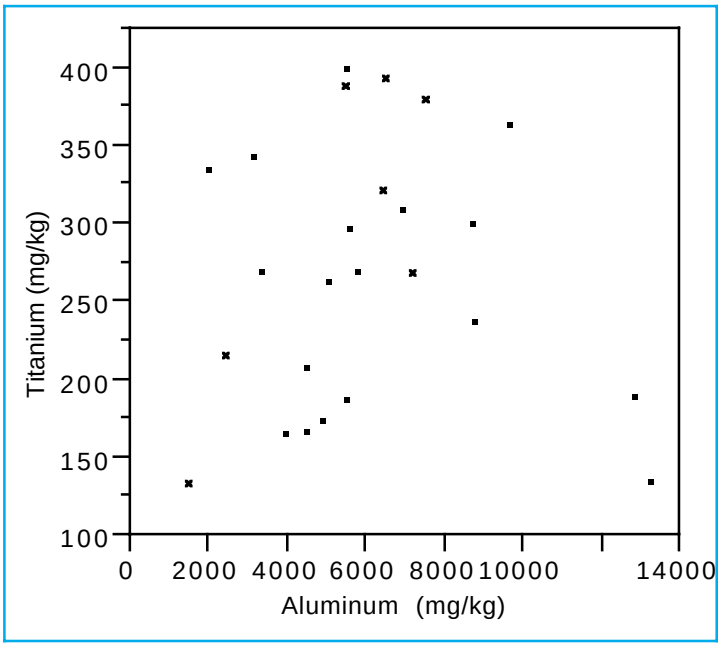

Figure E1-24b. Scatter plot for titanium versus aluminum.

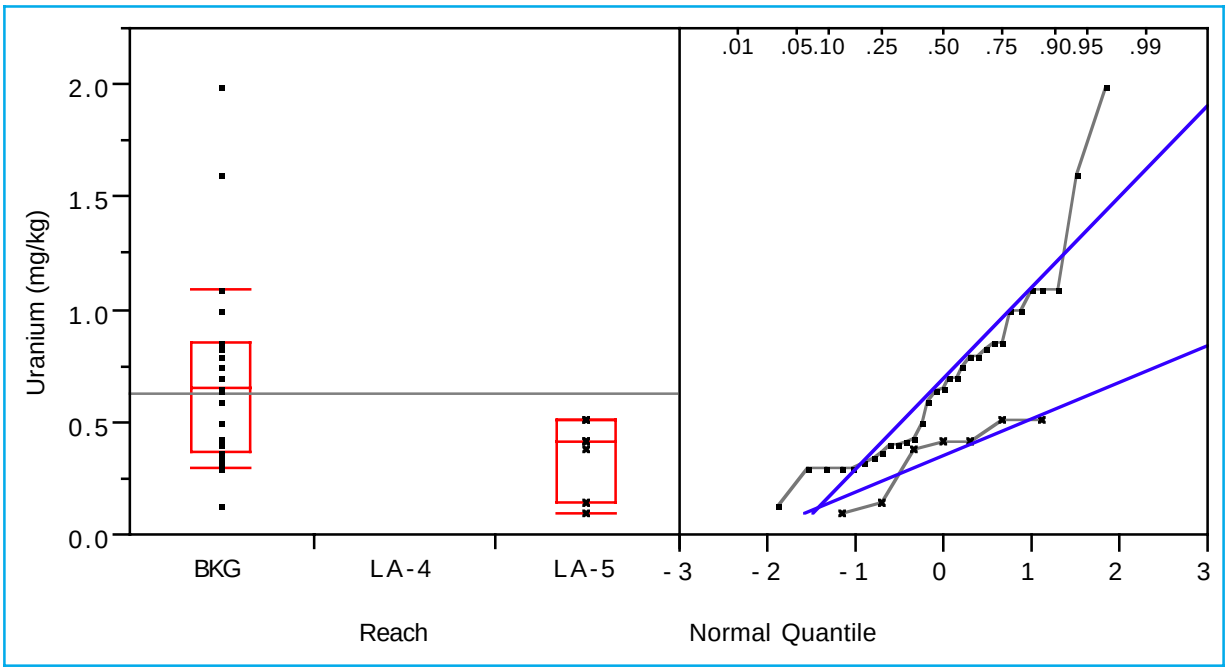

Figure E1-25a. Box plot for uranium.

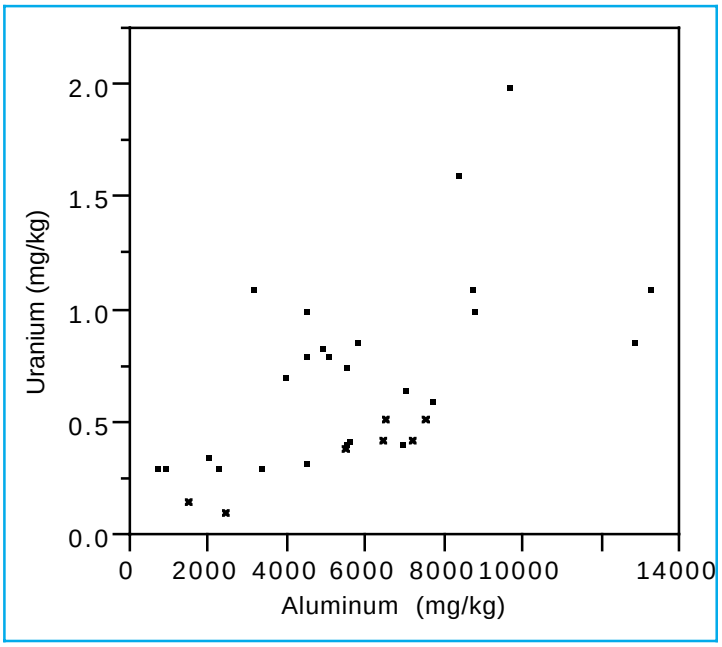

Figure E1-25b. Scatter plot for uranium versus aluminum.

E-1.2.26 Vanadium

Results of the statistical testing (Table E1-1) suggest that reach LA-5 results are elevated relative to background data. A review of the data plotted by reach (Figure E1-26a) and versus aluminum (Figure E1-26b) confirms these results. Because of the statistical difference between LA-5 data and background data, vanadium is retained as a COPC.

E-1.2.27 Zinc

Results of the statistical testing (Table E1-1) suggest there are no differences between reach data and background data. A review of the data plotted by reach (Figure E1-27a) and versus aluminum (Figure E1-27b) confirms these results. Thus, zinc is not retained as a COPC.

E-2.0 STATISTICAL EVALUATIONS OF RADIONUCLIDE DATA

The objective of this section is to present graphical analyses that compare radionuclide data from lower 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. Statistical testing was also used to help determine which radionuclides should be retained as COPCs.

E-2.1 Methods

Two types of analyses were used to evaluate the concentrations of radionuclides 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. 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 sample results for each radionuclide. Most of the radionuclide results are not censored, which means that nondetect results, or results less than the MDA, are presented in all statistical plots and analyses. 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 data and background data).

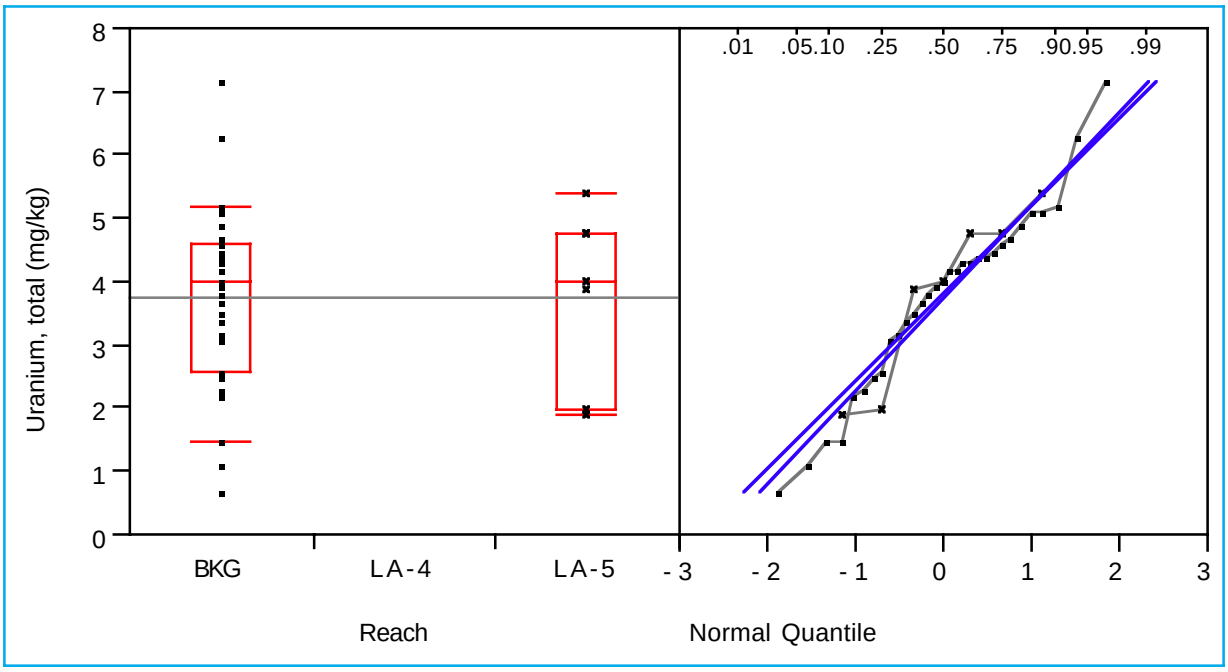

Figure E1-25c. Box plot for total uranium.

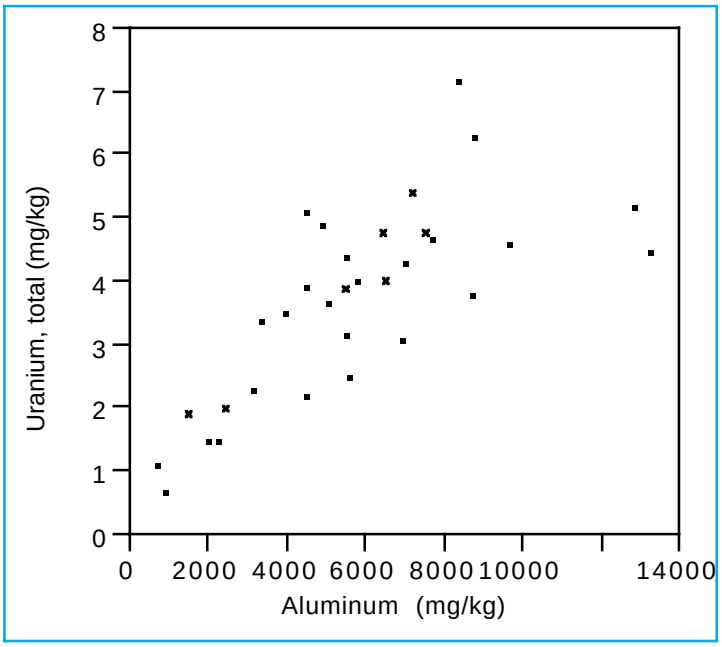

Figure E1-25d. Scatter plot for total uranium versus aluminum.

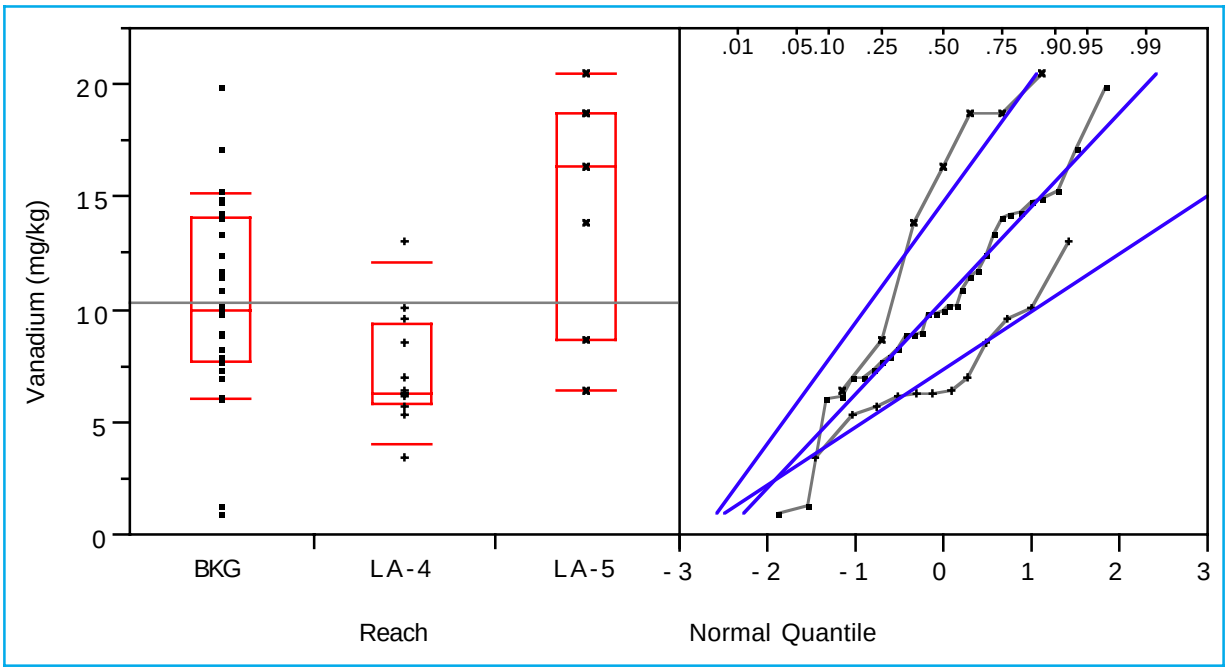

Figure E1-26a. Box plot for vanadium.

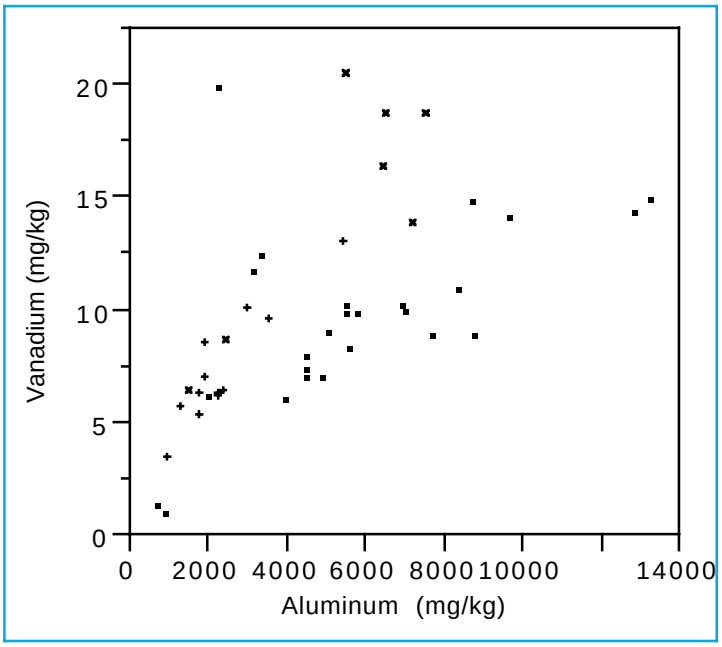

Figure E1-26b. Scatter plot for vanadium versus aluminum.

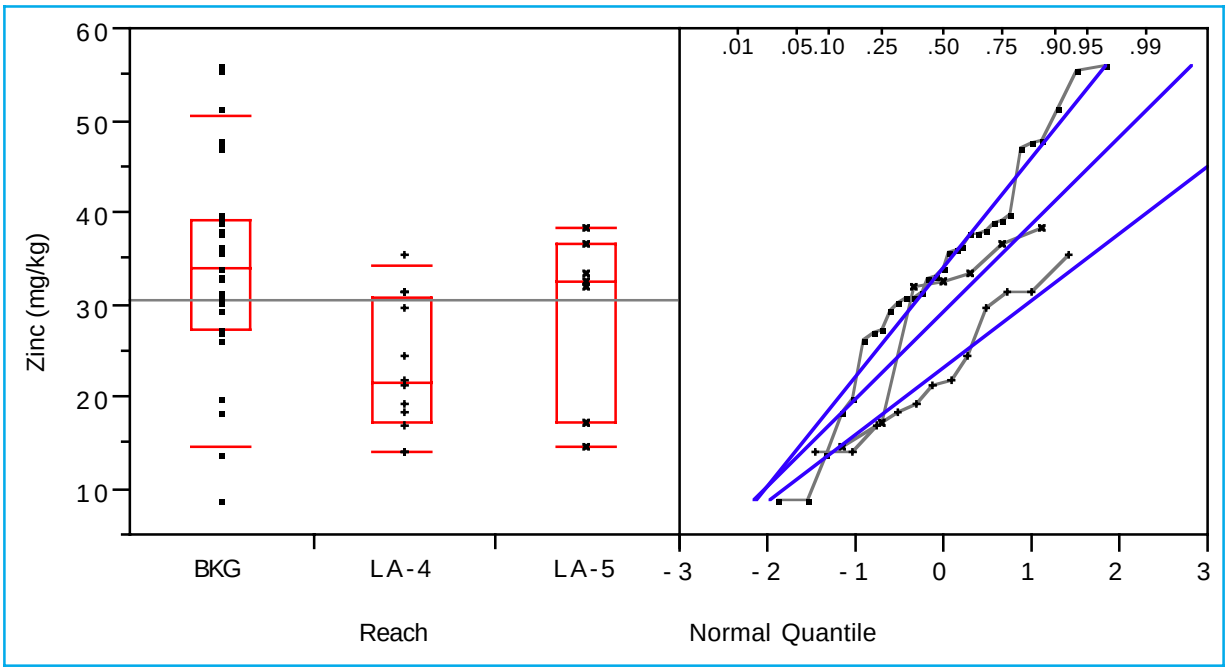

Figure E1-27a. Box plot for zinc.

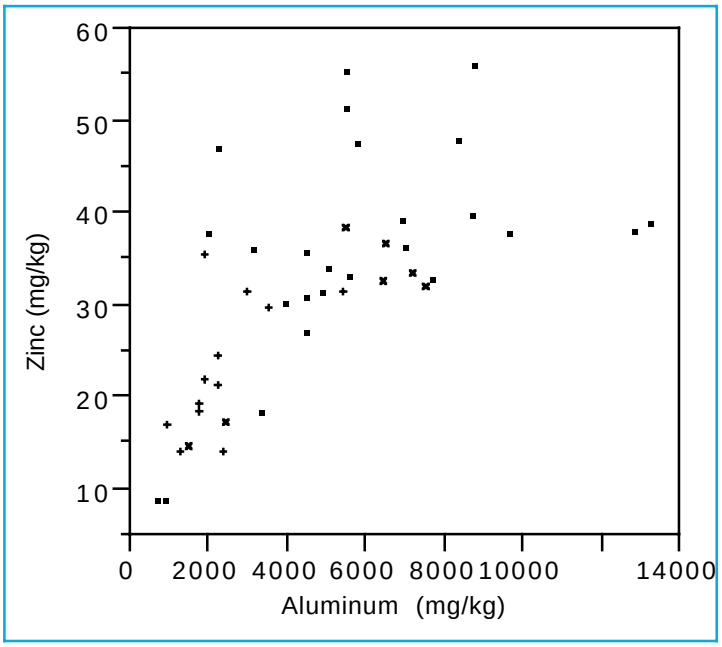

Figure E1-27b. Scatter plot for zinc versus aluminum.

