Middle Truckee River
Total Maximum Daily Load (TMDL)
Bed Conditions Monitoring Report
Water Years 2014
Nevada County, California

Report prepared for:

Beth Christman

Truckee River Watershed Council

Prepared by:

Peter Kulchawik, PE

David Shaw, PG

Eric Donaldson, PG

Balance Hydrologics, Inc.

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A report prepared for:
Truckee River Watershed Council
Ms. Beth Christman
P.O. Box 8568
Truckee, California 96162
(530) 550-8760

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by

Peter Kulchawik, PE #83062
Civil Engineer/Hydrologist

David Shaw, PG #8210
Geologist/Hydrologist

Eric Donaldson, PG #9209
Geomorphologist/Hydrologist

LICENSED PROFESSIONAL ENGINEER
PETER L. KULCHAWIK
83062
EXP. 9/30/16
CIVIL
STATE OF CALIFORNIA

PROFESSIONAL GEOLOGIST
S. David Shaw
No. 8210
EXP. 8/15
STATE OF CALIFORNIA

P.O. Box 1077
Truckee, California 96160
(530) 550-9776
www.balancehydro.com

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EXECUTIVE SUMMARY

Results from the second repeat monitoring effort on bed conditions in the Middle Truckee River are presented. Baseline monitoring was completed in WY 2010, and the first repeat monitoring effort in WY 2011. During water year 2014 (WY 2014)[1], the Middle Truckee River was subjected to record low precipitation and runoff conditions, and we expect that sediment transport through this reach of the Middle Truckee River was far below average. This study, along with accompanying flow and sediment transport monitoring (Hastings and others, 2011; Hastings and others, 2012; Hastings and others, 2013; Hastings and Shaw, 2014): 1) is a continued effort to compare the effectiveness of upstream erosion control and watershed management measures in reducing fine sediment loading in the Middle Truckee River, and 2) provides comparative observations among WY 2010, WY 2011, and WY 2014.

- Bed texture changes from WY 2011 to WY 2014 were observed at each of the reaches we evaluated. There was an overall fining of the bed at nearly all locations and an increase in the reach-wide sand fraction.

- We hypothesize that three consecutive below-average precipitation and runoff years through the Middle Truckee River in WY 2012, WY 2013, and WY 2014 resulted in an increase in settling of suspended sediment from upstream sources.

- We do not expect the "very large" fraction of the bed (e.g., large cobble-boulder material) to move frequently, and also anticipate that channel and bed form is largely controlled by many of these features.

- Filling of pools was documented at the Horseshoe Bend (MTHB) and San Francisco Fly Casters (MTFC) sites, however, at Hirschdale Road (MTHR) there was an increase in pool area. It is worth noting that MTHR is downstream of the mouth of the Little Truckee River, and Boca and Stampede Reservoirs, and may be influenced by flows from the Little Truckee River and the "sediment-starved" waters released from those impoundments.

[1] Monitoring is carried out on a water year basis, from October 1 to September 30. Water year 2014 began on October 1, 2013.

- An increase in milfoil mats was documented at all sites, and is likely a result of the drought conditions of WY 2012 through 2014 creating ideal environmental conditions for milfoil expansion.

- We recommend that streamflow and sediment transport measurements be continued and that a long-term physical monitoring plan be established. Continued repeated data collection including pebble counts, sketch maps, topographic surveys, and photography, along with additional sediment transport monitoring stations being established by the Town of Truckee in WY 2013, will better identify trends in fine sediment loading and transport, and better detect the potential effects of mitigation measures taken in the basin. Annual monitoring will provide the highest-fidelity record and will facilitate a more detailed look at the effects of annual variation in the hydrology and hydraulics of the Middle Truckee River and better differentiation of annual-scale changes from long-term fine sediment reduction trends and improvement of aquatic habitat.

1. INTRODUCTION

The State Water Resources Control Board (State Board) has placed the Middle Truckee River on the Clean Water Act 303(d) list as an impaired water body where sediment and siltation affect aquatic habitat. To address this impairment, the Lahontan Regional Water Quality Control Board developed a Total Maximum Daily Load (TMDL) for suspended sediment (Middle Truckee River Sediment TMDL). The TMDL, adopted in 2008, establishes sediment load allocations for particular sub-watersheds and intervening areas, with a total sediment load allocation for the entire Middle Truckee River Watershed of 40,300 tons per year. The TMDL consists of a number of indicators and target values for each indicator. The only *direct* indicator is suspended sediment concentration in the Middle Truckee River, with a target of less than or equal to 25 milligrams per liter (mg/L) as an annual 90^{th} percentile value measured at Farad (USGS Station 10346000). This target was established based on a review of scientific literature, analysis of suspended-sediment measurements taken in the Truckee River over a 30-year period, and continuous monitoring of turbidity during water years 2002 and 2003. Additional *indirect* indicators include implementation and maintenance of best management practices (BMPs) for road sand application and on ski runs, and restoration activities such as decommissioning of dirt roads and repair of legacy sites.

