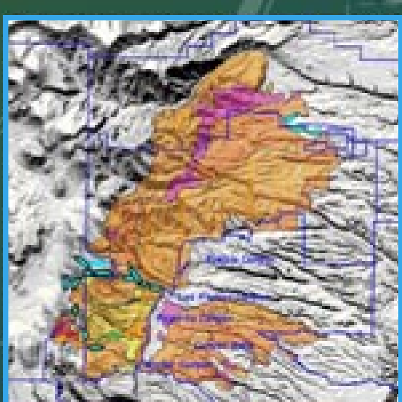
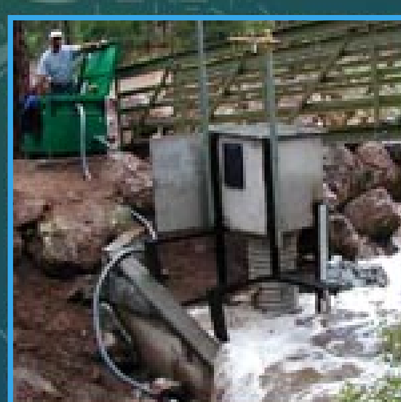
Water Quality and Stream Flow After the Cerro Grande Fire

A Summary





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LALP-05-009

Coordination among agencies and organizations is an integral part of responding to a major catastrophe like the Cerro Grande fire. We thank the following agencies and organizations that provided environmental data for this assessment or allowed access to their lands for sampling.

- County of Los Alamos
- National Park Service
- New Mexico Environment Department
- Pueblo de Cochiti
- Pueblo of San Ildefonso
- Pueblo of Santa Clara
- U.S. Army Corps of Engineers
- U.S. Department of Energy
- U.S. Department of Interior
- U.S. Environmental Protection Agency
- U.S. Department of Agriculture Forest Service
- U.S. Geological Survey
- U.S. National Weather Service

Front cover: Photographs by Los Alamos National Laboratory. Top: High-burn severity fire. Bottom Left: Shaded relief map showing boundaries of the Cerro Grande fire, proximity of the fire to the Jemez Mountains and Valle Grande, major canyons, and locations where retardant was dropped. The relief map was prepared by the U.S.D.A. Forest Service, and Los Alamos National Laboratory added the retardant drop locations. Middle: Typical stream gage and automated water quality sampling station on the Los Alamos National Laboratory. Right: Los Alamos National Laboratory technician collecting Cochiti Reservoir bottom sediments for analysis using a spring-loaded clamshell sampler and winch assembly.

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Water Quality and Stream Flow After the Cerro Grande Fire

A Summary

by

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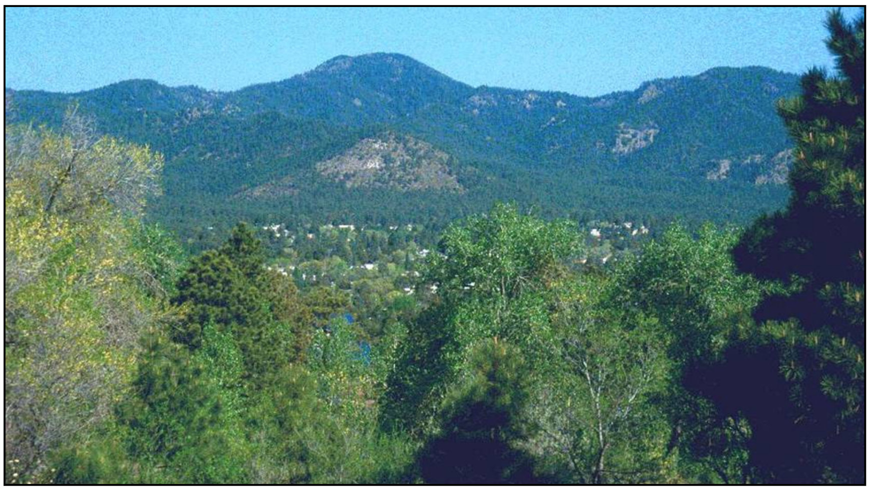
Contents

This report summarizes the results of testing and analysis performed on waters and sediments in stream channels that drain the areas burned by the Cerro Grande fire of 2000. The contaminant, hydrological, and meteorological monitoring conducted after the fire involved many entities. We have been provided with much of their results and include them in the analysis to broaden our understanding of the Cerro Grande fire impacts on the landscape. Numerous reports and public presentations have been made since the fire to share this information as readily as possible. This summary highlights the monitoring results and health risk assessments. More detailed and technical reports are available for interested readers (see the bibliography at the back). Much of the information in this summary report is included in a Laboratory technical report "Cerro Grande Fire Impacts to Water Quality and Stream Flow near Los Alamos National Laboratory: Results of Four Years of Monitoring," (Gallaher and Koch 2004). For more information, please contact the Laboratory's Water Quality and Hydrology Group at 505-665-0453.

The Cerro Grande Fire

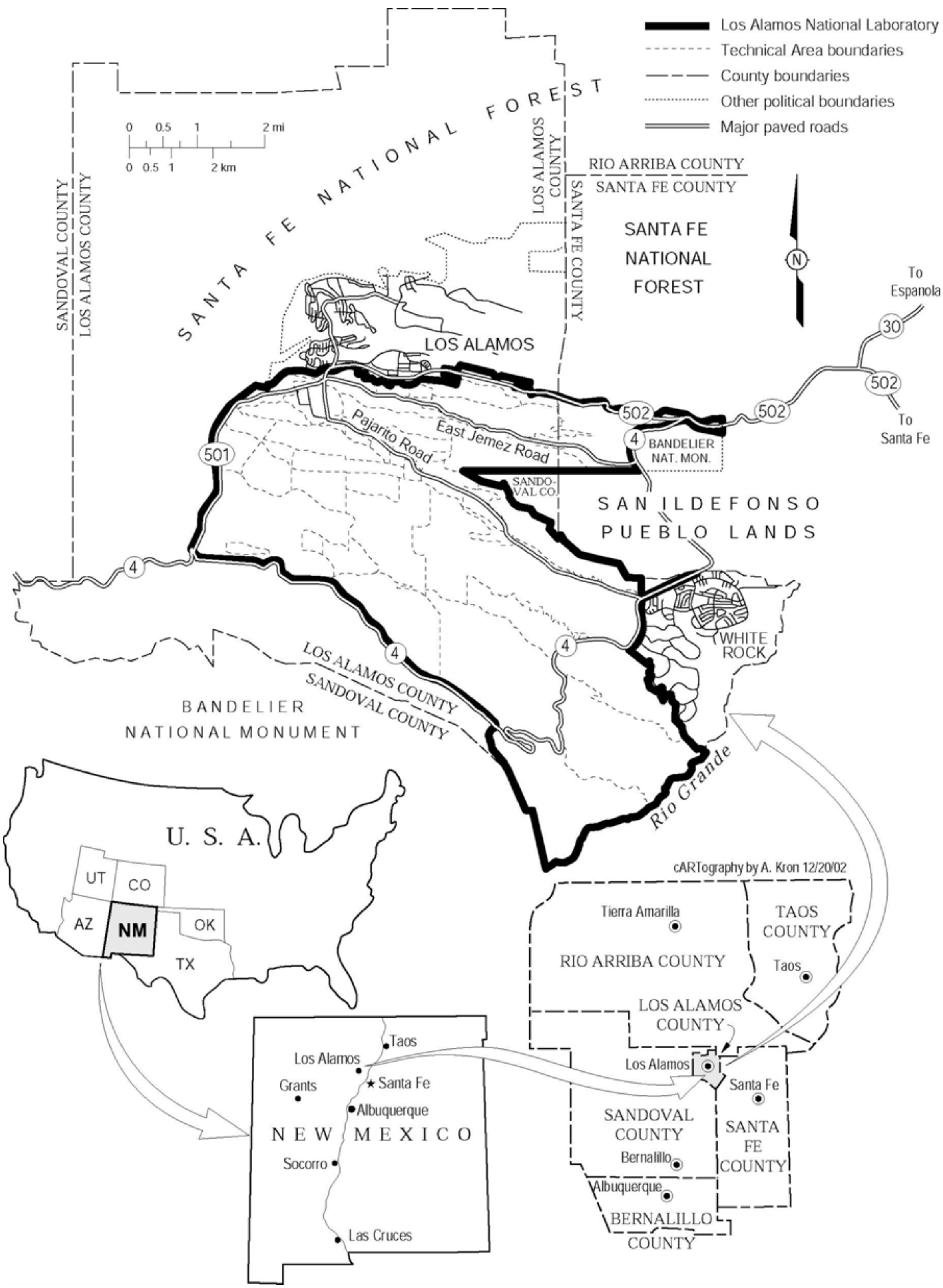
On May 4, 2000, a prescribed burn grew out of control and was declared a wildfire on the following day. Fanned by sustained winds of over 40 miles per hour, the fire spread along the flanks of the Jemez Mountains. By June 6, when the Cerro Grande fire was finally declared contained, nearly 43,000 acres of mixed conifer, ponderosa pine, piñon, and juniper forest were burned near Los Alamos, NM. In Los Alamos, 200 structures burned.

The fire burned about 7400 acres of forest on the Los Alamos National Laboratory (LANL), and much of the 10,000 acres of mountainside draining onto LANL was severely burned. The fire burned hot enough to melt aluminum and glass. The resulting burned landscapes raised concerns of increased storm runoff and transport of contaminants by runoff in the canyons traversing LANL.

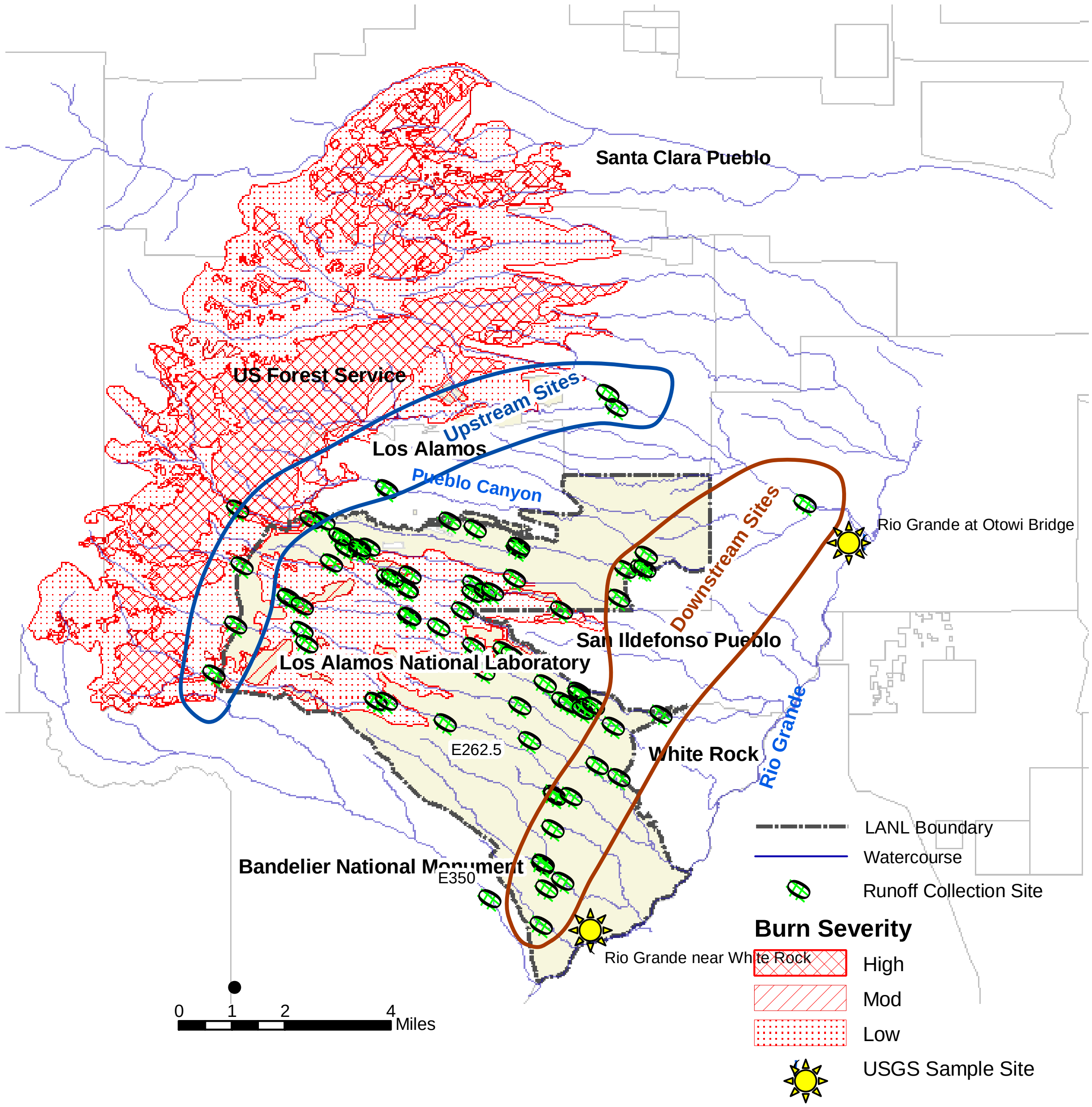


Before the fire, hillsides above Los Alamos were thick with vegetation and forest duff. Runoff was usually limited only to heavy snow years.