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 three 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 BKG, and the symbols are used consistently in all statistical plots in this section. Background data are represented by a filled square, reach LA-4 data by a plus symbol, and reach LA-5 data by an "x."

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 data 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 and 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 concentrations were determined through two analytical methods: alpha spectroscopy (reach LA-5 only) and gamma spectroscopy (reaches LA-4 and LA-5). Alpha spectroscopy has lower detection limits and higher precision than gamma spectroscopy. Fewer samples were analyzed by alpha spectroscopy because most americium-241 analyses were obtained during the gamma spectroscopy analyses for cesium-137, which was chosen as a key contaminant in LA-4. In addition, the concentrations of americium-241 provided by the gamma spectroscopy 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 the background value in both reaches (Figure E2-1a and E2-1b). Thus, americium-241 is retained as a COPC.

TABLE E2-1

SUMMARY OF P-VALUES FROM WRS STATISTICAL TESTS

Analyte	Reach LA-4	Reach LA-5
Americium-241 (alpha spectroscopy)	N.A.[a]	**0.011**[b]
Americium-241 (gamma spectroscopy)	no background detects	no background detects
Cesium-134	no background detects	no background detects
Cesium-137	**<0.001**	**0.005**
Cobalt-60	no background detects	no background detects
Europium-152	no background detects	no background detects
Plutonium-238	**<0.001**	0.985
Plutonium-239,240	**<0.001**	**<0.001**
Strontium-90	0.603	not detected
Thorium-228	N.A.	0.703
Thorium-230	N.A.	0.481
Thorium-232	N.A.	0.782
Tritium	N.A.	0.996
Uranium-234	N.A.	0.707
Uranium-235 (alpha spectroscopy)	N.A.	>0.999
Uranium-235 (gamma spectroscopy)	no background detects	no background detects
Uranium-238	N.A.	0.472

a. N.A. = not available (no data for this analyte in this reach)

b. Bolded values indicate reach sample results that are significantly greater than background.

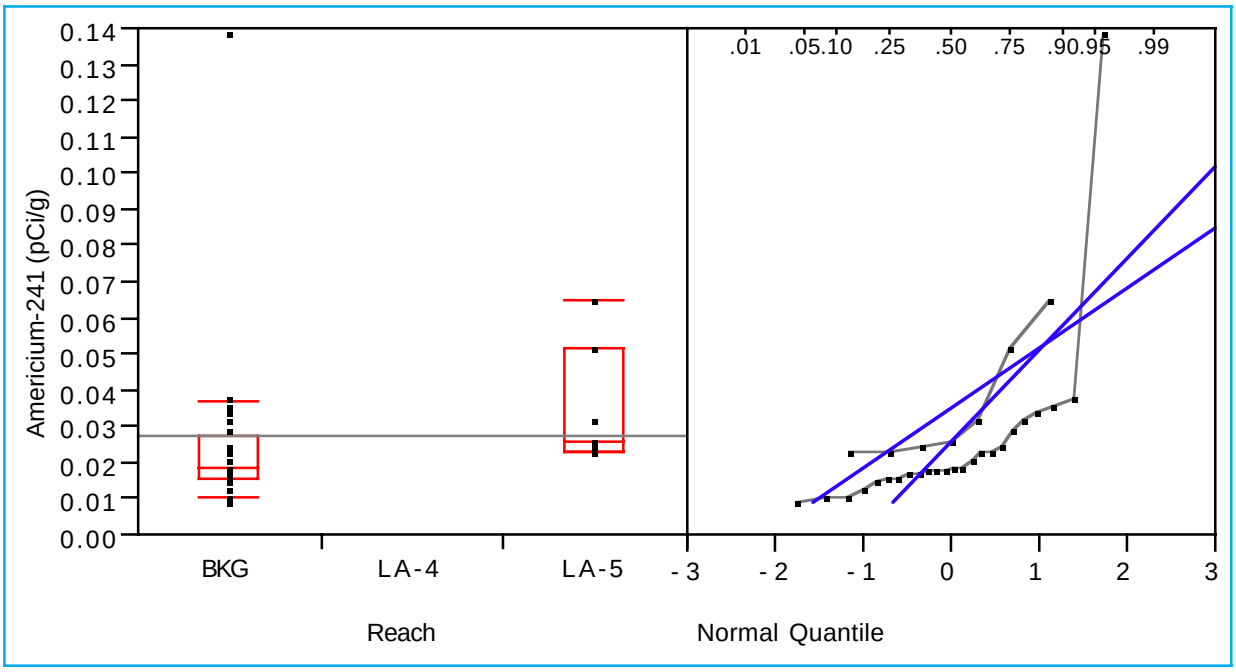

Figure E2-1a. Box plot for americium-241 by alpha spectroscopy.

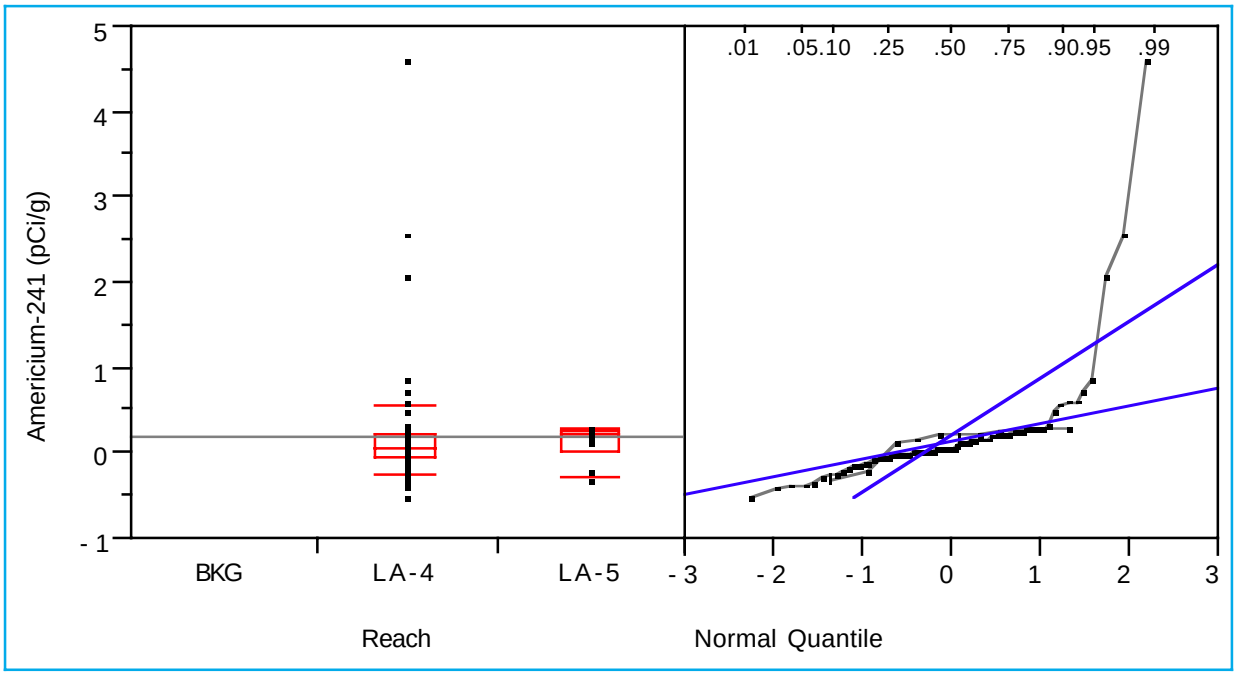

Figure E2-1b. Box plot for americium-241 by gamma spectroscopy.

E-2.2.2 Cesium-134

Cesium-134 was detected in a single sample collected in reach LA-5. 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 from LA-5 are greater than results from reach LA-4. This difference is an artifact of the LA-5 results being censored at the analytical laboratory minimum detectable activity (MDA) (i.e., LA-5 sample results are reported as no lower than the MDA, whereas reported LA-4 results are commonly less than the MDA). The purpose of 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

The box plot figure shows that cesium-137 is elevated relative to background data in reach LA-4 and possibly in reach LA-5 (Figure E2-3). Results of the statistical testing (Table E2-1) also show that there are significant differences between data from both reaches and background data. Thus, cesium-137 is retained as a COPC.

E-2.2.4 Europium-152

Europium-152 was detected in three samples collected in reach LA-4. 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 E2-4 shows that the magnitude of the europium-152 results from reach LA-5 are greater than results from LA-4. This difference is an artifact of the LA-5 results being censored at the analytical laboratory MDA. The purpose of 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-2.2.5 Plutonium-238

The box plot figure shows that plutonium-238 is elevated relative to background data in reach LA-4 (Figure E2-5). Results of the statistical testing (Table E2-1) also indicate there are significant differences between LA-4 data and background data. Thus, plutonium-238 is retained as a COPC.

E-2.2.6 Plutonium-239,240

The box plot figure shows that plutonium-239,240 is elevated relative to background data in both reaches LA-4 and LA-5 (Figure E2-6). Results of the statistical testing (Table E2-1) also indicate there are significant differences between data from both reaches and background data. Thus, plutonium-239,240 is retained as a COPC.

E-2.2.7 Thorium-228

Thorium-228 was determined in samples collected from reach LA-5. The box plot (Figure E2-7) and results of the statistical testing (Table E2-1) suggest that LA-5 results are not different from background data. Thus, thorium-228 is not retained as a COPC.

E-2.2.8 Thorium-230

Thorium-230 was determined in samples collected from reach LA-5. The box plot (Figure E2-8) and results of the statistical testing (Table E2-1) suggest that LA-5 results are not different from background data. Thus, thorium-230 is not retained as a COPC.

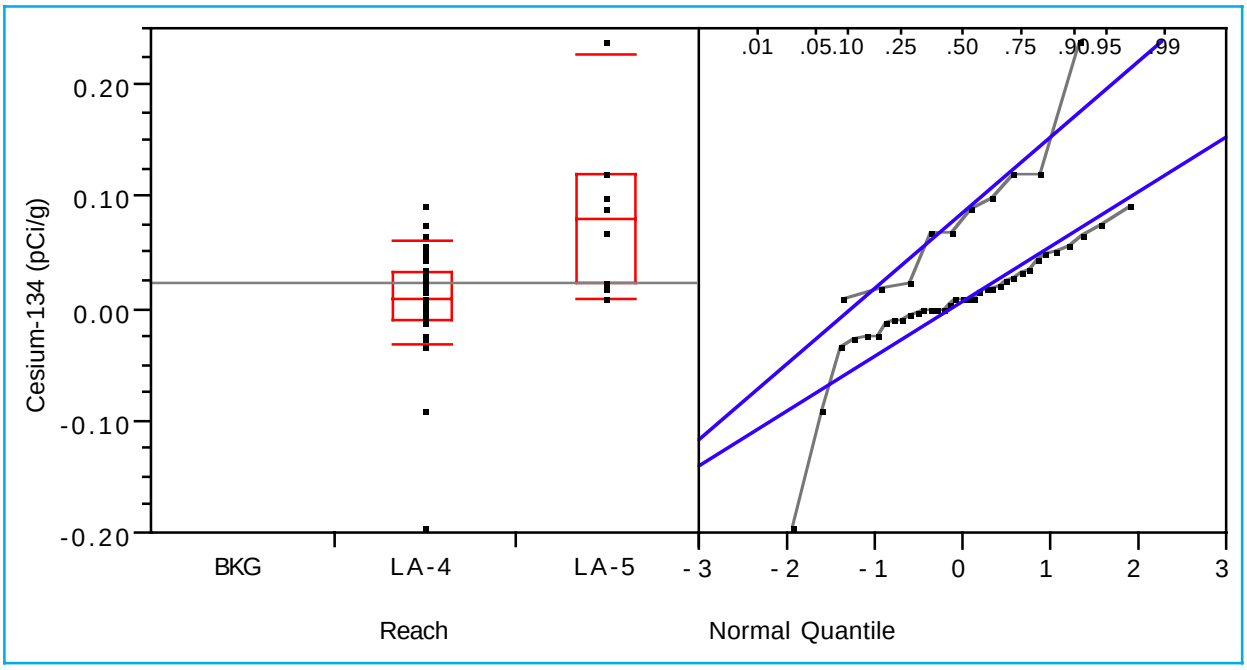

Figure E2-2. Box plot for cesium-134.

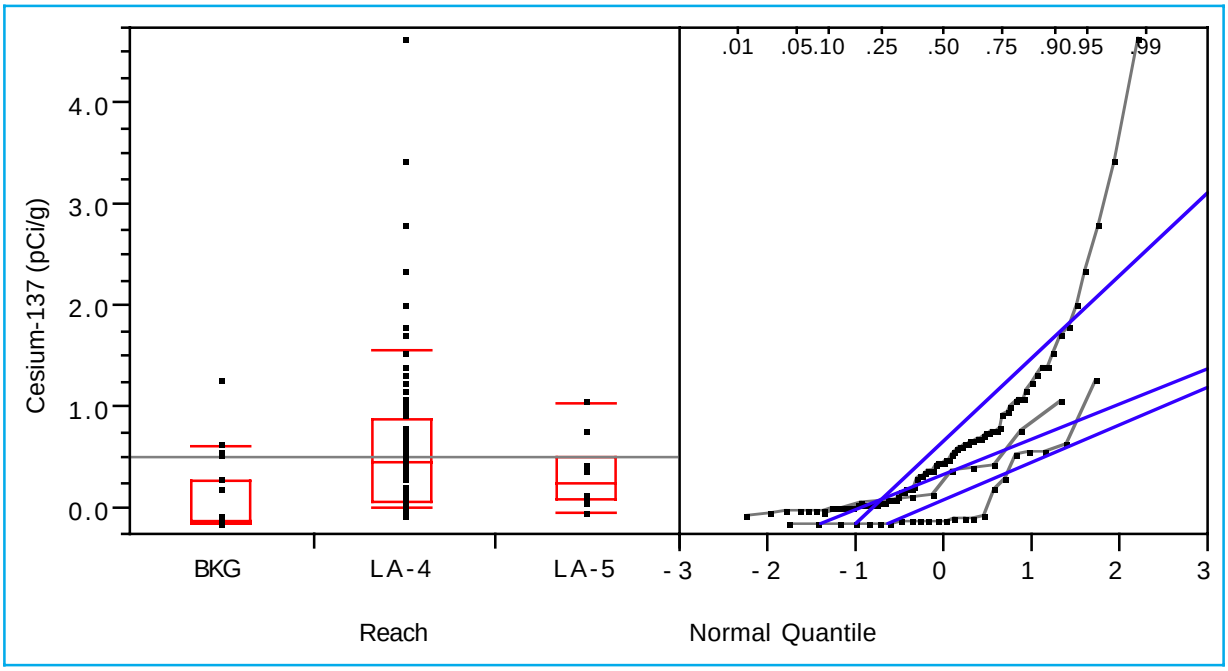

Figure E2-3. Box plot for cesium-137.

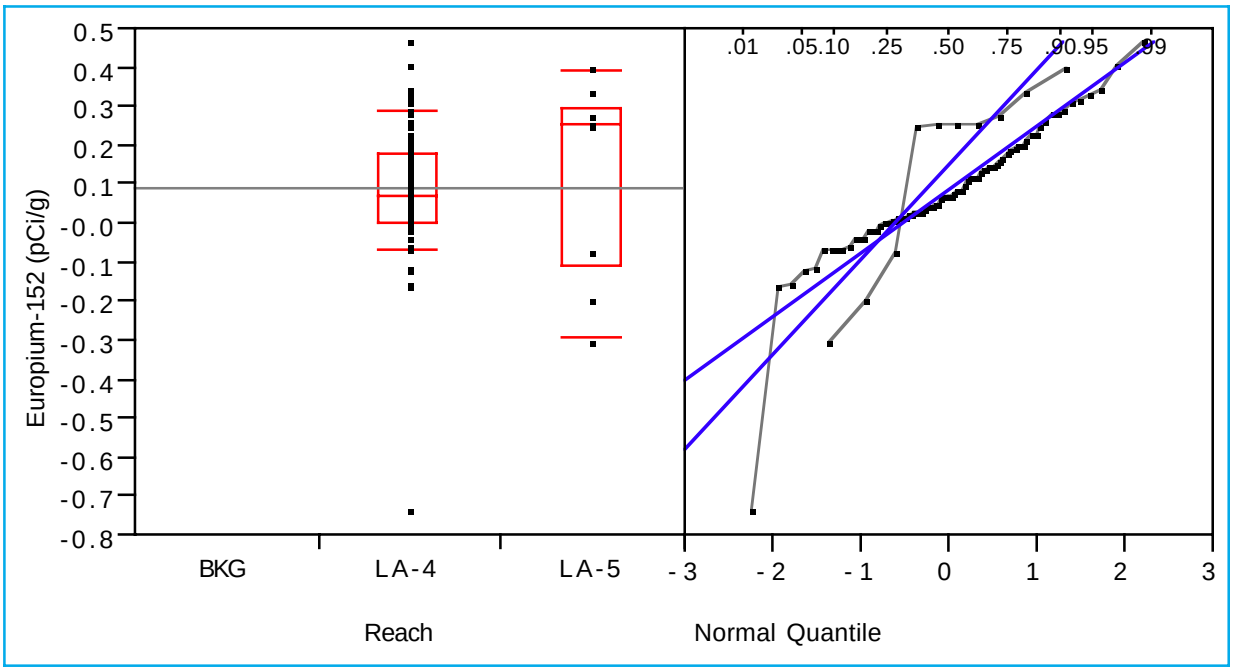

Figure E2-4. Box plot for europium-152.

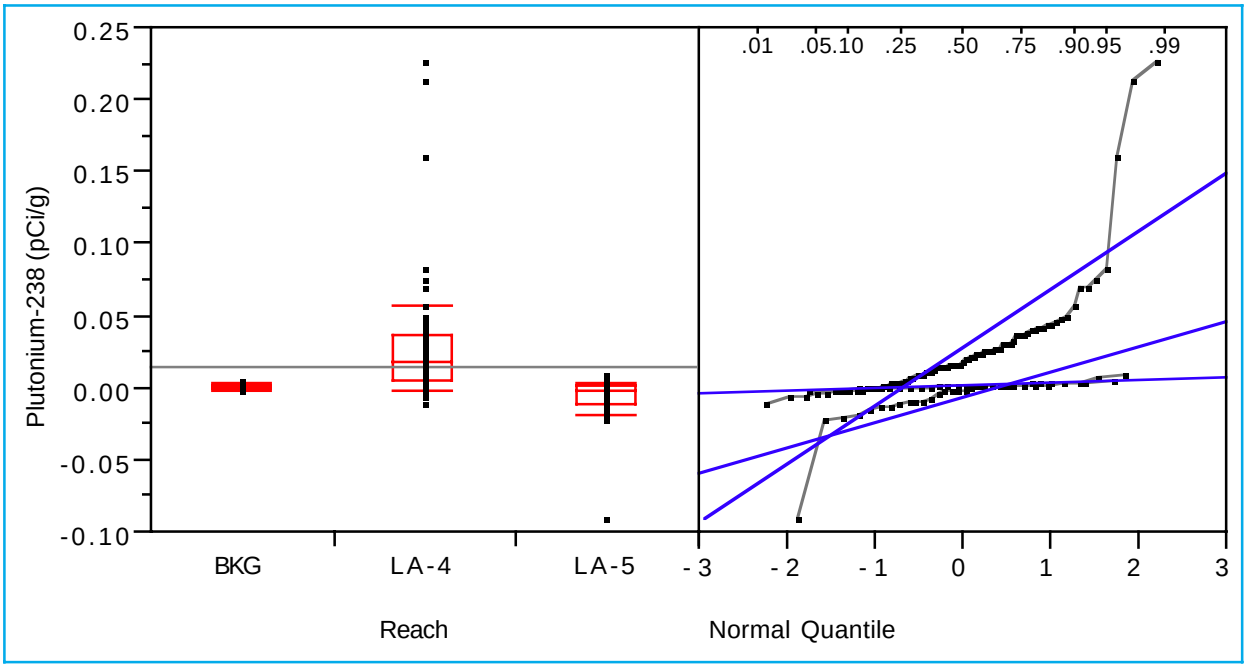

Figure E2-5. Box plot for plutonium-238.

