Appendix E

Reach 2A Sedimentation Evaluation (2012)

March 2013

SAN JOAQUIN RIVER RESTORATION PROGRAM

Reach 2A Sedimentation Evaluation (2012)

March 1, 2013

1. INTRODUCTION

The Settlement Agreement that is the basis for the San Joaquin River Restoration Program (SJRRP) will provide flows (247,000 AF in dry years and 555,000 AF in wet years) and physical modifications to the river system to restore 150 miles of the San Joaquin River between Friant Dam and the Merced River to facilitate reintroduction of previously extirpated spring- and fall-run Chinook salmon and other fish species to the SJRRP Restoration Area (**Figure 1**). To better understand potential impacts associated with implementation of the project, Tetra Tech dba Mussetter Engineering, Inc. (Tt-MEI) has performed various analyses to evaluate existing channel and levee capacities and sediment transport conditions along the restoration reach (MEI, 2008; Tt-MEI, 2010a, 2010b, and 2012).

Interim restoration flow and flood releases have been made from Friant Dam at varying magnitudes and durations since October 2009 (**Figure 2**). Concerns about sediment deposition in the river in Reach 2A upstream from the Chowchilla Bypass Bifurcation Structure (CBBS) have been expressed, and it has been suggested that the deposition may be related to the restoration flows. In late 2010, Tt-MEI was requested by California Department of Water Resources (DWR) to collect the necessary data to evaluate bed changes, conduct a preliminary evaluation of the potential for sedimentation, and predict the potential impacts on channel and levee capacity in Reach 2A and operation of the CBBS. To support this effort, field surveys of 27 cross sections in the downstream approximately 2.7 miles of Reach 2A were conducted by Provost and Pritchard on November 16 and 17, 2010 (**Figure 3**), and the results of the investigation that included 1-dimensional (1-D) modeling with the 2010 cross sections, were reported in Tt-MEI (2010c). The surveys and analysis were repeated in November 2011 and June 2012 to assess ongoing effects of the interim flow releases. Results from the November 2011 surveys were reported in Tt-MEI (2012).

In addition to the cross-section surveys, DWR performed detailed topographic surveys of 13 sites in Reach 2A in July 2009, February 2011 and August 2011 (**Figure 4**). Aggradation/ degradation trends indicated by the DWR data were also evaluated as part of this study.

This memorandum summarizes the changes in bed topography at the 27 cross sections and the DWR patch-survey sites.

2. CROSS SECTION SURVEYS BETWEEN CHOWCHILLA BYPASS AND RM 219

2.1. Aggradation/Degradation Trends

Details of the changes between the 2008 LiDAR mapping and the 2010 and 2011 surveys were described in Tetra Tech (2010a and 2012). These data generally indicate that the overall channel shape and width along the reach did not change significantly as a result of the interim flow and 2011 flood releases. Based on average-end-area calculations using the measured changes in cross sectional area, the upstream mile of the reach was approximately in sediment transport balance and the downstream 1.5 miles was mildly degradational between 2008 and November 2010, and the entire reach was degradational between November 2010 and November 2011 (**Figure 5**).

The June 2012 survey data were analyzed in a similar manner by converting the data to cross-section profile plots, overlaying then onto the earlier cross sections, and evaluating the differences (**Appendix A**). Relatively significant changes in thalweg elevation occurred between the 2011 and 2012 surveys at Cross Sections (XS) 515130, XS515424, XS515986, XS518453, XS522881, XS523952, XS525918, with XS515986 and XS523953 degrading and all of the other cross sections aggrading (**Figures 6a and 6b**)[1]. While the thalweg analysis quantifies the change in elevation of the deepest part of the channel, this is not necessarily a good indication of the overall aggradation/degradation tendency at each location because other parts of a particular cross section can build or degrade in the opposite direction from the thalweg change. To provide a more accurate assessment of the overall aggradation or degradation tendencies, the mean bed elevation at each cross section was computed by subtracting the hydraulic (or cross sectionally-averaged) depth from a common reference elevation, and the resulting elevations compared between the various surveys (**Figures 7a and 7b**). Based on this analysis, net aggradation occurred at 9 of the 20 cross sections and net degradation occurred at 11 cross sections. Changes in mean bed elevation of more than 0.5 feet occurred at XS515130 (degraded by ~0.9 feet) and XS515424 (aggraded by ~1.9 feet), both of which are located just upstream from the San Joaquin River Control Structure. The mean bed elevation also increased by more than 0.5 feet at XS517754 (~0.5 feet), located on the downstream limb of the large bend upstream from the CCBS, XS522366 (~1.6 feet), XS522881 (~0.9 feet) and XS523368 (~0.6 feet), at the apex and upstream limb of the next upstream bend, and at XS525918 (~0.7 feet) and XS528030 (~1.5 feet), both of which are located near the upstream end of the reach.

The overall aggradation/degradation response of the surveyed reach was quantified by computing the change in cross-sectional area between successive data sets and then using the average-end-area method to estimate the change in sediment volume based on the distances between the cross sections. These results indicate that the upstream approximately one mile of the reach aggraded by a small amount between the November 2011 and June 2012 surveys, and more significant aggradation occurred in the downstream portion of the reach (**Figure 8**). Overall, about 6.3 AF of sediment accumulated in the reach between the two surveys, with the bulk of the deposition occurring in locations where significant scour occurred along the toe of the bank during the 2011 high flows (**Figures 9a through 9d**). The changes in mean bed elevation represent an average of about 0.11 feet degradation spread over the entire survey reach between the 2008 LiDAR survey and the November 2010 survey, an additional approximately 0.18 feet of degradation the November 2010 and November 2011 surveys, and about 0.07 feet of aggradation between the November 2011 and June 2012 surveys. Based on the flows that occurred during the periods between the surveys, it appears that the 2011 flood flows caused general downcutting in the reach, with significant scour along the banks on the outsides of bends and in straight reaches where the main thread of the flow runs directly along

[1] The thalweg at each cross section was identified as the lowest elevation of the individual surveyed points. The typical spacing of the points is in the range of 15 to 20 feet, and the vertical accuracy of the RTK-GPS measurements is typically in the 2 to 3 centimeter range (i.e., ~1 inch). Considering the uncertainty associated with placement of the survey rod on the actual bed surface, particularly in the saturated sand in Reach 2A, the thalweg point elevations should be accurate to within about 0.2 to 0.3 feet. The LiDAR data used to identify the 2008 thalweg were collected to meet FEMA map accuracy standards, cross-referenced to the National Standards for Spatial Data Accuracy (NSSDA) developed by the Federal Geographic Data Committee (FGDC), for a 1-foot contour interval map. In general, these standards require the individual points to be within +/-0.3’ RMSE of coincident points independently surveyed using higher accuracy methods, with a 95-percent confidence interval of +/-0.6’.

one of the bank, and these scour areas tended to backfill during the moderate interim flow releases during the first half of 2012. Sufficient information is not available to assess the specific causes of the degradation that occurred between the 2008 LiDAR survey and the November 2011 survey, but it probably results from the moderately high interim flow releases that occurred in Spring 2010 that had maximum discharges in the range of 1,200 cfs for nearly a month.

In spite of the general degradational tendency within the overall reach, the average end-area calculations indicate that about 2.1 AF of sediment appears to have accumulated in the approximately 600-foot reach upstream from the CBBS between 2008 and 2010[2]. Based on the cross-section surveys, which may not completely describe the changes in the reach, the deposited material plus an additional 1.3 AF of material (total of 3.4 AF) appears to have been removed from this area between the 2010 and 2011 surveys. This area backfilled by about 2.7 AF between November 2011 and June 2012. These changes indicate that this portion of the reach fills and scours on a cyclical basis, most likely depending on the magnitude and duration of the flows, but there does not appear to be a systematic aggradational trend that would impact the operation of the CCBP Bifurcation Structure. In general based on the temporal patterns at XS 515424 that is located just upstream from the Chowchilla Bypass Control Structure, the area appears to back fill during low to moderate flows and then this material tends to be removed during higher flows, such as those that occurred during 2011.

2.2. Channel and levee capacity

The survey data collected in June 2012 was used to update the cross-sectional geometry in the existing conditions HEC-RAS hydraulic model, and the updated model was used to evaluate potential changes in the water-surface elevations over the range of restoration flows. Calibration of the updated model was checked by estimating the discharge associated with each measured point, running the model for the range of flows in the reach during the survey period, and comparing the estimated and measured water-surface elevations.

During the survey period on June 14, 2012, the discharge at the Gravelly Ford (GRF) gage, as reported on the California Data Exchange (CDEC) website, averaged 181 cfs declining trend, and discharge at this location was relatively constant at 170 cfs on June 15 (**Figure 10**). The flows during these time periods at the below Bifurcation Structure (SJB) gage were relatively constant at 107 and 101 cfs, respectively. This information was used to estimate the discharge associated with each of the water-surface elevation measurements by linearly interpolating between the reported flows at the two gages both along the reach and through time using the time-stamp from the survey datalogger. A total of 49 water-surface elevation measurements were made on June 14 that covered essentially the entire survey reach. These were collected from up- to downstream between about 7 a.m. and 2 p.m. at discharges ranging from approximately 125 cfs at the upstream end of the reach to approximately 105 cfs at the downstream end (**Figure 11**). An additional 7 points were surveyed on June 15, with four of the points located just upstream from the river control structure and the other 3 points located farther upstream at approximately Sta 519,910, Sta 522,365, and Sta 528,030. The provisional discharge at SJB gage that is located just downstream from the river control structure was 101 cfs at the time of the surveys, and the linearly-interpolated discharges at the upstream 3 cross sections ranged from 107 to 116 cfs.

[2] This was incorrectly reported as 900 feet in Tetra Tech (2012a).

The updated model with 2012 cross sections was executed for discharges of 100 and 125 cfs, with the hydraulic control for the downstream portion of Reach 2B established by the flow over the gate sill with a free water-surface elevation (i.e., not gate interference). The predicted water-surface profiles agree very well with the measured data over essentially the entire surveyed reach.

After completion of the calibration check, the model was executed for a range of flows up to 4,000 cfs and the predicted water-surface profiles were compared with the profiles developed using the 2008 LiDAR data and the 2010 and 2011 survey data (**Figures 12 and 13**). The predicted water surface in the approximately 1,500-foot reach just upstream from the CBBS is up to 0.3 feet higher at 1,000 cfs using the 2010 data than with the 2008 data, is about the same as 2008 using the 2011 data, and up to 0.35 feet higher using the 2012 data than with the 2008 data. In the middle and upstream portions of the reach, the 1,000-cfs water surface is 0.1 to 0.2 feet lower with the 2010 data than with the 2008 data. The 1,000-cfs water surface in this part of the reach lowers even farther with both the 2011 and 2012 data, with differences from the 2008 model of up to 0.5 feet in the middle portion of the reach between about Sta 519,000 and Sta 524,000. Similar trends occur at 2,000 and 4,000 cfs, but the differences from the 2008 model decrease with increasing discharge. These results suggest that the degradation in Reach 2A has tended to lower the water-surface elevations by a small amount at high flows, and this trend can be expected to continue with continued degradation.

3. DWR PATCH SURVEYS

DWR performed detailed surveys at 11 sites that are approximately evenly distributed through Reach 2A (**Figure 14**). These surveys were conducted using survey-grade RTK GPS and consisted of a series of closely spaced cross sections that were surveyed at a relatively high spatial resolution to facilitate development of detailed topographic surfaces at each site that can be directly compared between subsequent surveys (**Figure 15**). Surveys that included the entire active width of the channel at each site were conducted in July 2009 and February and August 2011, and the resulting data allow computation of the change in sediment volume over the entire channel width between the subsequent surveys. Additional surveys that included only the low-flow channel(s) at each site were conducted in January and October 2010. For these surveys, it is only possible to assess changes in the low-flow channel. Two of the patch-survey sites fall within the reach encompassed by the cross-section surveys described in the previous section: Site M12 is located near XS526981 and Site M13 is located near XS 523952.

The changes in bed sediment volume between the surveys was computed by overlaying the detailed topographic surfaces and subtracting the elevations from the January and October surveys from the corresponding elevations from the July 2009 survey. Images of these "difference" surfaces are provided in **Appendix B.1**. In general, most of the sites in approximately the upstream half of the reach (specifically, Sites M4, M6, M7 and M8) experienced net degradation between July 2009 and February 2011 and most of the sites in the downstream half of the reach (Sites M9, M10, M11 and M12) experienced net aggradation (**Figure 16**). With the exception of Site M8 (RM 222.1), the sites in the upstream half of the reach generally showed little net change during the high flows that occurred between February and August 2011, while the downstream sites, including Site M13, continued to show aggradation (**Figure 17**).

At most of the sites, the aggradation/degradation volumes correspond to relatively small average changes in bed elevation in the range of ±0.3 feet or less (**Figure 18**). The two sites where the elevation change is more significant (M8 and M11) are most likely not representative of the trends within the overall reach. Site M8 is located near the downstream end of a straight, relatively narrow reach where rock revetment has been placed along the right bank. Based on the surveyed topography and the available aerial photography, the 2009 topography reflects a relatively flat channel bottom after a period of low flows, and the 2011 topography reflects deepening of the bed due to a combination of contraction scour, and the extension of the local scour hole that forms along the revetment during high flows (**Figures 19a through 9c**). At Site M11, there is clear evidence of mechanical grading along the left approximately half of the channel in the 2009 aerial photograph (**Figure 20a**). The material that was removed from this area appears to have created a sediment trap that refilled with sediment during the high flow period between the surveys (**Figures 20b and 20c**).

A similar analysis was performed by comparing the January and October 2010 data with the corresponding data from the July 2009 surveys. As noted above, these surveys generally only included a limited part of the channel width that includes the low-flow channel; thus, the aggradation/degradation results cannot be directly compared with the above results that apply to the full channel width. The 2010 data do, however, provide a good indication of the changes that occurred within the most active part of the channel. Images of the change in elevation between each of the 2010 surveys and the July 2009 survey are provided in **Appendix B.2**. With the exception of Site M8, all of the sites were either degradational or approximately in balance between July 2009 to January 2010 (**Figure 21**). Based on the aerial photography and survey data, the significant aggradation at Site M8 appears to result from a sand wave that prograded from upstream to downstream across the site during the period. The low-flow channel at Sites M7, M9, M10 and M11 aggraded, Site M13 degraded, and the other sites did not change significantly during the period from January and October 2010.

4. DWR BED MATERIAL SAMPLING AT PATCH SURVEY SITES

DWR collected bed material sediment samples in conjunction with the surveys at the Patch Survey sites. The samples were collected at a minimum of one location at each site during each of the surveys by placing a suitable quantity of material from the top 6 inches at representative locations into an appropriate container. The samples were then analyzed using standard sieve analysis in a qualified soils engineering lab. The data sets for the sites within Reach 2A (Sites M4 through M13) include 102 individual samples that were collected during the five survey periods. The median (D_{50}) and D_{84} sizes were determined from the gradation curves for the samples and plotted to assess spatial and temporal trends in the bed material gradations during period encompassed by the surveys (**Figures 22 and 23**).

The data show that the material is primarily medium to coarse sand (0.5 mm $<D_{50}<$1 mm), with small amounts of gravel (D >2 mm) in the downstream part of the reach, transitioning to a mixture of coarse sand and gravel in the upstream part of the reach (Figure 22). The data also show significant variability at the three sites in the upstream approximately 2 miles of the reach (i.e., M4, M5 and M6). Part of the variability is related to the specific location within the channel at which the samples were taken, and part of the variability appears to be associated with the flows that preceded each of the sampling periods. For example, at the most upstream Site 4, both the D_{50} (average of two samples) was about 4.5 mm in July 2009, increasing to about 16 mm in January 2010 after the Fall 2009 interim flow releases, and then decreased back to the 6 mm to 7-mm range in October 2010 and February 2011 on either side of the December 2010 high flows. The D_{50} at this location then increased substantially back to about 15 mm in August 2011, after the extensive high flow period that occurred during that year. Although the material at Site M6 is somewhat finer (very coarse sand to fine gravel), the temporal pattern at this site was similar to the pattern at Site M4. At Site M5 that falls between Sites M4 and M6, the material showed a slight coarsening trend throughout the period from about 0.8 mm in July 2009 to about 1.1 mm in August 2011. As illustrated in the previous section, Sites M4 and M6 degraded by a small amount over the period encompassed by the surveys, and bed coarsening is a typical response to degradation in systems with bed material containing a substantial amount of gravel. A distinct temporal trend is not apparent at the remainder of the sites that fall downstream from Site M6.

These results indicate a general coarsening tendency with time, primarily in response to high flows in the gravel-to-sand transition zone in the upstream part of the reach, and no systematic trend in the remainder of the reach that is located within the Project levees. It is tentatively assumed that this coarsening trend will continue to progress downstream over time if the sand that is available to be transported through the upstream reaches is depleted. Previous studies indicate that about 628 ac-ft of sediment was evacuated from the bed of the river between Friant Dam and Highway 99 between 1998 and June 2010, and about 168 ac-ft of sand remained in storage upstream from Skaggs (Highway 145) Bridge (Tt-MEI, 2012). Based on a preliminary sediment-continuity analysis performed for the SJRRP Programmatic EIR/S, Tt-MEI (2012b) found that the average transport capacity of Reach 2A is about 45 ac-ft/yr. Depending on the sand supply from other unquantified sources along the reach, the effects of upstream sand depletion on bed coarsening, and potentially, additional downcutting should be seen within the next 5 to 10 years.