After the fire, the steepest slopes above Los Alamos easily shed rainfall and were more readily eroded initially. Flash flooding occurred often from relatively small summer rains.



Location of Los Alamos National Laboratory.



Location and burn severity of the Cerro Grande fire, May 2000, and storm runoff monitoring network.

The Burned Area Emergency Rehabilitation (BAER) team developed the burn severity map. The BAER team consisted of a multiagency group of federal experts that included members assembled to initiate emergency flood mitigation efforts within and below the burned areas**.**

The storm runoff monitoring network includes stations located along LANL's upstream boundary. These stations are immediately below the burned hill slopes of the Jemez Mountains and allow researchers to focus on the effects of fire on water quality and stream flow. The network also allows comparison of conditions above the Laboratory with those below.

Summary of Major Issues and Findings

Issue*: One of the most pronounced environmental effects from forest fires is increased runoff from precipitation events. The danger of flash flooding affecting LANL and Los Alamos during the summer rainy season increased substantially after the Cerro Grande fire.*

The Laboratory did not sustain serious flood damage during the first four rainy seasons following the fire; however, heavy rainfall events in the Los Alamos community during the summer of 2001 caused heavy flood damage in Pueblo Canyon, damaging part of a road and jeopardizing a utility corridor passing through the canyon floor.

- Peak runoff in many of the channels draining burned areas increased by 10 to 1000 times more than was measured in the five years before the fire.

- The maximum runoff yield before the fire from Cañon de Valle and Pajarito and Water Canyons along the flanks of the Jemez Mountains was 1.26 cubic feet per second per square mile (cfs/mi^2). During the first major storm after the fire, runoff yield for these same locations ranged from 250 to 540 cfs/mi^2, increasing more than 200 times from prefire peaks. However, large runoff rarely lasted more than a few hours.

- Peak runoff events in 2002 and 2003 were smaller than in the previous two years, indicating some recovery in the burned areas.

Issue: *Aside from contributing ash and sediment to storm runoff, how did the Cerro Grande fire affect the quality of water in stream channels draining burned areas?*

The water quality of stream channels draining the burned areas was temporarily degraded by elevated concentrations of radioactivity (primarily fallout-derived cesium-137, plutonium-239,240, and strontium-90), metals, minerals, cyanide, and nutrients; however, data indicate that most concentrations fell to near prefire levels within two to three years following the fire. Natural conditions appear to be associated with most of the elevated concentrations and many of these same changes have been recorded at other fires around the world.

- The initial postfire runoff events carried significant quantities of debris and sediment; water sample containers contained 25 percent or more of the volume as sediment. Much of the water quality recovery appears to be related to stripping the ash and burned surface soils from the landscape.

- Concentrations of 28 or more inorganic constituents were slightly to moderately elevated (by 2 to 10 times) due to fire effects in ash and storm runoff. Amongst these, the most elevated were three fallout radionuclides (cesium-137, plutonium-239,240, strontium-90) and 10 other inorganic constituents and elements (barium, bicarbonate, calcium, cyanide, magnesium, manganese, nitrogen, phosphorous, potassium, and elemental strontium).

- For decades, radioactivity from worldwide fallout had accumulated in the forest grasses, brush, and trees and generally remained in place until the fire. The first runoff events after the fire carried the fallout products downstream onto LANL as particles, rather than dissolved in the water. Metals, minerals, and nutrients from plants and burned soils were similarly moved downstream.

- Dissolved concentrations of 12 minerals, nutrients, and metals showed slight to moderate increases for two to three runoff seasons, consistent with other fires studied around the world. Dissolved concentrations were near prefire levels in the fourth runoff season.

- Suspended sediment concentrations downstream of the burned areas remained elevated through the fourth year by hundreds to several thousand times prefire levels. This indicates that the stream channels remain choked with excess sediment eroded from the burned hill slopes.

- In the first rainy season after the fire, some storm runoff samples collected below burned areas contained detectable semivolatile organic compounds, including benzoic acid, benzyl alcohol, 4-Methylphenol, phenol, and pyridine. Because these samples were collected above known human influences, it is likely that the semivolatile organic compounds were naturally created or mobilized by fire effects.

Issue: *Did the fire worsen the water quality downstream of the Los Alamos National Laboratory?*

The water quality in streams downstream of LANL deteriorated temporarily due to the abundance of ash and burned soils, combined with the rapid erosion and downstream movement of LANL-contaminated stream sediments (primarily from Pueblo Canyon). Fire-associated constituents, with the concentrations of many metals, minerals, and fallout radionuclides exceeding prefire maximums, dominated the water quality in the first rainy season after the fire. By the end of the first rainy season, most ash and burned soils had been stripped from the landscape, and the water quality in later years instead reflected erosion and downstream transport of historically LANL-contaminated sediments. In years two through four, movement of plutonium-239,240 beyond the Laboratory's downstream boundary is estimated to have increased by as much as 50 to 80 times over that seen in the late 1990s.

- The principal water quality impact was increased movement of sediment downstream by storm runoff events. Dissolved metals and radionuclide concentrations showed temporary increases but were usually within regulatory limits or guidelines.

- Heightened concentrations of radioactivity were found in some individual runoff samples, but annual average concentrations were well within federal and state guidelines for protection of the public health.

- Compared with amounts measured in the five years before the fire, the yearly average amount of radioactivity carried by storm runoff flows beyond the LANL downstream boundary in the two to three years following the fire increased about 20 times for cesium-137, about 55 times for plutonium-239,240, and 25 times for total uranium. The cesium-137, strontium-90, and uranium increases were predominantly due to fire effects, while the plutonium-239,240 increases were due mostly to erosion of LANL-contaminated sediments. Annually, the estimated postfire transport of plutonium-239,240 downstream ranged from 2 millicuries (mCi) in the first year after the fire to 28 mCi in year two, and a total of about 64 mCi of plutonium-239,240 was transported downstream in storm runoff through the four-year period from 2000 through 2003; this represents approximately six percent of the entire plutonium-239,240 inventory stored in Pueblo Canyon sediments before the fire.

- Total metals flow-weighted average annual concentrations measured in storm runoff flows at the LANL downstream boundary increased moderately, by four to eight times, for more than half of the metals tested. Aluminum, a natural component of soils, was the only metal consistently found in concentrations greater than current stream standards for protection of livestock watering and wildlife habitat.

Issue: *The Rio Grande is the master stream in northern New Mexico with a variety of uses; its quality after the fire is a major concern.*

Dissolved concentrations of radionuclides and metals in Rio Grande water samples collected after the fire were within U.S. Environmental Protection Agency (EPA) or U.S. Department of Energy drinking-water standards or guidelines, indicating no lasting impacts to the water column. Moderate increases in bed sediment concentrations of cesium-137, plutonium-239,240, barium, manganese, strontium, and zinc occurred after the fire; however, none of these concentrations exceeded applicable screening criterion for protection of aquatic life or residential activities.

- Median cesium-137 and plutonium-239,240 concentrations increased in Cochiti Reservoir bed sediments by three to six times above prefire levels. The cesium-137 concentrations peaked in 2001 and appear to be from the trapping of Cerro Grande fire ash in the reservoir. The largest increases in plutonium-239,240 concentrations in Cochiti Reservoir bed sediments began in 2001 after large postfire floods in Pueblo Canyon picked up LANL-contaminated stream sediments and carried them into the Rio Grande and Cochiti Reservoir. The concentrations of cesium-137 and plutonium-239,240 were not large enough to pose significant health threats.

- No high explosives, pesticides, or polychlorinated biphenyls (PCBs) were detected in bed sediments collected from the Rio Grande or Cochiti Reservoir after the fire.

- Several semivolatile polycyclic aromatic hydrocarbons were detected in bed sediments; the constituents, however, were within ranges measured before the fire.

Issue: *With so many radionuclides and chemicals possibly elevated in runoff after the fire, are there any lasting health concerns related to surface water?*

Three separate detailed risk assessments considered the risks to people from coming in contact with fire-related contaminants. Independent authorities, scientists from EPA, the State of New Mexico Health and Environment Departments, and LANL were involved in this effort. They calculated the maximum mixtures of chemicals and radioactivity people might be exposed to through activities like gardening, swimming, eating fish from the Rio Grande, and eating crops irrigated with Rio Grande water. The studies concluded that the risks were within EPA acceptable risk levels and not greatly different from the risks present before the fire.

- To be cautious, one study team recommended that gardeners not use ash as a soil amendment. The team was concerned that manganese might build up to potentially harmful levels in vegetables grown in ash.

- Another team concluded that the type of exposure contributing most to the potential risk was eating fish just downstream of LANL or from Cochiti Lake. Three contaminants of most concern in their worst-case calculation were the radionuclide cesium-137, the organic compound benzo(a)pyrene, and the high explosive compound RDX. Increased risks from eating the fish were small: about two to three in a million. The calculations were very conservative (protective) for predicted concentrations for these contaminants and are one to three orders of magnitude higher than measured in actual samples.

- Each team used some of the highest concentrations measured or predicted for the assessments. More typical or "average" contaminant concentrations found in the environment provide lower risk estimates.

What Kind of Monitoring Was Performed After the Fire?

Among other fires studied, the Cerro Grande fire is unique in terms of the scope of contaminant monitoring. Hundreds of environmental samples of storm runoff and persistent stream flow, shallow (alluvial) groundwater in the canyon floors, and sediment were collected and analyzed for radioactivity and chemicals. The results were compared against an extensive prefire data set. Analyses were performed for radionuclides, metals, and a large suite of organic compounds—PCBs, residual high explosive compounds, volatile and semivolatile organic compounds, dioxins and furans, and pesticides. The geographic area of sampling included streams in the Los Alamos area upstream of major confluences, at upstream and downstream LANL boundaries, and the Rio Grande upstream and downstream of LANL. Locations of the monitoring stations are shown in the fire location map.

Water samples were collected manually and automatically depending on the location. An extensive network of rain and stream flow monitoring stations, like the one in the photograph, alerted scientists when runoff was likely to occur. At remote locations, automatic equipment was used to sample the brief storm runoff events that followed summer thunderstorms. As soon as the gage "sensed" the presence of water in the normally dry stream channels, the water quality samplers were activated and runoff was pumped into clean sample containers.

LANL and the New Mexico Environment Department focused efforts on sampling surface waters, springs, and stream sediments below the burned areas and in the vicinity of LANL. The U.S. Geological Survey focused on sampling surface water and bed sediment of the Rio Grande. Independent analytical laboratories performed all of the chemical analyses. In addition to measuring the radioactivity and chemical concentrations, some tests were performed on storm runoff samples to determine if the water might be toxic to aquatic organisms.

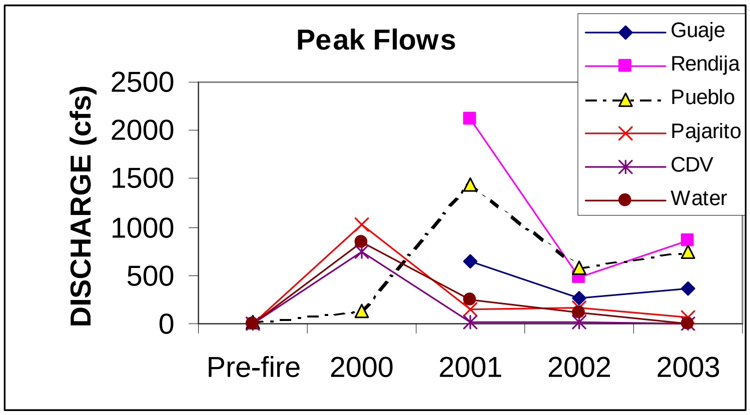
Storm runoff monitoring station on LANL, DP Canyon.

