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Storm Water Performance Monitoring in the Los Alamos/Pueblo Watershed during 2013, Revision 1

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EXECUTIVE SUMMARY

This fourth annual monitoring report provides a summary of analytical data, discharge measurements, geomorphic changes, and precipitation data associated with storm water samples collected from the Los Alamos and Pueblo (LA/P) watershed from June 2013 to November 2013. Monitoring objectives include collecting data to evaluate the effect of watershed mitigations installed in the LA/P watershed on stream flow and sediment and contaminant transport. Watershed mitigations being evaluated include the DP Canyon grade-control structure (GCS) and associated floodplains; Pueblo Canyon wing ditch, willow planting, wetland, and GCS; the Los Alamos Canyon low-head weir; and the storm water detention basins and associated willow planting below the Los Alamos Canyon Solid Waste Management Unit (SWMU) 01-001(f) drainage. Pursuant to Section VII of the Compliance Order on Consent, Los Alamos National Laboratory (the Laboratory) had implemented interim measures to reduce migration of contaminants within the LA/P watershed. These mitigations have been implemented with the overall goal of working together to minimize the potentially erosive nature of storm water runoff, to enhance deposition of sediment, and to reduce access of contaminated sediments to flood erosion.

Gage and sampling locations are situated within the LA/P watershed to monitor the hydrology and sediment transport along the length of the watershed, including stations that bound the mitigations. However, the topography, geology, geomorphology, and meteorology of the watershed are complex; thus, monitoring runoff and precipitation is also complex and challenging. Stage height, which is then converted to discharge using rating curves developed for each individual gage, is monitored at 5-min intervals at a series of gages using shaft-encoder float sensors, self-contained bubbler pressure sensors, and ultrasonic probe sensors. Precipitation data are collected across the Laboratory by means of five meteorological towers and an extended rain gage network. Sampling for analyte suites specific to each reach of the watershed is conducted using ISCO 3700 portable automated samplers configured to begin sampling routines when a preset stage height or after a discharge peak is recorded at the data logger. Sampling equipment and the extended rain-gage network are deactivated during the winter months (December to March) and reactivated in the spring.

Geomorphic changes were monitored at the nine sediment transport mitigation sites that have been established in the LA/P watershed. Cross-sections upgradient and downgradient and a thalweg profile of each site were surveyed following the summer 2013 monsoon season. Surveys were supplemented with sediment-thickness measurements obtained from hand-dug or hand-augered holes along the survey transect. The net changes in cross-sectional areas from the previous year were calculated and used to estimate total deposition or erosion over the surveyed area.

The Los Alamos Canyon watershed experienced a large number of runoff events in 2013, including runoff from the Las Conchas burn area in the upper watershed of Los Alamos and Guaje Canyons and the 1000-yr precipitation event on September 13. Runoff from the burn area had high concentrations of suspended sediment, which is typical after wildland fires. Pueblo Canyon, not affected by the fire, had 1 runoff event in 2013 beginning in the upper watershed that extended through the length of the wetland, past the GCS, and into lower Los Alamos Canyon. In contrast, Los Alamos Canyon had 6 events that extended through the watershed, past the low-head weir, and into lower Los Alamos Canyon. A large number of events (18) flowed past the DP Canyon GCS because a majority of the watershed is impervious Los Alamos County townsite that drains into the canyon above the GCS. Attenuation of flow and associated sediment transport through the Pueblo Canyon wetland and associated GCS, Los Alamos low-head weir and associated sediment retention basins, and DP Canyon GCS is a primary goal of the sediment transport mitigation activities conducted in LA/P watershed, and all structures performed as designed in 2013, despite damage incurred by flooding on September 13.

The 2013 monitoring data in upper Los Alamos Canyon indicate a substantial reduction in suspended sediment concentration (SSC) as floods passed through the low-head weir and associated sediment retention basins. In fact, approximately 6,000 cubic yards of sediment were removed from the weir in 2013. This structure is, therefore, performing as designed. By contrast, SSC was much higher at gaging station E109.9 in lower Los Alamos Canyon as a result of floods in Guaje Canyon originating from the Las Conchas burn area.

In DP Canyon, which primarily receives runoff from the Los Alamos townsite, direct comparison of runoff and sediment yield above and below the GCS and upstream floodplains was possible in four events in 2013. Sediment yield decreased downstream between bounding stations (E038 and E039.1), which is consistent with the intent of the GCS in this canyon. Peak discharge between these gages also decreased, indicating attenuation of flood energy.

Net sediment deposition occurred in most surveyed areas in the Los Alamos and DP Canyons in 2013, which is consistent with the goal of sediment transport mitigation control. In Pueblo Canyon, net erosion occurred during September 13 flooding. Although the September 2013 flood event resulted in significant erosion in most surveyed areas in Pueblo Canyon, the magnitude of the erosion was likely reduced by the sediment mitigation structures and willow plantings. The upper Los Alamos Canyon sediment detention basins appear to have contained much of the sediment transported by the small drainage below SWMU 01-001(f). The surveys document that the sediment transport mitigation sites are currently operating as desired and are not undergoing net erosion over the period of this monitoring program.

Concentrations of Polychlorinated biphenyls (PCBs) measured at E109.9 in lower Los Alamos Canyon are similar to those measured in upper Los Alamos Canyon above Laboratory sites, at E026, and are consistent with the transport of PCBs from the Las Conchas burn area down Guaje Canyon. PCB in the burn area have a source in atmospheric fallout and were released during the fire. Off-site transport of PCBs with Las Conchas burn area, Los Alamos townsite, and Laboratory sources occurred in 2013. The weir and associated sediment retention basins were effective at substantially reducing this transport. The transport of radionuclides in storm water with a Laboratory source was also substantially reduced by the settling of sediment above the Los Alamos Canyon weir.

Continued monitoring in 2014 is expected to confirm the sediment transport mitigation structures and associated wetlands, and floodplains in the LA/P watershed are performing as intended and document expected recovery of the wetland in Pueblo Canyon.

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Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
BDD	Buckman Direct Diversion
cfs	cubic feet per second
Consent Order	Compliance Order on Consent
DOE	Department of Energy (U.S.)
EPA	Environmental Protection Agency (U.S.)
GCS	grade-control structure
GPS	global positioning system
CVS	cross-vane structure
ICP	inductively coupled plasma
IMWP	interim measures work plan
Laboratory	Los Alamos National Laboratory
LANL	Los Alamos National Laboratory
LA/P	Los Alamos and Pueblo (watershed)
LIDAR	light detecting and ranging
MDL	method detection limit
MSS	Maintenance and Site Services (Laboratory group)
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMWQCC	New Mexico Water Quality Control Commission
PCB	polychlorinated biphenyl
RPD	relative percent difference
RPF	Records Processing Facility
SIMWP	supplemental interim measures work plan
SSC	suspended sediment concentration
SWMU	solid waste management unit
TAL	target analyte list (EPA)
TCDD	tetrachlorodibenzodioxin
TEF	toxicity equivalency factor
TEQ	toxic equivalency quotient
TSS	total suspended solids
UTL	upper tolerance limit
VE	vertical exaggeration
WWTP	wastewater treatment plant

1.0 INTRODUCTION

Los Alamos National Laboratory (LANL or the Laboratory) is a multidisciplinary research facility owned by the U.S. Department of Energy (DOE) that is managed by Los Alamos National Security, LLC. The Laboratory is located in north-central New Mexico approximately 60 mi northeast of Albuquerque and 20 mi northwest of Santa Fe. The Laboratory site comprises an area of 36 mi^2, mostly on the Pajarito Plateau, which consists of a series of mesas separated by eastward-draining canyons. It also includes part of White Rock Canyon along the Rio Grande to the east.

This fourth annual monitoring report provides a summary of analytical data, discharge measurements, and precipitation data associated with storm water collected from the Los Alamos and Pueblo (LA/P) watershed from June 2013 to November 2013. In addition, the geomorphic changes at the sediment transport mitigation sites in the LA/P watershed are also included in this report as Appendix A. This monitoring was performed pursuant to Section VII of the Compliance Order on Consent (the Consent Order) to reduce migration of contaminants within the LA/P watershed and pursuant to the New Mexico Environment Department– (NMED-) approved “Interim Measure Work Plan to Mitigate Contaminated Sediment Transport in Los Alamos and Pueblo Canyons” (IMWP) (LANL 2008, 101714; NMED 2008, 103007) and the approved “Supplemental Interim Measures Work Plan to Mitigate Contaminated Sediment Transport in Los Alamos and Pueblo Canyons” (SIMWP) (LANL 2008, 105716; NMED 2009, 105014). Hydrologic and geomorphic monitoring in 2013 were performed in accordance with the approved “2013 Monitoring Plan for Los Alamos and Pueblo Canyons Sediment Transport Mitigation Project, Revision 1” (LANL 2013, 243432; NMED 2013, 523106).

