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Storm Water Quality in Los Alamos Canyon following the Cerro Grande Fire

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STORM WATER QUALITY IN LOS ALAMOS CANYON FOLLOWING THE CERRO GRANDE FIRE

by

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ABSTRACT

In May 2000, the Cerro Grande Fire burned about 7400 acres of forest on the Los Alamos National Laboratory (LANL) and about 10,000 acres in watersheds above LANL on Santa Fe National Forest lands. The resulting burned landscapes raised concerns of increased storm water runoff and transport of contaminants by runoff in the canyons traversing LANL. On June 2 and 3, 2000, rain fell in the Los Alamos Canyon watershed generating storm water runoff in the canyon bottom. This event was important in that it was the first significant runoff on LANL following the fire and occurred in a canyon containing known legacy waste sites. Samples from this runoff were analyzed for radionuclide, metal, inorganic, and organic constituents. Results show radionuclide concentrations at or below previous (pre-fire) maximum levels at locations on LANL and downstream. However, greater concentrations of some fallout-associated radionuclides (cesium-137 and strontium-90) were seen arriving on LANL from upstream areas compared to pre-fire conditions. Tests indicate most of the radionuclides in the samples were bound to sediments, not dissolved in water. Most radionuclide concentrations in sediments were below LANL Screening Action Levels, with cesium-137 and strontium-90 as exceptions. Most radionuclide concentrations in samples taken at LANL's downstream boundary were greater than those taken upstream, indicating the presence of contributing sources on LANL. For comparison purposes, doses were calculated on a mrem per liter of unfiltered water basis for 11 radionuclides commonly associated with atmospheric fallout and with LANL operations. The maximum dose was 0.094 mrem per liter unfiltered water and was largely associated with plutonium-239/240. In contrast, all filtered samples had total doses less than 0.001 mrem per liter. Compared to past data, potential doses were not increased by the fire during this initial runoff event. Of the 25 metals tested for, seven were above pre-fire levels, including copper, lead, manganese, selenium, strontium, uranium, and zinc. However, dissolved metal concentrations did not exceed State livestock and wildlife standards. Of the 18 general chemistry parameters tested, eight exceeded historic norms, including calcium, potassium, total phosphorous, cyanide, and magnesium.

INTRODUCTION

This report follows from the Cerro Grande Fire that burned about 43,000 acres of mixed conifer forest near Los Alamos, NM, in May 2000. The fire burned about 7400 acres on the Los Alamos National Laboratory (LANL), about 6% of which was considered high severity burn (BAER 2000). On LANL, many small structures burned, typically utility buildings, and nearly 400 legacy waste sites (i.e., potential release sites) had at least some vegetation cover burned or are located in areas that may be affected by post-fire flooding. In addition to the burning that occurred on LANL, about 10,000 acres of watersheds draining onto LANL from adjacent Santa Fe National Forest lands burned, of which from about 20% to 60% was considered high severity depending on the watershed (BAER 2000).

Runoff and sediment yields generally increase after forest wildfires as shown by the 1977 La Mesa Fire (about 15,000 acres burned south of LANL), the 1996 Dome Fire (about 16,000 acres burned south of LANL), and the 1998 Oso Fire (about 5300 acres burned north of LANL). These fires caused dramatic increases in storm water flows compared to pre-burn conditions. For example, following the La Mesa Fire, maximum post-fire peak discharge was estimated at 3030 cubic feet per second (cfs) in Frijoles Canyon compared with a pre-fire maximum of 19 cfs. Following the Dome Fire, an estimated 3630 cfs peak occurred in Capulin Canyon compared to the pre-fire maximum of 25 cfs (Veenhuis 1999).

Similar increases in flow were predicted for post-fire conditions in the canyons at LANL by the Cerro Grande Burned Area Emergency Rehabilitation team and by LANL personnel. These predictions included the possibility of increased flood magnitudes of over 100 times in some canyons, substantial channel incision, extensive sheet and rill erosion, possible slope failures, and debris flows on some severely burned steep slopes (BAER 2000). During the first summer following the fire, runoff events carrying ash did occur in canyons traversing LANL, however, dramatic flooding did not occur in these canyons due to lighter than average summer rainfall amounts and to the extensive rehabilitation and flood control efforts implemented shortly after the fire.

The potential for large post-fire runoff and sediment increases raised concerns about erosion of contaminants that exist in soils at locations on LANL and about transport of these contaminants away from their source areas to offsite lands and the Rio Grande. These constituents can be dissolved in the runoff water itself or bound to transported sediments. The occurrence of runoff

from LANL is not new. Runoff events leaving LANL property occur most years and carry with them small amounts of both natural and LANL-derived constituents at near-background levels. Regular sampling of these waters is reported annually in the LANL Environmental Surveillance Reports. What was new after the Cerro Grande Fire was concern that greater levels of contamination could be mobilized than was historically observed.

In response to these concerns, LANL initiated a special program after the fire whereby storm water runoff was sampled more frequently and in more locations than usual. This report contains results from this special sampling for the June 2 and 3, 2000, storm water runoff event in Los Alamos (LA) Canyon. This event is important because it was the first significant runoff event on LANL following the fire and because LA Canyon has both a severely burned upper watershed (Figure 1) and, on LANL, contains potential release sites where legacy contamination exists from past operations.

In summary, this report provides details on the quality of storm water in LA Canyon during the first significant runoff event following the Cerro Grande Fire; provides results of testing for radionuclides, metals, general chemistry, and organics; and provides doses on a mrem per liter basis for radionuclides and gives comparisons to historical levels and standards. The value of this report is in providing information on the "first flush" from burned areas in LA Canyon. However, the data presented here are limited to the initial event in LA Canyon, additional data on later runoff events in this and other canyons are expected in other reports.