Major Issues and Findings

Stream Flow Increased After the Fire but Watersheds Show Signs of Recovery

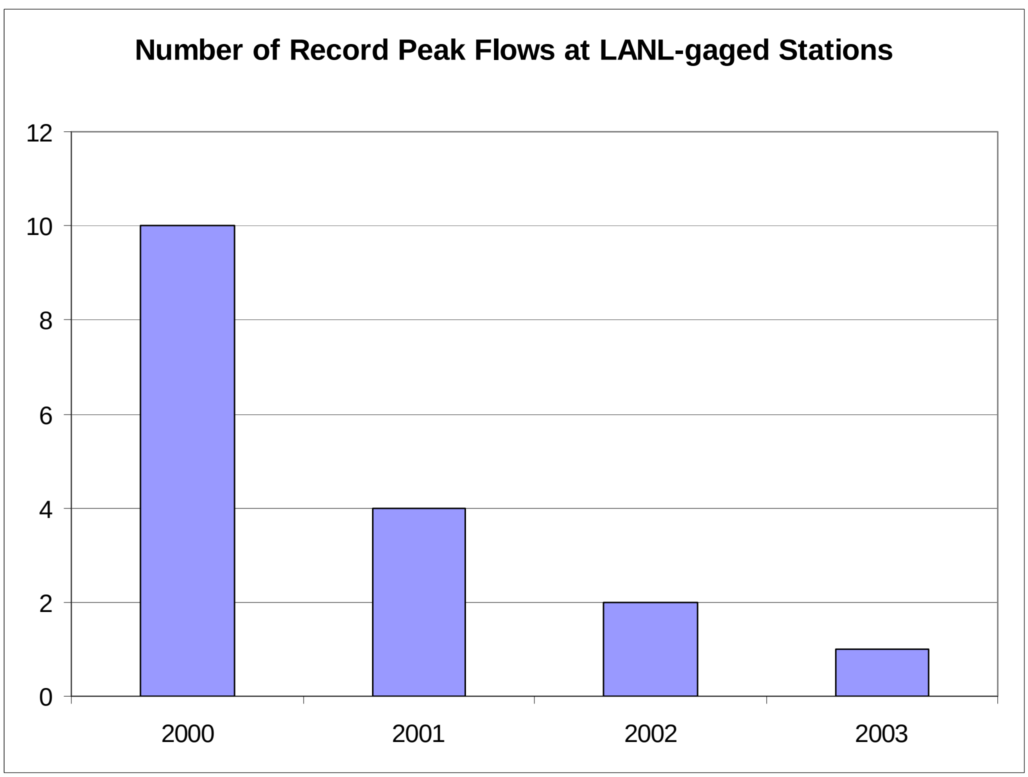
A flash flood in Pueblo Canyon on July 2, 2001, destroyed parts of North Road and exposed a buried natural gas pipeline. (Photographs courtesy of Mark Van Eeckhout, LANL, and Greg Kuyumjian, U.S.D.A. Forest Service.)

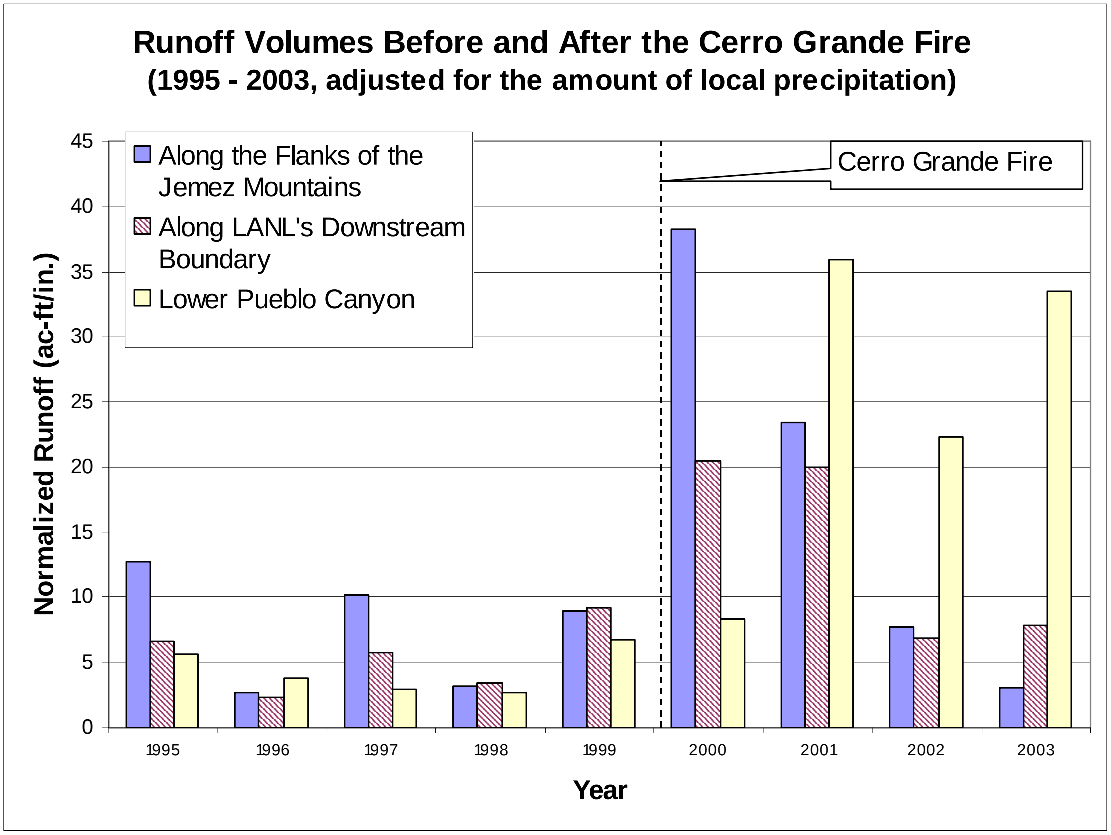
The Cerro Grande fire destroyed vegetation and changed the surface soils of the hill slopes upstream of Los Alamos, allowing greater quantities of storm water to flow through the canyons. Combustion vaporizes hydrophobic organic substances that may move downward and condense at cooler underlying soil layers. This increases the water repellency of the soils, along with the extreme dry state of the burned soils. The combination of steep slopes, high severity burn conditions, and water repellant soils caused record peak runoff flows to develop downstream of the burned areas.



Peak flows and recovery of stream flow were variable in canyons across the Pajarito Plateau. They reflected varying burn severity, rehabilitation efforts, and precipitation intensity.

Note: CDV = Cañon de Valle





Peak discharge during the first and second years following the fire often was 100 to 1000 times greater than the peak discharge measured before the fire. The largest peak runoff events after the fire were seen in the canyons most severely burned. Runoff in subsequent years decreased, probably due to a partial recovery in vegetation in the burned area. The southernmost canyons (Pajarito, Cañon de Valle, and Water) recorded peak runoff and recovery one year before the northernmost canyons (Pueblo, Guaje, Rendija), due to varying precipitation patterns. The burned hillsides shed 4 to 9 times more volume of runoff than the volume measured in the five years before the fire. The volumes of summer storm runoff carried in stream channels draining the burned areas returned to near prefire levels within three years at most locations.

In severely burned Pueblo Canyon, however, recovery was slower, as runoff volumes in the fourth rainy season after the fire were eight times larger than the prefire average. The upper segments of Pueblo Canyon have also undergone significant urbanization since the fire, and that might also be a factor in the delayed recovery.

Runoff volumes are total flows at gages along the upstream and downstream boundaries of current LANL lands and in lower Pueblo Canyon. To account for variation in yearly rainfall, we “normalized” the stream flow volumes by dividing the runoff volumes by the amount of summer precipitation measured at the Laboratory’s main meteorological tower at Technical Area 6.

The Fire Led to Increased Movement and Concentrations of Metals and Radioactivity

Regardless of where we live, streams and storm runoff usually carry measurable amounts of radioactivity and metals. This is simply because the waters carry along soils and sediments, which contain naturally occurring radioactive elements such as uranium, radionuclides deposited on the ground from worldwide atmospheric fallout (for example, strontium-90), and natural metals like iron. We refer to these baseline levels as "background" concentrations. The Cerro Grande fire temporarily altered "background" concentrations in surface waters and stream sediments downstream of the burned areas.

What are the Mechanisms?

Before the Fire

- Radionuclides from worldwide atmospheric fallout accumulate for decades in forests.
- Natural minerals, metals, and nutrients (for example, manganese, nitrogen) were drawn from the soils into the plant material of trees and grasses.
- Minerals from rotting vegetation return to the soil as fast as weather allows, making future plant growth possible. Fire can speed this decay process.

During the Fire

- High temperatures and oxidizing conditions alter surface soil chemistry and dry the soil.
- Combustion vaporizes hydrophobic organic substances, which may move downward and condense at cooler underlying soil layers. This increases the water repellency of the soils.

Fire reduces vegetation to ash; runoff increases**.**

- Record peak stream flows from generally "normal" precipitation events.
- Ash contains higher concentrations of metals, radionuclides, and some organic chemicals than previously measured in stream sediments.

Storm runoff moves sediment.

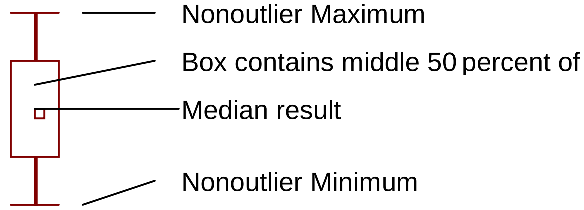
- 100 to 1000 times greater sediment loads in storm runoff postfire.
- Higher stream flows erode flood plain sediments from canyon floors.
- Increased erosion of LANL contaminants in Pueblo Canyon.

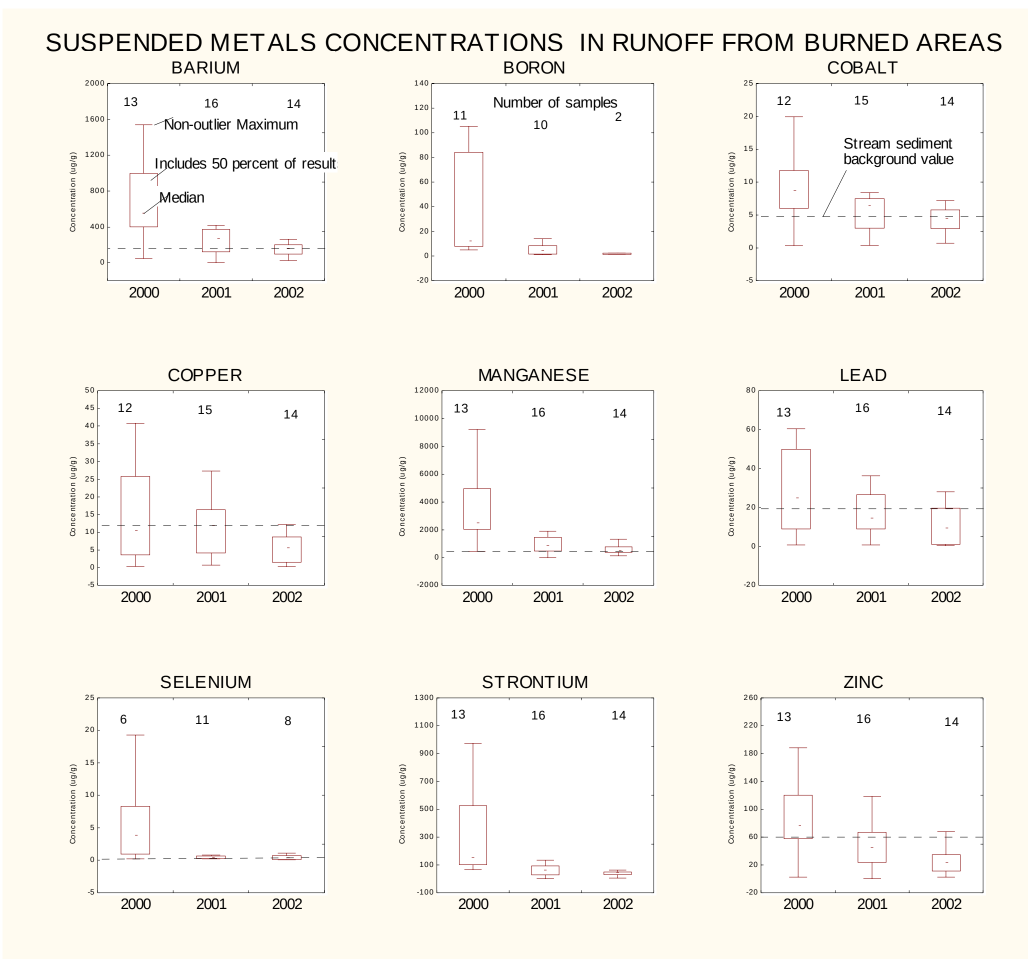
Contaminant Concentrations in Streams Draining Burned Areas Took Two to Three Years to Recover

In the first rainy season after the fire, water quality across the Los Alamos area was dominated by fire-created contaminants. The concentrations of manganese, calcium, cesium-137, and strontium-90, in particular, were heightened during the first runoff season.

