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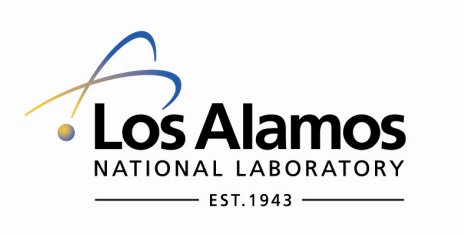
Results of 2011 Sediment Monitoring in the Pajarito Canyon Watershed



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EP2012-0058

Results of 2011 Sediment Monitoring in the Pajarito Canyon Watershed

March 2012

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1.0 INTRODUCTION

This report presents analytical data obtained from sediment samples collected in the Pajarito Canyon watershed in 2011 as part of the Los Alamos National Laboratory (LANL or the Laboratory) Environmental Surveillance Program. Sampling followed a September 2009 sampling and analysis plan (SAP) (LANL 2009, 107340). The New Mexico Environment Department (NMED) issued an approval with modifications for the SAP (NMED 2009, 108123) that included the requirement to provide the results of annual sampling in a report to NMED by March 31 of each calendar year, beginning in 2010. This report satisfies that requirement for the 2011 sampling. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to NMED in accordance with U.S. Department of Energy policy.

In June and July 2011, the Las Conchas fire burned most of the Pajarito Canyon watershed west of NM 501. A total of 9.3 km^2 was within the burn perimeter, which comprises 28% of the total watershed area. Of the area within the burn perimeter, 44% (4.1 km^2) was classified as high- or moderate-severity burn and the remainder as low-severity burn or unburned. Most of this area had been burned previously in the May 2000 Cerro Grande fire (BAER 2000, 072659). The Cerro Grande fire involved a larger part of the watershed (20.5 km^2 within the burn perimeter), including large areas east of NM 501, and had a larger area classified as high- and moderate-severity burn (5.9 km^2). The first large flood after the Las Conchas fire occurred on August 5, 2011, and extended into the Pajarito Canyon wetlands below Technical Area 18 (TA-18), leaving ash-rich sediment deposits ("muck") (Figure 1.0-1). A larger flood occurred on August 21–22, 2011, damaging stream gages in Pajarito and Twomile Canyons (LANL 2011, 206488) and extending past NM 4 and White Rock into White Rock Canyon. The planned sediment sampling in 2011 was expanded to evaluate the effects of the Las Conchas fire on sediment chemistry and contaminant transport, including an expanded analytical suite and baseline locations above NM 501 in Pajarito and Twomile Canyons as well as in other fire-affected canyons.

2.0 SAMPLES COLLECTED AND ANALYSES PERFORMED

The SAP indicated seven active stream channel samples would be collected each year in the Pajarito Canyon watershed, and up to an additional eight fine-grained sediment samples were identified as "contingency" samples, to be collected in the event large floods occurred (LANL 2009, 107340). Pajarito and Twomile Canyons both had large floods in 2011 following the Las Conchas fire, and seven of the planned fine-grained contingency samples were collected. In reach PA-4, only one of the two planned contingency samples was collected because new sediment deposits in this reach were largely too thin to sample. This is a result of attenuation of floods and deposition of entrained sediment in the upstream wetlands between reaches PA-3E and PA-4. In addition to the planned contingency samples, an additional four samples were collected in baseline reaches PA-0 and TW-1W, in Pajarito and Twomile Canyons west of NM 501 and upstream of solid waste management units (SWMUs) and areas of concern (AOCs). As part of the post-fire sampling, an additional 10 fine-grained baseline samples were collected from Frijoles, Guaje, Los Alamos, and Water Canyons and Cañon de Valle, and data from these samples are included in this report. In addition to the analyte suite specified in the SAP (LANL 2009, 107340), as modified by NMED (2009, 108123), the analytical suite for the fine-grained fire-affected samples was expanded to include total cyanide, cesium-137 (part of the gamma spectroscopy suite), and strontium-90, because these analytes were found to be elevated in sediment deposits and stormwater after the Cerro Grande fire (e.g., Katzman et al. 2001, 072660; Kraig et al. 2002, 085536; Gallaher and Koch 2004, 088747; LANL 2004, 087390). In addition, analysis of polychlorinated biphenyls (PCBs) in the fire-affected samples used U.S. Environmental Protection Agency (EPA) Method 1668A for PCB congeners,

instead of EPA Method 8082, for Aroclors, to provide more detailed characterization of the nature of PCBs transported in post-fire floods.

Of the seven planned active channel samples in the Pajarito Canyon watershed, five were collected in 2011, including two samples from the main stream channel of Pajarito Canyon, above NM 4 and above the Rio Grande, and three of the planned five samples from drainages below Material Disposal Area (MDA) G at TA-54. Samples were not collected from the MDA G-4 and MDA G-5 drainages because the thickness of new sediment was insufficient for sampling. Figure 2.0-1 shows the 2011 sampling locations in the Pajarito Canyon watershed, and Figure 2.0-2 shows the baseline sampling locations downstream from the Las Conchas burn area. Table 2.0-1 presents requested analytical suites for each sample collected from the Pajarito Canyon watershed in 2011, and Table 2.0-2 presents requested analytical suites for the 2011 baseline samples outside the watershed.

One deviation from the SAP is that tritium analyses were not obtained from the sediment samples collected in the Pajarito Canyon watershed in 2011. This follows a decision in 2010 to remove tritium from the analytical suite for Environmental Surveillance Program sediment samples because it is present as a component of water, not adsorbing onto sediment particles, and is included in the analytical suite for water samples, where appropriate (LANL 2010, 109107). In addition, tritium concentrations in sediment samples (a function of moisture content) are orders of magnitude below human health screening levels and do not pose a potential risk in sediment.

3.0 RESULTS

Analytical results for the sediment samples from the Pajarito Canyon watershed are included electronically as Attachment 1 (on CD), and analytical results for the additional baseline samples outside the watershed are included electronically as Attachment 2 (on CD). Tables in Attachment 3 (on CD) present samples collected, summarize the frequencies of detected results, and identify sampling results above the sediment background values (BVs) (LANL 1998, 059730) for inorganic chemicals and radionuclides or detected results for organic chemicals within the Pajarito Canyon watershed, which are identified as chemicals of potential concern (COPCs). Attachment 4 (on CD) presents particle size data from sediment samples collected from the Pajarito Canyon watershed in 2011. (Particle size data from the baseline sediment samples collected outside the watershed in 2011 are pending.)

3.1 Radionuclides

Five radionuclides were detected above sediment BVs in the samples collected in the Pajarito Canyon watershed in 2011, as summarized in Table 3.1-1: americium-241, cesium-137, plutonium-238, plutonium-239/240, and strontium-90. Table 3.1-1 also summarizes results from the baseline samples collected downstream from the Las Conchas burn area in 2011, from baseline samples collected previously downstream from the Cerro Grande burn area, and from Cerro Grande ash samples (LANL 2004, 087390). All these radionuclides have a source in atmospheric fallout and were also detected above BVs in ash and baseline samples collected after the Cerro Grande fire, and all, except strontium-90, were detected above BVs in the 2011 baseline samples.

Two of the five radionuclide COPCs, americium-241 and plutonium-239/240, had their highest concentrations in 2011 in the Pajarito Canyon watershed in the MDA G-7 drainage, and plutonium-238 was also detected above the BV at this location in 2011, consistent with previous data that indicated releases from MDA G (e.g., LANL 2011, 207316). As shown in Figure 3.1-1, concentrations of these three radionuclides in the MDA G-7 drainage have generally been decreasing over the last 10 yr (2002 to 2011), and the results from 2011 are the lowest measured during this period.

Excluding the MDA G samples, the highest concentrations of four of the radionuclides detected above BVs were measured in a sample of muck from reach PA-3E that represented the "first flush" from the Las Conchas burn area on August 5, 2011 (sample CAPA-12-1693). Concentrations in this sample were all lower than the maximum measured in the post-Cerro Grande baseline samples (Table 3.1-1). The other radionuclide, plutonium-238, had its highest concentration in a baseline sample from reach TW-1W (0.0498 pCi/g), very similar to the highest concentration measured in a post-Cerro Grande baseline sample (0.0486 pCi/g). Therefore, these data indicate a primary source for the radionuclide COPCs detected along the main channels of Pajarito and Twomile Canyons in 2011 is atmospheric fallout, concentrated in ash from the Las Conchas burn area. This finding is consistent with previous sediment investigations that indicated the dominant source for these radionuclides in Pajarito and Twomile Canyons was ash from the Cerro Grande burn area (LANL 2009, 106939).

3.2 Inorganic Chemicals

Nineteen inorganic chemicals were detected above sediment BVs in the samples collected in the Pajarito Canyon watershed in 2011, and two inorganic chemicals had only nondetected results above BVs, as summarized in Table 3.2-1. In the MDA G drainage samples, only zinc had a detected result above the BV. The elevated zinc was in a fine-grained sediment sample from the MDA G-6 lower retention pond. Two the 19 detected inorganic COPCs, calcium and cyanide, had higher results in the 2011 samples than in previous sediment samples from the watershed (LANL 2009, 106939) and also had higher results than in the 2011 baseline samples. Both results were from the muck sample from reach PA-3E (sample CAPA-12-1693) that also had elevated radionuclides derived from the Las Conchas burn area (section 3.1). The maximum calcium result (29,000 mg/kg) is less than the maximum measured in ash from the Cerro Grande fire (90,000 mg/kg, LANL 2004, 087390), supporting a source in Las Conchas ash. No cyanide data were obtained from Cerro Grande ash samples, although cyanide is also elevated above the BV of 0.82 mg/kg in 13 of the 14 baseline samples collected after the Las Conchas fire and in post-Cerro Grande baseline samples. It is notable that eight of the post-Las Conchas baseline samples have higher cyanide concentrations than the maximum measured in the post-Cerro Grande baseline samples (2.5 mg/kg), indicating either higher cyanide concentrations in Las Conchas ash than in Cerro Grande ash or differences in the analysis of cyanide at the analytical laboratories.