MATERIALS AND METHODS

Storm water at LANL is currently sampled from 53 automatic sampling stations that were established between 1994 and 1997. Four of these automated samplers are located in LA Canyon (Figure 2) and provided the data reported in this document. Samples were taken on both June 2 and 3 at the station near LANL's downstream boundary (E042). Samples were collected June 3 at the upstream boundary station (E025), and June 2 at stations below Technical Area (TA) 2 and at the mouth of DP Canyon, a tributary to LA Canyon. Samples were collected automatically at three stations (E030, E040, and E042) on June 2 and manually from two stations (E025 and E042) on June 3. Manual collection was necessary because the automated sampler reservoirs

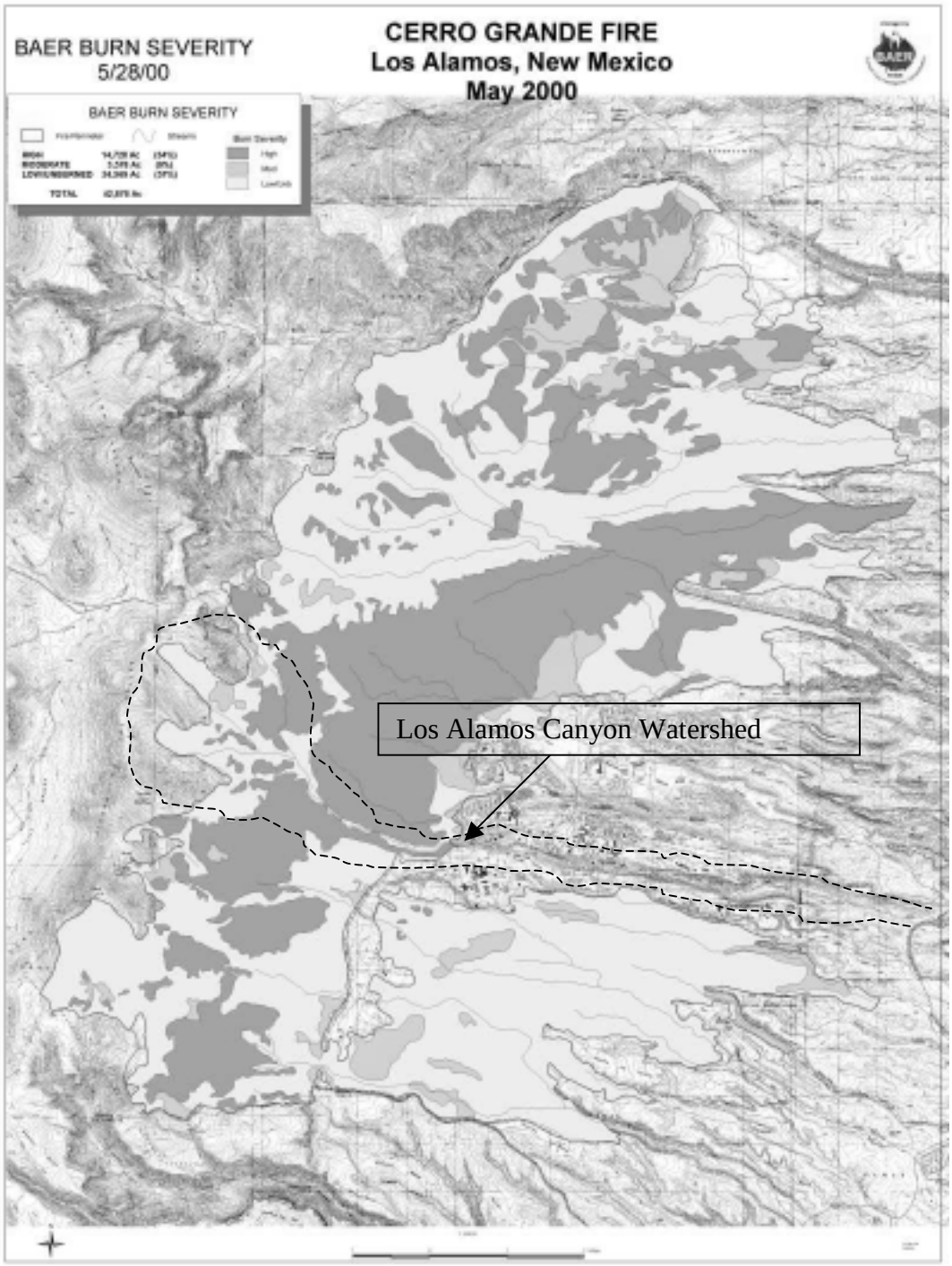

Figure 1. Cerro Grande Fire burn severity map showing the LA Canyon Watershed (modified from BAER Report 2000).