The Truckee River Watershed Council (TRWC) asked Balance Hydrologics (Balance) to evaluate fine sediment loadings to the Middle Truckee River to support implementation of the TMDL. Multiple lines of evidence were developed using a combination of sediment and bed conditions monitoring. In 2010 Balance established baseline conditions, and in 2011 implemented the first repeat monitoring effort. No monitoring was conducted in 2012 or 2013. This report is dedicated to presenting, comparing, and contrasting bed conditions in the fall of 2011 and 2014 at three sites on the Middle Truckee River where we repeated detailed bed conditions surveys for a second time. A location map that includes all pertinent water bodies and the sampling sites is included as Figure 1.

This document is a companion document to the streamflow and sediment gaging reports (Hastings and others, 2011; Hastings and others, 2012; Hastings and others, 2013; Hastings and Shaw, 2014) which summarize annual suspended-sediment loading on tributaries previously identified by Amorfini and Holden (2008) and McGraw and others (2001) as significant sources of elevated sediment loads to the Middle Truckee River. Additionally, work completed by Herbst and others (2013) demonstrated a clear impact of fine sediment deposits on benthic macroinvertebrate communities. The surveys completed in support of the study also indicated that excess sediment deposition may be fairly widespread throughout the Truckee River. To help gain an understanding of the extent of sediment deposition and evaluate changes in bed conditions over time, we felt that repeating the bed surveys would be valuable.

The study is intended to supplement, not supplant, monitoring being undertaken as part of the Truckee River Water Quality Monitoring Plan developed by the Town of Truckee and Placer County, both to comply with the TMDL for sediment and as a component of their respective Stormwater Management Programs under the Phase 2 NPDES Municipal Storm Water (Small MS4) Permit. Funding for this study is provided by the State of California, Department of Water Resources (DWR) through Proposition 50.

2. METHODS

2.1 Channel Conditions, Reconnaissance Streamwalks and Site Selection

During 2010, Balance staff conducted initial reconnaissance streamwalks of upper Trout Creek in the vicinity of the Tahoe Donner subdivision, and Alder Creek between Tahoe Donner and Highway 89, in order to: a) identify suitable locations and methods (i.e. pebble counts vs. V-star) for establishment of streambed monitoring stations; and b) document locations of fine sediment deposits and sources. We also conducted a 2-day, reconnaissance-level survey of the lower Middle Truckee River main stem between Martis Creek and Farad. During the stream reconnaissance, we made qualitative observations regarding channel condition and form, inferred sediment sources and input locations. Observation and photo locations were established using a hand-held Garmin 60CSx GPS receiver, as appended to the 2012 monitoring report (Donaldson and Shaw, 2012).

Based on conditions observed during the streamwalks, we concluded that Alder and Trout Creeks are not suitable to develop representative and repeatable bed condition analyses. The high variability in bed and sedimentation conditions within these two stream systems precludes the selection of sites which would adequately reflect long-term changes in the watershed. The influence of localized land uses and infrastructure appears to limit the representativeness of most potential monitoring locations. However, the reconnaissance did provide an opportunity to document sediment sources along these channels and establish baseline conditions for future comparison.

Three representative sites on the Middle Truckee River main stem were selected for bed condition surveys:

1) Downstream from Donner Creek and Trout Creek, between Martis and Prosser Creeks (Middle Truckee River at the San Francisco Fly Casting Club; station ID MTFC);
2) Between Prosser Creek and the Little Truckee River (Middle Truckee River at Horseshoe Bend; station ID MTHB); and
3) Below the Little Truckee River (Middle Truckee River at Hirschdale Road; station ID MTHR).

Each reach includes 3 sampled segments: a pool, a glide (or 'run'), and a riffle. The proportion of the bed covered by fine sediment was quantified using modified Wolman pebble counts in tandem with detailed geomorphic sketch maps showing channel facies, photo points, and survey monumentation to provide for year-to-year repeatability and comparison.

2.2 Sampling Procedures: Bed Conditions Surveys

Detailed sampling protocols are described in the project sampling and analysis plan (SAP), as provided to the TRWC and summarized below. The bed condition surveys were conducted in late summer when streamflow was at or near the lowest level for the year. Each bed-monitoring site consists of one contiguous pool-riffle-glide sequence. Individual pebble counts were conducted for each feature in the unit for a total three (3) pebble counts per monitoring site, with the exception of the MTFC site, where we added a fourth pebble count in the boulder riffle. Each random sub-sample was collected in a grid format to facilitate an even sample distribution across the bed and provide a solid spatial basis for year-to-year comparisons.