The PA-3 muck sample with elevated calcium and cyanide also has the highest detected concentrations of eight other inorganic COPCs in the 2011 samples collected from the Pajarito Canyon watershed (arsenic, barium, cobalt, copper, lead, manganese, potassium, and zinc). All these COPCs had higher detected concentrations in Cerro Grande ash (Table 3.2-1; LANL 2004, 087390), indicating Las Conchas ash is probably a major source of these COPCs. However, this sample also includes COPCs derived from Laboratory sites, indicating that the August 5, 2011, flood remobilized some contaminants previously deposited within the watershed. For example, silver is above the BV in this sample as well as the other PA-3E sample and the two samples from PA-2W and is also higher than concentrations measured in Cerro Grande ash, which is consistent with known releases of silver from TA-08 and TA-09 (LANL 2009, 106939). Silver had not been previously identified as a COPC in PA-3E, indicating the post–Las Conchas floods were more effective at transporting silver this far downcanyon than previous floods, including those after the Cerro Grande fire.

Six inorganic COPCs (aluminum, beryllium, chromium, iron, magnesium, and vanadium) have their maximum detected concentrations in the sample collected from reach PA-4, above NM 4 (Table 3.2-1). Previous sediment investigations have not indicated Laboratory sources for three of these COPCs (aluminum, iron, and magnesium) in the Pajarito Canyon watershed (LANL 2009, 106939), and these inorganic chemicals probably have a source in naturally occurring soils and/or Las Conchas ash. The other three inorganic COPCs (beryllium, chromium, and vanadium) may have partial sources at

Laboratory sites, combined with naturally occurring soils and/or Las Conchas ash. This sample had the highest clay content in samples collected from the Pajarito Canyon watershed in 2011 (36.5% clay; Attachment 4), and the elevated concentrations of inorganic COPCs are probably related to the high clay content.

Two inorganic chemicals identified as having a source at Laboratory sites in the Pajarito Canyon watershed above Twomile Canyon and detected above BVs in the 2011 samples are cadmium and copper. Figure 3.2-1 shows temporal variations in average concentrations of these metals in sediment samples from reach PA-2W, updated from a previous report (LANL 2009, 106939, Figure 7.1-18) with data from the 2011 samples. Cadmium concentrations show no apparent trend over time, whereas copper concentrations were highest soon after the Cerro Grande fire and have decreased since then. Both copper and cadmium were also above BVs in Cerro Grande ash, and the sources for these metals in the 2011 samples probably include a combination of Las Conchas ash and Laboratory releases, as well as naturally occurring soils.

3.3 PCBs

In the Pajarito Canyon watershed, PCBs were analyzed by the congener method in the 11 fine-grained sediment samples collected downstream from the Las Conchas burn area in 2011 and by the Aroclor method in the other 5 samples. Aroclor-1254 and Aroclor-1260 were detected in two of the five samples, in the lower retention pond in the MDA G-6 drainage (0.016 mg/kg total) and in the Pajarito Canyon stream channel above NM 4 (location PA-603937, 0.0048 mg/kg total). PCB congeners were detected in all 11 samples, and total detected PCBs ranged from 0.0002 mg/kg in reach PA-0, above NM 501, to 0.023 mg/kg in reach TW-4E. In the baseline samples, also measured by the congener method, total detected PCBs ranged from 0.00005 mg/kg in reach CDV-0 to 0.0035 mg/kg in reach LA-0. Longitudinal variations in total PCB concentration in the 2011 samples are presented in Figure 3.3-1, showing the elevated concentrations in TW-4E and decreasing concentrations downstream to reach PA-4, above NM 4. Previous sediment investigations indicated PCBs in Twomile Canyon have a primary source at TA-03 (LANL 2009, 106939).

PCB congeners from the sediment samples can be grouped together into 10 homologs, based on the number of chlorine atoms on the biphenyl rings, which allows visual comparison of similarities or differences between samples or groups of samples. The designations for the 10 homologs range from monochlorobiphenyl (or monoCB, with a single chlorine atom) to decachlorobiphenyl (or decaCB, with 10 chlorine atoms). Plots of PCB homologs in individual samples and plots of average values from an area are useful for evaluating the sources of PCBs because different sources can have different percentages of the individual homologs (LANL 2009, 108621; LANL 2010, 111232; LANL 2011, 207316).

Examination of PCB congener homologs in samples collected in 2011 indicates that, in detail, the composition of PCBs from undisturbed areas, representing atmospheric fallout, differs from areas that include electrical transformers and other potential nonatmospheric sources. These data also indicate nonatmospheric sources can be present in baseline areas unaffected by Laboratory activities. Figure 3.3-2a presents homolog data from the 7 samples collected downstream from Laboratory sites, and Figure 3.3-2b presents homolog data for all 14 baseline samples. Two distinct peaks can be seen in these samples, one for triCB and one for hexaCB. TriCB is the dominant homolog in the baseline samples from the least disturbed watersheds, including Cañon de Valle and Water Canyon above NM 501, where PCB concentrations are lowest, and hexaCB is the dominant homolog downstream from Laboratory sites. HexaCB is also the dominant homolog in samples collected in previous years in the Los Alamos Canyon and Pueblo Canyon watershed (e.g., LANL 2011, 207316, p. 6-36). Many samples from the Pajarito Canyon watershed have mixtures of these two components, including the “first-flush”

muck sample from reach PA-3E (CAPA-12-1693). The baseline samples with the highest total PCB concentrations from reaches LA-0 and TW-1W (0.0009 mg/kg to 0.0035 mg/kg) also have strong hexaCB signatures, differing from the other baseline areas where concentrations are lower (0.00005 mg/kg to 0.0004 mg/kg), as shown in Figure 3.3-2c. Camp May Road, leading to the Pajarito Mountain Ski Area, traverses the watersheds above both LA-0 and TW-1W, and the ski area is in the drainage above LA-0. This finding suggests that transformers along electrical lines leading to the ski area are a source for the elevated PCB concentrations detected in these reaches.

3.4 Dioxins and Furans

Dioxins were detected in all samples collected in 2011 from the Pajarito Canyon watershed, except for the active channel samples above NM 4 and above the Rio Grande, and were also detected in all the baseline samples collected downstream from the Las Conchas burn area, except the two Guaje Canyon samples. Furans were also detected in all of these samples, except the two active channel samples in Pajarito Canyon and one of the three MDA G drainage samples. Dioxin and furan results are reported as both individual congeners and as totals for different homologs, and in this section the total detected results for individual homologs and total detected dioxins and furans based on the sum of these homologs were used to evaluate sources and spatial variations. Similar to the case with PCB congeners, as discussed in section 3.3, dioxin and furan congener homologs are distinguished by the number of chlorine atoms on the dioxin or furan ring structures. In the samples discussed in this report, dioxins and furans both have five reported homologs, ranging from tetrachlorodibenzodioxin (tetraCDD, with four chlorine atoms) to octachlorodibenzodioxin (octaCDD, with eight chlorine atoms) and from tetrachlorodibenzofuran (tetraCDF) to octachlorodibenzofuran (octaCDF).

Total detected dioxins in the samples collected in the Pajarito Canyon watershed in 2011 downstream from SWMUs and AOCs have a maximum concentration of 2.6×10^{-4} mg/kg from reach TW-4E. In the baseline samples, total detected dioxins have a maximum concentration of 6.9×10^{-5} mg/kg from reach TW-1W. All sample areas downgradient of SWMUs and AOCs, except PA-4, have higher detected concentrations of dioxins than in the baseline samples, as shown in Figure 3.4-1a, indicating contributions from Laboratory sources. Figure 3.4-1b compares concentrations of dioxins in the 2011 samples from the Pajarito Canyon watershed with previous data from this watershed (LANL 2009, 106939; LANL 2011, 201574; LANL 2011, 207316), showing that maximum concentrations in the 2011 samples in each sample area are lower than previously measured. Figure 3.4-1b also shows that pre-2011 samples from the baseline reach TW-1W, in Twomile Canyon above NM 501, had higher dioxin concentrations than measured in the 2011 baseline samples, up to 1.3×10^{-4} mg/kg, indicating a larger range for dioxins in areas not affected by Laboratory activities.

Total detected furans in the samples collected in the Pajarito Canyon watershed in 2011 downstream from SWMUs and AOCs have a maximum of 8.5×10^{-5} mg/kg from reach TW-4E. In the baseline samples, total detected dioxins have a maximum of 1.1×10^{-5} mg/kg from reach TW-1W. As with dioxins, all sample areas downgradient of SWMUs and AOCs, except PA-4, have higher detected concentrations of furans than in the baseline samples, as shown in Figure 3.4-2a, indicating contributions from Laboratory sources. Figure 3.4-2b compares concentrations of furans in the 2011 samples from the Pajarito Canyon watershed with previous data from this watershed (LANL 2009, 106939; LANL 2011, 201574; LANL 2011, 207316), showing that maximum concentrations in the 2011 samples in most sample areas are lower than previously measured. The exception is TW-4E, where the maximum detected furan result in 2011 was slightly higher than the previous maximum. Figure 3.4-2b shows that the range of furan results from the baseline reach TW-1W, in Twomile Canyon above NM 501, in pre-2011 samples was similar to that measured in 2011.

Plots of dioxin and furan congener homologs in individual samples and average results from the different sampling areas were examined to identify if distinctive homolog signatures exist that can help distinguish sources. Figure 3.4-3a presents variations in the average concentration of each detected dioxin homolog in the 2011 sample areas, indicating that homolog signatures are essentially identical in baseline areas and in areas below Laboratory sites. Figure 3.4-3b presents variations in the average concentration of each detected dioxin homolog in previous samples from the Pajarito Canyon watershed (LANL 2009, 106939; LANL 2011, 201574; LANL 2011, 207316), showing that, with the exception of reach TW-1E, homolog signatures are also indistinguishable in these samples. In the TW-1E samples, tetraCDD and pentaCDD are higher and octaCDD is lower than in the other areas. Reach TW-1E is downstream from a former incinerator ash pond at TA-69 (SWMU 69-001), and the distinctive dioxin homolog signature in TW-1E is consistent with known releases from this SWMU. However, this homolog signature is not present in the next downcanyon reach, TW-2E, and dioxin concentrations are also higher in TW-2E (Figure 3.4-1b), indicating that SWMU-69-001 is not the primary source for dioxins in this watershed.