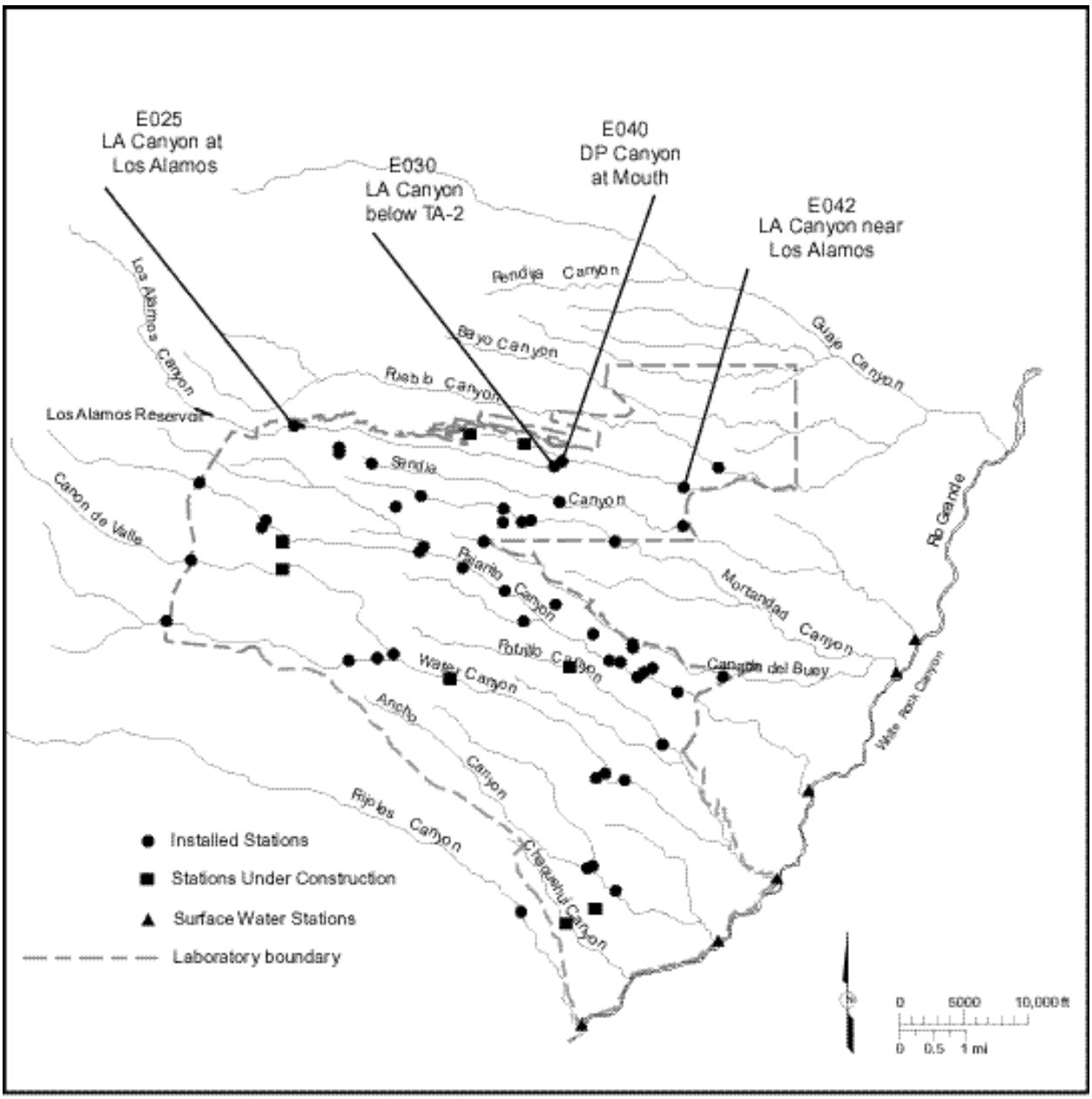

Figure 2. Locations of gaging stations at LANL. LA Canyon stations are flagged.

were still filled from June 2. Procedures used for these manually collected samples followed recommended operating procedures outlined by the Environmental Protection Agency (EPA) in "NPDES Storm Water Sampling Guidance Document, EPA 833-B-92-001" (EPA 1992).

Figure 3 shows a typical automated sampler. Sampling intake tubes are positioned approximately 6 inches above the streambed. The ISCO™ automated samplers (ISCO™ Series #3700 Portable Samplers) in LA Canyon are programmed to collect 24 liters of storm water, which is then used to test levels of radionuclides, metals, and other constituents.

Figure 3. Typical automated storm water sampler.

Although different samples from various stations are compared throughout this report because they represent the best data available, they differ in the portion of the runoff hydrograph they represent. Flows were higher on June 2 than on June 3 and represented the early portion of the hydrograph and consequently had higher total suspended solids than the samples collected the following day. Peak runoff flows on June 2 were as follows: 13 cfs at LA Canyon below TA-2 (E030), estimated flow of 20 cfs at DP Canyon at Mouth (E040), and 18 cfs at LA Canyon nearLos Alamos (E042). Runoff flows on June 3 were as follows: a peak flow of 8.6 cfs at LA Canyon at Los Alamos (E025) and an estimated average flow of 2 cfs at LA Canyon near Los Alamos (E042).

Once retrieved, the runoff samples were sent to Paragon Analytics, Inc., of Fort Collins, Colorado, for analyses of radionuclides, semivolatile (SVOA) and volatile organic compounds, metals, polychlorinated biphenyls (PCBs), high explosives compounds and breakdown products (HE), and general chemistry parameters. Radioactive analyses were completed as follows: alpha spectrometry was used for plutonium-238 and -239/240; uranium-234, -235, and -238; and thorium-228, -230, and -232; gamma spectrometry was used for cesium-137 and gross gamma; gas proportional counting was used for gross alpha, gross beta, and strontium-90; and liquid scintillation counting was used for tritium. SVOAs were analyzed using EPA Method 625, and volatiles were analyzed by EPA Method 624. Most of the metals were analyzed via EPA Method 200.7; however, cadmium, iron, lead, antimony, and thallium were analyzed using EPA Method 200.8; arsenic was analyzed via EPA Method 206.2; mercury via EPA Method 245.2; and selenium via EPA Method 270.2. PCBs were analyzed using EPA Method 608. HE constituents were analyzed using EPA Method 8330. The general chemistry parameters were derived as follows: CN (total) and CN (amenable) by EPA Method 335.3; nitrate-nitrogen (as N) by EPA Method 353.2; and P by EPA Method 365.4.

For organic chemistry analysis, the following quality control procedures were required:

- laboratory control samples,
- matrix spike/matrix spike duplicates,
- surrogate compound recoveries,
- initial calibration control criteria, and
- continuing calibration verification.

For inorganic chemistry (includes metals chemistry, radioactive chemistry, wet chemistry, and general inorganic chemistry), the following quality control procedures were required:

- laboratory control samples,
- matrix spikes/matrix spike duplicates,
- method blanks (for checking of contamination of samples during analysis),
- sample replicates,
- tracer carrier recovery (for determination of radioactive element recoveries),
- ICP-Atomic Emission Spectra and ICP-Mass Spectrometry analysis require serial dilutions,
- initial calibration control criteria,

- continuing calibration verification,
- continuing calibration blanks, and
- interference check samples.

Upon receipt of data packages, data validation was performed according to protocols developed by the LANL Environmental Restoration Program. The quality assurance assessment and validation process helped assure soundness of data.

RESULTS AND DISCUSSION

General Observations

Radionuclide and metal concentrations were significantly lower in filtered samples than in unfiltered samples; that is, almost all of the metals and radioactivity in the samples were associated with the sediments (ash, clay, silt, etc.) carried by the runoff, rather than dissolved in the water.

Radionuclide concentrations in filtered water did not exceed drinking water standards, however, many unfiltered samples containing sediments had concentrations surpassing standards. (Note: Drinking water standards do not apply to storm water and are used here for comparison only. See discussion below.)

Consistent with pre-fire conditions, concentrations of many constituents were higher for samples taken at LANL's downstream boundary compared to those taken above LANL, a condition that indicates the presence of contributing sources in LA Canyon on LANL.

On a dose per liter basis, post-fire doses were less than maximum pre-fire doses indicating that conditions in LA Canyon just after the fire did not cause greater potential doses than had been seen in the past. Note that these doses are hypothetical and would only occur in the unlikely event that someone ingested runoff water.

Concentrations of most constituents in post-fire runoff samples were similar to those from pre-fire runoff. For example, gross alpha and gross beta in post-fire samples were below pre-fire maximums. This indicates that for the June 2 and 3 events, the fire did not substantially change concentration of contaminants and runoff conditions relative to erosion of contaminant source areas. However, exceptions to this are concentrations of some fallout radionuclides that increased after the fire in samples taken upstream of LANL. For example, cesium-137 concentrations in unfiltered waters were elevated approximately 20 times higher upstream of LANL compared to

pre-fire levels. The results suggest that fire caused the transfer of fallout radionuclides bound to the forest canopy, or in the forest litter, and concentrated them in the ashy layer of the burned surface soil available for erosion. Concentration of fallout-associated radionuclides in ash, and subsequently, in runoff during fire has been documented at other locations where forest fires have occurred (Amiro et al. 1996, Paliouris et al. 1995).