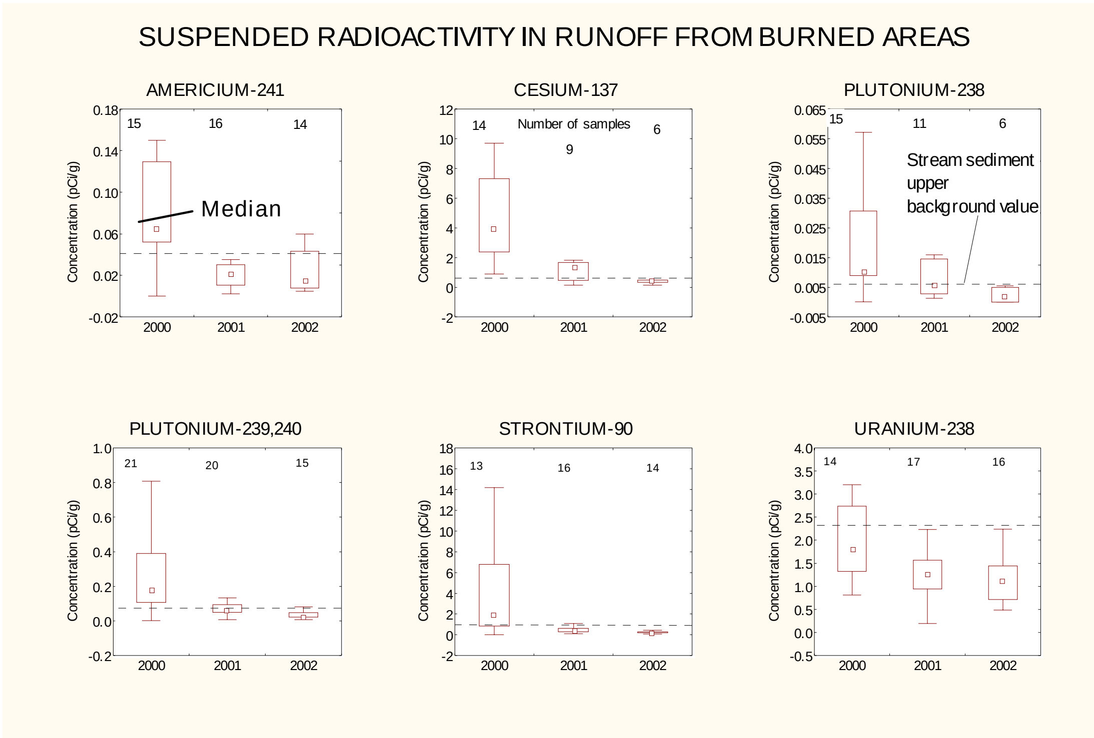
By the end of the third rainy season after the fire, concentrations of metals in suspended sediment carried by runoff from burned areas typically fell to near prefire background levels. The box plots below show the yearly trends in concentrations at all of the sampling stations located upstream of the Laboratory through 2002. The decreases in concentrations appear to be related to a flushing of ash and burned soils from the landscape by runoff events.

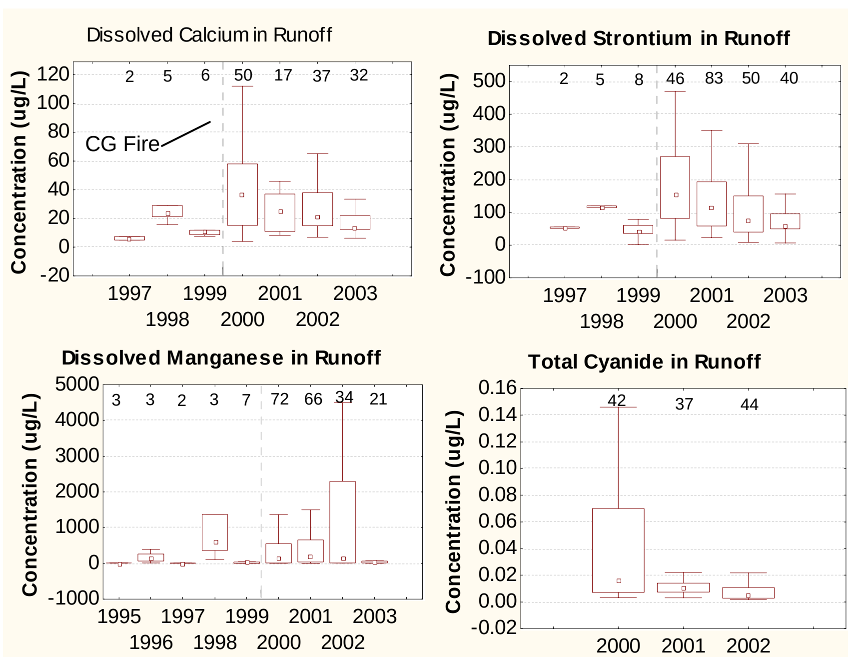
EXPLANATION
OF BOX PLOTS





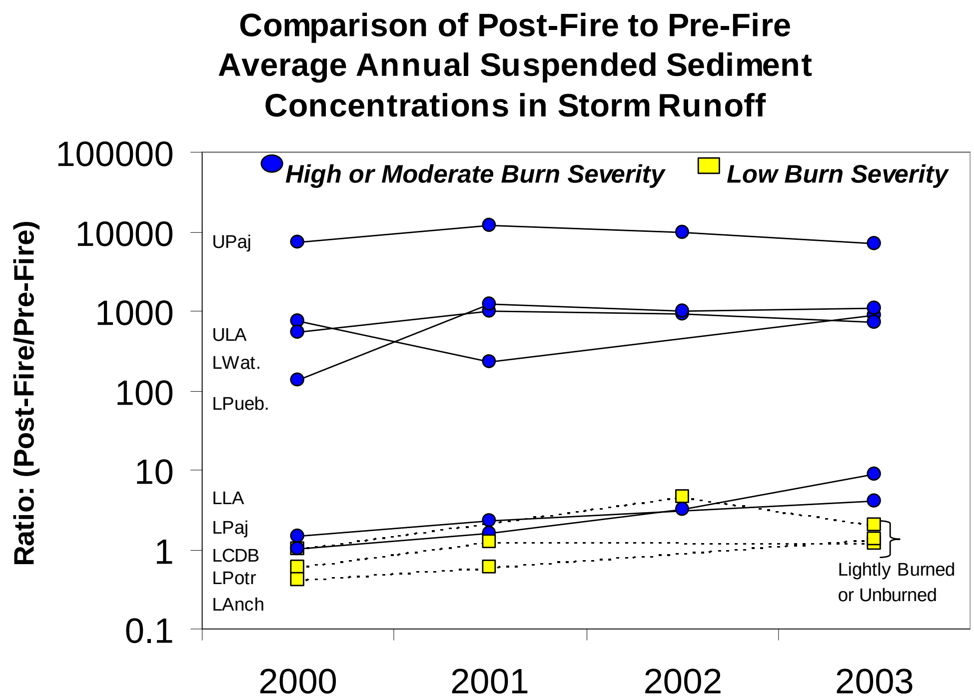
Concentrations of radionuclides in the suspended sediment below burned areas generally recovered to prefire background levels within two years after the fire. It took as long as three years for some dissolved chemical concentrations and cyanide to recover to prefire levels.





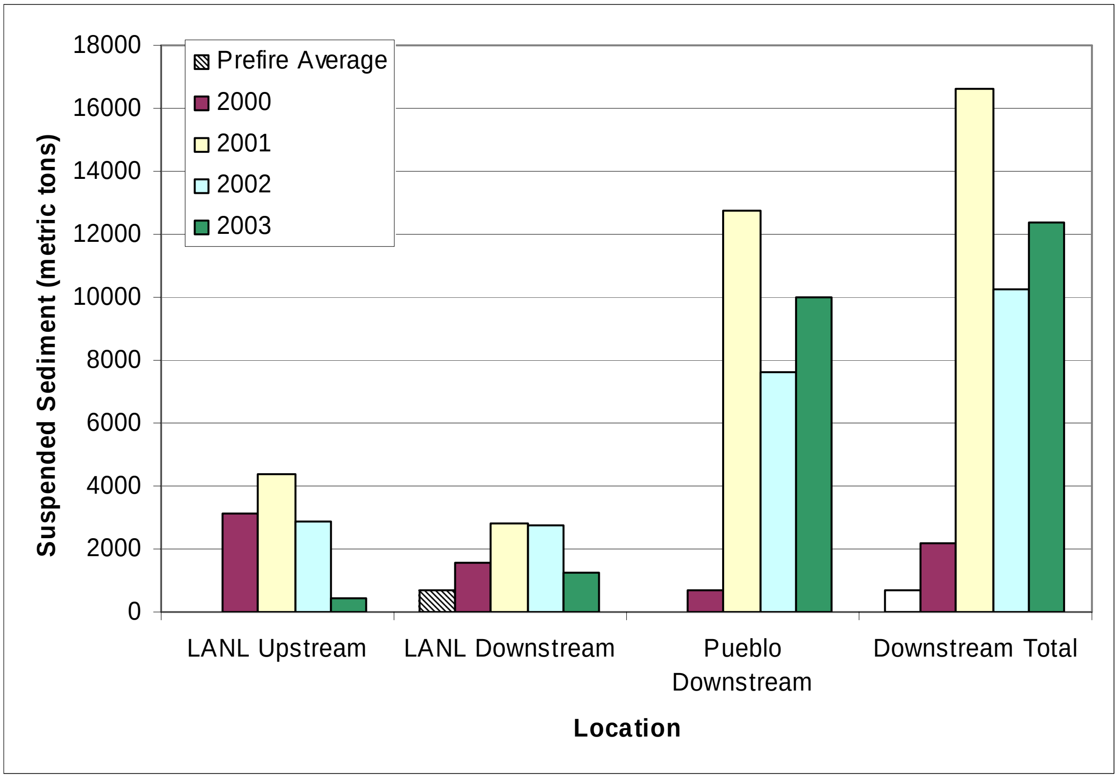
While Contaminant Levels in Runoff Have Declined, Erosion of Sediment Continues

Suspended sediment concentrations downstream of the burned areas remained elevated through the four-year study period by several hundred to several thousand times above prefire levels. This indicates that significant erosion of the burned areas or downstream areas continues after the initial stripping of the ashy surface soils. The channels are choked with excess sediment shed from the burned hill slopes and the suspended sediment concentrations will remain elevated as stream flow adjusts this material. The following chart shows the increase in average annual sediment concentrations from prefire levels, displayed as a ratio between the postfire averages to the prefire average. The largest increase occurred in upper Pajarito Canyon (UPaj) where concentrations were about 10,000 times larger after the fire.



Note: UPaj = upper Pajarito Canyon; ULA = upper Los Alamos Canyon, LWat = lower Water Canyon; LPueb = lower Pueblo Canyon; LLA = lower Los Alamos Canyon; LPaj = lower Pajarito Canyon; LCDB = lower Cañada del Buey; LPotr = lower Potrillo Canyon; LAnch = lower Ancho Canyon.

The larger suspended sediment concentrations, combined with more frequent runoff events, led to an increase in the total load of sediment carried in the stream channels. Over the four-year study period, the amount of sediment carried yearly beyond the Laboratory's historical downstream boundary increased on average by approximately 15 times the prefire average. Most of this increase was due to erosion in Pueblo Canyon. The suspended sediment loads in the drainages crossing the Laboratory peaked in 2001 and then gradually lessened as the runoff from the hillsides declined.



