Appendix A

2013 Geomorphic Changes at Sediment Transport Mitigation Sites in the Los Alamos and Pueblo Canyons Watershed

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Attachments

Attachment A-1 Photographs of Sediment Transport Mitigation Sites in the Los Alamos and Pueblo Canyons Watershed
Attachment A-2 Cross-Section Survey Data (on CD included with this document)

A-1.0 INTRODUCTION

This report evaluates geomorphic changes that occurred in 2013 at sediment transport mitigation sites in the Los Alamos and Pueblo Canyon watersheds within and near Los Alamos National Laboratory (LANL or the Laboratory). Survey data reported previously (LANL 2011, 200902; LANL 2012, 218411) are compared with subsequent survey data obtained in fall 2013 and winter 2014, following the summer 2013 monsoon season, as specified in the "Los Alamos National Laboratory Environmental Surveillance Program Sampling and Analysis Plan for Sediment, 2012" (LANL 2012, 213568). These surveys will be repeated after the 2014 monsoon season, and results will be presented in a report to the New Mexico Environment Department (NMED) by ~~March 31~~May 15, 2015. NMED has specified that results of inspections of stream bank armoring in the south fork of Acid Canyon be included in the annual report on geomorphic changes in the Los Alamos and Pueblo Canyon watersheds (NMED 2010, 109693), and these results are included herein. NMED has also specified that monitoring reports include information on the health and success of willow plantings and photographic documentation of willow plantings, grade-control structures (GCSs), and examples of erosion and deposition at surveyed cross-sections (NMED 2011, 204349), and these are also included herein. Figure A-1.0-1 shows the locations of sites discussed in this report, and Attachment A-1 presents photographs of the sediment transport mitigation sites.

A-2.0 HYDROLOGIC EVENTS DURING 2013 MONSOON SEASON

The largest runoff events in 2013 at the sediment transport mitigation sites in the Los Alamos and Pueblo Canyon watersheds occurred following heavy rains that fell on the Pajarito Plateau, the Los Alamos townsite and the Sierra de los Valles from September 10 through 15, 2013. Total rainfall measured by rain gages that recorded throughout this entire event ranged from 5.5 to 6.5 in. (Pueblo Canyon gages), 5.5 in. (LA Canyon gage), and 4.8 to 5.5 in. (DP Canyon gages).The maximum measured discharge at these sites occurred in Pueblo Canyon on September 13, 2013, at the E059 gaging station above the Los Alamos County wastewater treatment plant (WWTP). The peak discharge at E059 was 1540 cubic feet per second (cfs). No flow was recorded at this gaging station in 2012. Most gages in Pueblo, DP and Los Alamos Canyons were rendered inoperable due to this high-discharge event, and no data are available on September 14 and 15. Maximum discharges in Los Alamos and DP Canyons were also measured on September 13, as described below.

- Peak discharge was between 310 and 550 cfs below the DP Canyon GCS (310 cfs at E038 in upper DP Canyon and 550 cfs at E040 in lower DP Canyon. This discharge is an order of magnitude greater than the 2012 peak discharge, which was 79 cfs at E038, recorded on October 12, 2012, and 46 cfs at E040, recorded on October 12, 2012.
- Peak discharge in Los Alamos Canyon was 970 cfs at E030 in upper LA Canyon above the confluence with DP Canyon. This discharge is about 7.5 times greater than the 2012 peak discharge, which was 130 cfs at E030, recorded on July 11, 2012.

In some areas of Pueblo Canyon, the large September 2013 floods extended beyond the limits of the originally established cross-sections. These areas include the upper Pueblo willow sections, the lower Pueblo willow sections, and the Pueblo Canyon GCS sections. In each area some sections had to be extended whereas others were of sufficient length that 2013 floods did not extend beyond the existing section. In cases were cross-sections had to be extended, a series of potholes was dug to measure the thickness of 2013 sediment deposits within the newly established segments of the cross-sections. At each point, 2013 sediment thickness was subtracted from the elevation of the 2013 data point to determine the elevation of the pre-2013 profile at that location. These new points are referenced as "Pre-2013 sediment data point" in the legend for figures that include extended cross-sections.

A-3.0 SURVEYS AT SEDIMENT TRANSPORT MITIGATION SITES

Surveys were conducted at all sediment transport mitigation sites specified in the 2012 monitoring plan (LANL 2012, 213568). Surveys were conducted using a combination of a differentially-corrected global positioning system (GPS) and a total station tied to GPS control points, depending on tree cover. Surveys were supplemented with sediment thickness measurements obtained from hand-dug or hand-augered holes at some locations. The general locations of all survey areas are shown in Figure A-1.0-1, and these surveys are discussed below. Surveyed cross-sections are shown in figures with a vertical exaggeration (VE) of 2.5 times, and channel thalweg profiles are shown with a VE of 5 times, 15 times, or 20 times. Raw survey data (x and y coordinates using the New Mexico State Plane coordinate system and elevations of all survey points) for surveyed cross-sections are included electronically as Attachment A-2 (on CD included with this document). Distances along each cross-section and along each thalweg profile that are used for the figures in this report were calculated using basic geometry (Pythagorean theorem) and are also included in Attachment A-2.

Cross-section and thalweg figures include the latest resurvey data and previous survey data that the current data points were compared with, indicating where erosion and deposition have occurred along each section over the last year. Each surveyed cross-section was field checked to confirm elevational differences between surveys and verify that erosion or deposition indicated by the plotted data were not artifacts of the surveys (such as can result from different survey point spacing or slight differences in survey location) or topographic changes not related to flooding (e.g., gopher mounds, road blading outside the floodplain, or slope wash from side hills/drainages). The net changes in cross-sectional area caused by 2013 flooding along each section were calculated and used to estimate total deposition or erosion over the surveyed area, normalized as m^3 per 100 m of channel for comparison with previous studies, and are presented as summary tables in this report. The net deposition or erosion that occurred in each area in 2013 is compared with changes that occurred in previous years. At each cross-section, the changes in thalweg elevation from 2009 to 2013 are compiled in tables and are used to indicate whether, on average, the channel elevation has been stable, aggrading, or incising. In the figures showing channel thalwegs, the distance along the survey can vary between the original survey and the resurvey because of changes in thalweg sinuosity, resulting in changes in thalweg gradient. These changes in thalweg gradient are also summarized in this report.