For metals and general chemistry parameters, some increases were seen consistent with what has been observed following fire in studies at other locations (Chambers and Attiwill 1994, Parra et al. 1996, Auclair 1977). These studies identified a pathway from plant (before the fire) to ash, water, and deposited sediments and soil after fire.

Radionuclides

Sources. Radionuclides found in runoff at LANL are derived from natural sources such as uranium from natural rocks, from anthropogenic (human-caused) sources external to LANL such as fallout of radioactive plutonium, strontium, and cesium from atmospheric testing of nuclear weapons, and from LANL sources such as discharges from facilities or dispersion from legacy waste sites. The main LANL facilities in or near LA Canyon include former TA-1 (the first technical area located in the Los Alamos townsite near Ashley Pond), TA-21 on DP Mesa, TA-53, which includes the LANSCE linear accelerator facility, and TA-2, including the Omega West Reactor (LANL 1995).

Comparison with historical levels and background levels. When comparing to historical levels, two useful benchmarks are the pre-fire, 1995–1999, maximum concentration from storm water samples collected in LA Canyon and average concentration over the same period. The 1995–1999 data set is used for comparison, because, although runoff data were collected before 1995, the post-1995 data have similar sampling methods to the current data.

In general, measurements of radioactivity in the June 2 and 3 storm water are within the range of pre-fire maximums seen for LA Canyon, including gross alpha and gross beta. For example, the pre-fire maximum and average for plutonium-239/240 in unfiltered water samples were 15.7 picoCuries per liter and 2.8 picoCuries per liter, respectively. The post-fire June 2 and 3 maximum and average were 13.5 picoCuries per liter and 5.8 picoCuries per liter, respectively. This indicates that a dramatic increase in plutonium concentrations was not seen during these first runoff events after the fire. In general, the data indicate the fire did not cause large increases

in erosion of contaminant source areas or in concentrations of contaminants in runoff during these initial events.

However, upstream of LANL some radionuclide concentrations increased as compared to pre-fire records. For example, cesium-137 concentrations were elevated approximately 20 times higher, on a picoCurie per gram sediment basis, than pre-fire levels. This suggests that fire caused the transfer of part of these radionuclides bound to the forest canopy and in the forest litter and concentrated them in the ashy layer of the burned surface soil available for erosion. This process has been observed elsewhere and reported in the scientific literature (Amiro et al. 1996, Paliouris et al. 1995). In addition, fire removed groundcover, such as the layer of duff (decomposing pine needles), thus exposing soils having accumulated fallout radionuclides. Measurements after the fire showed that ash on the ground and soils in burned areas contained much higher levels of certain radionuclides than soils in unburned areas. As a result of the movement of ash and soils containing fallout radionuclides, greater concentrations of these radionuclides began to arrive at sampling stations upstream of LANL than had been seen in the past.

Comparison with standards. Water quality standards have not been established specific to most radionuclides in storm water runoff, which causes some difficulty when evaluating the June 2 and 3 data for LA Canyon. However, rather than provide no context for the sampling results reported, the following sections make indirect comparisons of sampling results to Screening Action Levels (SALs) for sediments (most meaningful comparison), Department of Energy (DOE) Derived Concentration Guides (DCGs), EPA Drinking Water Standards, and New Mexico Water Quality Control Commission (NMWQCC) Standards for livestock watering.

While we provide here a comparison of contaminant levels in storm water to various standards, the value of these indirect comparisons is limited, particularly the comparison with drinking water standards. Untreated storm water runoff is not considered a drinking water source, as it is typically brown in color, laden with sediments and floating detritus, and generally understood to be non-potable. However, indirect comparisons to various standards are given here to provide some limited context.

- SALs referred to in this report were developed by LANL's Environmental Restoration Project as screening levels for use in clean up decisions. When sediment concentrations were

found above these SALs, more thorough evaluation of the site and associated risks was warranted. When radionuclide levels in the suspended sediment fraction of the runoff from the June events are compared to LANL SALs, two radiounuclides, cesium-137 and strontium-90, were above their respective sediment SALS (Table 1). These measurements occurred in samples taken at the upstream boundary of LANL. Radionuclides found in samples collected upstream of the LANL boundary are expected to be primarily derived from fallout radionuclides that had been bound in plants and became mobilized by the fire. Both of the elevated cesium-137 and strontium-90 measurements were from the same sample taken at the upstream boundary on June 3. This sample had comparatively low total suspended solids (sediment), so had relatively high concentrations on a picoCurie per gram sediment basis. No other SALs were exceeded for the radionuclides measured at all stations.

As a consideration when comparing runoff concentrations to SALs, sediment in a runoff sample tends to have higher concentrations of radionuclides than sediments found in deposits after the runoff event. This is because runoff samples tend to capture the finer sediment particles that have a greater affinity for sorbing radionuclides. So it is expected that the cesium-137 and strontium-90 concentrations in sediment deposits formed after the runoff event will be closer to their SALs than shown in Table 1. Also, the concentrations in sediment reported in Table 1 are maximums seen among all samples. Average concentrations are lower, but the maximums were shown here as a worst case.

- A DCG for public dose is the concentration of a radionuclide that, under conditions of continuous exposure for one year, would result in an effective dose equivalent of 100 mrem. All radionuclides tested for were less than their respective DCGs in both unfiltered and filtered samples when compared to the DOE DCGs for public exposure to waters in uncontrolled areas (DOE DCG for public dose).

Table 1. Maximum Radionuclide Concentrations of Sediment Carried by the Runoff Compared to LANL Sediment SALs

	Maximum value in storm water (pCi/g)	*SAL for deposited sediments* (pCi/g)
cesium-137	20.8	5.1
plutonium-238	0.09	27.0
plutonium-239/240	4.0	24.0
strontium-90	18.0	4.4
tritium	ND	260.0
uranium-234	6.0	13.0
uranium-235	0.3	10.0
uranium-238	6.6	67

ND means non-detect

However, gross alpha concentrations (from all natural and anthropogenic alpha-emitting radionuclides) were greater than public dose DCG levels in unfiltered samples at all four sampling locations. The gross alpha DCG is based on the most restrictive anthropogenic alpha emitters and is commonly exceeded by runoff laden with sediments containing naturally derived alpha emitters. Of the specific alpha emitters tested for, none were above their respective DCGs for public dose. In addition, DOE has established a more stringent set of DCGs for drinking water systems (DOE DCG for drinking water) that is based on a water ingestion dose of 4 mrem per year. Although storm water is not considered to be drinking water, the results from testing runoff from the June 2 and 3 events are compared here to provide better understanding. Of the radionuclides tested for, plutonium-239/240 and thorium-232 in unfiltered runoff were greater than their DCGs for drinking water. Gross alpha and gross beta in unfiltered runoff were also at levels greater than their drinking water DCGs. No DCGs were exceeded for filtered runoff. As a further consideration, DCGs allow for water ingestion over an entire year. In other words, the filtered runoff water could have been ingested for an entire year without exceeding any DOE dose limits for drinking water.