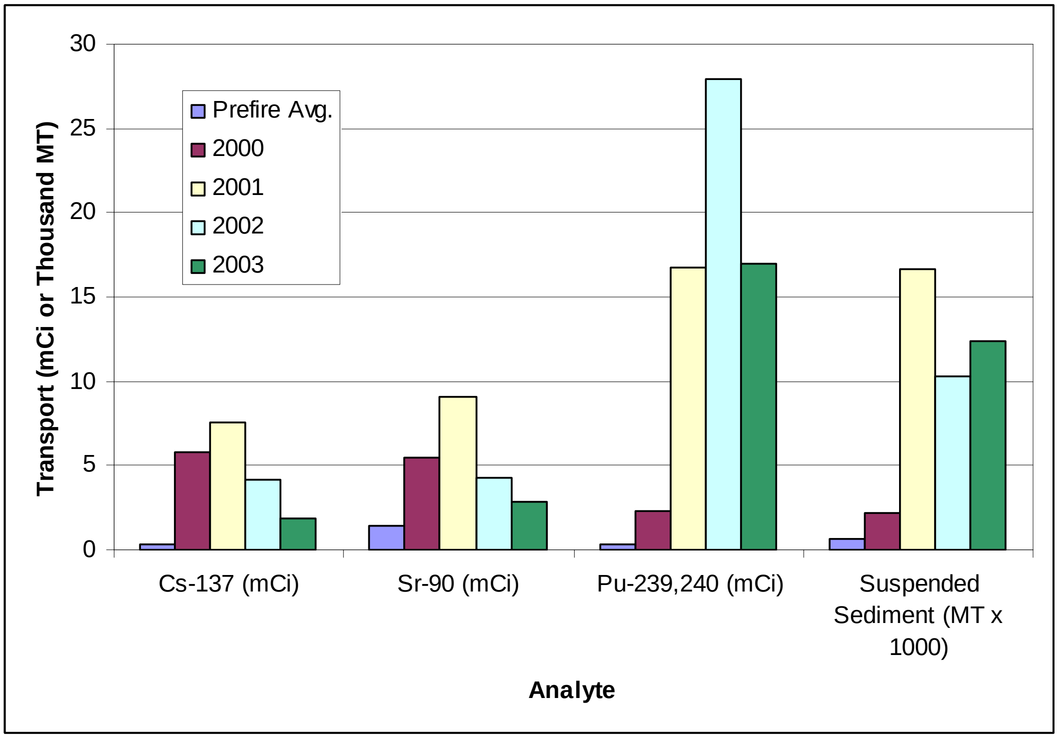
Estimated annual suspended loads on the Pajarito Plateau before and after the fire.

Accelerated Downstream Movement of Metals and Radionuclides

After the Cerro Grande fire, increased flows in watercourses accelerated the downstream movement of stream sediments and contaminants into the Rio Grande. During the largest runoff events of each of the postfire years, flows extended across the Pajarito Plateau into the Rio Grande. Measurements of stream flow, in combination with water-quality samples, allowed us to estimate the amount of material transported in the runoff events. The graph shows the estimated quantity of cesium-137, strontium-90, plutonium-239,240, and suspended sediment transported yearly beyond the Laboratory's downstream boundary, in comparison with averages from the five years before the fire.

In the first and second year, transport of cesium-137 and strontium-90 increased by as much as about 20 times over that seen in the late 1990s, then fell to near pre-fire levels in the fourth year. This pattern appears to show the natural effects of ash passing through the drainages. In contrast, the increase in plutonium-239,240 transport is mainly due to erosion of LANL-derived plutonium-contaminated sediments from Pueblo Canyon by large storm events that hit the drainage starting in the second year, 2001. Over the four-year study period, we estimate plutonium-239,240 transport beyond the Laboratory's downstream boundary increased by as much as 50 to 80 times over that seen in the late 1990s.

Transport of Sediment and Radionuclides in Runoff Downstream of LANL

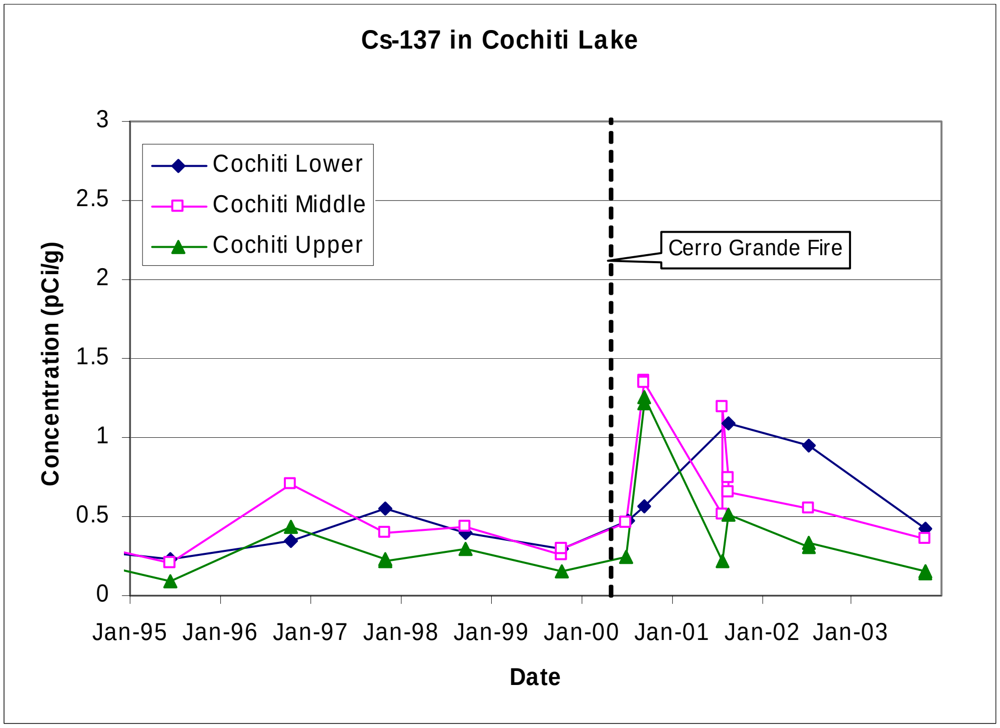


Increases in the transport of cesium-137 and strontium-90, plutonium-239,240, and suspended sediment are mainly from the flushing of ash from the burned areas, greater erosion of LANL-contaminated sediments in Pueblo Canyon, and greater erosion in Pueblo Canyon, respectively.

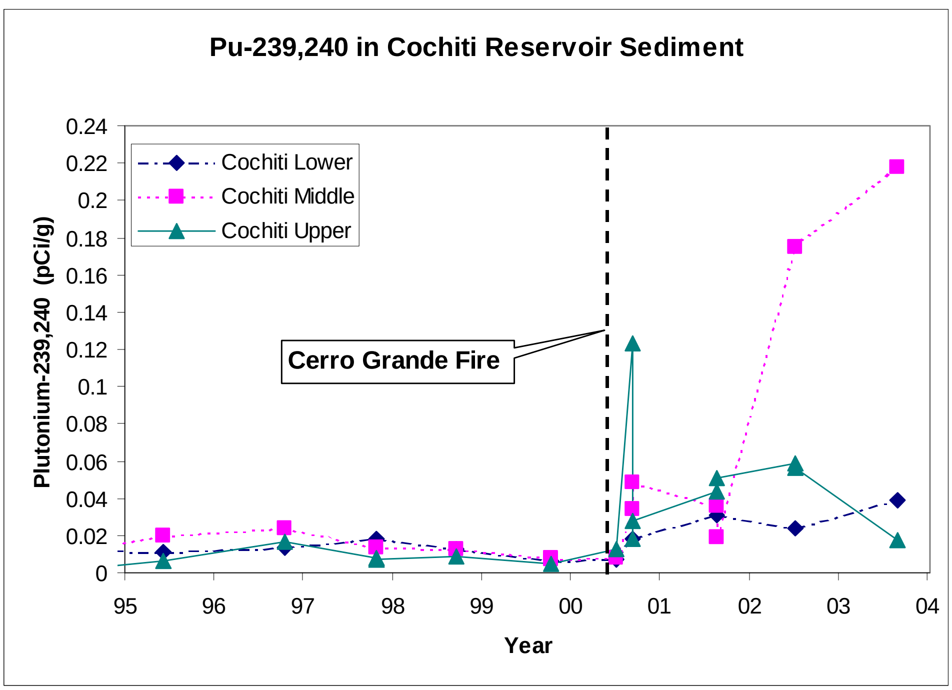
Impacts to the Rio Grande

Several risk analyses of the early sampling results concluded that health risks associated with use of Rio Grande water did not significantly increase when compared with prefire conditions. Additionally, there appears to have been minimal lasting impact to the water column in the Rio Grande. Dissolved metal concentrations in 17 Rio Grande samples collected after the fire were lower than levels prescribed in EPA primary drinking water standards and generally comparable to prefire values.

The main impact to the Rio Grande was to sediment quality in a downstream reservoir. Of the two dozen or more fire-associated constituents, moderate increases in Cochiti Reservoir bed sediment concentrations were measured for cesium-137, plutonium-239,240, and four metals (barium, manganese, strontium, and zinc). The concentration increases for the constituents, except for plutonium-239,240, appear to be predominantly from ash and sediment from fire-impacted areas. As shown in the graph below, cesium-137 concentrations in Cochiti Reservoir bottom sediments increased quickly after the fire by three to five times in September 2000, but in later years decreased to near pre-fire levels at most sampling locations. The downward trend in cesium-137 activities since September 2000 indicates that the increase probably was associated with the initial flush of fallout-derived cesium-137 in ash from the burned areas into the Rio Grande.



Time series showing cesium-137 trends in reservoir bottom sediments before and after the May 2000 Cerro Grande fire.

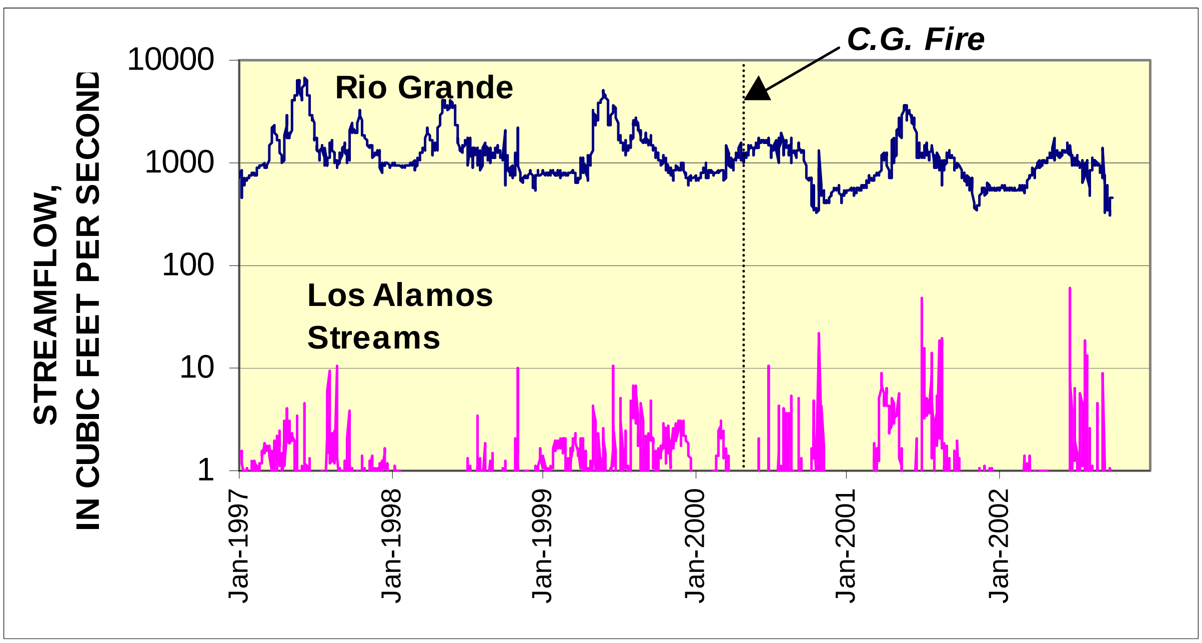


Time series showing plutonium-239,240 trends in Cochiti Reservoir bottom sediments before and after the Cerro Grande Fire.

Plutonium-239,240 activities in Cochiti Reservoir bottom sediments showed increases after the Cerro Grande fire in the upper and middle sections of the reservoir, yet remained far below the health-based residential soil screening level. The plutonium-239,240 increases were mostly due to the large runoff events in Pueblo Canyon in 2001, 2002, and 2003 that accelerated the transport of LANL-derived plutonium-239,240 into lower Los Alamos Canyon and the Rio Grande.

At the upper Cochiti sampling location, concentrations continually increased throughout the four-year period 2000–03 to approximately six times higher than pre-fire levels. At the middle Cochiti sampling location, plutonium-239,240 activities reached a historical high in 2003, increasing to approximately 22 times above prefire levels. A slight increase was found in the lower Cochiti station near Cochiti Dam.

