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2010 Geomorphic Changes at Sediment Transport Mitigation Sites in the Los Alamos and Pueblo Canyon Watersheds

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1.0 INTRODUCTION

This report evaluates geomorphic changes at sediment transport mitigation sites in the Los Alamos and Pueblo canyon watersheds within and near Los Alamos National Laboratory (LANL or the Laboratory) that occurred in 2010. Baseline survey data reported previously (LANL 2011, 200902) are compared with subsequent survey data obtained in 2010 and 2011, following the summer 2010 monsoon season, as specified in the Monitoring Plan for Los Alamos and Pueblo Canyons Sediment Transport Mitigation Project (LANL 2009, 107457). The New Mexico Environment Department (NMED) issued an approval with modifications for this plan (NMED 2010, 108444), which approved the submittal of an annual report presenting survey data and evaluating geomorphic changes by May 30, beginning in 2011. This report is being submitted pursuant to that requirement. These surveys will be repeated after the 2011 monsoon season, and results will be presented in a report to NMED by May 30, 2012. In addition, NMED 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. Figure 1 shows the locations of sites discussed in this report.

2.0 HYDROLOGIC EVENTS DURING 2010 MONSOON SEASON

The largest runoff events in 2010 at the sediment transport mitigation sites in the Los Alamos and Pueblo canyon watersheds occurred on August 16, associated with heavy rainfall on the Los Alamos townsite (LANL 2011, 111808). This event caused damage to the Pueblo Canyon cross-vane structures (CVSs) and grade-control structure (GCS) (LANL 2010, 111125). At the E060.1 gaging station in lower Pueblo Canyon, estimated peak discharge from the August 16, 2010, event is 132 cubic feet per second (cfs), which is the largest discharge event measured in lower Pueblo Canyon since 2006, when a much larger event with an estimated peak discharge of 1930 cfs occurred (Romero et al. 2007, 100140). At other gages near the sediment transport mitigation sites, the August 16, 2010, peak discharges are estimated as follows:

- Above the Los Alamos County wastewater treatment plant (WWTP) outfall at gage E059, peak discharge is estimated at 250 cfs.
- At gage E055.5 in the south fork of Acid Canyon, peak discharge is estimated at 69 cfs.
- At gage E039.1 below the DP Canyon GCS, peak discharge is estimated at 315 cfs.
- At gages E042.1 and E050.1, above and below the Los Alamos Canyon low-head weir, peak discharges are estimated at 99 and 79 cfs, respectively.

The August 16, 2010, event is also the largest event measured in this part of Los Alamos Canyon since 2006, when a peak discharge of 240 cfs was estimated at the gage above the low-head weir. No damage was recorded to the DP Canyon GCS or the low-head weir during the August 16, 2010, event.

3.0 SURVEYS AT SEDIMENT TRANSPORT MITIGATION SITES

Surveys were conducted at all sediment transport mitigation sites specified in the monitoring plan (LANL 2009, 107457) and at the upper Los Alamos Canyon sediment detention basins, as required by NMED (2010, 108444). 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 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) are included electronically as Attachment 1 (on CD). The calculated distances along each cross-section and along each thalweg profile that are used for the figures in this report are also included in Attachment 1. These calculations involved basic trigonometry (Pythagorean theorem). The figures showing cross-sections include both the original survey data and the resurvey data, indicating where erosion and deposition have occurred along each section. The net changes in cross-sectional area along each section are calculated and used to estimate total deposition or erosion over the surveyed area, normalized as m^3 per km of channel for comparison with previous studies. 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.

3.1 Pueblo Canyon Cross-Vane Structures

Two cross-sections were originally surveyed in the vicinity of each of the three Pueblo Canyon 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. Cross-section and thalweg profile locations are shown in Figure 2, and the cross-sections and thalweg profiles for the upper, middle, and lower CVSs are shown in Figures 3, 4, and 5, respectively. Net sediment deposition occurred at each CVS cross-section, above and below each structure, during the summer 2010 monsoon season, as summarized in Table 1. Maximum aggradation (net sediment deposition) was 2.0 ft at CVS#1 +50 ft, and the maximum incision (net erosion) was 0.6 ft, also at this same section. Normalized net sediment deposition at the CVSs averaged 1526 m^3/km, compared with an estimated 17,680 m^3/km of post-1942 sediment in reach P-2W, which contains CVS#1, as measured in 1997 (LANL 2004, 087390). This net deposition, 9% of the estimated 1942–1997 total, represents a significant increase in a single year. Most of this sediment deposition probably occurred during the August 16, 2010, runoff event, which caused damage to the CVSs (LANL 2010, 111125). Whether this deposition was related to the CVSs or would have occurred anyway is uncertain. Figures 3 through 5 also indicate changes to the channel thalweg that occurred during the summer 2010 monsoon season. At each CVS the surveyed thalweg length decreased because of decreases in sinuosity, and at two of the CVSs the decreases in length resulted in increases in thalweg gradient.

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, and 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 2011. Cross-section and thalweg profile locations are shown in Figure 6. The cross-sections and thalweg profiles in the upper, middle, and lower thirds of the willow-planting area are shown in Figures 7, 8, and 9, respectively. Geomorphic changes that occurred at these cross-sections during the summer 2010 monsoon season are summarized in Table 2.

Maximum deposition of new sediment was 2.0 ft at sections UW-1 and UW-5 in the upper third of the upper willow-planting area, and the maximum erosion was 5.5 ft at section LW-4 in the lower third of this area. The new sediment at section UW-1 was associated with burial of the previous channel in an area of extensive sediment deposition, and the new sediment at section UW-5 was associated with development of a natural levee adjacent to the channel. The erosion at section LW-4 was associated with lateral migration of the stream bank, and bank migration was also recorded at several other sections (UW-2, MW-4, LW-5, and LW-6). Fourteen of the cross-sections had net sediment deposition during the summer 2010 monsoon season, and four had net erosion. Normalized net sediment deposition in the upper willow-planting area averaged 322 m^3/km, compared with an estimated 33,570 m^3/km of post-1942 sediment in reach P-3W, which includes part of the surveyed area, as measured in 1997 (LANL 2004, 087390). This net deposition, 1% of the estimated 1942–1997 total, represents a small increase. Most of this sediment deposition probably occurred during the August 16, 2010, runoff event and may have been aided by decreases in flow velocity associated with the thick patches of willow adjacent to the channel. Figures 7 through 9 also indicate changes to the channel thalweg gradient that occurred during the summer 2010 monsoon season. In the upper third of the willow-planting area, the thalweg gradient increased since the original survey in 2009, and at the other two areas, the thalweg gradient decreased, associated with changes in sinuosity and bed elevation.

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 an 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. 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 the August 16, 2010, runoff event. Runoff flowed directly over the road above the culverts and also to the east at the location of an abandoned channel, partially flowing directly into the abandoned channel below the road and bypassing the wing ditch. Some of the runoff also flowed down the road to the east. As of May 2011, the County of Los Alamos is rebuilding the road crossing to better withstand large runoff events and to pass flow more effectively. Some of the south-side cross-section endpoints were lost during this construction work, and new endpoints were established during the resurveys. Cross-section and thalweg profile locations are shown in Figure 10. The cross-sections are shown in Figure 11, and the thalweg profiles are shown in Figure 12. Geomorphic changes that occurred at these cross-sections during the summer 2010 monsoon season are summarized in Table 3.

Maximum sediment deposition was 2.3 ft at section WD-1, and the maximum incision (net erosion) was 1.2 ft at section WD-3. Four of the cross-sections had net sediment deposition during the summer 2010 monsoon season, and one had net erosion. Normalized net sediment deposition over the surveyed area below the wing ditch averaged 284 m^3/km, compared with an estimated 69,910 m^3/km of post-1942 sediment in reach P-3E, a short distance east of the surveyed area, as measured in 1997 (LANL 2004, 087390). This net deposition, 0.4% of the estimated 1942–1997 total, represents a small increase. Most of this sediment deposition probably occurred during the August 16, 2010, runoff event and was probably not related to the presence of the wing ditch because much of the flow bypassed the ditch. As presented in Figure 12, the average thalweg gradient of the active channel decreased between 2009 and 2011 associated with some channel aggradation. In the abandoned channel to the south, the thalweg gradient increased slightly.

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. 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. These cross-sections and thalweg profiles were resurveyed in April and May 2011. Cross-section and thalweg profile locations are shown in Figure 13, cross-sections are shown in Figure 14, and the channel thalweg profiles are shown in Figure 15. Geomorphic changes that occurred at these cross-sections during the summer 2010 monsoon season are summarized in Table 4.

In the upper half of the lower willow-planting area (reach P-3FE), maximum deposition of new sediment was 2.5 ft at cross-section PU −500 ft (500 ft upstream from the transition zone), and the maximum erosion was 2.8 ft, also at section PU −500 ft (Figure 14 and Table 4). The erosion and deposition were both associated with lateral bank migration. Ten of the 11 cross-sections above the approximate transition point (PU 0-ft section) had net sediment deposition, and 1 had net erosion. There was also net erosion at the PU 0-ft section. Normalized net sediment deposition in the upper half of the lower willow-planting area averaged 109 m^3/km, compared with an estimated 51,172 m^3/km of post-1942 sediment in reach P-3FE, which includes the surveyed area, as measured in 1997 (LANL 2004, 087390). This net deposition, 0.2% of the estimated 1942–1997 total, represents a small increase. Most of this sediment deposition probably occurred during the August 16, 2010, runoff event and was probably not affected by the willows because they were planted in a thin strip along the channel and the runoff spread over a much wider area.

In the lower half of the lower willow-planting area (reach P-4W), maximum deposition of new sediment was 1.6 ft at cross-section PU +600 ft, and the maximum erosion was 5.6 ft, also at section PU +600 ft (Figure 14 and Table 4). The erosion and deposition were both associated with lateral bank migration. Six of the 11 cross-sections below the approximate transition point had net sediment deposition, and 5 had net erosion. Normalized net sediment deposition in the lower half of the lower willow-planting area averaged 3 m^3/km, compared with an estimated 98,710 m^3/km of post-1942 sediment in reach P-4W, which includes the surveyed area, as measured in 1997 (LANL 2004, 087390). This calculated net deposition is minimal and indicates there were approximately equal amounts of erosion and deposition in this area.

Figure 15 presents thalweg profiles in the upper willow-planting area in October 2009 (top panel) and May 2011 (bottom panel). Average channel gradients above and below an outcrop of Puye Formation bedrock did not change between these surveys, although some local scour and fill occurred.

3.5 Pueblo Canyon Grade-Control Structure

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. A longitudinal channel thalweg profile was also surveyed over this 1800-ft interval, and was extended downstream past the E060.1 gaging station. These data were reported in the baseline geomorphic conditions report (LANL 2011, 200902). 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. The June 2010 survey data are included in Attachment 1 (on CD), and these data are used to evaluate changes that occurred because of runoff events and other activities during the 2010 monsoon season. Extensive erosion occurred on both the upstream and downstream sides of the Pueblo Canyon GCS during the August 16, 2010, runoff event, including piping that let stormwater and associated sediment pass through the structure (LANL 2010, 111125). Resurveys of this area were completed in April 2011 following completion of site restoration work at the GCS. The geomorphic changes that are recorded by these repeat surveys therefore include both direct effects of the runoff event (erosion and deposition) and subsequent topographic changes associated with site repair and restoration.

Cross-section and thalweg profile locations are shown in Figure 16, and the cross-sections and the channel thalweg profile are shown in Figure 17. During the summer 2010 monsoon season, net sediment deposition occurred at some cross-sections above the GCS and net sediment erosion occurred at others, as summarized in Table 5. Maximum sediment deposition was 1.5 ft at section PUGCS, −1300 ft (1300 ft above the GCS), and the maximum erosion was 3.8 ft at section PUGCS, −1500 ft. The maximum erosion was at a location where the stream bank eroded laterally about 8 ft. Averaged over the 1500-ft distance above the GCS, net sediment deposition occurred, normalized to 274 m^3/km. For comparison, there was an estimated 70,210 m^3/km of post-1942 sediment in reach P-4E, which includes the GCS, as measured in 1997 (LANL 2004, 087390). This net deposition, 0.4% of the estimated 1942–1997 total, represents a small increase. This deposition was probably not significantly affected by the presence of the GCS because most of it occurred far upstream from the structure, where there would have been no related hydrologic effects.

Below the Pueblo Canyon GCS, net erosion occurred at all three cross-sections in 2010 (Table 6). The estimated total net erosion over the 300-ft distance below the GCS (69 m^3) is 55% of the estimated net deposition in the 1500 ft above the GCS (125 m^3). As mentioned previously, this change represents a combination of the effects of the August 16, 2010, runoff event and the subsequent site repair and restoration.

Above the GCS, the thalweg elevation remained relatively stable between April 2010 and April 2011, with local aggradation (raising of the channel bed) being more prominent than local incision (Figure 17). In particular, the knickpoint that was present about 600 ft above the GCS in April 2010 did not migrate upstream during the August 16, 2010, runoff event. Below the GCS, the thalweg elevation locally increased and locally decreased, but the overall channel elevation and gradient remained unchanged. (Note that the apparent decrease in gradient shown in Figure 17 is an artifact of extending the thalweg profile farther east in 2011 relative to 2010.)

3.6 Upper Los Alamos Canyon Sediment Detention Basins

A general topographic survey was conducted in March 2010 that encompassed the area of the upper Los Alamos Canyon sediment detention basins, at the base of the drainage below solid waste management unit 01-001(f) (LA-SMA-2 or Hillside 140) (LANL 2011, 200902). The basins were visited in November 2010 to examine sediment deposition that occurred during the 2010 monsoon season. In the western basin (basin 1), a delta had formed where the drainage entered the basin, with a maximum thickness of 21 cm of sediment measured in hand-dug holes (14 cm of coarse-grained sediment overlying 7 cm of fine-grained sediment). In the center of basin 1, 6 cm of fine-grained sediment was measured. No appreciable sediment deposition was observed in basin 2. In December 2010, the basins were resurveyed, and the topography existing at that time is presented in Figure 18. Based on surveyed areas and estimated average sediment thickness, approximately 2 m^3 of coarse sediment and 8 m^3 of fine sediment were deposited in basin 1 during the 2010 monsoon season.

3.7 DP Canyon Grade-Control Structure

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, downstream from the E039.1 gaging station. A longitudinal channel thalweg profile was also surveyed over this 1325-ft interval. The area above the GCS was resurveyed in November and December 2010, and the area below the GCS was resurveyed in March 2011 (after ice melted from the channel bed). Cross-section and thalweg profile locations are shown in Figure 19, and the cross-sections and thalweg profile are shown in Figure 20. In December 2010, the elevation of the DP Canyon GCS was raised by 3.2 ft to enhance upstream deposition of sediment. This new elevation is shown in Figure 20.

Net sediment deposition occurred at each cross-section above the GCS during the summer 2010 monsoon season, as summarized in Table 7. Maximum sediment deposition was 1.2 ft at the section 300 ft above the GCS, and the maximum erosion was 1.0 ft at sections 100 ft and 800 ft above the GCS. Normalized net sediment deposition above the GCS averaged 729 m^3/km, compared with an estimated 7490 m^3/km of post-1942 sediment in reach DP-2, which contains the GCS, as measured in 1999 (LANL 2004, 087390). This net deposition, 10% of the estimated 1942–1999 total, represents a significant increase in a single year. Most of this sediment deposition probably occurred during the August 16, 2010, runoff event and was probably not significantly affected by the presence of the GCS because most of it occurred far upstream from the structure, where there would have been no related hydrologic effects. Net sediment deposition also occurred at both cross-sections below the GCS, with 1.9 ft of channel aggradation at the section 125 ft below the GCS (Figure 20 and Table 8). Normalized net sediment deposition below the GCS averaged 1216 m^3/km. As shown in Figure 20, no net change occurred to the channel thalweg gradient above the GCS, and a slight decrease in gradient occurred below the GCS.

3.8 Los Alamos Canyon Low-Head Weir

Three general topographic surveys have been conducted at the sediment retention basins above the Los Alamos Canyon low-head weir since it was excavated and modified in May 2009. These surveys were conducted in June 2009, July 2010, and February and March 2011. These surveys, in combination with sediment thickness measurements made in hand-dug holes and auger holes, document the thickness and volume of sediment accumulation in these basins and year-to-year variations in sedimentation. Figure 21 presents the “as-built” topography of this area as of May 2009. Figure 22 presents the topography in July 2010 and also shows variations in total sediment thickness determined by subtracting the May 2009 contours from the July 2010 contours. Figure 23 presents the topography in March 2011 and also shows the variations in total sediment thickness. Table 9 summarizes volume changes in each of the three sediment retention basins, presenting both net increases and net decreases in each basin. Local net decreases in each basin resulted from local erosion, including erosion along the spillways between basins, which accounts for some of the net increases in each basin. The “total net change” columns in Table 9 represent sediment accumulation resulting from upstream transport to the weir, with net decreases subtracted from net increases.

An estimated 280 m^3 of sediment has accumulated in the upstream, western basin (basin 1) above the weir (Table 9), and most of this sedimentation probably occurred during the 2010 snowmelt runoff period. Auger holes in July 2010 indicated that up to 0.9 m (3.1 ft) of sediment had been deposited in basin 1 and that approximately 70% of this was coarse-grained sediment that is transported as bed load. The remainder of the basin fill is fine-grained sediment that is transported as suspended load. Additional, largely coarse-grained, sediment was deposited in basin 1 during the summer 2010 monsoon season. An estimated 380 m^3 of sediment has accumulated in the middle basin (basin 2), and most of this sedimentation probably also occurred during the 2010 snowmelt runoff period. Auger holes in July 2010 indicated that up to 1.5 m (4.8 ft) of sediment had been deposited in basin 2 and that approximately 90% of this was coarse-grained sediment. Most of the sediment in basin 2 is in the form of a delta in the western part of this basin, and this delta grew eastward in summer 2010. An estimated 123 m^3 of sediment has accumulated in the eastern basin (basin 3). Approximately 43% of this sedimentation occurred during the summer 2010 monsoon season, the remainder being from the summer 2009 monsoon season and the 2010 snowmelt runoff period. Hand-dug holes in May 2011 indicated that up to 21 cm (0.7 ft) of fine-grained sediment had been deposited in the lowest part of basin 3, with mostly smaller thicknesses elsewhere. Exceptions were found in the western part of basin 3 where up to 42 cm (1.4 ft) of mostly coarse-grained sediment had accumulated, derived from local erosion of the spillway between basin 2 and basin 3. Sediment accumulation rates in the basins above the weir in the last 2 yr were within the range measured in previous years, although below the average for 2000–2011, as shown in Table 10.

4.0 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 August 16, 2010, runoff event. The rock armoring remained intact, as shown in Figure 24.

5.0 SUMMARY AND RECOMMENDATIONS

Net sediment deposition occurred in all surveyed areas in the Los Alamos and Pueblo canyon watersheds in 2010 except for the area downstream of the Pueblo Canyon GCS. This is consistent with the goal of the sediment transport mitigation work plans (LANL 2008, 101714; LANL 2008, 105716). Except for sediment accumulated behind engineered structures, such as the Los Alamos Canyon low-head weir, it is not certain if the mitigation actions enhanced sediment deposition, as sediment deposition is a natural geomorphic process. Nevertheless, the surveys document that these parts of the watersheds are currently operating as desired and are not undergoing net erosion. Bank erosion was documented in several areas, but bank erosion is to be expected, associated with lateral channel migration, and the surveys indicate that this eroded sediment was largely redeposited within each canyon. In addition, some of this bank erosion includes noncontaminated pre-1943 sediment, and erosion of these areas does not contribute to the contaminant load in stormwater. No actions are recommended at this time except for continued annual resurveys and inspections after large runoff events.

6.0 REFERENCES AND MAP DATA SOURCES

6.1 References

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

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

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)

LANL (Los Alamos National Laboratory), February 2008. "Interim Measure Work Plan to Mitigate Contaminated Sediment Transport in Los Alamos and Pueblo Canyons," Los Alamos National Laboratory document LA-UR-08-1071, Los Alamos, New Mexico. (LANL 2008, 101714)

LANL (Los Alamos National Laboratory), October 2008. "Supplemental Interim Measures Work Plan to Mitigate Contaminated Sediment Transport in Los Alamos and Pueblo Canyons," Los Alamos National Laboratory document LA-UR-08-6588, Los Alamos, New Mexico. (LANL 2008, 105716)

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LANL (Los Alamos National Laboratory), April 2010. "Documentation of Completion of Stream Bank Stabilization in the South Fork of Acid Canyon," Los Alamos National Laboratory document LA-UR-10-1877, Los Alamos, New Mexico. (LANL 2010, 109280)

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LANL (Los Alamos National Laboratory), February 2011. "Stormwater Performance Monitoring in the Los Alamos/Pueblo Watershed During 2010," Los Alamos National Laboratory document LA-UR-11-0941, Los Alamos, New Mexico. (LANL 2011, 111808)

LANL (Los Alamos National Laboratory), March 2011. "Baseline Geomorphic Conditions at Sediment Transport Mitigation Sites in the Los Alamos and Pueblo Canyon Watersheds, Revision 1," Los Alamos National Laboratory document LA-UR-11-0936, Los Alamos, New Mexico. (LANL 2011, 200902)

NMED (New Mexico Environment Department), January 11, 2010. "Approval with Modifications, Los Alamos and Pueblo Canyons Sediment Transport Monitoring Plan," New Mexico Environment Department letter to G.J. Rael (DOE-LASO) and M. Graham (LANL) from J.P. Bearzi (NMED-HWB), Santa Fe, New Mexico. (NMED 2010, 108444)

NMED (New Mexico Environment Department), May 11, 2010. "Approval, Documentation of Completion of Armoring of Stream Banks in South Fork Acid Canyon," New Mexico Environment Department letter to G.J. Rael (DOE-LASO) and M. Graham (LANL) from J.P. Bearzi (NMED-HWB), Santa Fe, New Mexico. (NMED 2010, 109693)

Romero, R.P., D. Ortiz, and G. Kuyumjian, August 2007. "Surface Water Data at Los Alamos National Laboratory: 2006 Water Year," Los Alamos National Laboratory report LA-14328-PR, Los Alamos, New Mexico. (Romero et al. 2007, 100140)

6.2 Map Data Sources

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

Title; Owner ID; Intended Scale; Publication Date.

2000 LIDAR Hypsography; Los Alamos National Laboratory, Earth and Environmental Sciences GISLab; 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 GISLab; 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 GISLab; Unknown; August 16, 2010.

Pueblo and DP Canyon cross sections and thalwegs; Los Alamos National Laboratories, Earth and Environmental Sciences GISLab; 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.