5. SUMMARY

Based on the surveyed cross sections, the channel did not experience significant aggradation or degradation during the period between the November 2011 and June 2012 surveys in the upstream approximately half of the 2.5-mile survey reach; however, the downstream portion of the reach aggraded by about 5 AF. Most of the aggradation occurred through low-flow backfilling of areas on the outsides of bends and along the banks where significant local scour appears to have occurred during the 2011 high flows. The effect of these changes on the water-surface profiles for flow up to 4,000 cfs is relatively minor, with the most significant effects occurring at lower flows.

The patch surveys that were conducted by DWR in 2009, 2010 and 2011 at 11 sites that are approximately evenly distributed through Reach 2A indicate a mild degradation tendency in the portions of the reach upstream from about RM 222, and a mild aggradation tendency downstream from RM 222. With the exception of Sites M8 and M11, the average changes in bed elevation at the surveys were generally in the range of ±0.3 feet or less. The significant changes that occurred at Sites M8 and M11 results from local scour along a revetted bankline during the 2011 high flows (M8) and backfilling of an area that appears to have been excavated prior to the July 2009 survey (M11).

6. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn based on the above information:

1. Average end-area calculations based on repeat surveys of cross 27 cross sections between November 2010 and June 2012, using the 2008 LiDAR mapping as the baseline, indicate a general degradation trend in the downstream 2.5 miles of Reach 2A. Based on these

analyses, about 21 ac-ft of sediment was evacuated from the reach over this approximately 4-year period, with the bulk of the degradation occurring in the approximately 0.5 miles reach from the apex of the bend near Sta 518,400 through the relatively straight upstream reach to about Sta 520,500.

2. Most of the indicated degradation occurred between the November 2010 and November 2011 surveys, a period of significant flood releases, and the downstream portion of the reach backfilled by about 6 ac-ft in response to the comparatively low Restoration releases between November 2011 and November 2012.

3. Detailed patch surveys at 11 sites within Reach 2A that were conducted by DWR indicate that the upstream approximately 5.5 miles of the reach was net degradational, between July 2009 and August 2011, with relatively small average degradation depths of less than a few tenths of feet, but ranging up to about 0.5 feet (Site M8). These data also indicate that the downstream approximately 5.5 miles of the reach was net aggradational by a small amount over the period. (Note that the relatively significant aggradation that occurred at Site M11 resulted from filling-in of an area that had been excavated prior to the surveys and is not representative of the behavior of the remainder of the reach.)

4. Patch Survey Sites M12 and M13 are located in the vicinity of XS 523,952 and XS 526,891 that were included in the average end-area calculations for the downstream 2.5 miles of the reach. XS 523,952 degraded significantly between the 2008 LiDAR flight and the November 2010 survey, and then about half of the evacuated material was replaced during the high flows between November 2010 and November 2011. The resulting, slight overall degradational tendency is consistent with the net degradation that occurred at Site M12 between July 2009 and August 2011. In contrast, Site M12 showed a slight aggradational tendency between July 2009 and August 2011, while the surveys at XS 526,981 indicate a slight degradational tendency. Some of this apparent discrepancy likely result from the different time-periods between the surveys, but it also highlights the potential for error in basing conclusions about aggradation/degradation tendencies on individual cross sections rather than more comprehensive surfaces. As discussed in the context of the 2-dimensional modeling results presented in Tetra Tech (2013), this can be a potentially significant issue.

5. Evaluation of the DWR bed material samples that were collected in conjunction with the patch surveys indicates that the bed material is significantly coarser in the reach upstream from the Project levees than it is in the downstream part of the reach. These data also indicate a general coarsening trend in the upstream portion of Reach 2A, with no systematic trend in the downstream portion. The data at Sites M4 and M6 also show a cyclical trend of coarsening in response to high flows, followed by fining during low flow period, trends that are consistent with the expected response in a reach that is generally degradational.

6. Detailed evaluation of the surveyed cross sections in the downstream part of the reach indicate that, in spite of the general degradational tendency within the overall reach about 2.1 AF of additional sediment appears to have accumulated in the approximately 600-foot reach upstream from the CBBS between 2008 and 2010. Based on the cross-section surveys, which may not completely describe the changes in the reach, the deposited material plus an additional 1.3 AF of material (total of 3.4 AF) was removed from this area between the 2010 and 2011 surveys, and this area backfilled by about 2.7 AF between November 2011 and June 2012. These changes indicate that the reach at and immediately upstream from the CCBP Bifurcation Structure tends to aggrade during low to moderate flows and then scour during high, flood releases., but there does not appear to be a systematic long-term aggradational trend that would impact the operation of the structure.

Based on the above conclusions, the following recommendations are made for future monitoring activities in Reach 2A and the vicinity of the CCBP:

1. Because of the sensitivity the operation of the CCBP Control Structure to the bed response to Restoration flows and flood releases and the potential for error in evaluating detailed aggradation/degradation trends only on individual cross sections, additional survey data should be collected in the reach between the structure and XS 516952 at sufficient spatial resolution to create a complete topographic surface.
2. Based on our experience with similar monitoring cameras on other project, we also tentatively suggest that one or more wide-angle monitoring cameras be installed in a location near the CCBP Structure to obtain time-lapse views of the river upstream from the structure during future Restoration Flow releases. While the imagery would not be suitable for quantitative analysis, it would provide a qualitative record of changes in response to the flows, and would provide information on which to base a maintenance response, if an unacceptable amount of aggradation were to occur.
3. The DWR bed material sampling program that is part of the Patch Surveys is providing very useful data for assessing temporal and spatial changes in the bed material in response to the Restoration and flood releases. This program could be strengthened by insuring that the samples are collected from equivalent geomorphic surfaces, such as the heads of mid-channel bars or the upstream end of bank-attached point bars. Samples from near the channel thalweg (when feasible) would also be very useful to assess the degree to which sorting affects the surface gradation. Given the relative ease with which bulk samples of the generally sand-sized material can be collected and the relatively low cost for analysis, we also recommend that a minimum of 6 samples be collected from each of the sites during each survey period to expand the data base and provide a better sense of the variability within each site. Careful notes and representative photographs should be taken of each sample site to provide information with which to interpret the sample data.

7. REFERENCES

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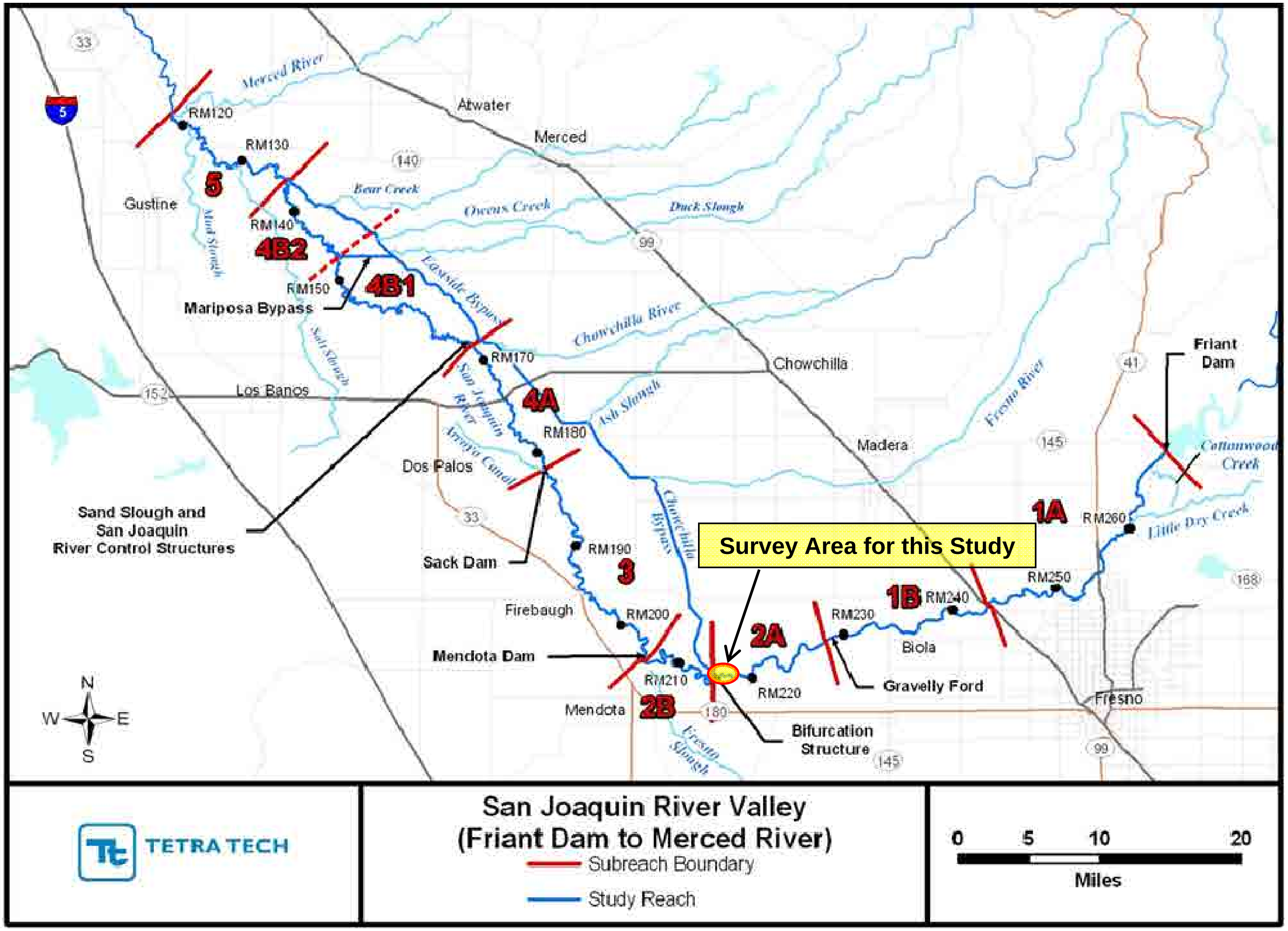

Figure 1. Map of the San Joaquin River Restoration Project Reach showing the subreach boundaries and the area of concern for this study.

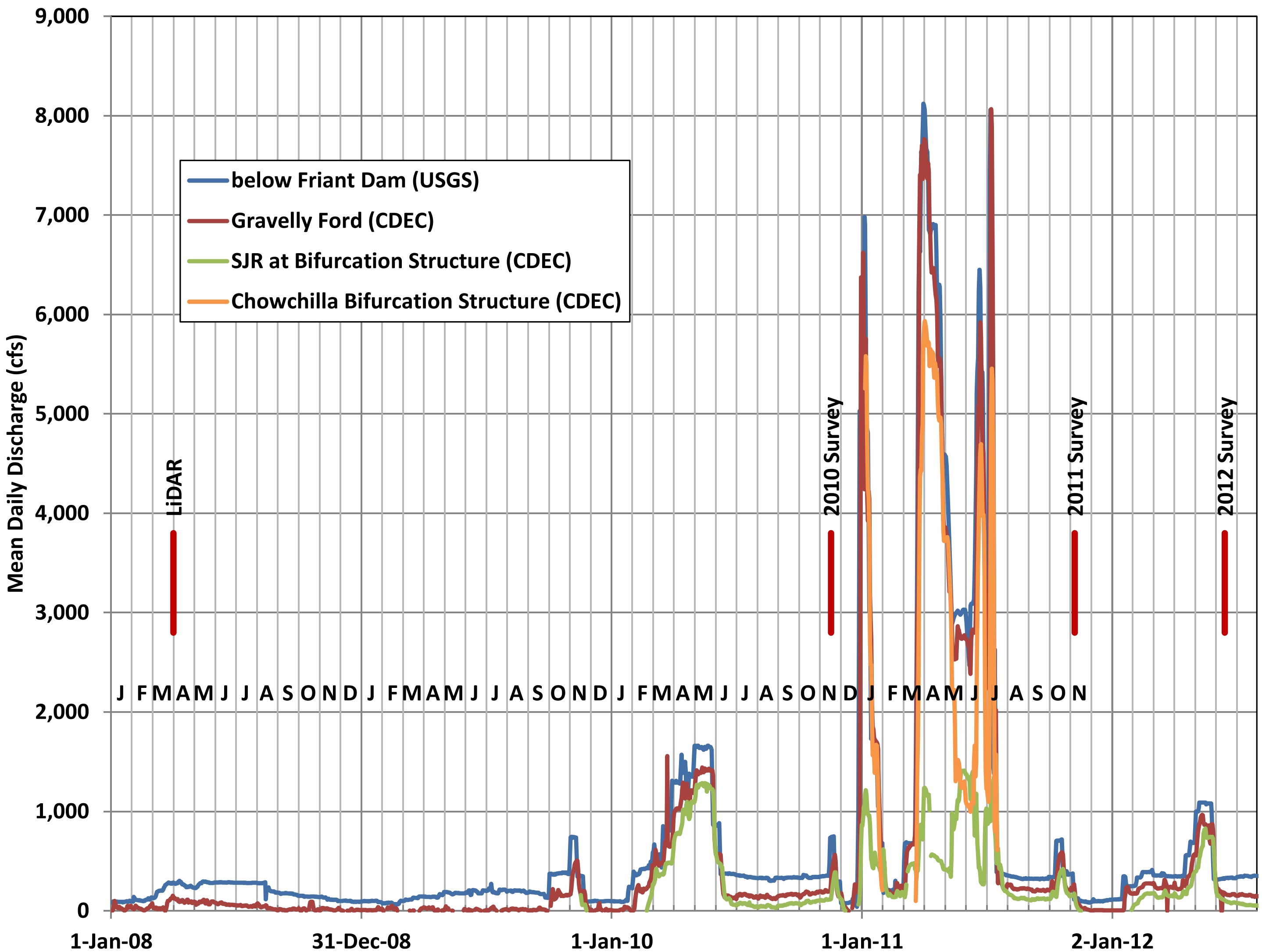

Figure 2. Reported mean daily discharges during the period encompassed by the LiDAR and field surveys at the USGS below Friant Dam gage and the CDEC Gravelly Ford (GRF), San Joaquin River below Bifurcation (SJB), and Chowchilla Bypass (CBP) gages.

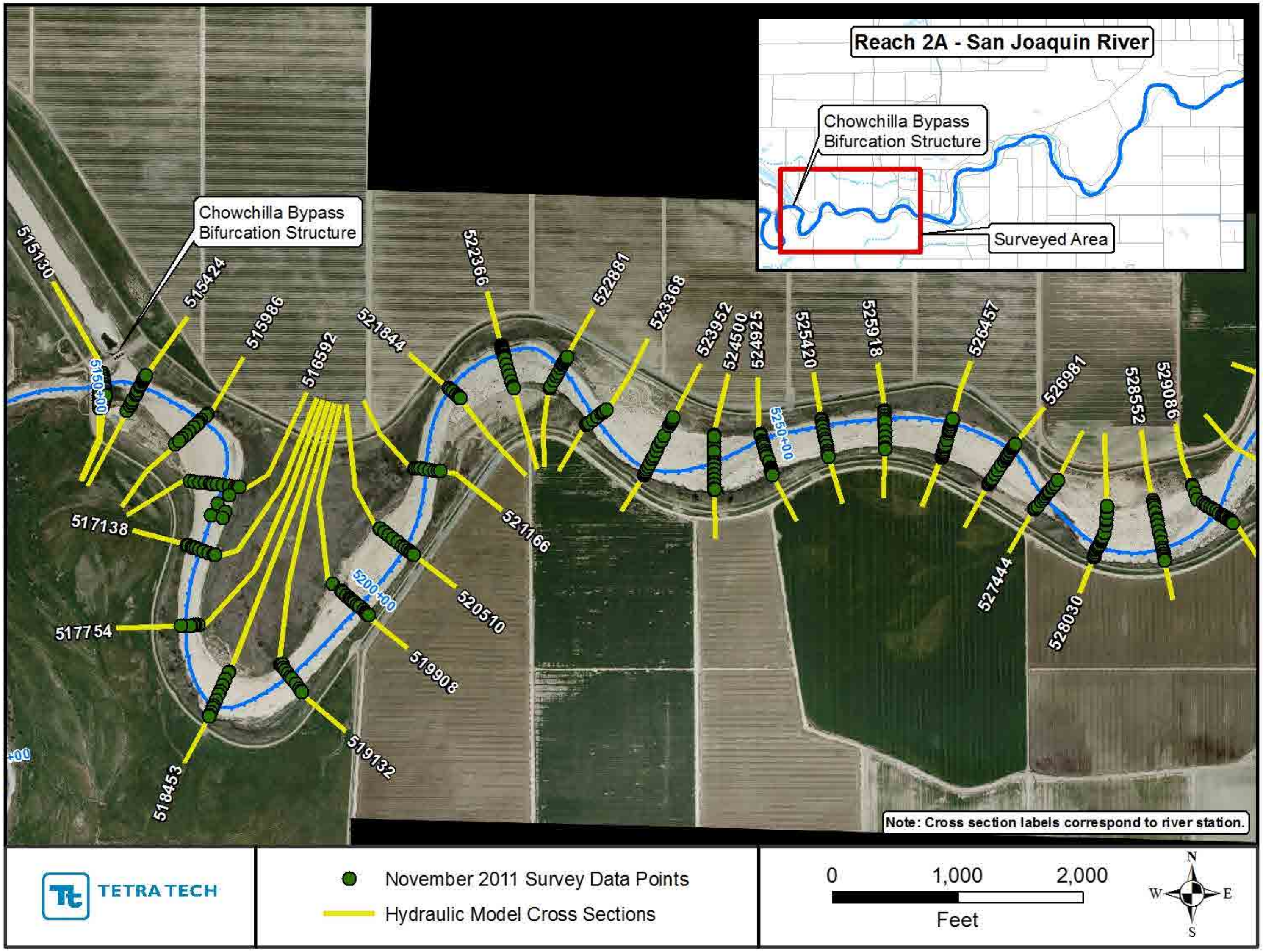

Figure 3. Map of lower portion of Reach 2A showing the locations of survey data collected during November 2011.