After the fire, approximately two to four times the volume of water flowed beyond the LANL downstream boundary than was measured before the fire. Even with higher flows, however, the average daily stream flow from all LANL-gaged canyons combined was typically less than 1 cfs. By comparison, flows in the Rio Grande near Los Alamos commonly average approximately 1000 cfs, as shown in the following graph.



Stream flow of the Rio Grande and LANL-gaged streams near Los Alamos.

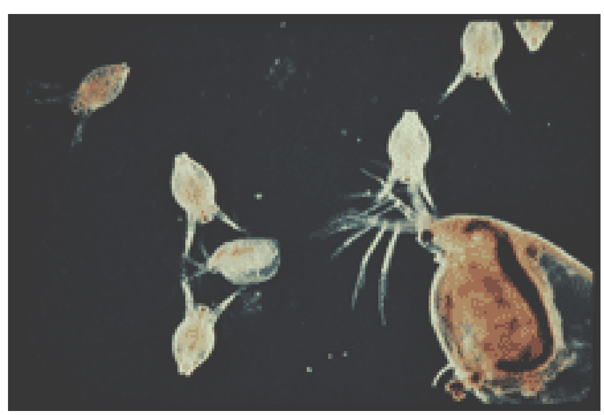
Implications of Monitoring Results

Aquatic Life

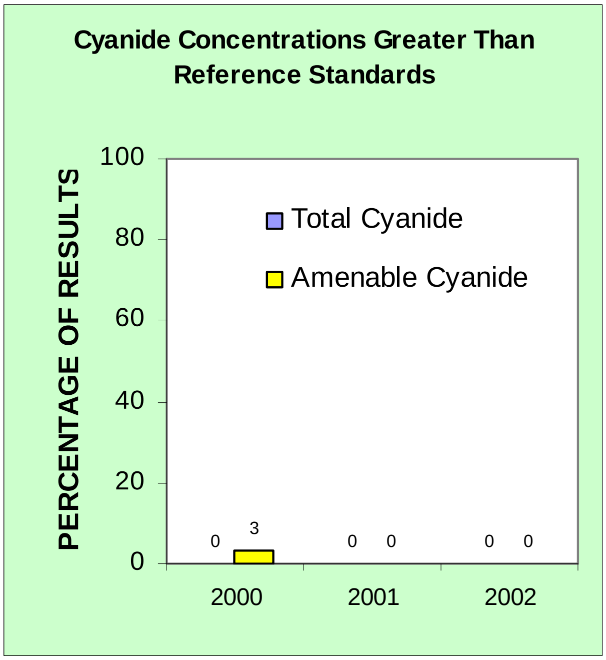
The EPA has established water-quality criteria for the protection of aquatic organisms for short-term (acute) and long-term (chronic) exposures. These guidelines have been established for 13 metals, cyanide, 14 pesticides, and PCBs. These criteria are used by the State of New Mexico to establish local ambient criteria. The only metal found in more than one Rio Grande water sample above the criteria was aluminum, a natural component of soils. Average annual concentrations for aluminum remained below the criteria, however, throughout the three-year period. Several pesticides were detected in concentrations above the chronic criteria, but their significance to water quality could not be fully evaluated because of limitations with the standard analytical methods. The pesticides are not considered to be fire associated. Regardless, no fish kills were reported in the Los Alamos area or in the Rio Grande after the Cerro Grande fire.

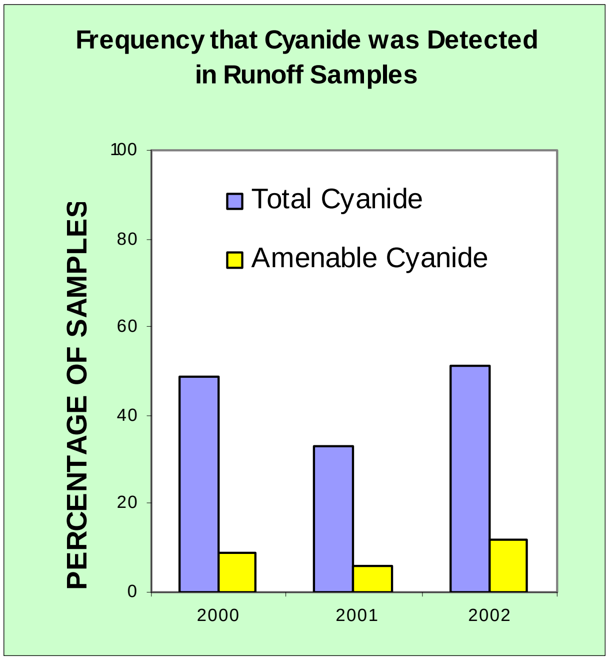
Sediment quality guidelines published by EPA, Environment Canada, and others were compiled by the U.S. Geological Survey's National Water Quality Assessment Program. The guidelines are not enforceable standards; however, they do provide a basis for evaluating the sediment data for the Rio Grande. They identify concentrations for 33 organic compounds that are frequently associated with biological effects. None of the Rio Grande sediments contained concentrations greater than the aquatic life guidelines.

Biotoxicity Testing of Surface Water. Fifteen water samples collected in 2000 and 2001 were tested to determine if they might be potentially toxic to aquatic organisms. In the tests, fat head minnows (bottom left) and Ceriodaphnia water fleas (bottom right) were exposed to the water samples for periods up to seven days and studied for reduced reproduction, genetic changes, and mortality rates. All samples showed no significant short-term (acute) effects. In long-term (chronic) tests, 13 of the 15 samples showed no significant effects. Two ash-rich samples collected below burned areas showed reduced reproduction rates and high mortality. The specific cause of the toxicity has not been identified. Overall, most of the results showed no toxicity.



Early in our investigations we were concerned with the frequency that cyanide was detected in runoff samples below burned areas. If present in certain forms (amenable, weak acid dissociable, or free cyanide), cyanide can be toxic to aquatic life and wildlife. Cyanide is a minor component of the retardant used to fight the Cerro Grande fire and can also be naturally created through slow burning. The results of testing over 200 water samples indicate that while cyanide was detected in about 40 percent of the samples, it rarely was present at biologically harmful levels.





Irrigation, Livestock Watering, and Wildlife Habitat

Excessive water contaminant concentrations can impair these uses over long-term time periods. The State of New Mexico Water Quality Control Commission has stream standards to protect these uses.

The Rio Grande is used for irrigation; concentrations in all but one sample (dissolved aluminum) were below the irrigation criteria. Annual average concentrations from the Rio Grande are well within acceptable irrigation criteria.

For livestock watering and wildlife habitat protection, most of the stream standards are for metals. On the Pajarito Plateau, metals concentrations from background stations are comparable to those downstream of LANL operations. The metal most often found at high concentrations relative to the livestock watering and wildlife habitat criteria was selenium, followed by mercury. Each of these metals is a natural component of soils, and the Laboratory also uses mercury for research. While several of the metals concentrations are frequently greater than the stream standards in short-term storm runoff events, the concentrations are usually less than the proposed criteria in more long-term persistent waters—such as spring-supported, effluent-supported, or snowmelt flows. A review of 2003 stream flow records indicated that storm runoff was present in stream channels across the Pajarito Plateau approximately three to five percent of the time. Thus, any livestock or wildlife regularly watering on the Pajarito Plateau will rely on the more persistent waters and drink surface water of acceptable quality.

In the Rio Grande, dissolved aluminum was detected above the Livestock Watering stream standard in one-fourth of the water samples. This likely reflects the natural sediment load in the river, rather than a Cerro Grande fire effect. Annual average concentrations from the Rio Grande are well within acceptable levels.

Public Health

Several regulatory agencies have adopted standards or guidelines for protection of public health, reflecting a wide range of possible ways that people may be exposed to a specific contaminant. For water, the primary concerns are for drinking water quality and accumulation of contaminants in fish. For sediments, the concerns are for contaminants possibly being transferred to people by some less direct means such as inhaling dust while hiking along a streambed. In nearly every environmental investigation, the predominant concern is for long-term exposures, usually over many decades.

Three separate teams of public health risk assessors evaluated the long-term risks posed by post-Cerro Grande fire contaminants. They calculated the risks to people from over 100 different chemicals and radioactive substances that were actually measured in environmental samples or were hypothesized to be present. The risk calculations tracked the combined effect of all the individual contaminants on people from assumed normal daily activities. The three studies differed in their assumed exposure times and activities, yet the conclusions were similar: studies concluded that the overall risks were within acceptable EPA risk levels, below international radiological dose guidelines, and not significantly higher than prefire risk levels.

Summary

The after-effects of the Cerro Grande fire to streams and rivers in the Los Alamos area have been significantly reduced from what could have happened if large precipitation events had occurred. Precipitation intensity in the first few years after the fire was relatively moderate, which allowed recovery of vegetation in the burned areas.

In summary, the effects of the fire have been as follows:

- Greater flow volumes and higher flow rates concurrent with higher sediment loads in storm runoff.
- Increased movement of
  - fallout radionuclides cesium-137 and strontium-90 from burned areas,

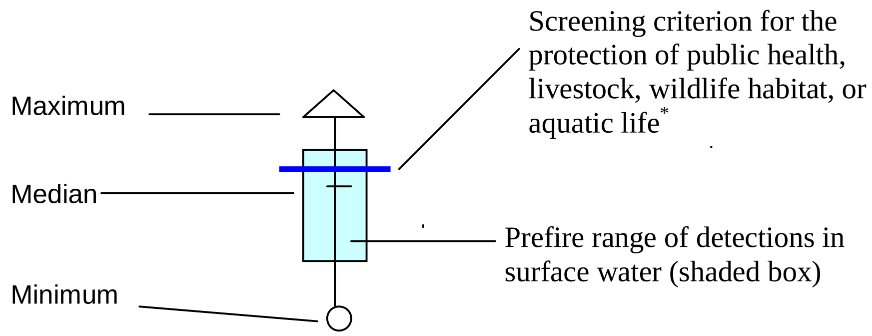
  - LANL-derived plutonium-239,240 from Pueblo Canyon, and
  - naturally occurring uranium and metals from burned areas.

- Relatively small environmental hazards include the following:
  - contaminant concentrations of sediment deposited in flood plains on the Pajarito Plateau and in the Rio Grande or Cochiti Reservoir were small compared to several risk measures,
  - dissolved metals and radionuclide concentrations in the Rio Grande waters were within federal drinking water standards or guidelines.
  - health risks are within EPA acceptable levels, andsome health risks were driven by naturally occurring chemicals, but on a temporary basis.

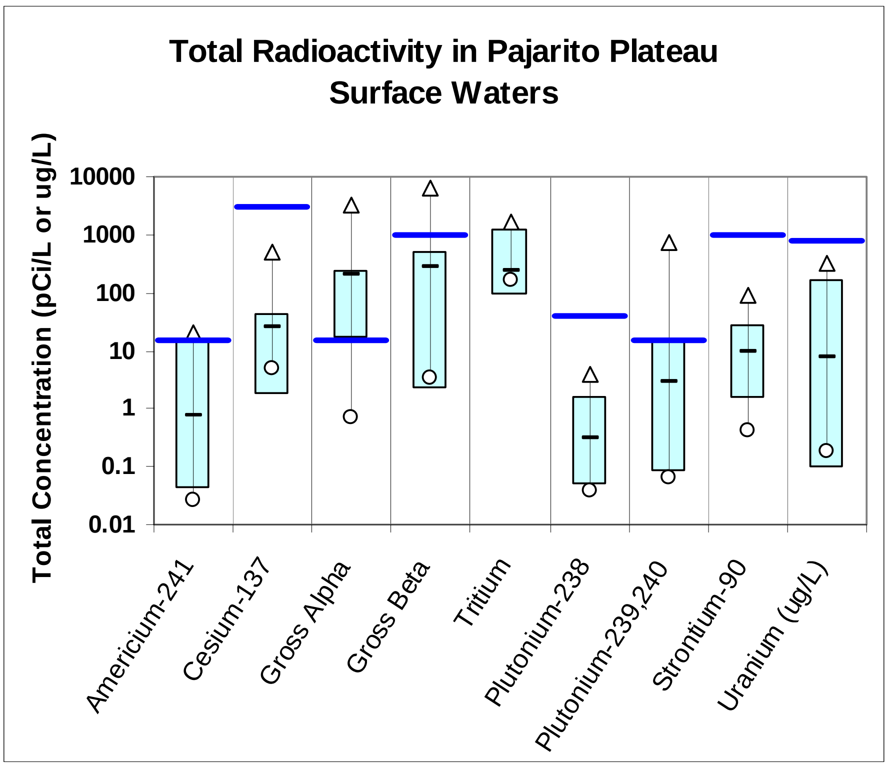
Summary of Compound Detections and Concentrations