A-3.1 Pueblo Canyon Cross-Vane Structures

Two cross-sections were originally surveyed in the vicinity of each of the three Pueblo Canyon cross-vane structures (CVSs) in April 2010, one 50 ft upcanyon and one 50 ft downcanyon of the apex rock of each structure. Channel thalweg profiles were also surveyed over these 100-ft distances. These cross-sections and thalweg profiles were resurveyed in December 2010, October 2011, November 2012, and February–March 2014. Cross-section and thalweg profile locations for all CVSs are shown on an orthophotograph in Figure A-3.1-1, and the cross-sections and thalweg profile for the upper CVS (CVS #1) are also shown on a geomorphic map in Figure A-3.1-2 (geomorphic mapping from 1997; LANL 2004, 087390). The cross-sections and thalweg profiles for CVS #1, CVS #2, and CVS #3 are shown in Figures A-3.1-3, A-3.1-4, and A-3.1-5, respectively, and in Photos A1-1, A1-2, and A1-3 in Attachment A-1. Net sediment deposition occurred at two of the six CVS cross-sections, and net sediment erosion occurred at the other four cross-sections during the summer 2013 monsoon season, as summarized in Table A-3.1-1.

Maximum aggradation (net sediment deposition) was 1.7 ft at CVS #3 +50 ft (Photo A1-1, Attachment A-1), and the maximum incision (net erosion) was 2.4 ft, at CVS #1 -50 ft (Photo A1-2, Attachment A-1). Normalized net erosion at the CVSs averaged −162 m^3/100 m. An estimated 1768 m^3/100 m of post-1942 sediment exists in reach P-2W, which contains CVS #1, as measured in 1997 (LANL 2004, 087390). Net erosion in 2013, therefore, removed approximately 9% of the estimated 1942–1997 sediment total. This net erosion represents a moderate to large decrease in sediment volume. Net deposition occurred at these sites in 2010 and 2011, and net erosion occurred in 2012, resulting in a net deposition of 163 m^3/100 m from 2010–2012 (Table A-3.1-1). Therefore, the net 2010–2012 sediment deposition was eroded in 2013 (Table A-3.1-1). Repeat photographs taken in March 2012 and May 2014 show the change from aggradation in 2011 to channel incision and lateral migration during the 2013 monsoon seasons, respectively (Photo A1-3, Attachment A-1). On average, the channel thalweg at the CVS cross-sections incised by 0.3 ft in 2013, compared with 0.1 ft of incision in 2012 (Table A-3.1-1). Figures A-3.1-3 through A-3.1-5 also indicate changes to the channel thalweg (net incision) that occurred during the summer 2013 monsoon season.

These data contrast with conclusions from previous assessments, which indicated this part of Pueblo Canyon had been relatively stable with net sediment deposition since 1998 (LANL 2012, 218411). The net erosion which occurred in 2013 transported an amount of this sediment equivalent to the total net deposition from 2010-2012 an unknown distance downstream, to be redeposited within Pueblo Canyon, deposited in lower LA Canyon, or transported out of the LA/Pueblo watershed.

A-3.2 Upper Pueblo Canyon Willow-Planting Area

A total of 18 cross-sections were surveyed in November 2009 in the part of Pueblo Canyon downstream from the new Los Alamos WWTP outfall and upstream from the access road to the WWTP where willows were planted in spring 2008 and spring 2009. These cross-sections were divided into groups of six within the upper, middle, and lower thirds of the willow-planting area (UW, MW, and LW, respectively). Within each group the cross-sections were spaced at 100-ft intervals. Longitudinal channel thalweg profiles were also surveyed over 500-ft intervals through each of these three areas. These cross-sections and thalweg profiles were resurveyed in April 2010, October 2011, November 2012–January 2013, and January–February 2014. Stream banks in this area were surveyed in January–February 2014. Cross-section locations, thalweg profile locations, and stream banks are shown on an orthophotograph in Figure A-3.2-1, and the cross-sections, thalweg profile, and stream banks for the middle and lower thirds of the area are also shown on a geomorphic map in Figure A-3.2-2 (geomorphic mapping from 1997; LANL 2004, 087390). The cross-sections and thalweg profiles in the upper, middle, and lower thirds of the willow-planting area are shown in Figures A-3.2-3, A-3.2-4, and A-3.2-5, respectively. Geomorphic changes that occurred at these cross-sections during 2013 are summarized in Table A-3.2-1.

Maximum deposition of new sediment was 4.4 ft at cross-section MW-1 in the middle third of the upper Pueblo Canyon willow-planting area (also referred to as the upper willow-planting area), and the maximum erosion was 6.6 ft at cross-section LW-6 in the lower third of this area. The new sediment at cross-section MW-1 was associated with deposition of a sand lobe in the previous channel location in an area where the channel migrated to the north (Photo A1-4, Attachment A-1). The erosion at section LW-6 was associated with channel widening and lateral migration of the stream bank (Photo A1-5, Attachment A-1). Channel widening and/or bank migration was recorded at all of the LW cross-sections and at the majority of the MW cross-sections. Eight of the cross-sections had net sediment deposition during 2013, and all were at the most upstream cross-sections (UW-1 to MW-2). The 10 downstream cross-sections had net erosion. Normalized net sediment erosion in the upper Pueblo Canyon willow-planting area averaged -369 m^3/100 m (Table A-3.2-1). Post-1942 sediment deposition in reach P-3W, which includes part of the surveyed area, was estimated to be 3357 m^3/100 m as measured in 1997 (LANL 2004, 087390). Net erosion in 2013, therefore, removed approximately 11% of the estimated 1942–1997 sediment. This net erosion represents a moderate to large decrease in sediment volume.