Figure 3.4-4a presenting variations in the average concentration of each detected furan homolog in the 2011 sample areas, indicating only relatively small variations in homolog signatures occur between baseline areas and areas below Laboratory sites. Figure 3.4-4b presents variations in the average concentration of each detected furan homolog in previous samples from the Pajarito Canyon watershed (LANL 2009, 106939; LANL 2011, 201574; LANL 2011, 207316), showing furans in most areas have homolog signatures similar to the 2011 samples. As seen with dioxins, samples from reach TW-1E, downstream from SWMU-69-001 have a different homolog signature from other sample areas, particularly in elevated tetraCDF percentages. Elevated tetraCDF is also present in the next downstream reach, TW-2E, in the pre-2011 samples, indicating SWMU-69-001 is a source for furans detected in TW-2E, although farther downstream the contributions from SWMU-69-001 are no longer recognizable.

3.5 Semivolatile Organic Compounds

Sixteen semivolatile organic compounds (SVOCs) were detected in sediment samples collected in the Pajarito Canyon watershed in 2011, as summarized in Table 3.5-1. Table 3.5-1 also summarizes results from areas receiving runoff from large developed areas in the Los Alamos townsite (reaches AC-1 and DP-1W, in upper Acid and DP Canyons) and baseline samples collected after the Cerro Grande fire (data from LANL 2004, 087390). The highest detected concentrations for 12 of these SVOCs in the Pajarito Canyon watershed were in sediment collected from reach TW-4E, downstream from large developed areas at the Laboratory, including TA-03. The highest detected concentrations for three of these SVOCs were in the next downstream reach, PA-3E, and the highest detected concentration for the remaining SVOC was from the lower MDA G-6 retention pond. As shown in Table 3.5-1, higher detected concentrations of 15 of these 16 SVOCs have been measured in samples collected below the Los Alamos townsite, indicating a source in urban runoff. Studies in other areas have also shown urban runoff to be a source of SVOCs (e.g., Edwards 1983, 082302; Lopes and Dionne 1998, 082309; Van Metre et al. 2000, 082262). The remaining SVOC, methylphenol[4-], had higher detected concentrations in ash-rich sediment collected after the Cerro Grande fire than in the Pajarito Canyon watershed samples (Table 3.5-1). Therefore, these data indicate the primary source for the SVOCs detected in the Pajarito Canyon watershed is runoff from developed areas, and runoff from the Las Conchas burn area is a secondary source for these SVOCs.

Figure 3.5-1 shows temporal variations in average concentrations of one SVOC, benzo(a)pyrene, in sediment samples from reach TW-4E, updated from a previous report (LANL 2009, 106939, Figure 7.1-19) with data from the 2011 samples. The average concentration in 2011 is slightly higher than results from samples of sediment deposited in 2005 and 2006, consistent with temporal increases in

benzo(a)pyrene concentration seen in previous years. Continued future increases associated with continued runoff from developed areas in this watershed are also possible.

3.6 Explosive Compounds

Analyses for explosive compounds were obtained from the 11 fine-grained sediment samples collected in the Pajarito Canyon watershed in 2011 downstream from the Las Conchas burn area. Analyses for explosive compounds were also obtained from four additional fine-grained sediment samples from baseline areas in Cañon de Valle and Water Canyon above NM 501. No explosive compounds were detected in these samples.

4.0 SUMMARY

Analytical results from sediment samples collected in the Pajarito Canyon watershed and in baseline areas downstream from the Las Conchas burn area in 2011, combined with results from previous sediment samples, indicate that concentrations of most COPCs released from Laboratory sites decrease downstream from the sources and also decrease over time. This finding is consistent with the conceptual model presented in a previous investigation (LANL 2009, 106939). Dissipation of flood energy and deposition of entrained sediment in the extensive wetlands between TA-18 and NM 4 contributed to greatly reducing the downstream transport of contaminants derived from SWMUs or AOCs farther west in the watershed. These data also indicate that many COPCs detected in the 2011 sediment samples have a primary source in the Las Conchas burn area, associated with the transport of ash, which is consistent with previous results after the Cerro Grande fire. Other COPCs detected in the 2011 sediment samples have a source in runoff from developed areas, consistent with results downstream from urban areas such as the Los Alamos townsite.

5.0 RECOMMENDATIONS

Based on evaluation of the sediment data discussed in the previous sections, the Laboratory proposes to modify the analytical suite specified in the SAP (LANL 2009, 107340) as follows.

Because uranium isotopes have not been detected above sediment BVs in drainages below MDA G, the Laboratory proposes to remove isotopic uranium from the analytical suite at the MDA G drainage locations. Isotopic uranium analyses would continue at the remaining locations because uranium isotopes have been identified as COPCs elsewhere in the Pajarito Canyon watershed (LANL 2009, 106939).

Because SVOCs are only detected at low concentrations in sediment samples collected in the Pajarito Canyon watershed at concentrations below what is measured in areas receiving urban runoff and are not useful for evaluating potential impacts from SWMUs or AOCs, the Laboratory proposes to remove SVOCs from the analytical suite at all locations.

In addition, the Laboratory proposes to maintain the elimination of tritium from the analytical suite for sediment that began in 2010 (LANL 2010, 109107) because tritium is present as a component of water, is not adsorbing onto sediment particles, and is included in the analytical suite for water samples, where appropriate. In addition, tritium concentrations in sediment samples (a function of moisture content) are orders of magnitude below human health screening levels and do not pose a potential risk in sediment.

6.0 REFERENCES AND MAP DATA SOURCES

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The following list includes all documents cited in this report. Parenthetical information following each reference provides the author(s), publication date, and ER ID. This information is also included in text citations. ER IDs are assigned by the Environmental Programs Directorate's Records Processing Facility (RPF) and are used to locate the document at the RPF and, where applicable, in the master reference set.

Copies of the master reference set are maintained at the NMED Hazardous Waste Bureau and the Directorate. The set was developed to ensure that the administrative authority has all material needed to review this document, and it is updated with every document submitted to the administrative authority. Documents previously submitted to the administrative authority are not included.

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NMED (New Mexico Environment Department), November 13, 2009. "Notice of Approval with Modifications; Sampling and Analysis Plan for Sediment Monitoring in the Pajarito Canyon Watershed," New Mexico Environment Department letter to D. Gregory (DOE-LASO) and D. McInroy (LANL) from J.P. Bearzi (NMED-HWB), Santa Fe, New Mexico. (NMED 2009, 108123)

Van Metre, P.C., B.J. Mahler, and E.T. Furlong, 2000. "Urban Sprawl Leaves Its PAH Signature," *Environmental Science & Technology,* Vol. 34, pp. 4064-4070. (Van Metre et al. 2000, 082262)

6.2 Map Data Sources

Title; Owner, ID; Intended Scale; Publication Date.

2000 LIDAR Hypsography; Los Alamos National Laboratory, Earth and Environmental Sciences GISLab; 1:1,200; Draft.

Boundary, LANL; Los Alamos National Laboratory, SSMO Site Planning and Project Initiation Group; Unknown; December 2, 2008.

Boundary, Technical Area; Los Alamos National Laboratory, SSMO Site Planning and Project Initiation Group; Unknown; August 16, 2010.

Dirt Roads; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating, and Mapping Section; Unknown; August 17, 2011.

Drainage; Los Alamos National Laboratory, Environment and Remediation Support Services; Unknown; May 15, 2006.

Land Ownership; Los Alamos National Laboratory, SSMO Site Planning and Project Initiation Group; Unknown; December 2, 2008.

Location IDs; Los Alamos National Laboratory, Waste and Environmental Services Division; 1:2,500; March 8, 2012.

Perimeter of the Las Conchas fire burn area; Los Alamos National Laboratory, Earth and Environmental Sciences GISLab; Unknown; July 19, 2011.

Primary Roads; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating, and Mapping Section; Unknown; August 17, 2011.

Security Fence; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating, and Mapping Section; Unknown; August 17, 2011.

Structures; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating, and Mapping Section; Unknown; August 17, 2011.

Watersheds; Los Alamos National Laboratory, Environment and Remediation Support Services; 1:2,500; October 27, 2006.

Figure 1.0-1 Photograph of ash-rich sediment deposited by August 3, 2011, flood in reach PA-3E, along Pajarito Road east of TA-18

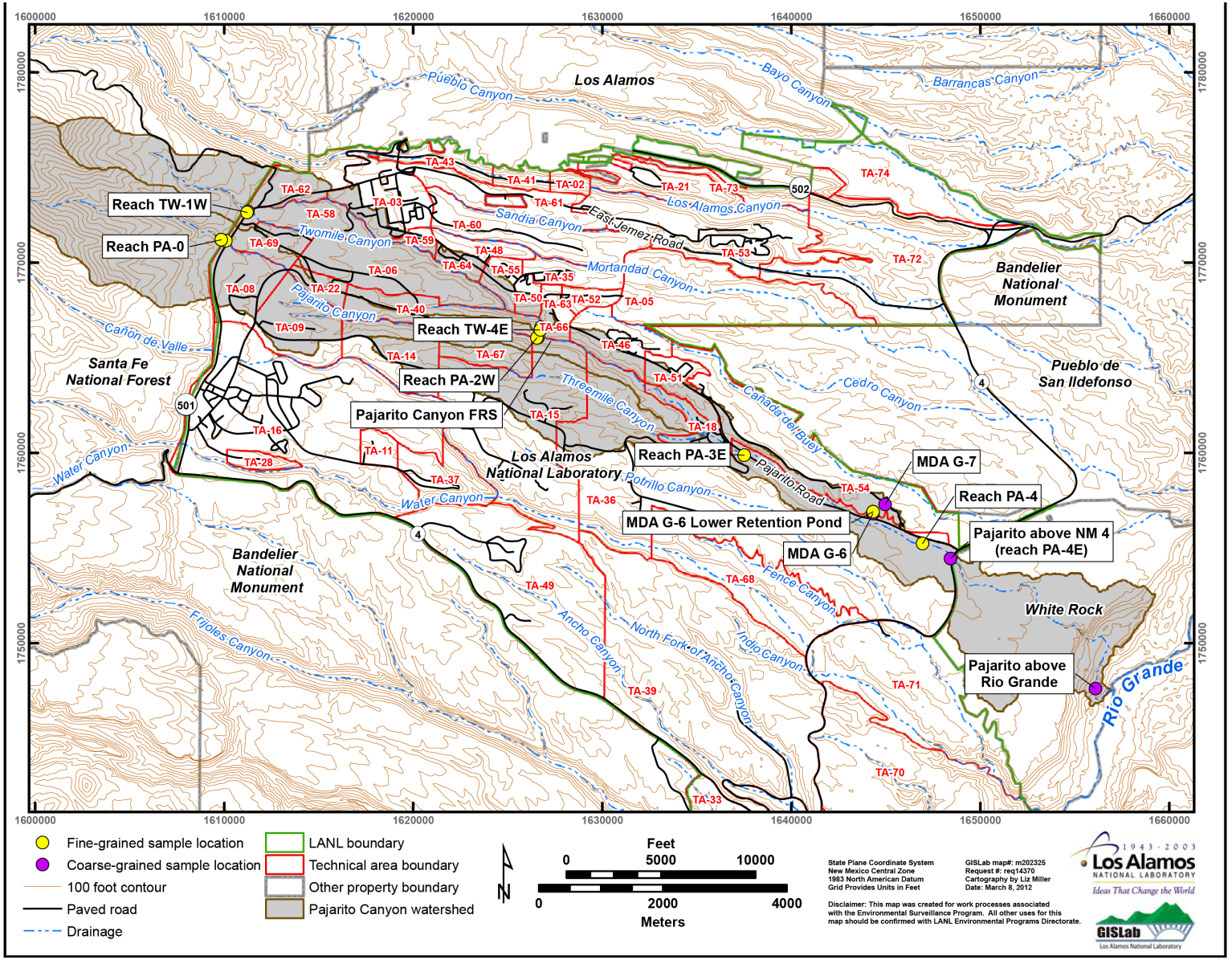

Figure 2.0-1 Sediment sampling locations in the Pajarito Canyon watershed in 2011