2.3 Sketch Maps

During the 2010, 2011, and 2014 bed conditions surveys, Balance staff drew detailed sketch maps to: 1) generate baseline conditions maps for future work, and 2) compare changes in bed conditions, if any, between years. The maps, which are designed to capture stream unit to reach-scale (e.g., a temporal shift from sand bar to gravel-cobble), include documentation of general bed texture, prominent features and boulders, vegetation, and approximate transitions between geomorphic units (i.e. riffles, pools and glides). During 2014, the 2010 and 2011 sketch maps were taken into the field and used to reference possible changes to the bed morphology. We then digitized the maps to facilitate future comparisons.

2.4 Modified Wolman Pebble Counts

The particle-size distribution of the bed surface material was quantified as part of the bed census, which also results in measurements of cobble abundance and the percentage of fine sediment on the bed. The protocol we implemented was modified from Wolman (1954) as described below.

1. Stretch a single measuring tape along the bank for use in defining a grid over the entire active bed area of each morphological unit, where “active bed area” is defined as the parts of the pool, glide or riffle which are submerged at typical summer flow levels. The limits—as defined by the stationing on the measuring tape—of each morphological unit may not necessarily be the same as in previous monitoring years. Upstream and downstream stationing of morphological units may be adjusted if the observer feels they have migrated since the previous monitoring effort.

2. The goal is to collect a stratified random sample of 80 to 150 points. Since transect lengths will vary with each segment, the next step is to calculate the interval length between sampling points needed to collect the necessary number of samples.

3. Walking alongside a tape, when reaching the pre-selected sampling point, collect a sample by reaching into the water with eyes averted and retrieving the first particle touched on the channel bed. Using a ruler, the sample is measured along its intermediate axis and classified as fine sediment (< 4 mm), coarse sediment (gravel, cobble, boulder), bedrock, large organic debris (sizeable enough to provide local habitat value, or anthropogenic in origin (construction materials, trash).

4. The sizes of all coarse particles are measured along their intermediate axis. Following the widespread adaptation of the standard Wolman (1954) criteria, each particle is classified within standard metric size categories which vary as the square root of 2 (e.g., 4 mm to 5.6 mm, 5.6 mm to 8 mm, 8 mm to 11.3 mm, 11.3 mm to 16 mm, and so on up to large boulder sizes). Results may be expressed either as a frequency distribution or by the equivalent size of specified percentiles: the 16^{th}, 50^{th} and 84^{th} percentiles (D-16, D-50, D-84) are most commonly used in stream habitat analysis.

5. Careful quality control is needed to optimize the quality of particle size data and minimize variance in estimates collected by different observers. New observers are trained by experienced staff and their performance is monitored in the field as data collection proceeds in order to confirm that sampling occurs at the correct interval and that particle size is measured along the intermediate axis.

6. The percent of the bed covered by fine sediment is the percent of sampling points within the pool, glide or riffle at which fine material was encountered during the bed census when measuring directly below the sampling point.

2.5 Cross Section Surveys

Cross sections were surveyed with an auto-level or total station, recording points at significant grade breaks within the channel and along the banks. All bed elevations were recorded to the nearest 0.01-foot. Sequential repeated surveys recorded pool fill and scour. Surveys were conducted in general accordance with the methods described by Harrelson and others (1994). Cross sections within each reach were correlated to the same arbitrary vertical datum, and cross section endpoints were established using rebar placed during baseline monitoring. In WY 2014, several of the rebar monuments were not recovered, and are presumed to have been removed by humans. However, for all cross sections at least one of the two rebar monuments was recovered allowing elevations to be reliably compared to previous years. In instances where rebar was missing, the cross section endpoint was estimated from sketch maps and photo documentation from previous years.

2.6 Photography

Photo points were added to the monitoring program during the 2011 surveys to provide a baseline for repeatable comparisons during future monitoring efforts. Photo points were established at or near the cross section locations or, in the case of the MTHR site, at locations where erosion and sedimentation may occur in the future. Photo points were repeated during the 2014 surveys. This report assumes that the reader has available the baseline bed conditions monitoring report (Donaldson and Shaw, 2012) to compare photos from 2011.

3. RESULTS

3.1 Hydrology

To provide context for the results of our bed conditions monitoring, we briefly summarize snowpack and annual streamflow conditions in the Middle Truckee River for water years 2012, 2013, and 2014. In Figure 2 we present the snow-water equivalent precipitation values as measured at the Central Sierra Snow Lab in Soda Springs, California for both years, and in Figure 3 we present daily mean flow at the USGS Truckee River gage near Truckee California (USGS 10338000). The Truckee River near Truckee gage is located downstream of Lake Tahoe and upstream from the Donner Creek, Trout Creek, Prosser Creek, and Little Truckee River tributaries. Donner Lake, Prosser Creek Reservoir, and Boca Reservoir are managed reservoirs and downstream releases vary.