Monitoring objectives include collecting data to evaluate the effect of watershed mitigations installed in the LA/P watershed on stream flow and sediment and on contaminant transport. The discussion of flow and analytical results for suspended sediment and constituent concentrations focuses on an evaluation of the overall watershed performance, with specific emphasis on the effects of the mitigations implemented per the IMWP and SIMWP. The discussion of geomorphic stability in Appendix A focuses on sediment stability and mobility in the watershed as a measure of the overall stability of the watershed and the performance of the sediment-mitigation structures.

The NMED approval with modifications for the 2013 monitoring plan for sediment transport mitigation (LANL 2013, 243432; NMED 2013, 523106) also directed the Laboratory to monitor storm water above and below the detention basins below the Solid Waste Management Unit (SWMU) 01-001(f) drainage in upper Los Alamos Canyon. Watershed mitigations evaluated in this report include the DP Canyon grade-control structure (GCS) and associated floodplain; Pueblo Canyon willow planting, wetlands, and GCS; the Los Alamos Canyon low-head weir; and the storm water detention basins and associated vegetative buffer below the SWMU 01-001(f) drainage in Los Alamos Canyon.

The watershed addressed in this monitoring report is potentially contaminated with both hazardous and radioactive components. Corrective actions at the Laboratory are subject to Consent Order. Information on radioactive materials and radionuclides, including the results of sampling and analysis of radioactive constituents, is voluntarily provided to the NMED in accordance with DOE policy.

1.1 Project Goals and Methods

The mitigations specified in the IMWP and SIMWP have been implemented with the overall goal of minimizing the potentially erosive nature of storm water runoff to enhance deposition of sediment and to reduce or eliminate the susceptibility of contaminated sediments to flood erosion. Figure 1.1-1 shows the locations of the mitigations and monitoring stations, including stream gages, in the LA/P watershed. In the

Pueblo Canyon watershed, the central focus of the mitigations is to maintain a physically, hydrologically, and biologically functioning wetland that can reduce peak flows and trap suspended solids because of the presence of thick wetland vegetation. Stabilization and enhancement of the wetland were partially addressed with installation of a GCS designed to inhibit headcutting at the terminus of the wetland and to potentially promote establishment of additional riparian or wetland vegetation beyond the current terminus of the wetland. Mitigations in upper portions of Pueblo Canyon above the wetland are designed primarily to reduce the flood peaks and to enhance channel/floodplain interaction before floods reach the wetland. Gages are situated within the watershed to monitor the overall hydrology and sediment transport along the length of the watershed, including stations that bound the wetland.

In DP and Los Alamos Canyons, mitigations included stabilizing and potentially partially burying the channel and adjacent floodplains in reach DP-2 in DP Canyon, which is a source of contaminants entrained in frequent floods that originate from a portion of the Los Alamos County townsite. A GCS was installed in the lower part of reach DP-2 with a height that may encourage channel aggradation, thus reducing the potential for erosion of contaminated sediment deposits in adjacent banks during floods. Channel aggradation in reach DP-2 should also encourage spreading of floodwaters, thus reducing peak discharge because of transmission loss within the reach and enhancing sediment deposition. Lower flood peaks should also reduce the erosion of contaminated sediment deposits downcanyon of the GCS. Mitigations in Los Alamos Canyon several kilometers below the DP Canyon confluence involved removing accumulated sediment behind the low-head weir to increase the residence time of floodwaters and to enhance settling of suspended solids and associated contaminants.

Additional mitigations were implemented in Los Alamos Canyon under a separate administrative requirement (LANL 2008, 104020; NMED 2009, 105858) to address polychlorinated biphenyl (PCB) contamination associated with SWMU 01-001(f). The mitigation actions at that location involved removing contaminated sediment from the canyon wall and constructing detention basins at the bottom of the associated hillside drainage to promote the settling of contaminated sediments in runoff from the canyon wall.

Between September 10 and 17, 2013, New Mexico and Colorado received a historically large amount of precipitation (Figure 1.1-2). Los Alamos County, New Mexico, received between 200% and 600% of the normal precipitation for this time period (Figure 1.1-3), and the Laboratory received approximately 450% percent of its average precipitation for September (Figure 1.1-4). As a result, the Laboratory was inundated with rain, including the extremely large, greater-than-1000-yr return period precipitation event that occurred between September 12 and 13 (Table 1.1-1). With saturated antecedent soil conditions from the September 10 storm, when the September 12 to September 13 storm hit, the flooding damaged the Laboratory's environmental infrastructure, including access roads, groundwater monitoring wells, gage stations, watershed controls, and control measures installed under the National Pollutant Discharge Elimination System Permit.

2.0 DISCHARGE AND PRECIPITATION MEASUREMENTS AND SAMPLING IN THE LA/P

2.1 Discharge and Precipitation Measurements and Sampling in the LA/P Watershed

Measurements of discharge and surface-water sampling were conducted at 13 gages in the LA/P watershed in 2013. Gages located at five concrete, trapezoidal, supercritical-flow flumes are designated Los Alamos above the Rio Grande (E109.9), Los Alamos below low-head weir (E050.1), Pueblo below grade-control structure (E060.1), DP below grade-control structure (E039.1), and Los Alamos above low-head weir (E042.1). Eight other gages that complete the monitoring network in the LA/P watershed are designated as Pueblo above Acid (E055), South Fork of Acid Canyon (E055.5), Acid above Pueblo (E056), Los Alamos below Ice Rink (E026), Los Alamos above DP Canyon (E030), DP above Technical Area 21 (E038), Pueblo above the wastewater treatment plant (E059), and DP above Los Alamos Canyon (E040). Although gage station E099 in lower Guaje watershed is not part of the formal Los Alamos/Pueblo monitoring network, post-fire floods emanating from burn scars in the Guaje watershed consistently impact E109.9, and thus E099 is discussed in this report. Figure 1.1-1 shows the locations of stream gages and watershed mitigations within the Laboratory's property boundary and on adjacent land owned by the County of Los Alamos and Pueblo de San Ildenfonso.

Stage height was monitored at each LA/P gage at 5-min intervals in the LA/P watershed. Sutron 9210 data loggers stored each recorded stage-height measurement as it was made. Discharge was computed for each 5-min stage measurement using rating curves for each individual gage. Shaft-encoder float sensors installed in stilling wells were used to measure water levels at E026, E030, E039.1, E042.1, E050.1, E059, E060.1, E099, and E109.9. Self-contained bubbler pressure sensors (Sutron Accubar) were used to measure water levels at E038, E055, E055.5, and E056 and to provide backup sensing at E109.9, E050.1, and E060.1. An ultrasonic probe sensor (Siemens Miltronics "The Probe") was used to measure water levels at E040 and provided additional backup sensing at E109.9. In 2013, approximately 1,000,000 individual stage measurements were recorded at the 13 gage stations monitored within the LA/P watershed.

A complete record of 5-min stage height measurements for the monitoring period from June 1, 2013, to October 31, 2013, exists at E030, E038, E039.1, E050.1, E055, E055.5, and E056. Five-minute stage height measurements are incomplete at seven gage stations damaged by the September 13 high-flow event: E026, E040, E059, E099, and E109.9 incomplete from September 13 to November 30; E042.1 incomplete from September 13 to September 20; and E060.1 incomplete from September 13 to September 19.

Storm water programs at the Laboratory use precipitation data collected at the Laboratory's meteorological towers. In addition, a seasonal, extended rain gage network is deployed during the months from April to November to coincide with storm water monitoring periods. Using a geographic information system, storm water monitoring stations are assigned to an individual rain gage using the method of Thiessen polygons. Rain gages, meteorological towers, Thiessen polygons, and the drainage area for each stream gage associated with the LA/P watershed are presented in Figure 2.1-1.

Sampling was conducted using ISCO 3700 portable automated samplers. At E026, E038, E039.1, E042.1, E050.1, E059, E060.1, and E109.9, two ISCO samplers were installed. At locations where two samplers were installed, one sampler was configured with a 24-bottle carousel to monitor primarily suspended sediment, and the second sampler was configured with a 12-bottle carousel to monitor inorganic and organic chemicals and radionuclides. At locations where a single sampler was installed, the sampler was configured with a 12-bottle carousel to monitor suspended sediment, inorganic and organic chemicals, and radionuclides. Sampler intake lines were set above the bottom of the channel or gage and were placed perpendicularly to the direction of flow. The placement of trip levels and sampler intake lines is presented in Table 2.1-1.