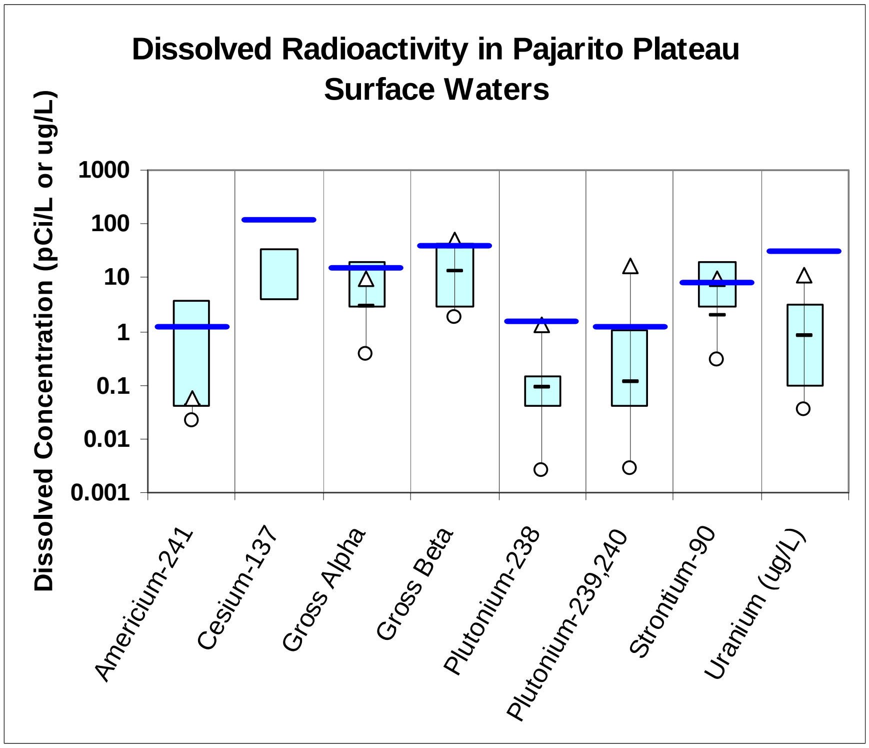
The following figures summarize data collected after the Cerro Grande fire from 2000–2002 by showing results from the Pajarito Plateau (Los Alamos area) and from the Rio Grande compared to prefire range for each compound detected. When prefire data were not available, the results were compared against equivalent post-fire results from environmental samples collected above LANL. The data were collected at a wide variety of locations and times. In order to represent the wide concentration ranges observed among the compounds, logarithmic scales are used to emphasize the general magnitude of concentrations (such as 10, 100, or 1000), rather than the precise number. For organic compounds, the focus is on those compounds that were detected in two or more samples. Individual detections of chemicals are displayed if the results can be clearly depicted, otherwise the overall range and median of the detections are shown. The complete dataset used to construct these charts is available on request.

EXPLANATION

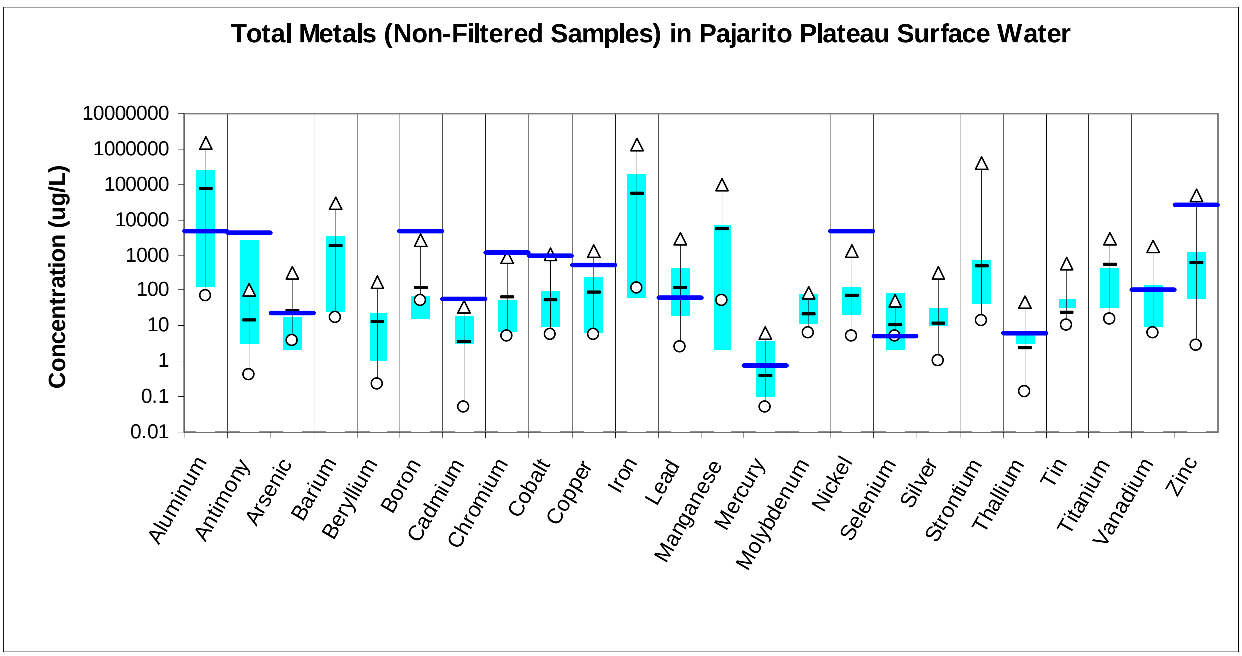


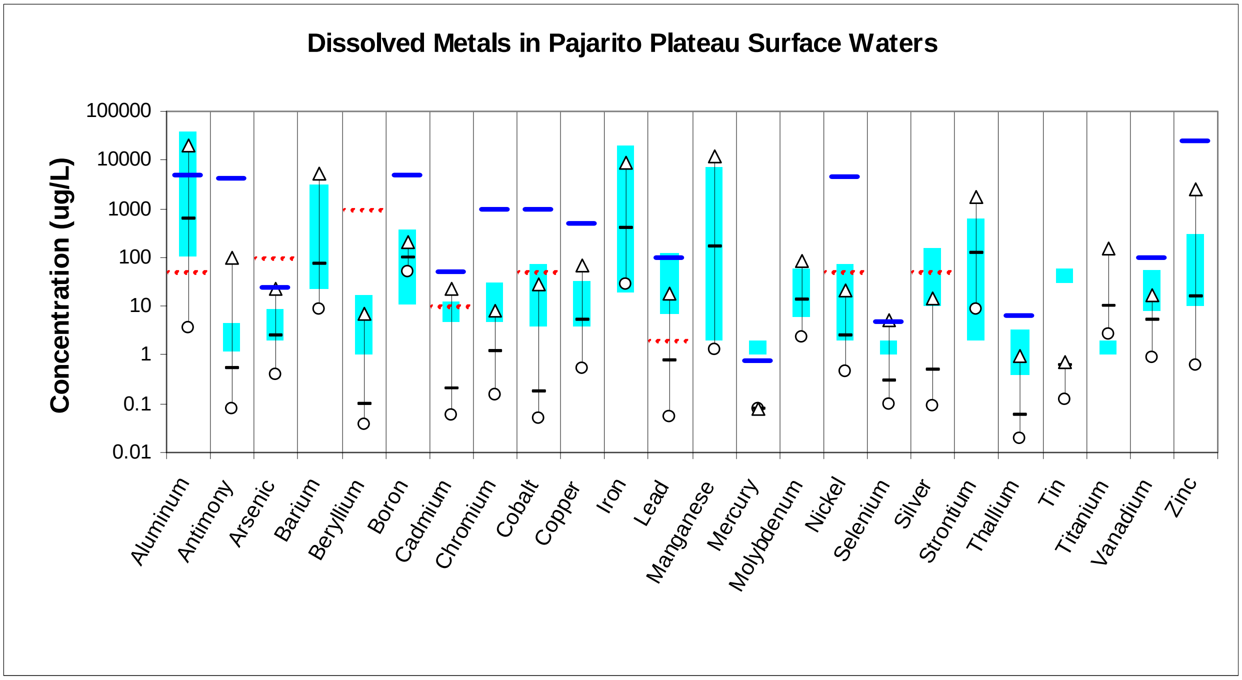
*Selected water quality standards and guidelines were drawn from a variety of sources. Public health standards were predominantly from U.S. Department of Energy (1990), New Mexico Water Quality Control Commission (2002a, 2002b), EPA (2002, 2003), Gilliom et al. (1997), and LANL (2001a). Standards or guidelines for protection of irrigation, livestock watering, wildlife habitat, and aquatic life were taken from New Mexico Water Quality Control Commission (2002a, 2002b), EPA (1989, 2003), Gilliom et al. (1997), and Environment Canada (2002). Further details about selection of the standards or guidelines are provided in Gallaher and Koch (2004).





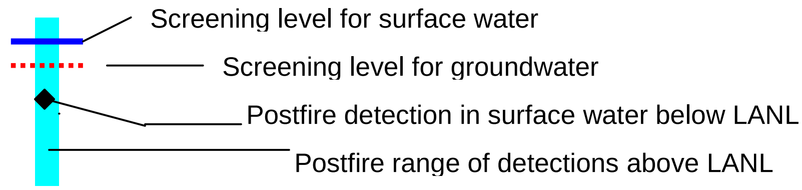
Concentrations of radionuclides in Pajarito Plateau storm runoff samples showing prefire ranges (shaded), guideline for protection of public health (blue thick bar) [pCi/L = picocuries per liter; µg/L = micrograms per liter].