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

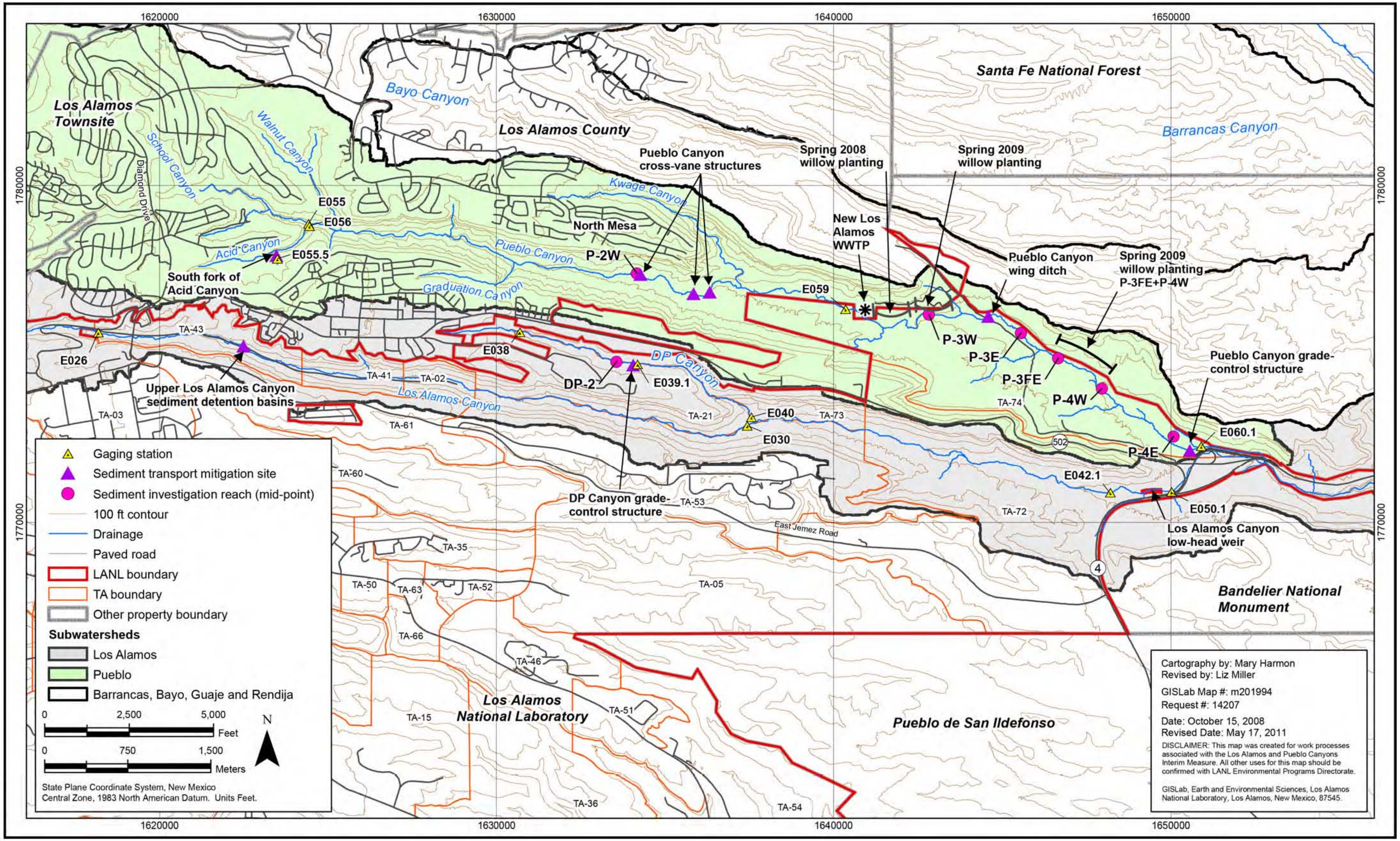


Figure 1 Map of the Los Alamos and Pueblo canyon watersheds showing sediment transport mitigation sites and stream gages

Figure 2 **Orthophoto showing the locations of surveyed cross-sections and thalweg profiles at the Pueblo Canyon cross-vane structures**

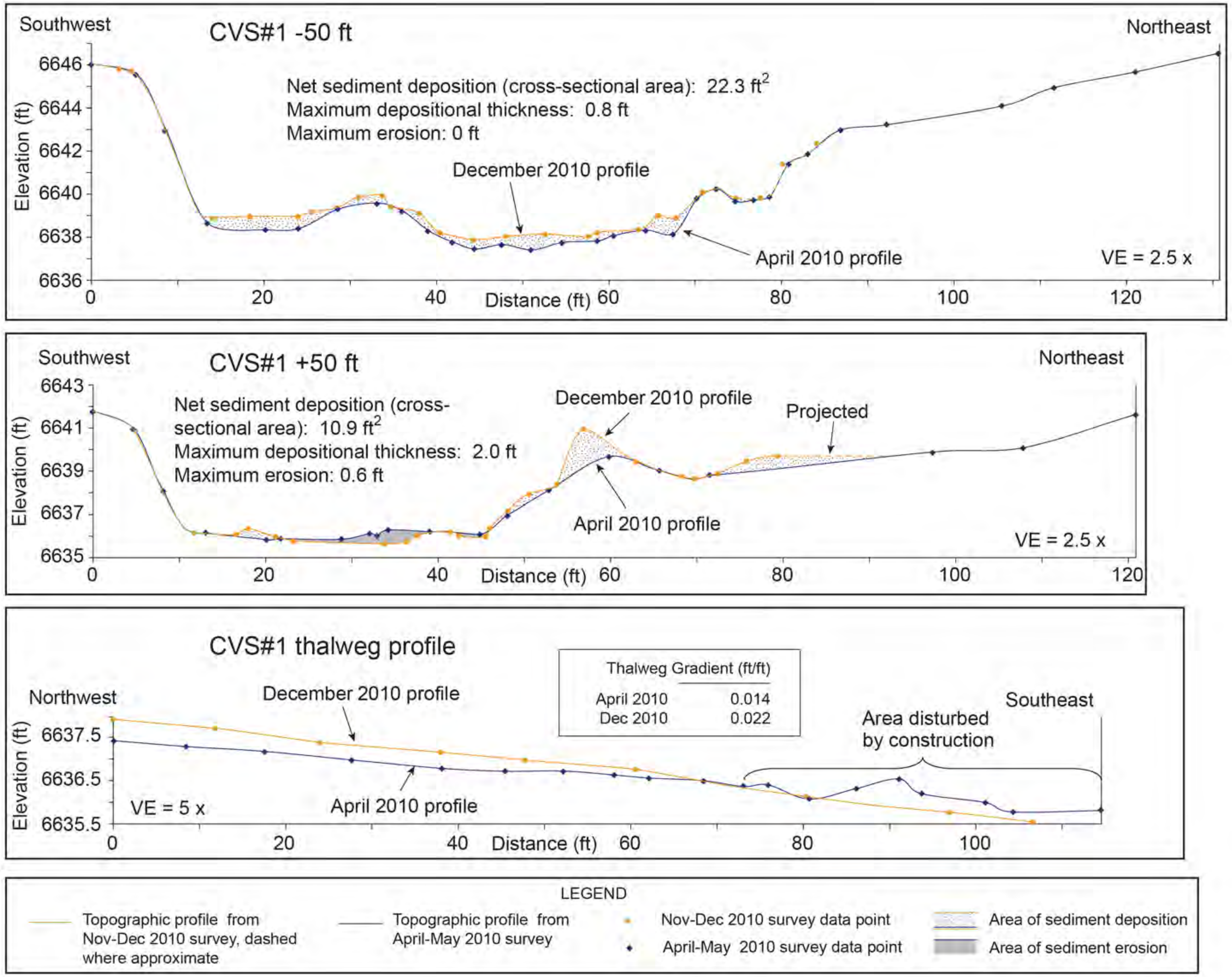


Figure 3 Cross-sections and thalweg profile at upper CVS in Pueblo Canyon

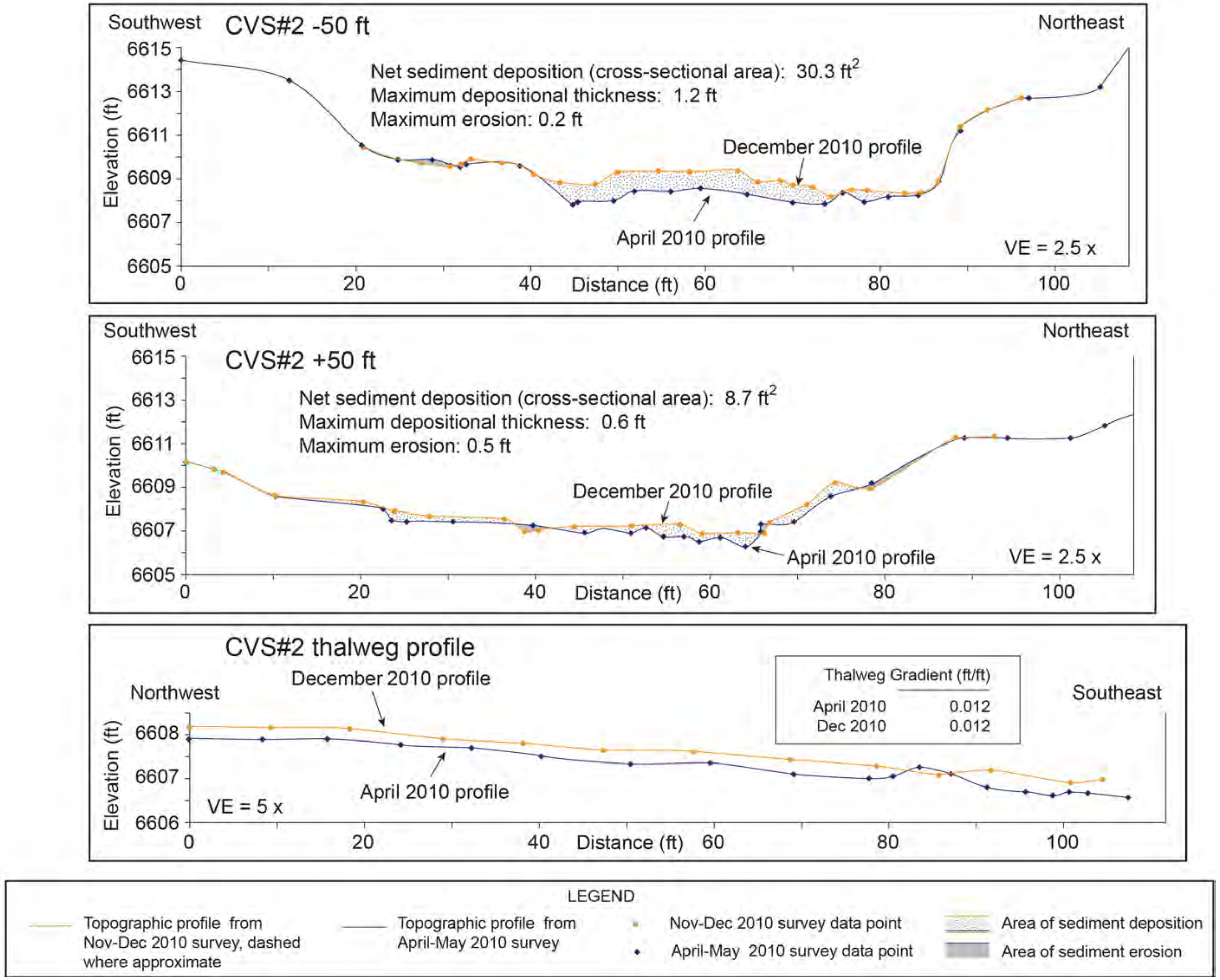


Figure 4 **Cross-sections and thalweg profile at middle CVS in Pueblo Canyon**

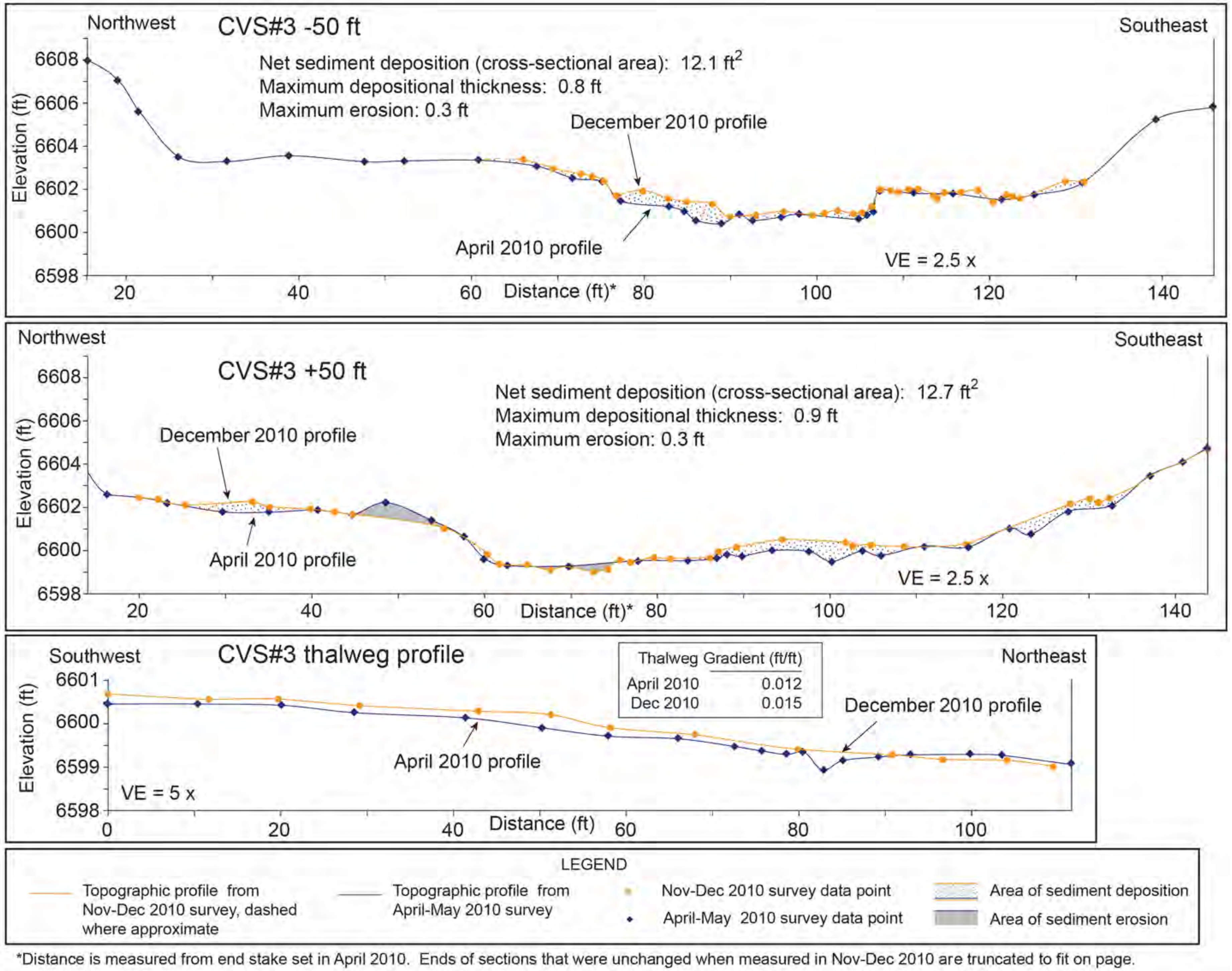


Figure 5 Cross-sections and thalweg profile at lower CVS in Pueblo Canyon

Figure 6 **Orthophoto showing the locations of surveyed cross-sections and thalweg profiles in the upper Pueblo Canyon willow-planting area**

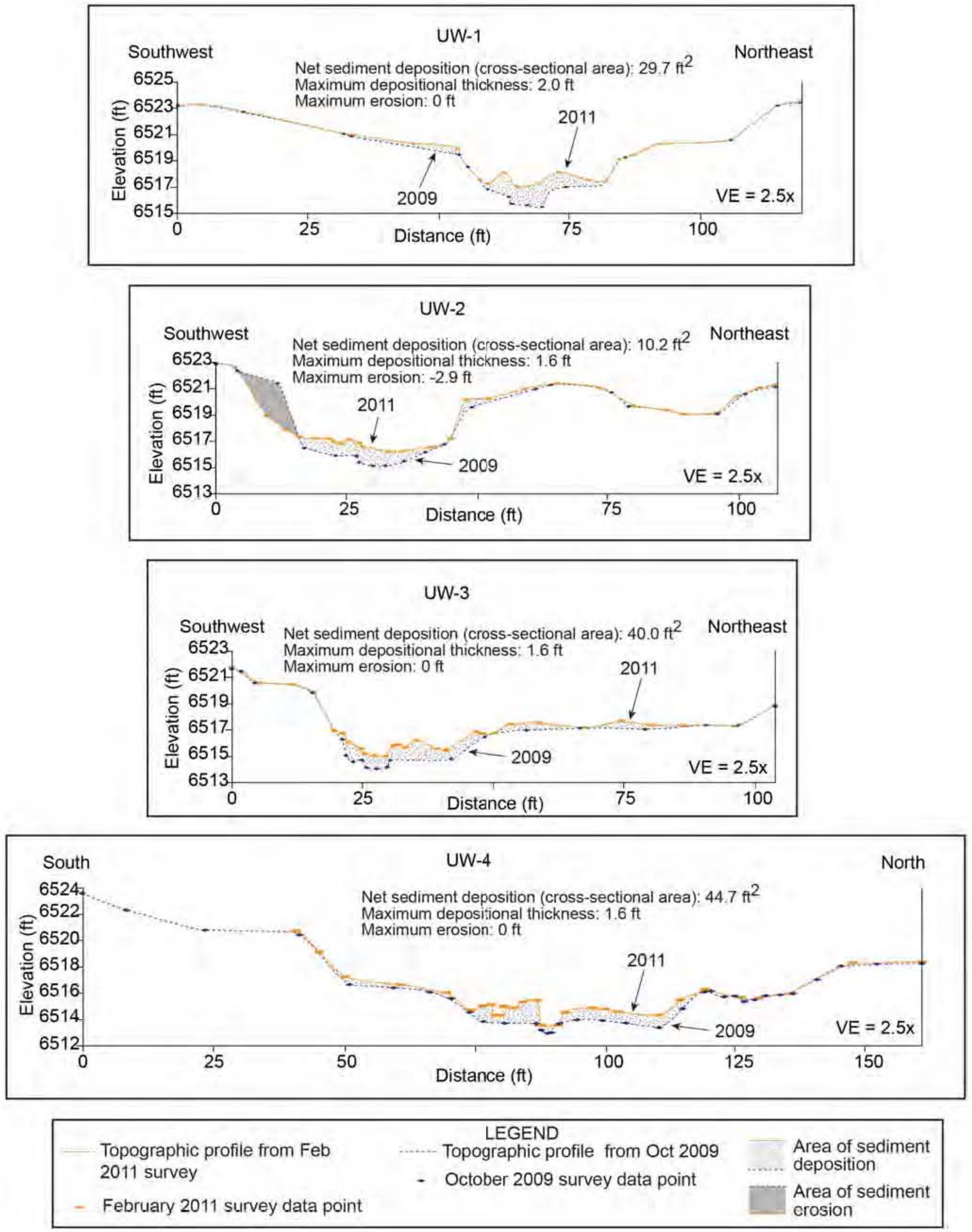


Figure 7 **Cross-sections and thalweg profile in upper third of upper Pueblo Canyon willow-planting area**

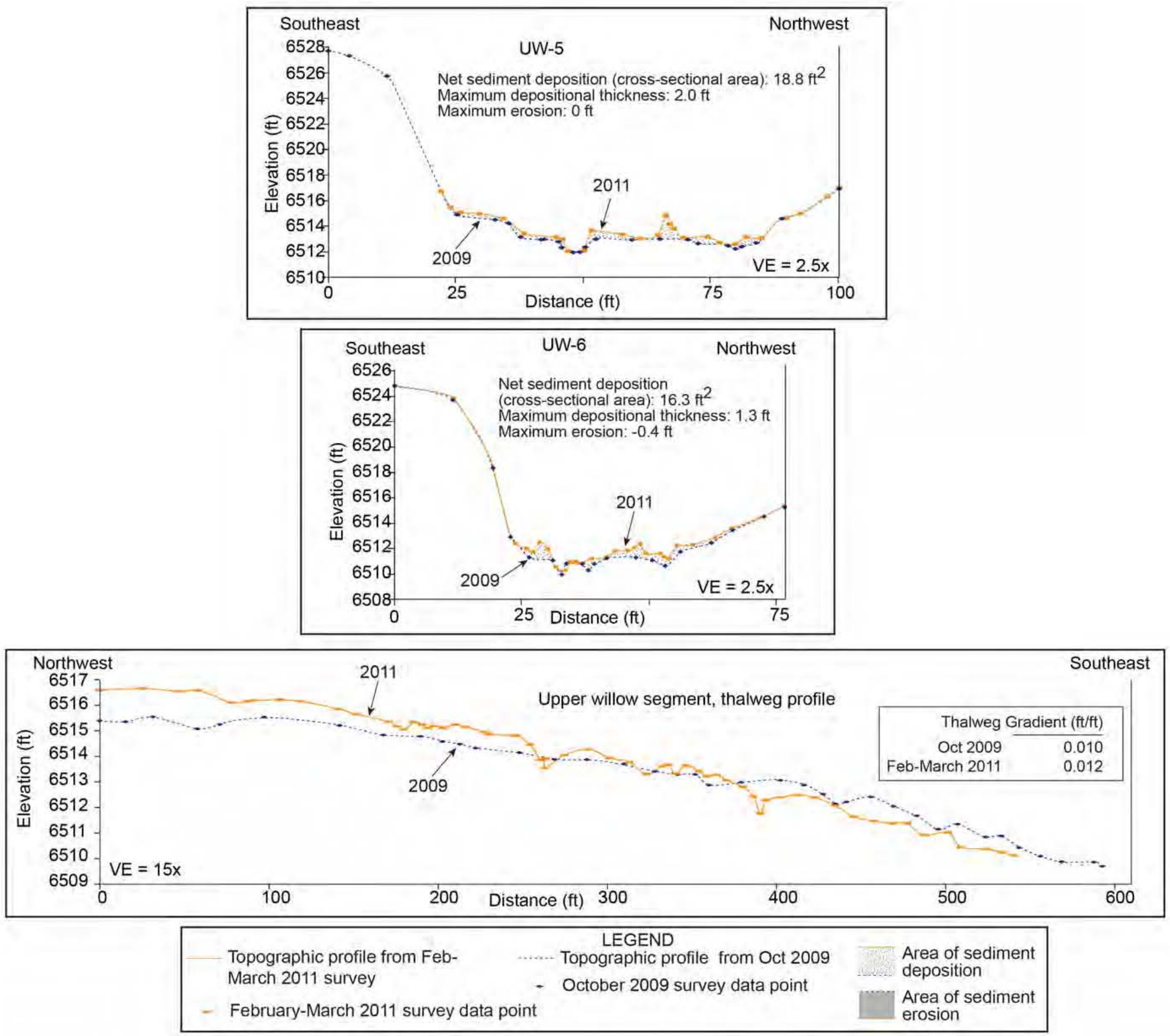


Figure 7 (continued) **Cross-sections and thalweg profile in upper third of upper Pueblo Canyon willow-planting area**