Net deposition occurred at these sites in 2010, 2011, and 2012, resulting in 161 m^3/100 m sediment deposition from 2010–2012 (LANL 2011, 200902). The 2013 net erosion is approximately 2.3 times the total 2010–2012 net deposition, mainly from erosion that occurred in the lower half of the upper

Pueblo Canyon willow-planting area in 2013 (Table A-3.2-1). Over most of its lengh, the channel thalweg in the upper third of the upper Pueblo willow-planting area aggraded by 0.6 to 2 ft in 2013 (average aggradation of 1.3 ft), whereas the channel thalweg incised 0.1 to 2.5 ft (average incision of 0.9 ft) over most of its length in the lower two-thirds of the upper Pueblo willow-planting area (Table A-3.2-1). This is greater in magnitude but broadly similar to a general pattern of upstream aggradation and downstream incision that occurred in 2012, 2011, and 2010 (LANL 2011, 200902). Figures A-3.2-3 through A-3.2-5 also indicate changes to the channel thalweg gradient that occurred in 2013. In the upper third of the willow-planting area, the thalweg gradient decreased since the previous survey; in the middle third, the thalweg gradient increased, and in the lower third the thalweg gradient decreased. Gradient changes in the upper Pueblo Canyon willow-planting area are associated with changes in sinuosity and bed elevation.

These data contrast with conclusions from previous assessments that indicated that net sediment deposition/eroision in this part of Pueblo Canyon has been relatively stable since 1998 (LANL 2011, 200902). The net erosion observed in 2013 has removed approximately 2.3 times the sediment deposited in 2010 through 2012. Sediment eroded from the upper Pueblo Canyon willow-planting area has been transported an unknown distance downstream, to be redeposited wihin Pueblo Canyon, deposited in lower Los Alamos Canyon, or transported out of the Los Alamos/Pueblo watershed.

A-3.3 Pueblo Canyon Wing Ditch

Five cross-sections were surveyed at 100-ft intervals downcanyon from the Pueblo Canyon wing ditch in November 2009. Longitudinal thalweg profiles of the active channel and a formerly abandoned channel to the south where the wing ditch directs water were also surveyed over this distance. These cross-sections and thalweg profiles were resurveyed in May 2011, October 2011, January 2013, and December 2013 (LANL 2011, 200902). The wing ditch is a short distance downstream from where the road to the Los Alamos County WWTP crosses the Pueblo Canyon stream channel, and the culverts at this crossing were plugged during a runoff event on August 16, 2010. In 2011, the County of Los Alamos rebuilt the road crossing to better withstand large runoff events and to pass flow more effectively (LANL 2011, 200902). The formerly abandoned channel to the south now receives flow during periods of high effluent discharge and stormwater runoff, helping to effectively distribute water across this part of the wetland (a function that the wing ditch was designed to perform; it is no longer needed for this purpose). September 2013 floods overtopped the road adjacent to the wing ditch, and the County of Los Alamos conducted some additional regrading and road construction subsequent to this flood event that extended onto the southern end of all of the cross-sections (Figure A-3.3-1). Cross-section and thalweg profile locations are shown on an orthophotograph in Figure A-3.3-1, and the cross-sections and thalweg profile locations are also shown on a geomorphic map in Figure A-3.3-2 (geomorphic mapping from 1996–1997; LANL 2004, 087390). The cross-sections are shown in Figure A-3.3-3, and the thalweg profiles are shown in Figure A-3.3-4. Geomorphic changes that occurred at these cross-sections during 2013 are summarized in Table A-3.3-1.

Maximum sediment deposition was 2.9 ft in an area in the southern part of cross-section WD-3 that was regraded after the September 2013 floods (Photo A1-6, Attachment A-1). It is possible that the regrading resulted in a thicker deposit than was actually deposited by the flood, but field examination of the sediments suggests that this was an area of significant sedimentation during flooding. The maximum incision (net erosion) was 1.4 ft in a side channel adjacent to the road at cross-section WD-4 (Photo A1-7, Attachment A-1). All five of the cross-sections had net deposition during 2013 (Table A-3.3-1). Normalized net deposition over the surveyed area below the wing ditch averaged 2120 m^3/100 m (Table A-3.3-1) compared with an estimated 6991 m^3/100 m of post-1942 sediment in reach P-3E, a short distance east of the surveyed area, as measured in 1997 (LANL 2004, 087390). This calculated net deposition, 30% of the estimated 1942–1997 total, represents a large increase in total sediment volume. The 2013 net deposition is approximately 24 times the 2010–2012 net deposition of 87 m^3/100 m. The wing ditch appears to be an area where sediment eroded from upstream areas by 2013 floods was redoposited a short distance downcanyon. Repeat photographs taken in January 2013 and May 2014 show the change from channel incision to deposition of sand lobes in the wing ditch area during the 2012 and 2013 monsoon seasons, respectively (Photo A1-8, Attachment A-1). On average, the main channel thalweg near the wing ditch aggraded by 0.5 ft in 2013 compared with 0.5 ft of incision in 2012 (Table A-3.3-1). As presented in Figure A-3.3-4, the average thalweg gradient of the active channel increased slightly in 2013. This decrease was from greater deposition in the upper end of the wing ditch area relative to the lower end.

A-3.4 Lower Pueblo Canyon Willow-Planting Area

A total of 23 cross-sections were surveyed in September 2009 at 100-ft intervals within reaches P-3FE and P-4W in an area where willows were planted in spring 2009 (Figure A-1.0-1). The surveys extended for 1100 ft above and below a transition area separating a broad upcanyon wetland (P-3FE) from a narrower downcanyon wetland within incised geomorphic surfaces (P-4W). A longitudinal channel thalweg profile was also surveyed over this 2200-ft interval (Figure A-3.4-1). These cross-sections and thalweg profiles were resurveyed in April and May 2011, and in October and November 2011 (LANL 2011, 200902). Cross sections were resurveyed in November and December 2012, but the thalweg was not resurveyed at this time (LANL 2013, 239233, Appendix C). Cross-sections and thalweg profiles were resurveyed in December 2013 to February 2014. Stream banks in this area were surveyed in January and March 2012 and resurveyed in January and February 2014. Cross-section and thalweg profile locations and stream banks are shown on an orthophotograph in Figure A-3.4-1 and on a geomorphic map in Figure A-3.4-2 (geomorphic mapping from 1996–1997; LANL 2004, 087390). The cross-sections are shown in Figure A-3.4-3, and the channel thalweg profiles are shown in Figure A-3.4-4. Geomorphic changes that occurred at these cross-sections during 2013 from monsoonal flooding are summarized in Table A-3.4-1.