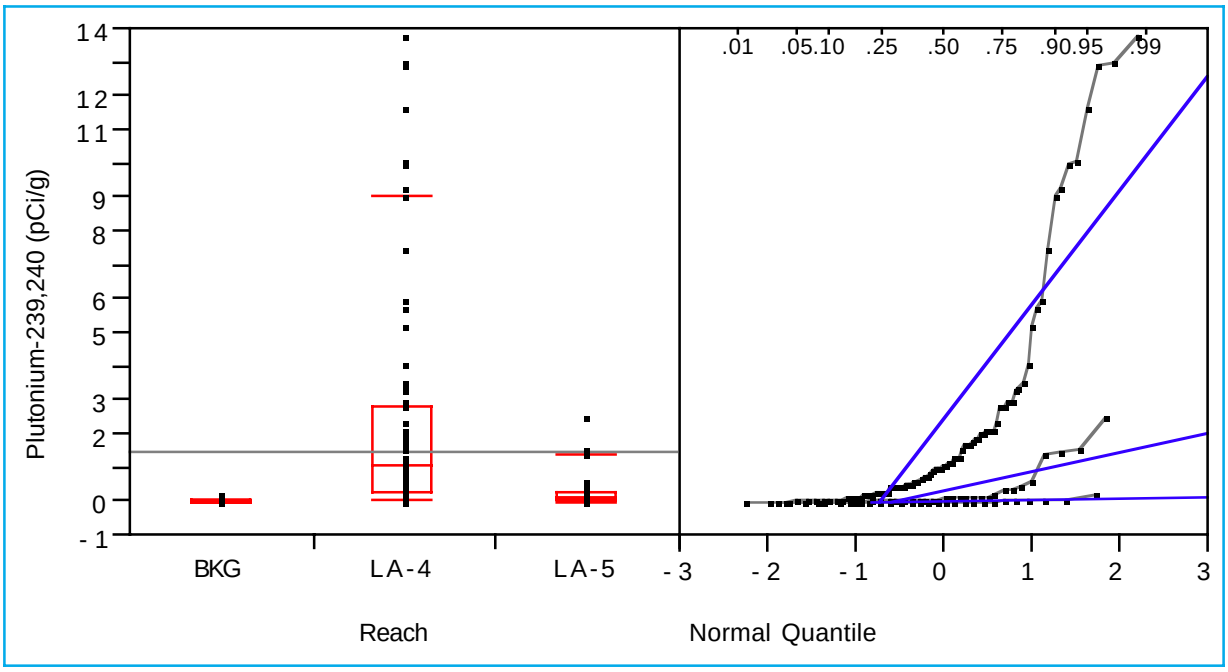

Figure E2-6. Box plot for plutonium-239,240.

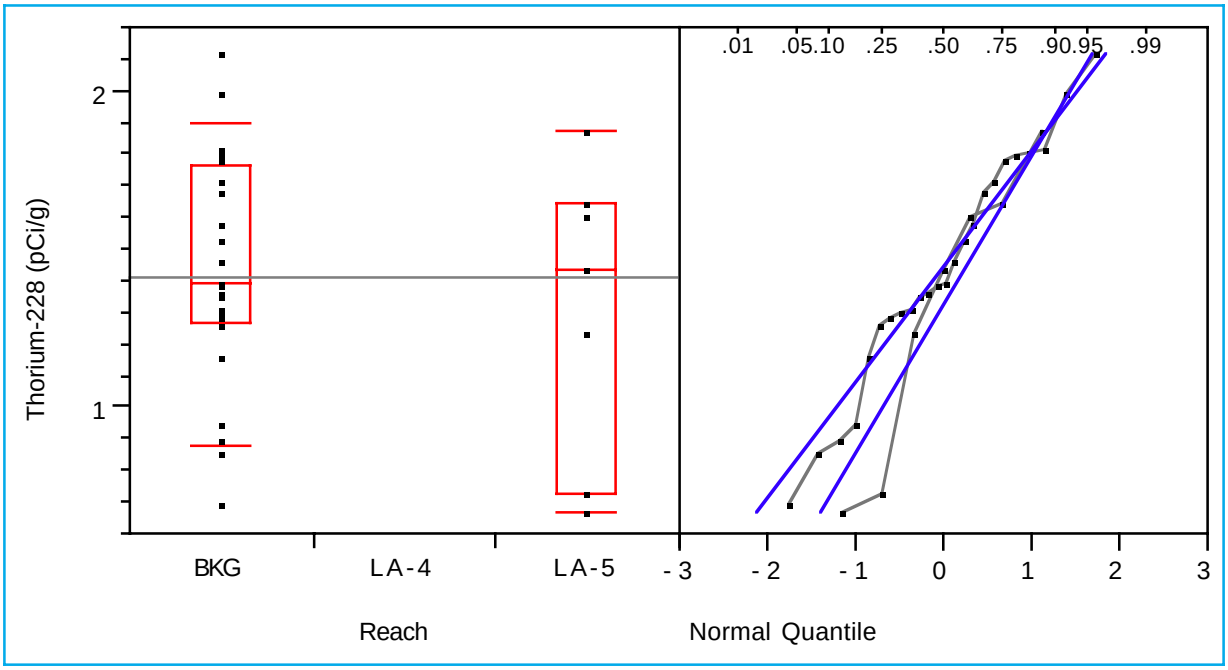

Figure E2-7. Box plot for thorium-228.

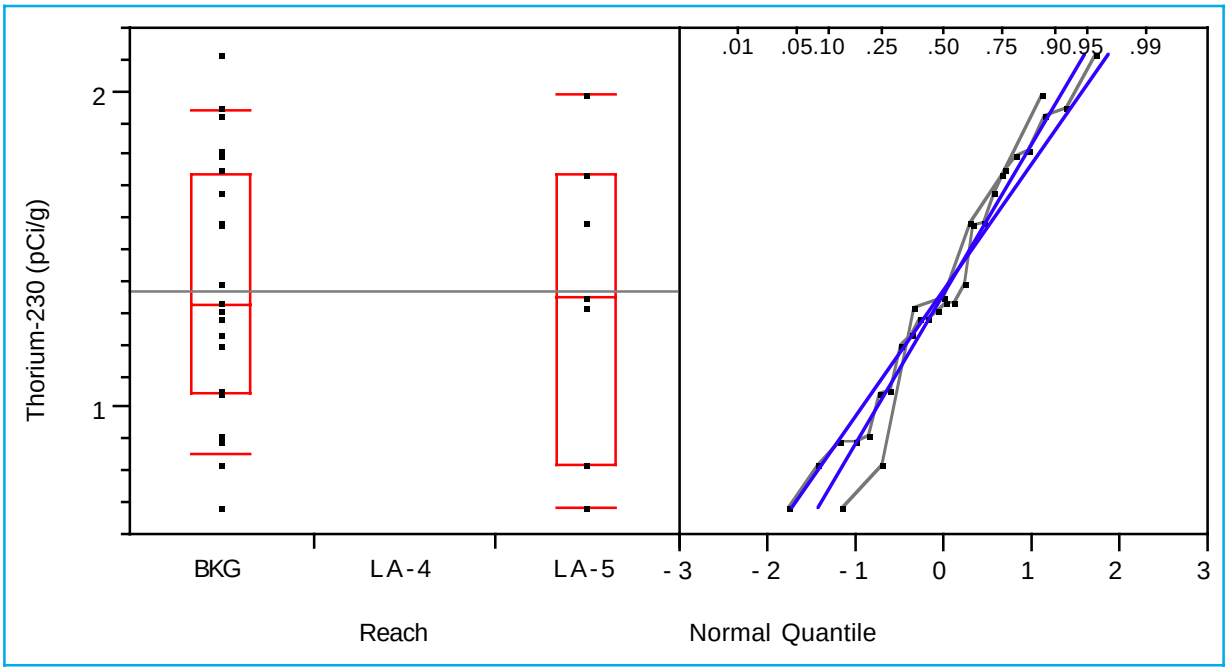

Figure E2-8. Box plot for thorium-230.

E-2.2.9 Thorium-232

Thorium-232 was determined in samples collected from reach LA-5. The box plot (Figure E2-9) and results of the statistical testing (Table E2-1) suggest that LA-5 results are not different from background data. Thus, thorium-232 is not retained as a COPC.

E-2.2.10 Tritium

Tritium was determined in samples collected from reach LA-5. The box plot (Figure E2-10) and results of the statistical testing (Table E2-1) suggest that LA-5 results are not different from background data. Thus, tritium is not retained as a COPC.

E-2.2.11 Uranium-234

Uranium-234 was determined in samples collected from reach LA-5. The box plot (Figure E2-11) and results of the statistical testing (Table E2-1) suggest that LA-5 results are not different from background data. Thus, uranium-234 is not retained as a COPC.

E-2.2.12 Uranium-238

Uranium-238 was determined in samples collected from reach LA-5. The box plot (Figure E2-12) and results of the statistical testing (Table E2-1) suggest that LA-5 results are not different from background data. Thus, uranium-238 is not retained as a COPC.

E-3.0 COLLOCATION OF COPCs

The collocation, or correlation of concentrations, of COPCs was evaluated through a series of figures and statistical analyses. Four radionuclides (americium-241; cesium-137; plutonium-238; and plutonium-239,240) were selected as key radionuclides because of their abundance in lower Los Alamos Canyon sediments. Contaminant sources can be linked to two of these four radionuclides. Cesium-137 can be used an indicator of sediment derived from upper Los Alamos Canyon. Plutonium-239,240 can be used as an indicator of sediment derived from Pueblo 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. These plots contain two types of symbols: the “x” symbols represent nondetected sample results, and the solid squares represent detected sample results. For radionuclide and inorganic COPCs the plots also show background results with the same symbols. Cesium-137 values less than the background value of 0.9 pCi/g primarily represent background concentrations, and most cesium-137 values less than 0.9 pCi/g on the scatter plots are either background samples or reach LA-5 samples. Plutonium-239,240 values less than the background value of 0.068 pCi/g primarily represent background concentrations, and few of the lower Los Alamos Canyon sediment samples have concentrations that are less than the background value. Collocation is suggested by observing an increasing trend in the COPC concentration for increasing concentrations of cesium-137 or plutonium-239,240 (especially for concentrations above the background value). A lack of collocation is suggested by observing elevated COPC values associated with low cesium-137 or low plutonium-239,240 (or concentrations less than the background value).

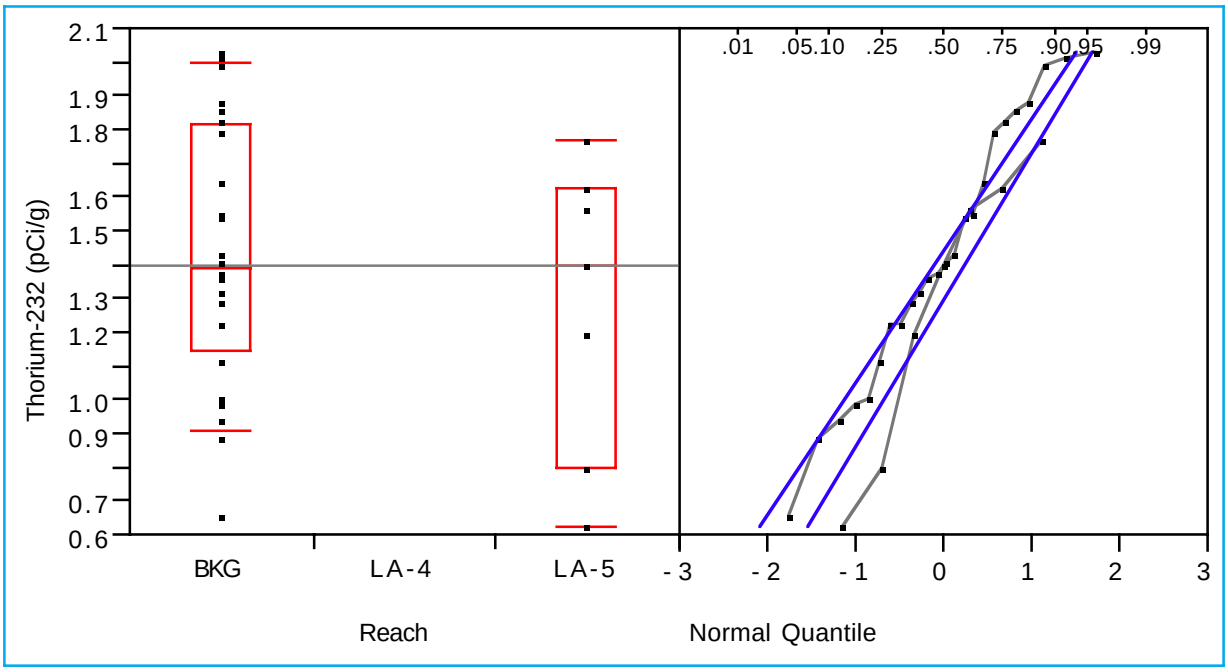

Figure E2-9. Box plot for thorium-232.

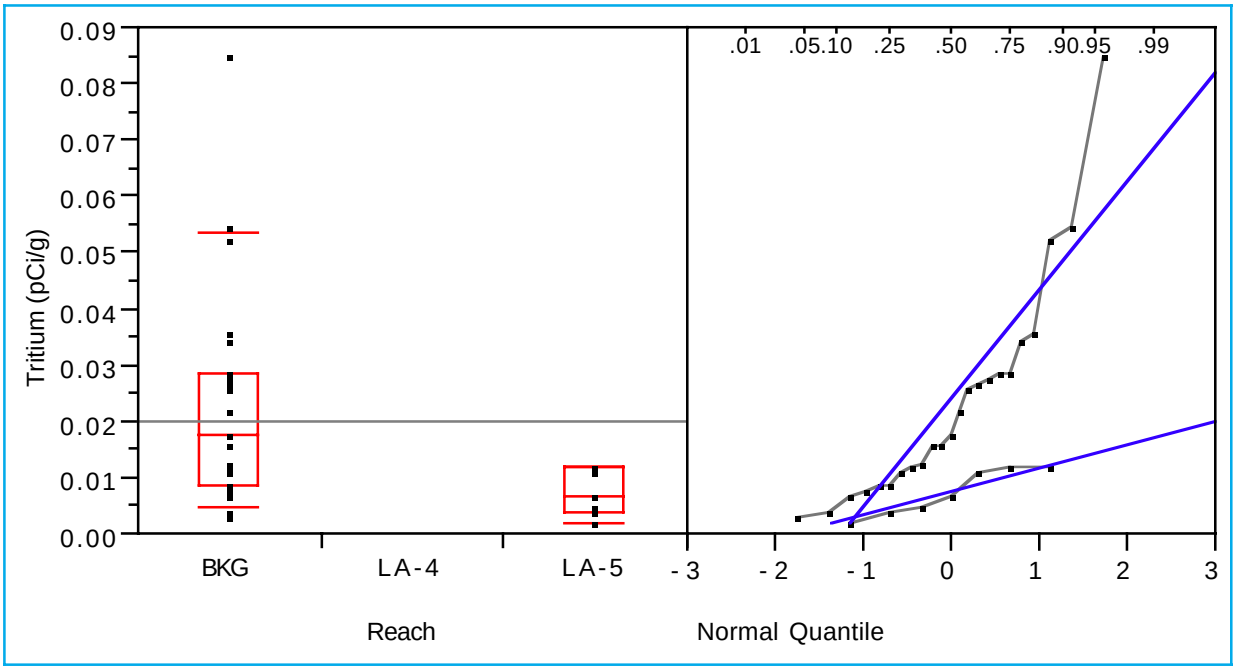

Figure E2-10. Box plot for tritium.

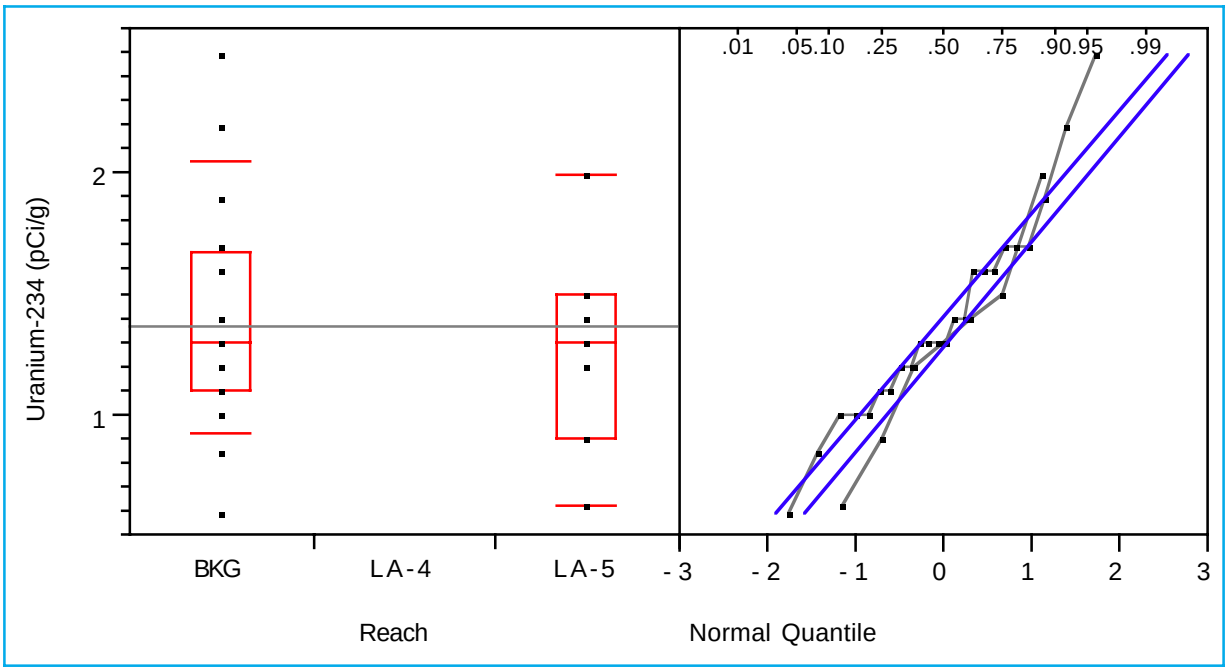

Figure E2-11. Box plot for uranium-234.