Water year 2012 was characterized by below-average snowpack and streamflow conditions. The snowpack at the Central Sierra Snow Laboratory (CSSL) held well below-average water content into the late winter (Figure 2), until a series of early spring storms delivered more than half of the year's snowpack. Warm spring temperatures melted the snow quickly; the maximum daily mean flow of 819 cubic feet per second (cfs) in the Truckee River occurred on April 27, 2012, and by early May the snowpack at CSSL was zero. The peak instantaneous stream flow was 1,140 cfs on January 21, 2012.

Water year 2013 began as slightly above average with a large early December storm, however throughout the winter months there was nearly zero precipitation. The net result was another well below-average snowpack and streamflow year. The snowpack at CSSL was zero by mid-April. The peak streamflow in the Middle Truckee River was a response to the early December storm; both the maximum daily mean and maximum instantaneous streamflow occurred on December 2, 2012, and were 976 and 1,810 cfs, respectively. Thereafter the daily mean streamflow did not exceed 400 cfs.

Water year 2014 was characterized by record low snowpack and streamflow conditions, and marked the third consecutive below-average precipitation year. Consistently warm temperatures and low precipitation amounts resulted in the snow water equivalent being less than one third of the long-term average for the entire water year. The snowpack at CSSP was zero by May 1, 2014. Both the maximum daily mean and maximum instantaneous streamflow in the Middle Truckee River occurred on February 9, 2014, and were 613 and 724 cfs, respectively.

3.2 Reconnaissance

Geomorphic reconnaissance stream walks were conducted in August 2010 on Alder Creek, Trout Creek, and the Truckee River. Repeat reconnaissance was not conducted, but we have included a summary of the Truckee River reconnaissance herein because it explains the rationale for bed condition monitoring site selection.

3.2.1 Truckee River

Channel reconnaissance on the Truckee River took place during August 2010, focused on the Truckee Canyon reach from Glenshire Drive to Floriston, and was conducted via kayak during releases from Prosser and Boca Reservoirs. This reach is largely confined within the youngest glacial outwash features, including large boulders that are rarely transported by modern flows. These boulder riffles are interpreted to be remnants of Pleistocene glacial outburst floods ('jokulhlaups' of Birkeland, 1964) and are considered to be immobile at nearly all modern flood flows. The boulder riffles are separated by lower-gradient gravel and cobble reaches that exhibit a more dynamic riffle-and-pool morphology. Channel migration throughout much of this section is limited by both glacial deposits and infrastructure, such as the Union Pacific Railroad and I-80 crossings. The railroad maintenance roads and embankments do not appear to be maintained for sediment and erosion control; in many places, the railroad is essentially built within the channel, with dry ravel and exposed sediment readily available for transport and deposition.

The gravel-cobble reaches appear to be more dynamic than the boulder riffles and follow a somewhat predictable form (i.e. riffle-pool-glide), so these reaches should be more comparable to each other, and should also respond more readily to changes in land use and watershed management. For these reasons, we targeted these more mobile and dynamic reaches for bed conditions surveys.

3.3 Bed Conditions Surveys

Bed condition survey results are presented below for each of the three reaches surveyed on the Middle Truckee River reaches. For each reach, we discuss the geomorphic maps developed in 2010, 2011, and 2014 and any changes in channel and bed conditions we inferred during development and review of those maps. We then outline bed material grain-size distributions as statistical values developed from pebble count data and percent of bed cover by fines. Finally, for each reach, we provide plots of cross section data and photos.

3.3.1 San Francisco Fly Casting Club (MTFC)

Fieldwork was conducted at the MTFC reach on October 7, 2014 at a streamflow of approximately 55 cfs, and on October 16, 2014 at a flow of approximately 53 cfs—considerably lower than the flows during WY2010 and WY2011 surveys.

3.3.1.1 Sketch map

Figure 4 presents the sketch map of the boulder riffle-pool-glide-gravel riffle sequence at the MTFC reach, annotated to highlight observed geomorphic changes. Downstream, the mapped reach transitions to a deep forced pool in a left bend.

Generally we observed very little change within the MTFC reach between 2010 and 2011, but did observe change between 2011 and 2014. Some of this observed change may be attributed to differences in water levels; however, we observed areas of the bed that had become finer, most notably on the right side of the channel from station 200 to station 320. Sand and silt was mapped in this area where cobble and boulders had previously been mapped. Similarly, the riffle has expanded roughly 80 feet into the downstream pool, likely a result of both lower water levels as well as deposition of fines in the upstream end of the deep forced pool. We also observed expanded areas of vegetated mats in the riffle, that were first noted in 2011.

3.3.1.2 Pebble Counts

Tables 1, 2, and 3 present the results of the pebble counts for the 2010, 2011, and 2014 site visits, respectively. In comparing the particle-size measurements across years, we observe four main trends: 1) The pool and glide appear to have become finer; 2) The riffle and boulder riffle appear to have not changed substantially; 3) The percent of the streambed covered by fines (sand-size and finer) at the pool, riffle, and boulder riffle appear to have increased; and 4) The percent of the streambed covered by fines at the glide appears to have decreased slightly, however, the magnitude of the decrease is within the measurement error.