In the upper half of the lower Pueblo Canyon willow-planting area (also referred to as the lower willow-planting area, which is reach P-3FE), maximum deposition of new sediment was 2.0 ft at cross-section PU −700 ft (700 ft upstream from the transition zone), and the maximum erosion was 6.4 ft at cross-section PU −800 ft (Figure A-3.4-3 and Table A-3.4-1). The deposition at PU −700 ft was associated with aggradation at the former main channel location, (Photo A1-9, Attachment A-1) , and the erosion at PU −800 ft was associated with channel incision, which created a new, much deeper and wider channel on the north side of the valley floor (Photo A1-10, Attachment A-1). The three cross-sections farthest upstream above the approximate transition point (PU 0-ft section) had net sediment deposition and the remaining eight had net erosion (Table A-3.4-1). Repeat photographs taken in March 2012 and May 2014 show the channel incision and widening that occurred in this area (Photo A1-11, Attachment A-1). Normalized net erosion in the upper half of the lower willow-planting area averaged –861 m^3/100 m (Table A-3.4-1) compared with an estimated 5117 m^3/100 m of post-1942 sediment in reach P-3FE, which includes the surveyed area, as measured in 1997 (LANL 2004, 087390). This net erosion, 16.8% of the estimated 1942–1997 total, represents a large change. Net deposition occurred in this area in 2010 and 2011, and net erosion occurred in 2012, resulting in 141 m^3/100 m net deposition from 2010–2012 (LANL 2011, 200902). Therefore, 2013 net erosion is approximately 6 times the 2010–2012 net sediment deposition.

In the lower half of the lower Pueblo Canyon willow-planting area (reach P-4W), maximum deposition of new sediment was 4.6 ft at cross-section PU +600 ft, and the maximum erosion was 6.5 ft, at section PU +500 ft (Figure A-3.4-3 and Table A-3.4-1). The erosion was associated with lateral bank migration (Photo A1-12, Attachment A-1), and the deposition was associated with channel aggradation adjacent to an area of lateral bank migration. Cross-section PU +600 ft had the highest measured erosion and deposition in 2010, indicating the channel is continuing to adjust in this downstream area (Figure A-3.4-3 and Table A-3.4-1). Six of the 11 cross-sections below the approximate transition point had net sediment deposition, and five had net erosion (Table A-3.4-1). Net erosion also occurred at cross-section PU 0 ft, where the emergence of alluvial groundwater perched on Puye Formation bedrock resulted in seepage erosion in previous years (Figure A-3.4-3 and Table A-3.4-1). During and following the September 2013 flood event, the headcut formerly located at PU 0 ft migrated nearly 1000 ft upstream (between PU-900 and PU −1000 ft), and Puye Formation bedrock is now exposed as isolated outcrops in the channel floor for a distance of approximately 400 to 500 ft upstream of PU 0 (Figures A-3.4-3 and A-3.4-4). Repeat photographs taken in March 2012 and May 2014 show the channel incision and widening that occurred in this area. (Photo A1-13, Attachment A-1). Net sediment erosion occurred in the lower half of the lower Pueblo Canyon willow-planting area, averaging −365 m^3/100 m (Table A-3.4-1) compared with an estimated 9871 m^3/100 m of post-1942 sediment in reach P-4W, which includes the surveyed area, as measured in 1997 (LANL 2004, 087390). This calculated net erosion, 3.7% of the estimated 1942–1997 total, represents a modest decrease in post-1942 sediment volume. Net erosion occurred in this area in 2010 and 2011, and net deposition occurred in 2012, resulting in 12.5 m^3/100 m net deposition from 2010–2012 (LANL 2011, 200902). Therefore, 2013 net erosion is approximately 29 times the 2010–2012 net sediment deposition.

On average, the thalweg incised by 2.5 ft above the former transition point (PU 0) and aggraded by 1.2 ft below PU 0 in 2013 compared with no change above the transition and 0.2 ft of aggradation below the transition point in 2012 (Table A-3.4-1). As presented Figure A-3.4-4, the average thalweg gradient increased above the transition point and decreased below the transition point between 2011 and 2013. The increase in gradient above the transition point is due to channel aggradation at the upper end and channel incision in the lower end of the area above the transition point. The decrease in gradient below the transition point is primarily from channel incision at the upper end, along with minor channel aggradation in the lower part of the area below the transition point.

A-3.5 Pueblo Canyon GCS

A total of 15 cross-sections were surveyed in April 2010 at 100-ft intervals upstream of the Pueblo Canyon GCS, and 3 cross-sections were surveyed at 100-ft intervals downstream from the GCS (Figure A-3.5-1). A longitudinal channel thalweg profile was also surveyed over this 1800-ft interval. Because some ground disturbance associated with site restoration occurred after the April 2010 surveys were completed, the area of disturbance was resurveyed in June 2010 (LANL 2011, 206488). These surveys were repeated in April and October 2011 (LANL 2011, 200902) and most recently in February 2014. Because of the lack of monsoonal flows through this area in 2012, downstream attenuation of WWTP effluent discharge and the absence of significant net deposition or incision in the lower Pueblo willow-planting area upstream of the Pueblo Canyon GCS survey area; this area was not resurveyed following the summer 2012 monsoon season. Stream banks in this area were surveyed in January 2012 and were resurveyed in February 2014. Cross-section and thalweg profile locations and stream banks are shown on an orthophotograph in Figure A-3.5-1 and on a geomorphic map in Figure A-3.5-2 (geomorphic mapping from 1996–1997; LANL 2004, 087390). The cross-sections and the channel thalweg profile are shown in Figure A-5.5-3. Geomorphic changes that occurred at these cross-sections during 2013 from monsoonal flooding are summarized in Tables A-3.5-1 and A-3.5-2. In May 2014, the Pueblo Canyon GCS was revisted to document the condition of the structure. Photographs of the GCS are included in Attachment A-1, Photo A1-14.