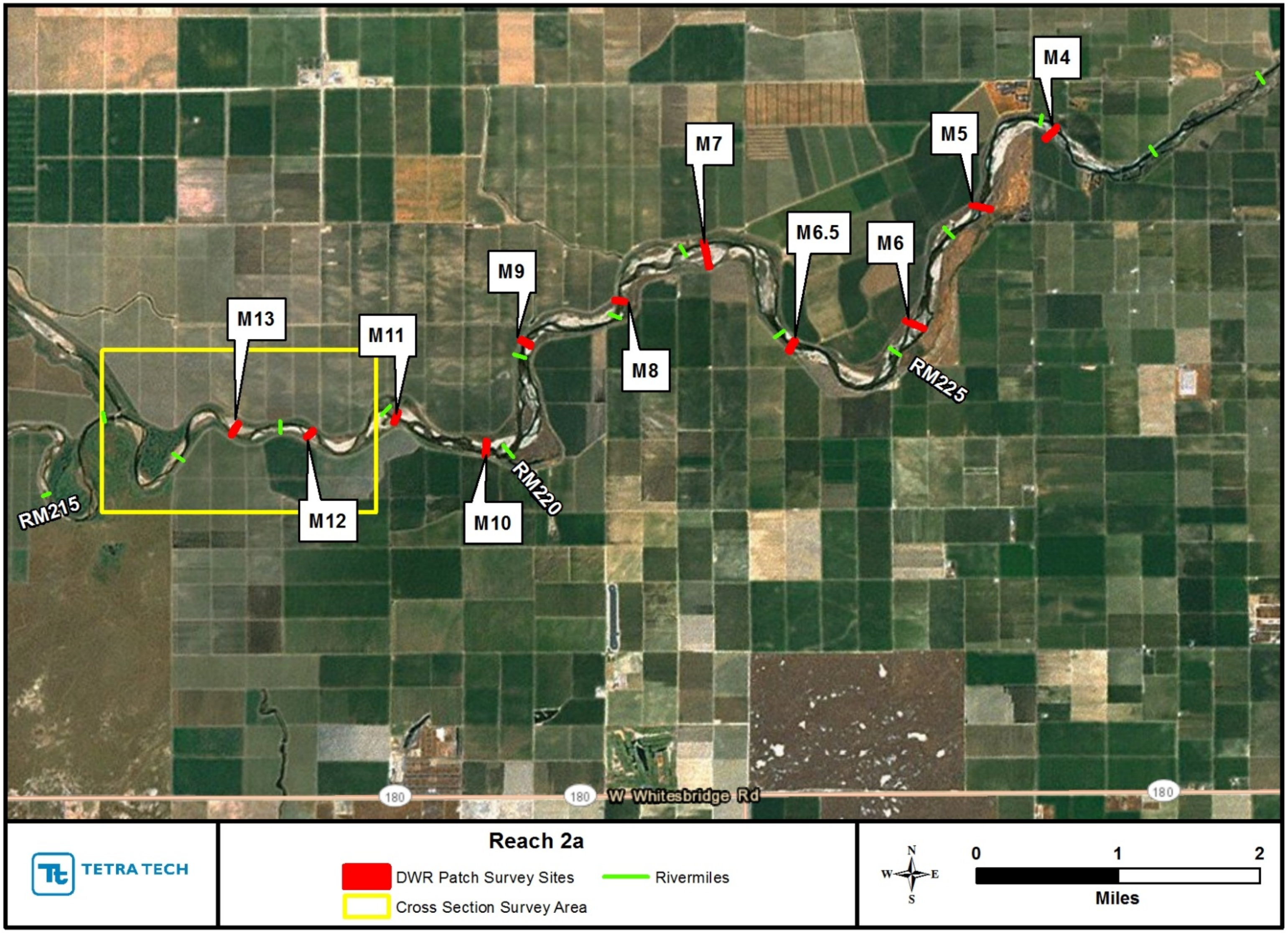

Figure 4. Location of DWR patch survey sites.

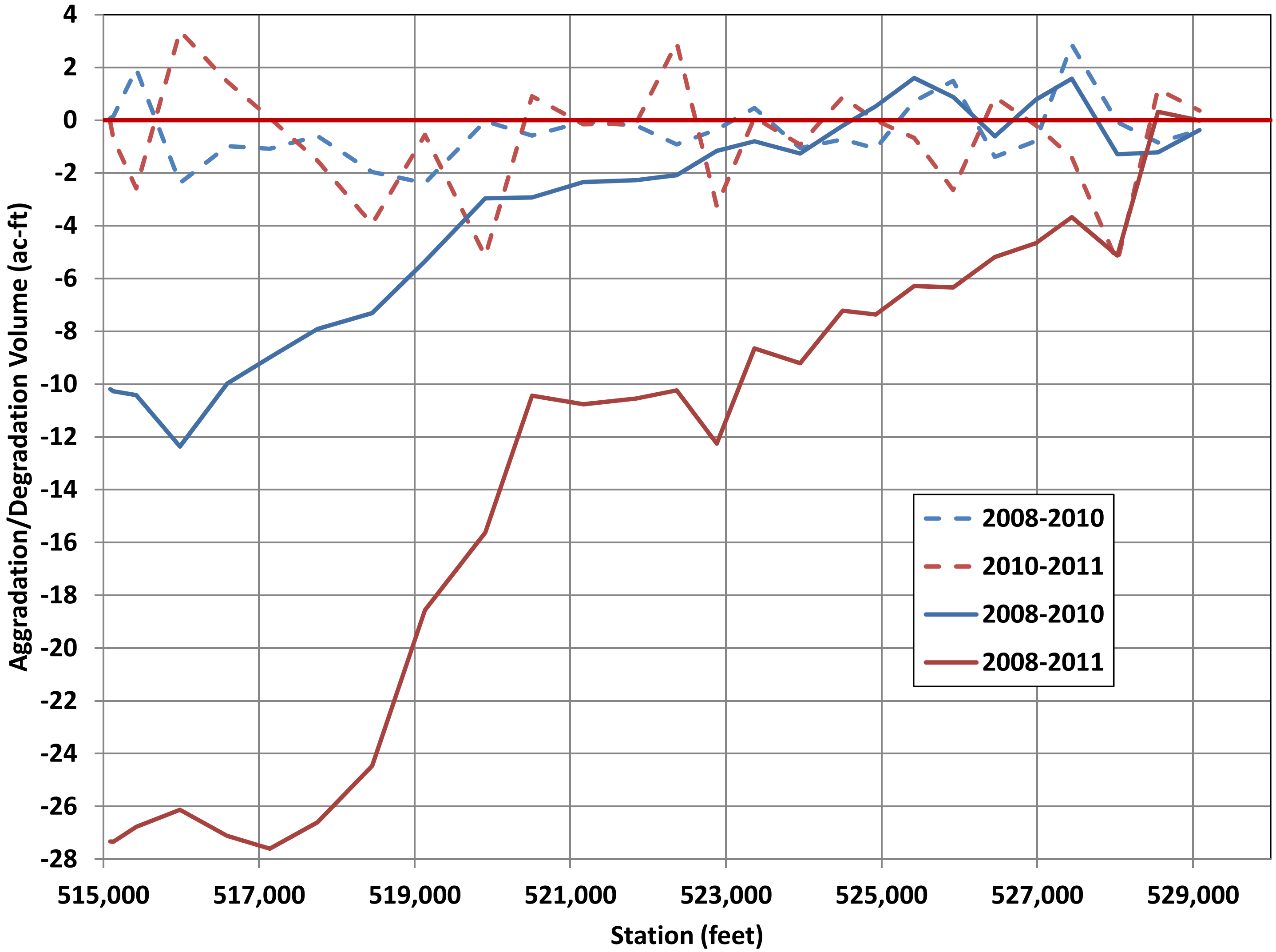

Figure 5. Aggradation/degradation volume between the 2008 LiDAR and November 2010 surveys and between the November 2010 and November 2011 surveys. Also shown is the cumulative aggradation/degradation volume from the upstream end of the survey reach between the 2008 LiDAR survey and two later surveys.

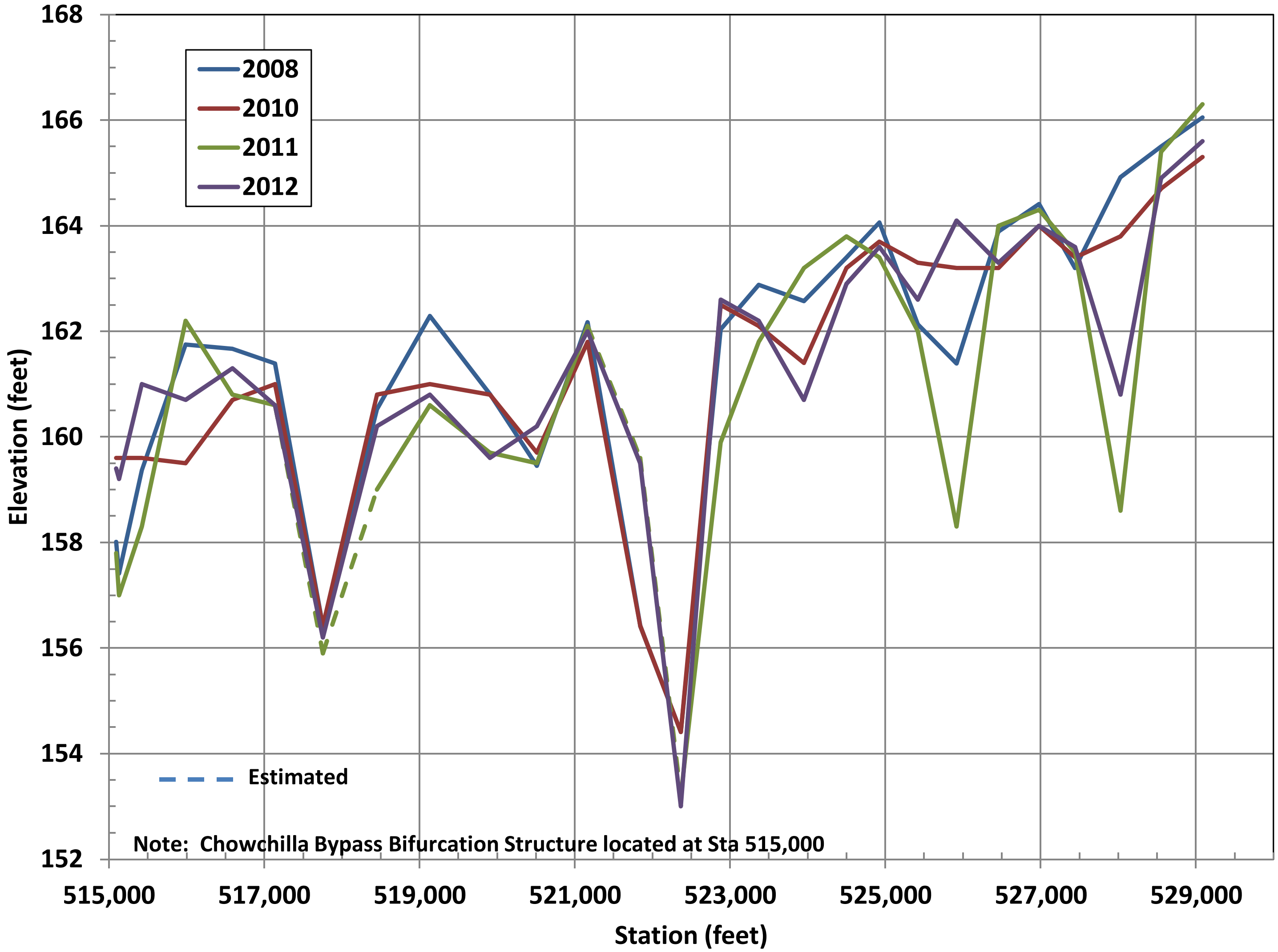

Figure 6a. Thalweg profiles for the downstream three miles of Reach 2A based on the 2008 LiDAR mapping, and the November 2010, November 2011 and June 2012 cross-section surveys.

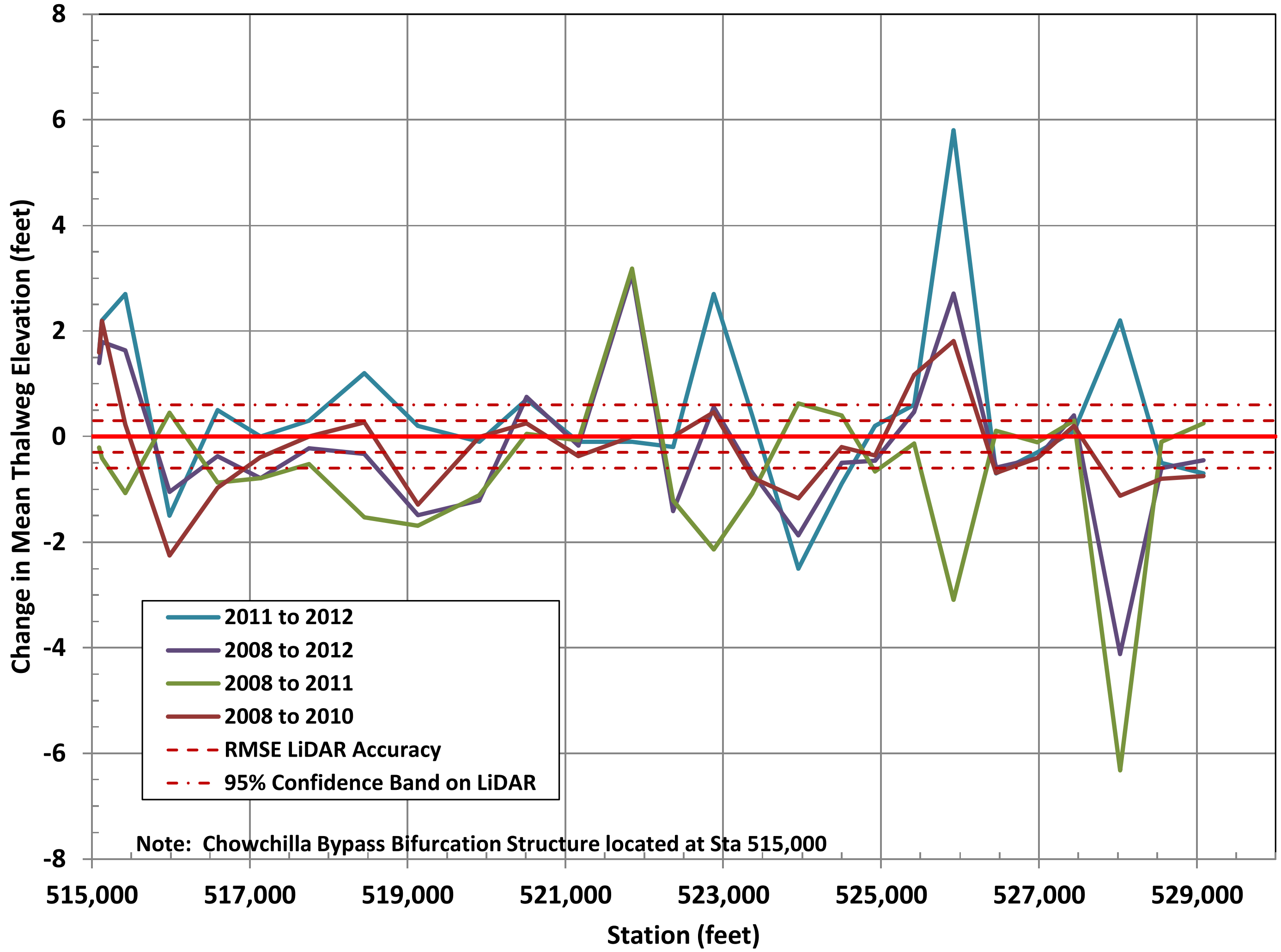

Figure 6b. Change in thalweg elevations in the downstream three miles of Reach 2A based on the 2008 LiDAR mapping, and the November 2010, November 2011 and June 2012 cross-section surveys. RMSE and 95% Confidence Bands from LiDAR map accuracy standards are also shown. Error in surveyed cross section points is believed to be of similar magnitude.