Sampling equipment at gages in LA/P watershed was shut down during the winter months and reactivated in the spring. During the 2013 monitoring period, requests were issued weekly to field personnel to inspect activated gages and sampling equipment. Gaging and sampling equipment at the 13 LA/P gaging stations was connected via telemetry to a base station, allowing real-time access to gage discharge measurements and battery state of charge. Inspectors reviewed telemetry daily to ensure gages were functioning correctly. Inspectors inspected gaging stations and samplers when telemetry readings indicated discharge had occurred or the equipment problems existed.

2.2 Sampling at the Detention Basins below the SWMU 01-001(f) Drainage and in Graduation Canyon

In 2013, nine storm water samples were collected with automated samplers above two constructed detention basins below the SWMU 01-001(f) drainage at location CO111041. Storm water discharge ponded in the detention basins, and sampling was triggered on two occasions at CO101038, at the culvert at the terminus of the vegetative buffer below the lower basin. Sampling locations and storm water control features at the detention basins below the SWMU 01-001(f) drainage are identified in Figure 2.2-1.

2.3 Sampling at the Gage Stations in the LA/P Watershed

During the monitoring period in 2013 (June 1 to October 31), discharge ~~was measured above~~exceeded 5~~10~~ cubic feet per second (cfs) at E050.1, E060.1, or E109.9; 40 cfs at E038; or 10 cfs at other ~~any~~ gage stations during 28 storm events on 30~~1~~ d. Sampling and analyses of inorganic and organic chemicals, radionuclides, and suspended sediment occurred on 17 d with runoff events from 1 or more of the 13 gage stations in the LA/P watershed. A total of 45 sampling events occurred, with a sampling event defined as the collection of one or more samples from a specific gaging station during a specific runoff event. Several sampling events spanned midnight. Maximum daily discharge at all gages on days when flow reached or exceeded 5 cfs at E050.1, E060.1, or E109.9; 40 cfs at E038; or 10 cfs at the other gages is presented in Table 2.3-1. Table 2.3-1 also summarizes the runoff events sampled at each station. In 2013, the threshold discharge at a station was reached 100 times, and sampling was conducted 50 of these times, resulting in an overall sampling efficiency of 50%. The reasons discharge was not analyzed at each storm event are categorized and presented in Table 2.3-2.

2.4 Samples Collected in the LA/P Watershed

Sample suites presented in the monitoring plan vary according to the monitoring location and are based on key indicator constituents for a given portion of the watershed. Following the Las Conchas fire, americium-241 was added to the analytical suite at E026 and E030, and cyanide was added at all stream gages downstream from the burn area in Los Alamos Canyon (E026, E030, E042.1, E050.1, and E109.9). Analyses were obtained from storm water collected at sampling locations as presented in Table 2.4-1. In cases where insufficient water was collected to perform all planned analyses, analyses were prioritized in the order presented in Table 2.4-1. Up to 24 samples per event were collected for suspended sediment analysis from a single ISCO sampler containing a 24-bottle carousel at the lower watershed gages (E042.1, E050.1, E059, E060.1, and E109.9); gages in upper DP Canyon (E038 and E039.1); and the upstream gage in Los Alamos Canyon, downstream from the Las Conchas burn area (E026) (Figures 1.0-1 and 2.1-1). Suspended sediment analyses at all other locations were obtained from the first and last sample in an ISCO sampler containing a 12-bottle carousel. Suspended sediment analyses when conducted using U.S. Environmental Protection Agency (EPA) Method 160.2, from an aliquot of sample, were reported using the designation “Total Suspended Solids” (TSS). Suspended sediment analyses when conducted using American Society for Testing and Materials method D3977-97, from an entire sample, were reported using the designation “Suspended Sediment Concentration” (SSC).

EPA target analyte list (TAL) metals were analyzed in filtered and unfiltered samples at all locations. When a sufficient sample volume was collected, radionuclides were analyzed in filtered and unfiltered samples at E109.9. Other required analyses were conducted from unfiltered samples. Sample collection times were recorded for each individual sample bottle filled, which allowed more precise estimation of discharge and SSCs at the time samples were collected.

Analyses were conducted using the analytical methods presented in Table 2.4-2. Detection limits are provided for comparison purposes but are affected by sample-specific factors that are not fully known until after the sample is analyzed. Such sample-specific factors can include available sample volume, matrix interferences, and sample dilution. In samples with suspended sediment content of approximately 10% or greater, analyses for selected radionuclides and metals were conducted on separate solid and liquid fractions. The final result reported by the analytical laboratory was a calculated concentration of the recombined solid phase and liquid phase analyses. Table 2.4-3 presents the prioritization matrix that was used to help guide the submission of analyses during 2013. The complete sequence and timing of analyses planned, samples collected, and analyses requested at each gage station are presented in Table 2.4-4.

Analyses planned and analyses performed differ during the year for several reasons including the following:

1. Incomplete sample volumes were collected.
    a. Minimum volumes are required to obtain specified detection limits.
    b. Lowest priority analyses are omitted when incomplete volumes are collected.
2. Samples are collected in glass or polyethylene bottles.
    a. Organic chemical analyses are conducted on samples collected in glass bottles.
    b. Boron was analyzed as an addition to the TAL metal suite, and samples were collected in polyethylene bottles.
3. The high sediment content of samples collected precluded the analysis of samples using analytical techniques designed for water matrixes; instead, samples with the highest sediment content were separated into solid and liquid fractions, which were analyzed separately and mathematically recombined.
4. The 12-bottle ISCO sampler at E109.9 was programmed incorrectly, causing incomplete sample collection during several storm events. The 12-bottle ISCO sampler was programmed to collect the first eight samples at 2-min intervals, then pairs of samples after 60- and 105-min following the peak of discharge. At E109.9, the 2-min interval between samples was not sufficient on several occasions. The effect of the programming error was to cause the 7th and/or 8th sample not to be collected. Table 2.3-2 includes a description of each case where programming was suspected of causing incomplete sample collection.~~Several samplers were programmed incorrectly, causing incomplete sample collection during several storm events.~~

2.5 Operational Issues

During 2013, the Laboratory authorized field crews to perform weekly inspections at gages and samplers in the LA/P watershed. Inspections were authorized to occur at sampling and stage measurement equipment following a rain event that resulted in discharge. Additionally, flumes at E039.1, E042.1, E050.1, E060.1, and E109.9 were inspected for sedimentation after each discharge event and cleaned on the first workday after sedimentation occurred. If inspectors were unable to repair damaged equipment at the time of inspection, additional resources were made available as quickly as possible to make repairs.

In a letter dated August 9, 2013, and received by the Laboratory on August 12, 2013, Pueblo de San Ildefonso notified the Laboratory that access to gage station E109.9 was being terminated. Pursuant to Section III.N of the Consent Order, on August 27, 2013, the Laboratory notified NMED of a force majeure event resulting from the termination of access to gaging station E109.9 on Pueblo land (LANL

2013, 249066). NMED responded on October 16, 2013, with a notice of agreement of the force majeure event (NMED 2013, 523698). The flume and stilling well at E109.9 were cleared of sediment 12 times during the 2013 monitoring season before access restrictions went into effect. The gage and equipment at E109.9 and E099 that had been damaged by flooding on September 13 have not been repaired.

Pursuant to Section III.H.3 of the Consent Order, on September 25, 2013, the Laboratory notified NMED of another force majeure event resulting from flooding on September 13 (LANL 2013, 250037). NMED responded on January 3, 2014, with a notice of agreement that a force majeure event had occurred (NMED 2014, 524130).

The sampling efficiency within the Los Alamos and Pueblo watershed before access restrictions at E099 and E109.9 caused by the August 12 Pueblo de San Ildefonso restrictions and the September 13 flooding was 74%, with 46 samples collected from 62 events. The sampling efficiency after September 13 flooding and after Pueblo de San Ildefonso access restrictions on August 12 was 11%, with 4 samples collected from 38 events.

2.6 Deviations from Work Plan

Gaging equipment at E050.1, E060.1, and E109.9 were to be inspected weekly throughout the year; automated samplers and equipment at other gages were to be inspected weekly from June 1 to October 31 and at least monthly from November 1 to May 31. Equipment found to be damaged or malfunctioning was to be repaired within 5 business days after the problem was discovered. Samples were to be retrieved from the field within 1 business day of sample collection using the following priority order, if necessary:

- Los Alamos above the Rio Grande at E109.9. Before access restrictions, 8 of 8 samples were collected within 1 business day.
- Lower watershed at E042.1, E050.1, E059, and E060.1. Before the September 13 storm, 7 of 7 samples were collected within 1 business day.
- Upper watershed at E026, E030, E055, E055.5, E056, CO101038, and CO111041. Before the September 13 storm, 7 of 15 samples were collected within 1 business day.
- DP Canyon at E038, E039.1, and E040. Before the September 13 storm, 3 of 15 samples were collected within 1 business day.