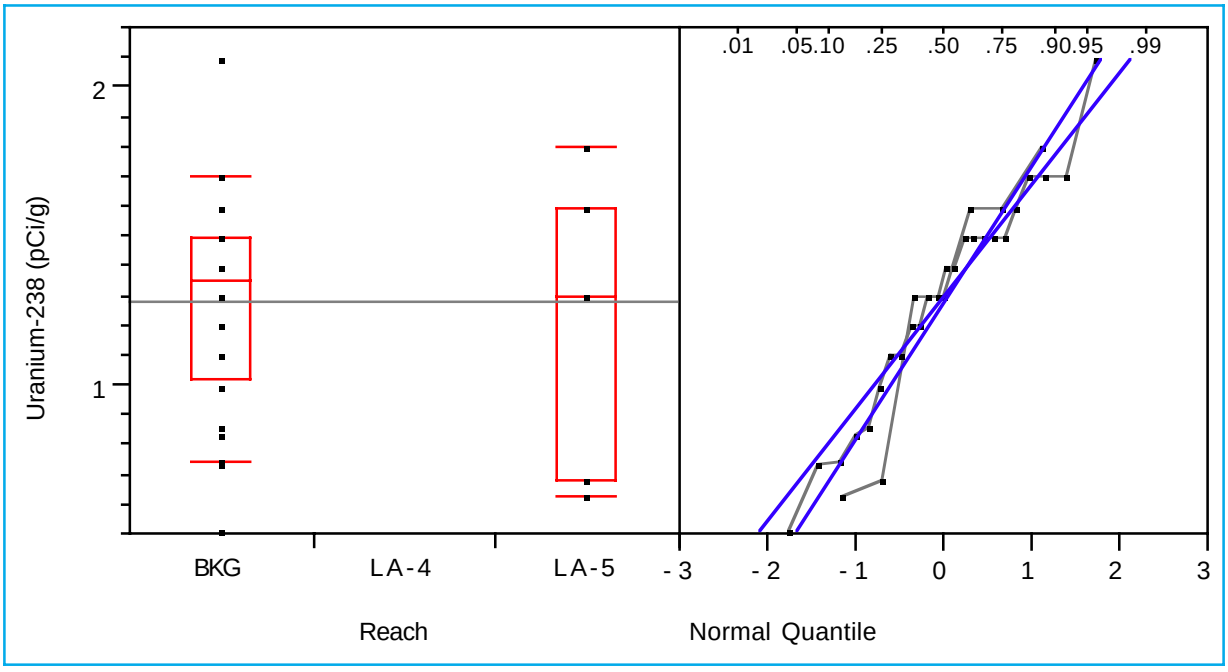

Figure E2-12. Box plot for uranium-238.

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 for 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 cesium-137 or plutonium-239,240 and the other COPCs. There are some statistically significant correlations between the inorganic and radionuclide COPCs with either cesium-137 or plutonium-239,240. Only two organic chemicals in the polychlorinated biphenyl (PCB)/pesticide group were detected, and neither is correlated to the indicator radionuclides. No semivolatile organic compounds (SVOCs) were detected in lower Los Alamos Canyon; thus, no SVOCs were identified as COPCs. Typically, statistically significant correlations are observed with both or neither indicator COPCs because there is a statistically significant rank correlation between cesium-137 and plutonium-239,240, as shown in Table E3-1.

Figures E3-1 through E3-6 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 (by gamma spectroscopy) and plutonium-238 tend to have better correlations with cesium-137 than with plutonium-239,240. Americium-241 (by alpha spectroscopy) and plutonium-238 (rank correlation only) tend to have a better correlation with plutonium-239,240 than with cesium-137. Interpretation of these correlations is confounded by several factors. First, americium-241 (by alpha spectroscopy) was obtained only in samples collected in reach LA-5. Second, the relationships presented in the scatter plots are clearly not linear, and evidence of discrete sediment packages associated with either upper Los Alamos Canyon or Pueblo Canyon are apparent. For example, the americium-241 (by gamma spectroscopy) versus plutonium-239,240 scatter plot (Figure E3-2b) shows three apparent data groups. First are samples with low americium-241 and greater than 2 pCi/g of plutonium-239,240. These samples appear to show americium-241 in ratios expected from radiological ingrowth and would represent sediments primarily derived from Pueblo Canyon. Second are the six samples with more than 0.5 pCi/g of americium-241 and low plutonium-239,240 concentration (less than 2 pCi/g). These samples appear to have isotopic ratios more indicative of an upper Los Alamos Canyon origin. Lastly are samples with concentrations too low to make clear distinctions as to their origin based on visual inspection of this scatter plot (americium-241 <0.5 pCi/g and plutonium-239,240 <2 pCi/g). Inspection of the cesium-137 versus plutonium-239,240 scatter plot (Figure E3-4) also leads to conclusions regarding the main sources of sediment packages in lower Los Alamos Canyon (high cesium-137 concentrations being associated with upper Los Alamos Canyon sediments and high plutonium-239,240 concentrations likely associated with Pueblo Canyon sediments). However, Figure E3-4 also provides some evidence for mixing of discrete sediment packages because two samples with more than 5 pCi/g of plutonium-239,240 also have concentrations of cesium-137 above the background value. The high plutonium-239,240 concentrations suggest a Pueblo Canyon source for these sampled sediments, and cesium-137 would not be expected to be above background values in these samples based on reach P-4 results.

TABLE E3-1

PEARSON AND SPEARMAN RANK CORRELATION VALUES

Analyte	Cesium-137					Plutonium-239,240				
	Count	Pearson Corr.	Signif. Prob. (p)	Spearman Rank Corr.	Signif. Prob. (p)	Count	Pearson Corr.	Signif. Prob. (p)	Spearman Rank Corr.	Signif. Prob. (p)
Antimony	36	0.032	0.852	-0.175	0.307	**36**[a]	**-0.504**	**0.002**	**-0.401**	**0.016**
Boron	27	0.238	0.232	0.222	0.267	27	0.276	0.164	0.338	0.084
Cadmium	43	**0.576**	**<0.001**	**0.350**	**0.022**	43	-0.039	0.804	0.194	0.213
Calcium	43	0.113	0.469	**0.440**	**0.003**	43	**0.469**	**0.002**	0.337	0.027
Copper	43	**0.469**	**0.002**	**0.397**	**0.008**	43	0.376	0.013	0.348	0.022
Lead	43	**0.707**	**<0.001**	**0.480**	**0.001**	43	0.247	0.110	0.328	0.032
Magnesium	41	-0.125	0.437	0.076	0.638	41	-0.176	0.271	-0.033	0.840
Potassium	41	-0.271	0.087	-0.276	0.081	41	**-0.343**	**0.028**	**-0.352**	**0.024**
Selenium	43	0.005	0.976	0.475	0.001	43	**0.326**	**0.033**	**0.731**	**<.0001**
Sodium	43	-0.072	0.647	-0.148	0.345	43	-0.264	0.087	-0.137	0.380
Vanadium	41	-0.195	0.223	-0.176	0.271	41	-0.239	0.132	-0.262	0.098
Americium-241	31	0.050	0.789	0.182	0.328	31	0.312	0.087	**0.426**	**0.017**
Americium-241[b]	84	**0.780**	**<0.001**	**0.436**	**<0.001**	84	0.028	0.803	0.301	0.005
Cesium-134	45	**-0.317**	**0.034**	-0.246	0.104	45	-0.102	0.504	-0.196	0.197
Cesium-137	N/A[c]	N/A	N/A	N/A	N/A	108	0.180	0.062	**0.598**	**<0.001**
Europium-152	84	0.151	0.170	**0.220**	**0.044**	84	0.018	0.868	0.029	0.794
Plutonium-238	108	**0.774**	**<0.001**	0.492	<.0001	129	0.334	0.000	**0.592**	**<0.001**
Plutonium-239,240	108	0.180	0.062	**0.598**	**<0.001**	N/A	N/A	N/A	N/A	N/A
Aldrin	14	0.245	0.399	0.261	0.367	14	0.290	0.314	0.173	0.555
4,4'-DDT	14	0.379	0.181	0.353	0.216	14	0.292	0.311	0.277	0.337

a. Bolded values indicate the most significant correlations for a COPC (between Cs-137 and Pu-239,240).

b. Analyzed by gamma spectroscopy

c. N/A = not applicable (correlation analysis is not appropriate to the same analyte)

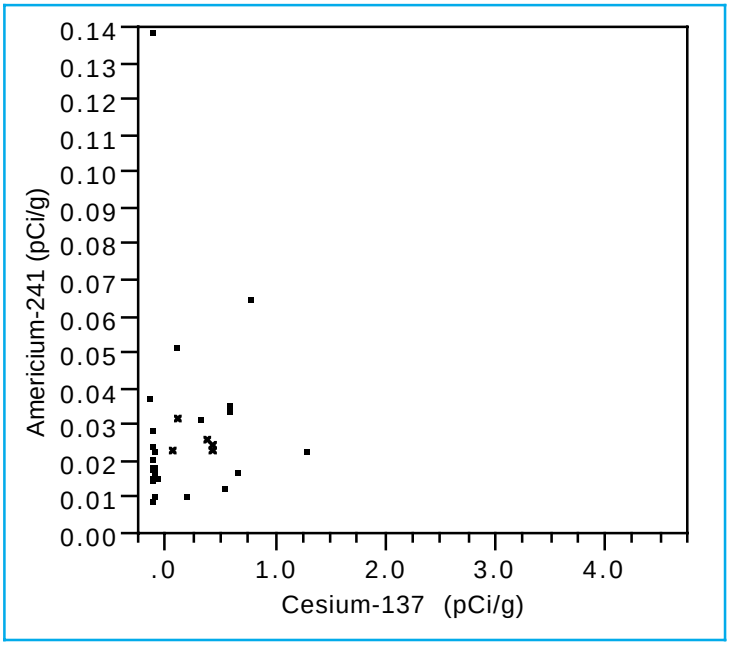

Figure E3-1a. Scatter plot for americium-241 (alpha spectroscopy) versus cesium-137.

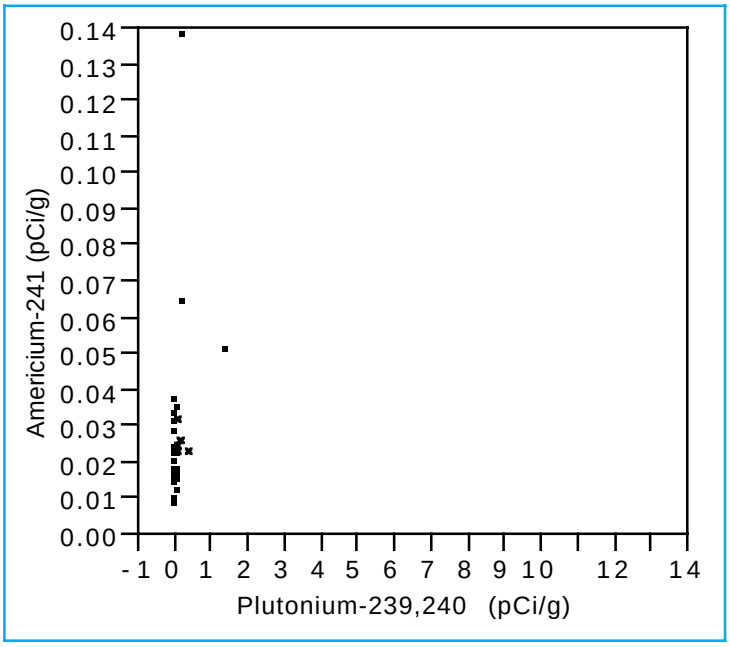

Figure E3-1b. Scatter plot for americium-241 (alpha spectroscopy) versus plutonium-239,240.

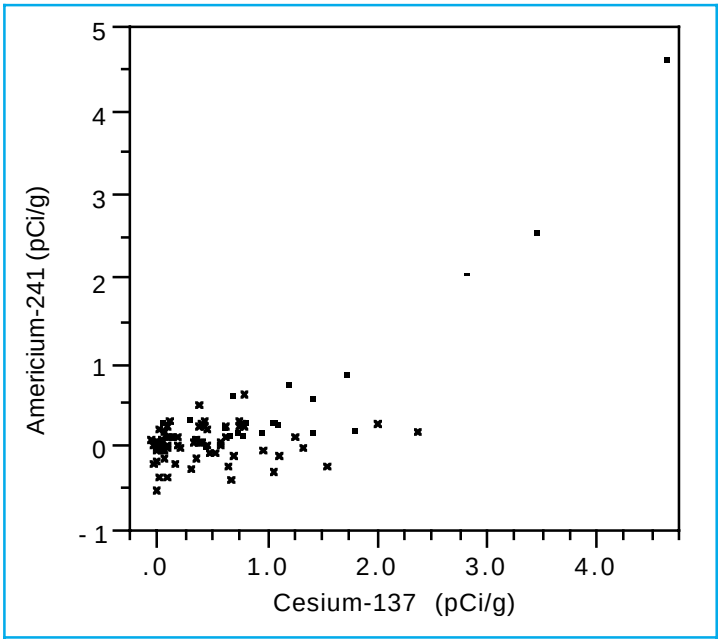

Figure E3-2a. Scatter plot for americium-241 (gamma spectroscopy) versus cesium-137.

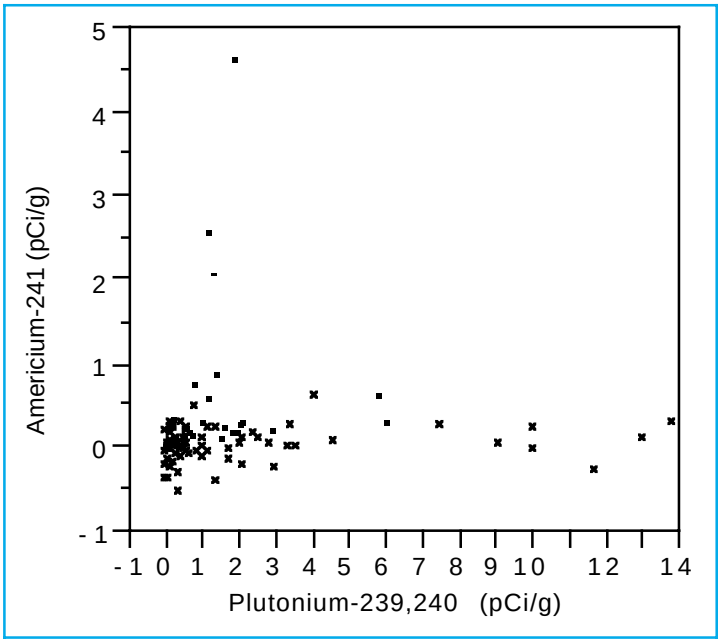

Figure E3-2b. Scatter plot for americium-241 (gamma spectroscopy) versus plutonium-239,240.

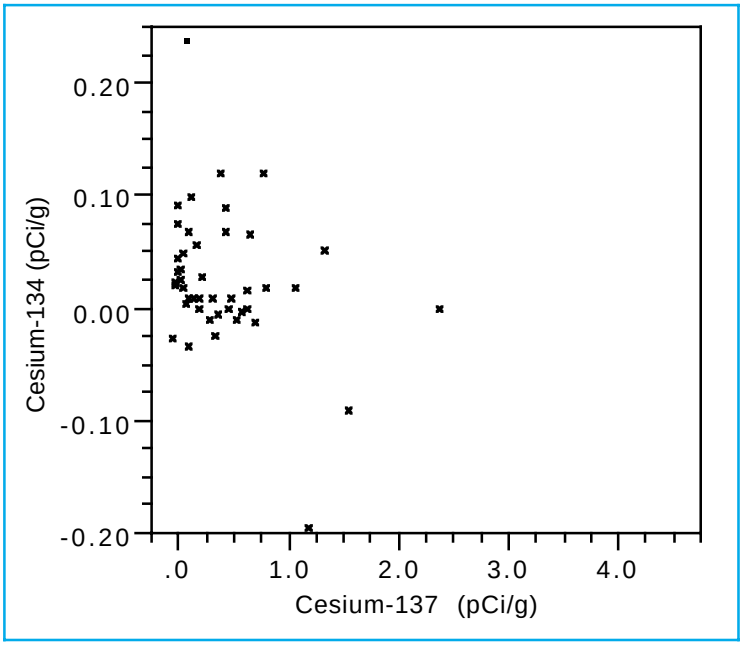

Figure E3-3a. Scatter plot for cesium-134 versus cesium-137.

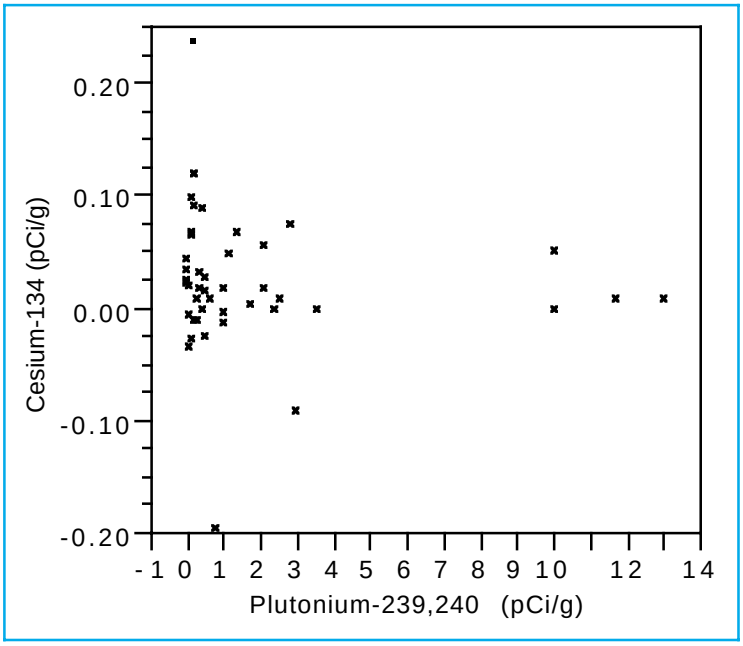

Figure E3-3b. Scatter plot for cesium-134 versus plutonium-239,240.

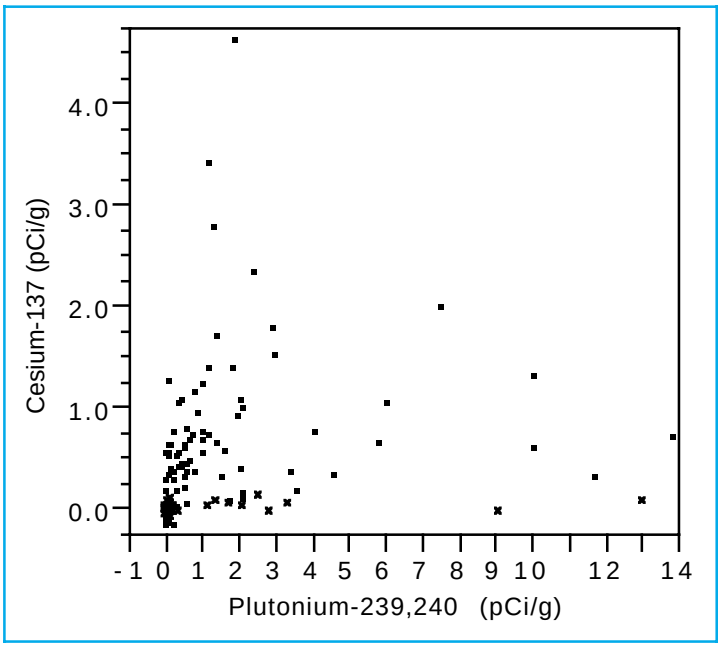

Figure E3-4. Scatter plot for cesium-137 versus plutonium-239,240.