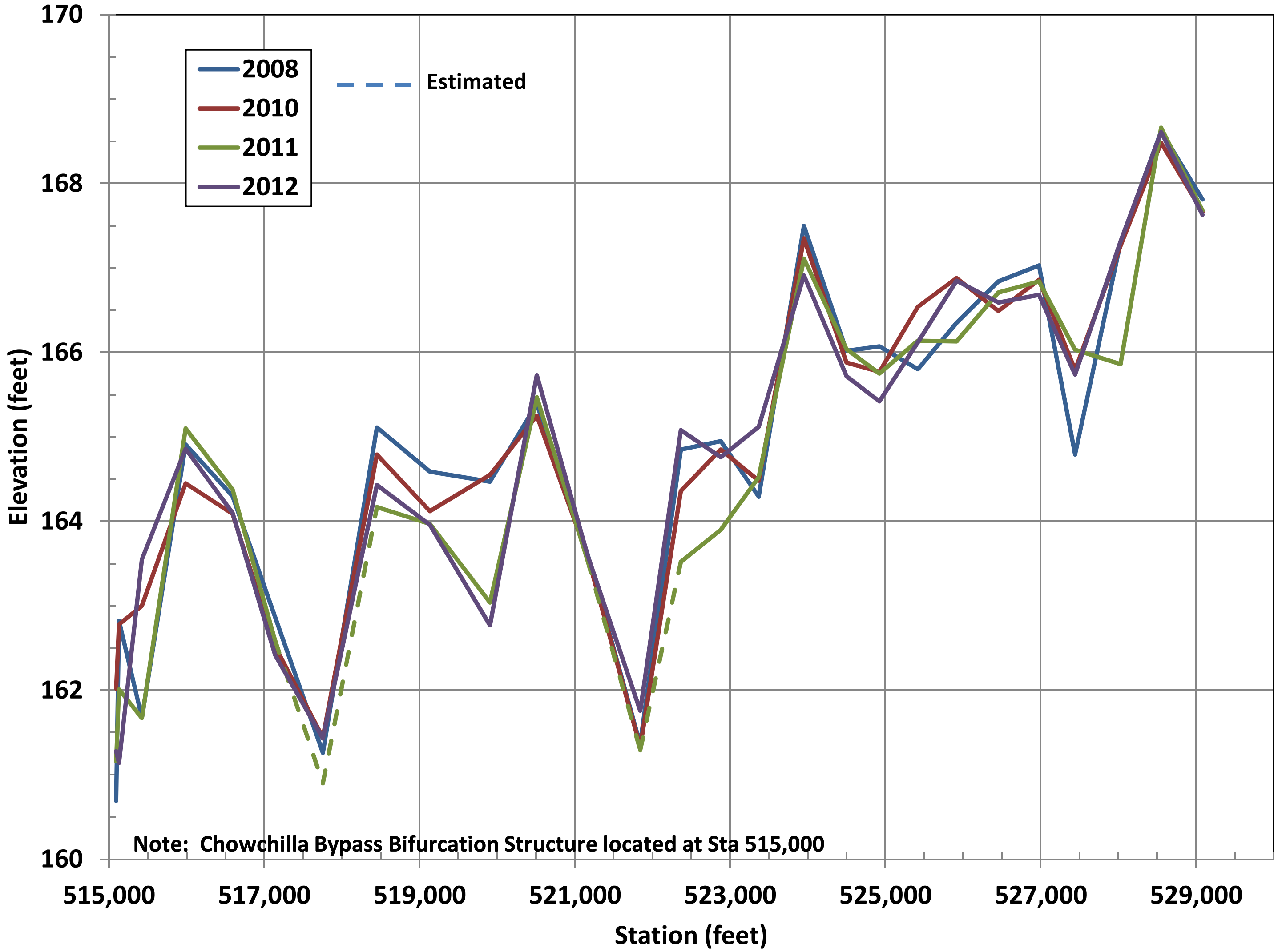

Figure 7a. Mean bed elevation profiles for the downstream three miles of Reach 2A based on the 2008 LiDAR mapping, and the November 2010, November 2011 and June 2012 cross-section surveys.

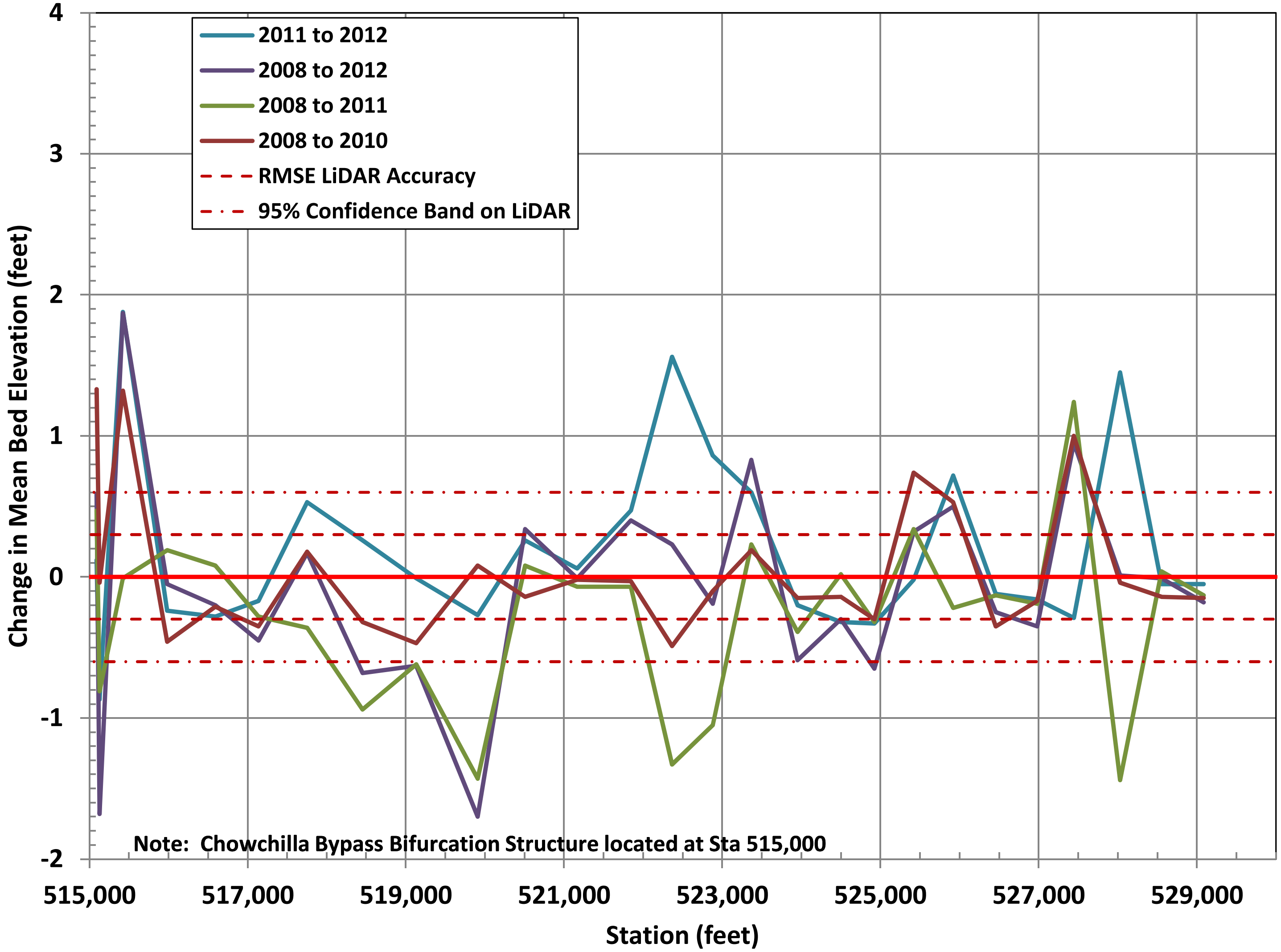

Figure 7b. Change in mean bed elevations in the downstream three miles of Reach 2A based on the 2008 LiDAR mapping, and the November 2010, November 2011 and June 2012 cross-section surveys.

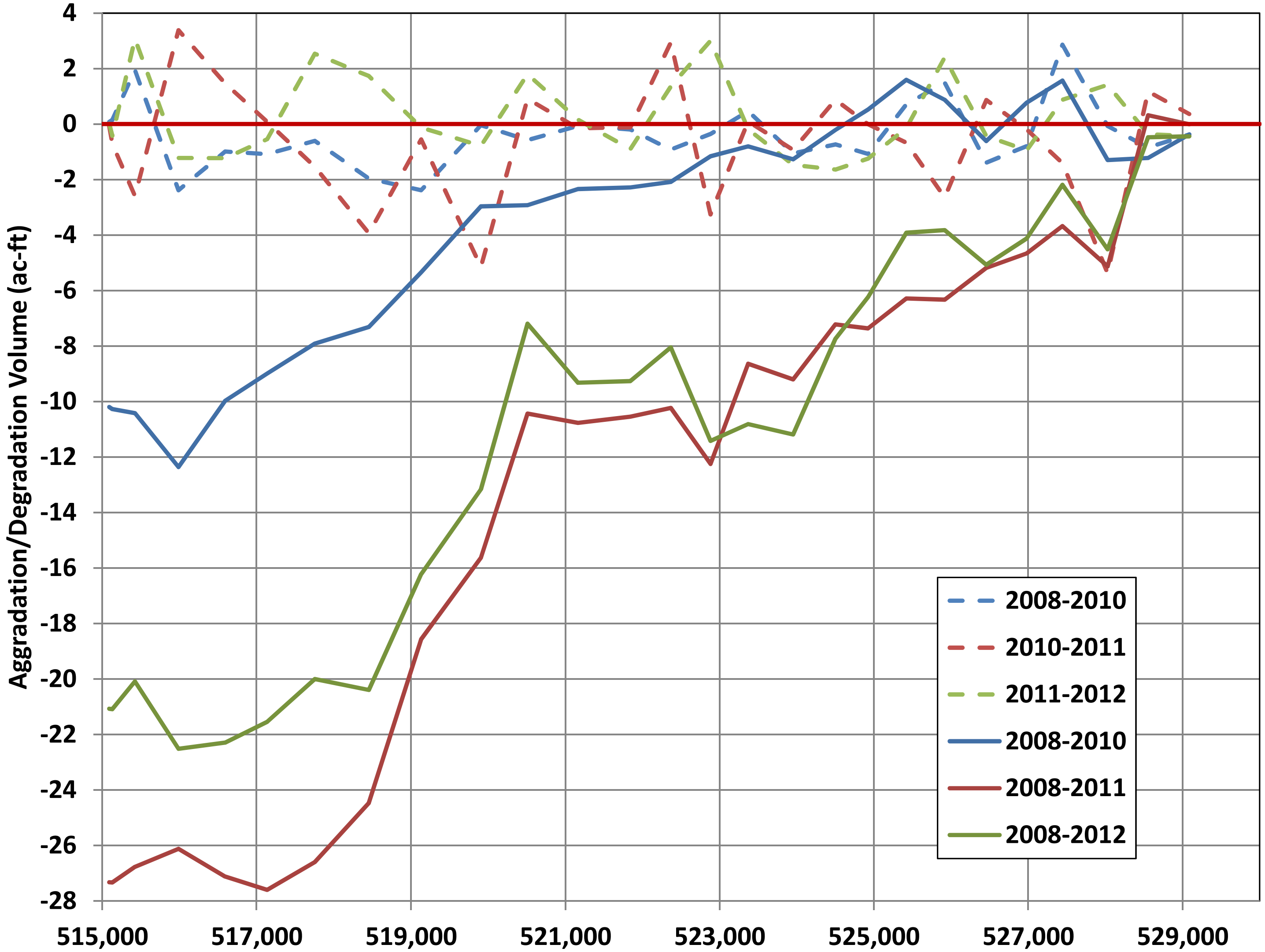

Figure 8. Aggradation/degradation volumes between the 2008 LiDAR survey and the subsequent ground surveys that were conducted in November 2010, November 2011 and June 2012. Also shown is the cumulative aggradation/degradation volume from the upstream end of the survey reach between the 2008 LiDAR survey and each of the surveys.

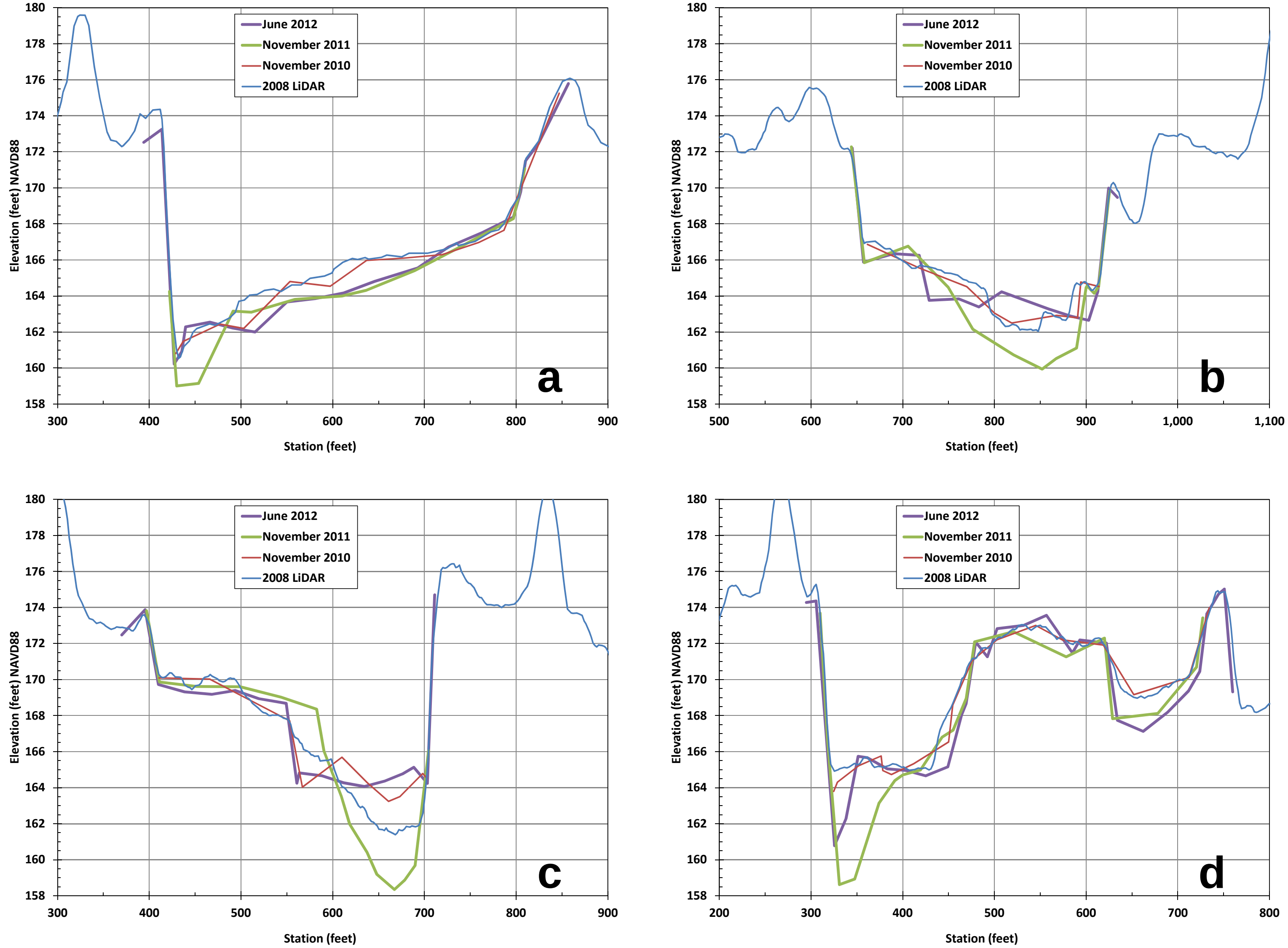

Figure 9. Profiles of four typical cross sections that experienced significant deposition between the November 2011 and June 2012 surveys: (a) XS518453, (b) XS522881, (c) XS525918, (d) XS528030. Profiles from the 2008 LiDAR and November 2010 surveys are also shown.