The duration between sample collection and sample retrieval is documented in Table 2.6-1. In 2013, samples were retrieved from gage stations 58 times. Samples were collected at gages 26 times within the first business day. The 9 samples collected on September 12 and 13 were all retrieved more than 1 d after collection because the Laboratory restricted access to gage stations and samplers to ensure safe working conditions. The sample collected on August 9 at E109.9 was not retrieved until September 11 during a temporary lifting of access restrictions.

Damage occurring to samplers and gage monitoring equipment is documented in Table 2.6-2. In 2013, 10 stations were damaged or malfunctioned a total of 28 times. The stations monitoring and sampling equipment were repaired within 5 business days on 22 of these occasions. Discharge could have exceeded triggering stage heights on 11 d because of silting or damage to gages, as noted in Table 2.6-2.

Battery voltage, stage height, and sensor function at each gage station were remotely monitored daily. An on-site inspection was performed if any malfunction or sample collection event was observed. Samplers and monitoring equipment at E050.1, E060.1, and E109.9 were physically inspected weekly between November 1, 2012, and October 31, 2013, except between December 18, 2012, and January 3, 2014, during Laboratory closure. Also, inspections were performed infrequently at E109.9 after August 12, 2013. Because gage station functionality was assessed daily using telemetry, physical inspections at other gages were performed on a more varied schedule that ranged from 1 to 23 d between inspections from June 1 to October 31, 2013, and ranged from 1 to 58 d between inspections from November 1, 2012, to May 31, 2013. The dates of each physical inspection at each station are documented in Table 2.6-3.

A lapse in federal appropriations beginning on October 1, 2013, continued for 18 d, until October 18, 2013. Following this programmatic pause, an additional 5 working days were necessary to safely restart field activities to allow subcontractors to return to work. Normal operations resumed on October 28, 2013. With the exception of inspections required at E050.1 and E060.1 to maintain the early notification system for the Buckman Direct Diversion Project, no inspections, maintenance, or repairs were performed between early October and early November (LANL 2013, 250080).

3.0 Watershed HYDROLOGY

The topography, geology, geomorphology, and meteorology of the LA/P watershed are quite complex and include mesas, canyons, and large elevation gradients; alluvium, volcanic tuff, pumice, and basalt; ephemeral streams, evolving stream networks (both laterally and vertically), and sediment-laden stream discharge; winter snowfall that can create spring snowmelt, intense summer monsoonal rainfall, and occasional late summer to fall tropical storm activity. Consequently, monitoring of the LA/P watershed runoff is also complex and challenging.

3.1 Drainage Areas and Impermeable Surfaces

Drainage areas unique to each gage station (Figure 2.1-1) were developed using the ArcHydro Data Model in ArcGIS. Model inputs were developed using an elevation grid created from 4-ft light detecting and ranging (LIDAR) images, a digital elevation model from 2000, surface-water drainage culverts from the Laboratory and the County of Los Alamos, and manual site-specific controls based on field assessments. Each drainage area defines the area that drains to the particular gage station from either the next upstream gage station or the headwaters of the watershed, as determined by the model inputs.

The impermeable surface area was derived from the urban-sparse-bare rock land cover type within the taxonomic-level classification system developed in the Land Cover Map for the Eastern Jemez Region (McKown et al. 2003, 087150). The specific grid data set selected to provide the land cover type was the quarter-hectare smoothed taxonomic level. Within each gage station drainage area, the urban-sparse-bare rock land cover type was spatially queried for total acreage based upon the number of 50-ft × 50-ft grid cells that fell within the drainage boundary. This total area was then divided by the total area of the entire drainage area to derive the percent impermeable surface area. The following assumptions were made in determining the percent impermeable surface area: (1) the only available land cover data were from 2002–2003, and therefore newer impermeable surfaces may not be captured; and (2) urban-sparse-bare rock grid cells that may have overlapped two drainage areas were spatially queried based upon where the center of the cell resided rather than the exact amount of each cell that fell within each drainage area.

A significant factor in the frequency of discharge at each gage is the ratio of permeable to impermeable surface area discharging to the gage or within the canyon drainage (Table 3.1-1). The Las Conchas fire affected this relationship because of soil hydrophobicity (infiltration decreases), lack of vegetation (through fall increases and evapotranspiration decreases), and lack of litter (infiltration decreases) following a medium- to high-intensity forest fire, leading to an increase in runoff, as occurred after the Cerro Grande fire (Gallaher and Koch 2004, 088747). The effect of the fire was particularly evident at

E109.9, which measures discharge from a total drainage area of 37,800 acres, with 11% impermeable surface area before the fire and an additional 13% of the watershed experiencing high- or moderate-severity burn during the fire. Gage E109.9 recorded discharge greater than 5 cfs only 4 times during the 2010 monitoring period (pre-fire), 15 times during the 2011 monitoring period (1 yr post-fire), 14 times during the 2012 monitoring period (2 yr post-fire), and 17 times before being destroyed by September 13, 2013, flooding (3 yr post-fire).

3.2 Water and Sediment Transmission

Figure 3.2-1 is a flow diagram of the LA/P watershed displaying each gage station and the location of sediment transport mitigation sites. Figure 3.2-2 shows box and whisker plots of suspended sediment (both TSS and SSC) for DP, Los Alamos, and Pueblo/Acid Canyons from up- to downstream over the past 4 yr of monitoring. September 13, 2013 plots are shown on a different scale. As expected, Los Alamos Canyon had higher concentrations of suspended sediment as a result of the Las Conchas fire (compare the pre-fire year 2010 with the post-fire years 2011, 2012, and 2013). Indeed, the SSCs in DP and Pueblo/Acid Canyons (with the exception of E059) are significantly less than in Los Alamos Canyon. In general, the suspended sediment in Los Alamos Canyon decreases from E026 to E050.1, particularly after crossing the Los Alamos Canyon low-head weir (between E042.1 and E050.1), increases greatly after the Guaje Canyon confluence (E099), and decreases slightly at E109.9. The influence of Guaje Canyon is extreme because 15% of the 21,000-acre watershed experienced moderate- to high-burn severity during the Las Conchas fire.

For runoff events exceeding sampling triggers in 2013, Figure 3.2-3 shows hydrographs for DP, Los Alamos, and Pueblo/Acid Canyons from up to downstream. Figure 3.2-3 also shows separate hydrographs for E099, which is a baseline station in Guaje Canyon not on Laboratory property but upstream of E109.9, along with E050.1, E060.1, and E109.9, which are lower boundary stations in the LA/P watershed. Table 3.2-1 summarizes the flood bore transmission downstream in the lower LA/P watershed, including travel time of flood bore from the upstream to the downstream station, peak discharges of the flood bore at the station, and the percent reduction in peak discharge between the stations for every sampled runoff event in 2013. The flood bore is defined as the leading edge of the storm hydrograph as it transmits downcanyon and peak discharge is the maximum 5-min instantaneous flow rate measured during a flood. The focus was on peak discharge because it is related to stream power, and in ephemeral streams in semiarid climates, the greater the stream power, the greater the erosive force, hence the greater the sediment transport (Bagnold 1977, 111753; Graf 1983, 111754; Lane et al. 1994, 111757).

As flood bores move from up- to downstream, peak discharge can either increase by means of alluvial groundwater and/or tributary contributions or decrease because of transmission losses (infiltration). In some events, downstream stations experienced discharge before upstream stations because of inputs from intermediate tributary drainages or localized storms centered closer to the downstream station. In 2013, this occurred one time between E050.1 and E109.9 because of discharge from Guaje Canyon, four times between E099 and E109.9 because of the close proximity of the two stations (the peaks occur within 10 to 20 min of one another), and one time on September 12, 2013, between E099 and E109.9, possibly because of localized precipitation in the E109.9 area. A summary of the peak discharge increases and decreases (Table 3.2-2) between stations provides insight into the stream network.

In the lower part of Los Alamos Canyon, between E050.1 and E109.9, the peak discharge increased for all 23 runoff events (96% average increase), indicating this section tends to gain rather than lose volume. Discharge above 5 cfs was measured at E050.1 for 11 events, 10 of which may have contributed to discharge at E109.9. Of the 10 events where E050.1 may have contributed to E109.9: during 4 events E099 may also have contributed; during 2 events E099 did not contribute; and during 4 events E099 and

E109.9 were not operational. Discharge above 5 cfs was measured at E060.1 for 2 events, both of which may have contributed to E109.9, 1 of which E099 may also have contributed, and 1 of which E099 and E109.9 were not operational. In the stretch from E060.1 to E109.9, peak discharge increased in all 24 runoff events (99% average increase), indicating this channel section tends to gain rather than lose volume. Gain in this channel comes from tributaries between the confluence of Pueblo and upper Los Alamos Canyon and E109.9 in lower Los Alamos Canyon.