- Comparing runoff concentrations to EPA drinking water standards, there exist standards for a limited set of radionuclides including uranium-234, -235, and -238, strontium-90, tritium, gross alpha, and gross beta. These standards do not directly apply to storm water (see discussion above). They typically target dissolved constituents and are applied to filtered or treated water with low amounts of suspended solids. Of the filtered samples from June 2 and 3, no EPA drinking water standards were exceeded. The filtered samples closest to standards were gross beta and strontium-90, each less than half the standard. For the

unfiltered runoff, EPA drinking water standards were surpassed in many of the samples where standards exist. The highest levels were associated with gross alpha, over 100 times higher than standards, likely associated with natural decay products of uranium and thorium found in sediments suspended in the storm water. Gross beta was exceeded in 5 of 5 unfiltered samples, but not in filtered samples, and strontium-90 exceeded standards in 2 of 5 unfiltered samples, but not in filtered samples. In summary, the filtered water met EPA drinking water standards, but the unfiltered water did not. The storm water runoff in LA Canyon is not a drinking water supply so the EPA standards do not apply, but are presented here for context.

- State of New Mexico Livestock Watering Standards exist for tritium and gross alpha. Tritium was not detected in runoff samples. Gross alpha was measured in levels up to 570 picoCuries per liter in unfiltered samples and 1.9 in filtered samples. The gross alpha levels in unfiltered samples are higher than the Livestock Watering gross alpha standard of 15 picoCuries per liter. Most of the gross alpha levels in the runoff are associated with naturally derived radionuclides in sediments and none of the individual alpha emitters tested for were above the standard.

Dose Assessment - Radiological Doses on a per Liter Basis

Doses are presented here for a scenario of ingestion of water containing the maximum levels of radionuclides reported in Table 2. These doses are presented on a per liter basis and use the assumption that a person directly drinks storm water runoff. That is, a hypothetical person sees storm water in the channel of LA Canyon and drinks it even though it is untreated and has a muddy appearance. Although this assumption is unrealistic, it provides a context for better understanding the concentration levels reported in Table 2. No attempt was made here to provide a cumulative dose over time.

Doses for both filtered (<0.45 micron filter) and unfiltered water were calculated for 11 radionuclides commonly associated with fallout from atmospheric weapons testing, with LANL operations, and from naturally occurring sources (cesium-137, plutonium-238 and -239/240, strontium-90, tritium, thorium-228, -230, and -232, and uranium-234, -235, and -238). These doses are shown in Table 3 and represent the Committed Effective Dose Equivalents, which

Table 2. Radiochemical Analysis of Runoff Samples for June 2 and 3, 2000 (pCi/L)

	^{137}Cs (Cesium)				^{238}Pu (Plutonium)				$^{239.240}$Pu (Plutonium)			
	Filtered		Unfiltered		Filtered		Unfiltered		Filtered		Unfiltered	
June 2, 2000												
LA Canyon below TA-2			0.0	0.35			0.08	0.011			13.5	0.475
DP Canyon at Mouth			14.2	1.225			0.64	0.035			3.3	0.125
LA Canyon near Los Alamos			13.9	0.875			0.78	0.0425			10.9	0.4
June 3, 2000												
LA Canyon at Los Alamos	-0.1	0.725	5	0.575	0.003	0.00275	-0.006	0.003	0.011	0.00375	0.194	0.01575
LA Canyon near Los Alamos	0.2	0.75	21.8	1.95	0.018	0.0045	0.074	0.0095	0.015	0.00475	1.26	0.055
1995–1999 Max	2.07		42.28		0.15		1.5308		0.99		15.777	
1995–1999 Average	0.3438		10.447		0.0145		0.2542		0.0819		2.888	
DOE DCG for Public Dose	3000				40				30			
DOE DCG for Drinking Water	120				1.6				1.2			
EPA Primary Drinking Water Std.												
EPA Screening Level												

	^{90}Sr (Strontium)				^{228}Th (Thorium)				^{230}Th (Thorium)			
	Filtered		Unfiltered		Filtered		Unfiltered		Filtered		Unfiltered	
June 2, 2000												
LA Canyon below TA-2			1.63	0.0925			5.67	0.1975			3.44	0.125
DP Canyon at Mouth			23.9	1.075			6.88	0.2375			4.18	0.1475
LA Canyon near Los Alamos			25.2	1.15			13.4	0.45			8.8	0.3
June 3, 2000												
LA Canyon at Los Alamos	3.04	0.1475	4.34	0.2075	-0.025	0.00925	0.61	0.03	0.089	0.0095	0.77	0.035
LA Canyon near Los Alamos	3.54	0.17	6.8	0.325	-0.016	0.0095	3.06	0.1125	0.126	0.012	2.12	0.08
1995–1999 Max	12.8		25									
1995–1999 Average	4.94		8.28									
DOE DCG for Public Dose	1000				400				300			
DOE DCG for Drinking Water	40				16				12			
EPA Primary Drinking Water Std.	8											
EPA Screening Level												

Table 2. Radiochemical Analysis of Runoff Samples for June 2 and 3, 2000 (pCi/L) (Cont.)