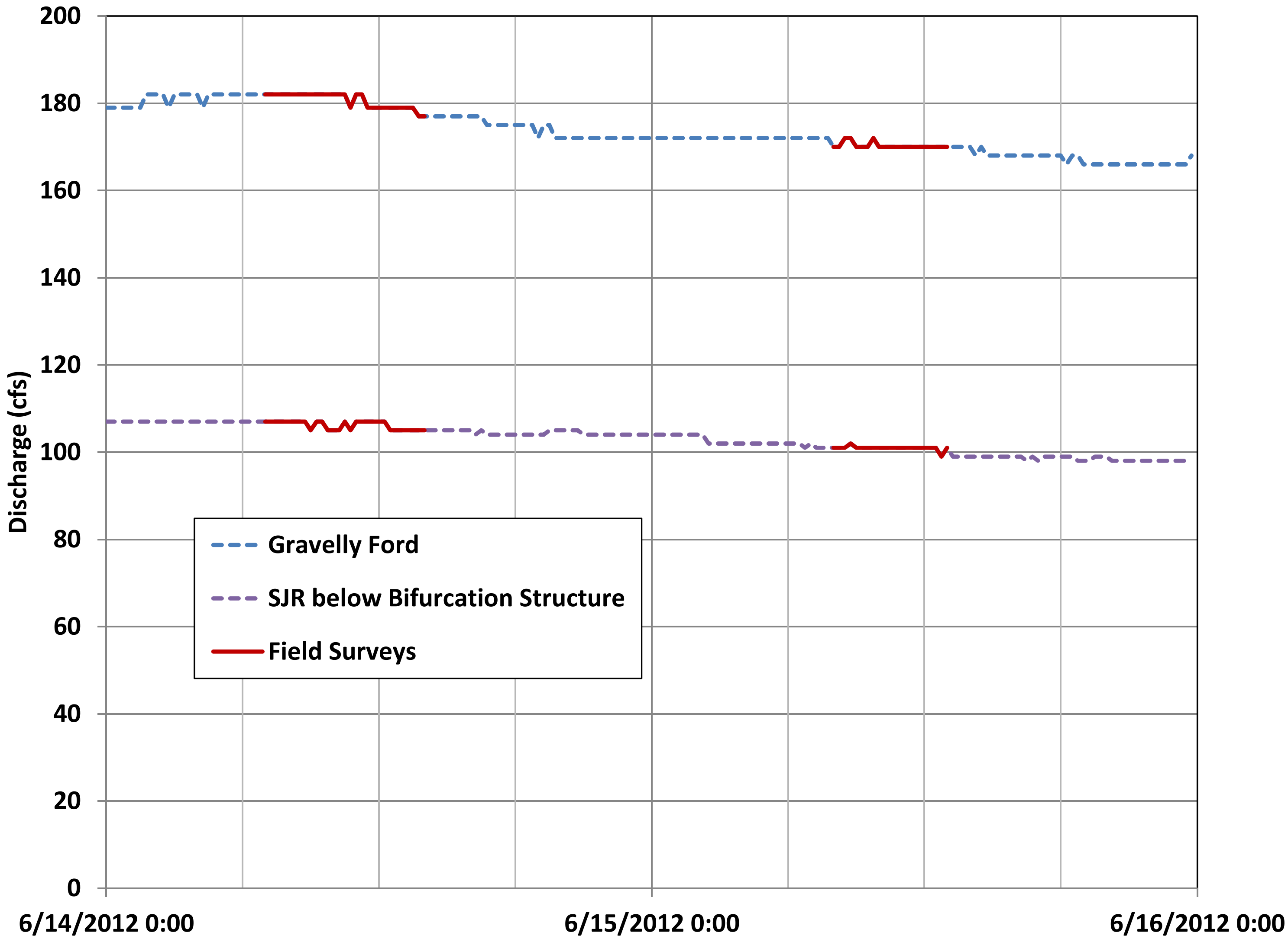

Figure 10. Discharge hydrograph during the June 2012 survey period at the Gravelly Ford (GRF) and San Joaquin River below Bifurcation (SJB) gages, based on data from the CDEC website. **(Note that these discharges are provisional and subject to change upon review of the gage rating curves.)**

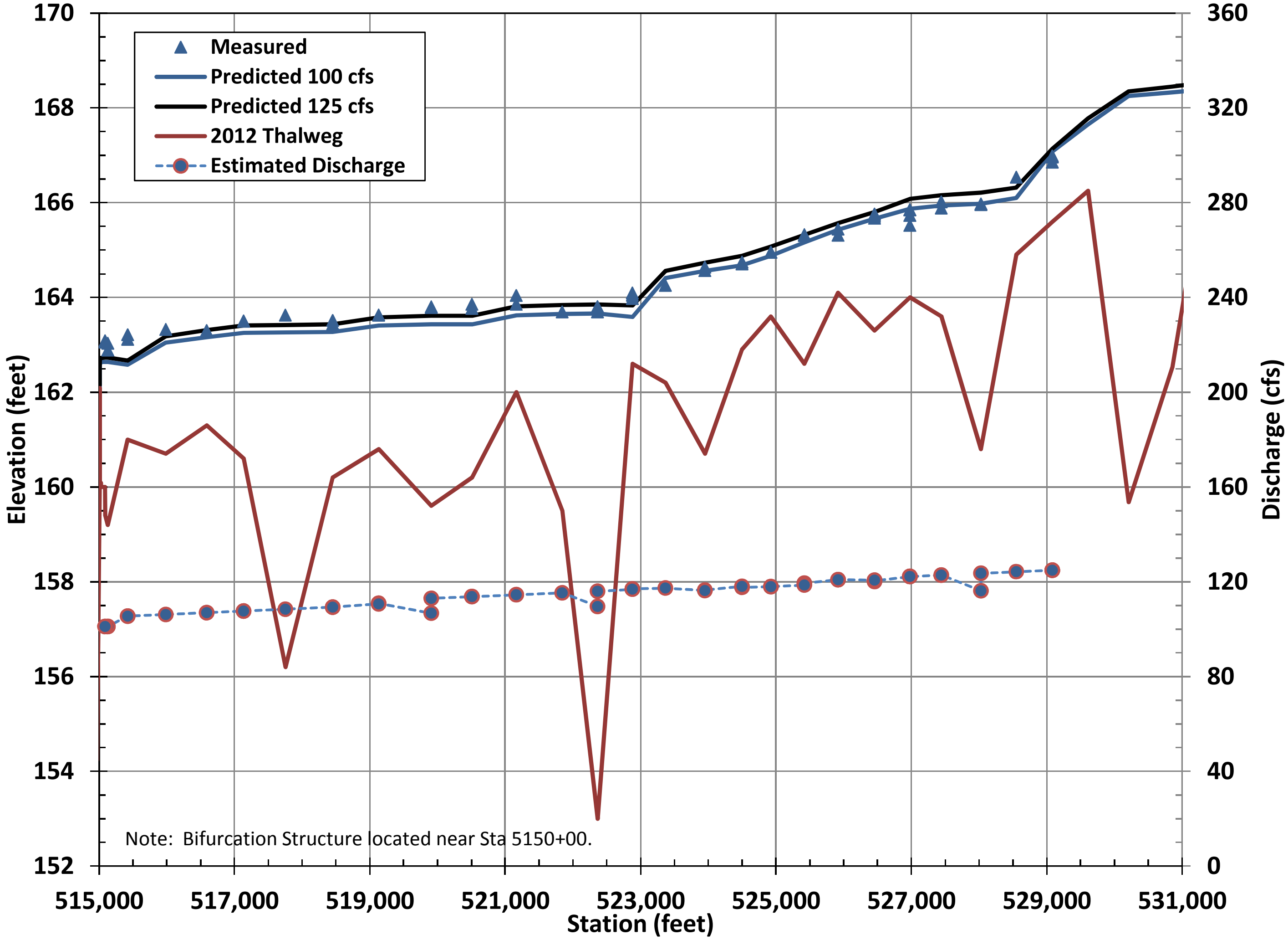

Figure 11. Surveyed water-surface elevations in the downstream three miles of Reach 2A from the June 2012 survey when the discharge ranged from about 100 cfs near the downstream end of the reach to about 125 cfs near the upstream and of the reach. Also shown are the water-surface profiles at discharges of 100 and 125 cfs predicted by the HEC-RAS model updated with the 2012 cross sections.

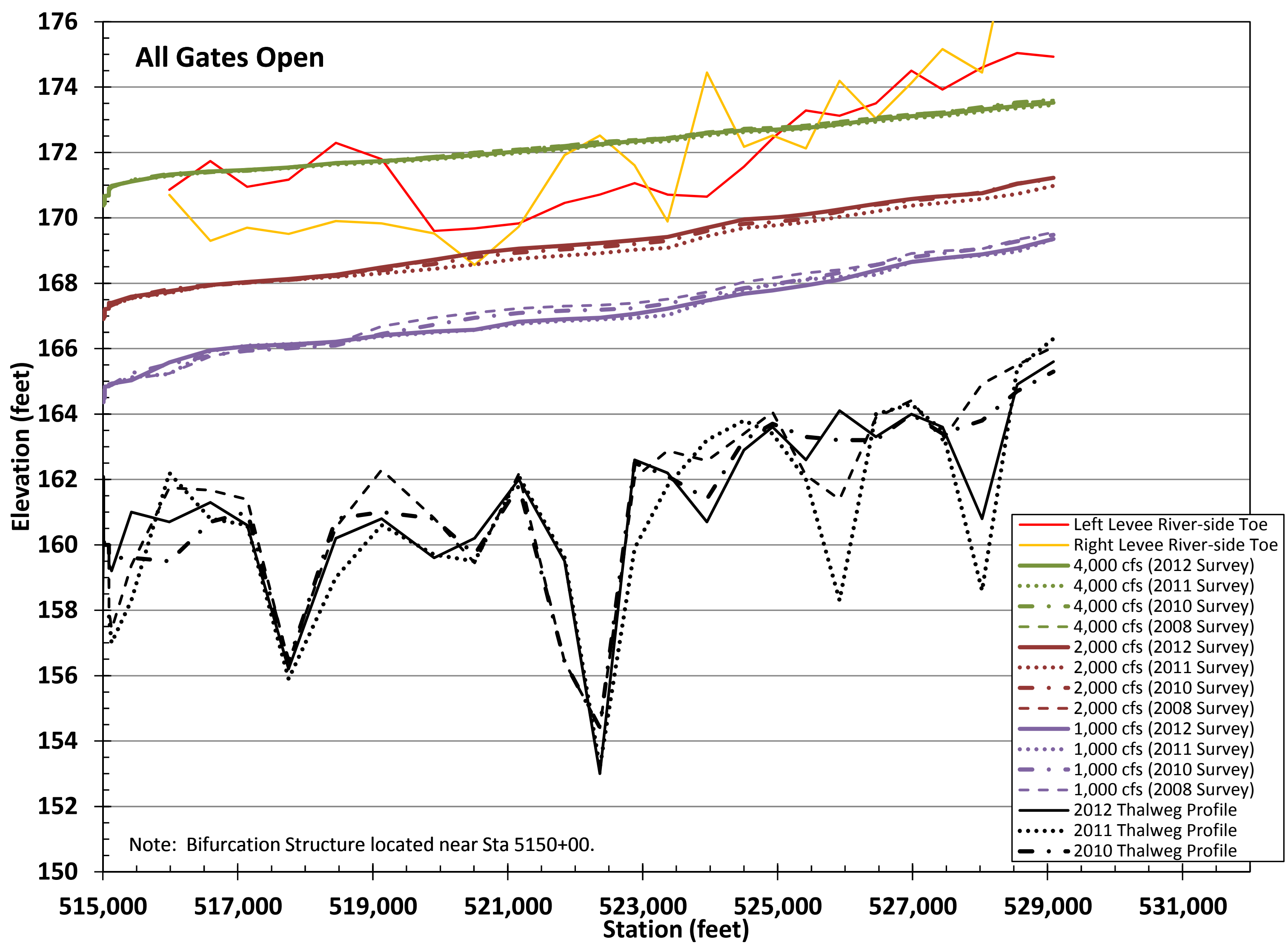

Figure 12. Water-surface profiles for discharges of 1,000, 2,000 and 4,000 cfs predicted by the HEC-RAS models with cross sections from the 2008 LiDAR mapping, and the November 2010, November 2011, and June 2012 surveys.

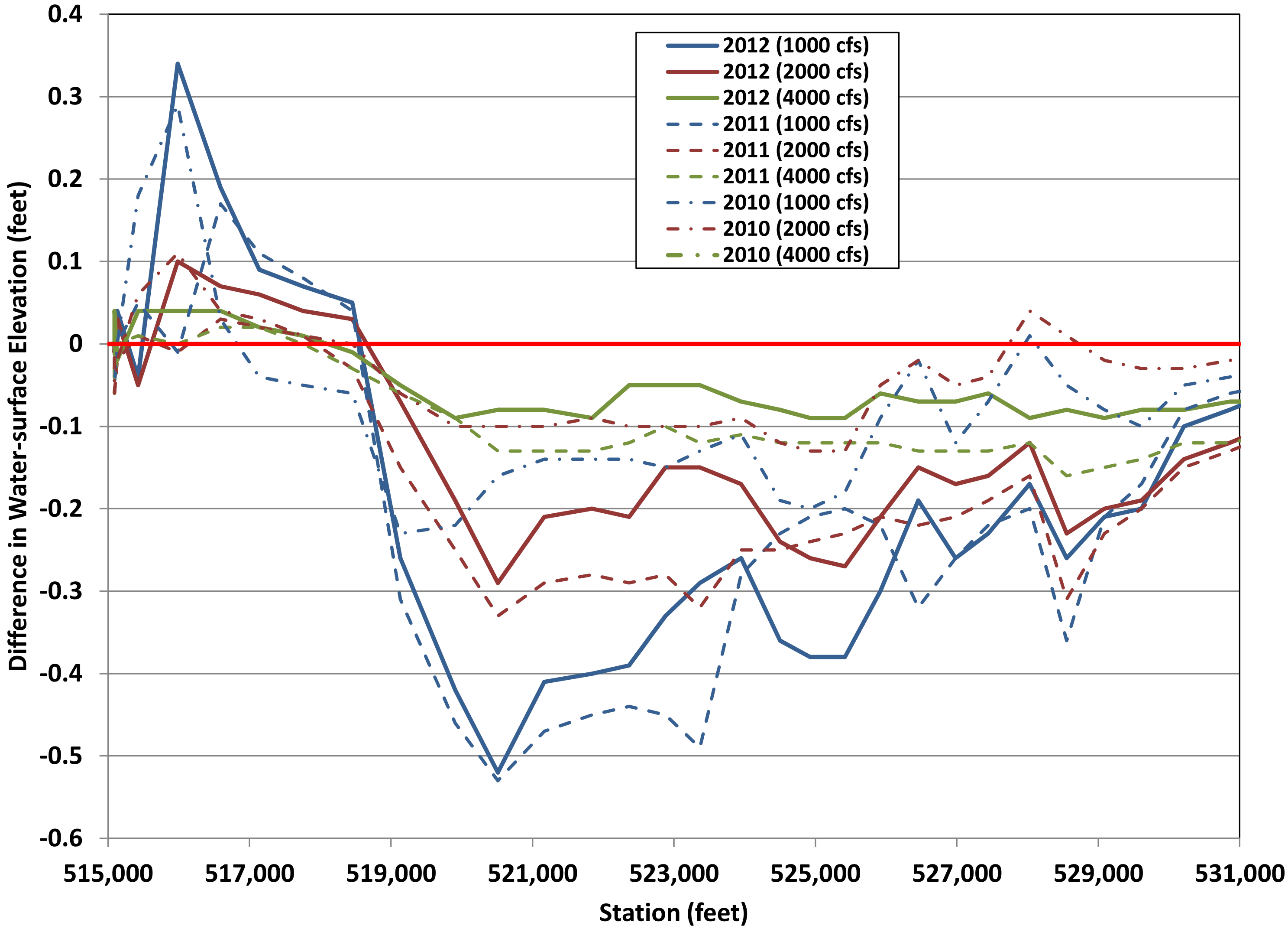

Figure 13. Difference between the predicted water-surface elevations using the November 2010, November 2011 and June 2012 cross sections and the 2008 LiDAR cross sections.

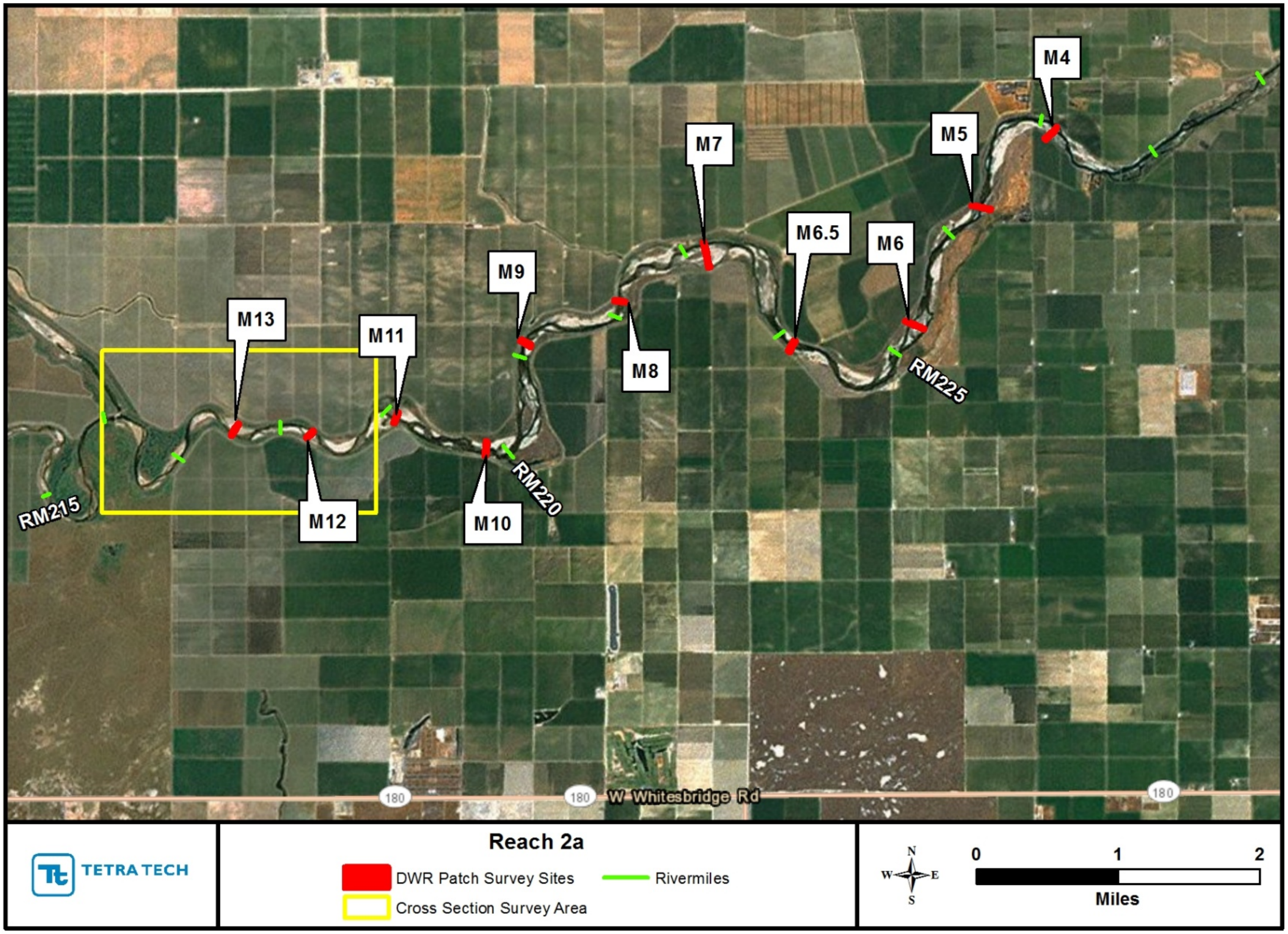

Figure 14. Location of Reach 2A patch surveys. Also shown is the general location of the cross section surveys analyzed in the previous sections.