3.3.1.3 Cross section surveys

Cross section survey locations are shown in Figures 5 to 8. Cross section 1, at station 162 feet, crosses the upstream pool unit (Figure 5). Cross section 2, at station 234 feet, crosses the pool-glide transition unit (Figure 6). Cross section 3, at station 324 feet, crosses the glide-riffle transition unit (Figure 7). Cross section 4, at station 451 feet, crosses the downstream riffle-pool unit (Figure 8).

Most differences between WY 2011 and WY 2014 cross sections can be attributed to differences in point locations and interpolation between points. A small amount of aggradation (roughly 0.25 ft) was detected in Cross section 2, the pool at the bottom of the boulder riffle. Small shifts in the channel bed can be discerned in Cross section 3 (glide) and Cross section 4 (riffle) in areas corresponding to those where geomorphic mapping indicated change. The bed material in these sections is dominated by loose, coarse gravel, and it is plausible—even in below-average hydrologic years—that the bed shifted slightly.

3.3.1.4 Photo-Documentation

Figure 9 presents four photos of the MTFC study reach. Every attempt was made to duplicate the field of view to facilitate comparison with WY 2011 (baseline) photos, although a decision was made to shift the photo points for Cross sections 3 and 4 to increase the focus on the active channel. Most noticeable differences between WY 2011 and WY 2014 photos arise from the different river levels during monitoring (e.g. more boulders are visible in WY 2014 photos because the stage was lower).

3.3.2 Horseshoe Bend (MTHB)

Fieldwork was conducted at the MTHB reach on October 1 and 2, 2014 at a streamflow of approximately 63 cfs.

3.3.2.1 Sketch map

Figure 10 presents the sketch map of the riffle-pool-glide sequence at the MTHB reach, annotated to highlight observed geomorphic changes. The upstream riffle on the sketch map was not included in the pebble count, and may be under the influence of hydraulic conditions associated with the I-80 Bridge. As with the other reaches surveyed, very large boulders are considered to be immobile at all but the highest flows.

Generally, we observed little to no change from 2010 to 2011 in the location and extent of channel facies along most of the Horseshoe Bend reach, but a number of changes were noted in 2014, largely associated with lower water levels. For example, the left bank channel margin has become exposed, such that a nearly continuous sand, silt, and gravel bar extended throughout the reach. The formerly flooded bar at the upstream end of the reach was exposed during the

2014 survey. Coverage by aquatic vegetation appears to have changed, with increases in the right bank channel margin and decreases in the left bank channel margin, and as in previous years, small mounds or bars of sand and gravel were trapped in the lee of aquatic vegetation mats. Decreases in pool depth and area were observed, and appear to be associated with filling by sand and silt. As observed at Station MTFC, thin layers of silt were observed in areas of slow-moving water, covering gravel and cobble. Overall, the bed, banks, and riparian vegetation through this reach appear to have remained fairly stable through the sustained high flows of 2011 and peak flow of the monitoring period on December 2, 2012.

3.3.2.2 Pebble counts

Tables 1, 2, and 3 present the results of the pebble counts for the 2010, 2011, and 2014 site visits, respectively. In comparing the particle-size measurements across years, we observe four main trends: 1) The amount of organics (mid-channel vegetation mats and milfoil patches along the channel margins) increased at all units; 2) The average size of the fine, medium, and coarse fraction decreased at all units since 2011; 3) The grain size distribution of the riffle bed decreased since 2011; and 4) The fine fraction (the percent of the bed covered by sand and finer material) universally increased since 2011; the percent of fines in the pool increased by an order of magnitude, in the glide by 50 percent, and in the riffle by a factor of 3.

3.3.2.3 Cross sections

Cross section locations are shown on Figures 11 to 14. Cross section 1, at Station 55 feet, is located in the upstream riffle unit (Figure 11). Cross section 2, at Station 402 feet, crosses the glide unit (Figure 12). Cross section 3, at station 667 feet, crosses the glide-riffle transition unit (Figure 13). Cross section 4, at station 667 feet crosses the downstream riffle unit (Figure 14).

Most differences between WY 2011 and WY 2014 cross sections can be attributed to differences in point locations and interpolation between points. One notable difference was the decrease in the top of the gravel bar elevation (roughly 0.25 feet lower than in WY 2011) on the right bank of Cross section 4 (Figure 14). Data points for the left half of Cross section 4 were collected, but are not shown in the results due to user error that could not be reliably corrected.

3.3.2.4 Photo-documentation

Figure 15 presents four photos of the MTHB study reach. Every attempt was made to duplicate the field of view to facilitate comparison with WY 2011 (baseline) photos. Most noticeable differences between WY 2011 and WY 2014 photos arise from the different river levels during monitoring (e.g. more boulders are visible in WY 2014 photos because the stage was lower).