	^{232}Th (Thorium)				^{3}H (Tritium)				^{234}U (Uranium)			
	Filtered		Unfiltered		Filtered		Unfiltered		Filtered		Unfiltered	
June 2, 2000												
LA Canyon below TA-2			4.81	0.17			100	30			3.83	0.15
DP Canyon at Mouth			6.58	0.2275			140	30			3.54	0.145
LA Canyon near Los Alamos			12.9	0.425			130	30			7.9	0.325
June 3, 2000												
LA Canyon at Los Alamos	0.004	0.00425	0.453	0.02425	80	30	120	30	1.04	0.0525	1.45	0.065
LA Canyon near Los Alamos	0.03	0.00725	2.65	0.0975	30	27.5	150	30	1.06	0.0525	2.55	0.1075
1995–1999 Max					200		338					
1995–1999 Average					32.428		16.666					
DOE DCG for Public Dose	50				2.E+06				500			
DOE DCG for Drinking Water	2				80000				20			
EPA Primary Drinking Water Std.					20000							
EPA Screening Level												

	^{235}U (Uranium)				^{238}U (Uranium)				Gross Alpha			
	Filtered		Unfiltered		Filtered		Unfiltered		Filtered		Unfiltered	
June 2, 2000												
LA Canyon below TA-2			0.36	0.025			3.46	0.1375			268	10.75
DP Canyon at Mouth			0.258	0.02225			2.28	0.1			328	13.25
LA Canyon near Los Alamos			0.56	0.04			6.2	0.25			570	23.75
June 3, 2000												
LA Canyon at Los Alamos	0.041	0.00775	0.067	0.01075	1.09	0.055	1.58	0.07	1.7	0.325	13.8	0.675
LA Canyon near Los Alamos	0.099	0.01325	0.235	0.021	1.12	0.055	2.61	0.11	1.9	0.325	109	4.5
1995–1999 Max									16.8		640.8	
1995–1999 Average									1.5052		136.91	
DOE DCG for Public Dose	600				600				30			
DOE DCG for Drinking Water	24				24				1.2			
EPA Primary Drinking Water Std.									15			
EPA Screening Level									5			

Table 2. Radiochemical Analysis of Runoff Samples for June 2 and 3, 2000 (pCi/L) (Cont.)

	Gross Beta			
	Filtered		Unfiltered	
June 2, 2000				
LA Canyon below TA-2			310	11.75
DP Canyon at Mouth			403	15
LA Canyon near Los Alamos			930	35
June 3, 2000				
LA Canyon at Los Alamos	18.3	0.85	44.8	1.625
LA Canyon near Los Alamos	19.1	0.85	177	6.5
1995–1999 Max	40		1637	
1995–1999 Average	11.195		229.03	
DOE DCG for Public Dose	1000			
DOE DCG for Drinking Water	40			
EPA Primary Drinking Water Std.				
EPA Screening Level	50			

Two columns are listed: the first is the analytical result; the second is the laboratory measurement uncertainty (1 std dev)

assume part of the radionuclide stays in the body and continues to provide a dose for up to 50 years following ingestion.

The maximum dose was found to be 0.094 mrem per liter of unfiltered water for the June 2 and 3 event (Table 3). By comparison, the dose associated with pre-fire maximums (1995–1999) was larger at 1.3 mrem per liter. This is important in that it shows conditions in LA Canyon just after the fire did not cause greater potential doses than had been seen in the past. For overall comparison of doses, the DOE has established a public dose limit of 100 mrem per year for radionuclide releases from its facilities for all pathways. Typical background radiation in the Los Alamos area is about 350 mrem per year, greater than 99% of which is from natural sources.

In calculating these doses (Table 2), no attempt was made to distinguish between LANL sources, natural sources, or atmospheric fallout sources. Part of these doses likely come from natural and fallout sources. However, plutonium contributed the greatest percentage of dose (41 percent), and the results shown in Table 3 suggest little plutonium arriving on LANL from upstream sources and most plutonium contribution occurring on LANL. The maximum dose associated with plutonium alone for the June 2 and 3 event was 0.048 mrem per liter, while the maximum pre-fire dose was higher at 0.056 mrem per liter.

The doses shown in Table 3 are derived from the 11 radionuclides listed above. Data for other radionuclides associated with LANL operations, such as americium-241, were not measured but are likely to be present and contribute an additional small incremental dose. Average uncertainty associated with the unfiltered doses was 0.0008 mrem per liter. Average uncertainty for the filtered doses was 0.00012 mrem per liter.

Metals

Analysis of runoff waters was performed for 25 trace metals (Table 4) and compared to historical levels and EPA and New Mexico standards.

Comparison with historical levels. Trace metal concentrations in runoff were compared to the 1995–1999 average and maximum concentrations for storm water runoff in LA Canyon and the general soil background level.

Trace metals in runoff that exceeded their historic (1995–1999) maximums included the following: copper (unfiltered), lead (unfiltered), manganese (unfiltered), selenium (unfiltered), strontium (unfiltered and filtered), uranium (unfiltered and filtered), and zinc (unfiltered).

Table 3. Dose per Liter from Unfiltered and Filtered Storm Water in LA Canyon (June 2 and 3, 2000) from 11 Radionuclides Associated with LANL Operations and with Fallout from Atmospheric Weapons Testing

	Dose per liter of storm water (mrem per liter)	
	Unfiltered Samples	Filtered Samples
LA Canyon at Los Alamos (upstream LANL boundary)	0.004	<0.001
LA Canyon below TA-2 (on LANL)	0.067	No data
LA Canyon near Los Alamos (downstream LANL boundary)	0.094	0.001
Maximum Pre-Fire Dose (1995–1999)	1.30	0.08

Dose conversion factors from "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion." EPA-520/1-88-020, EPA 1988.

With the exceptions of antimony and molybdenum, metals concentrations in filtered samples are lower than concentrations in unfiltered samples. This relationship indicates that the metals are generally associated with the particulate and sediment carried by the runoff rather than dissolved in the water.

Other studies provide some insight into increased metal concentrations following fire. Total manganese, for example, found in plants before fire is easily reducible by fire processes leading to subsequent increased concentrations in soil and water (Chambers and Attiwill 1994, Parra et al. 1996, Auclair 1977). Similar conclusions were reached in studies on copper and zinc (Auclair 1977).

Comparison with standards. For metals, standards and benchmarks include the following: EPA Primary Drinking Water Standard; EPA Secondary Drinking Water Standard; NMWQCC Livestock Watering Standard; NMWQCC Wildlife Habitat Standard. Standards have not been established for all of the metals measured and shown in Table 4. Drinking Water Standards apply to treated public drinking water systems, not sediment-laden storm water runoff, and are included here only to provide some context for interpreting the data in Table 4.

In comparing to drinking water standards, concentrations of metals in runoff were greater than the EPA Primary or Secondary Drinking Water Standards for aluminum (unfiltered), beryllium (unfiltered), iron (unfiltered), and manganese (unfiltered and filtered).