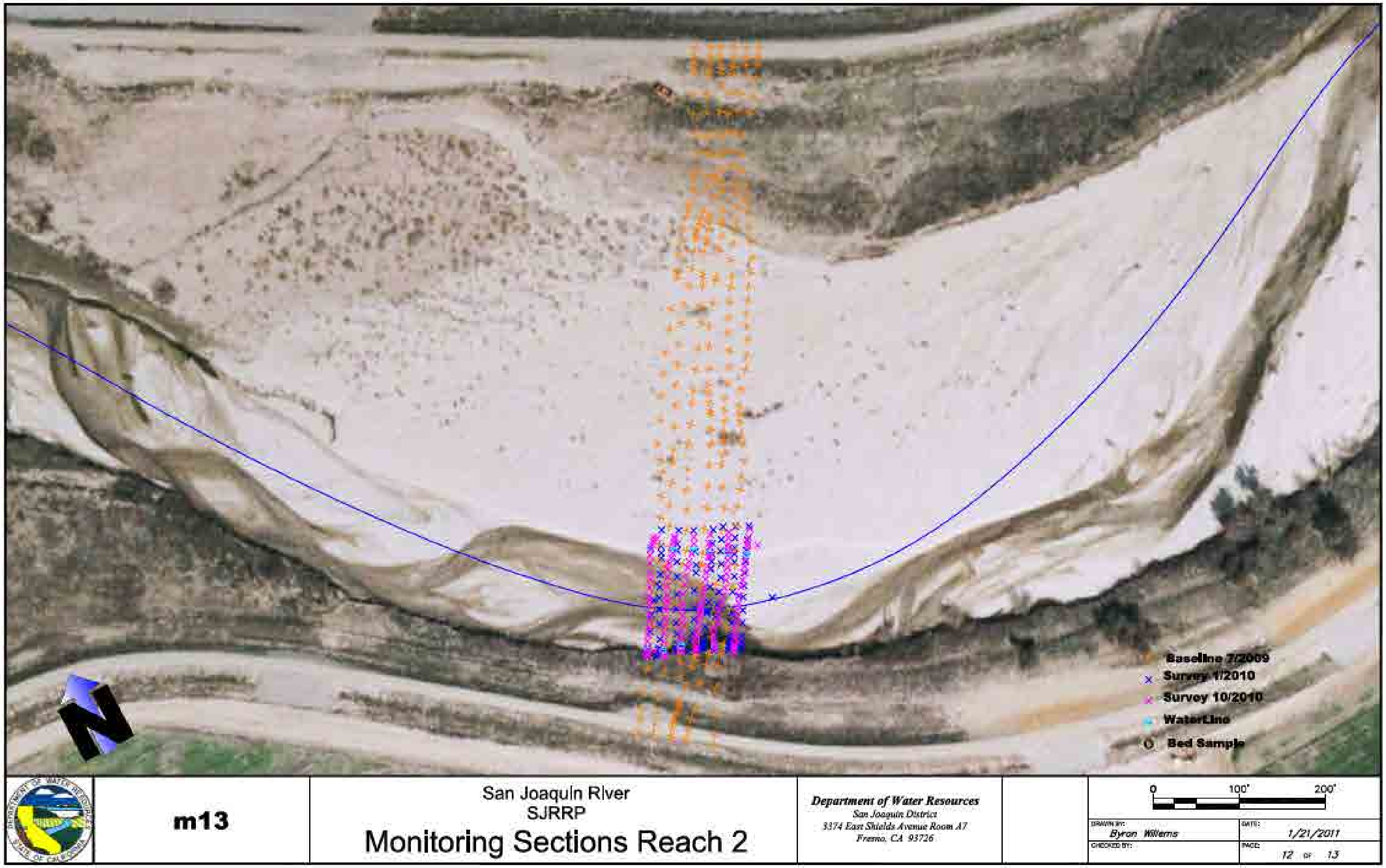

Figure 15. Survey points at Patch Survey Site M13, illustrating the typical layout and resolution at the sites. Similar images of the other sites can be found in Appendix H of BOR (2012).

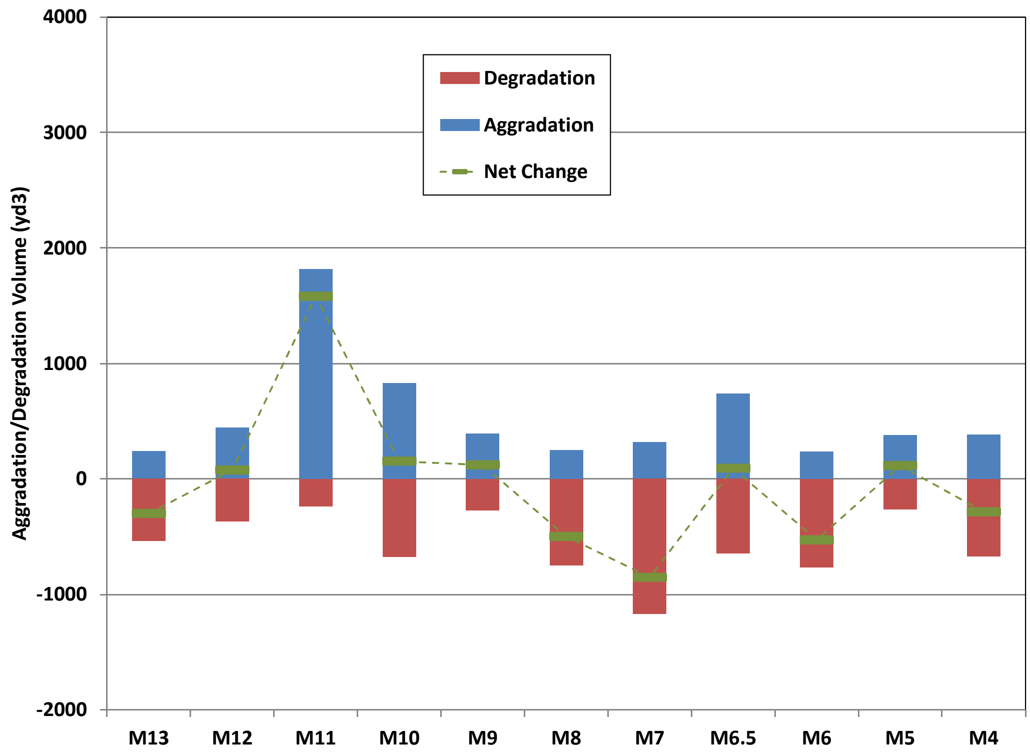

Figure 16. Total and net aggradation (+)/degradation(-) volumes at the DWR patch surveys sites between the July 2009 and February 2011 surveys.

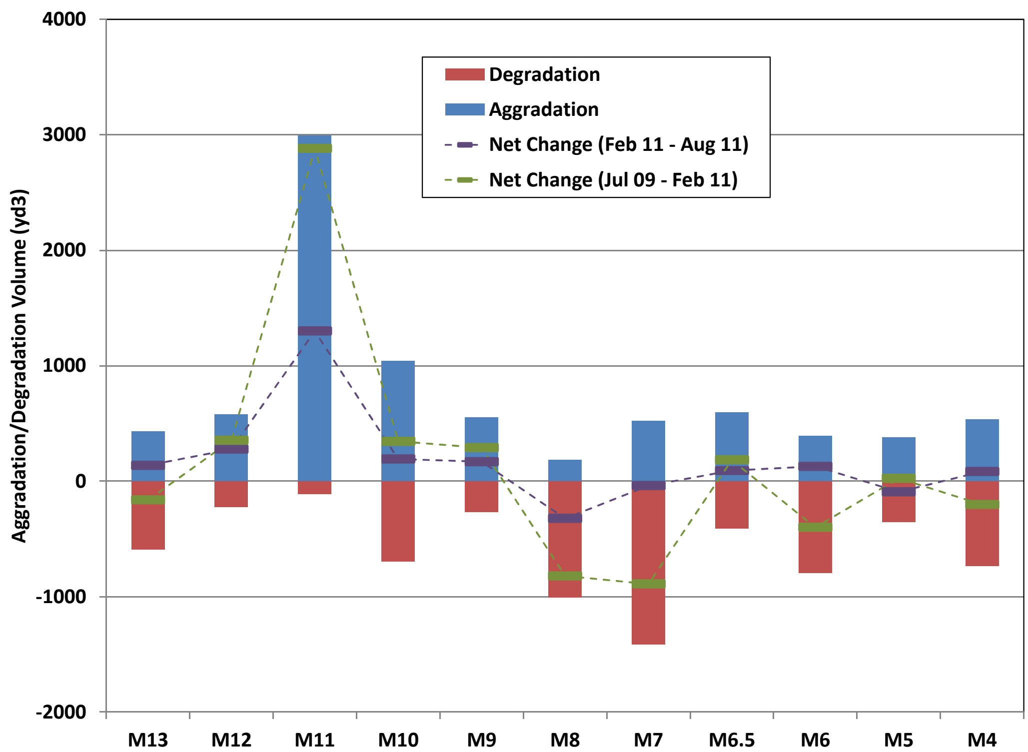

Figure 17. Total and net aggradation (+)/degradation(-) volumes at the DWR patch surveys sites between the July 2009 and August 2011 surveys. Also shown is the net change between February and August 2011.

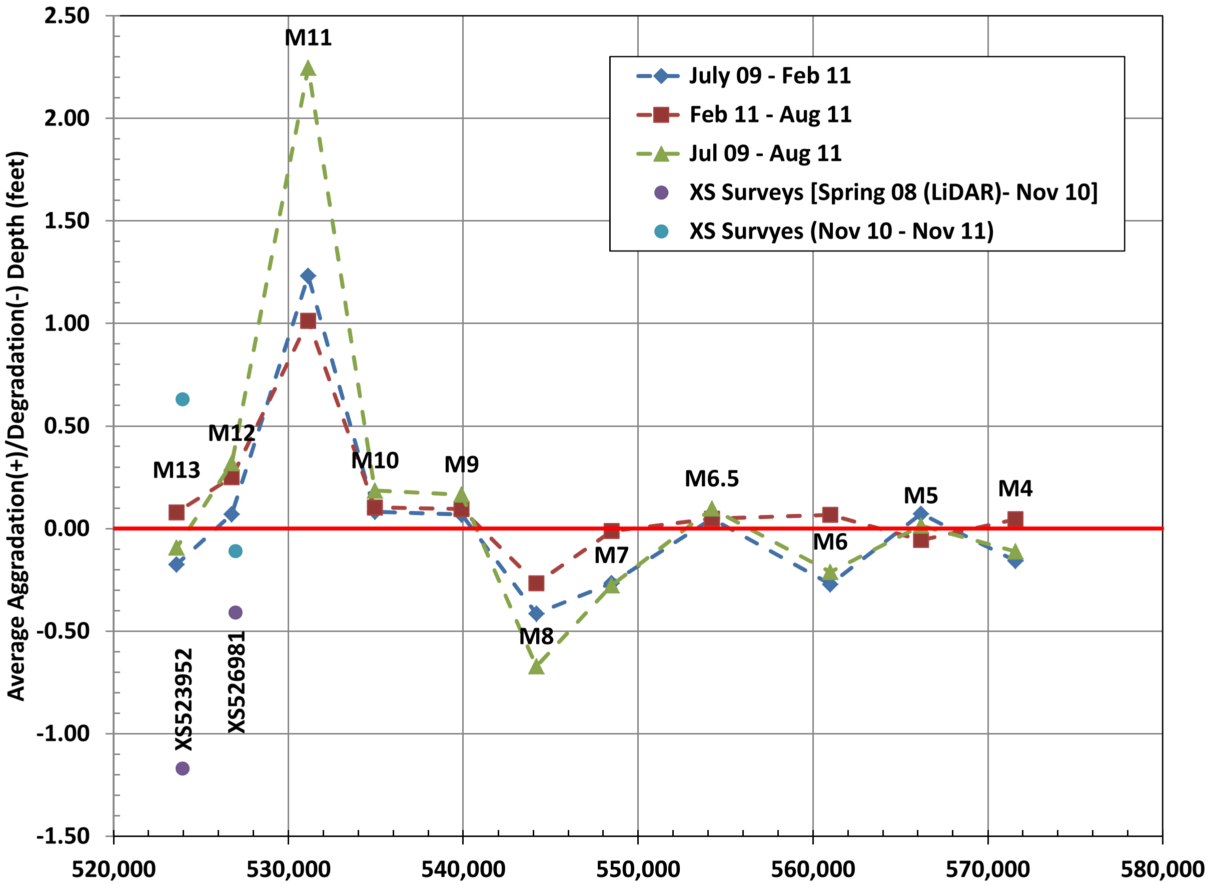

Figure 18. Average aggradation (+)/degradation(-) depth at the patch survey sites between the July 2009, February 2011 and August 2011 surveys. Also shown are the average aggradation/degradation depths at the two surveyed cross sections closest to Sites M12 and M13.

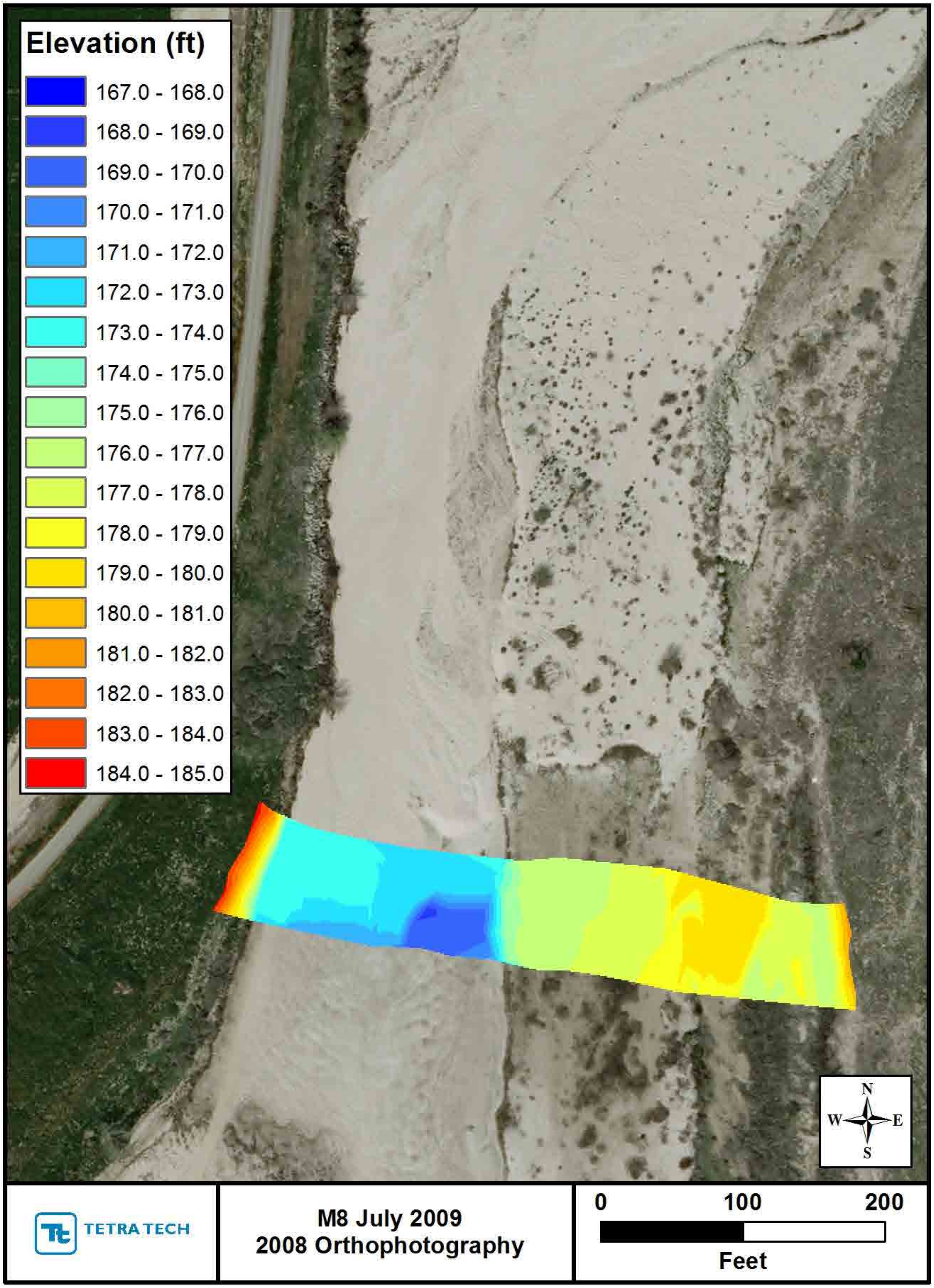

Figure 19a. Topographic surface from July 2009 DWR patch survey data at Site M8 overlaid onto the 2008 aerial photograph.