3.3.3 Hirschdale Road Bridge (MTHR)

Fieldwork was conducted at the MTHR reach October 9, 2014 at a streamflow of approximately 64 cfs.

3.3.3.1 *Sketch map*

Figure 16 presents the sketch map of the riffle-pool-glide sequence at the MTHR reach, annotated to highlight observed geomorphic changes. As with the other reaches surveyed, very large material is considered to be immobile at all but the highest flows.

Generally, we observed more macro-scale changes in morphology at MTHR than at the MTFC and MTHB sites. We observed a newly-formed pool within the upstream riffle that was not present in previous years, and the material on the left bank bar adjacent to the riffle appears to have become finer. The extent of aquatic vegetation on the left bank appears to have increased. Finally, he submerged medial bar noted in previous years between stations 70 and 115 was not present in 2014. Overall, the banks and higher terraces have remained stable.

3.3.3.2 *Pebble counts*

Tables 1, 2, and 3 present the results of the pebble counts for the 2010, 2011, and 2014 site visits, respectively. In all years, the pool was too deep to collect grain size data using a modified Wolman count, and data were only collected at the riffle and glide units. In comparing the particle-size measurements across years, we observe four main trends: 1) The glide unit generally became finer with the largest decrease in the average size of the fine fraction; 2) There was a significant increase in the amount of organics in the glide, apparently associated with the increase in aquatic vegetation; 3) Since 2011, the average size of all size fractions in the riffle was relatively unchanged; and 4) Since 2011, the fine fraction (sand-size and finer) in the glide was 20 times higher in WY 2014 than in WY 2011, and in the riffle was 5 times higher.

3.3.3.3 *Cross sections*

Cross section locations are shown in Figures 17 to 19. Cross section 1, at station 499 feet, is located in the riffle unit (Figure 17). Cross section 2, at station 130 feet, crosses the pool-glide transition (Figure 18). Cross section 3, at station 50 feet, crosses the glide unit (Figure 19).

Most differences between WY 2011 and WY 2014 cross sections can be attributed to differences in point locations and interpolation between points. Very little change was detected at MTHR from the repeat cross section surveys. The only exception is the left toe of bank on Cross section 3 that appears to have laterally incised by roughly three feet. The large wood debris located just downstream from Cross section 3 on the left bank appeared to have shifted slightly since WY 2011, and it is plausible that its new position is related to minor change in channel shape.

3.3.3.4 Photo-documentation

Figure 20 presents three photos of the MTHR study reach. Different photo points were established for Cross sections 1 and 2 because we felt the photo points selected for baseline monitoring could be improved upon by increasing the focus on the active channel. No photo point was established during baseline monitoring for Cross section 3; the WY 2014 photo clearly shows multiple patches of milfoil, deposits of fine sediment on the bed, and large wood debris on the left bank.

4. DISCUSSION

4.1 Hydrology

This study, together with flow and sediment transport monitoring reported separately (Hastings and Shaw, 2011; Hastings and Shaw, 2012; Hastings and Shaw, 2013; Hastings and Shaw, 2014), serves: a) to provide comparisons of changes in bed conditions since WY 2011 at several representative reaches; and b) as a predictive tool on what channel changes should be anticipated in the absence of flushing flows.

The three years since the previous monitoring effort in WY 2011 are characterized by below-average precipitation and snowpack in the Middle Truckee River watershed. Consequently, total flow in the Middle Truckee River was also below average, although the peak flow of the monitoring period did occur on December 2, 2012. The most important components of the annual hydrograph with respect to the observed changes in bed conditions are the magnitude and duration of peak flows. Together, the magnitude and duration of annual high flows have direct implications on the quantity and size of sediment transported and deposited within channel reaches. While the magnitudes of the annual peak in water years 2013 exceeded those in water years 2010 and 2011 (an average and above-average hydrologic year, respectively) the snowpack was not substantial enough to drive a prolonged high flow. Annual peaks in water years 2012, 2013, and 2014 were relatively flashy for a snowmelt dominated system, and did not last for more than a few days. For context, flow in the Middle Truckee was greater than 500 cfs for eight consecutive days in WY 2010, and for an entire month in WY 2011. Water years 2012, 2013, and 2014 *combined* had only nine days over 500 cfs.

A number of significant summer thunderstorms occurred during this period, several of which are known to have mobilized sediment from undammed tributaries such as Cold Creek and Squaw Creek. These high-intensity rainfall events have been documented to produce sediment at higher rates than more widespread winter storms, without producing significant runoff and streamflow increases in the Truckee River.

4.2 Pebble Counts

Figure 21 summarizes the percentage of fines on the bed for each unit within each reach. Because no bed monitoring was conducted during WY 2012 or WY 2013 we can only analyze the data as the cumulative change resulting from three consecutive dry years, and cannot draw conclusions on the incremental effects of each individual year.