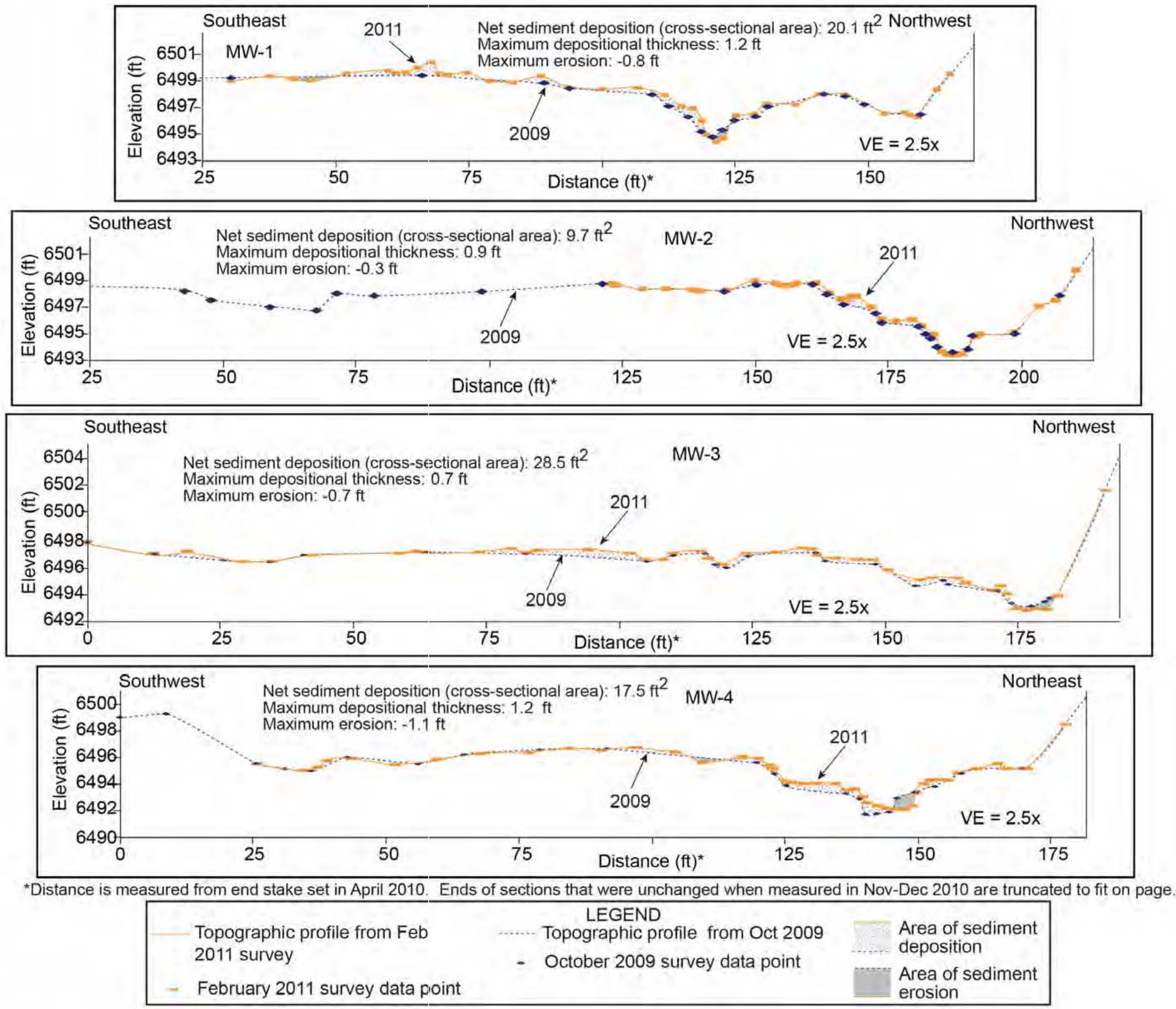


Figure 8 **Cross-sections and thalweg profile in middle third of upper Pueblo Canyon willow-planting area**

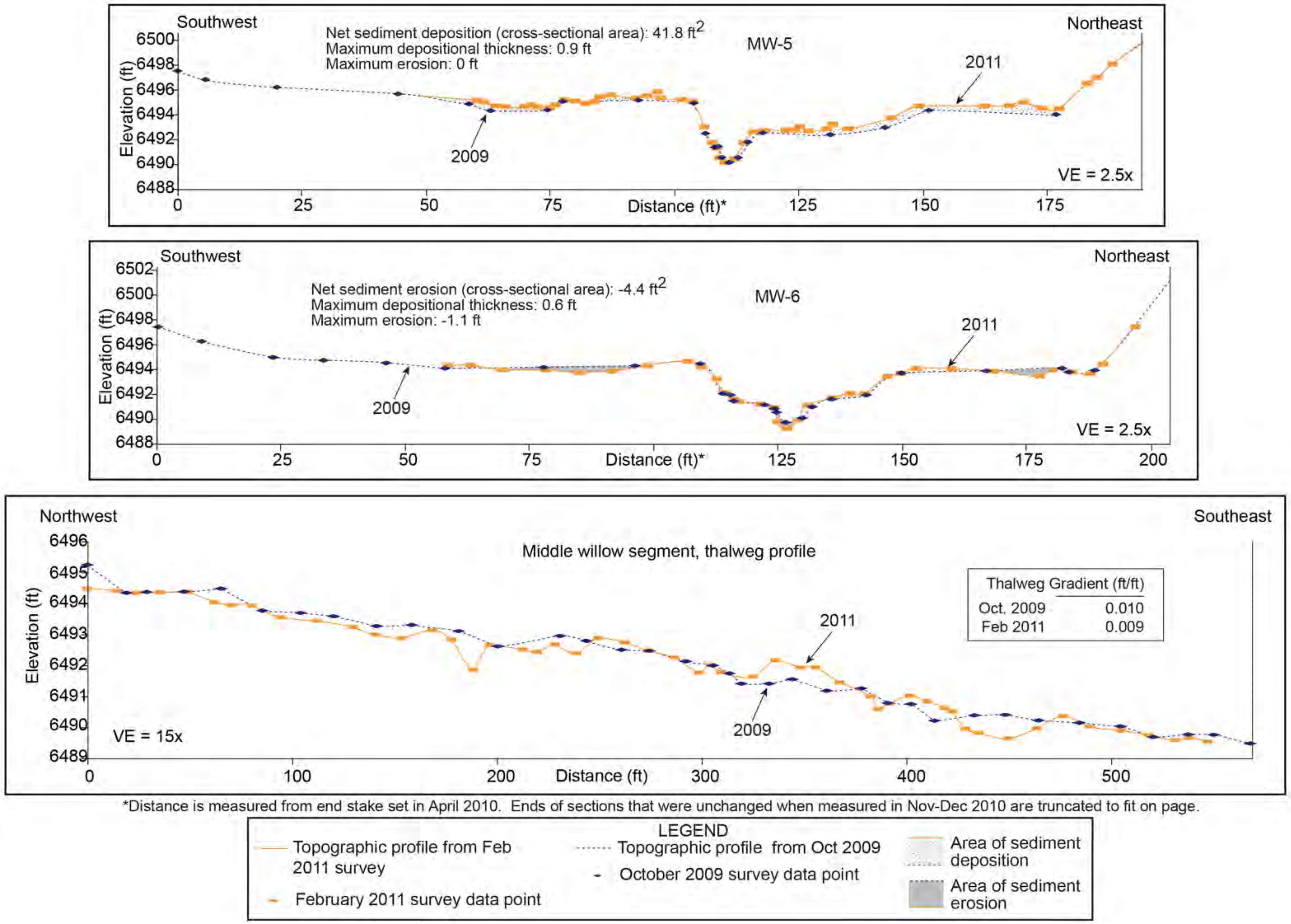


Figure 8 (continued) **Cross-sections and thalweg profile in middle third of upper Pueblo Canyon willow-planting area**

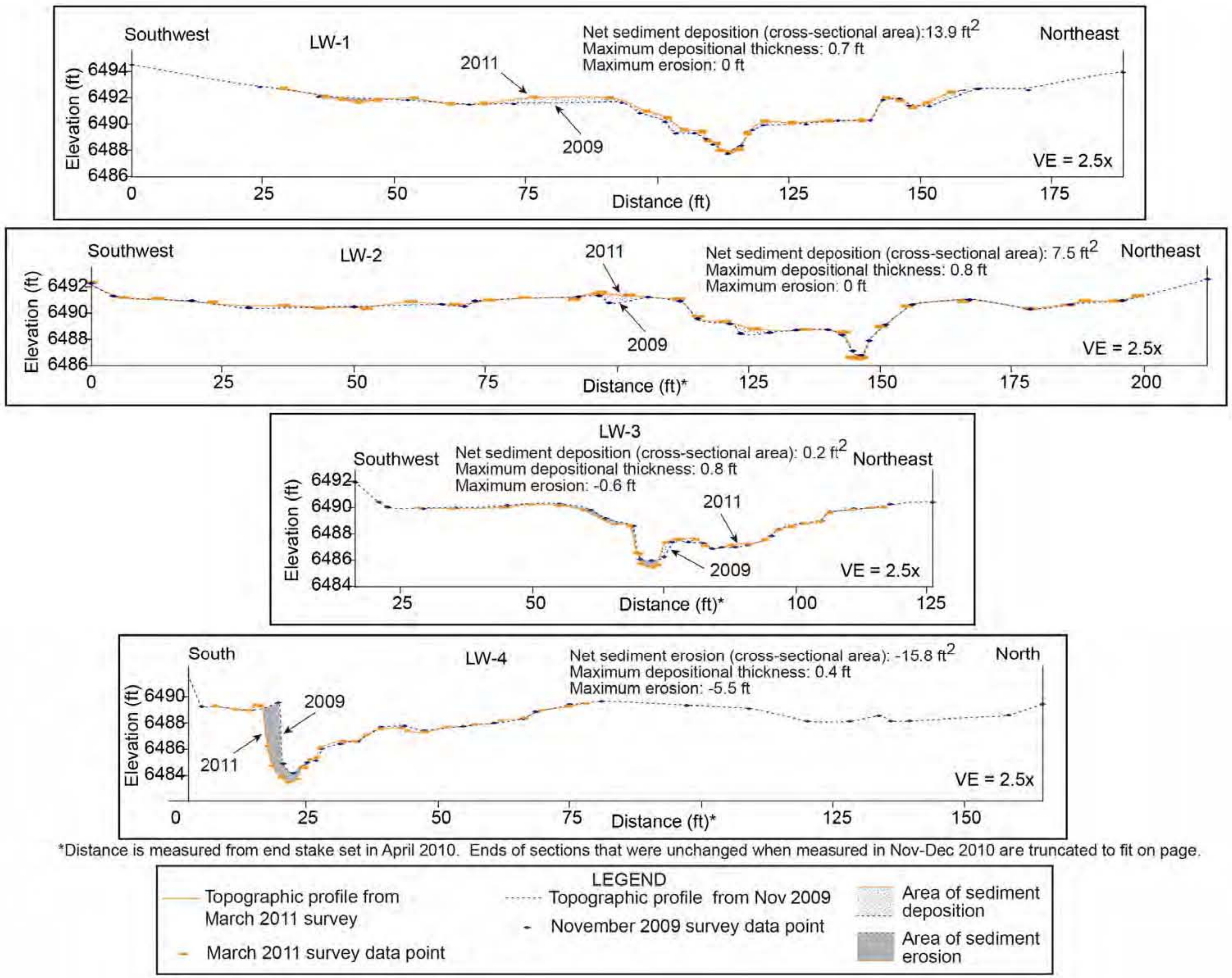


Figure 9 **Cross-sections and thalweg profile in lower third of upper Pueblo Canyon willow-planting area**

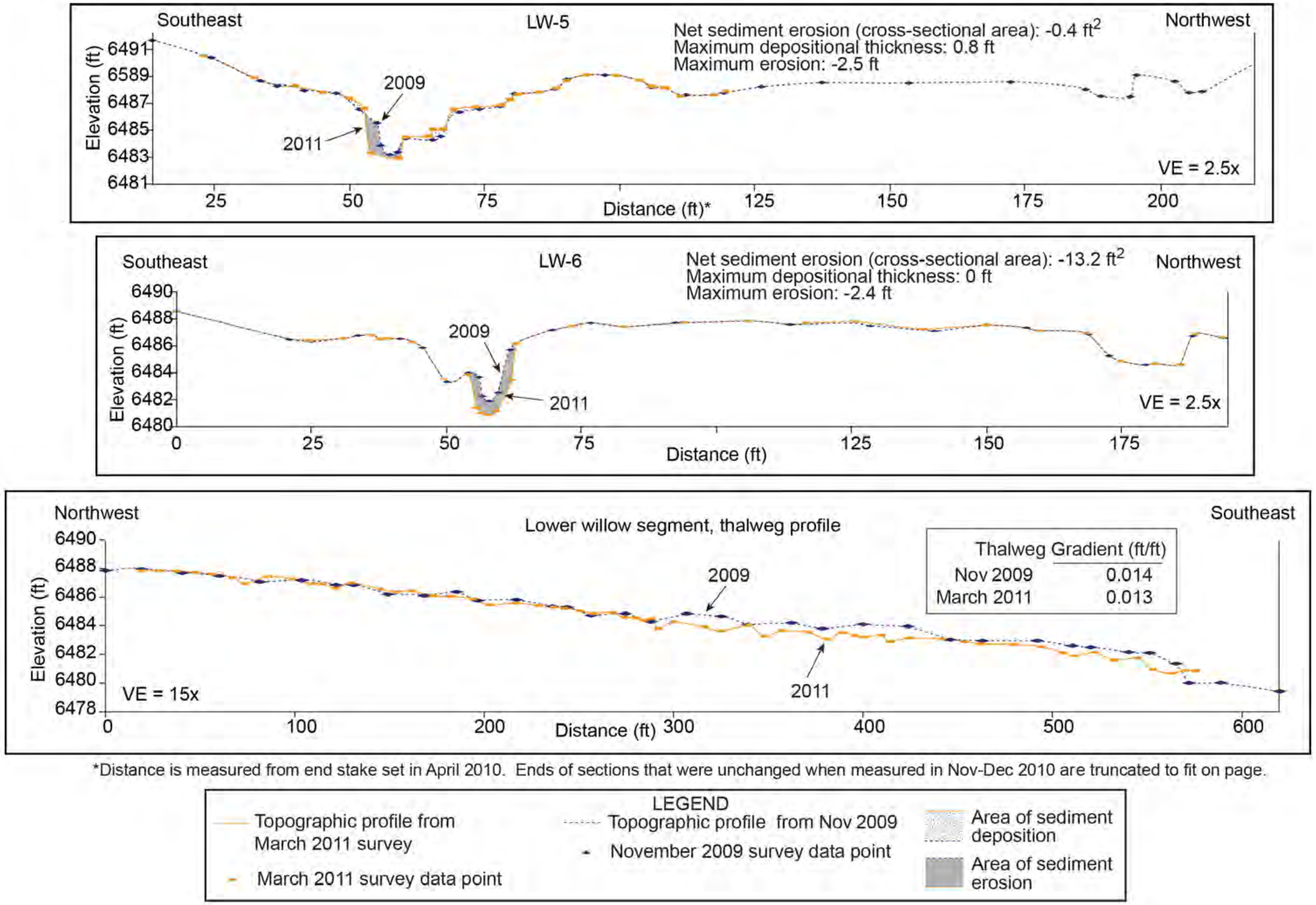


Figure 9 (continued) **Cross-sections and thalweg profile in lower third of upper Pueblo Canyon willow-planting area**

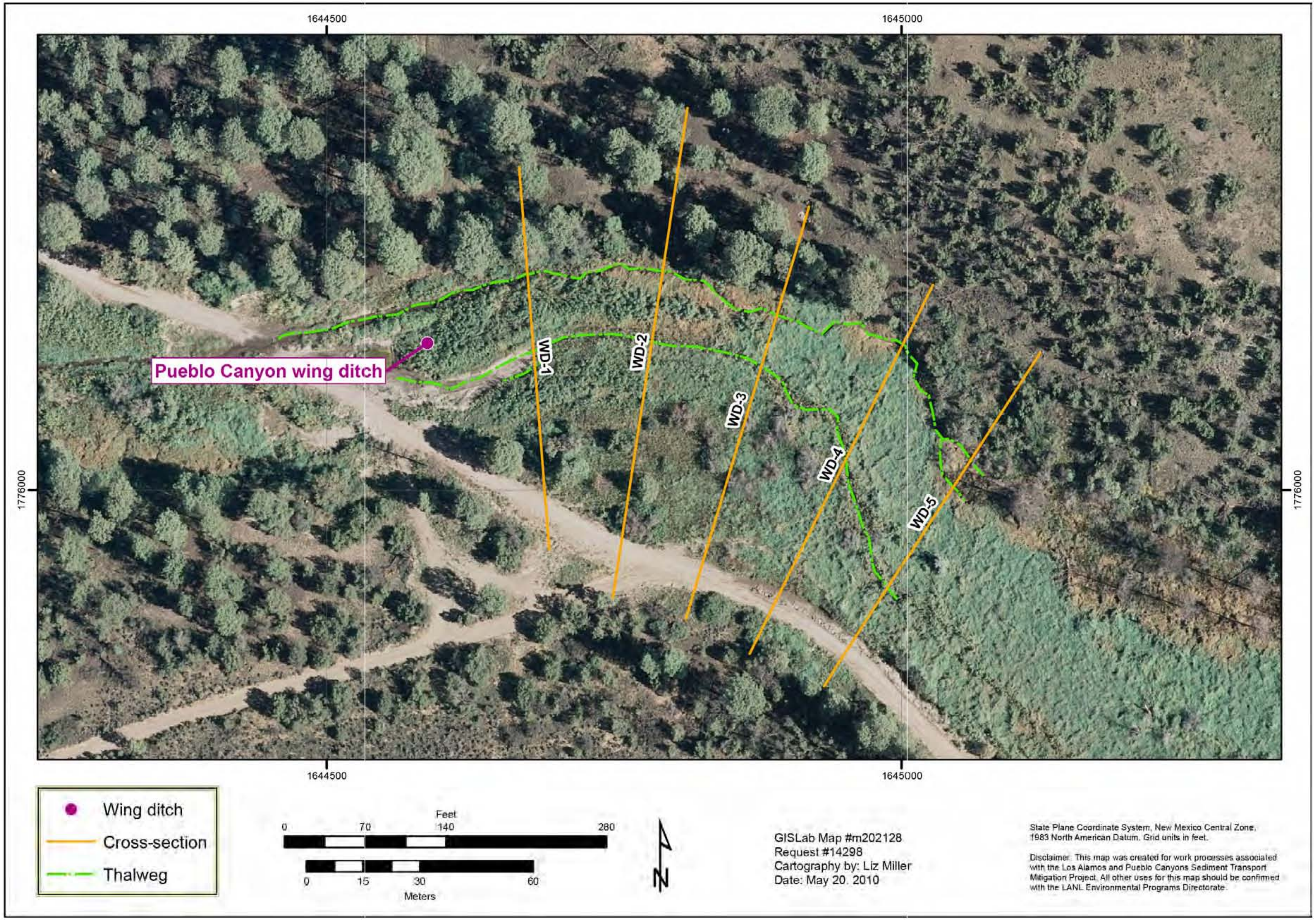
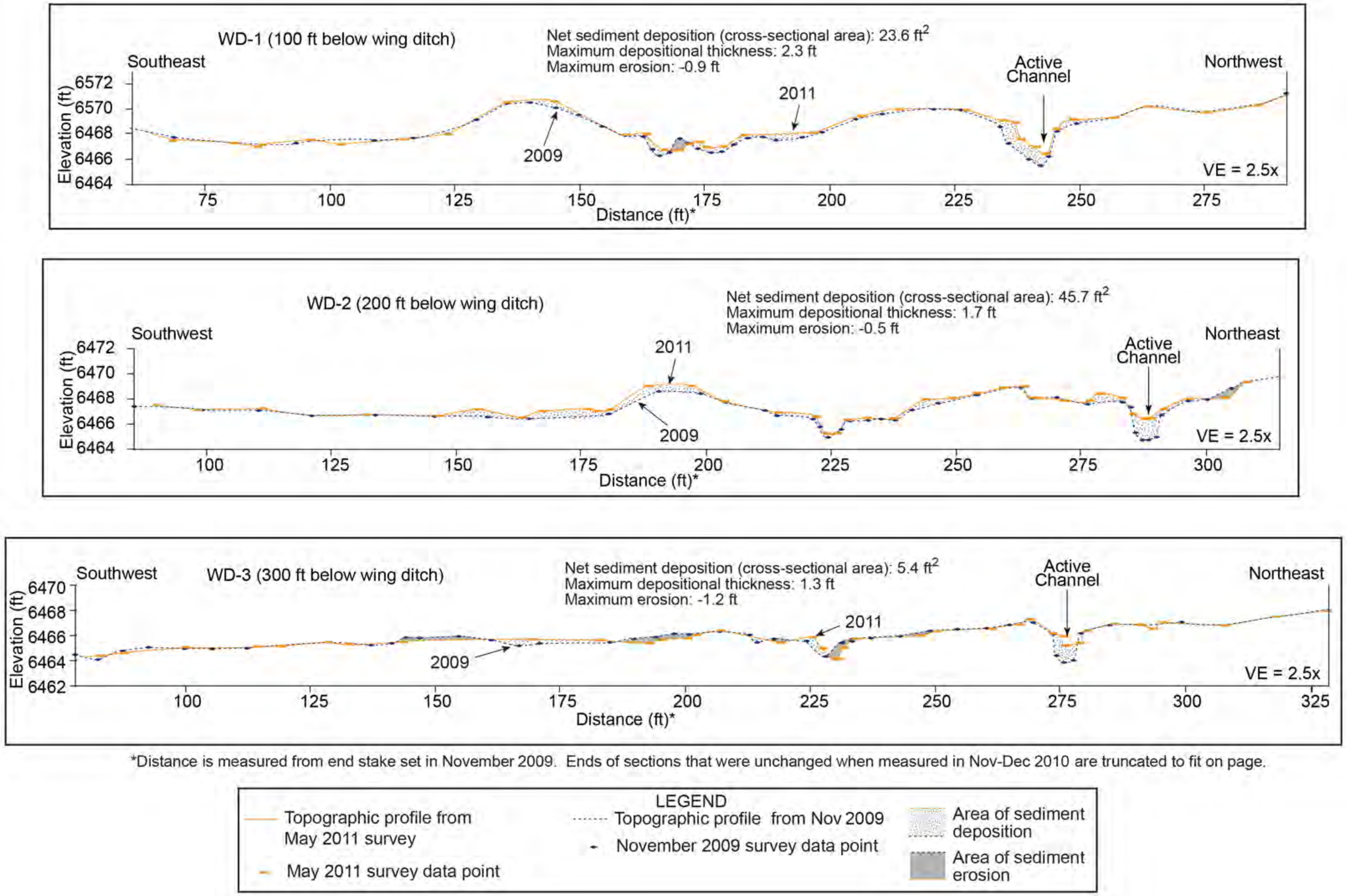


Figure 10 Orthophoto showing the locations of surveyed cross-sections and thalweg profiles near the Pueblo Canyon wing ditch



*Distance is measured from end stake set in November 2009. Ends of sections that were unchanged when measured in Nov-Dec 2010 are truncated to fit on page.