Above the Pueblo Canyon GCS (PUGCS) maximum sediment deposition was 3.3 ft at cross-section PUGCS −100 (100 ft above the GCS), and a maximum erosion of 4.1 ft occurred at PUGCS −1400 (Table A-3.5-1). The erosion at PUGCS −1400 was associated with incision and lateral bank migration (Photo A1-15, Attachment A-1), and deposition at PUGCS −100 was associated with channel aggradation in the area immediately upstream of the PUGCS (Photo A1-16, Attachment A-1). Repeat photographs taken in March 2012 and May 2014 show the channel incision, widening, and deposition of 2013 sediment deposits that occurred in the upper part of the GCS area, at PUGCS-1100 ft. (Photo A1-17, Attachment A-1). Eight of the 15 cross-sections above the GCS had net erosion and seven had net deposition. Normalized net erosion above the GCS averaged −256 m^3/100 m (Table A-3.5-1). For comparison, there was an estimated 7021 m^3/100 m of post-1942 sediment in reach P-4E, which includes the GCS, as measured in 1997 (LANL 2004, 087390). This net erosion, 3.6% of the estimated 1942–1997 total, represents a modest decrease in post-1942 sediment volume. Cross-sections with the greatest net erosion were at the upstream end of the GCS area, and cross-sections with the greatest net deposition were within the lower GCS area, 200 ft above the structure (Table A-3.5-1). Deposition within the lower GCS area was enhanced by the presence of the GCS. Net deposition occurred in this area in 2010 and 2011, and minimal change occurred in 2012, resulting in 286 m^3/100 m net deposition from 2010–2012 (LANL 2011, 200902). Therefore, 2013 net erosion is slightly less than 2010–2012 net sediment deposition.

Below the Pueblo Canyon GCS, maximum sediment deposition was 2.5 ft at cross-section PUGCS +300 (300 ft below the GCS), and a maximum erosion of 6.7 ft occurred at PUGCS +200 (Figure A-3.5-3 and Table A-3.5-2). The erosion at PUGCS +200 was associated with incision and lateral bank migration, and deposition at PUGCS +300 was associated with channel migration and aggradation in the former channel location. Net sediment erosion occurred below the GCS, averaging −1395 m^3/100 m (Table A-3.5-1).

On average, the main channel thalweg above the PUGCS aggraded by 0.9 ft in 2013 compared with 0.2 ft of aggradation in 2011 (Table A-3.5-1). As presented in Figure A-3.5-3, the average thalweg gradient of the active channel remained unchanged between 2011 and 2013. This was from channel aggradation in both the upper and lower PUGCS area. On average, the channel thalweg below the PUGCS incised by 0.3 ft, and the channel gradient decreased between 2011 and 2013 (Table A-3.5-1; Figure A-3.5-3). The decrease in gradient is from channel aggradation above the gaging station (Figure A-3.5-3).

A-3.6 Upper Los Alamos Canyon Sediment Detention Basins

The upper Los Alamos Canyon sediment detention basins, constructed at the base of the drainage below Solid Waste Management Unit (SWMU) 01-001(f) (LA-SMA-2 or Hillside 140), were excavated on July 8 to July 11, 2011, after the Las Conchas fire (LANL 2011, 206488). The basins were resurveyed in July 2011, and Basin 1 was resurveyed in October 2011 (LANL 2011, 200902). Following the excavation of 2011 monsoon season sedimentation, Basin 1 was resurveyed in January 2013 (LANL 2013, 239233, Appendix C). No appreciable sediment was deposited in Basin 2 between July 2011 and January 2013 (LANL 2011, 200902). In April, 2014, Basin 1 was resurveyed folowing the excavation of the accumulated 2012 moonsoon season sediment, and the topography at that time is presented in Figure A-3.6-1. Figure A-3.6-1 also shows variations in total sediment thickness determined by subtracting the January 2013 topographic surface from the April 2014 surface. Maximum sediment thickness resulting from the 2013 monsoon season is 40 cm (1.3 ft) in the northern part of the small delta where the drainage enters the northeast part of the basin (Figure A-3.6-1). Sediment in the delta proximal to the drainage is mostly coarse-grained, whereas fine-grained sediment was observed in hand-dug holes in the center of the basin. Based on field observations, 2013 sediment in the central part of the basin is 6–7 cm thick. This is consistent with sediment thickness determined from the survey data (Figure A-3.6-1). An estimated 71 m^3 of sediment accumulated in Basin 1 during the summer 2013 monsoon season compared with approximately 30 m^3 of sediment that was deposited in Basin 1 during the 2012 monsoon season (LANL 2013, 239233, Appendix C). Based on the area and 2013 sediment thickness in the delta and the remainder of Basin 1, it is estimated that 25% of the 2013 sediment in upper Los Alamos Canyon sediment detention Basin 1 is coarse-grained, and 75% of the sediment is fine-grained. Although floodwater clearly spilled into Basin 2, sediment deposition in Basin 2 was minimal (maximum sediment thickness in Basin 2 is less than 0.5 cm). Based on the deposition of sediment observed in Basin 1, and the absence of any appreciable sediment deposition in Basin 2, nearly all of the sediment transported by the small drainage below SWMU 01-001(f) is being contained in the upper Los Alamos Canyon sediment detention basin. Photographs of the sediment detention basins are shown in Photo A1-18, Attachment A-1.