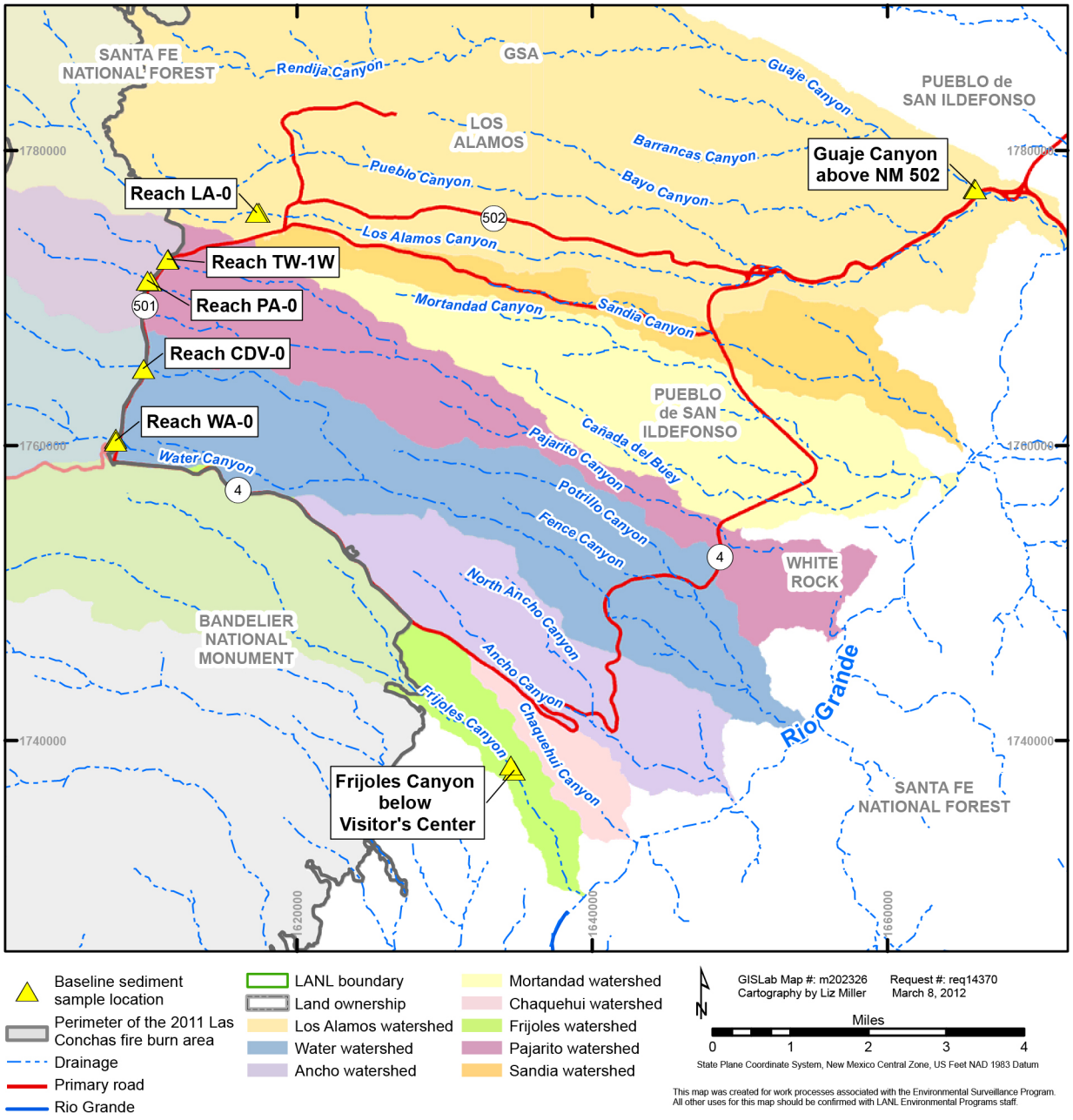

Figure 2.0-2 Baseline sediment sampling locations downstream from the Las Conchas burn area

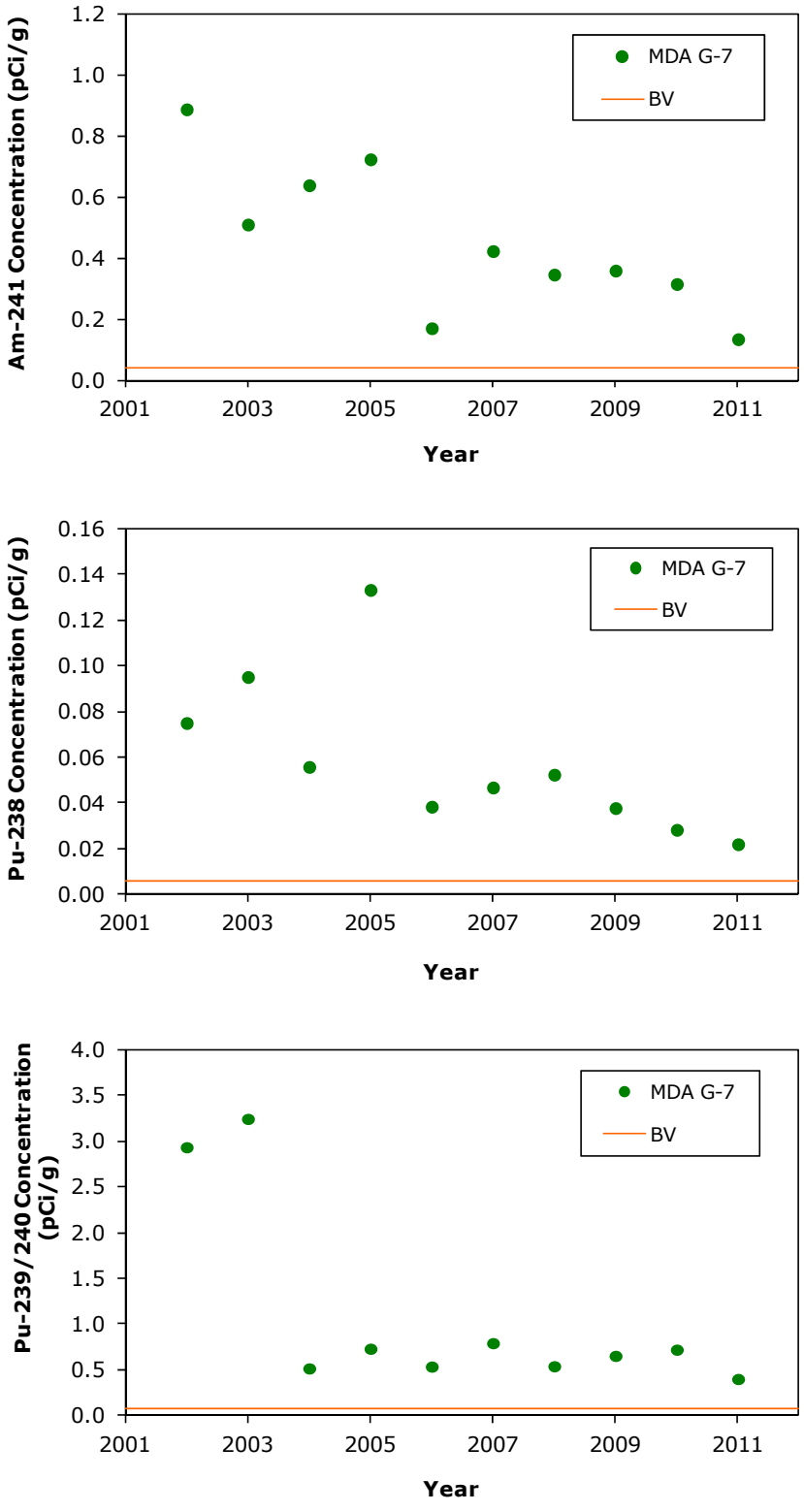

Figure 3.1-1 Concentrations of americium-241, plutonium-238, and plutonium-239/240 in the MDA G-7 drainage, 2002 to 2011