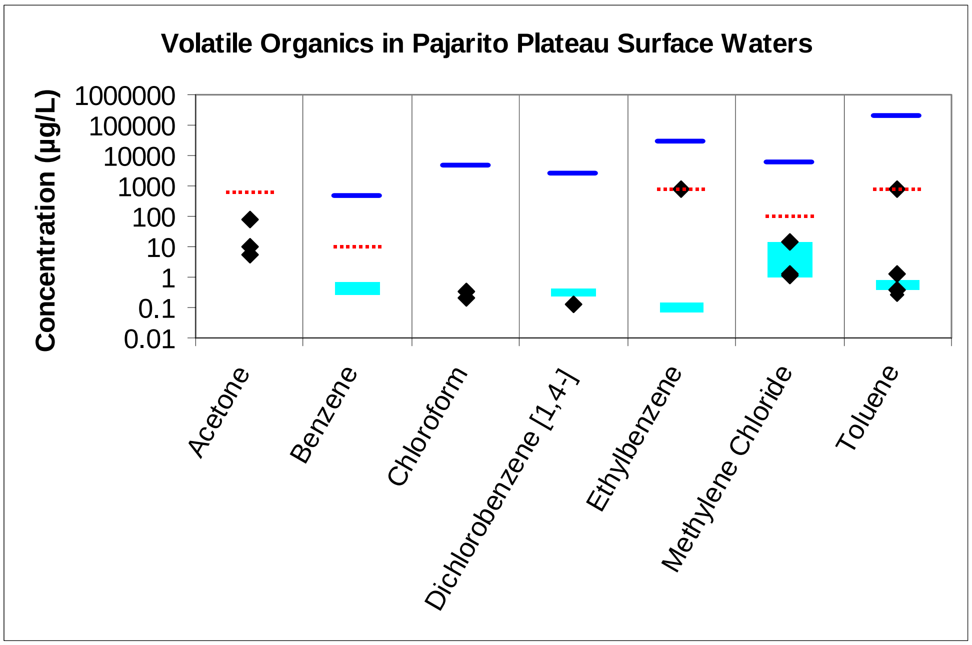


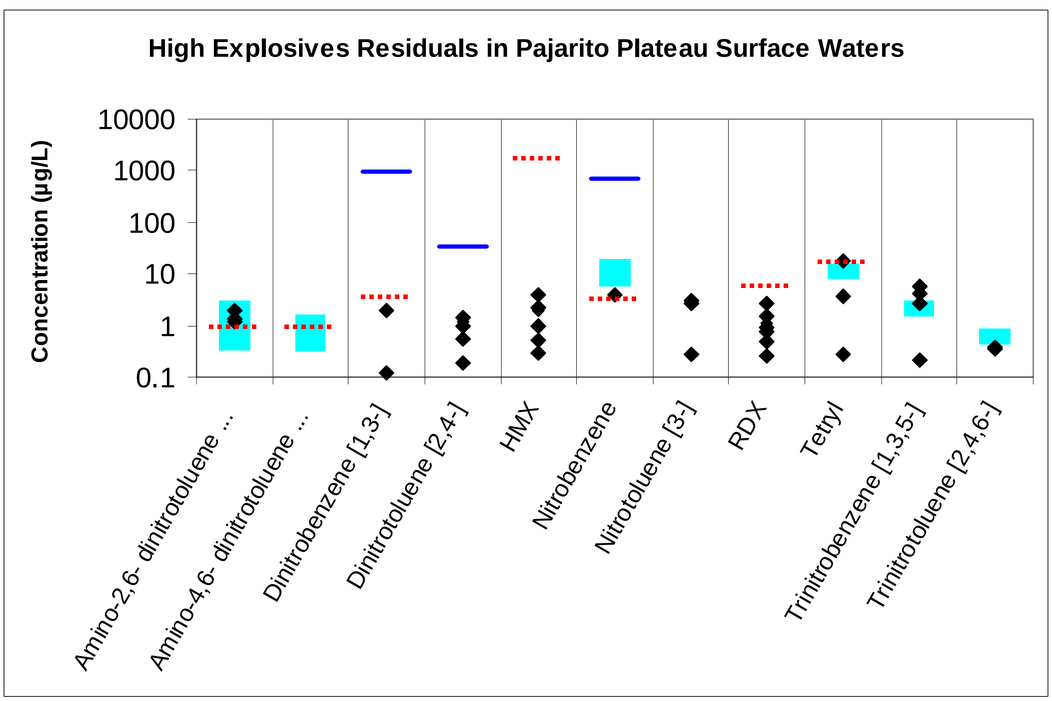


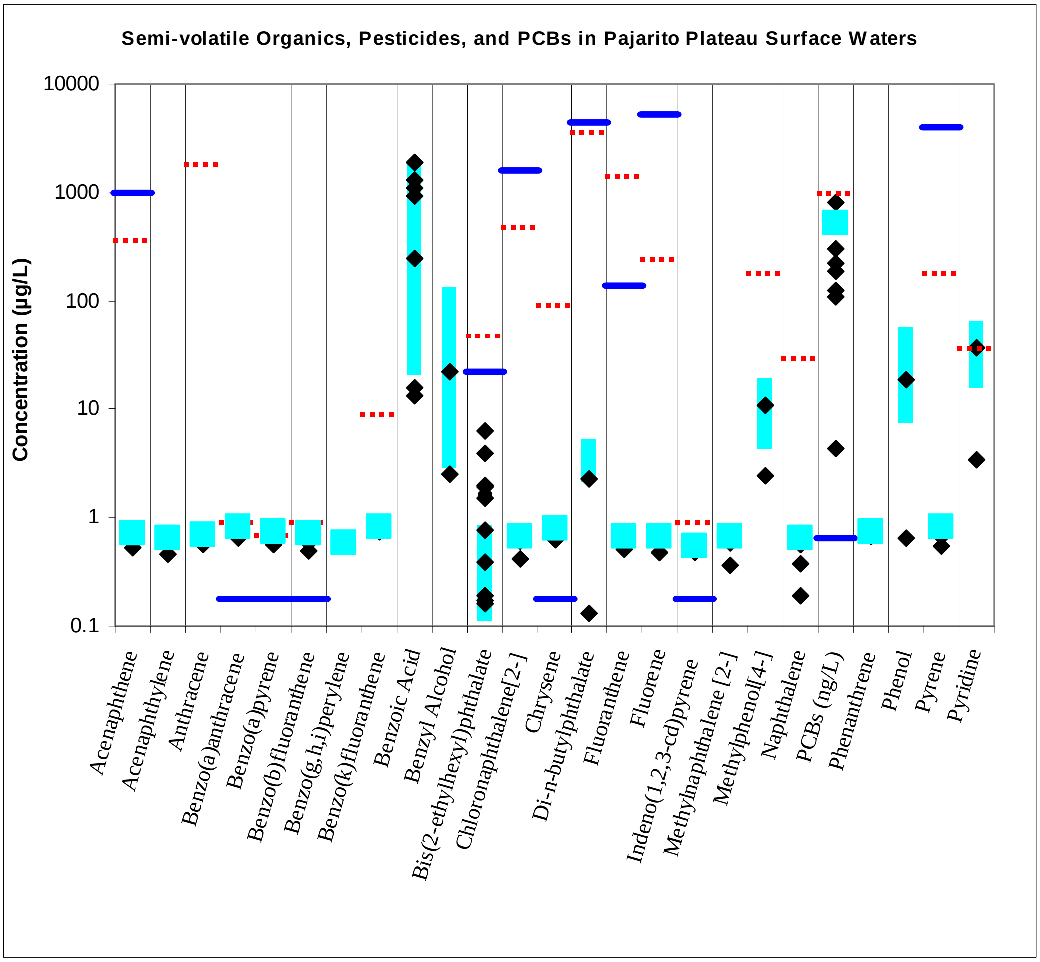
Concentrations of metals in Pajarito Plateau storm runoff samples showing prefire range (shaded), surface water screening level (blue thick bar; minimum of Livestock Watering, Wildlife Habitat, and Human Health Persistent Toxic stream standards), and groundwater standard or guideline (red dashed bar) [µg/L = micrograms per liter].

EXPLANATION

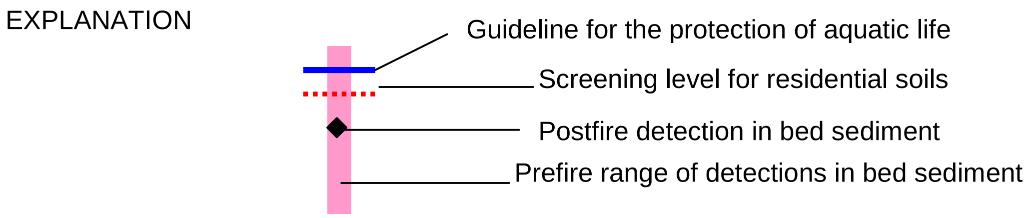




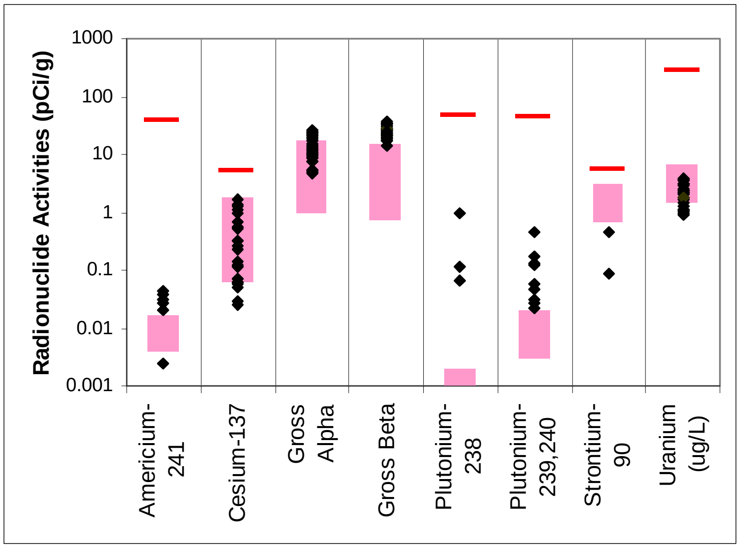




Concentrations of pesticides, volatile and semivolatile organic compounds, and high explosives detected in two or more Pajarito Plateau surface water samples [µg/L = micrograms per liter].

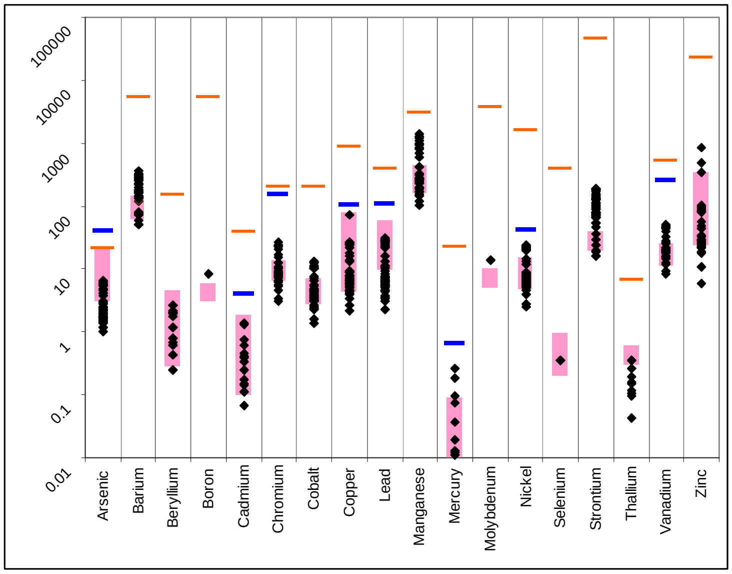


Radionuclide Concentrations in Bed Sediments in the Rio Grande and Cochiti Reservoir



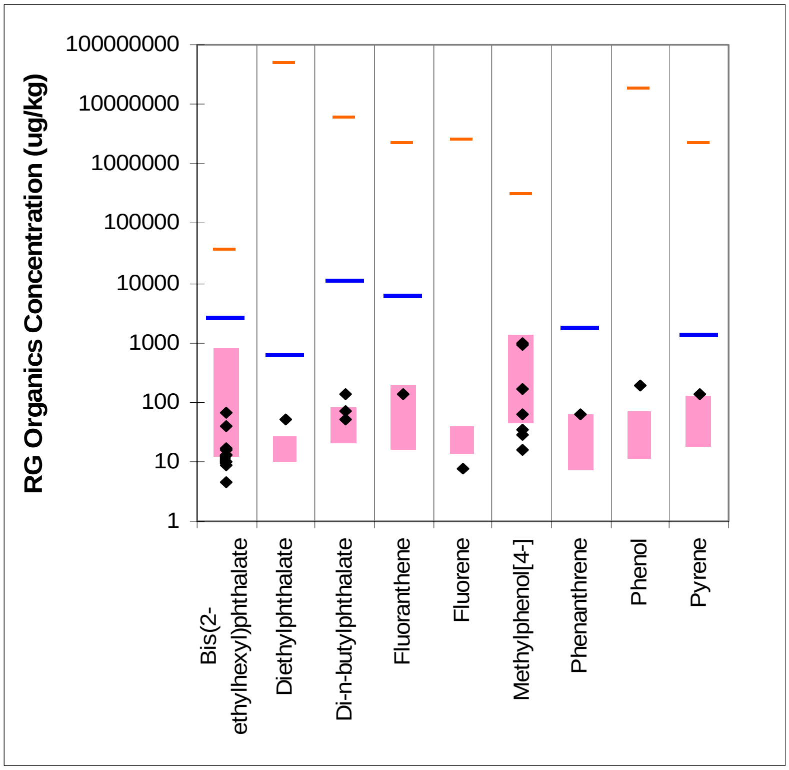
Radionuclide concentrations in bed sediments in the Rio Grande and Cochiti Reservoir showing prefire ranges (shaded) and screening level (bar) for protection of public health (residential activities) [pCi/L = picocuries per liter; µg/L = micrograms per liter].

Metals Concentrations in Bed Sediments in the Rio Grande and Cochiti Reservoir



Metals concentrations in bed sediments in the Rio Grande and Cochiti Reservoir showing prefire ranges (shaded) and screening level (bar) for protection of public health (residential activities).

Organics Concentrations in Bed Sediments in the Rio Grande and Cochiti Reservoir



Organics concentrations in bed sediments in the Rio Grande and Cochiti Reservoir showing prefire ranges (shaded) and screening level (bar) for protection of public health (residential activities) [ug/kg = micrograms per kilogram].

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For Additional Information on the Cerro Grande Fire:

The bibliography at the back of this report provides some sources of information regarding the water-related aftermath of the Cerro Grande fire. Much additional information pertaining to other aspects of the fire, such as air quality studies, is also available on the Internet via the World Wide Web. You may connect to a list of these other studies using the following Universal Resources Locator (URL): http://www.airquality.lanl.gov/CerroGrandeFire/CGF_biblio.htm


RIO ARRIBA COUNTY
SANTA FE COUNTY
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