A-3.7 DP Canyon GCS

A total of 11 cross-sections were surveyed in April and May 2010 at 100-ft intervals upstream of the DP Canyon GCS, and 2 cross-sections were surveyed at 125 ft and 225 ft downstream from the GCS, below the E039.1 gaging station (LANL 2012, 218411). A longitudinal channel thalweg profile was also surveyed over this 1325-ft interval. The area above the GCS was first resurveyed in November and December 2010, and the area below the GCS was resurveyed in March 2011 after ice melted from the channel bed (LANL 2011, 200902). The area above and below the GCS was resurveyed in October 2011 and in November–December 2012 (LANL 2013, 239233, Appendix C). In February 2013, an additional cross-section was surveyed 20 ft above the GCS (DPGCS –20 ft). All DPGCS cross-sections were resurveyed in March and April 2014. Cross-section and thalweg profile locations are shown on an orthophotograph in Figure A-3.7-1 and on a geomorphic map in Figure A-3.7-2 (geomorphic mapping from 1998; LANL 2004, 087390). The cross-sections and thalweg profile are shown in Figure A-3.7-3. Geomorphic changes that occurred at these cross-sections during 2013 from monsoonal flooding are summarized in Tables A-3.7-1 and 3.7-2. Photographs of the GCS are shown in Photo A1-19 Attachment A-1.

Net sediment deposition occurred at 11 of the 12 cross-sections above the GCS during the summer 2013 monsoon season and net sediment erosion occurred at one cross-section (Table A-3.7-1). Maximum sediment depositional thickness was 1.5 ft at the cross-section 600 ft above the GCS, and the maximum erosion was 2.5 ft, at the cross-section 200 ft above the GCS (Figure A-3.7-1 and Table A-3.7-1). Maximum sediment deposition was associated with aggradation of the main channel at −600 ft (Photo A1-20, Attachment A-1) and maximum incision was associated with progressive channel incision at −200 ft (Photo A1-21, Attachment A-1 and Figure A-3.7-3). Normalized net sediment deposition above the GCS averaged 120 m^3/100 m (Table A-3.7-1) compared with an estimated 749 m^3/100 m of post-1942 sediment in reach DP-2, which contains the GCS, as measured in 1999 (LANL 2004, 087390). This net deposition, 16% of the estimated 1942–1999 total, represents a large yearly increase. The 2013 net sediment deposition is 2.6 times the 2012 net deposition and is slightly less than the combined 2010–2012 net deposition (Table A-3.7-1). Most of the 2013 sediment occurred between DPGCS-200 ft and DPGSC-800 ft, with the greatest sediment volume deposited at DPGSC-600 ft (Figure A-3.7-1). This sediment deposition includes both channel aggradation and overbank deposition and is similar to sediment deposition observed in this area during previous monitoring efforts (LANL 2011, 200902). It appears that the locus of sediment deposition is prograding downstream and migrating laterally.

In the area below the GCS net sediment erosion occurred at both cross-sections (Figure A-3.7-3 and Table A-3.7-2). Maximum sediment deposition was 0.2 ft, within the channel at the cross-section 225 ft below the GCS and maximum sediment erosion was 1.4 ft at the cross-section 125 ft below the GCS (Figure A-3.7-1).

On average, the stream channel upstream of the GCS aggraded by 0.4 ft in 2013 compared with 0.2 ft of aggradation in 2012 (Table A-3.7-1). Downstream of the GCS, the channel incised by an average of 0.7 ft in 2013, compared with 0.1 ft of aggradation in 2012 (Table A-3.7-2). As shown in Figure A-3.7-3, the channel thalweg gradient increased slightly both above and below the GCS in 2012.

A-3.8 Los Alamos Canyon Low-Head Weir

The sediment retention basins above the Los Alamos Canyon low-head weir (LA weir) were excavated from July 8 to July 11, 2011, following the Las Conchas fire (LANL 2011, 206488). The upper two basins (Basins 1 and 2) were resurveyed in October 2011 after the 2011 monsoon season, and the lower basin (Basin 3) was resurveyed in March 2012 after ponded water had evaporated (LANL 2012, 218411). Basins 1 and 3 were resurveyed in November 2012; Basin 2 had standing water and was not resurveyed in November 2012 (LANL 2013, 239233, Appendix C). All three basins were resurvey in May 2013 following excavation in March–April 2013. Basins 1 and 2 were resurveyed in December 2013, and Basin 3 was resurveyed in February 2014. Figure A-3.8-1 shows variations in total sediment thicknesses in LA weir sediment basins, determined by subtracting the May 2013 surface from the December 2013-February 2014 surface (sediment deposition between December 2013 and February 2014 is inferred to be neglible because of the absence of runoff or minimal runoff that occurred during this time interval). Maximum sediment thickness in Basin 3 resulting from the 2013 monsoon season is 2.16 m (7.1 ft). This maximum sediment thickness is in an area where a delta prograded from Basin 2 into the western end of Basin 3. An estimated 2694 m^3 of sediment accumulated in Basin 3 during the summer 2013 monsoon season. Maximum sediment thickness in Basin 2 resulting from the 2013 monsoon season is 2.1 m (6.9 ft), and is in the central part of the basin (Figure A-3.8-1). An estimated 1932 m^3 of sediment accumulated in Basin 2 during the summer 2013 monsoon season. Maximum sediment thickness in Basin 1 resulting from the 2013 monsoon season is 1.4 m (4.6 ft), and is in the central part of the basin (Figure A-3.8-1). An estimated 540 m^3 of sediment accumulated in Basin 1 during the summer 2013 monsoon season. Table A-3.8-1 summarizes volume changes in each of the three sediment retention basins during this period. The weir is shown in Photo A1-22, Attachment A-1; the delta in the lower retention basin is shown in Photo A1-23, Attachment A-1. As a point of reference, approximately 6000 yd^3 of sediment was removed from the LA weir in 2013 (LANL 2013, 251741).