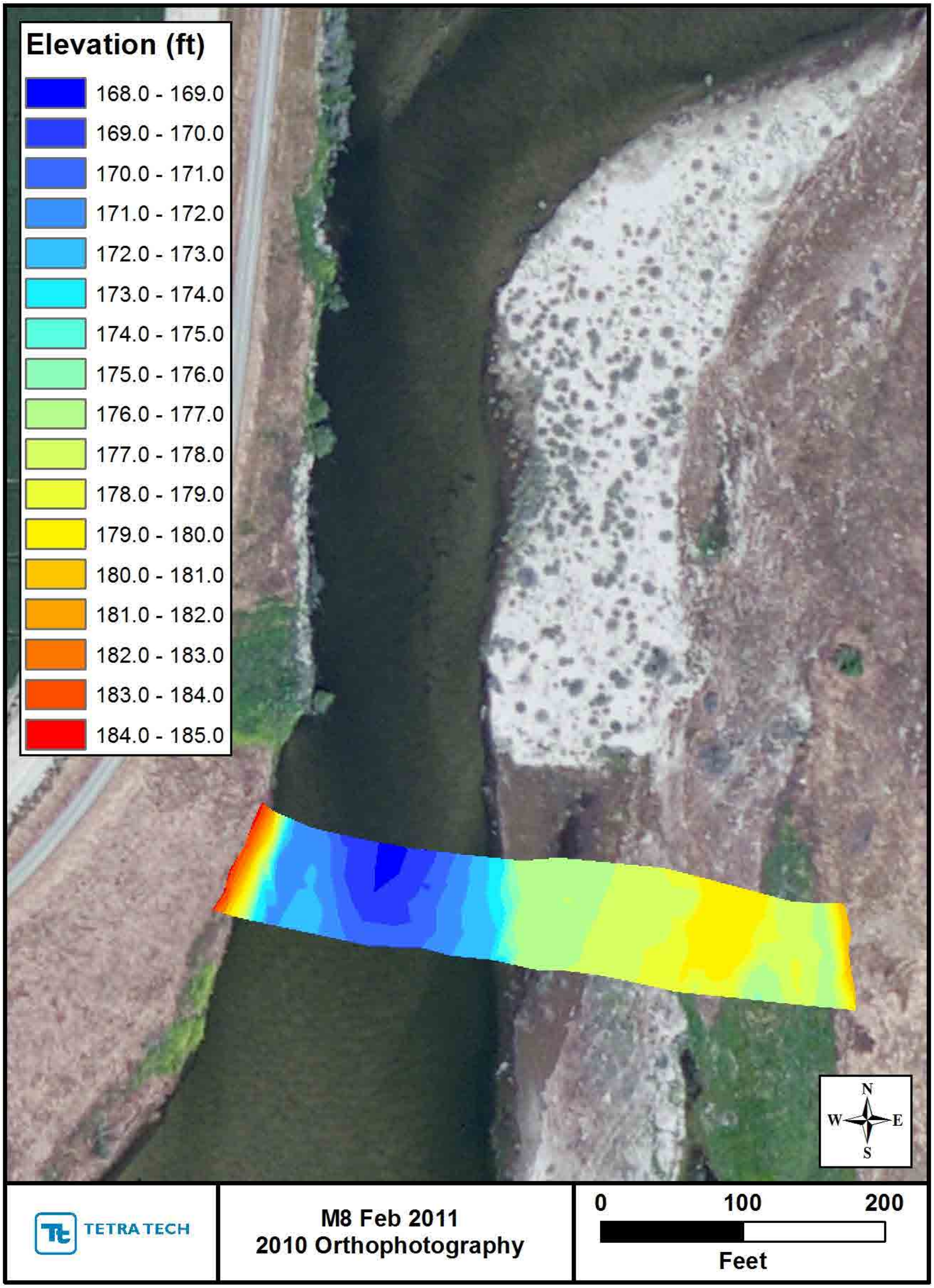

Figure 19b. Topographic surface from the February 2011 DWR patch survey data at Site M8 overlaid onto the 2010 aerial photograph.

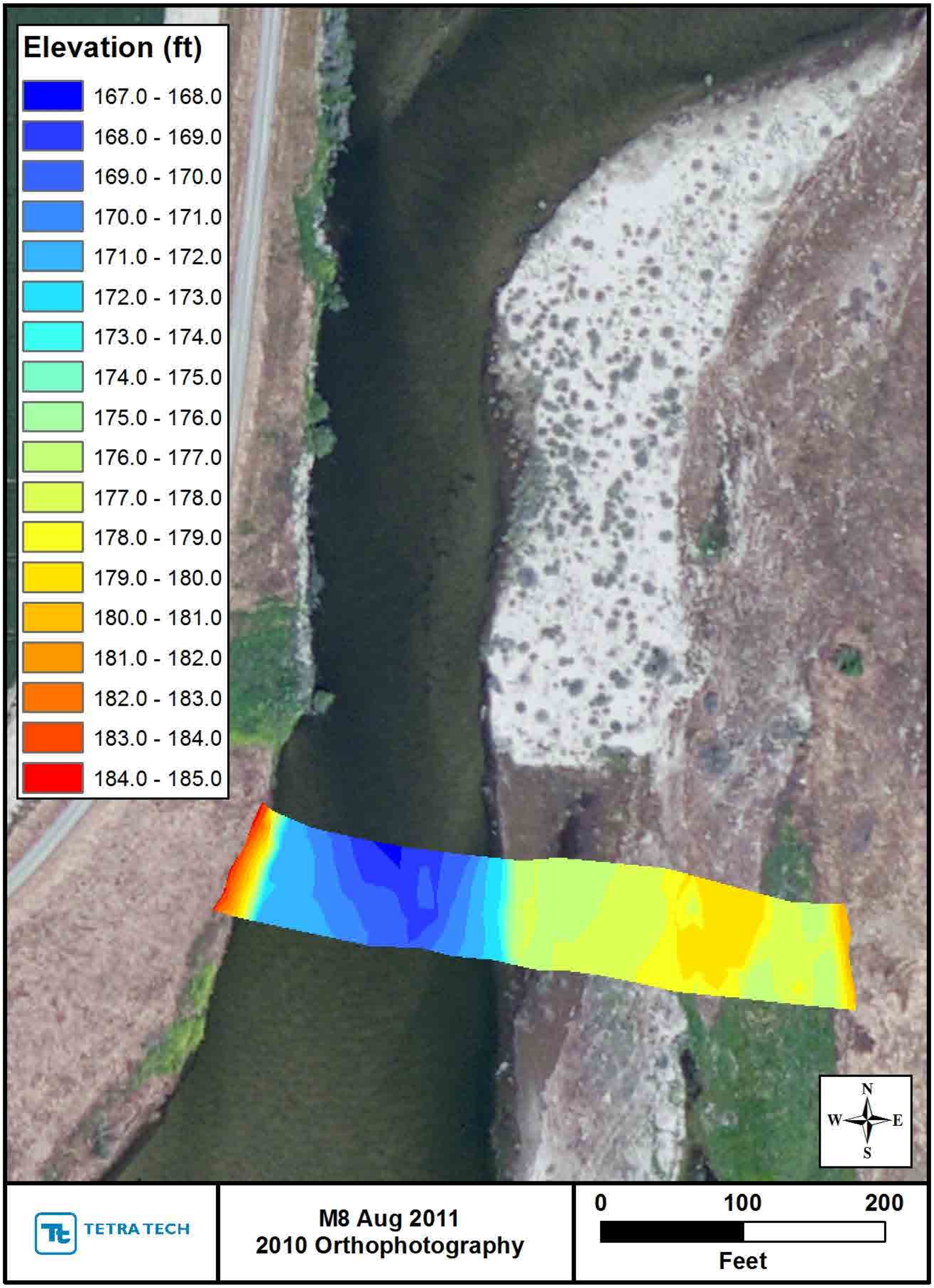

Figure 19c. Topographic surface from the August 2011 DWR patch survey data at Site M8 overlaid onto the 2010 aerial photograph.

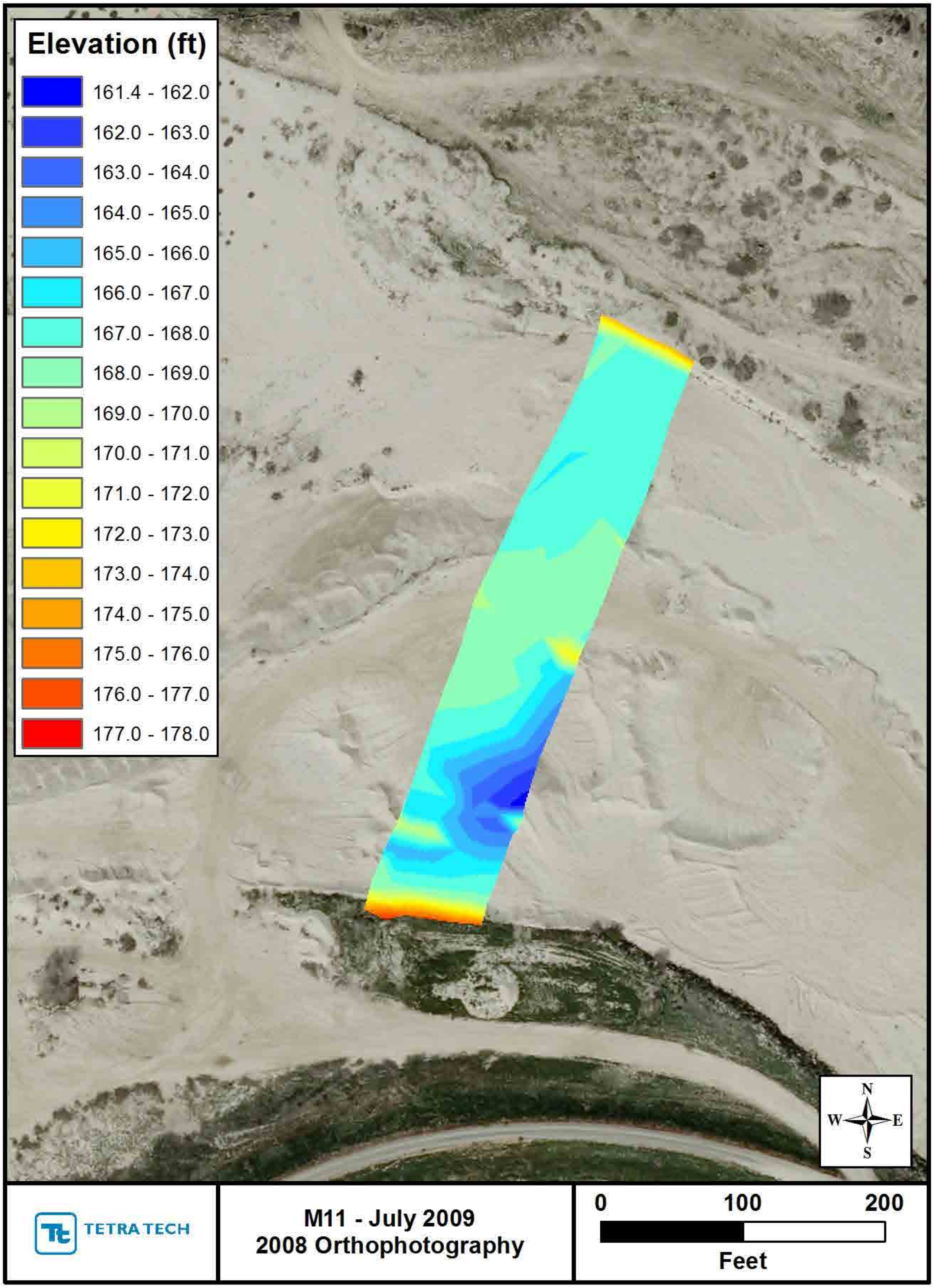

Figure 20a. Topographic surface from July 2009 DWR patch survey data at Site M11 overlaid onto the 2008 aerial photograph.

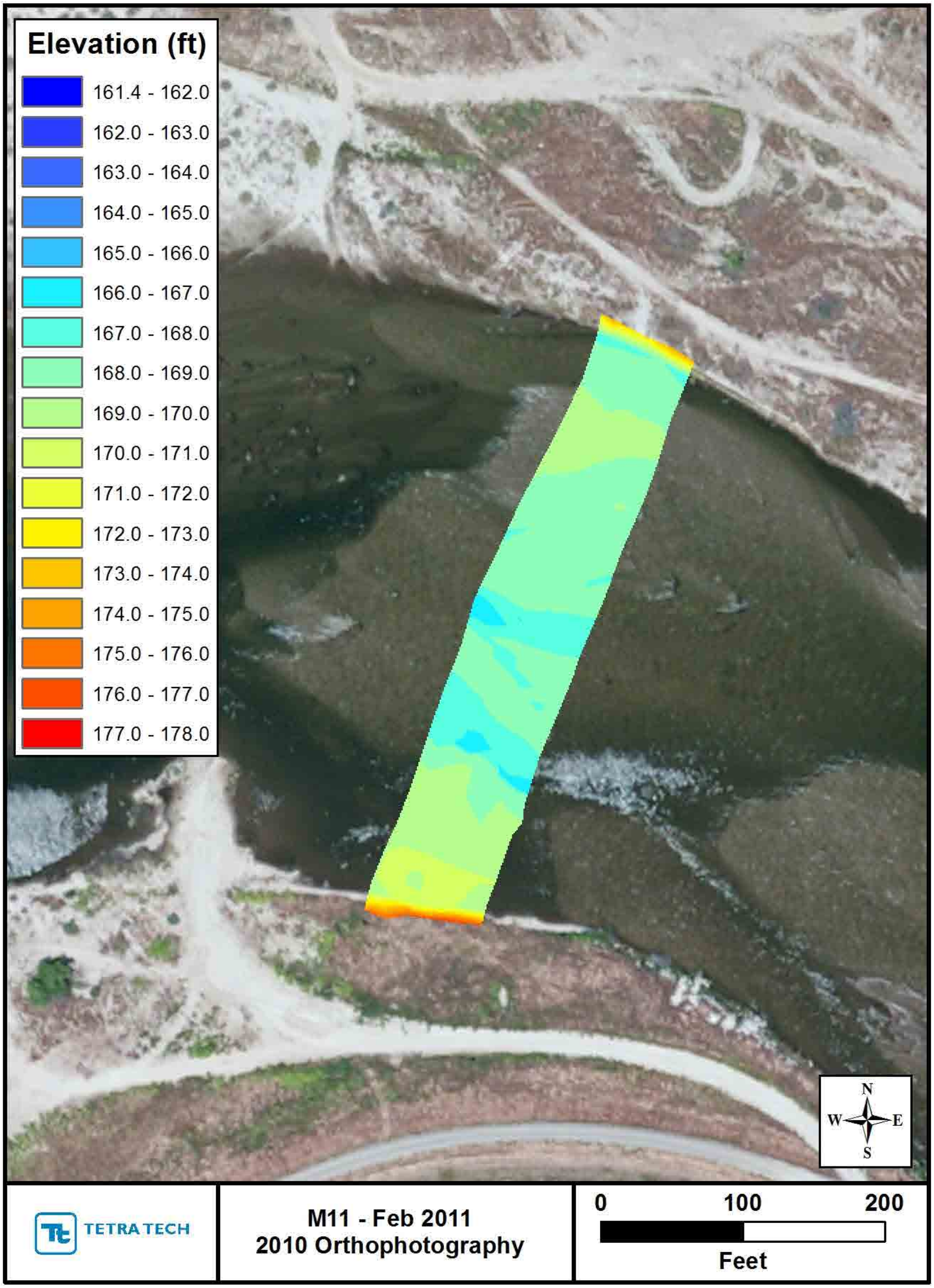

Figure 20b. Topographic surface from the February 2011 DWR patch survey data at Site M11 overlaid onto the 2010 aerial photograph.