In addition to drinking water standards that apply to water systems used by humans, other standards exist for livestock and wildlife. The NMWQCC Livestock Watering Standard and the

NMWQCC Wildlife Habitat Standard for metals apply primarily to the dissolved fraction of metals that are measured in filtered samples. Livestock watering standards exist for aluminum, arsenic, boron, cadmium, chromium, cobalt, copper, lead, mercury (total), selenium, vanadium, and zinc. Wildlife habitat standards exist for total mercury and total recoverable selenium. Of these, no exceedences were measured in the LA Canyon runoff during the June 3 event (Table 4).

General Chemistry (common minerals and nutrients)

The June 2 and 3 storm water runoff events were analyzed for eight general chemistry parameters that are commonly tested for in surface waters. Studies at other locations show increases in many minerals and nutrients following fire (DeBano et al. 1979, Helvey et al. 1985, Tiedemann et al. 1978, Belillas and Ferran 1993). This increase was generally due to release of these constituents by fire, changes in chemical states and complexation, and changes in the post-fire environment such as increased pH.

Similar to the pattern for metals, the concentrations of the general chemistry parameters are almost always greater in the unfiltered samples. Like the metals, this pattern indicates that the general chemistry parameters are mainly attached to the runoff particulate and sediment rather than dissolved in the water. Of the parameters measured (Table 5), calcium (Ca), potassium (K), total phosphorous (PO_4-P), magnesium (Mg), and cyanide (CN) show anomalous levels in comparison to historic maximum concentrations. For all five of these parameters, the levels that were elevated above historic maximum concentrations (both unfiltered and filtered) occurred on June 3.

Table 4. Trace Metals in Runoff Samples for June 2 and 3, 2000 (µg/L)

	Aluminum		Antimony		Arsenic		Barium		Beryllium		Boron	
	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF
June 2, 2000												
LA Canyon below TA-2		4300		0.428		6.6		530		5.94		31
DP Canyon at Mouth		5400		0.932		5.3		510		7.16		28
LA Canyon near Los Alamos		8800		1.03		6.4		890		11.9		40
June 3, 2000												
LA Canyon at Los Alamos	89	2900	0.822	1.03	3.4	7.1	120	370	<0.34	0.992	67	74
LA Canyon near Los Alamos	59	8700	0.878	0.85	<3	8.1	110	830	<0.34	3.17	66	81
1995–1999 Max	37529	46753	2	5	7	15	355	1194	3	13	369	171
1995–1999 Average	6086.6	18888.1	1.7	2.1	2.1	5.6	107.7	329.5	1.2	3.2	74.2	42.3
EPA Primary Drinking Water Standard			6		50		2000		4			
EPA Secondary Drinking Water Standard	50-200											
NMWQCC Livestock Watering Standard	5000				200						5000	
NMWQCC Wildlife Habitat Standard												

	Cadmium		Chromium		Cobalt		Copper		Iron		Lead	
	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF
June 2, 2000												
LA Canyon below TA-2		2.3		6.8		17		64		5200		211
DP Canyon at Mouth		2.39		6.3		17		58		3600		215
LA Canyon near Los Alamos		4.48		11		30		95		5900		361
June 3, 2000												
LA Canyon at Los Alamos	0.121	0.652	<0.38	1.4	3.9	6.1	2.5	6.8	87	2000	0.131	26.8
LA Canyon near Los Alamos	0.137	2.13	<0.38	4.6	1.1	15	2	13	76	4700	0.077	103
1995–1999 Max	3.5	4.5	25	45	10	38	28	93	19329	30136	115	260
1995–1999 Average	2.4	2.7	7.7	16.1	5	11.0	10.4	23.9	3194	12553.3	38.6	97.8
EPA Primary Drinking Water Standard	5		100									
EPA Secondary Drinking Water Standard							1000		300			
NMWQCC Livestock Watering Standard	50		1000		1000		500				100	
NMWQCC Wildlife Habitat Standard												

Table 4. Trace Metals in Runoff Samples for June 2 and 3, 2000 (µg/L) (Cont.)

	Manganese		Mercury		Molybdenum		Nickel		Selenium			
	F	UF	F	UF	F	UF	F	UF	F	UF		
June 2, 2000												
LA Canyon below TA-2		2500		<0.01		<4.8		19		<3.5		
DP Canyon at Mouth		1900		<0.01		<4.8		18		<3.5		
LA Canyon near Los Alamos		4100		<0.01		<4.8		33		<3.5		
June 3, 2000												
LA Canyon at Los Alamos	340	1500	<0.01	<0.01	<4.8	<4.8	2.9	6.8	<3.5	<3.5		
LA Canyon near Los Alamos	390	4800	<0.01	<0.01	6.7	<4.8	3	18	<3.5	4.3		
1995–1999 Max	1370	3837	0.1	1	15	65	10.5	38	2	4		
1995–1999 Average	258.4	1079	0.1	0.235	11.1	18.6	10.1	18.8	1.25	1.6		
EPA Primary Drinking Water Standard			2				100		50			
EPA Secondary Drinking Water Standard	50											
NMWQCC Livestock Watering Standard			10						50			
NMWQCC Wildlife Habitat Standard				0.77						5.0		
	Silver		Strontium		Thallium		Tin		Titanium		Uranium	
	F	UF	F	UF	F	UF	F	UF	F	UF	F	UF
June 2, 2000												
LA Canyon below TA-2		<0.87		190		0.675		<16		51.8		6.94
DP Canyon at Mouth		<0.87		150		0.476		<16		247		4.82
LA Canyon near Los Alamos		<0.87		300		1.11		<16		376		10.2
June 3, 2000												
LA Canyon at Los Alamos	<0.87	<0.87	230	310	<0.014	0.223	<16	<16	2.77	171	3.5	4.48
LA Canyon near Los Alamos	<0.87	<0.87	240	480	<0.014	0.542	<16	<16	2.85	228	3.44	6.35
1995–1999 Max	14	72	114	345	1.5	1.5	36.5	30			2.82	8.2
1995–1999 Average	6.0	10.0	72.2	121.6	1.5	1.4	24.5	24.2			0.4	3.1
EPA Primary Drinking Water Standard					2	~~2~~					20	
EPA Secondary Drinking Water Standard	100											
NMWQCC Livestock Watering Standard												
NMWQCC Wildlife Habitat Standard												

Table 4. Trace Metals in Runoff Samples for June 2 and 3, 2000 (µg/L) (Cont.)