Figure 11 **Cross-sections below the Pueblo Canyon wing ditch**

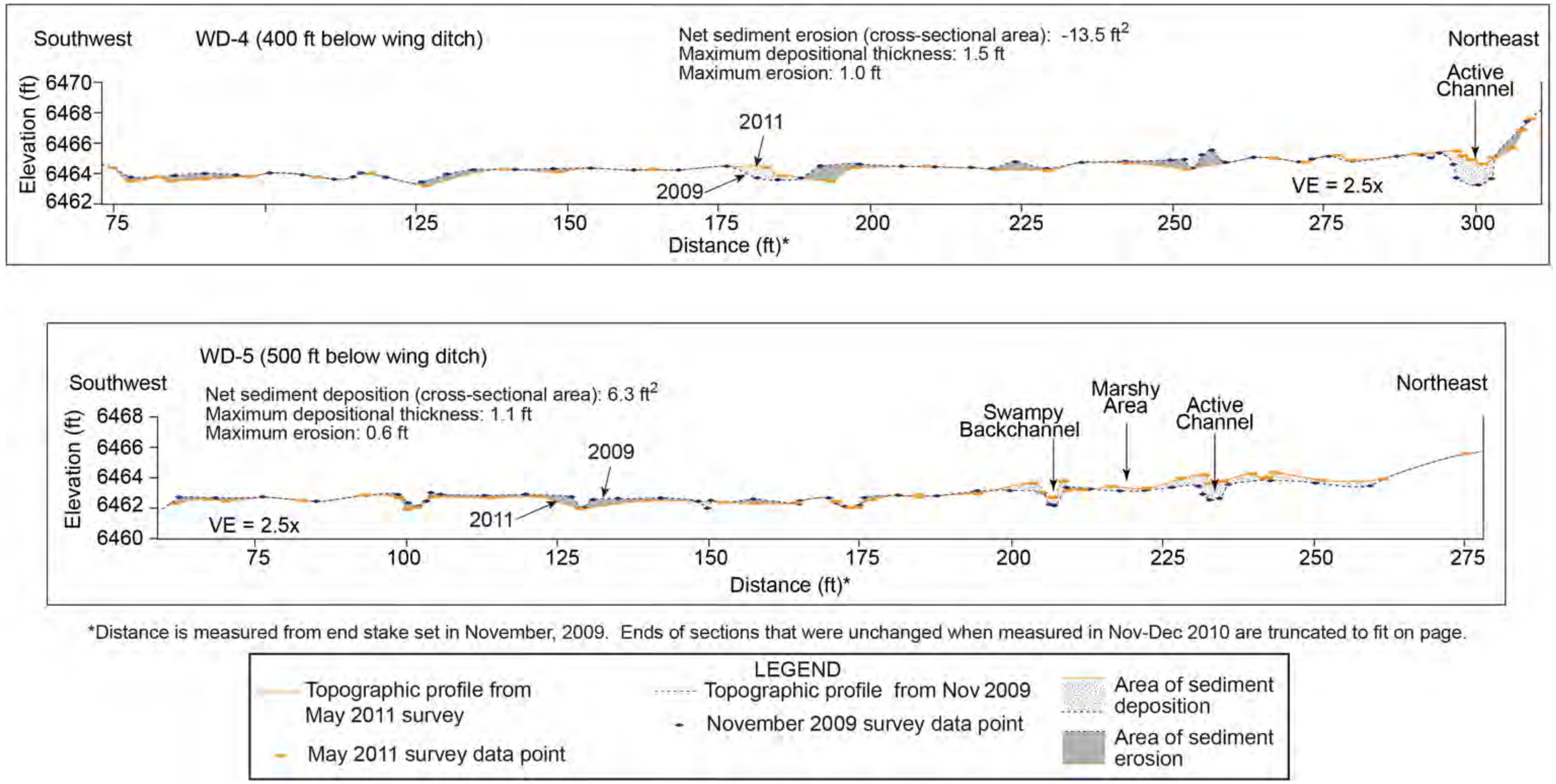


Figure 11 (continued) **Cross-sections below the Pueblo Canyon wing ditch**

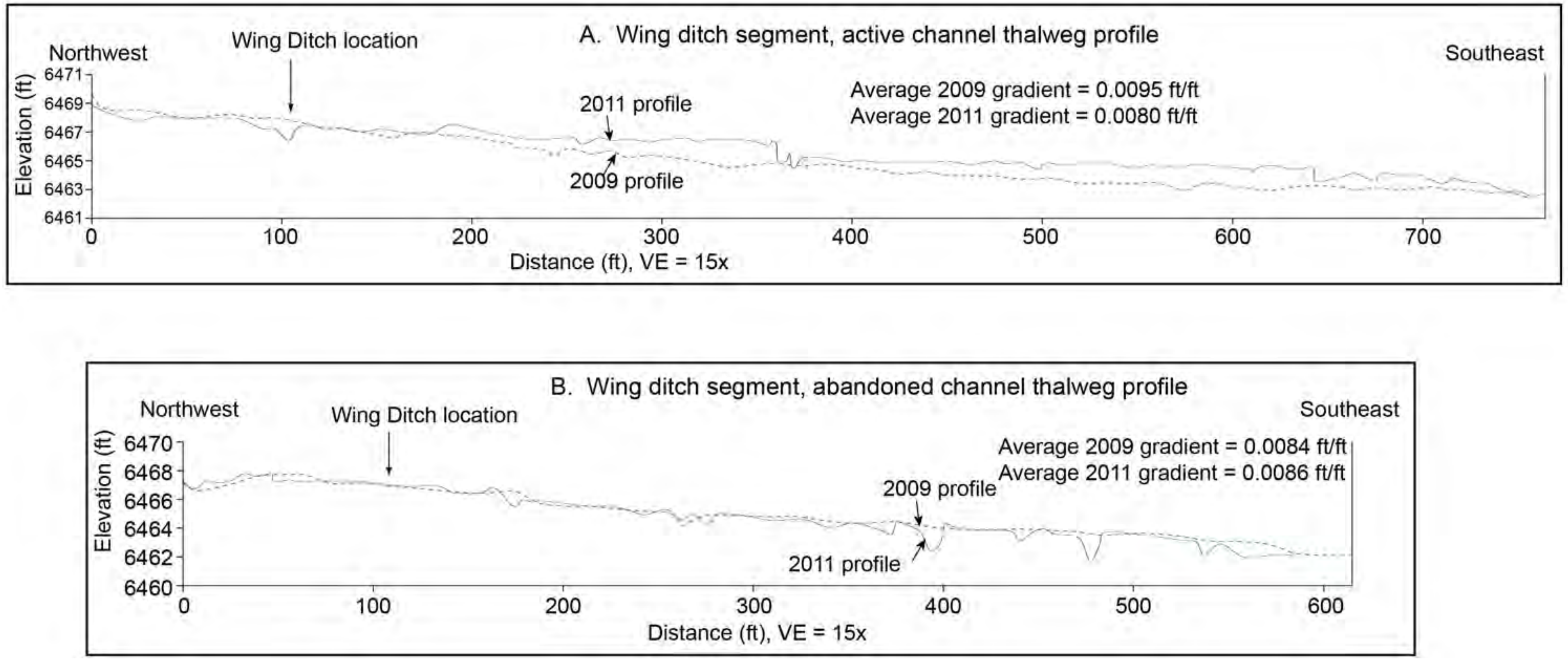


Figure 12 Thalweg profiles near the Pueblo Canyon wing ditch

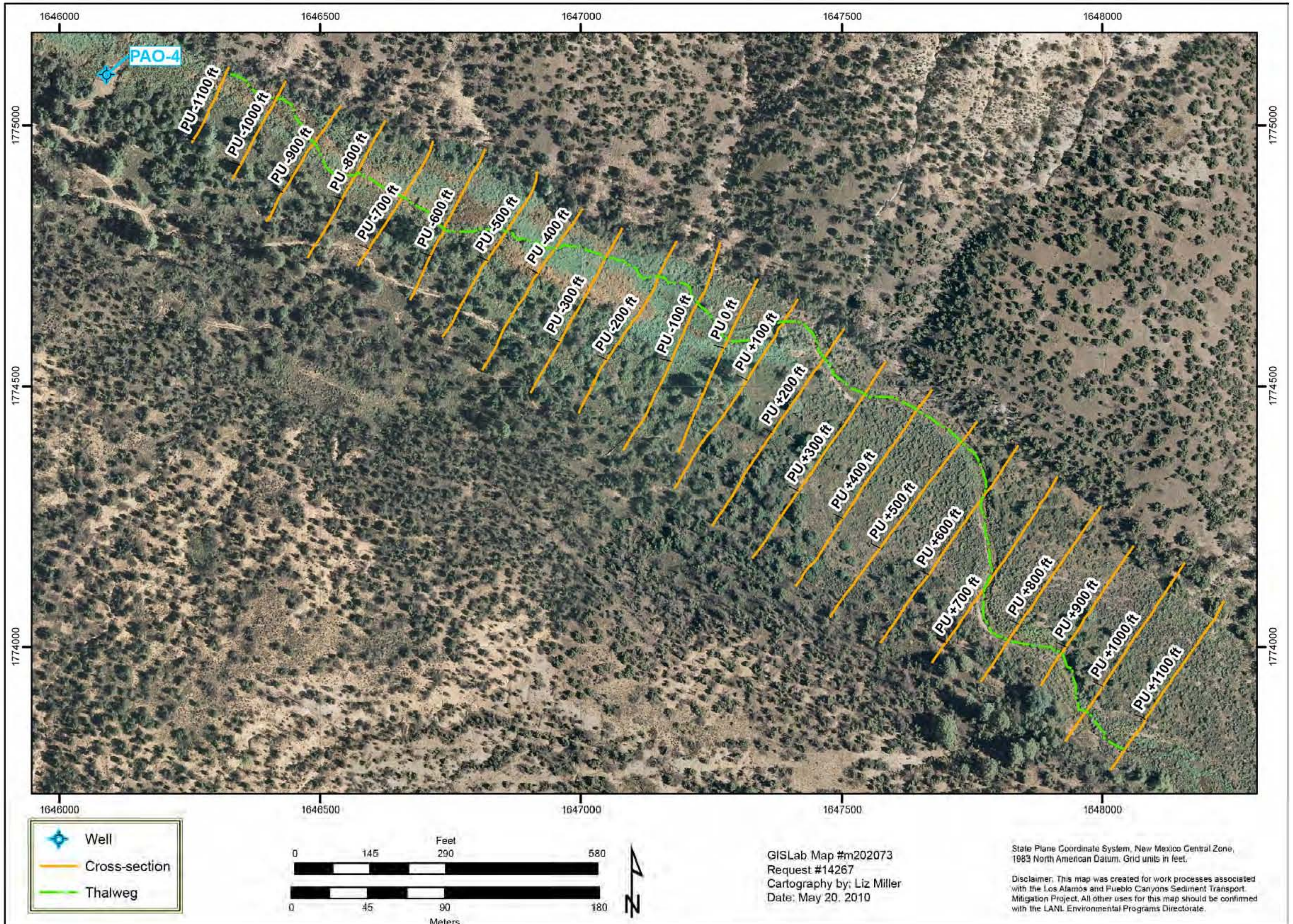


Figure 13 **Orthophoto showing the locations of surveyed cross-sections and thalweg profiles in the lower Pueblo Canyon willow-planting area**

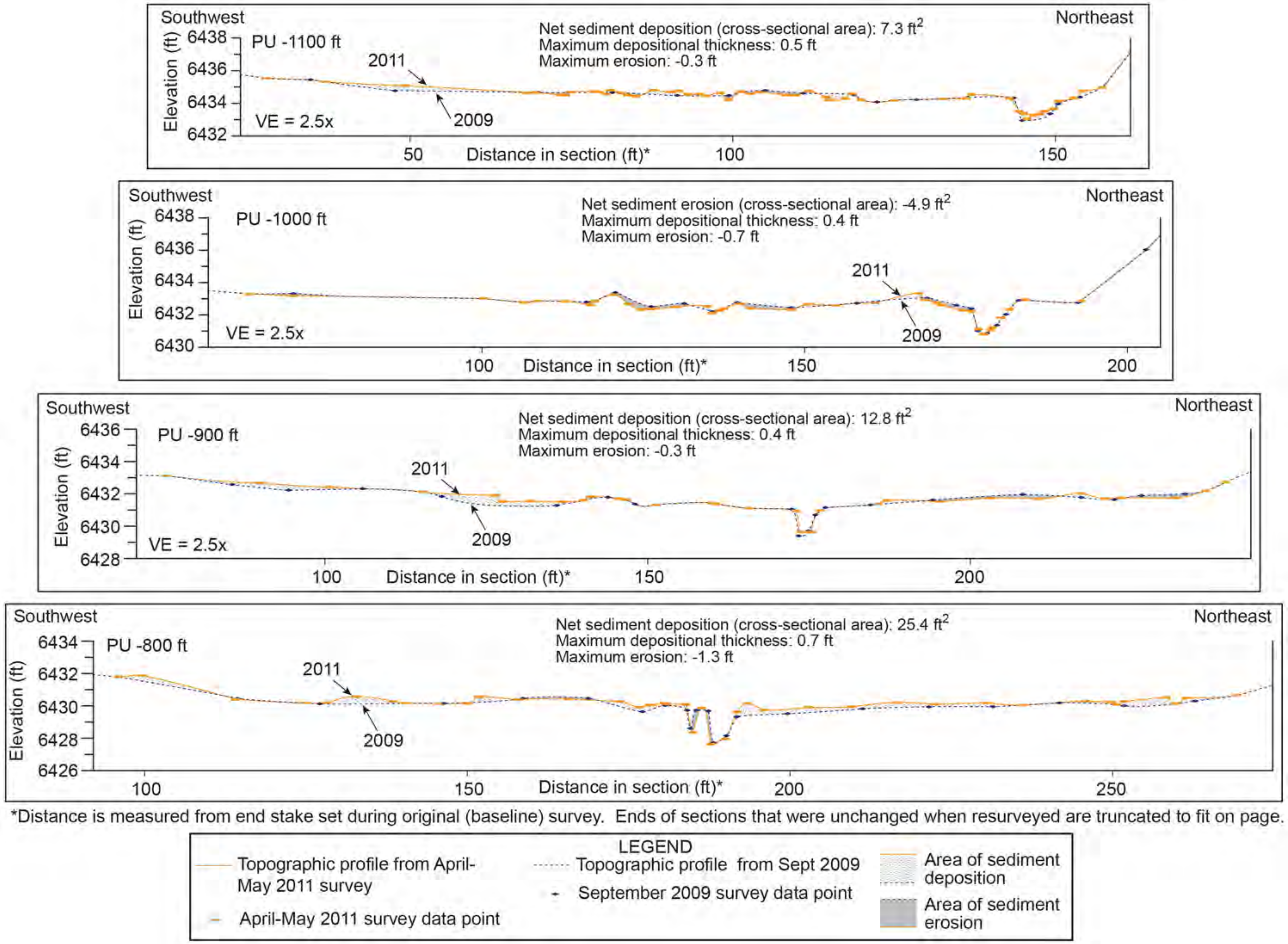


Figure 14 Cross-sections in the lower Pueblo Canyon willow-planting area

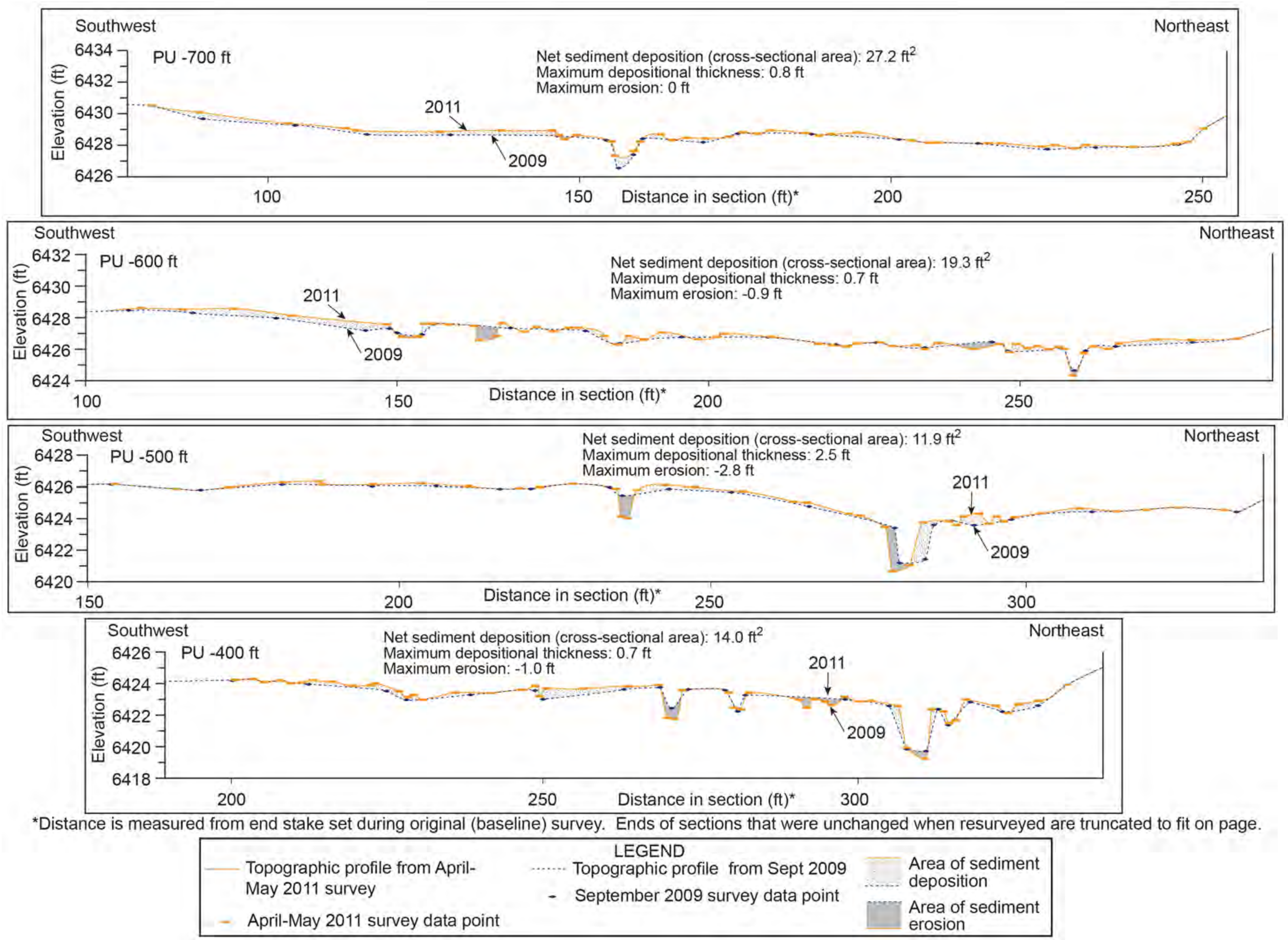
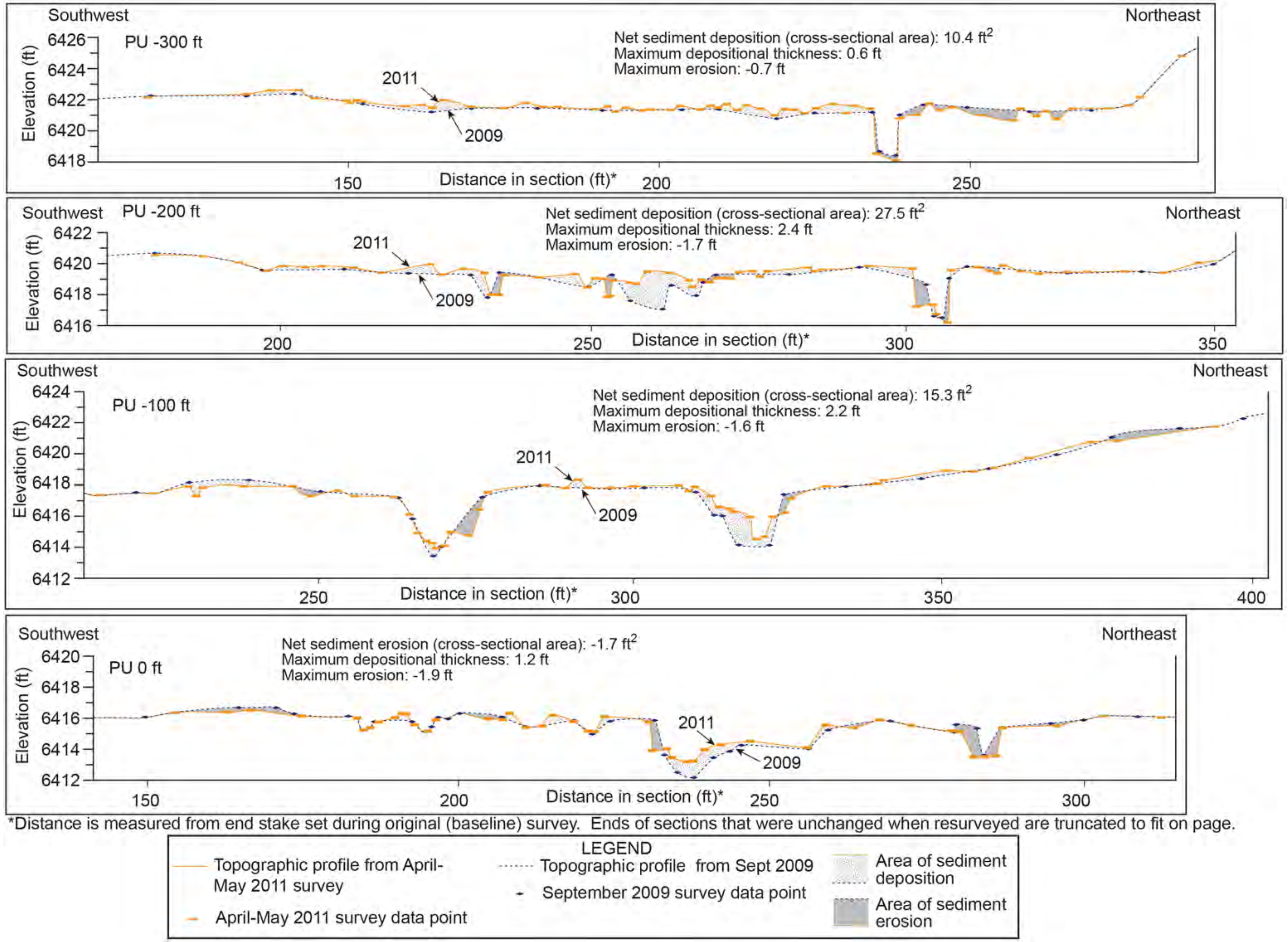
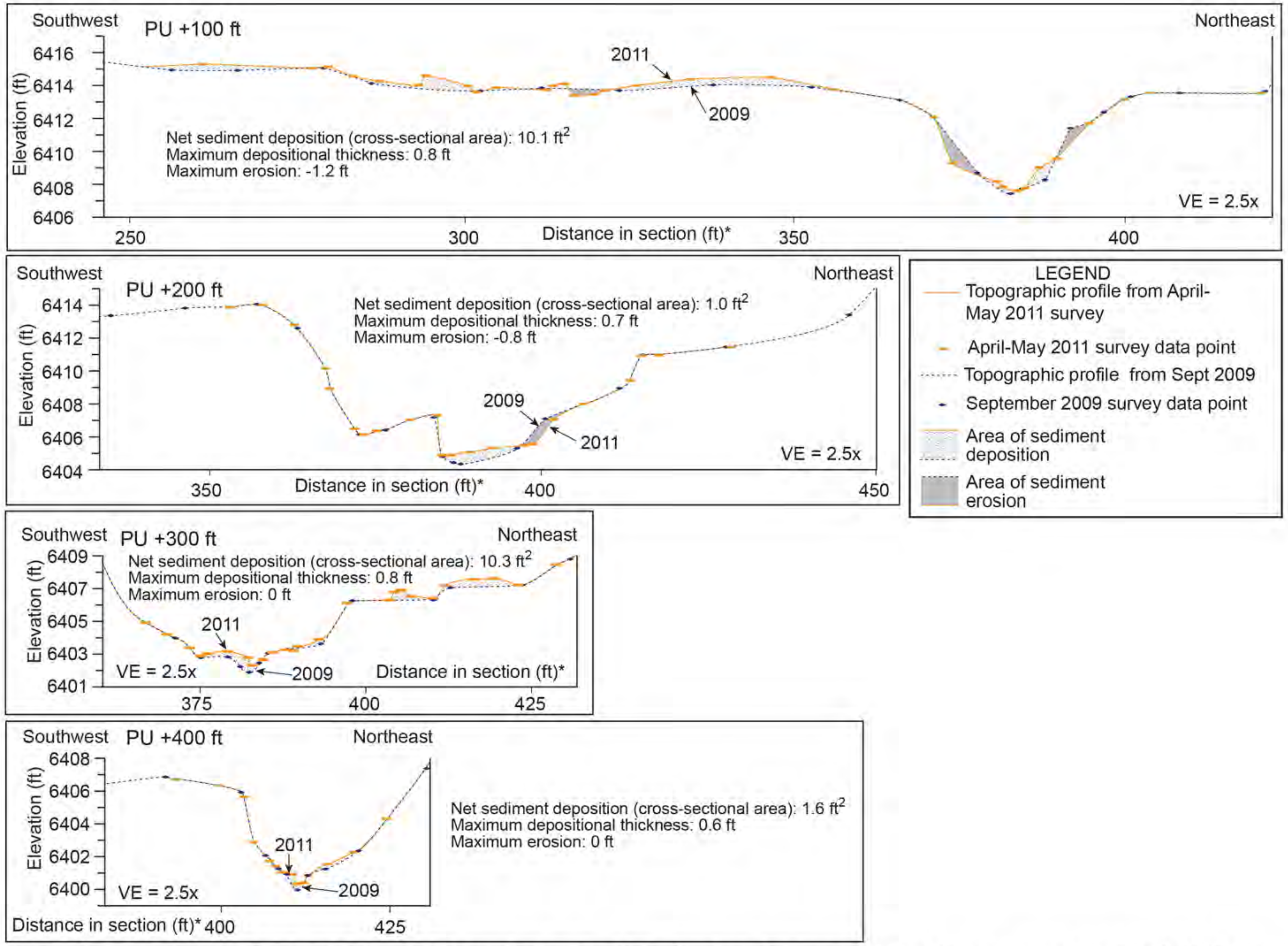