These relationships indicate runoff from Guaje Canyon and localized precipitation contributed to discharge measured at E109.9 in multiple events (also see Figure 3.2-3). The discharge values for E099 are considered estimates because of the wide open channel and the validity of a rating curve for this site; however, when E099 was operational, the peak discharge increased for 17 of 20 runoff events (87% average increase) and decreased for 3 events (43% average decrease), indicating this section tends to gain rather than lose volume. Discharge above 5 cfs was measured at E099 for 14 events, 13 of which may have contributed to discharge at E109.9. Discharge above 5 cfs was measured at E109.9 for 24 events, 10 of which had no or very little discharge at E050.1, E060.1, and E099, indicating a fair number of localized precipitation events occurred.

Figure 3.2-4 shows the hydrograph and sedigraph for each station sampled through all or most of the duration of a runoff event plotted as time since the peak. The SSC data for September 12, 2013, for E026 and E109.9 was not used in calculations or plots because the sampler intake clogged (Figure 3.2-4).

Table 3.2-3 shows the Pearson's correlation coefficients between discharge and SSC for these stations and runoff events. Concurrent times as well as various time lags are displayed. Pearson's correlation coefficients are computed as follows:

$$corr_{Q_t,TSS_t} = \frac{\sum_{t=0}^{n}(Q_t-\bar{Q})(SSC_t-\overline{SSC})}{\sqrt{\sum_{t=0}^{n}(Q_t-\bar{Q})^2\sum_{t=0}^{n}(SSC_t-\overline{SSC})^2}}$$ **Equation 3.2-1**

where Q_t is the discharge at time t, SSC_t is the SSC at time t, n is the number of measurements to be correlated ($t = 1, 2, \ldots, n$), and

$$\bar{Q} = \frac{\sum_{t=0}^{n} Q_t}{n}$$ **Equation 3.2-2**

$$\overline{SSC} = \frac{\sum_{t=0}^{n} SSC_t}{n}$$ **Equation 3.2-3**

The peak SSC can occur after the peak discharge; thus, lags between 0 and 30 min are presented with the discharge lagging behind the SSC to align the peaks (after 30 min, the correlations were reduced for all stations and all runoff events). For example, when the Pearson's correlation coefficient between Q_t and SSC_{t+5}, is computed, the SSC time series begins 5 min after the discharge time series.

For stations E038, E039.1, E042.1, E050.1, E099, and E109.9, discharge is reasonably positively correlated to SSC with little to no lag. The exceptions are when the sampler intake clogged. Figure 3.2-5 shows the linear relationship between sediment yield and runoff volume for the stations where SSC was measured throughout the runoff event over the past 2 yr of monitoring; Table 3.2-4 presents the 2012 and 2013 values shown in Figure 3.2-5. Although SSC and instantaneous discharge are not always highly correlated as a result of localized precipitation, sediment availability, or antecedent conditions, the linear relationship between sediment yield and runoff volume is well established (Onodera et al. 1993, 111759; Nichols 2006, 111758; Mingguo et al. 2007, 111756). The July 2011 Las Conchas fire greatly affected this relationship during 2011 (LANL 2012, 222836); however, in 2012, and even more so in 2013, the relationship is tighter, perhaps indicating that the LA/P watershed is recovering.

The runoff volume for each event was computed as follows:

$$V = \sum_{i=0}^{n} Q(t_i)(t_{i+1} - t_i) \quad , \qquad \textbf{Equation 3.2-4}$$

Where n = the number of instantaneous discharge measurements taken throughout the runoff event,

t = the time, i, at which an instantaneous discharge measurement is taken, and

$Q(t_i)$ = the discharge (ft^3/s) at time t_i (multiplied by 60 to convert from ft^3/s to ft^3/min).

The mass of sediment for each runoff event was computed by

$$M = \sum_{j=0}^{n} Q(t_j)(t_{j+1} - t_j)\, SSC(t_j) \quad , \qquad \textbf{Equation 3.2-5}$$

Where n = the number of SSC samples taken throughout the storm event,

t_j = the time, j, at which an SSC sample is taken,

$Q(t_j)$ = the discharge (ft^3/s) at time t_j interpolated from the instantaneous discharge measurements taken at time t_i (multiplied by 60 to convert from ft^3/s to ft^3/min), and

$SSC(t_j)$ = SSC (mg/L) at time t_j (multiplied by 28.3×10^{-6} to convert from mg/L to kg/ft^3).

Figure 3.2-6, like Figure 3.2-5, shows the linear relationship between sediment yield and peak discharge, which is not as robust as the relationship between sediment yield and runoff volume during the past 2 yr. The effects of the Las Conchas fire can also be seen in the peak discharge relationship, which is tighter in 2012 and 2013 than it was in 2011.

Appendix B presents plots of discharge (hydrographs), precipitation (hyetographs) and SSC (sedigraphs) versus time for each date and station when samples were collected. The precipitation shown is associated with the precipitation-station-based Thiessen polygons that overlay the individual gage's watershed area, thus potentially contributing to the discharge measured at the station. As expected, discharge lags precipitation, and when several pulses occur in the hyetograph, consequential peaks occur in the hydrograph.

3.3 Geomorphic Changes

Topographic surveys to measure sediment deposition and erosion were conducted at the following sediment transport mitigation sites: Pueblo Canyon cross-vane structures, upper Pueblo Canyon willow-planting area, Pueblo Canyon wing ditch, lower Pueblo Canyon willow-planting area, upper Los Alamos Canyon sediment detention basins, DP Canyon GCS, and Los Alamos Canyon low-head weir. A complete summary of the methods and detailed results is provided in Appendix A.

Although the September 2013 flood event resulted in significant erosion in most surveyed areas in Pueblo Canyon, the magnitude of the erosion was likely reduced by the sediment mitigation structures and willow plantings. The engineered structures in Los Alamos and DP Canyons appear to have enhanced sediment deposition in these areas. No actions are recommended at this time, except for continued annual resurveys.

3.3.1 Pueblo Canyon

Net erosion occurred in most surveyed areas in the Pueblo Canyon watershed during monsoonal flood events in 2013. This is in contrast to net deposition measured in most surveyed areas in 2010, 2011, and 2012. The Cross Vane Structure, Upper Pueblo Willow, Lower Pueblo Willow, and Pueblo Canyon GCS sediment mitigation areas all experience net erosion, whereas the Wing Ditch area experienced net deposition. The relatively large magnitude of the September 2013 flood event resulted in significant channel widening and incision in the areas that experienced net erosion. Many previously established willows were uprooted and washed downstream, reducing the density of willows in all willow planting areas. However, in areas with previously established thick willow patches (the upper two-thirds of the upper Pueblo willow planting area), willows that were laid down by monsoonal floods have resprouted and should effectively recolonize the area. ~~Willows have also been replanted in the lower Pueblo willow planting area.~~ The Pueblo Canyon GCS was effective in causing sediment deposition in the lower part of the Pueblo Canyon GCS monitoring area. The survival of thick willow patches and sedimentation above the Pueblo Canyon GCS and in the Wing Ditch area are consistent with the goal of the sediment transport mitigation work plans (LANL 2008, 101714; LANL 2008, 105716). Field observations indicate that much of the eroded sediment in Pueblo Canyon was originally deposited in the floods that occurred after the Cerro Grande fire, which contains relatively low contaminant concentrations. In addition, some of the bank erosion includes uncontaminated pre-1943 sediment, and erosion of these areas does not contribute to the contaminant load in storm water. However, some areas of post-1942, pre–Cerro Grande sediment deposits were also eroded, adding to the contaminant load in storm water.

3.3.2 Los Alamos Canyon

Net sediment deposition occurred in most surveyed areas in the Los Alamos Canyon watershed in 2013, which is consistent with the goal of the sediment transport mitigation work plans (LANL 2008, 101714; LANL 2008, 105716). Net sediment deposition in DP Canyon, the upper Los Alamos Canyon sediment detention basins, and the Los Alamos weir in 2013 is greater than recorded in 2012 (or in previous years). In fact, approximately 6000 yd^3 of sediment was removed from the weir in 2013 (LANL 2013, 251741). It appears that sediment deposition behind the engineered structures in the Los Alamos Canyon watershed has been enhanced by the construction of these structures, although how far this effect propagates upstream behind the DP Canyon GCS is uncertain.

3.4 Impact and Efficiency of Watershed Mitigations

The DP and Pueblo Canyon GCSs were constructed to help reduce erosive flood energy and to cause upstream aggradation to bury existing stream channels, potentially to bury existing floodplain deposits, and in Pueblo Canyon, to stabilize an eroding wetland. As a result, the GCSs should help reduce sediment transported during flood events. The Pueblo Canyon wing ditch was designed to divert floodwater from the main channel into an adjacent abandoned channel, spreading water more broadly over a wetland and decreasing surface water flow velocities. Willows were planted in Pueblo Canyon to aid in surface stabilization, flow reduction, and sediment accumulation.