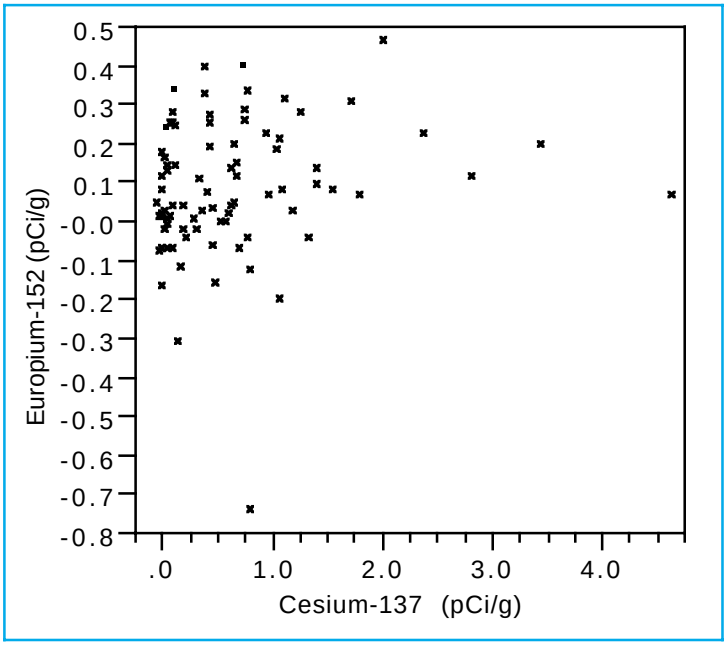

Figure E3-5a. Scatter plot for europium-152 versus cesium-137.

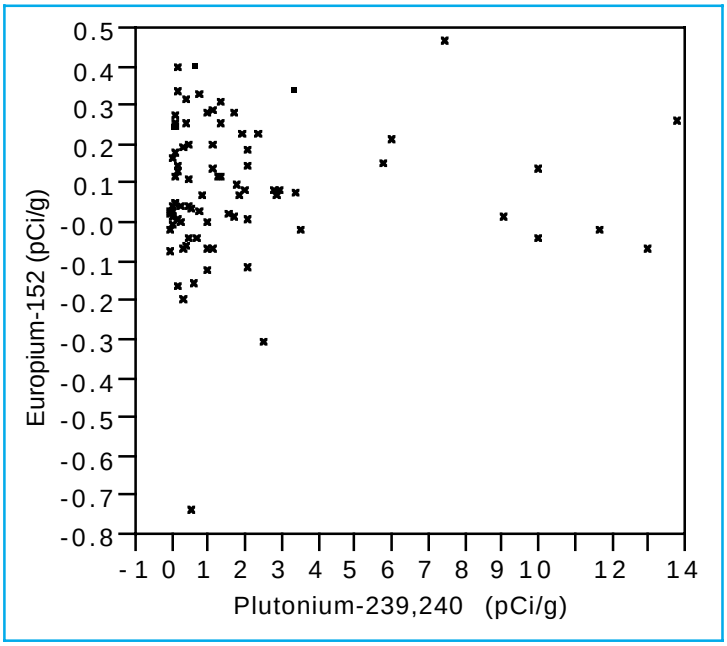

Figure E3-5b. Scatter plot for europium-152 versus plutonium-239,240.

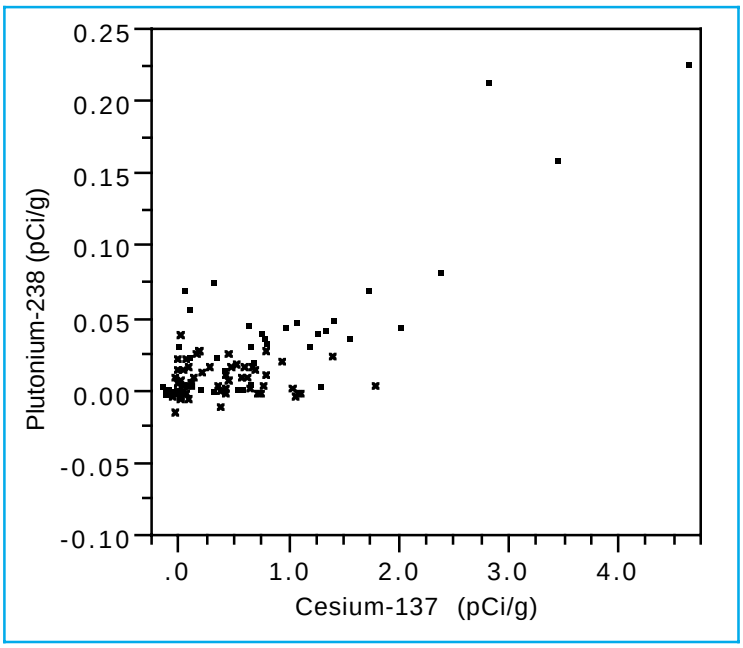

Figure E3-6a. Scatter plot for plutonium-238 versus cesium-137.

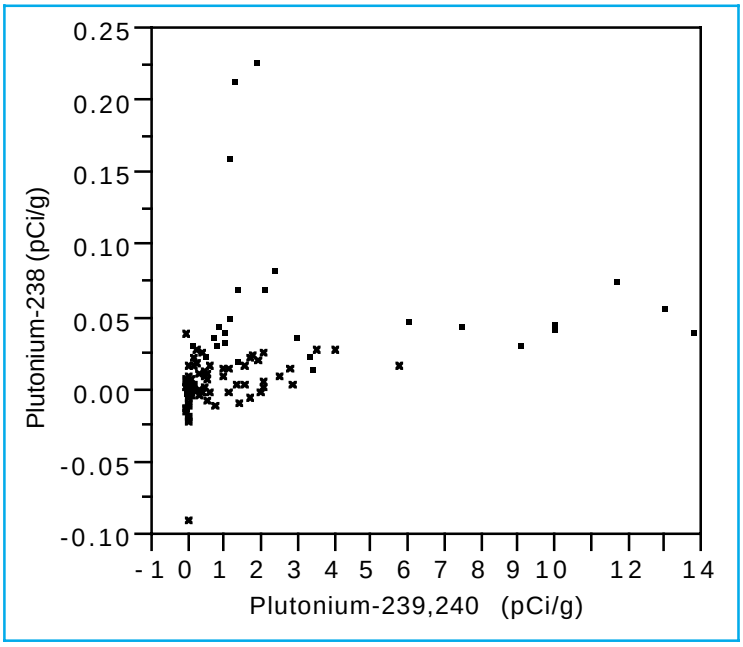

Figure E3-6b. Scatter plot for plutonium-238 versus plutonium-239,240.

Figures E3-7 through E3-17 show the relationships of cesium-137 or plutonium-239,240 with the inorganic COPCs. Recall that "x" symbols shown on some of these plots represent nondetected values. Antimony, cadmium, and selenium were not detected with sufficient frequency to draw conclusions regarding possible collocation. Copper and lead tend to exhibit better correlations with cesium-137 than with plutonium-239,240. Calcium, magnesium, potassium, sodium, and vanadium have negative correlations with the key radionuclides because the higher concentrations for these inorganic chemicals occur in reach LA-5. This negative correlation, or noncorrelation, suggests that boron, calcium, magnesium, potassium, sodium, and vanadium are elevated relative to Laboratory background data in LA-5 because the sampled sediment is derived from a different parent material than was associated with the background sediment samples. Specifically, bedrock upstream from the background sample sites is dominated by the Bandelier Tuff, the Tschicoma Formation, and locally the Puye Formation, whereas erodible Santa Fe Group sediments are exposed in lower Los Alamos Canyon and may be a significant source for sediment with different background geochemistry. Additional samples from Santa Fe Group-derived material could help establish a more site-specific background data set for LA-5 and other areas downstream of Santa Fe Group outcrops. Another possible explanation for detecting these inorganic COPCs is the presence of an additional contaminant sources at former Laboratory sites in either Bayo Canyon or Rendija Canyon. However, a Bayo Canyon or Rendija Canyon source seems to be a remote possibility because of the types of Laboratory activities that occurred in these canyons (firing sites that could be associated with solid releases or airborne deposition of contamination).

Figures E3-18 and E3-19 show the relationships of cesium-137 or plutonium-239,240 with the organic COPCs. Recall that "x" symbols shown on these plots represent nondetected values. Neither organic COPC exhibits significant correlations with either cesium-137 or plutonium-239,240. The low detection frequency of these organic COPCs greatly limits the interpretation and meaning of the correlation analysis.

E-4.0 ANALYSIS OF KEY RADIONUCLIDE FIELD QA SAMPLES AND RESAMPLES

An important aspect of the uncertainty associated with determining either the contaminant inventory or risk resulting from contaminants in lower 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 collocated samples will be based only on data for the key radionuclides. Table E4-1 provides the sample results for two types of collocated samples. Quality assurance (QA) duplicates are basically field splits of single field samples. Although strontium-90 is not a key radionuclide in lower Los Alamos Canyon, it is a key radionuclide in upper Los Alamos Canyon, and it is included in this table for reasons discussed below. Resamples are collocated field samples that are collected at key geomorphic sampling locations in later sampling events, such as layers with exceptionally high plutonium-239,240 or strontium-90 concentrations 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 collocated samples is provided in Figure E4-1. This figure shows the first sample result for these collocated 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. In general, the QA duplicates showed little variation between the two samples, except for pairs of samples that are less than the detection limit. For example, two of the three QA duplicates for americium-241 show >100% relative per cent difference (RPD) because the sample results are less than the typical MDA for americium-241 by gamma spectroscopy. It is notable that resampling of the layer in reach LA-4 West that yielded the highest plutonium-239,240 result in the first sampling round of 13.8 pCi/g (sample 04LA-97-0172) provided a similar result of 12.9 pCi/g when resampled (sample 04LA-97-0552).

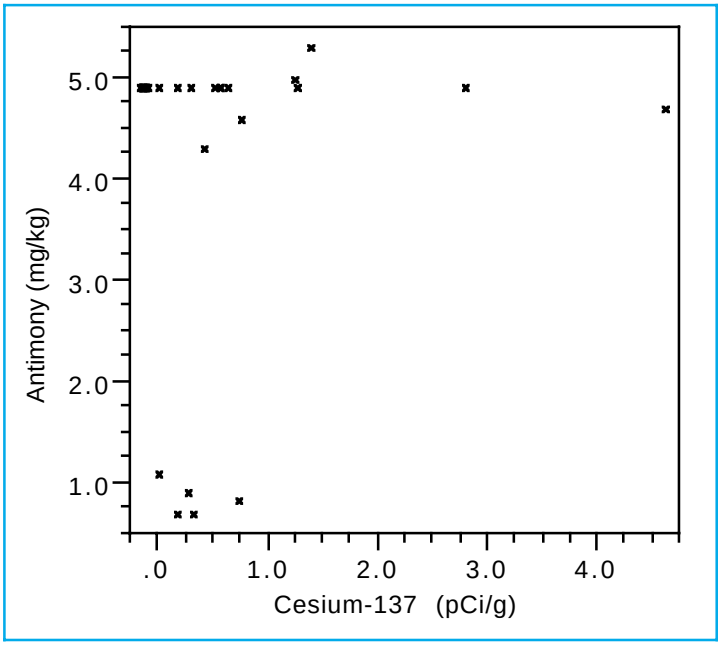

Figure E3-7a. Scatter plot for antimony versus cesium-137.

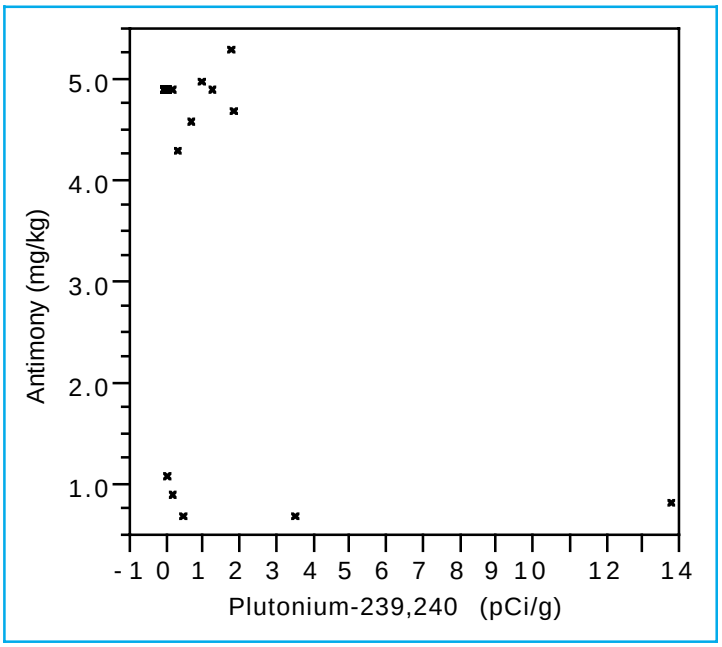

Figure E3-7b. Scatter plot for antimony versus plutonium-239,240.

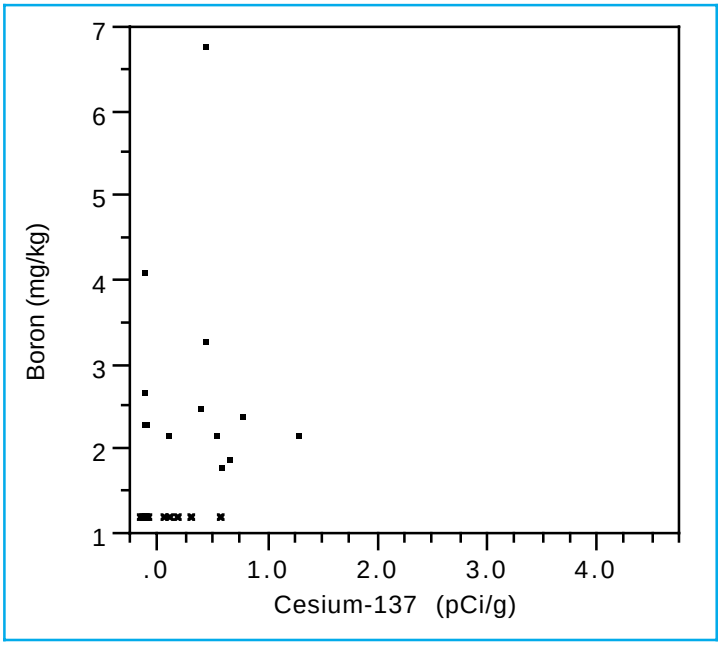

Figure E3-8a. Scatter plot for boron versus cesium-137.

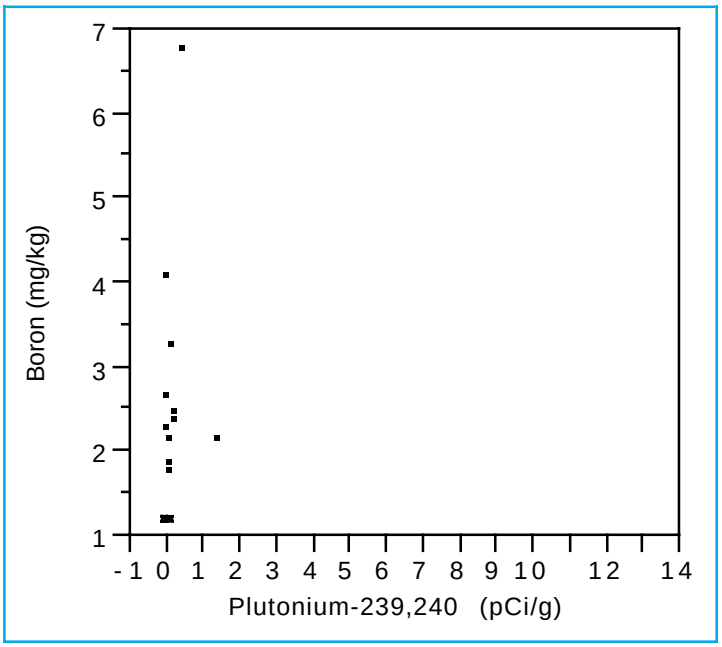

Figure E3-8b. Scatter plot for boron versus plutonium-239,240.

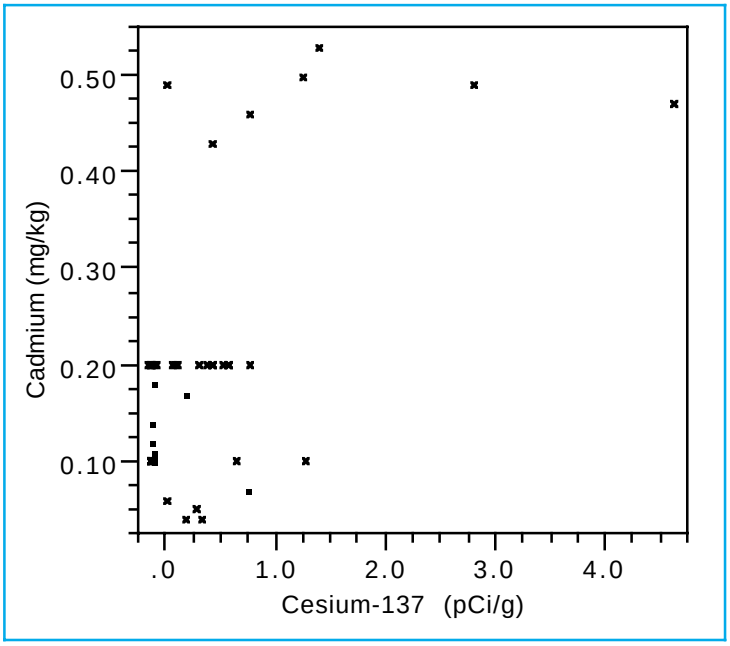

Figure E3-9a. Scatter plot for cadmium versus cesium-137.

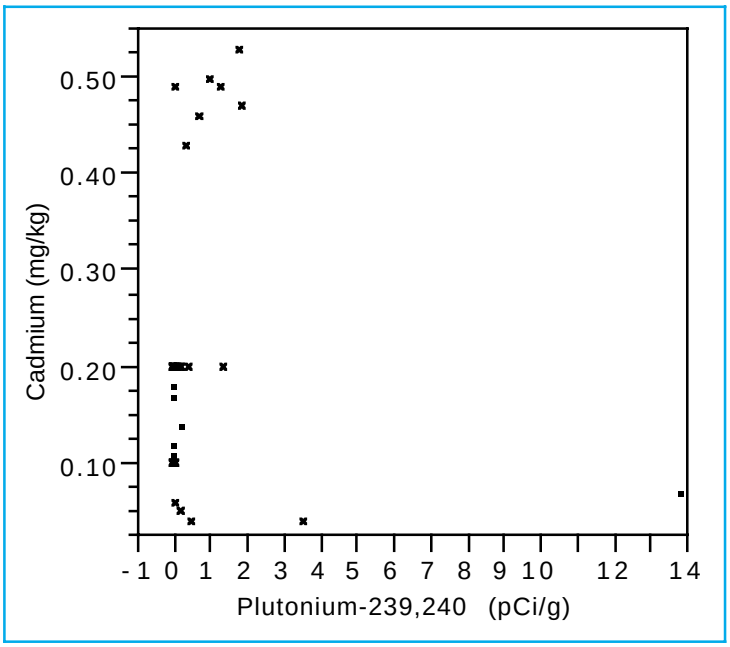

Figure E3-9b. Scatter plot for cadmium versus plutonium-239,240.