Figure 14 (continued) **Cross-sections in the lower Pueblo Canyon willow-planting area**



*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

Figure 14 (continued) **Cross-sections in the lower Pueblo Canyon willow-planting area**



*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

Figure 14 (continued) **Cross-sections in the lower Pueblo Canyon willow-planting area**

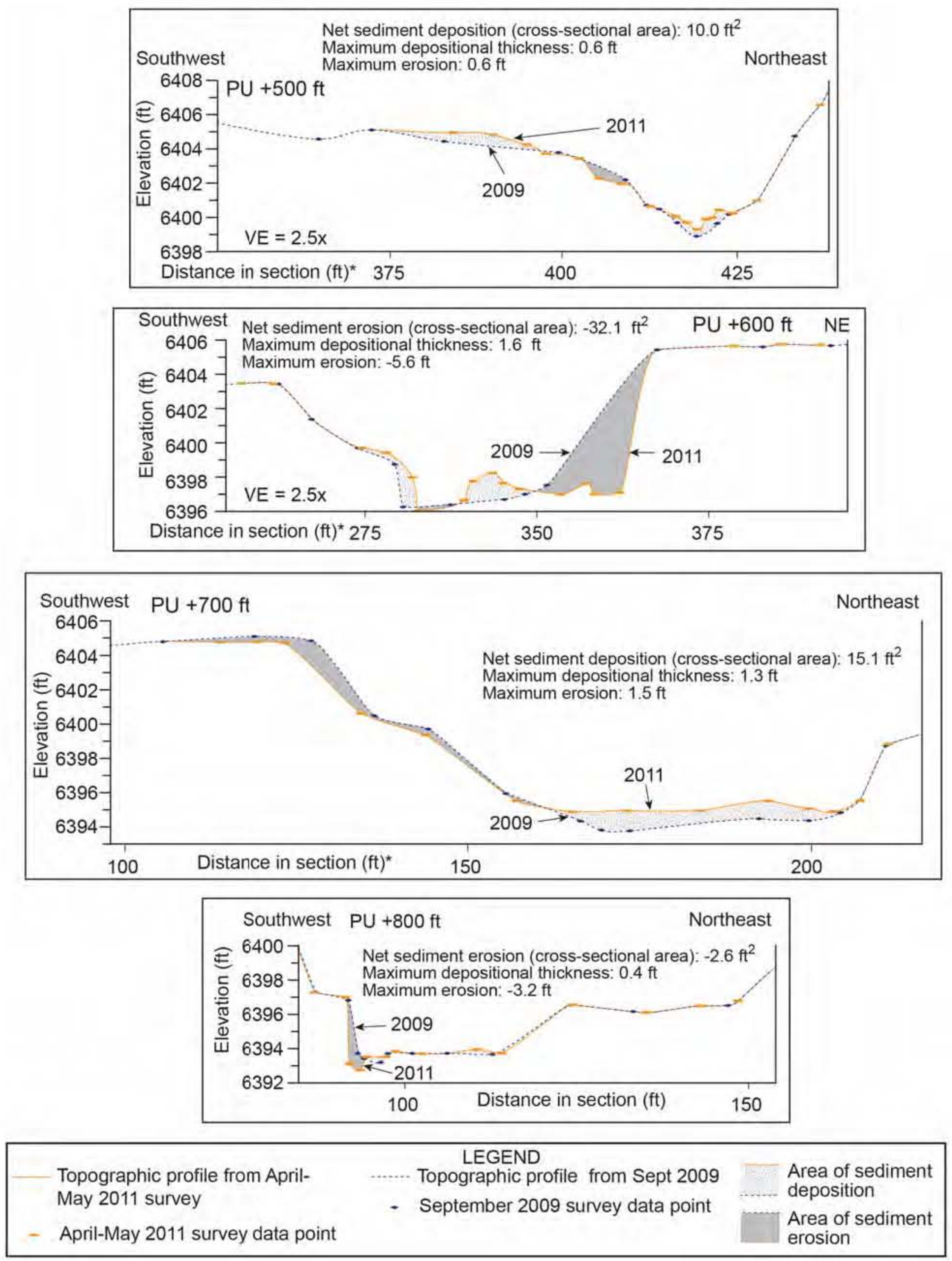


Figure 14 (continued) **Cross-sections in the lower Pueblo Canyon willow-planting area**

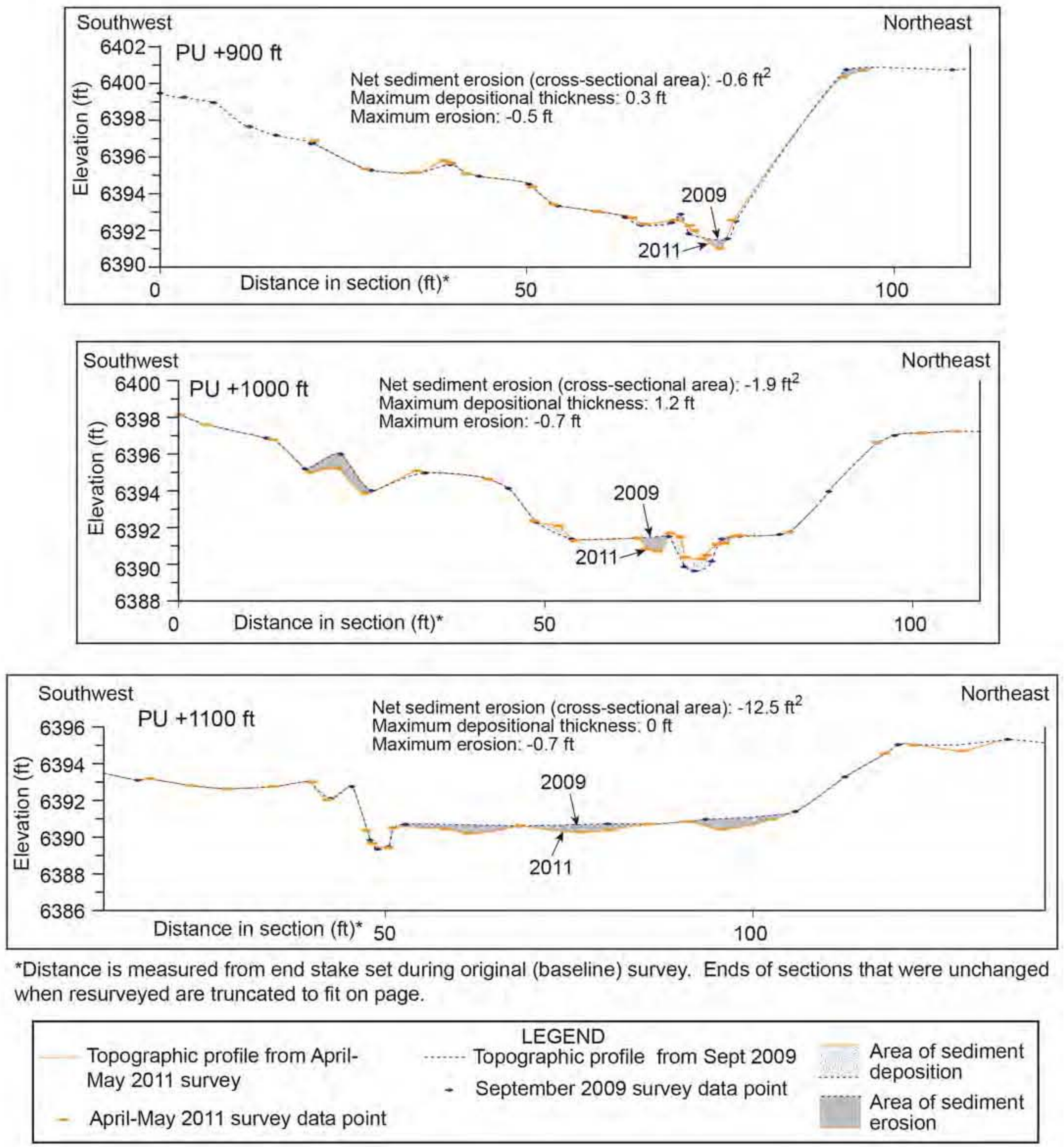


Figure 14 (continued) **Cross-sections in the lower Pueblo Canyon willow-planting area**

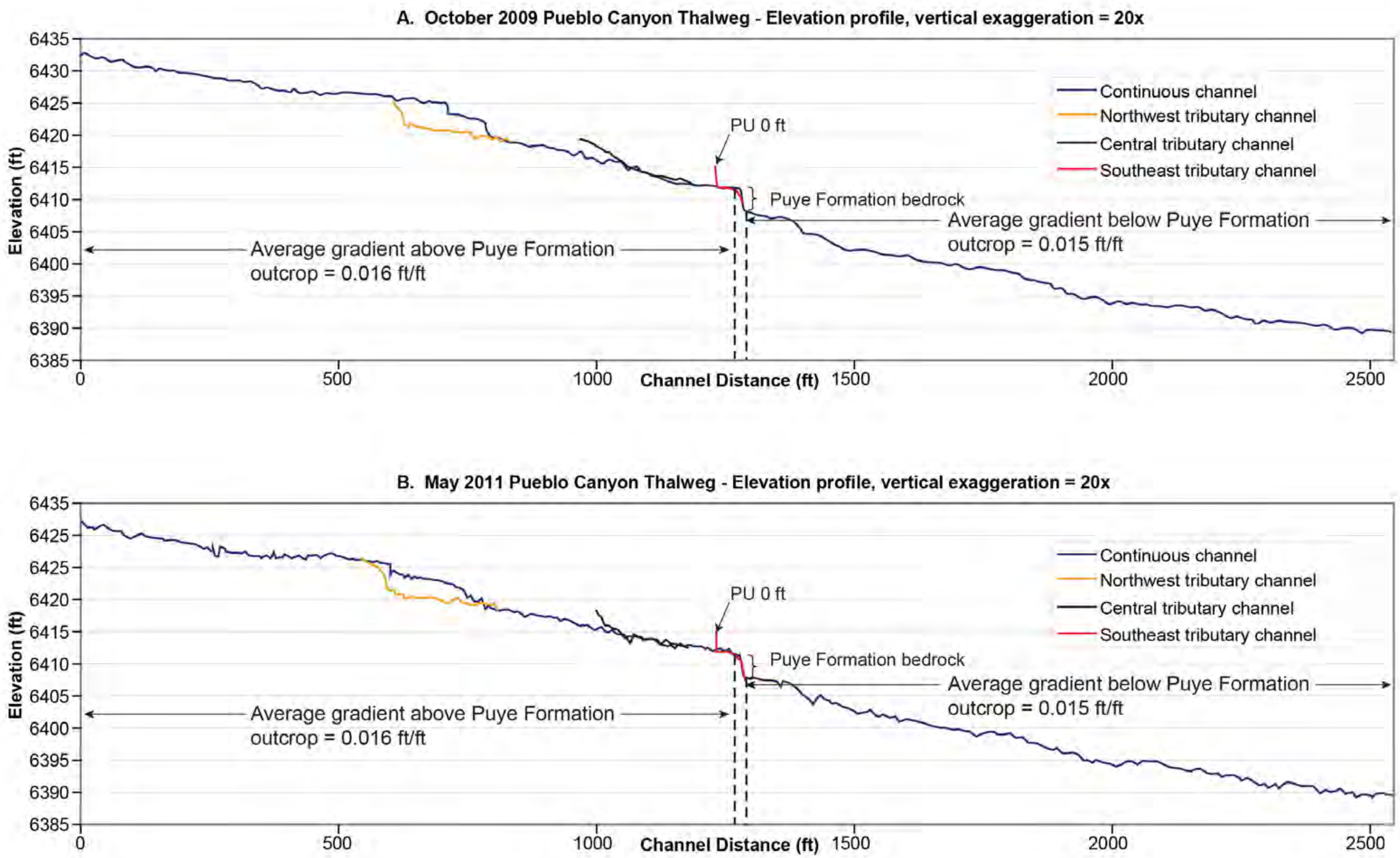


Figure 15 Thalweg profiles in the lower Pueblo Canyon willow-planting area

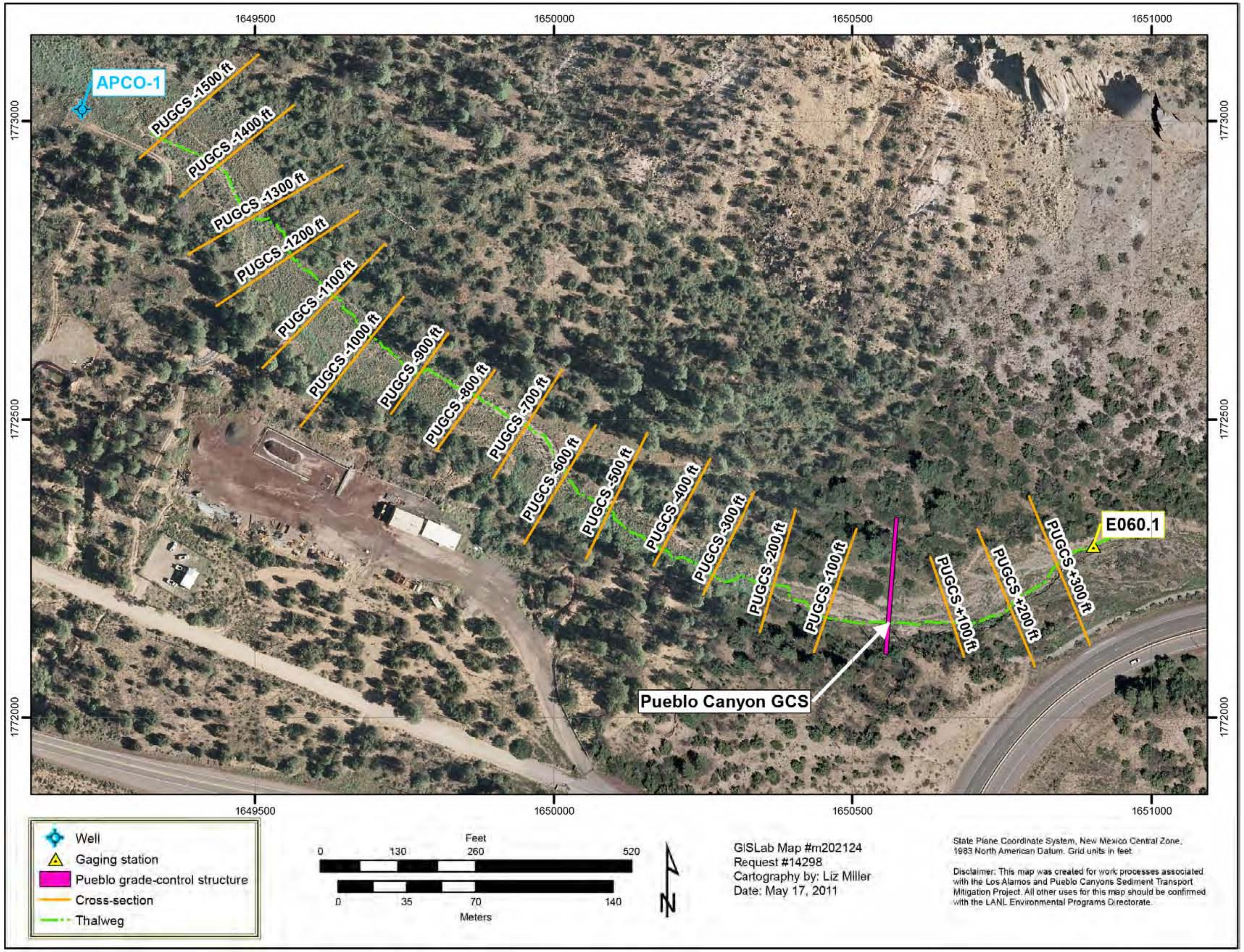
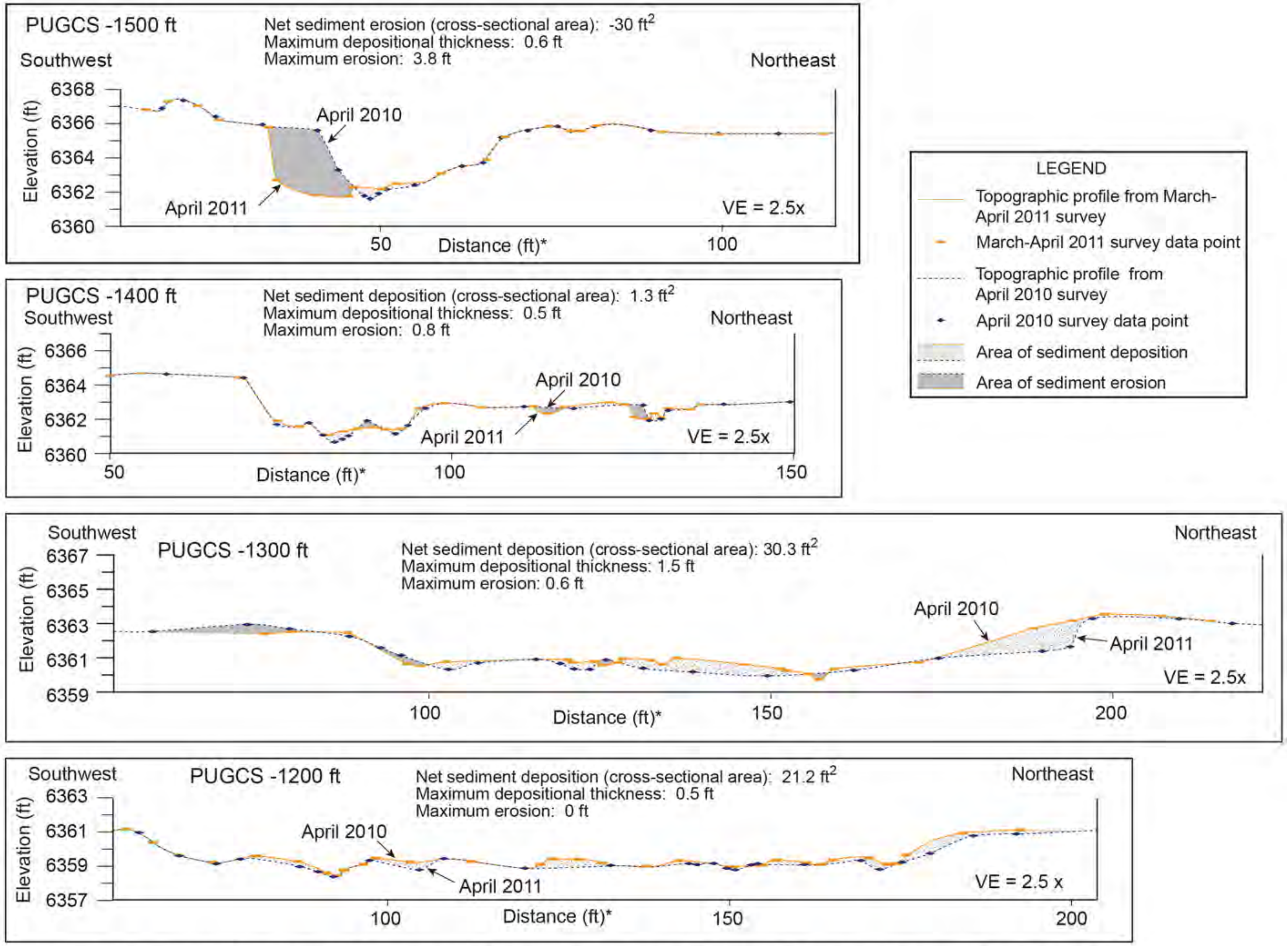
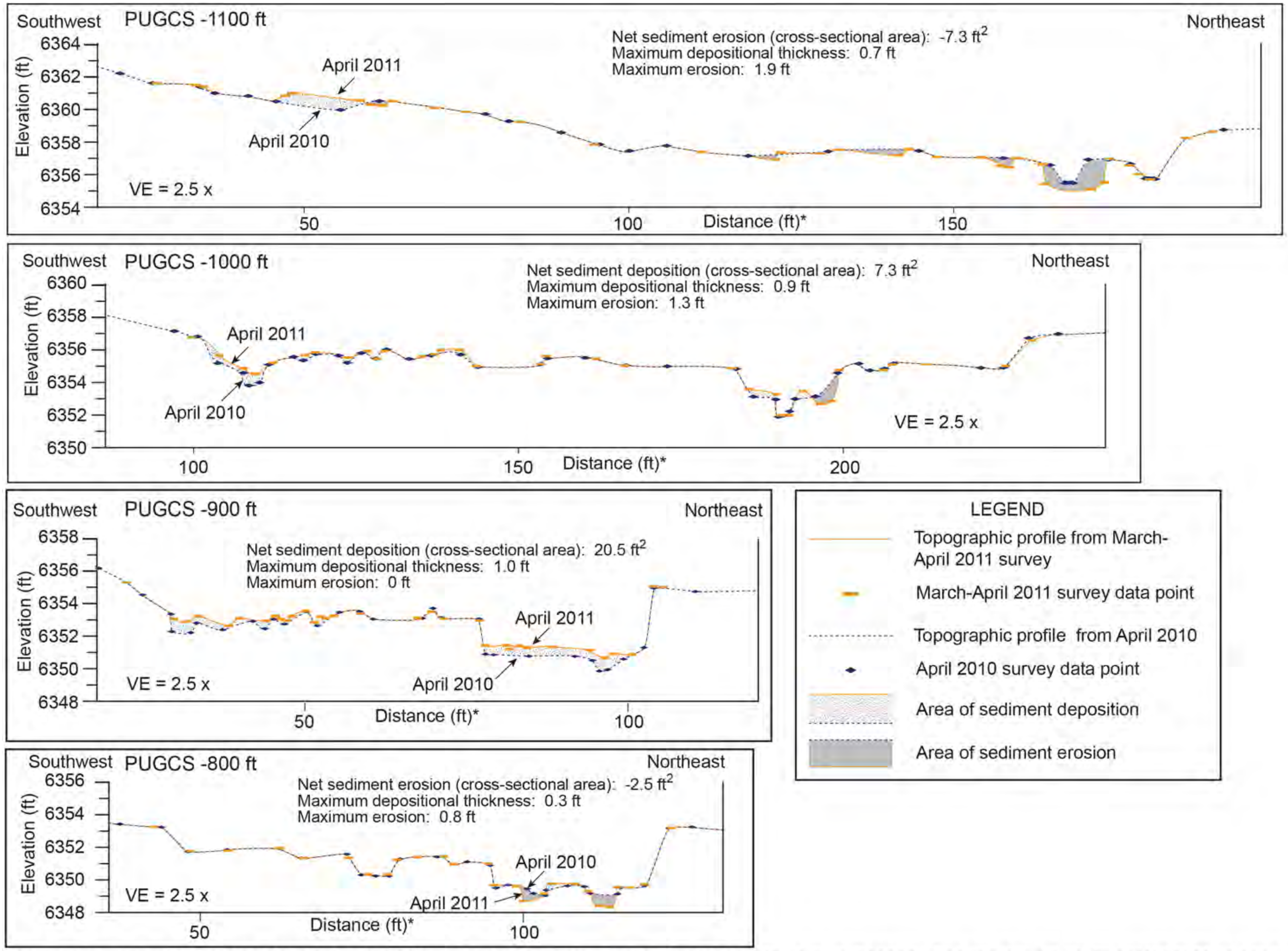