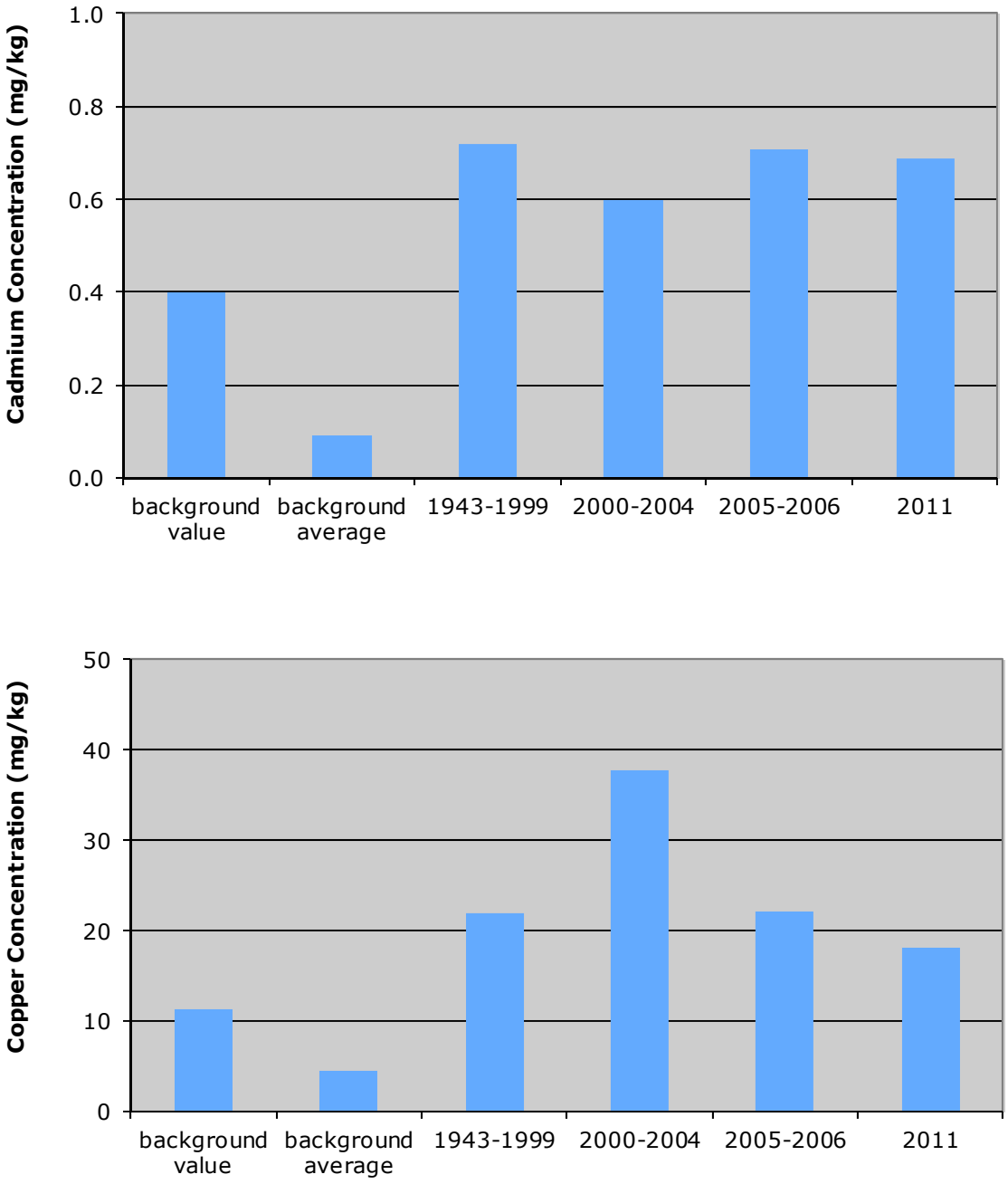

Figure 3.2-1 **Temporal variations in the average concentrations of cadmium and copper in fine facies sediment in reach PA-2W**

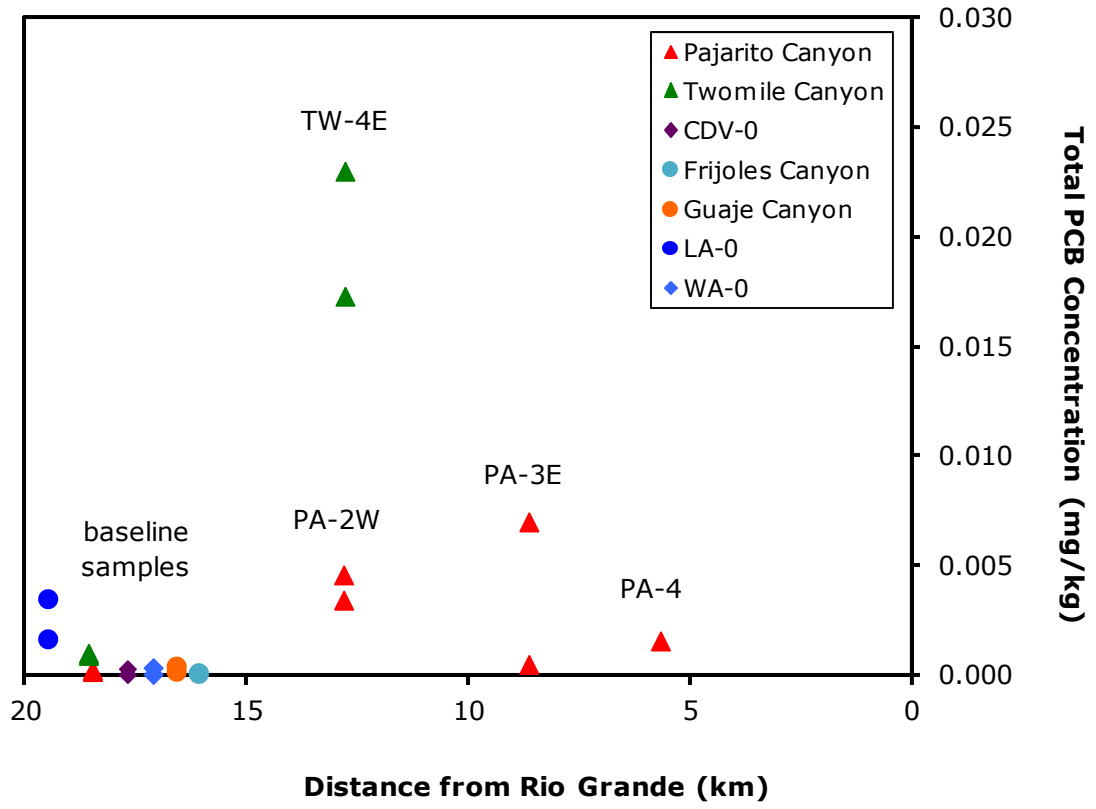

Figure 3.3-1 **Total detected PCB concentration in 2011 sediment samples plotted versus distance from the Rio Grande; Frijoles Canyon and Guaje Canyon samples arbitrarily plotted at 16–17 km**

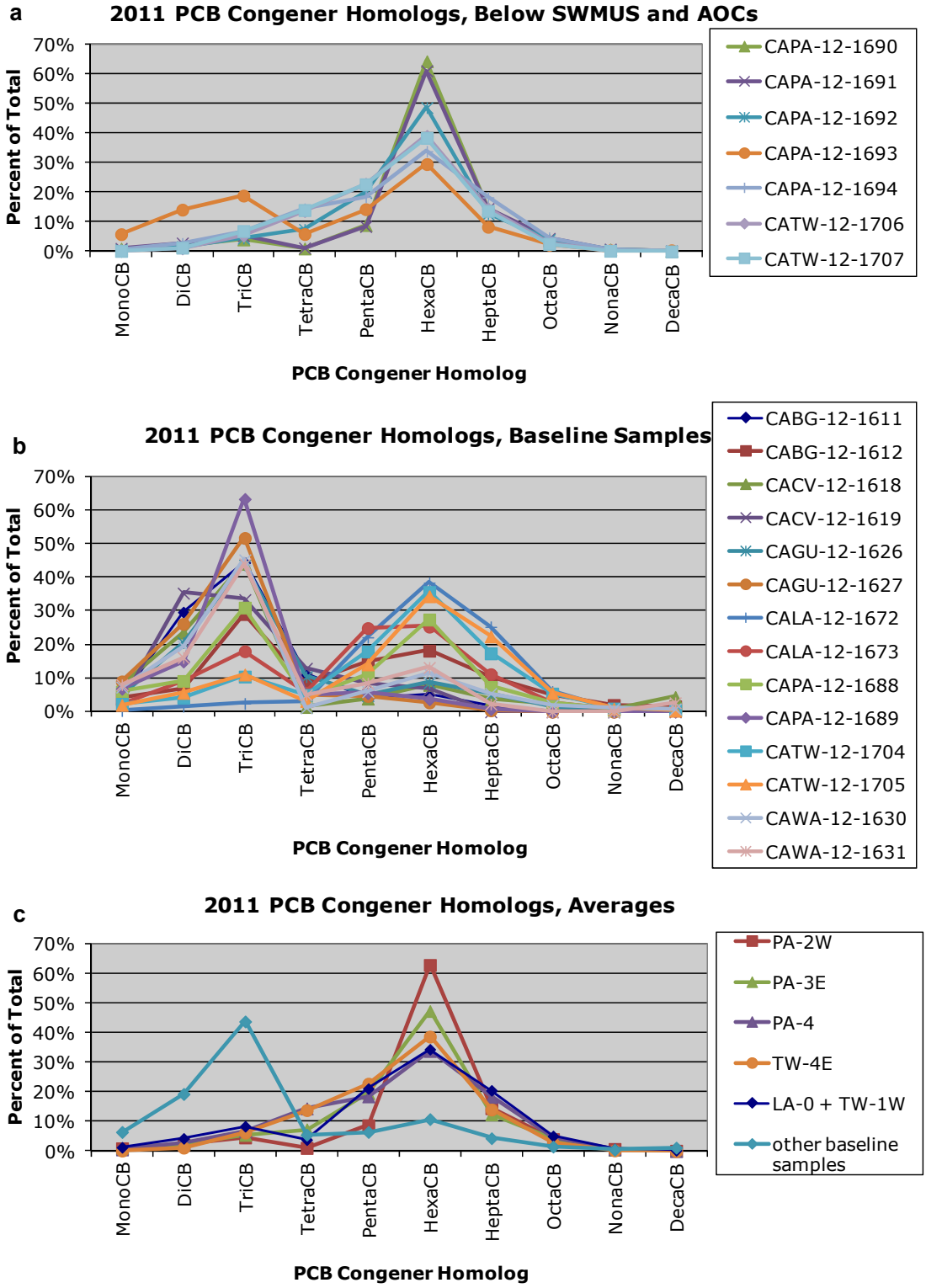

Figure 3.3-2 **Plots of PCB congener homologs in 2011 sediment samples: (a) samples collected downstream from SWMUs and AOCs in the Pajarito Canyon watershed, (b) samples collected from baseline areas downstream from the Las Conchas burn area, and (c) average values for samples collected from different areas**