Field observations indicate that approximately 100% of the 2013 sediment deposited in Basins 1 and 2 was coarse-grained sediment transported as bed load. This is in contrast to 2012 sediment deposits in Basin 1, which were approximately 20% coarse-grained sediment that was transported as bed load and 80% fine-grained sediment transported as suspended load, and Basin 2, which was 100% fine-grained sediment transported as suspended load (LANL 2013, 239233, Appendix C). In Basin 3, 2013 deposits comprised approximately 40% coarse-grained sediment and 60% fine-grained sediment, compared with 100% fine-grained sediment in 2011 and 2012. The total sediment accumulation rate in the basins above the weir during the 2013 monsoon season was greater than measured in previous years, as shown in Table A-3.8-2. Annual sediment deposition at the LA weir in 2011, 2012, and 2013 was approximately an order of magnitude greater than the annual sediment deposition recorded in 2010, the year before the Las Conchas fire (Table A-3.8-2). The high sedimentation rate after the Las Conchas fire is probably related to operation of the Los Alamos Reservoir. After the Cerro Grande fire, the reservoir was maintained to impound floodwaters, which let most of the sediment from the burn area settle out (Lavine et al. 2006, 213454; Reneau et al. 2007, 102886). In contrast, after the Las Conchas fire, floodwaters were allowed to bypass the dam because it was being rebuilt when the fire occurred and was not considered able to withstand large floods. The predominance of coarse sediment accumulated above the weir in 2013 differs from observations after the Las Conchas and Cerro Grande fires when the transport of fine-grained sediment was much higher than that of coarse-grained sediment in the first two to three years, and the transport distance greater for fine-grained sediment (Lavine et al. 2006, 213454; Reneau et al. 2007, 102886). The predominance of coarse sediment at the weir in 2013 is likely from the large runoff events that occurred in September 2013, during which small tributary drainages appear to have contributed significant volumes of coarse sediment. The large increase in sediment in Basins 1 and 2 in 2013 compared with 2012 is attributable to the higher volume of coarse sediment bedload in the flood waters, which was deposited in the upper basins where the floodwaters spread and the gradient decreased. This resulted in the basins filling to a higher level than in previous years. The decrease in sediment volume in Basin 3, field observations showing that the flood overtopped the weir, and the large increase in coarse sediment compared with fine-grained sediment indicate that fine sediment was transported downstream past the LA weir during the Septermber 2013 flood event.

A-4.0 OBSERVATIONS OF WILLOWS IN PUEBLO CANYON

From 2008 to 2010, willows were planted in three areas in Pueblo Canyon downstream from the new Los Alamos WWTP, with the goal of enhancing riparian habitat, stabilizing surfaces, and slowing floodwaters. These areas are referred to as the upper Pueblo Canyon willow-planting area (section A-3.2), the lower Pueblo Canyon willow-planting area (section A-3.4), and the Pueblo Canyon GCS (section A-3.5). Observations were made of willows in these areas during fall 2011, winter 2013, and spring 2014. Willow success was variable in these areas and appears to be related to substrate conditions and preexisting vegetation as well as to the occurrence and persistence of water and substrate stability, as discussed below. Willow success was also affected by the large September 2013, flood event, which laid down and/or uprooted many willows, resulting in substantial willow mortality.

In 2014, the upper Pueblo Canyon willow-planting area had the tallest willows and the thickest stands of willows in the surveyed areas. In the upper third of the upper willow planting area the monsoon floods of summer 2013 either completely uprooted or laid down existing willows (Photo A1-24, Attachment A-1). Because of the unobstructed impact of flood waters at the upstream segment of the upper planting area, more willows were uprooted at the upstream end of the planting. Willows that were laid down but were not uprooted appear to have a good survival rate, and many laid-down willows were observed to be resprouting during a May 2014 site visit (Photo A1-25, Attachment A-1). The greatest number of laid-down and resprouting willows were observed at the center and downstream end of an island in the channel at the UW-5 cross-section (Figure A-3.2-1). Few laid-down survivors are present upstream of the island. The middle third of the upper Pueblo Canyon willow planting area fared better with numerous survivors present between cross-sections MW-1 and MW-4 (Figure A-3.2-1 and Photo A1-26, Attachment A-1). Downstream of MW-4, the channel was completely scoured and few if any willows survived (Figure A-3.2-1). At the lower third of the upper Pueblo Canyon willow planting area, willows were completely scoured from the channel and only a few willows survived on the banks of the current incised channel (Figure A-3.2-1 and Photo A1-27, Attachment A-1). This is similar to previous findings: In the lower third of the upper Pueblo Canyon willow-planting area, willows were less continuous, and generally gaps were observed between the foliage from nearby stems. No willows were observed in 2014 (following 2013 monsoon floods) in most of the area between the LW-3 and LW-5 cross-sections, and they were sparse or nonexistent between the LW-5 and LW-6 cross-sections (Figure A-3.2-1), which is similar to the extent of willows observed in 2012 (LANL 2013, 239233, Appendix C). This corresponds to an area of unstable conditions from 2010 through 2012, with eroding banks and an incising channel (Figure A-3.2-5 and Photo A1-5, Attachment A-1).

It appears that willow flood survival was greatest in areas where the channel has bends or contains islands, whereas very few willows withstood the force of the flood waters in straight reaches. Overall, the upper two-thirds of the upper Pueblo Canyon willow-planting area has continuous surface-water flow and a sandy or gravelly, aggrading substrate, and the willows were planted in generally bare ground with little competition from other vegetation. These conditions appear to be ideal for the success of willow plantings, barring major flood events. Many willows that were laid down have resprouted and will likely revegetate areas that were damaged by 2013 floods. In the lower third of the upper Pueblo willow planting area willow success has been poor. The poor willow success in this area appears to be directly related to the unstable substrate conditions.

In the upper half of the lower Pueblo Canyon willow-planting area (Figures A-1.0-1 and A-3.4-1), above the transition zone, willows were planted in a thin strip along the main channel and locally along a side channel. This was an area with thick preexisting vegetation dominated by reed canary grass (*Phalaris arundinacea*), and much of the area has a fine-grained substrate. Most planted willow stalks did not survive, with willow success estimated to be less than 1% in this area in 2014 (compared with willow success ranging from 0% to about 30% in 2012 and 0% to about 50% observed in 2011). Poor success in this area was related to the thick preexisting vegetation, which would compete with the willows. The commonly fine-grained substrate and damage to willow stalks by animals observed during the previous willow surveys may also have contributed to the poor success rate in this area.