DP Canyon: In 2013, storm water sampling conducted in DP Canyon on June 14, June 30, July 12, and July 28 was performed above (E038) and below (E039.1) the GCS and associated floodplains (Figure 3.4-1). Analyses performed from samples collected during these runoff events allow direct evaluation of changes in discharge and sediment transport through this part of DP Canyon. Sample collection began within 5 min of initial discharge (triggered above 40 cfs for E038 and 10 cfs for E039.1). For E038 and E039.1, respectively, the calculated sediment yield is: June 14, 5.1 and 0.3 yd^3; June 30, 5.0 and 0.1 yd^3; July 12, 38.8 and 33.7 yd^3; and July 28, 2.1 and 0.4 yd^3 (Table 3.2-4). Between these two stations, or from above to below the GCS, there is a 178%, 192%, 14%, and 136% relative percent difference (RPD) decrease in sediment yield for these events, respectively.

Decreasing storm water velocity allows for infiltration to be increased. Increasing infiltration reduces the distance that a storm surge travels in the stream channel and decreases the distance that sediment and associated contaminants entrained in the water column travel. Increasing infiltration reduces peak discharge but can also decrease the total volume of storm water passing through a gage station. In 2013, the peak discharge decreased in 12 of 20 runoff events between E038 and E039.1, with an average decrease of 66%, and increased in 8 of 20 events with an average increase of 22% (Table 3.4-1). For the June 14, June 30, July 12, and July 28 events, the runoff volume for E038 and E039.1, respectively, is 3.0 and 1.3 acre-ft; 1.9 and 0.8 acre-ft; 13.7 and 16.3 acre-ft; and 1.6 and 1.2 acre-ft (Table 3.2-4). Between these two stations, or from above to below the GCS, there is a 77%, 82%, and 26% RPD decrease in runoff volume on June 14, June 30, and July 28, and a 17% RPD increase in runoff volume on July 12, most likely caused by additional contributions from local runoff because of the widespread nature of the July 12 storm.

In addition to examining coinciding sampling events, watershed mitigation performance can be assessed by examining overall statistics over time. Figure 3.4-2 shows box and whisker plots for E038 and E039.1 for TSS, SSC, and peak discharge over the past 4 yr of monitoring. These plots indicate overall reductions in TSS and SSC over the 4 yr and minor reductions in mean peak discharge (i.e., erosive force) over the 4 yr through this part of DP Canyon, consistent with the goals of the sediment transport mitigation activities.

Pueblo Canyon: In 2013, no sampling was performed in Pueblo Canyon above (E059) or below (E060.1) the GCS and upstream wetland for the same runoff event because the only event with discharge at both stations was the September 13 event, which destroyed both stations (Table 3.4-1). Therefore, overall statistics over the past 4 yr of monitoring must be used to assess performance. Figure 3.4-2 shows box and whisker plots for E059 and E060.1 for TSS, SSC, and peak discharge. As these plots indicate, peak discharge was effectively attenuated through the Pueblo Canyon wetland in 2010 and 2013, resulting in little to no transport from the upper Pueblo watershed into lower Los Alamos Canyon. This is consistent with the goals of the sediment transport mitigation activities. It should also be noted that discharge was measured at E059 for three events during which no discharge was measured at E060.1, regardless of the tributary from the Los Alamos Airport that regularly discharges storm water runoff into the wetland. Thus, the discharge magnitude is being reduced through this area, which is a primary goal of the mitigation actions. In addition, TSS and SSC magnitude was reduced through the mitigation structures in 2010 (no samples were collected at E060.1 during 2011, 2012, or 2013).

Los Alamos Canyon: Sampling was performed in Los Alamos Canyon on July 12, August 5, and September 10 above (E042.1) and below (E050.1) the low-head weir. Analyses performed from samples collected during these runoff events allow direct evaluation of the effect of the weir and associated basins on flow and sediment transport. Each event had downstream decreases in peak discharge, total runoff volume, and SSC (Figure 3.4-3). More specifically, between E042.1 and E050.1 for the three events sampled at the same time, there is a 182%, 132%, and 144% RPD decrease in sediment yield, respectively, and a 129%, 139%, and 93% RPD decrease in runoff volume, respectively. In addition, in 2013, the peak discharge decreased in 12 of 15 runoff events between E042.1 and E050.1, with an average decrease of 80% (Table 3.4-1). The peak discharge increased in 3 of 15 runoff events between E042.1 and E050.1, with an average increase of 44%; however, these storms occurred after the September 13 event during which the low-head weir was filled and continued to dewater for several months. Sediment trapping efficiency is expected to be higher in smaller events and events early in the season before the retention basins have filled with water. Flow is reduced through the weir and the upstream sediment retention basins, allowing sediment to settle out of suspension; thus, this mitigation feature is performing as designed.

In addition to examining coinciding sampling events, performance of the weir and upstream sediment retention basins can be assessed by examining overall statistics over the past 4 yr of monitoring. Figure 3-4.2 shows box and whisker plots for E042.1 and E050.1 for TSS, SSC, and peak discharge. These plots show major reductions in TSS and SSC, particularly in response to the post-fire years (2011, 2012, and 2013) and minor reductions in mean peak discharge; thus, the weir is performing well.

4.0 ANALYTICAL RESULTS

Appendix C contains all analytical results obtained from storm water runoff samples collected in the LA/P watershed during 2013. Data packages for these analyses are included with this report (on CD).

4.1 Data Exceptions

Storm water samples collected at E109.9 on September 12, 2013, were impacted by flooding on September 13. During September 13 flooding, the Greenlee storage box was filled with flood water and sediment. The ISCO samplers were tipped on edge and sample bottles were filled with flood water. Samples were analyzed despite the loss of integrity to provide insight into water passing the gage during the peak of flooding on September 13. Figures 3.2-4 and 4.1-1 show the lack of correlation between September 12 discharge and SSC of the individual sample bottles.

Low bias of analytical results in high-solid content storm water has been observed in analyses performed by gamma spectroscopy, alpha spectroscopy, inductively coupled plasma (ICP) mass spectroscopy and ICP optical emission spectroscopy. This low bias can be avoided when the solid phase and liquid phase of each biphasic sample are analyzed separately and the results mathematically recombined. Both samples collected at E099 and 7 of 9 samples collected at E109.9 in 2013 contained sufficient sediment to perform biphasic analyses. Calculated biphasic results are reported with an analytical method ending in "_CALC."

4.2 Analytes Exceeding Comparison Values

As explained in the IMWP, several actions were taken as part of an interim measure under Section VII.B of the Consent Order to mitigate transport of contaminated sediments in the LA/P watershed (LANL 2008, 101714). The analytical results from monitoring are presented and evaluated within this context. The mitigation actions were not undertaken with the objective of reducing concentrations of water-borne contaminants to specific levels, and the analytical results are therefore not compared with water-quality standards or other criteria for that purpose or for the purpose of evaluating compliance with regulatory requirements. For this report, monitoring results are compared with water-quality standards ~~to narrow the list of specific constituents for conceptual model discussions in this report and~~at the request of NMED to provide a basis for potential future revisions to the analytical suites.

The New Mexico Water Quality Control Commission (NMWQCC) Standards for Interstate and Intrastate Surface Waters (New Mexico Administrative Code 20.6.4) establish surface water standards for New Mexico. ~~The NMWQCC classifies all surface water within the Laboratory boundary with segment-specific designated uses.~~ Surface water within Pueblo and Acid Canyons are unclassified, nonperennial waters of the state under the New Mexico Administrative Code (NMAC) 20.6.4.98, with segment-specific designated uses of livestock watering, wildlife habitat, marginal warm water aquatic life, and primary contact. The criteria applicable to the marginal warm water aquatic life designation include both acute and chronic aquatic life criteria and the human health organism only criteria. ~~The LA/P stream segments~~ Surface water within Los Alamos and DP Canyons is classified as ephemeral ~~or~~ and intermittent waters of the state under NMAC 20.6.4.128, with segment-specific designated uses of limited aquatic life, livestock watering, wildlife habitat, and secondary contact. The criteria applicable to the limited aquatic life designation include the acute aquatic life criteria and the human health-organism only criteria but do not include the chronic aquatic life criteria. In all cases, storm water results are compared with the lowest applicable criteria.