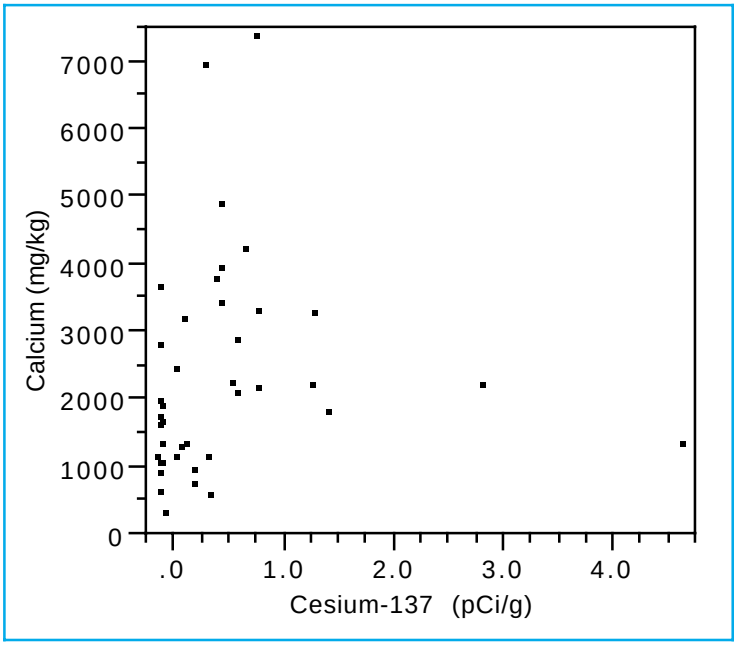

Figure E3-10a. Scatter plot for calcium versus cesium-137.

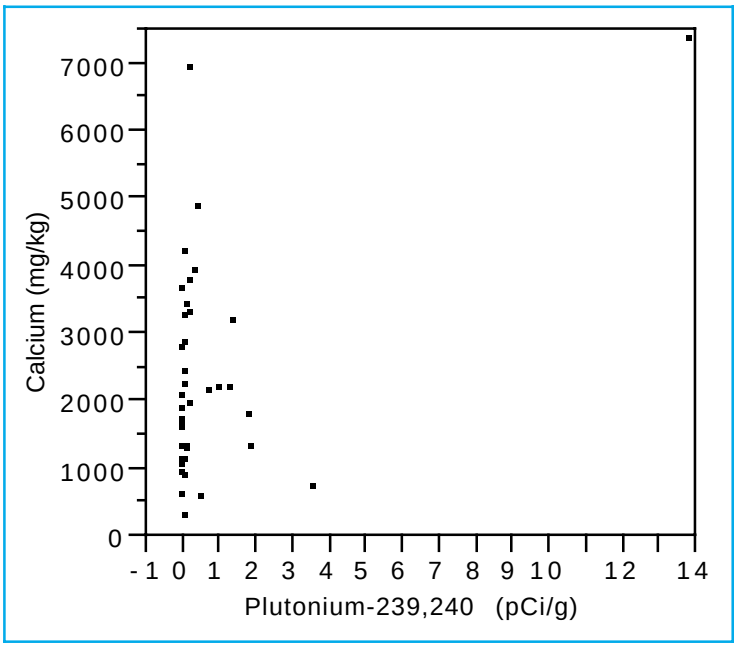

Figure E3-10b. Scatter plot for calcium versus plutonium-239,240.

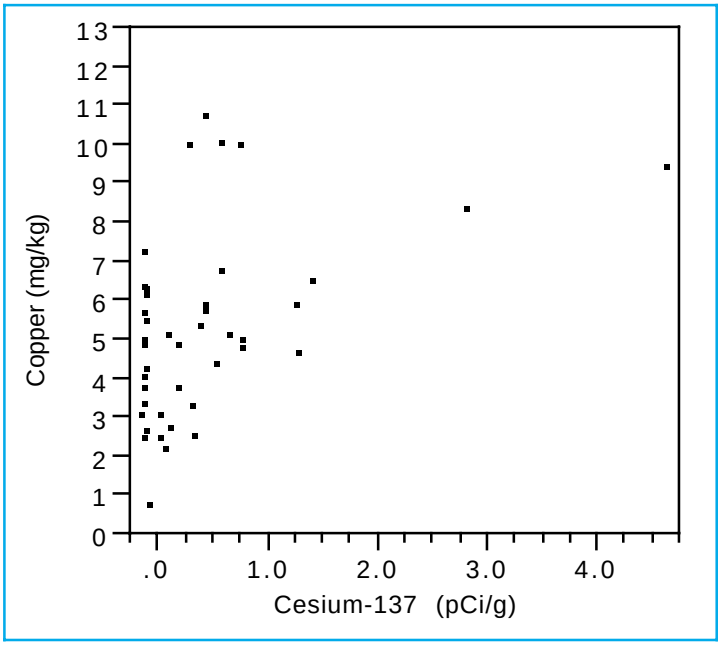

Figure E3-11a. Scatter plot for copper versus cesium-137.

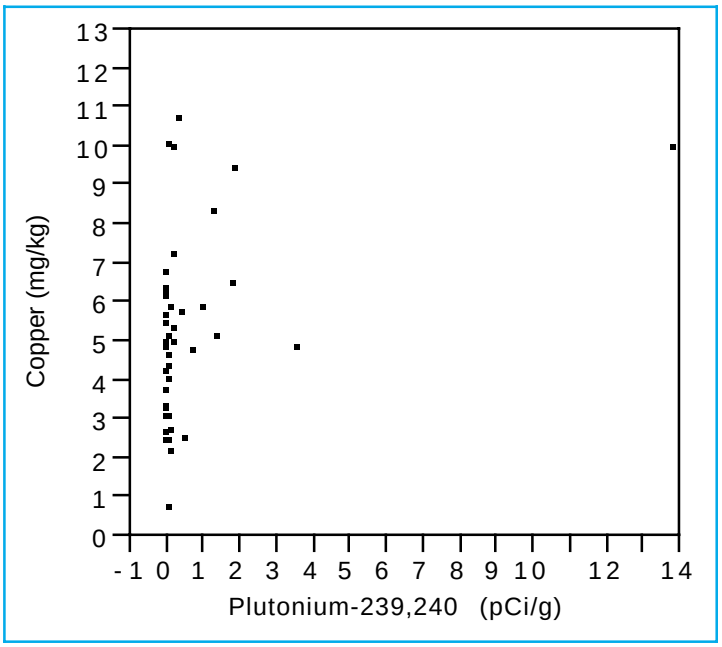

Figure E3-11b. Scatter plot for copper versus plutonium-239,240.

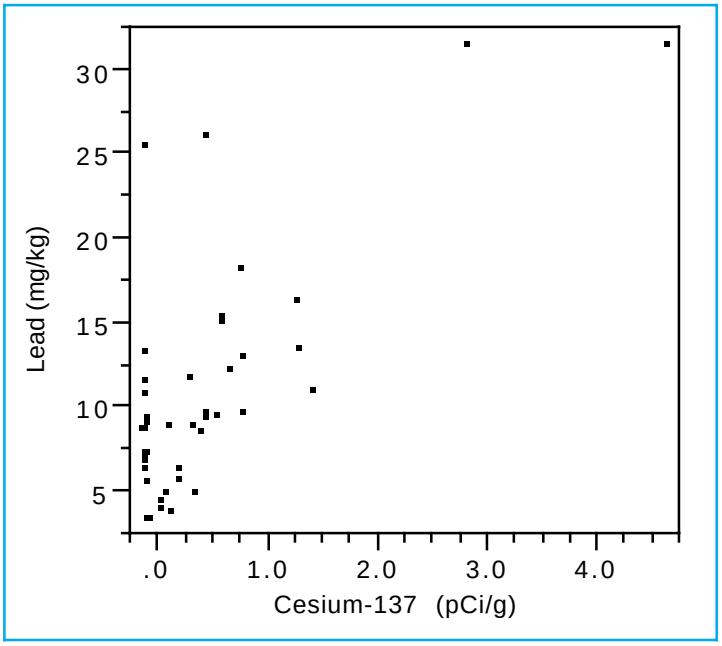

Figure E3-12a. Scatter plot for lead versus cesium-137.

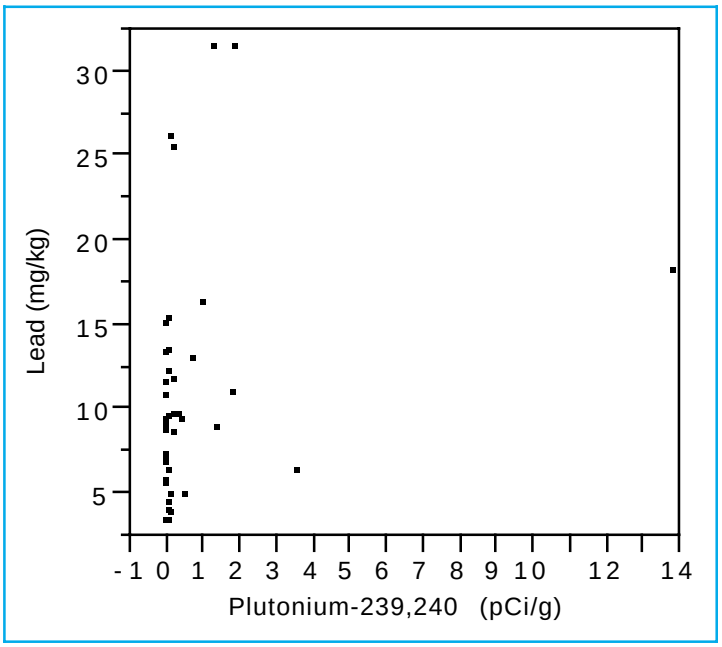

Figure E3-12b. Scatter plot for lead versus plutonium-239,240.

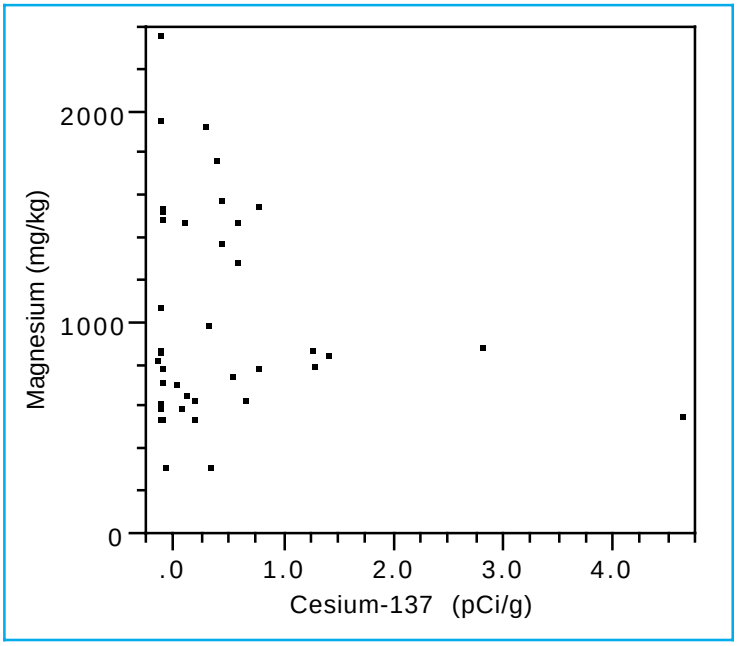

Figure E3-13a. Scatter plot for magnesium versus cesium-137.

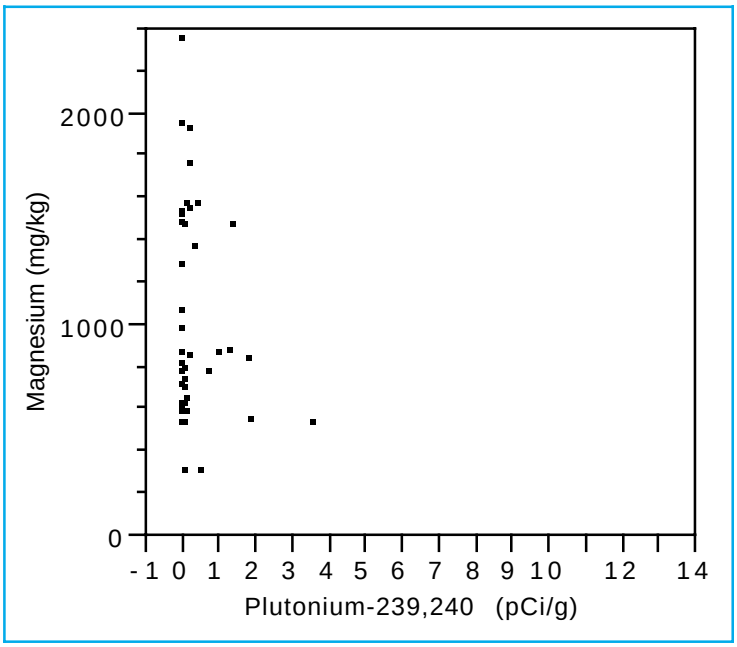

Figure E3-13b. Scatter plot for magnesium versus plutonium-239,240.

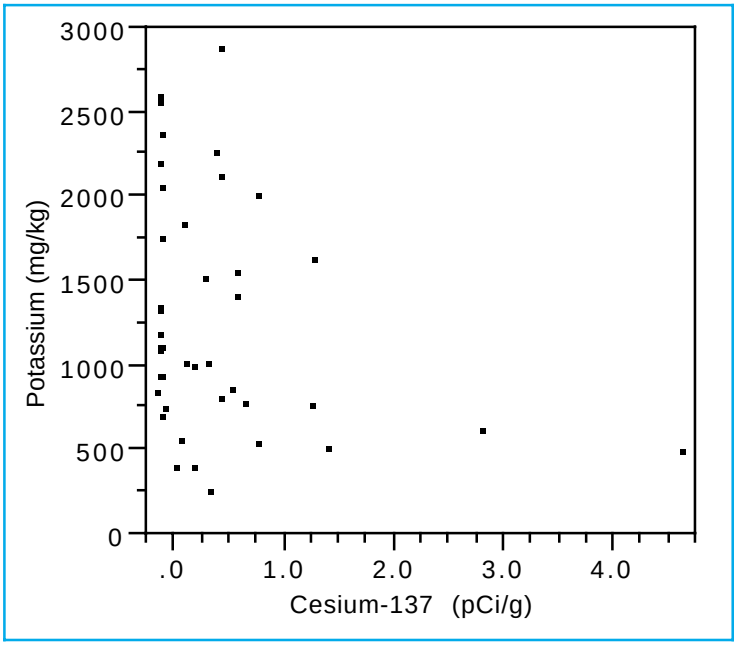

Figure E3-14a. Scatter plot for potassium versus cesium-137.

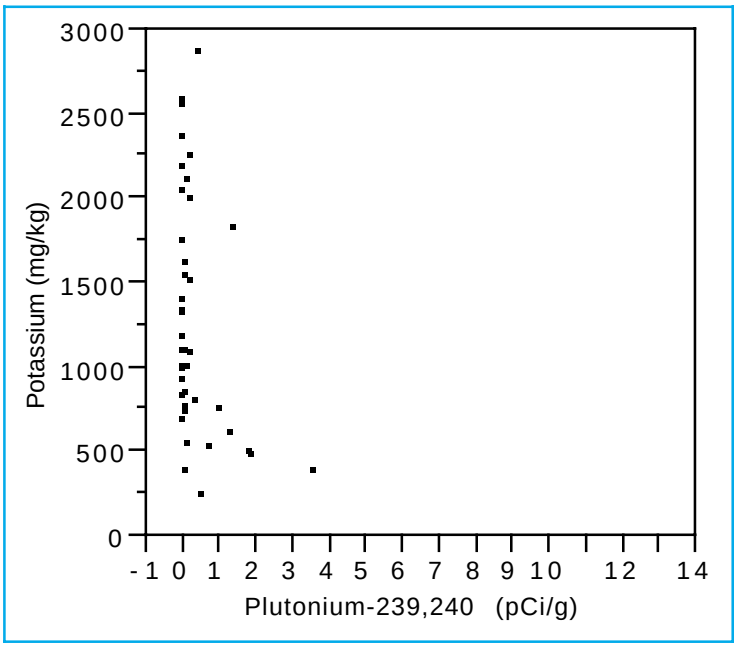

Figure E3-14b. Scatter plot for potassium versus plutonium-239,240.

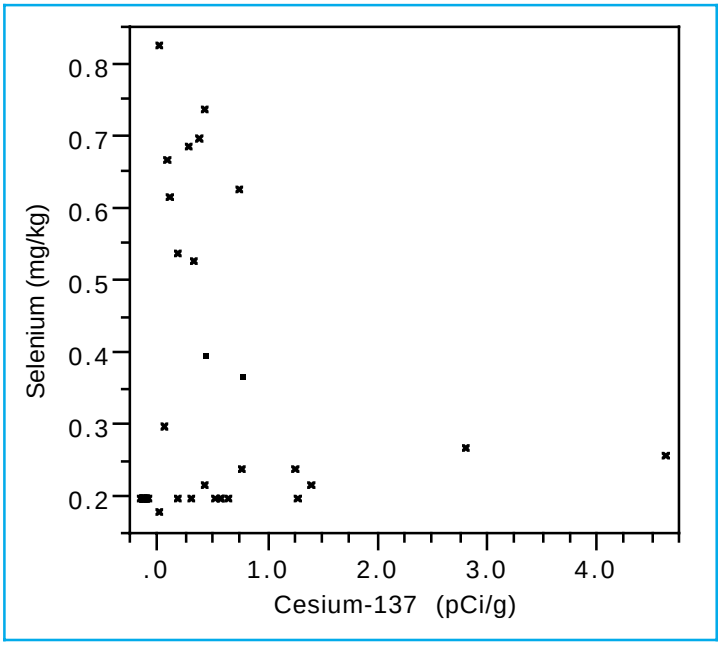

Figure E3-15a. Scatter plot for selenium versus cesium-137.

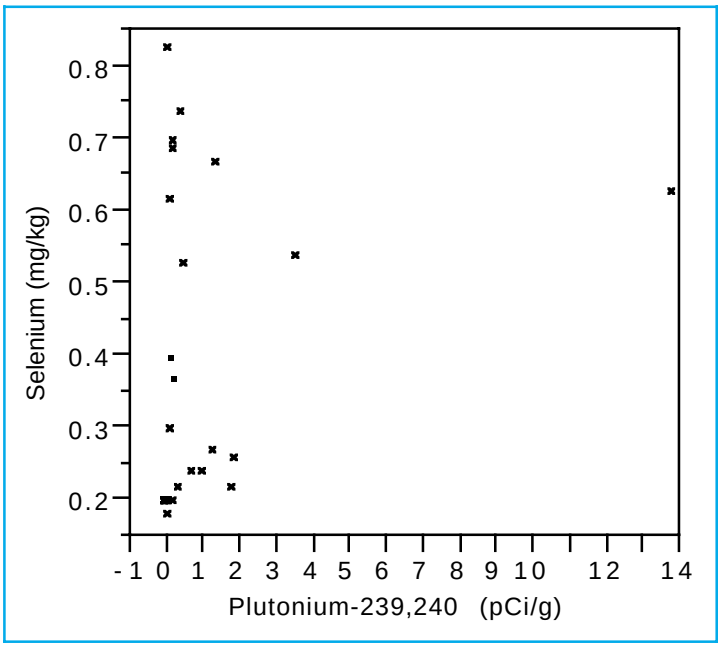

Figure E3-15b. Scatter plot for selenium versus plutonium-239,240.