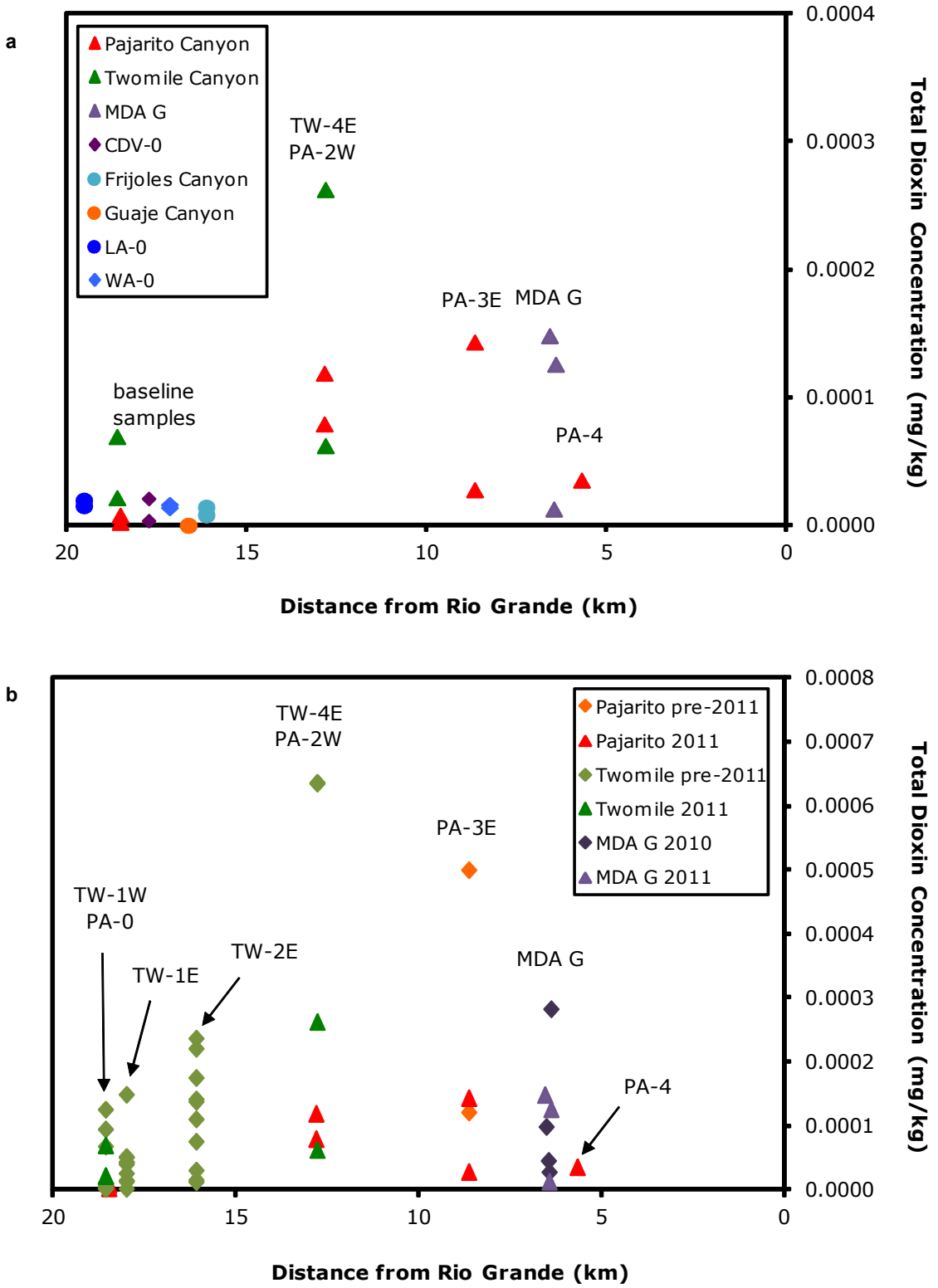

Figure 3.4-1 **Total detected dioxin concentration plotted versus distance from the Rio Grande: (a) 2011 sediment samples from Pajarito Canyon watershed and baseline areas with Frijoles Canyon and Guaje Canyon samples arbitrarily plotted at 16–17 km, and (b) 2011 and pre-2011 sediment samples from Pajarito Canyon watershed**

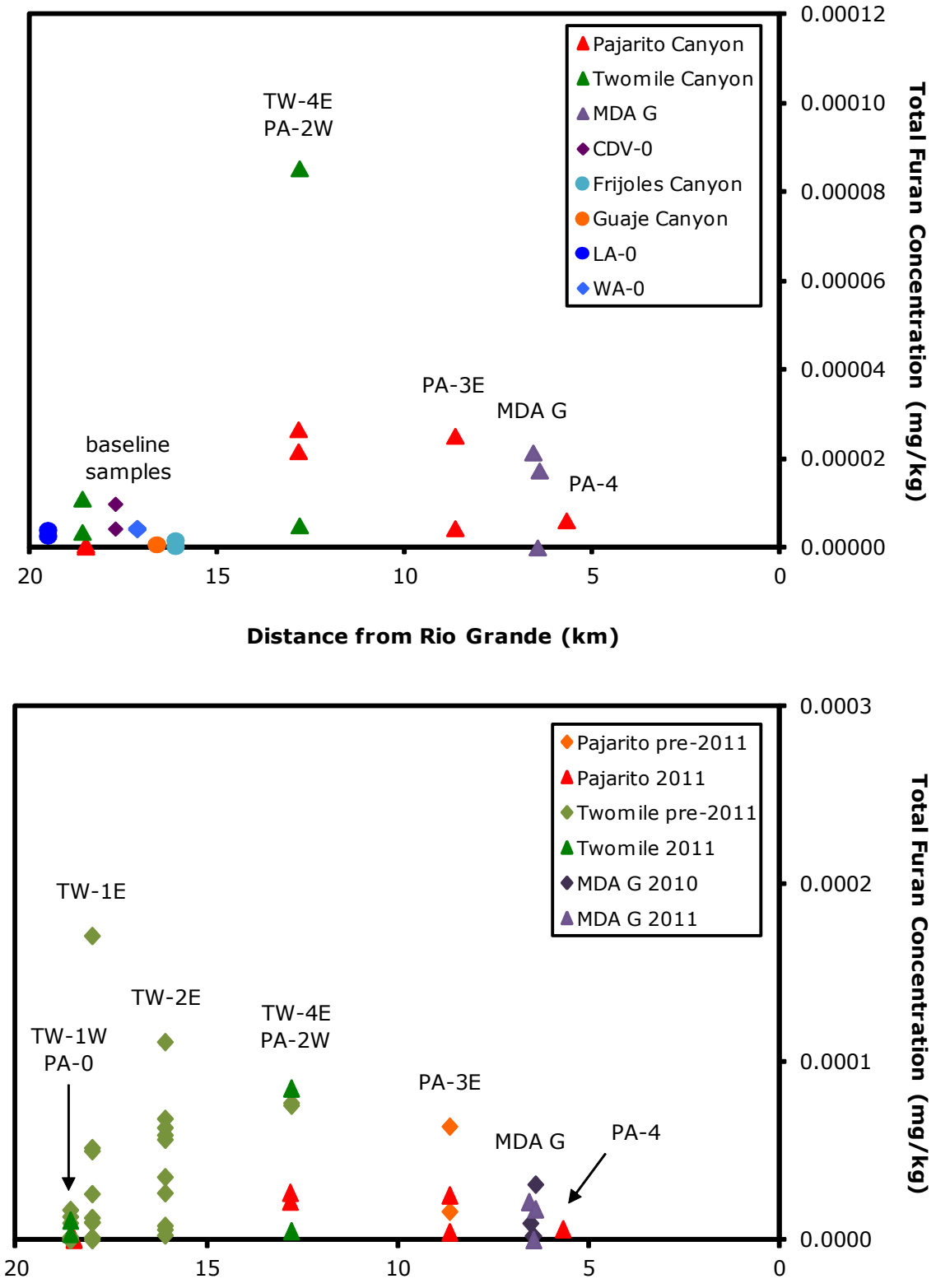

Figure 3.4-2 **Total detected furan concentration plotted versus distance from the Rio Grande: (a) 2011 sediment samples from Pajarito Canyon watershed and baseline areas with Frijoles Canyon and Guaje Canyon samples arbitrarily plotted at 16–17 km and (b) 2011 and pre-2011 sediment samples from Pajarito Canyon watershed**