Figure 16 Orthophoto showing the locations of surveyed cross-sections and thalweg profiles near the Pueblo Canyon GCS



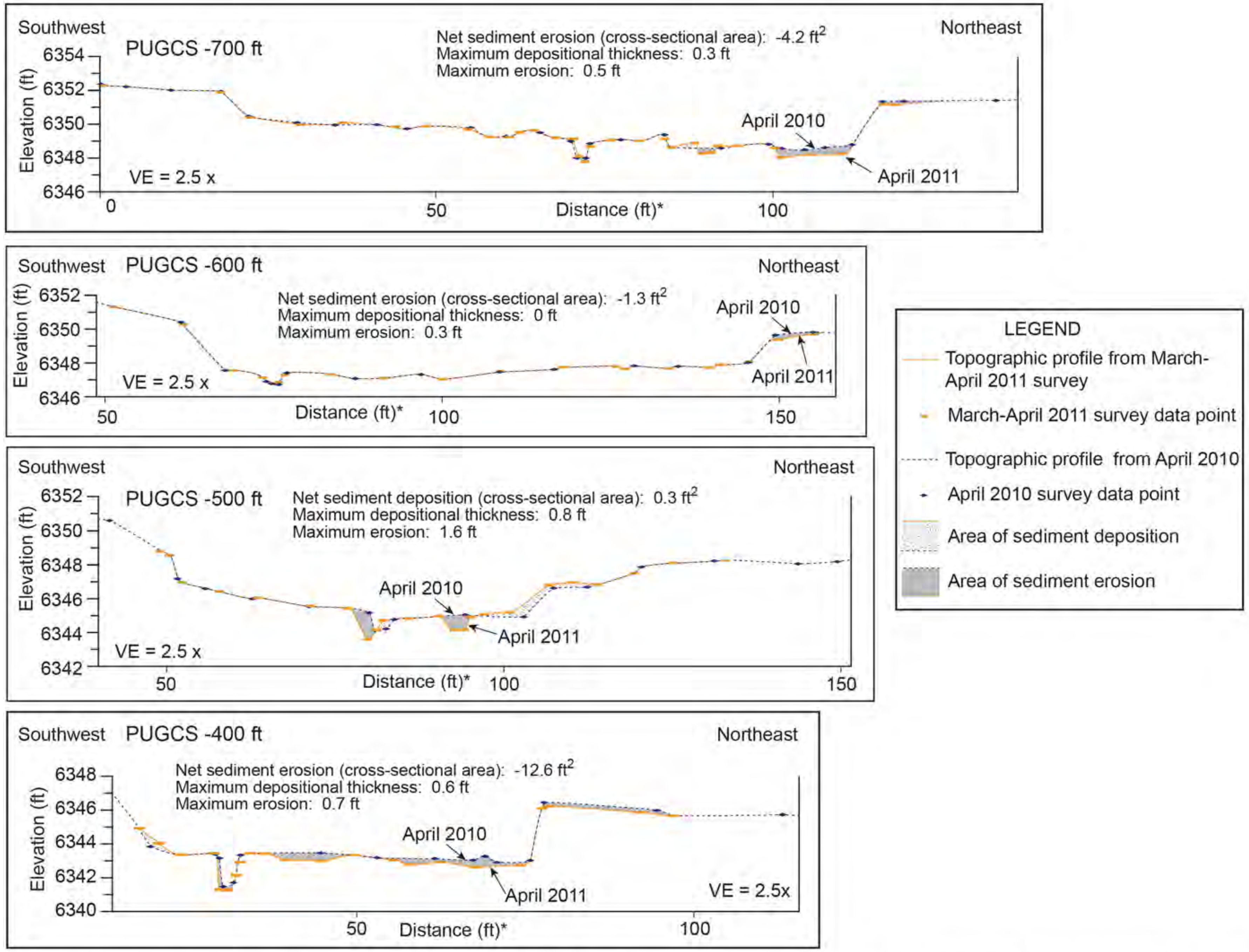
*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

Figure 17 Cross-sections and thalweg profile near the Pueblo Canyon GCS



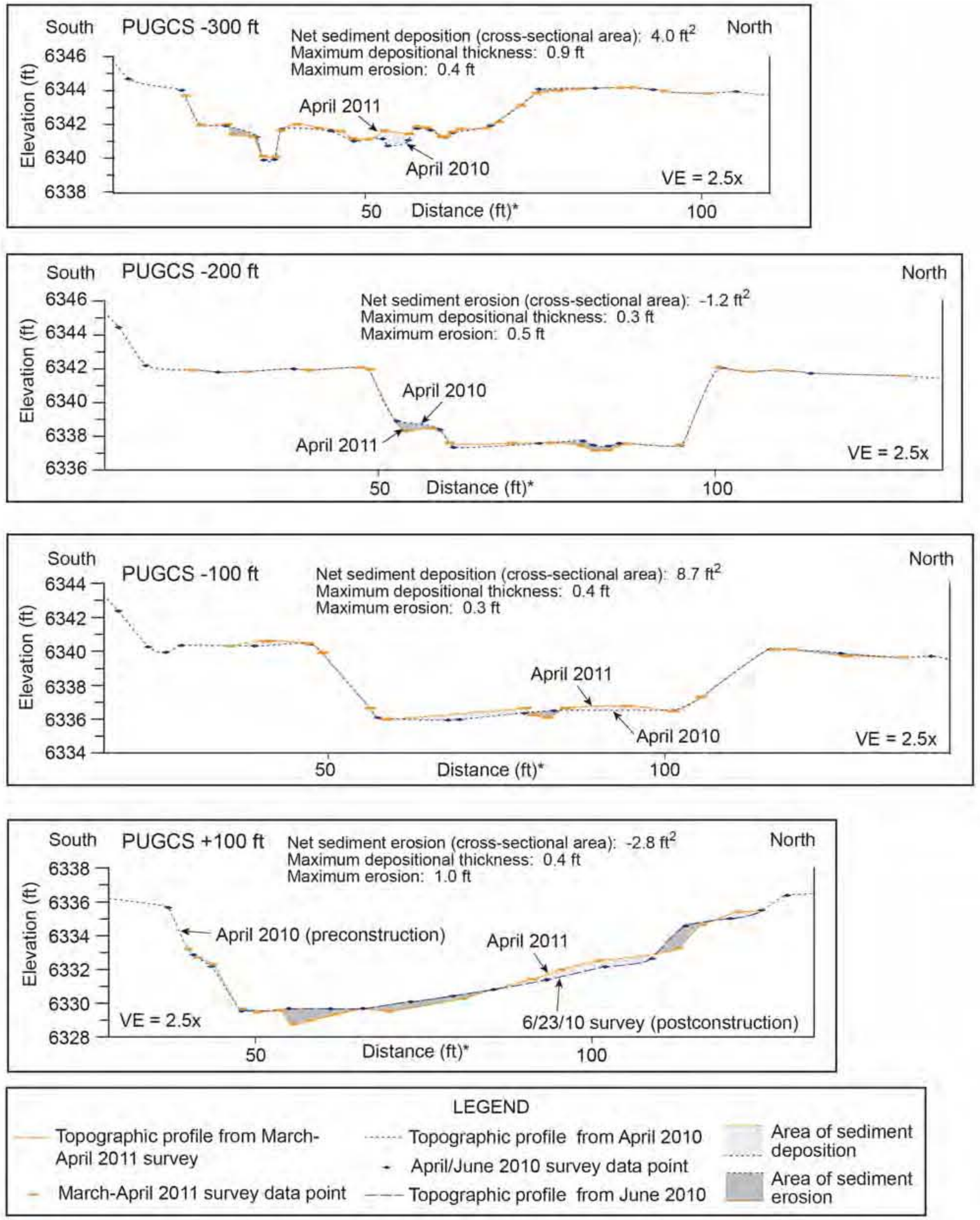
*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

Figure 17 (continued) **Cross-sections and thalweg profile near the Pueblo Canyon GCS**



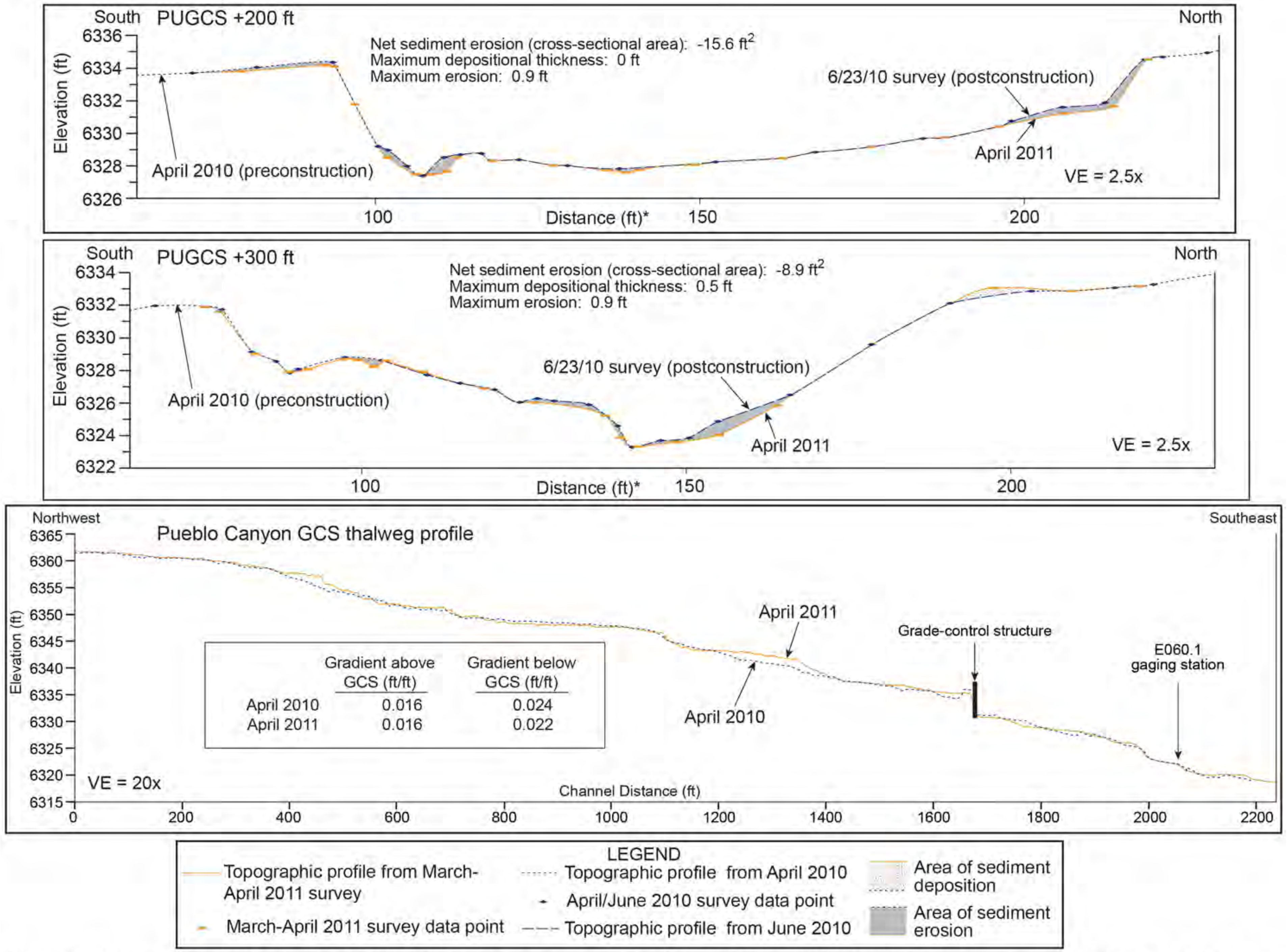
*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

Figure 17 (continued) **Cross-sections and thalweg profile near the Pueblo Canyon GCS**



*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

Figure 17 (continued) **Cross-sections and thalweg profile near the Pueblo Canyon GCS**



*Distance is measured from end stake set during original (baseline) survey. Ends of sections that were unchanged when resurveyed are truncated to fit on page.

Figure 17 (continued) **Cross-sections and thalweg profile near the Pueblo Canyon GCS**

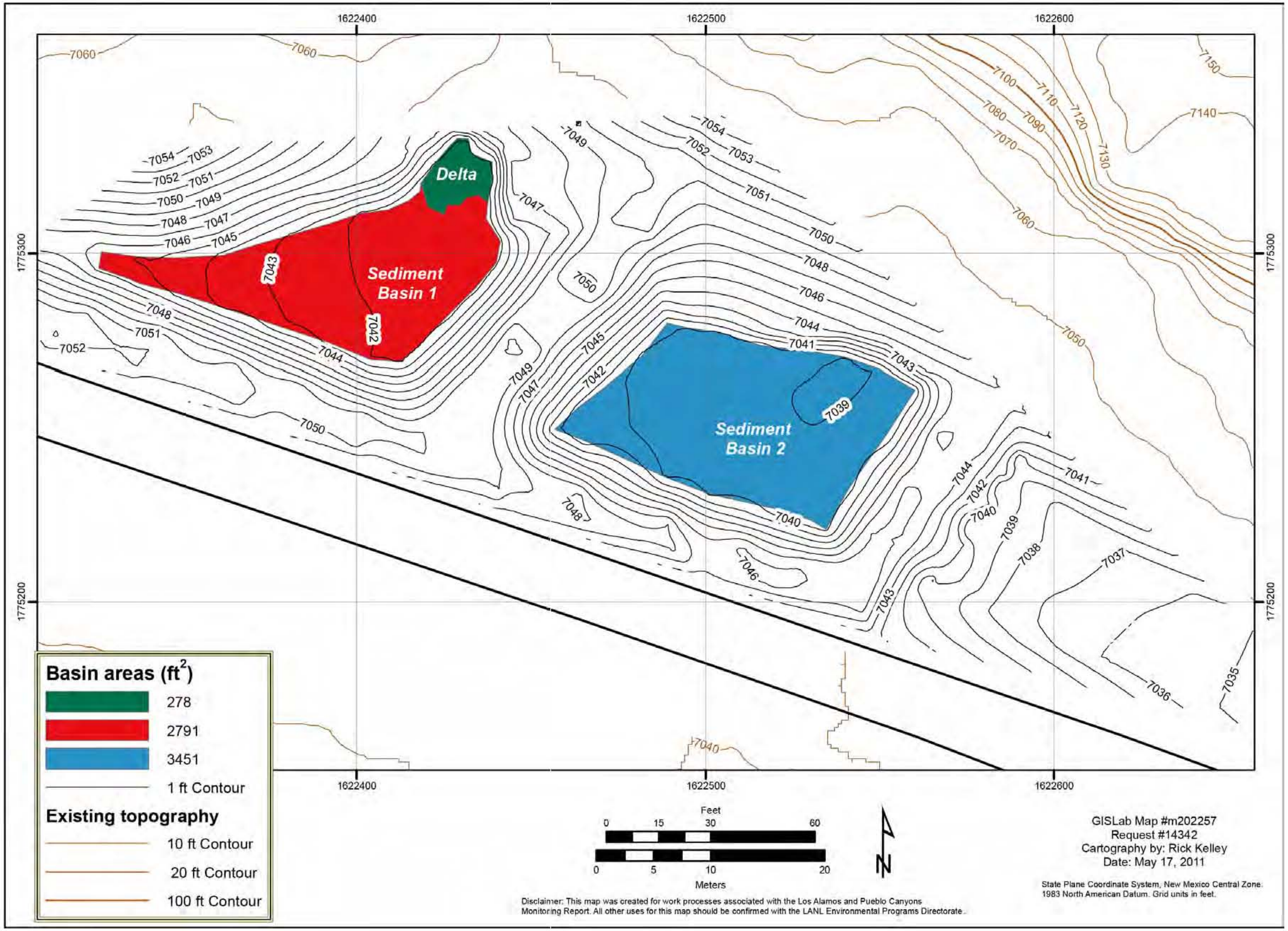


Figure 18 **December 2010 topography at the upper Los Alamos Canyon sediment detention basins**

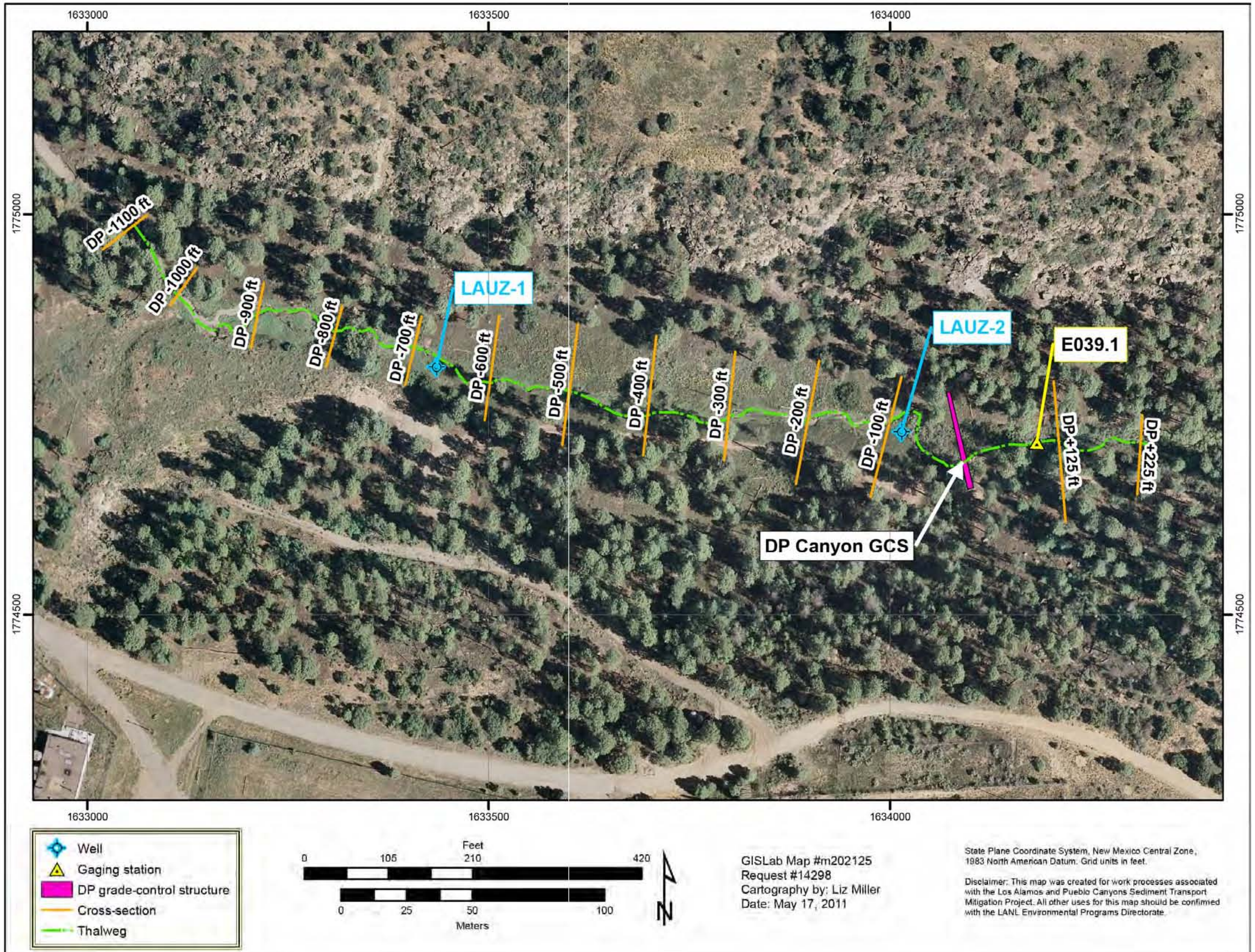


Figure 19 Orthophoto showing the locations of surveyed cross-sections and thalweg profile near the DP Canyon GCS