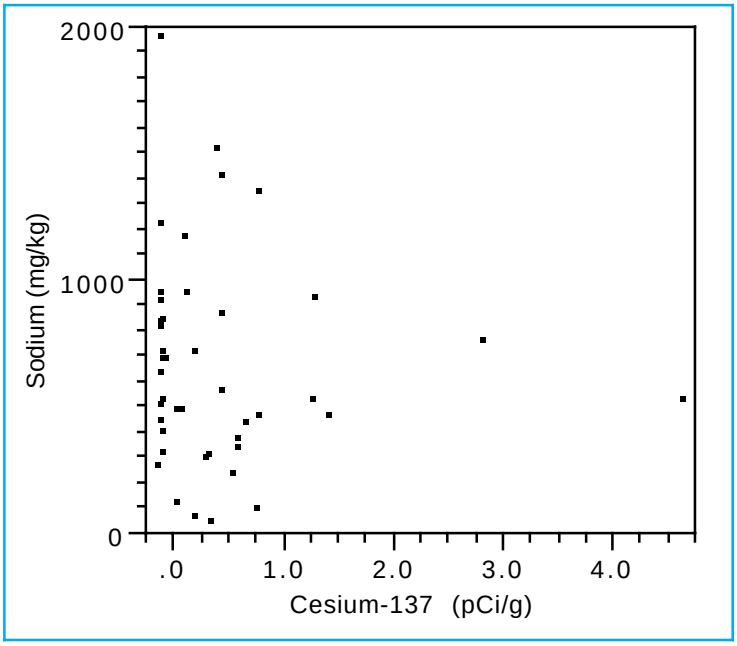

Figure E3-16a. Scatter plot for sodium versus cesium-137.

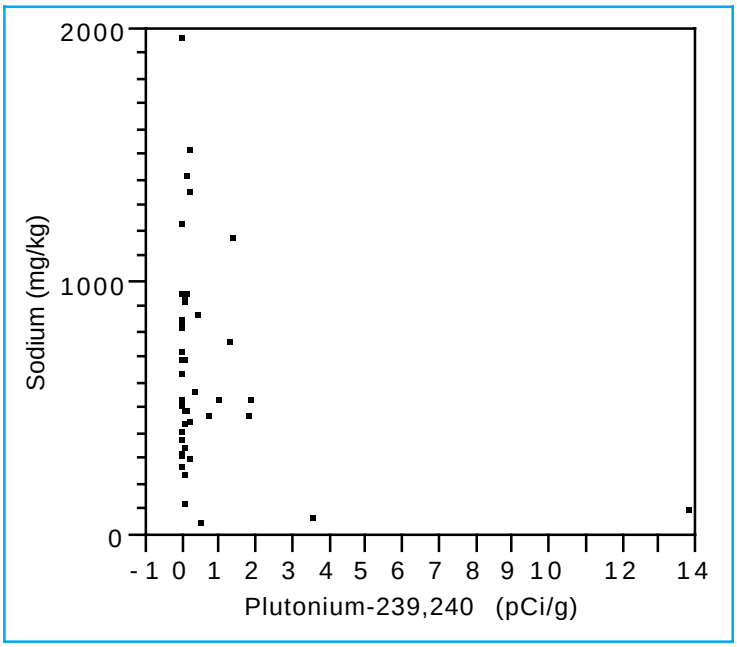

Figure E3-16b. Scatter plot for sodium versus plutonium-239,240.

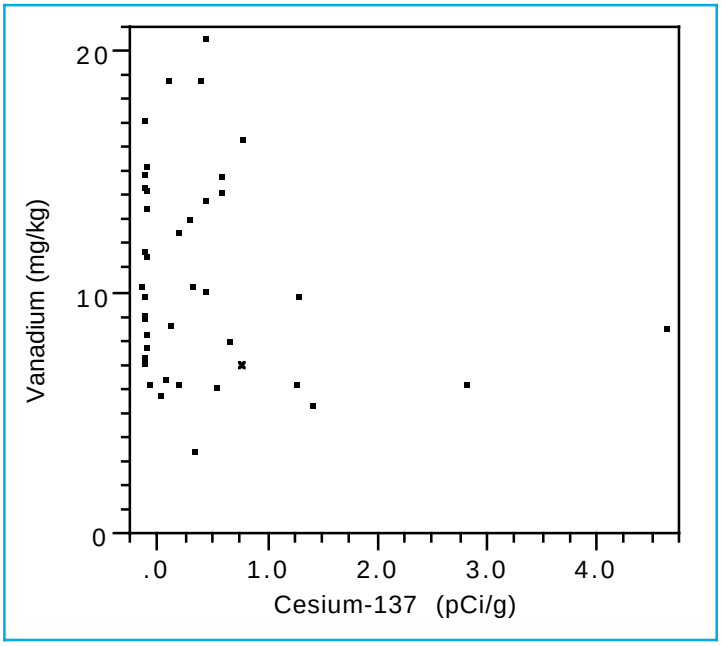

Figure E3-17a. Scatter plot for vanadium versus cesium-137.

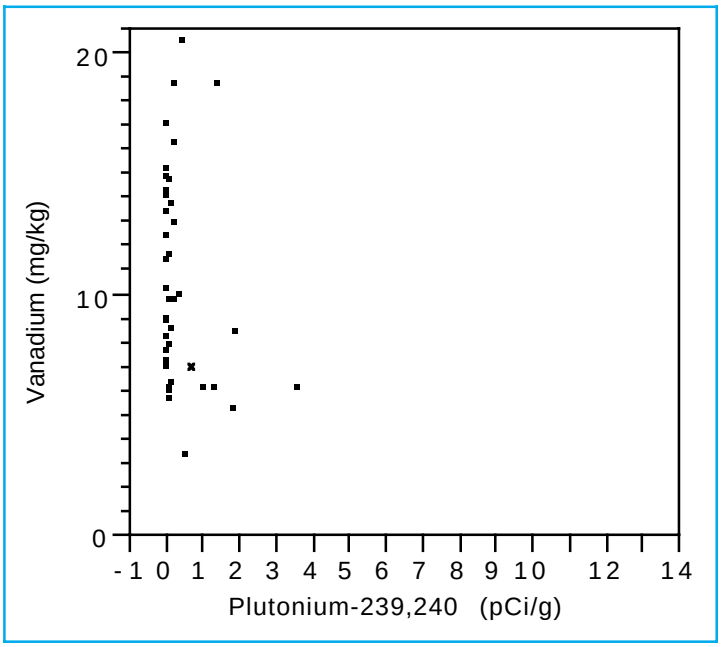

Figure E3-17b. Scatter plot for vanadium versus plutonium-239,240.

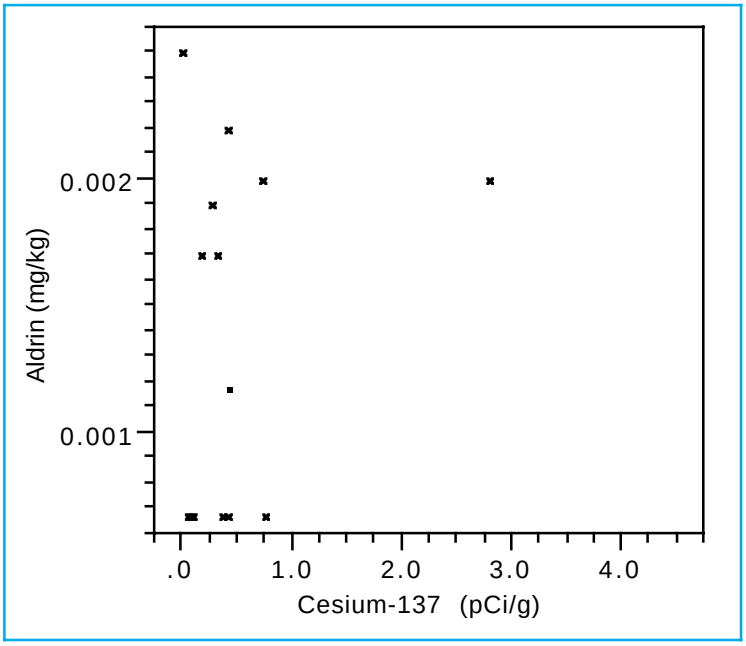

Figure E3-18a. Scatter plot for aldrin versus cesium-137.

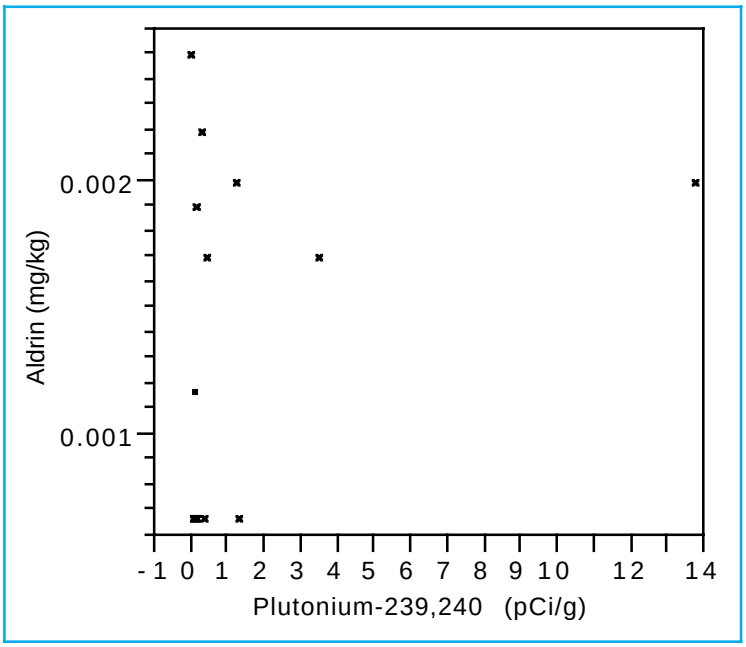

Figure E3-18b. Scatter plot for aldrin versus plutonium-239,240.

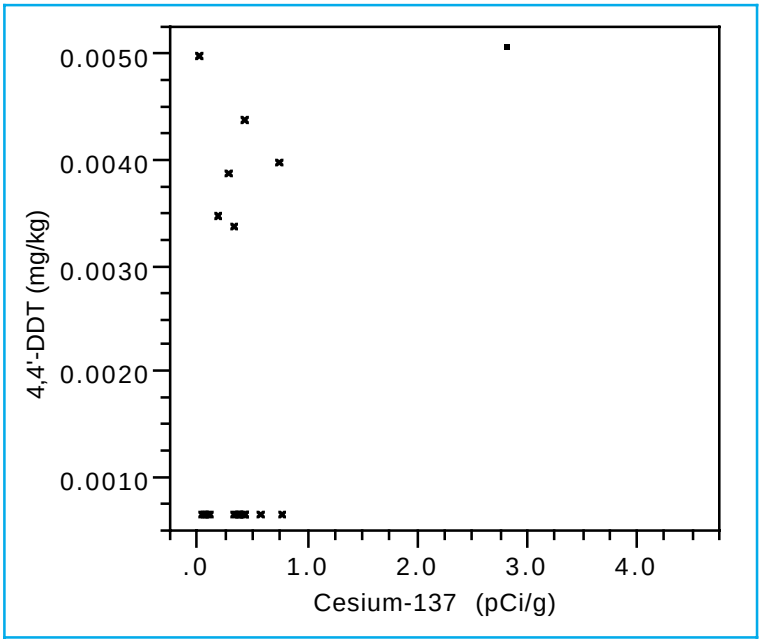

Figure E3-19a. Scatter plot for 4,4'-DDT versus cesium-137.

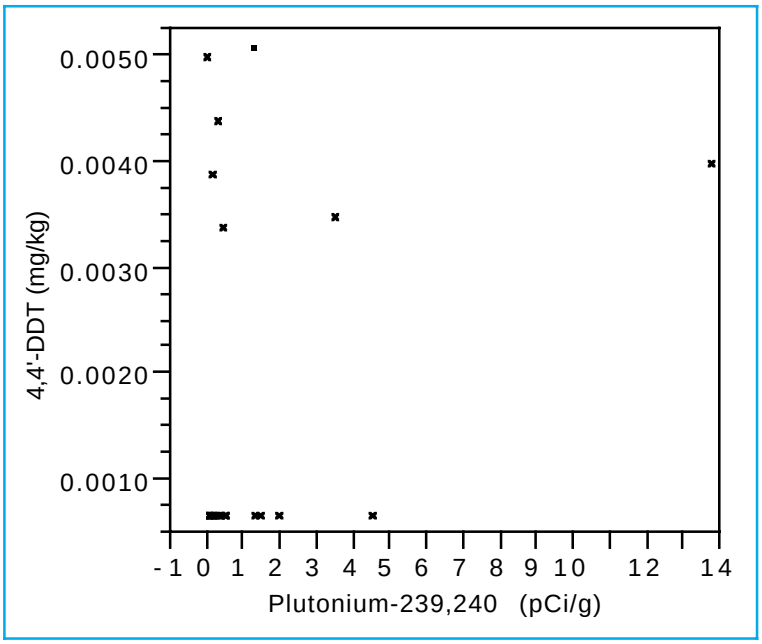

Figure E3-19b. Scatter plot for 4,4'-DDT versus plutonium-239,240.

TABLE E4-1

SUMMARY OF KEY RADIONUCLIDE FIELD QA RESULTS

Type	Original Sample ID[a]	Analyte	First Sample Result	Second Sample Result	RPD[b]
QA duplicate	04LA-97-0185	Americium-241 (gamma spec)	0.117	0.011	-117%
QA duplicate	04LA-97-0521	Americium-241 (gamma spec)	0.246	-0.016	-161%
QA duplicate	04LA-97-0532	Americium-241 (gamma spec)	-0.245	-0.314	17%
QA duplicate	04LA-96-0217	Cesium-137	0.32	0.28	-9%
QA duplicate	04LA-97-0185	Cesium-137	0.134	0.164	14%
QA duplicate	04LA-97-0521	Cesium-137	0.635	0.4	-32%
QA duplicate	04LA-97-0532	Cesium-137	0.331	0.488	27%
QA duplicate	04LA-97-0027	Plutonium-238	0.002	-0.009	222%
QA duplicate	04LA-97-0185	Plutonium-238	0.006	0.011	42%
QA duplicate	04LA-97-0521	Plutonium-238	0.047	0.037	-17%
QA duplicate	04LA-97-0532	Plutonium-238	0.075	0.0265	-68%
QA duplicate	04LA-97-0027	Plutonium-239,240	0.105	0.007	-124%
QA duplicate	04LA-97-0054	Plutonium-239,240	3.89	4.39	9%
QA duplicate	04LA-97-0185	Plutonium-239,240	2.13	2.98	24%
QA duplicate	04LA-97-0521	Plutonium-239,240	10.07	9.31	-6%
QA duplicate	04LA-97-0532	Plutonium-239,240	11.68	5.18	-55%
QA duplicate	04LA-97-0558	Strontium-90	0.3	0.31	2%
Resample	04LA-97-0172	Plutonium-238	0.041	0.042	2%
Resample	04LA-97-0172	Plutonium-239,240	13.8	12.91	-5%
Resample	04LA-97-0222	Strontium-90	12.8	0.74	-126%

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 percent difference between the two results

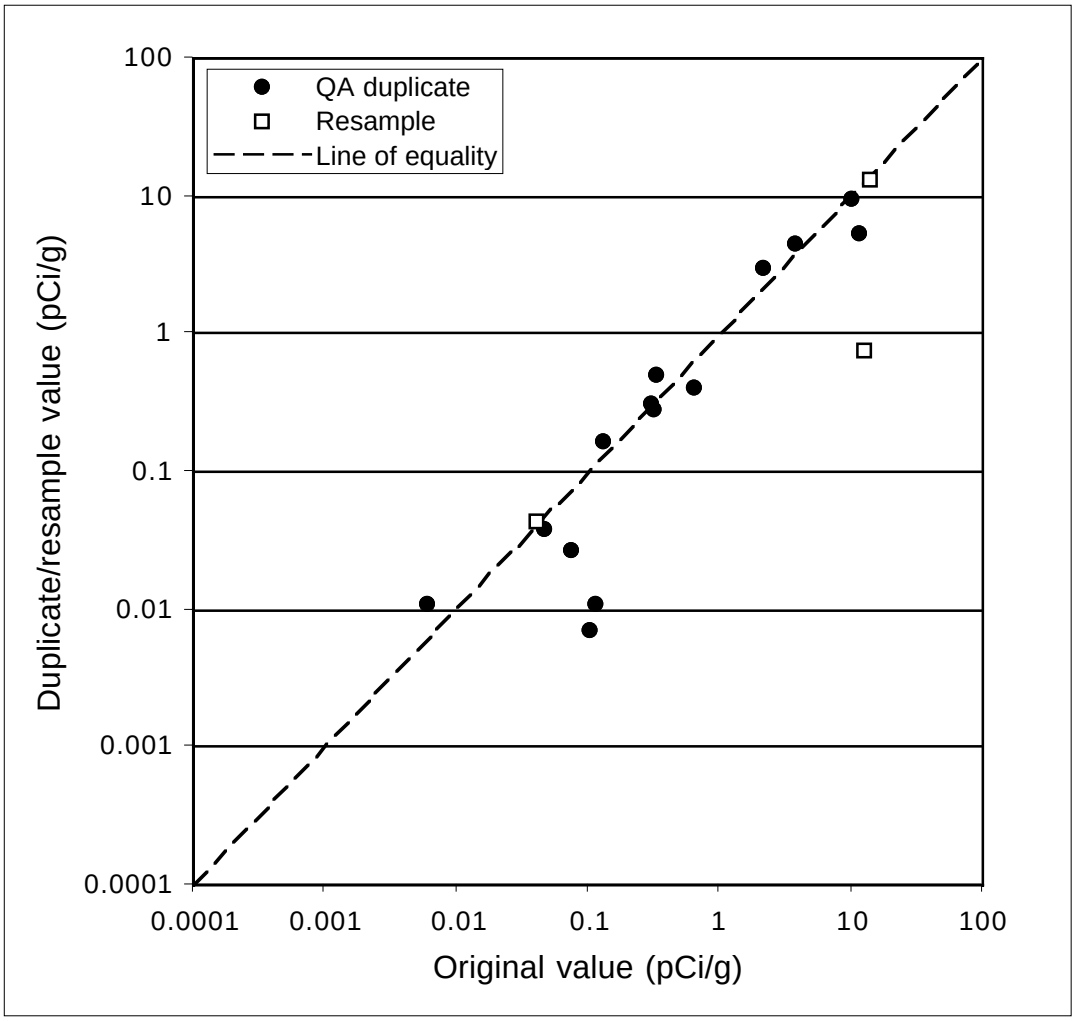

Figure E4-1. Evaluation of QA duplicate samples and resamples for lower Los Alamos Canyon.