Based on the pebble count data, there was a universal increase—with the exception of the glide in MTFC which was relatively static—in the amount sand and silt on the bed since 2011. The magnitude of increases ranged from 150% to over 2,000% of WY 2011 values. We hypothesize that the marked increases is the cumulative result of three consecutive dry years, and such increases would not be expected on an incremental-year basis. We surmise two primary mechanisms caused the change in bed composition: 1) lack of sustained, high magnitude flows competent of flushing fine sediment through the system, and 2) prolonged duration of very low flows leading to increase deposition of suspended sediment generated during high-intensity rain-on-ground events. The Town of Truckee has monitored and compared suspended sediment transport rates upstream and downstream of the Town of Truckee. Data from this program indicate that suspended sediment loading generally increases as the Truckee River flows through town, but occasionally the trend is reversed for short periods during these flashy events, suggesting that material carried in suspension is deposited on the channel bed.

These findings are consistent with Herbst and others (2013) who quantified "patch-scale" coverage of fine sediment in the Middle Truckee River, and drew linkages to shifts in the number, size, and species of benthic macroinvertebrates. They found that more than 50 percent of sampling sites downstream of Truckee had greater than 80 percent fine sediment coverage, the threshold for severe biological impairment. Although this study quantified changes in bed composition through different methods, it supports conclusions by Herbst and others (2013) that there is excessive and increasing amounts of fine sediment in the Middle Truckee River which has direct implications on the food web.

There was a significant increase in the amount of organic material detected by pebble counts during WY 2014 monitoring. Organic material was mostly mid-channel vegetation mats, milfoil along the channel fringes, and to a lesser degree, deposits of woody debris along the banks. The increase in milfoil is likely related to the drought conditions of the past three years, as sedimentation, warmer temperatures, and slower water velocities are ideal physical conditions for milfoil expansion (Smith and Barko, 1990).

4.3 Sketch Maps

The Middle Truckee River has a history of repeated glaciation, most recently in the late Pleistocene. Glaciers moved large amounts of material from surrounding peaks to the valleys where it was deposited as till and glacial outwash. Consequently, there is an ample supply of large cobble-boulder material through these reaches that was deposited under much higher flow conditions. We do not expect this "very large" fraction of the bed to move frequently, and also anticipate that the river is largely controlled by many of these features. As a result, most of the change shown on geomorphic maps between 2011 and 2014 is associated with features comprised of cobble-and-smaller material.

Filling of pools was documented at the Horseshoe Bend (MTHB) and San Francisco Fly Casters (MTFC) sites, however, at Hirschdale Road (MTHR) there was an increase in pool area. MTHR is downstream of the mouth of the Little Truckee River, and Boca and Stampede Reservoirs, and may be influenced by flows from the Little Truckee River and the "sediment-starved" waters released from those impoundments.

Increases in milfoil mats were mapped at all sites during the 2014 site visits. These features have the potential to alter local hydraulics, thereby inducing sedimentation within the mat and immediately downstream. Deposits of fine sediment were also mapped at all sites in 2014; since milfoil grows best on fine sediment, these locations, along with the existing mats, should be monitored to see if the milfoil patches persist or increase.

5. CONCLUSIONS AND RECOMMENDATIONS

We recommend that streamflow and sediment transport measurements be continued and that a long-term physical monitoring plan be established. Continued repeated data collection including pebble counts, sketch maps, topographic surveys, and photography will better identify trends in fine sediment loading and transport, and better detect the potential effects of mitigation measures taken in the basin. Annual monitoring will provide the highest fidelity record, and facilitate a more detailed evaluation of the effects of annual variation in the hydrology and hydraulics of the Middle Truckee River and better differentiation of annual-scale changes from long-term fine sediment reduction trends and improvement of aquatic habitat.

6. REFERENCES

Amorfini, B. and Holden, A., 2008, Total Maximum Daily Load for Sediment, Middle Truckee River Watershed, Placer, Nevada, and Sierra Counties, Includes Gray and Bronco Creeks, California Regional Water Quality Control Board, Lahontan Region staff report, 5 chapters + appendices.

Birkeland, P.W., 1964, Pleistocene glaciation of the northern Sierra Nevada, north of Lake Tahoe, California, The Journal of Geology, v. 72 n. 6, p. 810-825.

Donaldson, E. and Shaw, D., 2012, Middle Truckee River total maximum daily load (TMDL) bed conditions monitoring report water years 2010 and 2011 Nevada County, California. 21 p. + figures.

Harrelson, C. C., Rawlins, C.L., Potyondy, J. P., 1994, Stream channel reference sites: an illustrated guide to field technique. Gen Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61p.