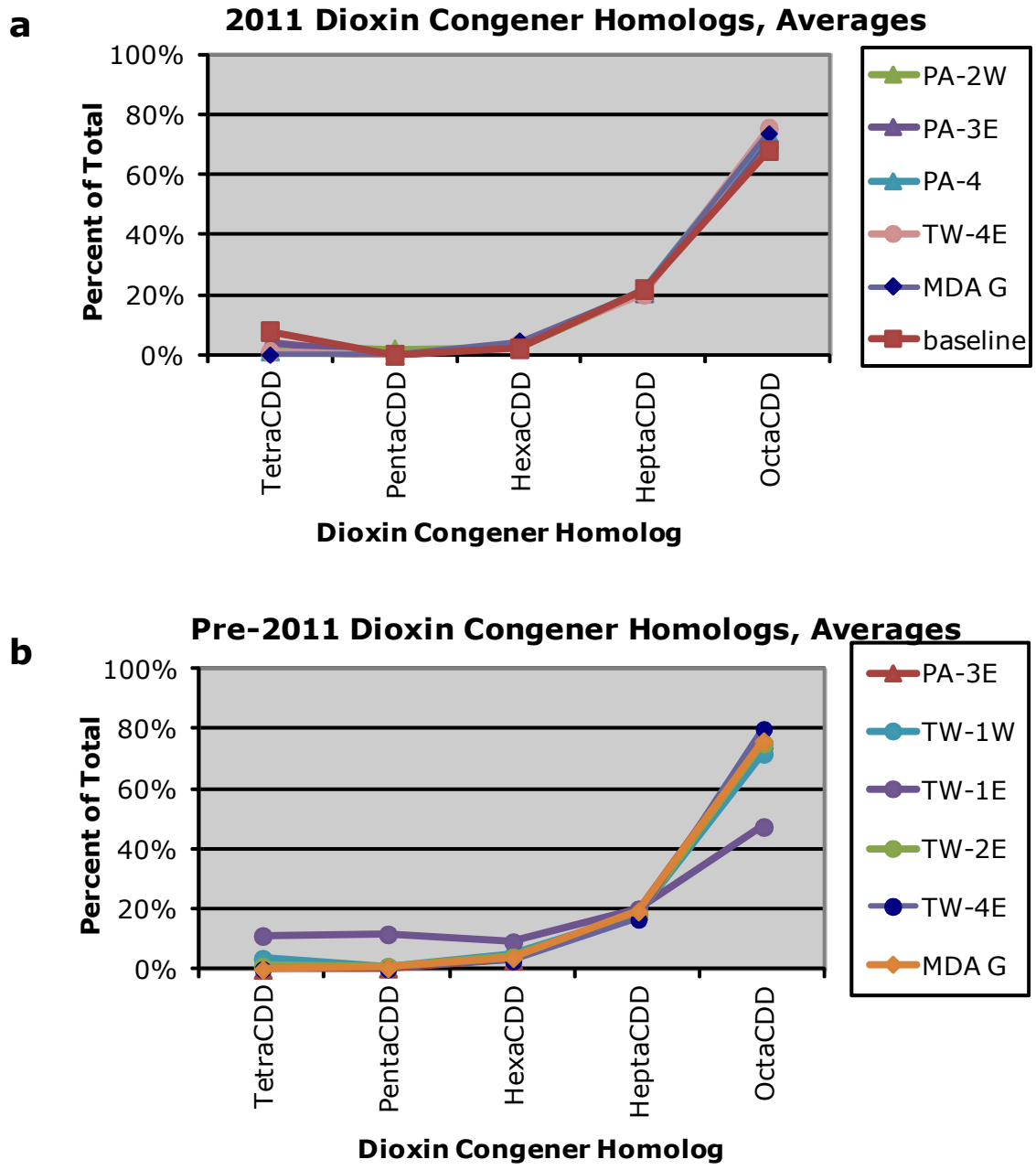

Figure 3.4-3 **Plots of dioxin congener homologs: (a) average values for samples collected downstream from SWMUs and AOCs in the Pajarito Canyon watershed and in baseline areas in 2011 and (b) average values for pre-2011 samples collected from the Pajarito Canyon watershed**

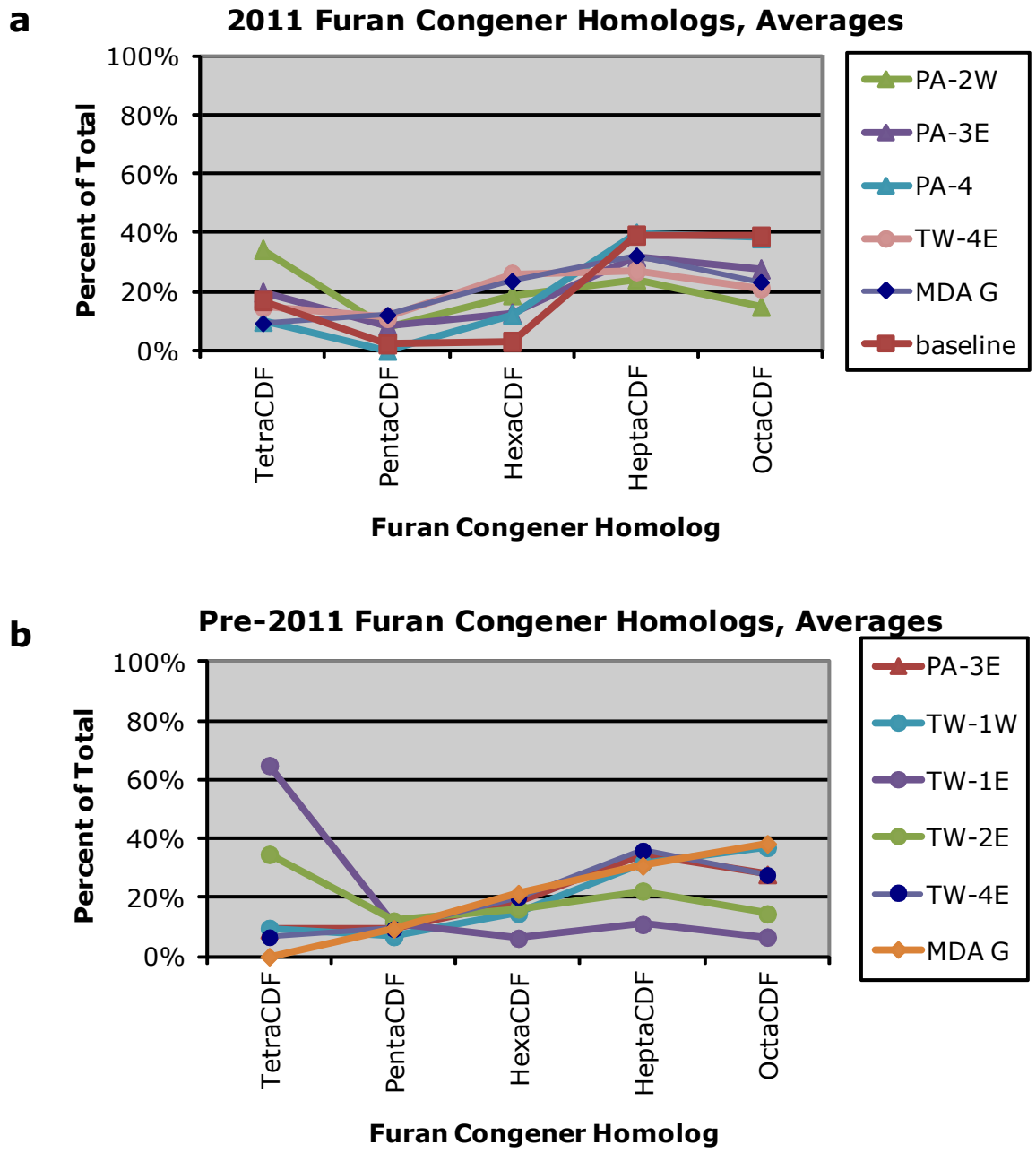

Figure 3.4-4 **Plots of furan congener homologs: (a) average values for samples collected downstream from SWMUs and AOCs in the Pajarito Canyon watershed and in baseline areas in 2011 and (b) average values for pre-2011 samples collected from the Pajarito Canyon watershed**

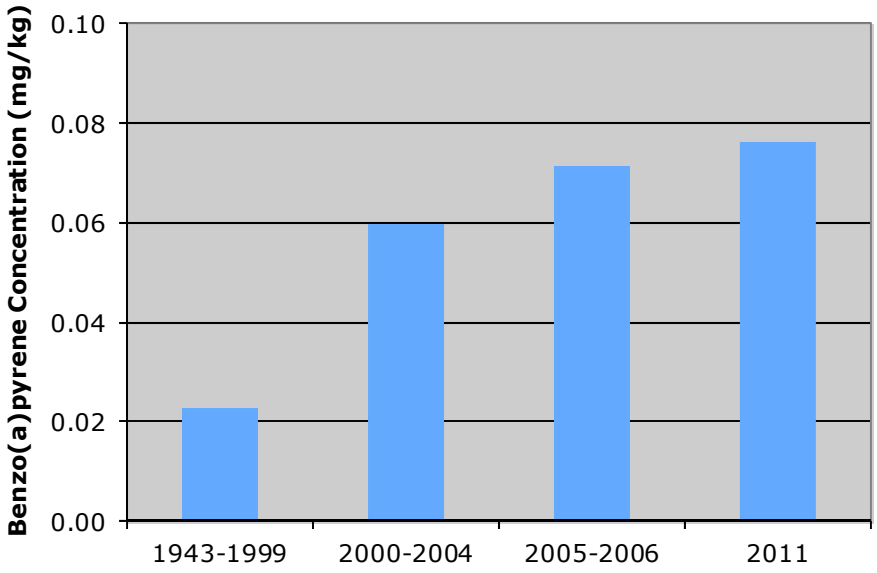

Figure 3.5-1 Temporal variations in the average concentration of benzo(a)pyrene in fine facies sediment in reach TW-4E

Table 2.0-1
Summary of Sediment Samples Collected and Analyses Requested in 2011 from the Pajarito Canyon Watershed

Sample ID	Reach or Area	Location ID or Location Name	Depth (cm)	Sediment Facies	Americium-241	Dioxins and Furans	Gamma Spectroscopy Radionuclides	Explosive Compounds	Isotopic Plutonium	Isotopic Uranium	Target Analyte List Metals	PCBs (Method 8082)	PCB Congeners (Method 1668A)	Strontium-90	Semivolatile Organic Compounds	Total Cyanide
CAPA-12-1685	MDA G	MDA G-6	0–3	Coarse	X[a]	X	—[b]	—	X	X	X	X	—	—	X	—
CAPA-12-1686	MDA G	MDA G-6 Retention Pond Lower	0–1	Fine	X	X	—	—	X	X	X	X	—	—	X	—
CAPA-12-1687	MDA G	MDA G-7	0–9	Coarse	X	X	—	—	X	X	X	X	—	—	X	—
CAPA-12-1688	PA-0	PA-614890	0–10	Fine	X	X	X	X	X	X	X	—	X	X	X	X
CAPA-12-1689	PA-0	PA-614891	0–4	Fine	X	X	X	X	X	X	X	—	X	X	X	X
CAPA-12-1690	PA-2W	PA-614892	2–18	Fine	X	X	X	X	X	X	X	—	X	X	X	X
CAPA-12-1691	PA-2W	PA-614893	0–15	Fine	X	X	X	X	X	X	X	—	X	X	X	X
CAPA-12-1692	PA-3E	PA-614894	0–9	Fine	X	X	X	X	X	X	X	—	X	X	X	X
CAPA-12-1693	PA-3E	PA-614894	9–21	Fine	X	X	X	X	X	X	X	—	X	X	X	X
CAPA-12-1694	PA-4	PA-22890	0–6	Fine	X	X	X	X	X	X	X	—	X	X	X	X
CAPA-12-1695	PA-4E	PA-603937	0–8	Coarse	X	X	—	X	X	X	X	X	—	—	X	—
CAPA-12-1696	Lower Pajarito Canyon	Pajarito at Rio Grande	0–5	Coarse	X	X	—	X	X	X	X	X	—	—	X	—
CATW-12-1704	TW-1W	TW-614905	0–15	Fine	X	X	X	X	X	X	X	—	X	X	X	X
CATW-12-1705	TW-1W	TW-614906	0–11	Fine	X	X	X	X	X	X	X	—	X	X	X	X
CATW-12-1706	TW-4E	TW-614907	0–7	Fine	X	X	X	X	X	X	X	—	X	X	X	X
CATW-12-1707	TW-4E	TW-614908	0–6	Fine	X	X	X	X	X	X	X	—	X	X	X	X

[a] X = Analysis was performed.