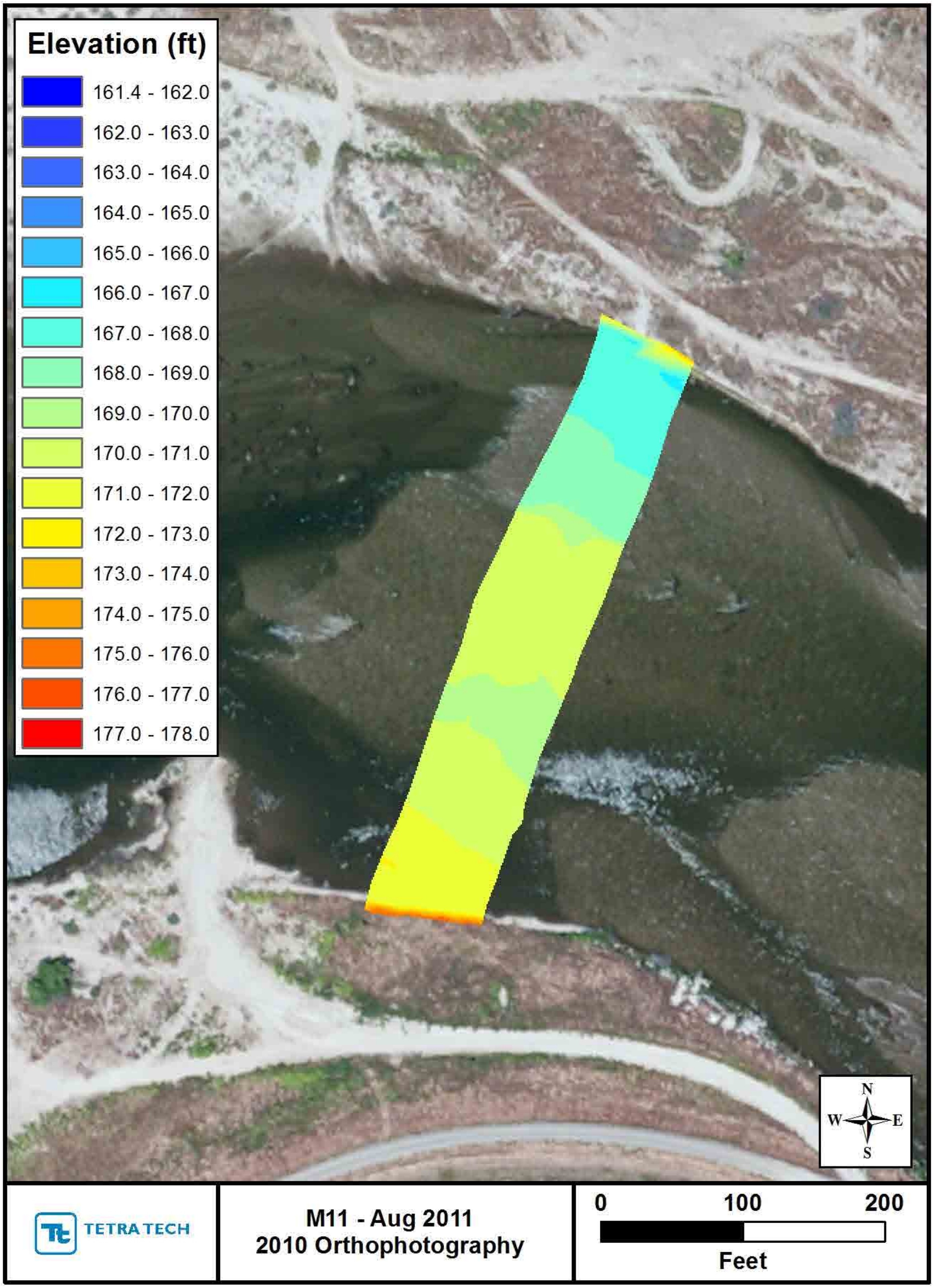

Figure 20c. Topographic surface from the August 2011 DWR patch survey data at Site M11 overlaid onto the 2010 aerial photograph.

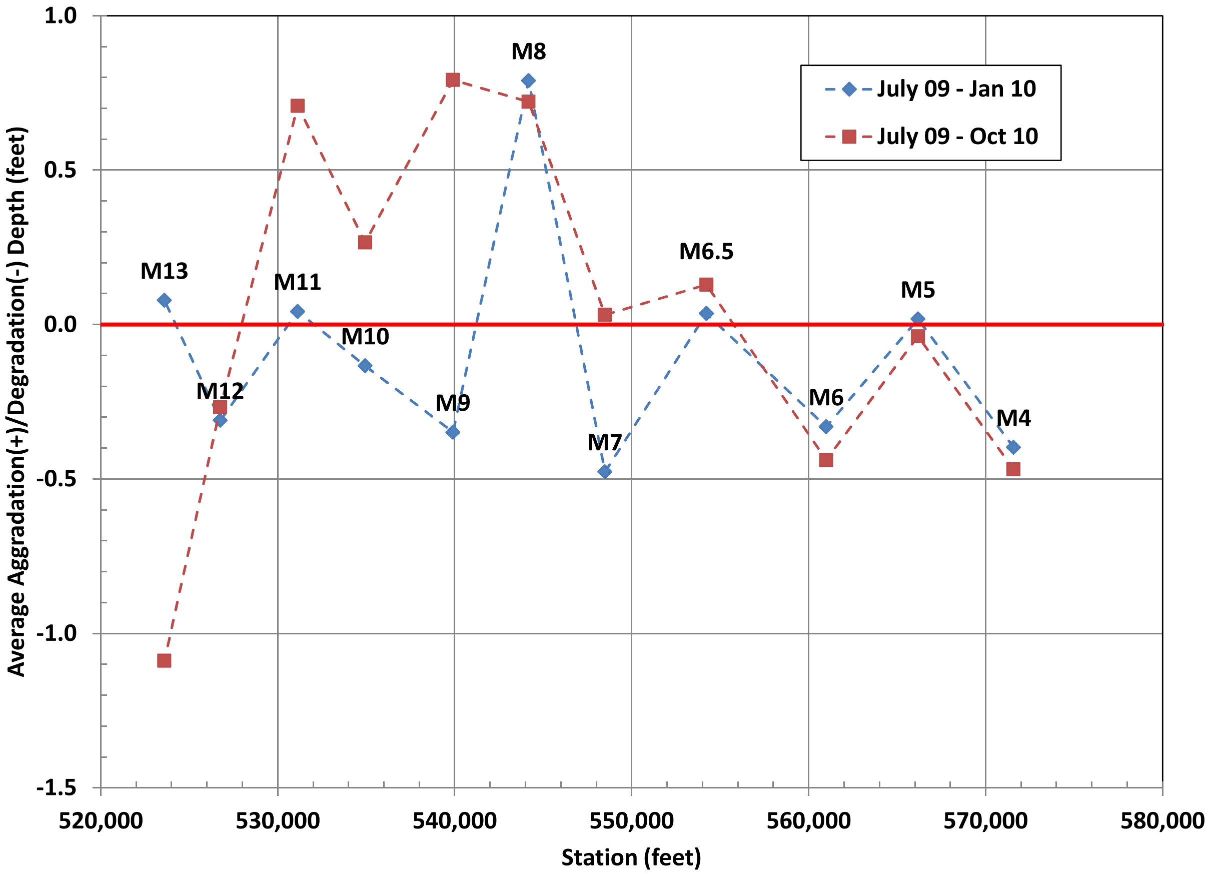

Figure 21. Average aggradation (+)/degradation (-) depth in the most active part of the channel at the patch survey sites between the July 2009 and January and October 2010 surveys.

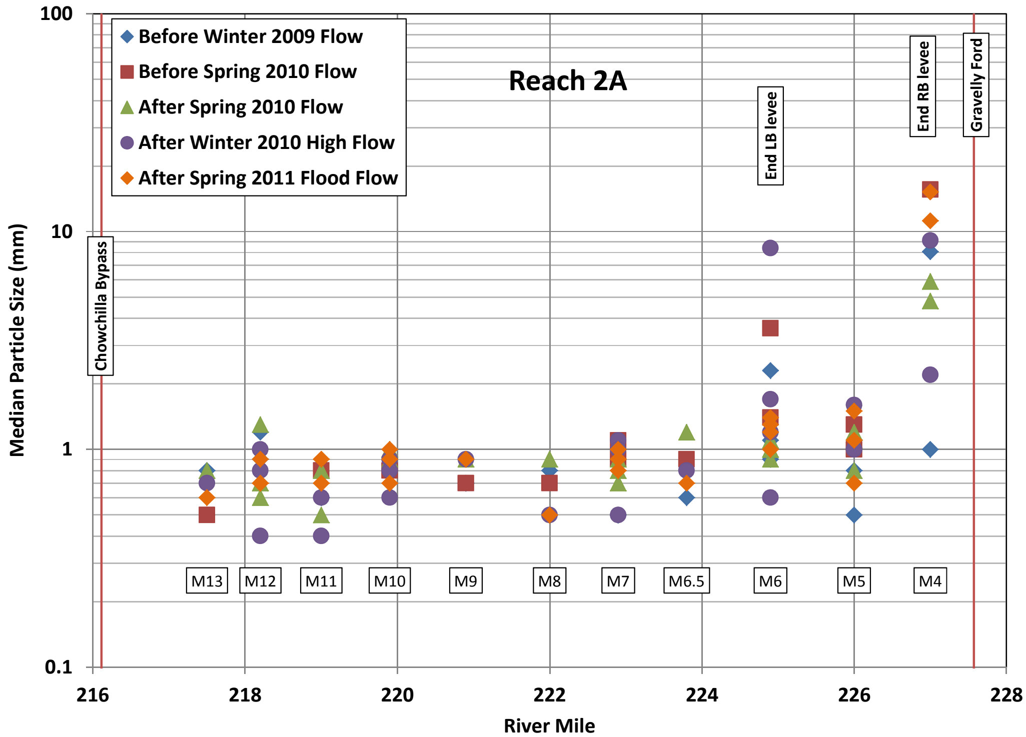

Figure 22a. Median (D_{50}) size of individual bed material samples collected by DWR in Reach 2A during the patch surveys.

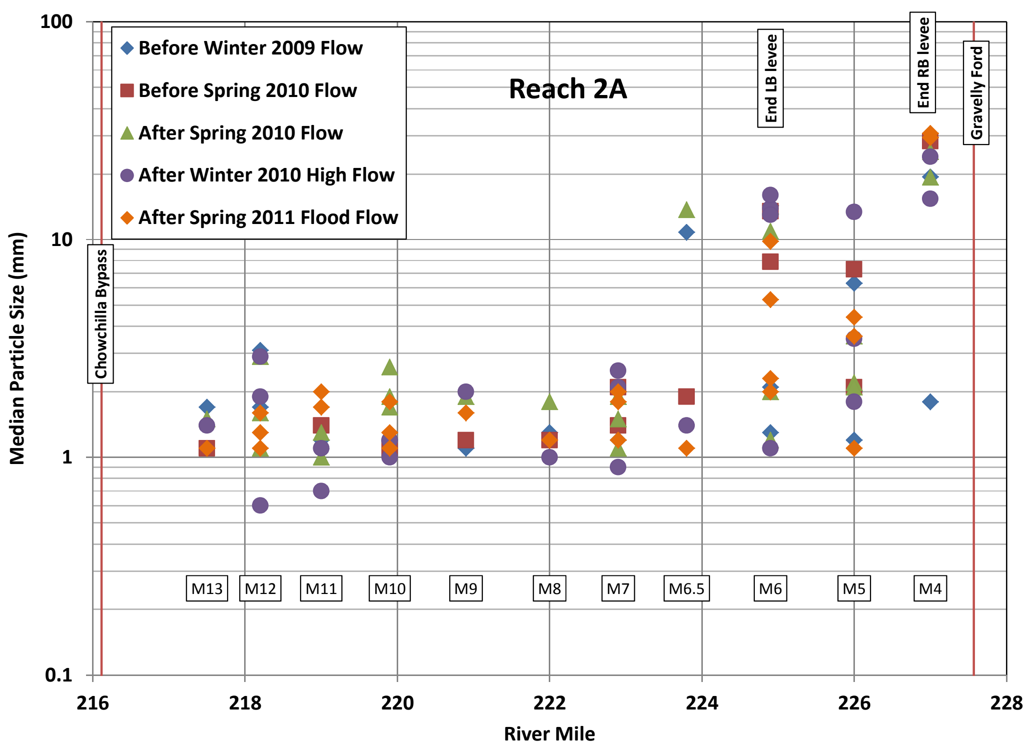

Figure 22b. D_{84} size of individual bed material samples collected by DWR in Reach 2A during the patch surveys.

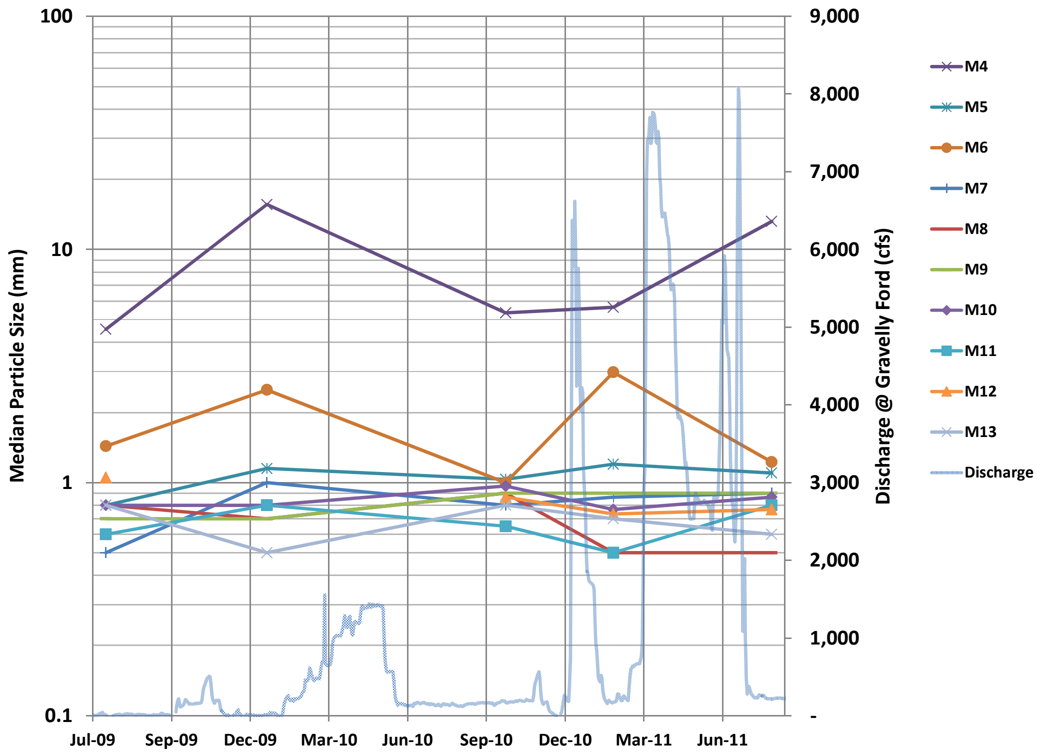

Figure 23a. Temporal changes in average median (D_{50}) size of all samples collected by DWR at each of the patch survey sites.

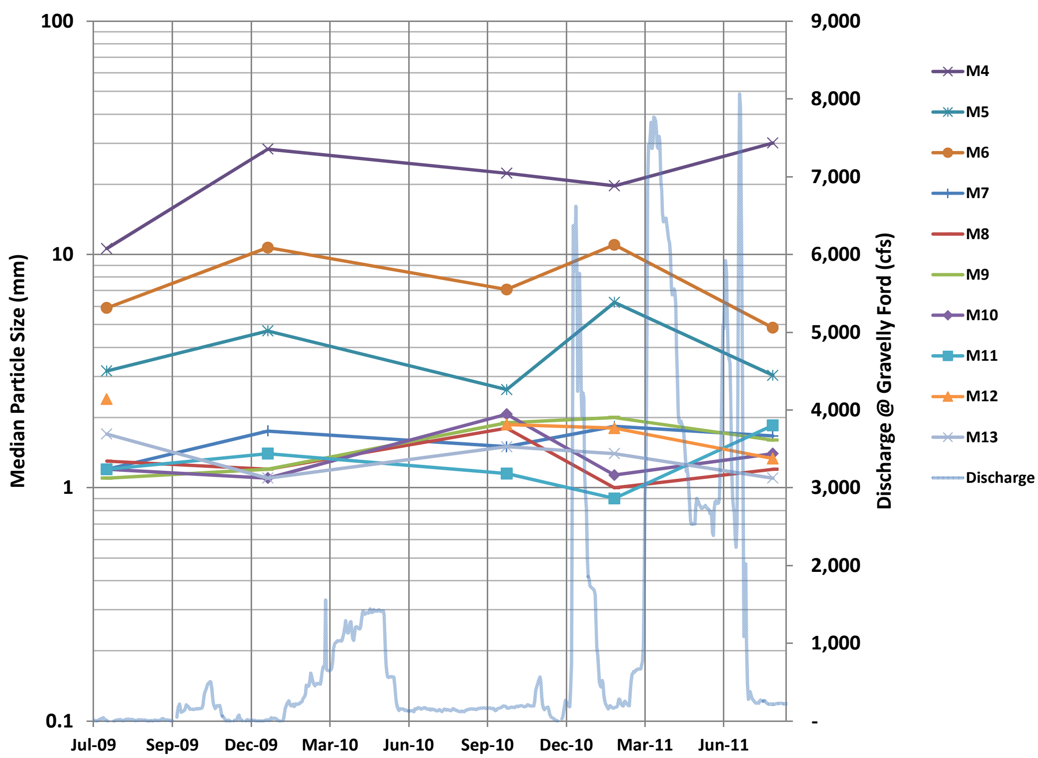

Figure 23b. Temporal changes in average D_{84} size of all samples collected by DWR at each of the patch survey sites.