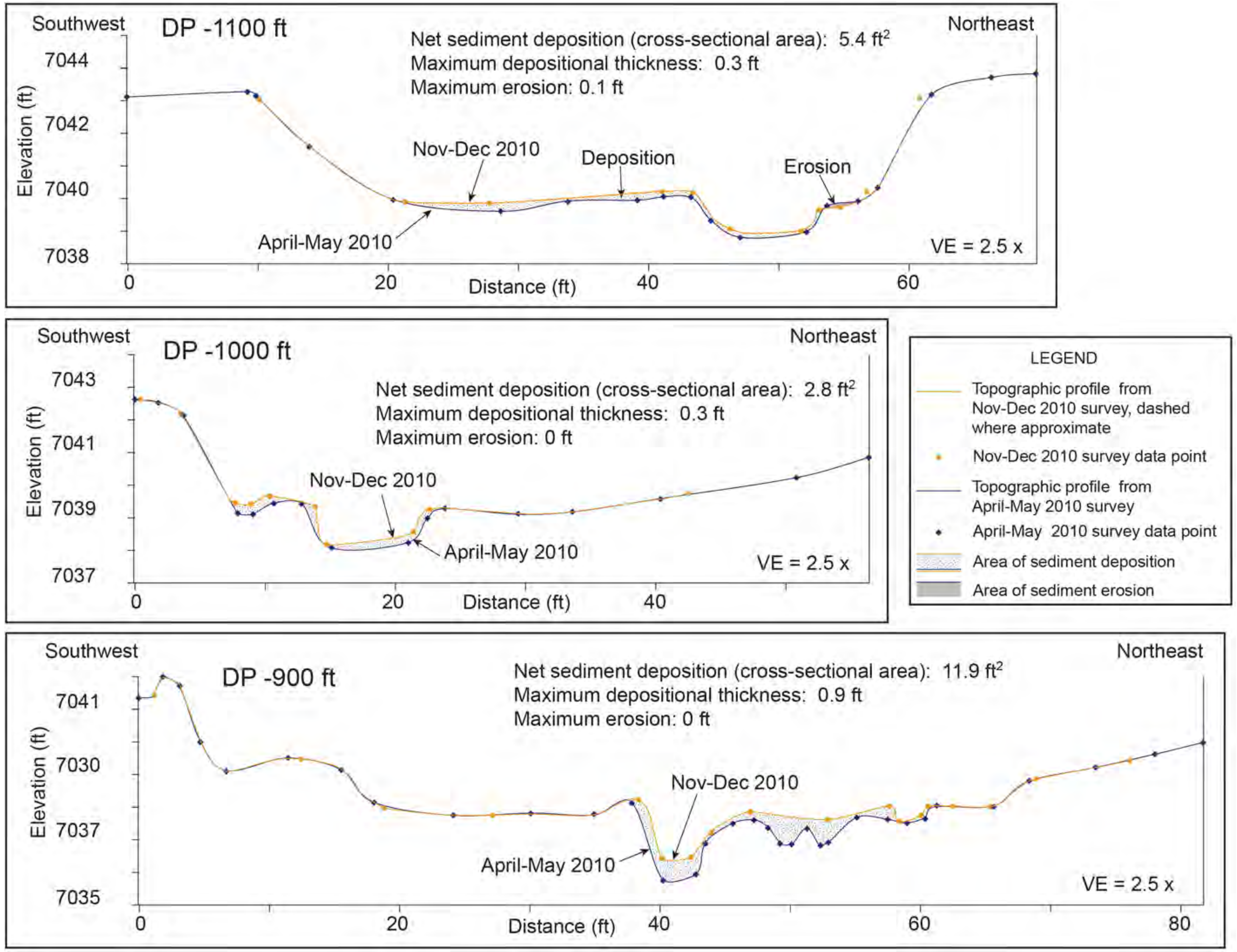


Figure 20 **Cross-sections and thalweg profile near the DP Canyon GCS**

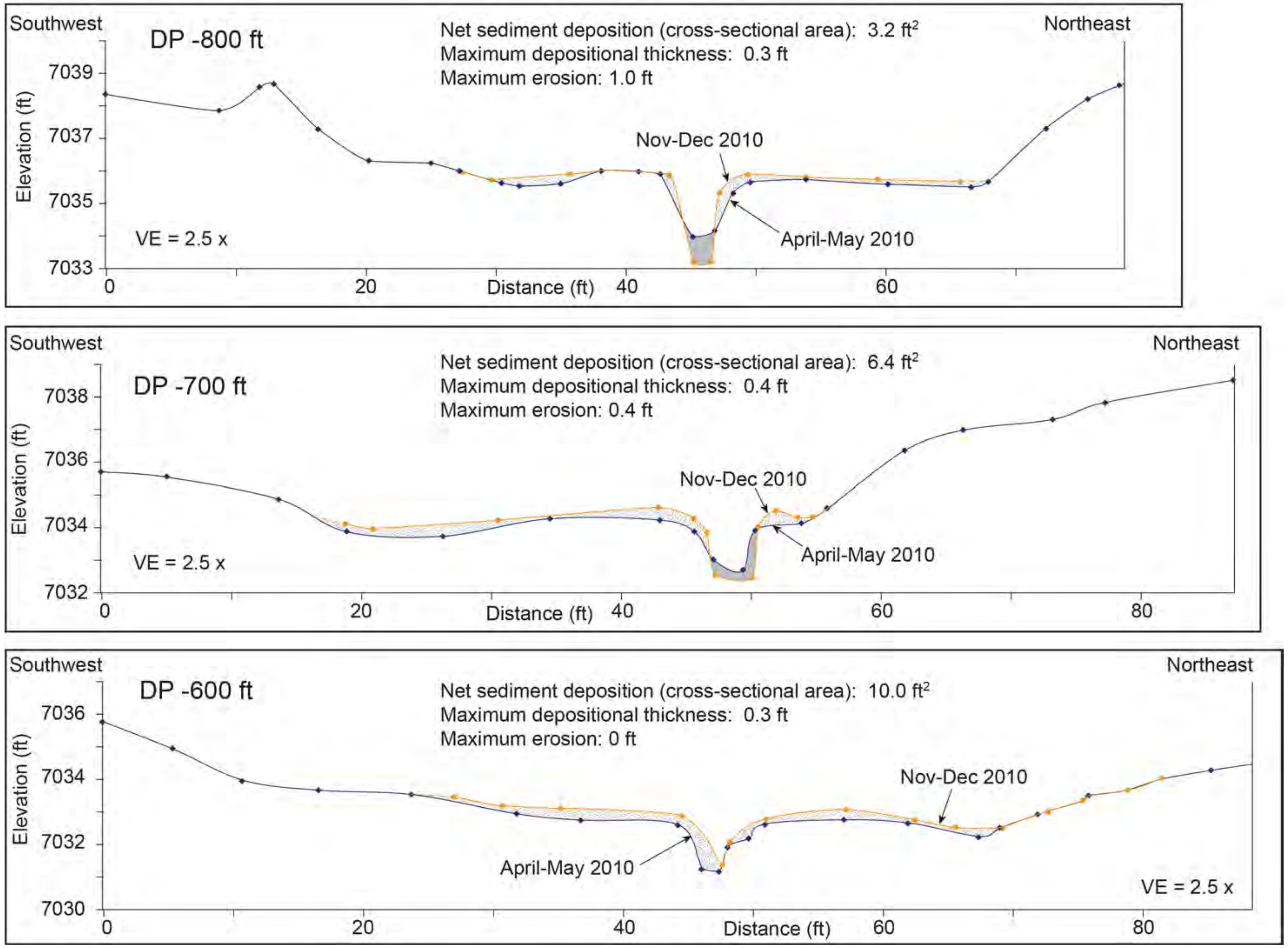
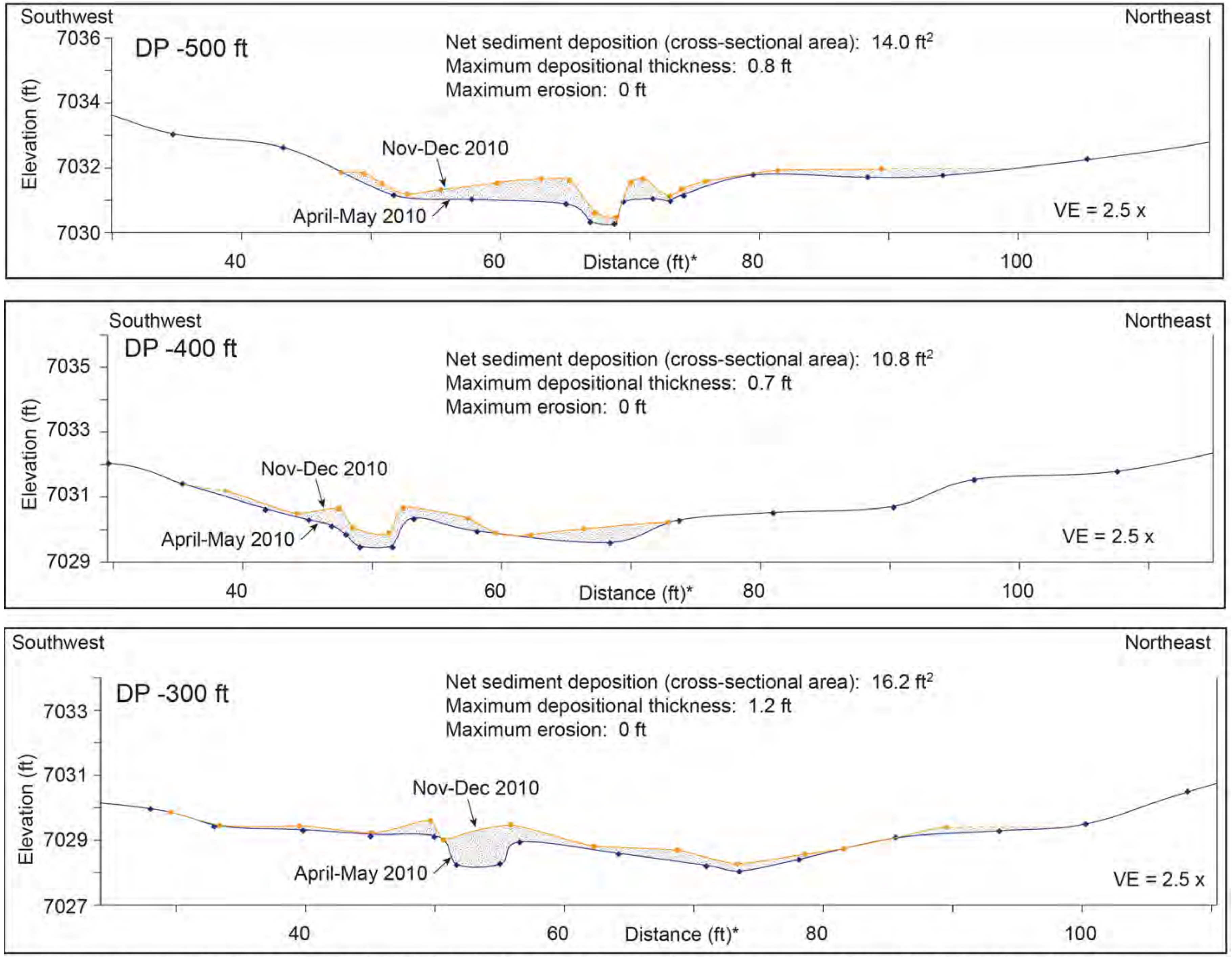
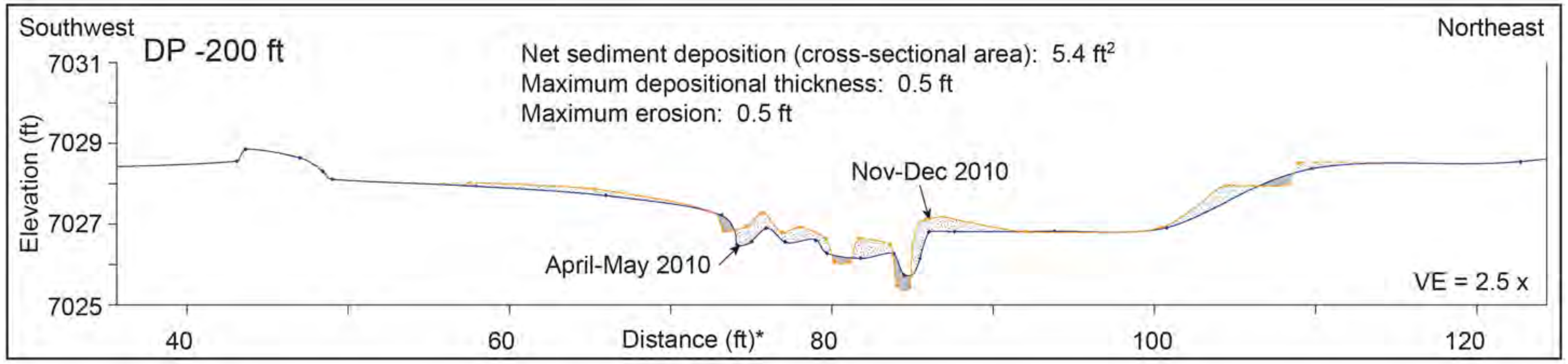


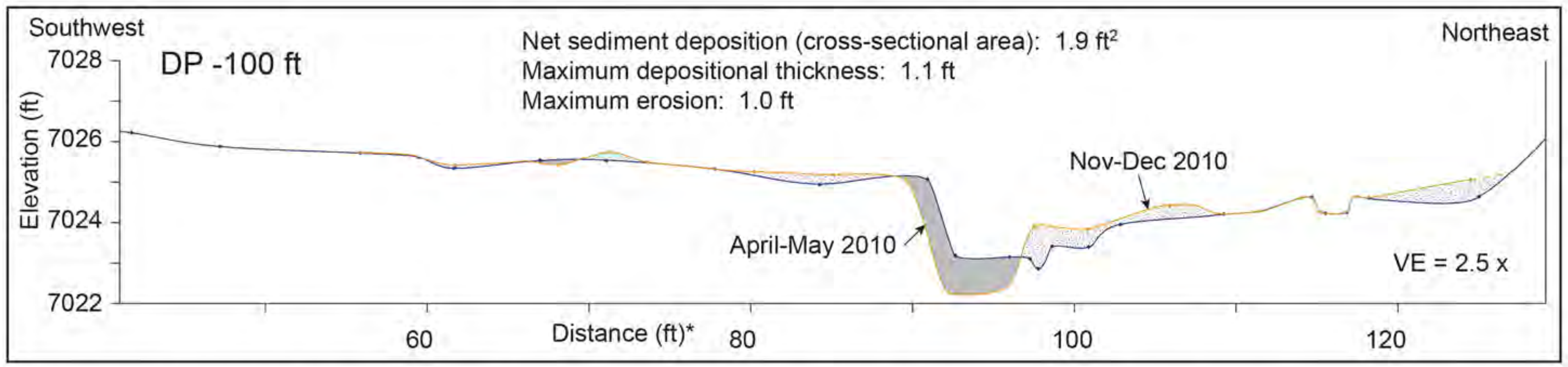
Figure 20 (continued) **Cross-sections and thalweg profile near the DP Canyon GCS**



*Distance is measured from end stake set in April 2010. Ends of sections that were unchanged when measured in Nov-Dec 2010 are truncated to fit on page.

Figure 20 (continued) **Cross-sections and thalweg profile near the DP Canyon GCS**





*Distance is measured from end stake set in April 2010. Ends of sections that were unchanged when measured in Nov-Dec 2010 are truncated to fit on page.

Figure 20 (continued) Cross-sections and thalweg profile near the DP Canyon GCS

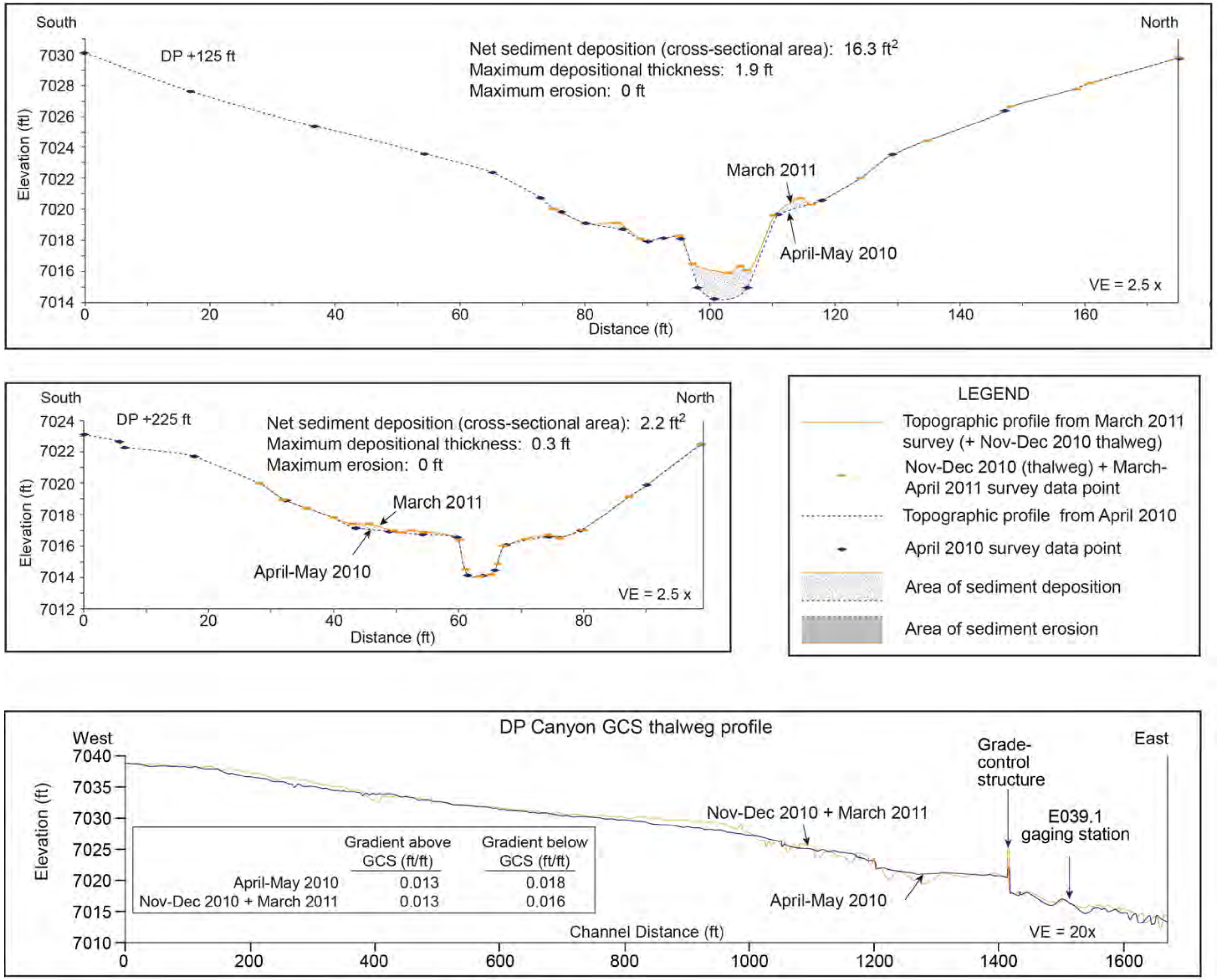


Figure 20 (continued) **Cross-sections and thalweg profile near the DP Canyon GCS**

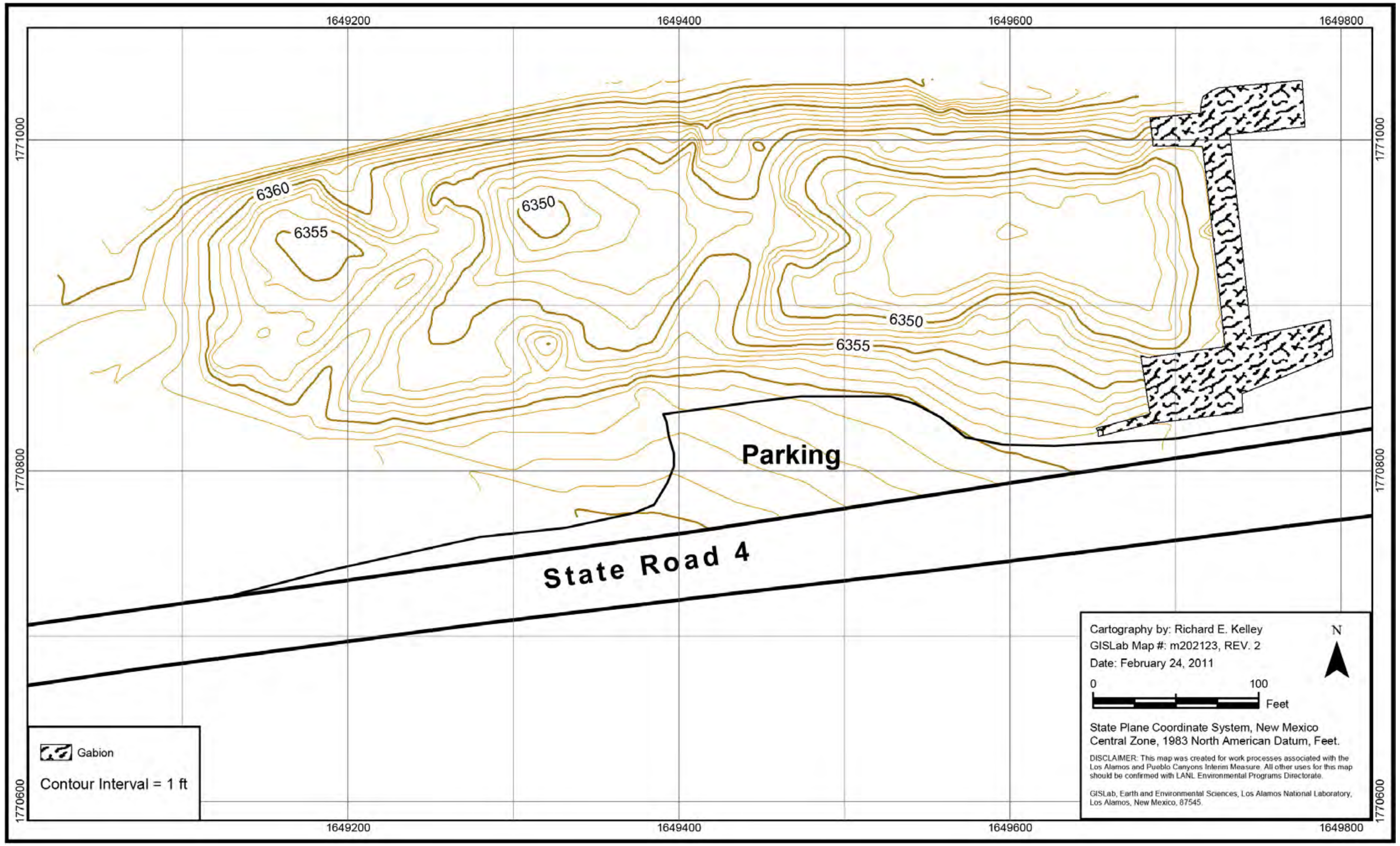


Figure 21 Postconstruction (May 2009) topographic map of sediment retention basins above the Los Alamos Canyon low-head weir