The most significant difference between paired samples is in strontium-90 results for one pair of resamples from reach LA-4 West, where the first result of 12.8 pCi/g (sample 04LA-97-0222) was significantly higher than the second result, which was reported as a nondetect (sample 04LA-97-0554). This layer was specifically resampled because the first result seemed anomalously high in relation to all other strontium-90 data from sediments sampled in reaches LA-3 or LA-4. Because strontium-90 concentrations are strongly correlated with cesium-137 concentrations in upper Los Alamos Canyon downstream from DP Canyon (Reneau et al. 1998, 59160), cesium-137 results can be used to predict the expected concentration of strontium-90 in a sample. Typical cesium/strontium ratios in reaches LA-2 East and LA-3 are approximately 5, but the cesium/strontium ratio calculated from sample 04LA-97-0222 is 0.2. This exceptionally low cesium/strontium ratio provides supporting evidence that the strontium-90 concentration in sample 04LA-97-0222 represents an analytical laboratory anomaly. This information provides grounds to discount the strontium-90 result for sample 04LA-97-0222; thus, this result is excluded from the data review for reach LA-4.

APPENDIX F ECOLOGICAL SCOPING CHECKLIST

F-1.0 PART A—SCOPING MEETING DOCUMENTATION

Site ID	Lower Los Alamos Canyon reaches
Nature of PRS releases **(indicate all that apply)**	**Solid** – Yes S~~s~~ee 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 (S~~s~~ee 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 regional groundwater could all be impacted. **Other, explain**
FIMAD vegetation class **(indicate all that apply)**	**Water** – Yes **Bare Ground/Unvegetated** – Yes **Spruce/fir/aspen/mixed conifer** – No **Ponderosa pine** – No **Piñon juniper/juniper savannah** – Yes **Grassland/shrubland** – No **Developed** – Yes
Is T&E Habitat Present? **list species if applicable**	Yes Lower Los Alamos Canyon is potential foraging habitat for the peregrine falcon, Mexican spotted owl, and bald eagle.
Provide list and description of Neighboring/ Contiguous/ Upgradient PRSs **(consider need to aggregate PRS for screening)**	Many potential release sites (PRSs) occur in the upper Los Alamos Canyon and Pueblo Canyon watersheds. See the Ecological Scoping Checklists for those canyons for the complete list of relevant PRSs. ~~Main~~ The main influences in these reaches are the PRS 21-011(k) outfall and TA-45.
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	Mixing of sediments from upper Los Alamos Canyon and Pueblo Canyon occurs in reach LA-4, diluting contaminants from each canyon. Addition of sediment from Bayo Canyon and Guaje Canyon upstream from reach LA-5 further dilutes contaminants.

F-2.0 PART B—SITE VISIT DOCUMENTATION

F-2.1 Reaches LA-4 West and LA-4 East

Site ID	Reaches LA-4 West and LA-4 East
Date of Site Visit	7/29/98
Site Visit Conducted by	R. Ryti, G. McDermott, S. Reneau

Receptor Information:

Estimate cover	**% vegetated** = approximately 90% in LA-4 West, somewhat less in LA-4 East **% wetland** = approximately 10% stream channel **% structures/asphalt, etc.** = none
Field notes on the FIMAD vegetation class	Riparian shrubs are evident; grassy banks along stream channel; LA-4 West is more mesic than LA-4 East, with more vegetation outside of stream channel.
Field notes on T&E Habitat, if applicable	Should consider the entire reach to be potential foraging habitat for the peregrine falcon and Mexican spotted owl; the hazard quotient (HQ)/hazard index (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 or Pueblo Canyon.
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 and/or perched groundwater may also be important. Because some contamination is surficial, dust is a potential pathway in areas of lower vegetative cover.

Ecological Effects Information:

Physical Disturbance **(provide list of major types of disturbances)**	Minimal: some effects of cattle grazing were noted (somewhat more effects noted in LA-4 West than LA-4 East).
Are there obvious ecological effects? **(yes/no/uncertain)** **Provide explanation**	No obvious effects of either physical disturbance or contaminants on vegetation; highest contamination levels in reach LA-4 West are actually associated with the greatest plant biomass.

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 mapping, sediment sampling, and radiological field screening provide~~s~~ information on the nature/rate/extent of contamination for sediments. No data for surface water exists, and the lack of surface water contaminant data represents a data gap for performing a more complete ecological assessment for lower Los Alamos Canyon.
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)**	Multiple PRSs are located in the upper Los Alamos Canyon and Pueblo Canyon watersheds. Key PRSs are the PRS 21-011(k) outfall and those at TA-45.

Additional Field Notes:

Provide additional field notes on the site setting and potential ecological receptors. Reach LA-4 West: Grassy banks were noted along the stream channel with some evidence of cattle grazing. The area directly adjacent to the banks is typically dense shrub thickets (many riparian species). Many seeps and springs are present (notably Basalt Springs) that maintain perennial water flow in this subreach. Some evidence of fossorial mammals were observed in the elevated stream banks or floodplains (outside of the flood zone). There is evidence of a recent flood that was at least ~~one foot~~1 ft in elevation above today's surface water flow. Few aquatic invertebrates were noted in the stream. Reach LA-4 East: Drier, broader canyon floor setting compared ~~to~~ with LA-4 West. Shrubs adjacent to stream include chamisa, apache plume, sage, and juniper. ~~Observed~~ There were more signs of cattle grazing in LA-4 East than in LA-4 West. Bioturbation was noted during the period of sample collection (test pits were often filled with sediments/soil by fossorial mammals overnight). Few aquatic invertebrates were noted in the stream.

F-2.2 Reach LA-5

Site ID	Reach LA-5
Date of Site Visit	7/29/98
Site Visit Conducted by	R. Ryti, G. McDermott, S. Reneau

Receptor Information:

Estimate cover	**% vegetated** = Variable~~.~~; g~~G~~enerally <50%, but some floodplain areas are >90% vegetated **% wetland** = Minimal; one seep area noted~~.~~ **% structures/asphalt, etc.** = ~~None~~none
Field notes on the FIMAD vegetation class	Riparian species (e.g., cottonwoods) noted~~.~~ Juniper/sage/shrub oak more prevalent~~.~~
Field notes on T&E Habitat, if applicable	Should consider the entire ~~this~~ reach to be potential foraging habitat for the peregrine falcon, Mexican spotted owl, and bald eagle. The HQ/HI analysis should address potential bioaccumulative effects for raptors. The uncertainty analysis should consider the quality of falcon foraging habitat present in reach LA-5 given the distance of this reach from potential nesting habitat in upper Los Alamos Canyon and Pueblo Canyon. The uncertainty analysis should also consider that bald eagles would ~~only~~ be expected to take prey ~~in the~~only near ~~vicinity of~~ nesting sites along the Rio Grande. Lower Los Alamos Canyon is expected to have low frequency of owl foraging.
Are ecological receptors present at the PRS? **(yes/no/uncertain)** **Provide explanation**	Yes~~.~~ ~~Yes.~~ Terrestrial receptors are present (aquatic receptors are potentially present, especially if the one seep noted has persistent flow).

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. Dust is a potential pathway ~~as~~ because some of the highest plutonium-239,240 results are from a floodplain surface layer.

Ecological Effects Information:

Physical Disturbance **(provide list of major types of disturbances)**	Minimal~~.~~; ~~S~~some effects of cattle grazing were noted.
Are there obvious ecological effects? **(yes/no/uncertain)** **Provide explanation**	No obvious effects of either physical disturbance or contaminants on vegetation were seen.

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 mapping and sediment sampling provide information on the nature/rate/extent of contamination for sediments. Radiological surveys were not useful for this reach, but examination of aerial photographs werase useful for evaluating nature and extent. No data for surface water exists, but the lack of surface water data would not be a significant data gap as because water flows only flows during large storm events.
Do existing data for the PRS address potential pathways of site contamination? **(yes/no/uncertain)** **Provide explanation** **(consider if other sites could be impacting this PRS)**	Yes. Plutonium-239,240 that was associated with TA-45 has been measured frequently above the background value in sediment samples, and other contaminants have been measured with lower frequency.

Additional Field Notes:

Provide additional field notes on the site setting and potential ecological receptors. There is potentially a large influence from the supply of sediments from Bayo Canyon and Guaje Canyon on the concentration of chemicals of potential concern (COPCs) in reach LA-5. The highest plutonium-239,240 concentration was measured on a floodplain -with large cottonwoods. -The channel is typically broad (>15 m across). Surface soils/sediment were damp from a recent rainstorm, but no evidence of a large flood in the main channel was observed. Bioturbation seems spatially spotty, suggesting the lack of much fossorial mammal activity. Many ant colonies were noted throughout the reach. A seep area was also noted near the active channel and in a floodplain area with more mesic vegetation.

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.

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:

There are some areas of surficial contamination, so this pathway is complete.

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:

This site 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:

Some evidence for Bayo Canyon WWTP constituents (e.g., nitrates) are observed in analyses from Basalt Springs in reach LA-4 West. Potential contamination in other springs in~~s~~ not known.

Question E:

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

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

Answer (likely/unlikely/uncertain) Unlikely

Provide explanation:

Subsurface contamination is not expected in these reaches away from the active channel except for sediment that is potentially contaminated by alluvial water.

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~~ 0 = no pathway
Terrestrial Animals: 0 = no pathway

Provide explanation:

No volatile organic chemical 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~~: : :~~ 3 = major pathway

Provide explanation:

Because of surficial contamination in some areas, dust could be an major pathway for animals, but minor for plants ~~due to~~because ~~-~~plutonium-239,240 ~~being~~ is the major COPC (little alpha dose is expected from dust adhering to the leaves).

Question I:

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

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

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

Terrestrial Plants: 3 = major pathway

Provide explanation:

This could be a major pathway via root uptake ~~as~~ because much of the contamination is shallow.

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 F3-1).**
- **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~~ There is a need to consider this a major pathway ~~as~~ because some COPCs are identified as potentially persistent bioaccumulators in aquatic environments, which are present in some parts of lower 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 could be major pathway because much of the contamination is surficial.

Question L:

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

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

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

Terrestrial Animals: 1 = unlikely pathway

Provide explanation:

~~Unlikely~~ This is an unlikely pathway ~~due to detecting~~because low concentrations of lipophilic COPCs were detected in reaches LA-~~-~~4 and LA-~~-~~5.

Question M:

Could contaminants interact with plants or animals through external irradiation?

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

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

Terrestrial Plants: 2 = minor pathway
Terrestrial Animals: 2 = minor pathway

Provide explanation:

~~Expect t~~This pathway is expected to be minor because cesium-137 concentrations are low in these reaches~~,~~ and are not detectable with field screening instruments.

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:

~~Could~~ This could be a major pathway in reach LA-4~~,~~ ~~and~~ but it is expected to be mostly a non-pathway in reach LA-5 ~~due to~~because of the lack of perennial surface water flow in LA-5.

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 F3-1)**
- **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-4~~,~~ but it is expected ~~it~~ to be a non-pathway in reach LA-5 ~~due to~~because of the lack of perennial surface water flow in LA-5.

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-4, ~~and~~ but it is expected ~~it~~ to be a non-pathway in reach LA-5 ~~due to~~because of the lack of perennial surface water flow in LA-5.

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:

This pathway is expected to be minor~~,~~ because low concentrations of lipophilic COPCs were measured in reaches LA-4 and LA-5.

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:	2 = minor pathway
Aquatic Plants:	2 = minor pathway
Terrestrial Animals:	2 = minor pathway
Aquatic Animals:	2 = minor pathway

Provide explanation:

~~Expect t~~This pathway is expected to be minor ~~as~~ because cesium-137 is measured at low concentrations in reach LA-4~~,~~ and ~~cesium-137~~ is mostly at background levels in reach LA-5.

TABLE F3-1

BIOACCUMULATING CHEMICALS

Volatile Organic Compounds	**PCBs/Pesticides**
1,4-Dichlorobenzene[1,4-]	All aroclors
1,2,4-Trichlorobenzene[1,2,4-]	βBeta-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

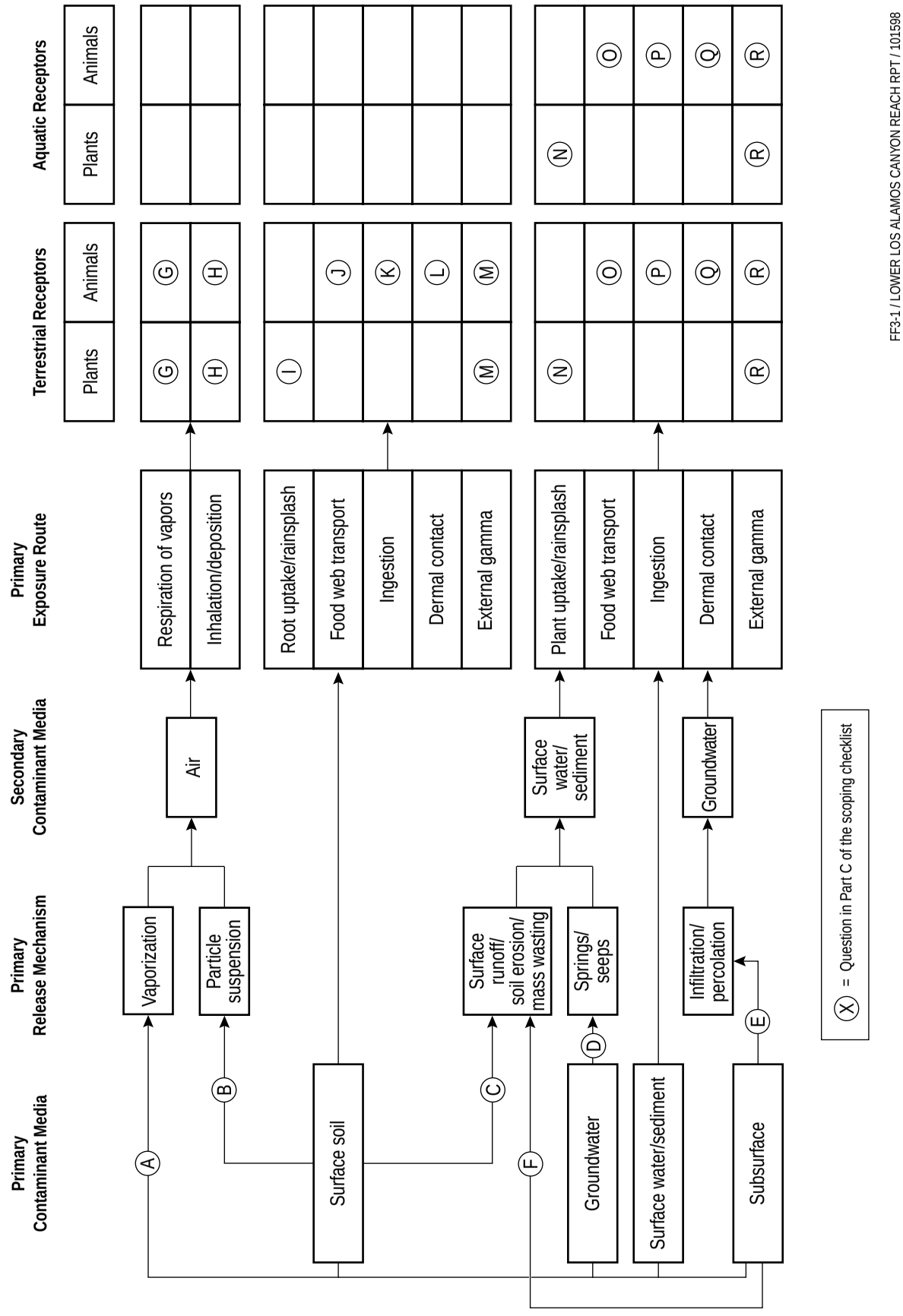

Figure F3-1. Conceptual exposure model for ecological pathways.

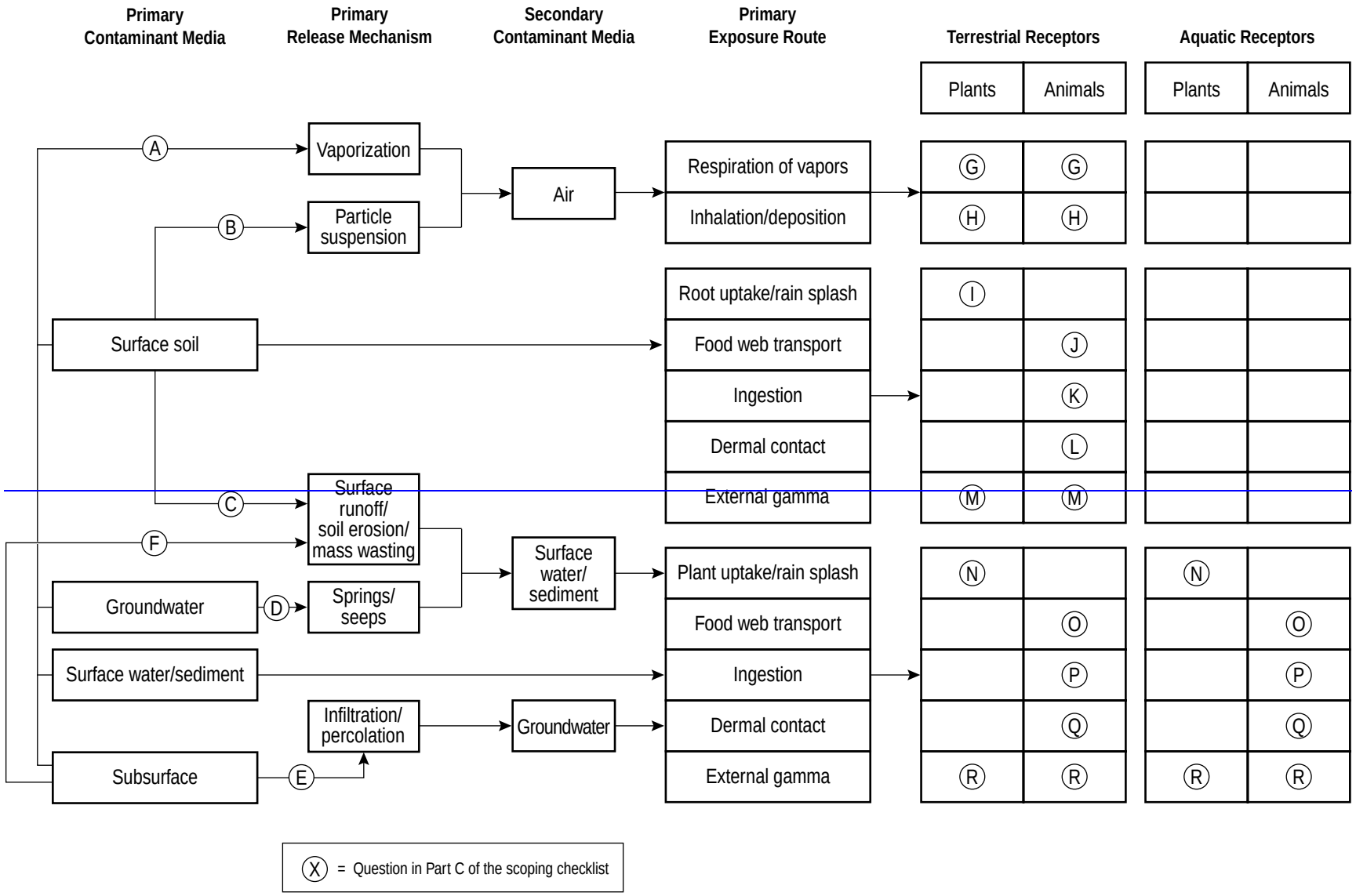

Figure F3-1. Conceptual exposure model for ecological pathways.

Signatures and certifications:

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

Name (printed): Randall Ryti

Name (signature):

Organization: Neptune and Company, Inc.

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Date completed: July 29, 1998

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

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