~~Some of the standards are for total concentrations, which are compared with data from unfiltered surface water samples. Other standards are for dissolved concentrations, which are compared with data from filtered samples.~~ Water-quality criteria for total and total recoverable pollutants are compared with unfiltered surface water sample concentrations. The water-quality criterion for total recoverable aluminum is for filtered storm water samples using a 10-µm pore size, which were not collected in 2013. Other water-quality criteria are for dissolved concentrations of pollutants, which are compared with filtered storm water samples using a 0.45-µm pore size. Acute and chronic aquatic life criteria for dissolved cadmium, chromium, copper, lead, manganese, nickel, and zinc; acute aquatic life criteria for dissolved silver are calculated based on the hardness of each sample. Because chromium is not analyzed as separate trivalent chromium and hexavalent chromium species, chromium results are compared with the lowest standard, hexavalent chromium, dissolved. The water-quality criteria for dioxins are the sum of the dioxin toxicity equivalents expressed as 2,3,7,8 tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD). Table 4.2-1 presents the NMWQCC standards used as numeric values for comparison with monitoring results for the purposes stated above. When chemicals have comparison values for multiple designated uses, the ~~smallest~~ lowest value was selected to compare with analytical results. Table 4.2-2 presents the comparison of detected analytical results from 2013 with the standards in Table 4.2-1. Analytical constituents ~~most frequently~~ detected above these comparison values are ~~aluminum,~~ copper, total cyanide, lead, total mercury, total selenium, adjusted gross alpha, total PCBs, and dioxins and furans.

Dioxin and furan congeners were detected in 4 of 6 samples analyzed in 2013. TCDD(2,3,7,8-) was not detected in the samples in which it was analyzed. These samples were analyzed for PCBs, including 11 PCB congeners with assigned toxicity equivalency factors (TEFs). ~~Additionally, 43 samples analyzed for PCBs were reported to contain detected concentrations of eleven PCB congeners with assigned toxicity equivalency factors (TEFs). These dioxin and furan and PCB results~~ PCB and other dioxin congeners with detected concentrations were converted to concentrations equivalent in toxicity (toxic equivalency quotients [TEQs]) to ~~2,3,7,8-tetrachlorodibenzodioxin (~~2,3,7,8-TCDD~~)~~ for comparison with the NMWQCC standard. The TEQs were calculated using the TEFs presented in Table 4.2-3 (Van den Berg et al. 2006, 106990). The detected concentration of each congener was multiplied by its TEF, and these products were summed for each detected congener to obtain the TEQ for a sample. The TEQs for each sample analyzed for dioxins and furans or PCBs are presented in Table 4.2-4, and range over 4 orders of magnitude (1.550×10^{-8} to 4.087×10^{-4} µg/L).

4.3 Relationships between Discharge, SSC, and Contaminant Concentrations

Discharge was calculated from stage height using a rating curve, which is the relationship between discharge in cubic feet per second and height of the water in feet, developed for each individual gage. Stage height was measured at 5-min interval and logged continuously during each sampled storm event. SSC and particle size were measured during each storm in conjunction with inorganic and organic chemicals and radionuclides. Because of low bias inherent in TSS analyses, TSS was measured less frequently in 2013 than in previous years.

TSS, SSC, and instantaneous discharge estimates were calculated for each sample using a linear relationship between the two corresponding analytically determined TSSs and SSCs or the two corresponding physically measured discharge, as follows:

$$y = mx+b, \qquad \textbf{Equation 4.3-1}$$

where y = the calculated TSS, SSC, or discharge at the time of sample collection,

m =the slope of the line,

x = the time differential in minutes between TSS or SSC sample collection or discharge measurements, and

b = the concentration of analytically determined TSS or SSC before sample analyses or corresponding physically determined discharge.

The slope m is determined by dividing the difference in TSS, SSC, or discharge by the difference in time, in minutes, between TSS or SSC sample collection or discharge measurements before and after analytical sample collection. Using this equation, TSS, SSC, and instantaneous discharge were calculated for samples collected. Where analytical results are not bounded by sediment results, the concentration of the nearest sediment result is used as an estimate of the sediment concentration at the time the sample was collected. If TSS or SSC was not measured during a storm an estimate was not produced. The calculated TSSs, SSCs, and instantaneous discharges are presented in Table 4.3-1.

Relationships between calculated SSC and filtered and unfiltered analytical results can be used to evaluate contaminant sources in the LA/P watershed. This evaluation in turn provides insight into ~~performance of watershed mitigations conducted in the watershed and~~ the ~~usefulness~~ utility of future monitoring strategies. Background concentrations of inorganic chemicals, naturally occurring radionuclides, and fallout radionuclides within uncontaminated canyon sediments at the Laboratory are presented in a report (LANL 1998, 059730) and accepted by regulatory authorities. In unfiltered storm water with known concentrations of suspended sediment, 95% of individual storm water samples containing only background concentrations of inorganic chemicals, naturally occurring radionuclides, and fallout radionuclides will be below an upper tolerance limit (UTL) for canyon sediments. These background sediment values are not interchangeable with surface water–quality values. Comparing background sediment values with unfiltered storm water is useful as a qualitative indicator of the presence and transport of a contaminant in storm water. Where the concentrations of metals and radionuclides in unfiltered storm water are greater than background concentrations, external contributions to background can be assumed.

Figures 4.3-1 through 4.3-32 present scatterplots of metals and radionuclides analyzed in Los Alamos and Pueblo Canyons with associated American Society for Testing and Materials (ASTM) method C1070-01 suspended sediment measurements collected in 2012 and 2013. Fewer results from 2012 were associated with the ASTM suspended sediment measurement method. Suspended sediment and associated analytical data points were removed from the plots from storm water collected at E038 on July 7, 2012, where suspended sediment was underestimated, from storm water collected at E109.9 on September 12, 2013, where sample integrity was not maintained, and from storm water collected at CO101038 and CO111041 at the detention basins below the SWMU 01-001(f) drainage where canyon sediments are not monitored.

Plots show unfiltered metals concentrations in storm water less than the background UTL for canyon sediments for 10 metals: aluminum (Figure 4.3-1), antimony (Figure 4.3-2), arsenic (Figure 4.3-3), beryllium (Figure 4.3-4), iron (Figure 4.3-5), mercury (Figure 4.3-6), nickel (Figure 4.3-7), selenium (Figure 4.3-8), silver (Figure 4.3-9), and thallium (Figure 4.3-10). Also, activities of unfiltered uranium-234 (Figure 4.3-11), uranium-235 (Figure 4.3-12), and uranium-238 (Figure 4.3-13) in storm water are less than the background UTL for canyon sediments at all LA/P watershed gages. Despite the lack of a source of these metals and radionuclides above background values, dissolved aluminum has concentrations of filtered metals in storm water above applicable water-quality standards.

Barium (Figure 4.3-14), cobalt (Figure 4.3-15), and manganese (Figure 4.3-16) frequently exceed concentrations expected solely from canyon sediment carried in unfiltered LA/P storm water. However, unfiltered barium, cobalt, and manganese concentrations in storm water are strongly correlated across all sediment concentrations and at all Los Alamos and Pueblo gage stations, Figure-4.3-17. The strong correlation indicates canyon sediments are the single naturally occurring background source for barium, cobalt, and manganese in the LA/P watershed. Filtered manganese results are sometimes above the acute aquatic life standard in samples with greater than 10% suspended sediment content. The three largest results for these three metals were obtained at E030 and E042.1 during 2012 and were not repeated during 2013.

Results for unfiltered cadmium (Figure 4.3-18), chromium (Figure 4.3-19), copper (Figure 4.3-20), lead (Figure 4.3-21), vanadium (Figure 4.3-22), and zinc (Figure 4.3-23) show results greater than would be expected of sediment background in low sediment content samples. Filtered zinc and copper results are sometimes above acute aquatic life standards. The “Evaluation of Sediment and Alluvial Groundwater in DP Canyon” (LANL 1999, 063915) showed that in DP Canyon cadmium, chromium, copper, lead, and zinc have a Los Alamos townsite origin. The Los Alamos and Pueblo Canyons investigation report (LANL 2004, 087390), which includes DP Canyon, paints a more complex picture of sources of metals from Los Alamos town site, historical releases from the Laboratory, and ash from wild fire. No metals originating from the Las Conchas fire, Laboratory activity or Los Alamos townsite were above concentrations expected in background canyon sediments at E109.9.

Non-detected metals are reported at the value of the quantitation limit but non-detect is determined to the value of the method detection limit (MDL). Nondetected filtered results for silver (Figure 4.3-9), cadmium (Figure 4.3-18), and thallium (Figure 4.3-10) are greater than their respective water-quality standards. The reported MDL for dissolved silver is 0.2 µg/L, the MDL for dissolved cadmium is 0.11 µg/L, and the MDL for dissolved thallium is 0.45 µg/L. Because the MDLs are below their respective water-quality standards, the analytes, if present, are detected at concentrations below the standards.