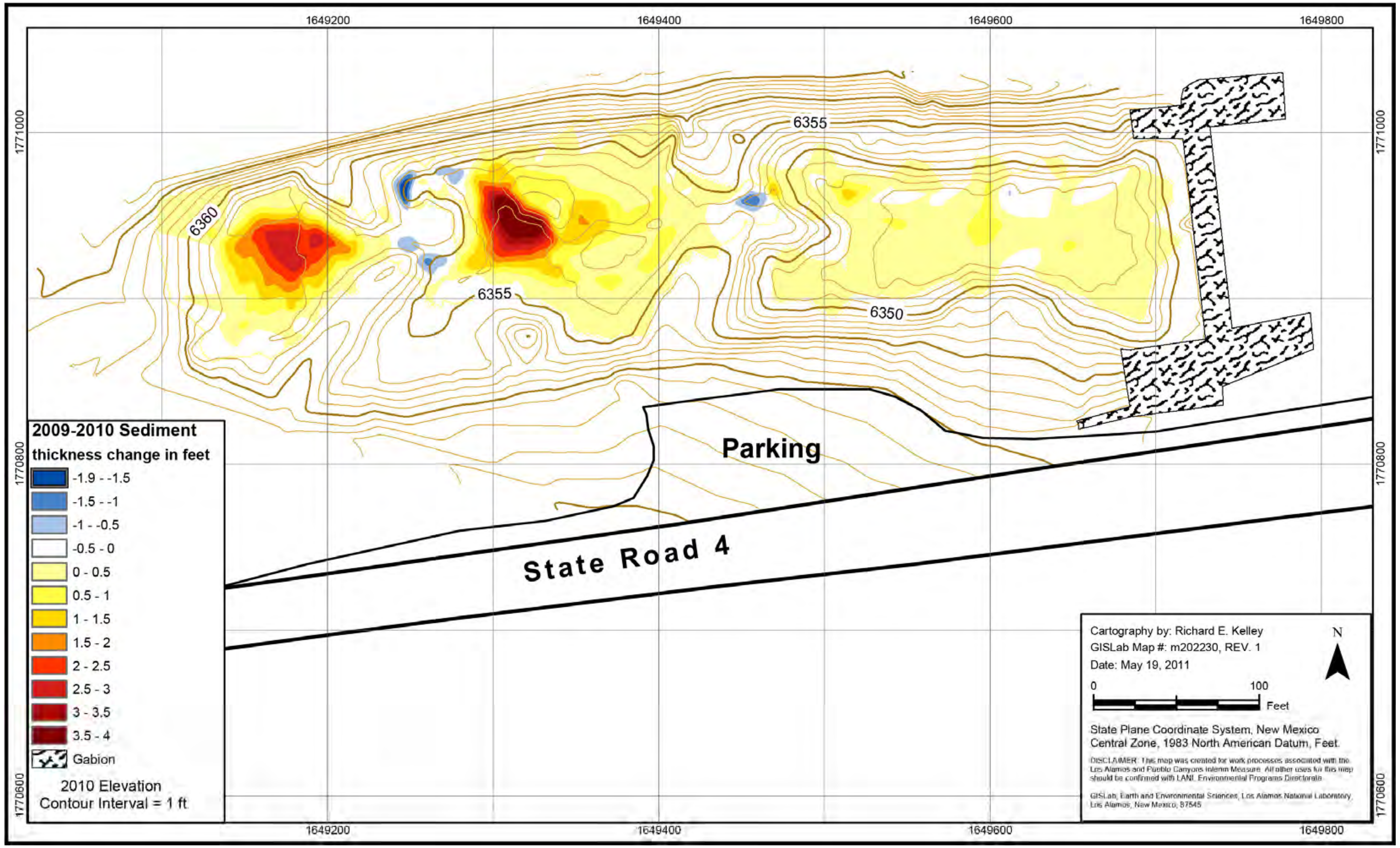


Figure 22 July 2010 topographic map of sediment retention basins above the Los Alamos Canyon low-head weir, showing total thickness of accumulated sediment

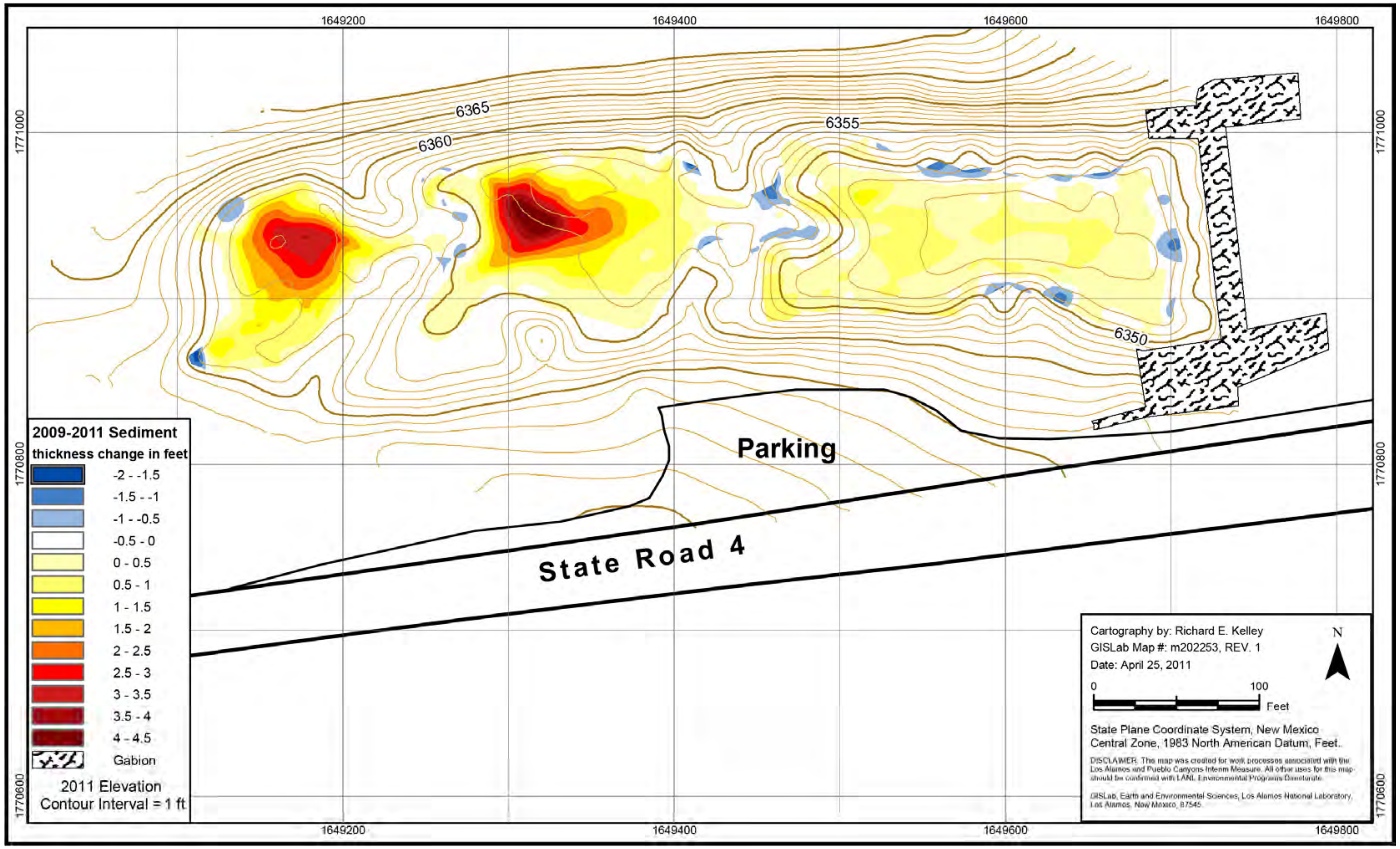


Figure 23 **March 2011 topographic map of sediment retention basins above the Los Alamos Canyon low-head weir, showing total thickness of accumulated sediment**

Figure 24 May 2011 photograph of rock armoring along stream banks in the south fork of Acid Canyon, looking upstream

Table 1
Summary of Geomorphic Changes at the Pueblo Canyon CVS Cross-Sections

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	Mean Cross-Sectional Area between Sections (ft^2)	Estimated Net Sediment Volume over 100-ft Distance (ft^3)	Estimated Net Sediment Volume over 100-ft Distance (m^3)	Normalized Net Sediment Deposition* (m^3/km)
CVS#1 −50 ft	0.8	0	22.3	16.6	1660	47.0	1567
CVS#1 +50 ft	2.0	0.6	10.9				
CVS#2 −50 ft	1.2	0.2	30.3	19.5	1950	55.2	1840
CVS#2 +50 ft	0.6	0.5	8.7				
CVS#3 −50 ft	0.8	0.3	12.1	12.4	1240	35.1	1170
CVS#3 +50 ft	0.9	0.3	12.7				
			Average	**16.2**	**1617**	**45.8**	**1526**

*Normalized net sediment deposition is total estimated volume divided by total length of surveyed area (0.030 km).

Table 2
Summary of Geomorphic Changes at the Upper Pueblo Canyon Willow-Planting Area Cross-Sections

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	Mean Cross-Sectional Area between Sections (ft^2)	Estimated Net Sediment Volume over 100-ft Distance (ft^3)	Estimated Net Sediment Volume over 100-ft Distance (m^3)	Normalized Net Sediment Deposition[a] (m^3/km)
Upper Third of Upper Willow-Planting Area							
UW-1	2.0	0	29.7	—[b]	—	—	—
UW-2	1.6	2.9	10.2	20.0	1995	56.5	372
UW-3	1.6	0	40.0	25.1	2510	71.1	468
UW-4	1.6	0	44.7	42.4	4235	119.9	789
UW-5	2.0	0	18.8	31.8	3175	89.9	591
UW-6	1.3	0.4	16.3	17.6	1755	49.7	327
Average, upper third				**27.3**	**2734**	**77.4**	**509**
Middle Third of Upper Willow-Planting Area							
MW-1	1.2	0.8	20.1	—	—	—	—
MW-2	0.9	0.3	9.7	14.9	1490	42.2	278
MW-3	0.7	0.7	28.5	19.1	1910	54.1	356
MW-4	1.2	1.1	17.5	23.0	2300	65.1	428
MW-5	0.9	0.0	41.8	29.7	2965	83.9	552
MW-6	0.6	1.1	−4.4	18.7	1870	52.9	348
Average, middle third				**22.1**	**2212**	**62.6**	**412**
Lower Third of Upper Willow-Planting Area							
LW-1	0.7	0.0	13.9	—	—	—	—
LW-2	0.8	0.0	7.5	10.7	1070	30.3	199
LW-3	0.8	0.6	0.2	3.9	385	10.9	72
LW-4	0.4	5.5	−15.8	−7.8	−780	−22.1	−145
LW-5	0.8	2.5	−0.4	−8.1	−810	−22.9	−151
LW-6	0.0	2.4	−13.2	−6.8	−680	−19.3	−127
Average, lower third				**2.3**	**233**	**6.6**	**43**
Average, upper willow-planting area				**17.3**	**1726**	**48.9**	**322**

[a] Normalized net sediment deposition is total estimated volume divided by total length of surveyed area (0.152 km).

[b] — = Not applicable.

Table 3
Summary of Geomorphic Changes at the Pueblo Canyon Wing Ditch Cross-Sections

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	Mean Cross-Sectional Area between Sections[a] (ft^2)	Estimated Net Sediment Volume over 100-ft Distance[a] (ft^3)	Estimated Net Sediment Volume over 100-ft Distance[a] (m^3)	Normalized Net Sediment Deposition[b] (m^3/km)
WD-1	2.3	0.9	23.6	23.6	2360	66.8	440
WD-2	1.7	0.5	45.7	34.7	3465	98.1	645
WD-3	1.3	1.2	5.4	25.6	2555	72.3	476
WD-4	1.5	1.0	−13.5	−4.1	−405	−11.5	−75
WD-5	1.1	0.6	6.3	−3.6	−360	−10.2	−67
			Average	**15.2**	**1523**	**43.1**	**284**

[a] Net sediment volume is shown for area between cross-sections, except for WD-1 to the wing ditch, which assumes the same change in cross-sectional area as measured at WD-1.

[b] Normalized net sediment deposition is total estimated volume divided by total length of surveyed area (0.152 km).

Table 4
Summary of Geomorphic Changes at the
Lower Pueblo Canyon Willow-Planting Area Cross-Sections

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	Mean Cross-Sectional Area between Sections (ft^2)	Estimated Net Sediment Volume over 100-ft Distance (ft^3)	Estimated Net Sediment Volume over 100-ft Distance (m^3)	Normalized Net Sediment Deposition[a] (m^3/km)
Upper Half of Lower Willow-Planting Area (P-3FE)							
PU −1100 ft	0.5	0.3	7.3	—[b]	—	—	—
PU −1000 ft	0.4	0.7	−4.9	1.2	120	3.4	10
PU −900 ft	0.4	0.3	12.8	4.0	395	11.2	33
PU −800 ft	0.7	1.3	25.4	19.1	1910	54.1	161
PU −700 ft	0.8	0	27.2	26.3	2630	74.5	222
PU −600 ft	0.7	0.9	19.3	7.2	720	20.4	61
PU −500 ft	2.5	2.8	11.9	15.6	1560	44.2	132
PU −400 ft	0.7	1.0	14.0	13.0	1295	36.7	109
PU −300 ft	0.6	0.7	10.4	14.9	1485	42.0	126
PU −200 ft	2.4	1.7	27.5	20.8	2075	58.7	175
PU −100 ft	2.2	1.6	15.3	12.9	1285	36.4	109
PU 0 ft	1.2	1.9	−1.7	6.8	680	19.3	57
			Average, upper half	**12.9**	**1287**	**36.4**	**109**
Lower Half of Lower Willow-Planting Area (P-4W)							
PU +100 ft	0.8	1.2	10.1	4.2	420	11.9	35
PU +200 ft	0.7	0.8	1.0	5.6	555	15.7	47
PU +300 ft	0.8	0.0	10.3	5.7	565	16.0	48
PU +400 ft	0.6	0.0	1.6	6.0	595	16.8	50
PU +500 ft	0.6	0.6	10.0	5.8	580	16.4	49
PU +600 ft	1.6	5.6	−32.1	−11.1	−1105	−31.3	−93
PU +700 ft	1.3	1.5	15.1	−8.5	−850	−24.1	−72
PU +800 ft	0.4	3.2	−2.6	6.3	625	17.7	53
PU +900 ft	0.3	0.5	−0.6	−1.6	−160	−4.5	−14
PU +1000 ft	1.2	0.7	−1.9	−1.3	−125	−3.5	−11
PU +1100 ft	0.0	0.7	−12.5	−7.2	−720	−20.4	−61
			Average, lower half	**0.3**	**35**	**1.0**	**3**

[a] Normalized net sediment deposition is total estimated volume divided by total length of surveyed area (0.335 km).

[b] — = Not applicable.

Table 5
Summary of Geomorphic Changes at Cross-Sections above the Pueblo Canyon GCS

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	Mean Cross-Sectional Area between Sections (ft^2)	Estimated Net Sediment Volume over 100-ft Distance[a] (ft^3)	Estimated Net Sediment Volume over 100-ft[a] Distance (m^3)
PUGCS −1500 ft	0.6	3.8	−30.0	−14.35	−1435	−40.6
PUGCS −1400 ft	0.5	0.8	1.3	15.8	1580	44.7
PUGCS −1300 ft	1.5	0.6	30.3	25.75	2575	72.9
PUGCS −1200 ft	0.5	0	21.2	6.95	695	19.7
PUGCS −1100 ft	0.7	1.9	−7.3	0	0	0.0
PUGCS −1000 ft	0.9	1.3	7.3	13.9	1390	39.4
PUGCS −900 ft	1.0	0	20.5	9	900	25.5
PUGCS −800 ft	0.3	0.8	−2.5	−3.35	−335	−9.5
PUGCS −700 ft	0.3	0.5	−4.2	−2.75	−275	−7.8
PUGCS −600 ft	0.0	0.3	−1.3	−0.5	−50	−1.4
PUGCS −500 ft	0.8	1.6	0.3	−6.15	−615	−17.4
PUGCS −400 ft	0.6	0.7	−12.6	−4.3	−430	−12.2
PUGCS −300 ft	0.9	0.4	4.0	1.4	140	4.0
PUGCS −200 ft	0.3	0.5	−1.2	3.75	375	10.6
PUGCS −100 ft	0.4	0.3	8.7	8.7	870	24.6
Estimated total net sediment deposition					**5385**	**125**
Normalized net sediment deposition[b] (m^3/km)						**274**

[a] Net sediment volume is shown for area between cross-sections, except for PUGCS −100 ft to the GCS, which assumes the same change in cross-sectional area as measured at PUGCS −100 ft.

[b] Normalized net sediment deposition is total estimated volume divided by total length of surveyed area (0.457 km).

Table 6
Summary of Geomorphic Changes at Cross-Sections below the Pueblo Canyon GCS

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	Mean Cross-Sectional Area between Sections (ft^2)	Estimated Net Sediment Volume Change over 100-ft Distance[a] (ft^3)	Estimated Net Sediment Volume Change over 100-ft Distance[a] (m^3)
PUGCS +100 ft	0.4	1.0	−2.8	−2.8	−280	−7.9
PUGCS +200 ft	0.0	0.9	−15.6	−9.2	−920	−26.0
PUGCS +300 ft	0.5	0.9	−8.9	−12.25	−1225	−34.7
				Estimated total net sediment erosion	**−2425**	**−69**
					Normalized net sediment erosion[b] (m^3/km)	**−1126**

[a] Net sediment volume is shown for area between cross-sections, except for from the GCS to PUGCS +100 ft where it is assumed that the change is equal to the cross-sectional area measured at PUGCS +100 ft.

[b] Normalized net sediment deposition is total estimated volume divided by total length of surveyed area (0.061 km).

Table 7
Summary of Geomorphic Changes at Cross-Sections above the DP Canyon GCS

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	Mean Cross-Sectional Area between Sections (ft^2)	Estimated Net Sediment Volume Change over 100-ft Distance[a] (ft^3)	Estimated Net Sediment Volume Change over 100-ft Distance[a] (m^3)
DP −1100 ft	0.3	0.1	5.4	4.1	410	11.6
DP −1000 ft	0.3	0	2.8	7.35	735	20.8
DP −900 ft	0.9	0	11.9	7.55	755	21.4
DP −800 ft	0.3	1.0	3.2	4.8	480	13.6
DP −700 ft	0.4	0.4	6.4	8.2	820	23.2
DP −600 ft	0.3	0	10.0	12	1200	34.0
DP −500 ft	0.8	0	14.0	12.4	1240	35.1
DP −400 ft	0.7	0	10.8	13.5	1350	38.2
DP −300 ft	1.2	0	16.2	10.8	1080	30.6
DP −200 ft	0.5	0.5	5.4	3.65	365	10.3
DP −100 ft	1.1	1.0	1.9	1.9	190	5.4
				Estimated total net sediment deposition	**8625**	**244**
					Normalized net sediment deposition[b] (m^3/km)	**729**

[a] Net sediment volume is shown for area between cross-sections, except for DPGCS −100 ft to the GCS, which assumes the same change in cross-sectional area as measured at DPGCS −100 ft.

[b] Normalized net sediment deposition is total estimated volume divided by total length of surveyed area (0.335 km).

Table 8
Summary of Geomorphic Changes at Cross-Sections below the DP Canyon GCS

Section Name	Maximum New Sediment Thickness (ft)	Maximum Erosion (ft)	Net Sediment Cross-Sectional Area (ft^2)	Mean Cross-Sectional Area between Sections (ft^2)	Estimated Net Sediment Volume Change over 100- or 125-ft Distance[a] (ft^3)	Estimated Net Sediment Volume Change over 100- or 125-ft Distance[a] (m^3)
DP +125 ft	1.9	0	16.3	16.3	2038	57.7
DP +225 ft	0.3	0	2.2	9.25	925	26.2
Estimated total net sediment deposition					**2963**	**84**
Normalized net sediment deposition[b] (m^3/km)						**1216**

[a] Net sediment volume is shown for area between cross-sections, except for DPGCS +125 ft to the GCS, which assumes the same change in cross-sectional area as measured at DPGCS +125 ft.

[b] Normalized net sediment deposition is total estimated volume divided by total length of surveyed area (0.069 km).

Table 9
Sediment Volume Changes at the Los Alamos Canyon Low-Head Weir, 2009–2011

Site	2009–2010			2010–2011			2009–2011
	Net Increase (m^3)	Net Decrease (m^3)	Total Net Change (m^3)	Net Increase (m^3)	Net Decrease (m^3)	Total Net Change (m^3)	Total Net Change (m^3)
Basin 1 (west)	191	3	188	115	23	92	280
Basin 2 (central)	279	27	252	141	13	128	380
Basin 3 (east)	82	12	70	102	50	53	123
Total	**551**	**42**	**510**	**359**	**85**	**274**	**783**

Table 10
Sediment Accumulation at the
Los Alamos Canyon Low-Head Weir, 2000–2011

Period	Total Sedimentation (m^3)	Approximate Annual Sedimentation (m^3/yr)
June 2000 to May 2002	822	411
May 2002 to August 2005	3377	1126
August 2005 to July 2007	2555	1278
July 2007 to September 2008	138	138
May 2009 to July 2010	510	510
July 2010 to March 2011	274	274
June 2000 to March 2011	**7676**	**698**

Attachment 1

Survey Data
(on CD included with this document)