	Vanadium		Zinc	
	F	UF	F	UF
June 2, 2000				
LA Canyon below TA-2		33		430
DP Canyon at Mouth		33		620
LA Canyon near Los Alamos		55		850
June 3, 2000				
LA Canyon at Los Alamos	3.3	8.7	2.9	54
LA Canyon near Los Alamos	3	21	4.6	210
1995–1999 Max	45	76	299	600
1995–1999 Average	11.1	18.8	71.6	245.4
EPA Primary Drinking Water Standard				
EPA Secondary Drinking Water Standard			5000	
NMWQCC Livestock Watering Standard	100		25000	
NMWQCC Wildlife Habitat Standard				

Table 5. Chemical Quality of Runoff Samples for June 2 and 3, 2000 (mg/L) except where noted

	Type	Flow (cfs)	PO_4-P (Total Phosphorus) Filtered	PO_4-P (Total Phosphorus) Unfiltered	NO_3-N (Nitrate-Nitrogen) Filtered	NO_3-N (Nitrate-Nitrogen) Unfiltered	Total CN (Cyanide) Filtered	Total CN (Cyanide) Unfiltered	TSS (Total Suspended Solids) Filtered	TSS (Total Suspended Solids) Unfiltered
June 2, 2000										
LA Canyon below TA-2	A	13 (gage)		0.24		0.093		<0.01		4500
DP Canyon at Mouth	A	20E		0.81		0.29		<0.01		3300
LA Canyon near Los Alamos	A	18 (gage)		0.82		0.34		<0.01		8800
June 3, 2000										
LA Canyon at Los Alamos	M	8.6 (gage)		1.8		0.068		0.018		240
LA Canyon near Los Alamos	M	~2 (gage)		3.7		<0.05		0.028		2300
1995–1999 Max			0.18	0.81	0.24	0.6	<0.01	0.01	244	25575
1995–1999 Average			0.105	0.285	0.15	0.395	<0.01	0.0067	123.5	5127.9
EPA Primary Drinking Water					10		0.2			
EPA Secondary Drinking Water										
EPA Health Advisory										
NMWQCC Groundwater Limit					10		0.2			

	Ca (Calcium) Filtered	Ca (Calcium) Unfiltered	Mg (Magnesium) Filtered	Mg (Magnesium) Unfiltered	K (Potassium) Filtered	K (Potassium) Unfiltered	Na (Sodium) Filtered	Na (Sodium) Unfiltered
June 2, 2000								
LA Canyon below TA-2		34		5.9		7.6		14.0
DP Canyon at Mouth		35		3.0		6.4		6.7
LA Canyon near Los Alamos		61		7.7		11.0		11.0
June 3, 2000								
LA Canyon at Los Alamos	42	59	6.2	7.1	12.0	13.0	6.7	6.8
LA Canyon near Los Alamos	45	96	6.8	9.5	12.0	15.0	12.0	12.0
1995–1999 Max	21.2	77.237	5.8	14.147	8.6	12.189	21.8	21.8
1995–1999 Average	15.03	22.28	2.9	5.51	4.18	7.18	10.7	13.4
EPA Primary Drinking Water								
EPA Secondary Drinking Water								
EPA Health Advisory							20	
NMWQCC Groundwater Limit								

Comparison with standards. For general chemistry, limited standards and benchmarks include the following: EPA Primary Drinking Water Standard, EPA Secondary Drinking Water Standard, EPA Health Advisory Level, and NMWQCC Groundwater Limit. Concentrations of the general chemistry parameters from the June 2 and 3 storm water events did not exceed any of these standards.

Cyanide. Potentially significant levels of cyanide have been detected in water and sediment samples taken from several canyons that drain burned areas. Cyanide in its free, unbound form is toxic to aquatic biota and wildlife. However, most of the cyanide appears in a far less toxic form bound with other elements. Table 5 shows total cyanide levels up to 28 micrograms per liter. Although this is higher than the NMWQCC Wildlife Habitat standard for free cyanide of 5.2 micrograms per liter, most of the cyanide (~90% to 95%) was found to be in a bound form, not as free cyanide, so the sampling indicates the cyanide standard was met. The highest concentrations of total cyanide have been found in ash-laden runoff waters both above and within the Laboratory. Possible sources of the cyanide may have been fire retardant used in the Cerro Grande Fire that contains a sodium ferrocyanide compound added as an anti-caking additive and as a corrosion inhibitor. Another possibility is that some cyanide may have been produced naturally through slow burning or smoldering of biomass and thus transported in the runoff along with ash.

Organics

Runoff was tested for a range of organic constituents of PCBs and SVOAs. Table 6 shows the locations of samples and the number of tests performed on each sample. Table 7 shows the results for those organics detected. PCBs were not found above detection limits. Testing positive were bis(2-ethylhexyl)phthalate, benzoic acid, methylphenol(4-), phenol, and pyridine. The benzoic acid, phenols, and pyridine are thought to be end products of combustion of forest fuels by wildfire. The bis(2-ethylhexyl)phthalate is commonly recognized as introduced in laboratory analysis. This report focused on radionuclides. Additional analysis of organics in runoff is expected in future reports.

Table 6. Number of Tests for Each Suite of Organic Compounds in Surface Water and Runoff Samples in June 2000

Station Name	Date	Organic Suite	
		PCB	SVOA
LA Canyon below TA-2	6/2/00	1	1
DP Canyon at Mouth	6/2/00	1	1
LA Canyon near Los Alamos	6/2/00	1	1
LA Canyon near Los Alamos	6/3/00	1	1
LA Canyon at Los Alamos	6/3/00	1	1

Table 7. Organics Found in Storm Water in June 2000 at Stations in LA Canyon

Station Name	Date	UF/F	Analyte	Value (µg/L)	Lab Qual.	Analyte Suite
LA Canyon below TA-2	6/2/00	UF	bis(2-ethylhexyl)phthalate	2	J	SVOA
DP Canyon at Mouth	6/2/00	UF	bis(2-ethylhexyl)phthalate	1.1	J	SVOA
LA Canyon near LA	6/3/00	UF	Benzoic acid	250	-	SVOA
LA Canyon at LA	6/3/00	UF	Benzoic acid	690	-	SVOA
LA Canyon near LA	6/3/00	UF	Methylphenol(4-)	11	J	SVOA
LA Canyon at LA	6/3/00	UF	Methylphenol(4-)	15	J	SVOA
LA Canyon near LA	6/3/00	UF	Phenol	19	J	SVOA
LA Canyon at LA	6/3/00	UF	Phenol	50	J	SVOA
LA Canyon near LA	6/3/00	UF	Pyridine	37	J	SVOA
LA Canyon at LA	6/3/00	UF	Pyridine	49	J	SVOA

UF-unfiltered; F-filtered; SVOA-semivolatile organics; J qualifier means the measured quantity is below the lab reporting limit, and the confidence in that result is limited.

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