[b] — = Analysis was not performed.

Table 2.0-2
Summary of Sediment Samples Collected and Analyses Requested in 2011 from Baseline Areas Outside the Pajarito Canyon Watershed

Sample ID	Reach or Area	Location ID	Depth (cm)	Sediment Facies	Americium-241	Dioxins and Furans	Gamma Spectroscopy Radionuclides	Explosive Compounds	Isotopic Plutonium	Isotopic Uranium	Target Analyte List Metals	PCB Congeners (EPA Method 1668A)	Strontium-90	Total Cyanide
CABG-12-1611	Frijoles Canyon	BG-614833	0–38	Fine	X[a]	X	X	—[b]	X	X	X	X	X	X
CABG-12-1612	Frijoles Canyon	BG-614834	0–9	Fine	X	X	X	—	X	X	X	X	X	X
CACV-12-1618	CDV-0	CV-614840	33–53	Fine	X	X	X	X	X	X	X	X	X	X
CACV-12-1619	CDV-0	CV-614840	53–71	Fine	X	X	X	X	X	X	X	X	X	X
CAGU-12-1626	Guaje Canyon	GU-614848	0–11	Fine	X	X	X	—	X	X	X	X	X	X
CAGU-12-1627	Guaje Canyon	GU-614849	0–5	Fine	X	X	X	—	X	X	X	X	X	X
CALA-12-1672	LA-0	LA-614883	0–8	Fine	X	X	X	—	X	X	X	X	X	X
CALA-12-1673	LA-0	LA-614884	0–7	Fine	X	X	X	—	X	X	X	X	X	X
CAWA-12-1630	WA-0	WA-614852	0–4	Fine	X	X	X	X	X	X	X	X	X	X
CAWA-12-1631	WA-0	WA-614853	0–12	Fine	X	X	X	X	X	X	X	X	X	X

[a] X = Analysis was performed.

[b] — = Analysis was not performed.

Table 3.1-1
Summary of Radionuclide COPCs in 2011 Sediment Samples from the Pajarito Canyon Watershed

Analyte	Sediment BV (pCi/g)	Maximum Detected Concentration in Pajarito Canyon Watershed, 2011 (pCi/g)	Location of Maximum Detected Concentration in Pajarito Canyon Watershed, 2011	Maximum Detected Concentration in Cerro Grande Ash (pCi/g)	Maximum Detected Concentration in 2011 Baseline Samples (pCi/g)	Location of Maximum Detected Concentration in 2011 Baseline Samples	Maximum Detected Concentration in Post-Cerro Grande Baseline Samples (pCi/g)*
Americium-241	0.04	0.135	MDA G-7	0.305	0.0533	TW-1W	0.13
Cesium-137	0.9	3.58	PA-3E	19.7	2.75	CDV-0	8.26
Plutonium-238	0.006	0.0498	TW-1W	0.117	0.0498	TW-1W	0.0486
Plutonium-239/240	0.068	0.406	MDA G-7	0.7	0.155	LA-0	0.343
Strontium-90	1.04	1.06	PA-3E	3.95	0.466	CDV-0	2

*All maximum concentrations in post–Cerro Grande baseline samples were from Pueblo Canyon above Diamond Drive.

Table 3.2-1
Summary of Inorganic COPCs in 2011 Sediment Samples from the Pajarito Canyon Watershed

Analyte	Sediment BV (mg/kg)	Maximum Detected Concentration in Pajarito Canyon Watershed, 2011 (mg/kg)	Location of Maximum Detected Concentration in Pajarito Canyon Watershed, 2011	Maximum Detected Concentration in Cerro Grande Ash (mg/kg)	Maximum Detected Concentration in 2011 Baseline Samples (mg/kg)	Location of Maximum Detected Concentration in 2011 Baseline Samples	Maximum Detected Concentration in Post–Cerro Grande Baseline Samples (mg/kg)	Location of Maximum Detected Concentration in Post–Cerro Grande Baseline Samples
Aluminum	15400	19200	PA-4	17000	13300	LA-0	33640	Los Alamos Reservoir
Antimony	0.83	ND[a]	n/a[b]	1	ND	n/a	0.92[c]	Guaje Canyon
Arsenic	3.98	4.07	PA-3E	6.6	2.63	TW-1W	5.4[c]	Garcia Canyon
Barium	127	687	PA-3E	1300	396	CDV-0	550	South fork of Pajarito Canyon
Beryllium	1.31	2.01	PA-4	1.1	1.55	LA-0	1.6[c]	Garcia Canyon
Cadmium	0.4	0.752	PA-2W	1.2	0.771	LA-0	0.705	Los Alamos Reservoir
Calcium	4420	29000	PA-3E	90000	16900	CDV-0	25000	South fork of Pajarito Canyon
Chromium	10.5	14.7	PA-4	11	10.8	LA-0	18.9	Los Alamos Reservoir
Cobalt	4.73	8.42	PA-3E	8.9	5.59	TW-1W	8.2	Garcia Canyon
Copper	11.2	32.2	PA-3E	45	15.7	CDV-0	24.6	Los Alamos Reservoir
Cyanide (Total)	0.82	14.4	PA-3E	NA[d]	8.7	CDV-0	2.5	Pajarito Canyon (PA-0)
Iron	13800	20200	PA-4	15000	14300	LA-0	15640	Los Alamos Reservoir
Lead	19.7	42.4	PA-3E	84	36.2	TW-1W	48[c]	Pueblo Canyon
Magnesium	2370	4150	PA-4	6100	2190	LA-0	3760	Los Alamos Reservoir
Manganese	543	2520	PA-3E	8200	1660	CDV-0	2200	South fork of Pajarito Canyon
Nickel	9.38	17.4	TW-4E	15	10.5	LA-0	15.7	Los Alamos Reservoir
Potassium	2690	4120	PA-3E	8800	2290	TW-1W	3670	Los Alamos Reservoir
Selenium	0.3	ND	n/a	4.7	ND	n/a	1.6	Guaje Canyon
Silver	1	3.52	PA-2W	0.64	0.356[e]	CDV-0	1.5	Garcia Canyon

Table 3.2-1 (continued)

Analyte	Sediment BV (mg/kg)	Maximum Detected Concentration in Pajarito Canyon Watershed, 2011 (mg/kg)	Location of Maximum Detected Concentration in Pajarito Canyon Watershed, 2011	Maximum Detected Concentration in Cerro Grande Ash (mg/kg)	Maximum Detected Concentration in 2011 Baseline Samples (mg/kg)	Location of Maximum Detected Concentration in 2011 Baseline Samples	Maximum Detected Concentration in Post–Cerro Grande Baseline Samples (mg/kg)	Location of Maximum Detected Concentration in Post–Cerro Grande Baseline Samples
Vanadium	19.7	33.4	PA-4	25	20.5	LA-0	32.2	Los Alamos Reservoir
Zinc	60.2	117	PA-3E	180	81.1	LA-0	104	Los Alamos Reservoir

[a] ND = Not detected.

[b] n/a = Not applicable.

[c] Excludes higher results from Rendija Canyon downstream from firing range where lead and other metals are elevated.

[d] NA = Not analyzed.

[e] Excludes higher silver results of 1.12 mg/kg and 1.31 mg/kg from Frijoles Canyon that may represent contamination.

Table 3.5-1
Summary of Detected SVOCs in 2011 Sediment Samples from the Pajarito Canyon Watershed

Analyte	Maximum Detected Concentration in Pajarito Canyon Watershed, 2011 (mg/kg)	Location of Maximum Detected Concentration in Pajarito Canyon Watershed, 2011	Maximum Detected Concentration Below Los Alamos Townsite (mg/kg)	Location of Maximum Detected Concentration Below Los Alamos Townsite	Maximum Detected Concentration in Post–Cerro Grande Baseline Samples (mg/kg)	Location of Maximum Detected Concentration in Post–Cerro Grande Baseline Samples
Anthracene	0.0213	TW-4E	3	AC-1	ND[a]	n/a[b]
Benzo(a)anthracene	0.0772	TW-4E	5.6	AC-1	ND	n/a
Benzo(a)pyrene	0.0843	TW-4E	5.9	AC-1	ND	n/a
Benzo(b)fluoranthene	0.122	TW-4E	6.7	AC-1	ND	n/a
Benzo(g,h,i)perylene	0.0564	TW-4E	1.4	AC-1	ND	n/a
Benzo(k)fluoranthene	0.0467	TW-4E	3.4	AC-1	ND	n/a
Bis(2-ethylhexyl)phthalate	0.122	MDA G-6 Retention Pond Lower	2	AC-1	ND	n/a
Chrysene	0.0909	TW-4E	5.3	AC-1	ND	n/a
Fluoranthene	0.175	TW-4E	12	AC-1	ND	n/a
Fluorene	0.0152	TW-4E	1.8	AC-1	ND	n/a
Indeno(1,2,3-cd)pyrene	0.0462	TW-4E	2.1	AC-1	ND	n/a
Methylnaphthalene[2-]	0.0237	PA-3E	0.73	AC-1	ND	n/a
Methylphenol[4-]	0.267	PA-3E	ND	n/a	0.96	South fork of Pajarito Canyon
Naphthalene	0.0768	PA-3E	2.4	AC-1	0.76	Pueblo Canyon
Phenanthrene	0.132	TW-4E	11	AC-1	0.072	Rendija Canyon
Pyrene	0.2	TW-4E	12	DP-1W	ND	n/a

[a] ND = Not detected.

[b] n/a = Not applicable.

Attachment 1

Analytical Data from
2011 Sediment Samples from the Pajarito Canyon Watershed
(on CD included with this document)

Attachment 2

Analytical Data from 2011 Sediment Samples from Baseline Areas Outside the Pajarito Canyon Watershed (on CD included with this document)

Attachment 3

Frequency of Detects and Results for COPCs in 2011 Sediment Samples from the Pajarito Canyon Watershed (on CD included with this document)

Attachment 4

Particle Size Data from
2011 Sediment Samples from the Pajarito Canyon Watershed
(on CD included with this document)