The Los Alamos and Pueblo Canyons investigation report (LANL 2004, 087390) identifies americium-241, cesium-137, plutonium-238, plutonium-239/240, and strontium-90 as radionuclide chemicals of potential concern. DP and Los Alamos Canyons downcanyon from SWMU 21-011(k) contain the largest amounts of americium-241, cesium-137, and strontium-90 in the watershed. Acid and Pueblo Canyons downcanyon from the TA-01 and TA-45 outfalls and from SWMU 00-030(g) contain an estimated 86% of the plutonium-239/240 inventory at the Laboratory.

Activities of cesium-137 (Figure 4.3-24) in storm water are detected above UTLs for canyon sediments at E040, E042.1, E050.1, and E109.9. Cesium-137 is below canyon sediment background at E026 and E030 in Los Alamos Canyon, at E038 and E039.1 in DP Canyon, and at all locations in Pueblo Canyon. Normalized concentrations of cesium-137 decrease from E040 downcanyon. This identifies DP canyon, below the gage at E039.1 as the current source of cesium-137 activity in the Los Alamos/Pueblo watershed and is consistent with the findings in the Los Alamos and Pueblo Canyons investigation report.

Activities of strontium-90 (Figure 4.3-25) in storm water are detected above UTLs for canyon sediments at E039.1, E040, E042.1, and E050.1. Strontium-90 is below canyon sediment background at E026, E030, and E109.9 in Los Alamos Canyon, at E038 in DP Canyon, and at all locations in Pueblo Canyon. Normalized concentrations of strontium-90 decrease from E039.1 downcanyon. This identifies DP Canyon, above the gage at E039.1 as the source of strontium-90 activity in the Los Alamos/Pueblo watershed and is consistent the findings in the Los Alamos and Pueblo Canyons investigation report (LANL 2004, 087390).

Activities of americium-241 (Figure 4.3-26) in storm water are detected above UTLs for canyon sediments at E030, E039.1, E040, E042.1, and E050.1. Americium-241 is below canyon sediment background at E026 and E109.9 in Los Alamos Canyon, E038 in DP Canyon, and at all locations in Pueblo Canyon. The largest normalized concentrations of americium-241 are at E040 and E042.1. This is consistent with SWMU 21-011(k) as the source of americium-241 activity in DP and Los Alamos Canyons.

Americium-241 was added to the analytical suite at E026 and E030 following the Los Conchas fire. Concentrations of americium-241 normalized to suspended sediment content increased to levels above canyon sediment background values in 2011 and 2012. In 2013, americium-241 decreased to levels below 0.04 pCi/g expected in canyon sediments not affected by Laboratory activities or ash at E026 and E030. Figure 4.3-27 shows the activities of americium-241 in storm water normalized to SSCs at E026 and E030 since 2000.

Activities of plutonium-239/240 (Figure 4.3-28) in storm water do not exceed background UTLs at E026 in Los Alamos Canyon or at the head of Pueblo Canyon at E055. Other gages in the LA/P watershed are found to contain plutonium-239/240 above canyon sediment background concentrations. The largest exceedances of background UTLs are measured at E055.5 and E056 in Acid Canyon. Exceedances of background UTLs are also observed at E030 in Los Alamos Canyon and at E039.1 and E040 in DP Canyon. Sources of plutonium-239/240 are identified in Los Alamos Canyon above the gage at E030, DP Canyon above the gage at E039.1, and most prominently in Acid Canyon. These observations are consistent with the findings in the Los Alamos and Pueblo Canyons investigation report (LANL 2004, 087390). Plutonium-239/240 normalized to suspended sediment measured at E109.9 was below canyon sediment background before the flooding of September 13. However, the flood carried storm water with sediments containing plutonium-239/240 approximately 10 times background from Pueblo Canyon.

Activities of plutonium-238 (Figure 4.3-29) in storm water do not exceed background UTLs at E026 and E030 in Los Alamos Canyon; at E038, E039.1, or E040 in DP Canyon; or at E055 in upper Pueblo Canyon. The largest exceedances of detected plutonium-238 are at E042.1 and E050.1, indicating a primary source in Los Alamos Canyon above E042.1, which is consistent with a primary source from SWMU 21-011(k) discharges. Activities of plutonium-238 normalized to SSCs in storm water collected on July 8 at E109.9 were 1.2 and 1.4 times the canyon sediment background of 0.006 pCi/g. The September 13 flood also contained storm water with sediments transporting plutonium-238 from Pueblo Canyon that were above canyon sediment background but were not detected.

Concentrations of total PCBs (Figure 4.3-30) in storm water do not correlate with the sediment content of the sample. In the LA/P watershed, the human health organism only standard of 0.00064 µg/L is exceeded at all gages in all samples. The acute aquatic life standard of 2 µg/L is not exceeded in storm water samples at any gage station. The distribution and concentration of PCBs in the LA/P watershed is consistent with a complex mixture of sources, including atmospheric deposition, townsite runoff, and Laboratory sources. The largest concentrations of total PCBs were detected at E030 in Los Alamos Canyon and at E059 in Pueblo Canyon from Laboratory sources.

Cyanide was added to the analytical suite at gages E026, E030, E042.1, E050.1, and E109.9, which were affected by ash after the Los Conchas fire. Concentrations of total cyanide in storm water were detected above the acute aquatic life standard of 22 µg/L twice in 2013 (Figure 4.3-31). Concentrations of cyanide normalized to suspended sediment content increased to levels above canyon sediment background values in 2011 and 2012. In 2013, cyanide decreased to levels below 0.82 mg/kg, as expected in canyon sediments not affected by Laboratory activity or ash. Figure 4.3-32 shows the activities of cyanide in storm water normalized to SSCs at all gage stations since 2000.

4.4 Storm Water Sampling below SWMU 01-001(f)

Results for the five storm water samples analyzed for total PCBs collected at the inlet to the upper detention basin below the SWMU 01-001(f) drainage range from 5.3 μg/L to 21.8 μg/L. Total PCB results for the two storm water samples collected at the culvert at the terminus of the vegetative buffer below the lower basin are 0.108 μg/L and 0.398 μg/L. Total PCB results are within the range of results for samples collected in 2011 and 2012. The higher result suggests the hill slope continues to be a source of PCBs even after sediment and rock were removed during corrective action at SWMU 01-001(f) in 2010. Analytical results from all samples collected at locations CO101038 and CO111041 are presented in Table 4.4-1.

5.0 CONCLUSIONS

The Los Alamos Canyon watershed experienced a large number of runoff events in 2013.Storms from September 10 to September 13, 2013, generated intense flooding, damaging the gaging network and storm water controls in the Los Alamos and Pueblo watershed. The Las Conchas burn area in the upper watersheds of Los Alamos Canyon and Guaje Canyon continue to contribute to increasing storm water discharges, but concentrations of fire-related cyanide and americium-241 have returned to pre-fire levels. Attenuation of flow and associated sediment transport is a primary goal of the sediment transport mitigation activities, and despite erosion through the Pueblo Canyon wetland, controls performed successfully and as intended in 2013.The 2013 monitoring data in upper Los Alamos watershed indicate a substantial reduction in SSC and peak discharge as floods passed through the low-head weir and associated sediment retention basins. These structures are, therefore, performing as designed. By contrast, the SSC was much higher at gaging station E109.9 in lower Los Alamos Canyon as a result of floods in Guaje Canyon from the Las Conchas burn area.

DP Canyon primarily receives runoff from the Los Alamos County townsite. Direct comparison of runoff and sediment yield above and below the GCS and upstream floodplains was possible during four storms. A reduction in sediment yield was observed between bounding stations (E038 and E039.1), and sediments continue to aggrade above the GCS. The DP Canyon mitigations are performing as designed.

Net sediment deposition occurred in most surveyed areas in the Los Alamos and DP Canyons experiencing monsoonal flood events in 2013, which is consistent with the goal of the sediment transport mitigation work plans. Pueblo Canyon experienced net erosion but the GCS and wetlands were effective in decreasing effects of the September 13 flood. Sediments containing plutonium-238 and plutonium-239/240 were transported to the Rio Grande from Pueblo Canyon during the September 13 flood.

Analytical data collected from storm water samples in 2013 indicate that for the 8 analytes exceeding NMWQCC water-quality standards (used as comparison values), total PCBs has a recognized source at Laboratory sites and off-site transport. The weir and associated sediment retention basins were effective at substantially reducing this transport. Concentrations of PCBs measured at E109.9 in lower Los Alamos Canyon are similar to those measured in upper Los Alamos Canyon above Laboratory sites at E026 and are consistent with the transport of PCBs from the Las Conchas burn area down Guaje Canyon. PCBs in the burn area have a global source because of atmospheric deposition and have accumulated in the watershed over time.

6.0 REFERENCES AND MAP DATA SOURCES

6.1 References

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