In the lower half of the lower Pueblo Canyon willow-planting area (Figures A-1.0-1 and A-3.4-1), below the transition zone, willows were also planted with a typical spacing of 1 m to 10 m in a thin strip along the main channel, and the success rate here was also generally low based on May 2014 observations. As noted in the 2011 and 2012 surveys, willow success was best near the lower end of the planting area, where the area between incised banks widens and coarse sediment was deposited (LANL 2011, 200902). However, September 2013 floods eroded the willows from this area (Photo 1-28, Attachment A-1). Willows also had been successfully established in an area of seepage in the transition zone near PU 0, but these were also eroded during the September 2013 floods.

One dense native willow patch is located on a post-1942 geomorphic surface near the PU +100 ft cross-section. This patch was partially eroded during September 2013 floods, with remaining willows up to 3 m tall. These willows were established before the ~~recent planting~~September 2013 flood and indicate locally favorable conditions on higher surfaces, at least at the time they were established.

~~During the 2014 surveys, areas with sufficient thickness of saturated coarse sediments were identified and willow cuttings were subsequently planted between the PU −200 ft and PU+1100 ft cross-sections (Photo A1-28b and A1-29, Attachment A-1). Several of these willow plantings were showing signs of basal sprouting/leafing out during an early-May 2014 site visit. Survival success of these plantings will be assessed in the next report.~~

Upstream from the Pueblo Canyon GCS, willows were planted in the disturbed area along the channel for a distance of approximately 250 ft. Approximately 10% to 20% of these willows were surviving in 2013, often consisting of short sprouts from the base of the stems or the roots. The 2013 flood event further reduced the number of surviving plants; very few surviving willows remain in this entire reach. Stream incision and an associated lowering of the water table may further reduce survival rates of both willows and reed canary grass. It appears that reed canary grass will reestablish on the newly eroded surfaces since several healthy clumps were observed in this reach in spring 2014.

A-5.0 SOUTH FORK OF ACID CANYON INSPECTION

The stream bank armoring that was emplaced in the south fork of Acid Canyon in April 2010 (LANL 2010, 109280) was inspected after the 2011 monsoon season (LANL 2012, 218411), after the 2012 monsoon season (LANL 2011, 200902, Appendix C; LANL 2013, 239233)LANL 2013, 239233, Appendix C), and again after the 2013 monsoon season. The rock armoring remained intact, as shown in Photo A1-30, Attachment A-1.

A-6.0 SUMMARY

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 CVS,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 widdening 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 is 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.

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 LA weir in 2013 is greater than recorded in 2012 (or in previous years). 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.

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.

A-7.0 REFERENCES AND MAP DATA SOURCES

A-7.1 References

The following list includes all documents cited in this appendix. Parenthetical information following each reference provides the author(s), publication date, and ER ID or ESH ID. This information is also included in text citations. ER IDs were assigned by the Environmental Programs Directorate's Records Processing Facility (IDs through 599999), and ESH IDs are assigned by the Environment, Safety, and Health (ESH) Directorate (IDs 600000 and above). IDs are used to locate documents in the Laboratory's Electronic Document Management System and, where applicable, in the master reference set.

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

LANL (Los Alamos National Laboratory), April 2004. "Los Alamos and Pueblo Canyons Investigation Report," Los Alamos National Laboratory document LA-UR-04-2714, Los Alamos, New Mexico. (LANL 2004, 087390)

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NMED (New Mexico Environment Department), July 1, 2011. "Approval with Modifications, 2010 Geomorphic Changes at Sediment Transport Mitigation Sites in the Los Alamos and Pueblo Canyon Watersheds," New Mexico Environment Department letter to G.J. Rael (DOE-LASO) and M.J. Graham (LANL) from J.E. Kieling (NMED-HWB), Santa Fe, New Mexico. (NMED 2011, 204349)

Reneau, S.L., D. Katzman, G.A. Kuyumjian, A. Lavine, and D.V. Malmon, February 2007. "Sediment Delivery After a Wildfire," *Geology,* Vol. 35, No. 2, pp. 151–154. (Reneau et al. 2007, 102886)

A-7.2 Map Data Sources

The following list provides data sources for maps included in the main body of this report.

2000 LIDAR Hypsography; Los Alamos National Laboratory, Earth and Environmental Sciences GIS Lab; 1:1,200; Work in progress.

Drainage; Los Alamos National Laboratory, Environment and Remediation Support Services; 1:24,000; May 15, 2006.

Gaging stations; Los Alamos National Laboratory, Waste and Environmental Services Division; 1:2,500; March 19, 2011.

Grade control structures; Los Alamos National Laboratory, Environment and Remediation Support Services; Unknown; May 17, 2011.

LANL boundary; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; Unknown; August 16, 2010.

LANL area orthophoto; Los Alamos National Laboratory, Earth and Environmental Sciences GIS Lab; 1'=200'; February 25, 2009.

Location IDs; Los Alamos National Laboratory, ESH&Q Waste and Environmental Services Division; 1:2,500; May 19, 2011.

Other property boundary; Los Alamos National Laboratory, Earth and Environmental Sciences GIS Lab; Unknown; August 16, 2010.

Pueblo and DP Canyon cross sections and thalwegs; Los Alamos National Laboratories, Earth and Environmental Sciences GIS Lab; Unknown; May 2011.

Roads, surfaced; Los Alamos National Laboratory, KSL Site Support Services, Planning, Locating and Mapping Section; Unknown; November 30, 2010.

Technical area boundary; Los Alamos National Laboratory, Site Planning and Project Initiation Group, Infrastructure Planning Office; Unknown; August 16, 2010.

Watershed; Los Alamos National Laboratory, Environment and Remediation Support Services; 1:2,500; November 2, 2006.

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