Hastings, B. K., Shaw, D., Owens, J., and Strasenburgh, C., 2011, Middle Truckee River total maximum daily load (TMDL) suspended sediment monitoring report, water year 2012, Nevada County, California. 38 p. + figures and appendices.

Hastings, B. K., Shaw, D., Owens, J., and Strasenburgh, C., 2012, Middle Truckee River total maximum daily load (TMDL) suspended sediment monitoring report, water year 2012, Nevada County, California. 38 p. + figures and appendices.

Hastings, B. K., Shaw, D., and Strasenburgh, C., 2013, Middle Truckee River total maximum daily load (TMDL) suspended sediment monitoring report, water year 2013, Nevada County, California. 37 p. + figures and appendices.

Hastings, B. K., and Shaw, D., 2014, (draft), Middle Truckee River total maximum daily load (TMDL) suspended sediment monitoring report, water year 2014, Nevada County, California. 36 p. + figures and appendices.

Herbst, D.B., Medhurst, R.B., and Bell, I.D., 2013, Benthic macroinvertebrate responses to sediment deposition as criteria for evaluating and monitoring the extent of habitat degradation on the Middle Truckee River, California, 28 p.

McGraw, D., McKay, A., Guohong, D., Bullard, T., Minor, T., and Kuchnicki, J., 2001, Water Quality Assessment and Modeling of the California Portion of the Truckee River Basin, Desert Research Institute Publication No. 41170 prepared for the Town of Truckee and Lahontan Regional Water Quality Control Board, 120 p. + appendices.

Smith, C.S. and Barko J.W., 1990, Ecology of Eurasion Watermilfoil, Journal of Aquatic Plant Management, v. 28, p. 55-64.

Wolman, M.G., 1954, A method of sampling coarse river-bed material: Transactions, American Geophysical Union, v. 35, p. 951-956

TABLES

Table 1. Summary of particle-size measurements for 2010.

Stream	Site	Water Year [2]	Sample Size	Proportion of bed area occupied by: Cobbles (>45mm)	Sand (<4mm)	Bedrock	Organics	Artifacts	D-size [1]: D-16	D-50	D-84
Middle Truckee River	MTFC Pool	2010	127	0.62	0.21	0.00	0.02	0.00	36.0	142.0	581.8
	MTFC Glide	2010	120	0.41	0.26	0.00	0.01	0.00	16.0	52.3	136.4
	MTFC Riffle	2010	131	0.18	0.18	0.00	0.02	0.00	12.1	28.5	51.5
	MTFC All			**0.40**	**0.22**	**0.00**	**0.02**	**0.00**	**21.4**	**74.3**	**256.6**
	MTHB Pool	2010	140	0.22	0.02	0.00	0.04	0.00	16.6	31.0	66.9
	MTHB Glide	2010	63	0.27	0.25	0.00	0.00	0.00	14.1	26.9	103.5
	MTHB Riffle	2010	105	0.68	0.08	0.00	0.02	0.00	30.8	79.2	154.9
	MTHB All			**0.39**	**0.12**	**0.00**	**0.02**	**0.00**	**20.5**	**45.7**	**108.4**
	MTHR Pool	2010	--	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	MTHR Glide	2010	103	0.25	0.02	0.00	0.08	0.00	17.0	35.9	78.5
	MTHR Riffle	2010	109	0.66	0.19	0.00	0.00	0.00	35.1	130.8	310.8
	MTHR All			**0.46**	**0.11**	**0.00**	**0.04**	**0.00**	**26.1**	**83.4**	**194.7**
		Mean for pools		*0.42*	*0.12*	*0.00*	*0.03*	*0.00*	***26.28***	***86.52***	***324.35***
		Mean for glides		*0.31*	*0.18*	*0.00*	*0.03*	*0.00*	***15.70***	***38.37***	***106.13***
		Mean for riffles		*0.50*	*0.15*	*0.00*	*0.01*	*0.00*	***26.01***	***79.49***	***172.41***

Table 2. Summary of particle-size measurements for 2011.

Stream	Site	Water Year [2]	Sample Size	Proportion of bed area occupied by: Cobbles (>45mm)	Sand (<4mm)	Bedrock	Organics	Artifacts	D-size [1]: D-16	D-50	D-84
Middle Truckee River	MTFC Pool	2011	97	0.75	0.09	0.00	0.00	0.00	41.8	190.2	636.7
	MTFC Glide	2011	115	0.38	0.13	0.00	0.01	0.00	10.8	40.5	129.2
	MTFC Riffle	2011	101	0.15	0.07	0.00	0.04	0.00	16.4	30.6	46.0
	MTFC Boulder Riffle [3]	2011	97	0.81	0.03	0.00	0.00	0.00	45.4	133.7	331.6
	MTFC All [4]	----		**0.43**	**0.10**	**0.00**	**0.02**	**0.00**	**23.0**	**87.1**	**270.7**
	MTHB Pool	2011	100	0.29	0.01	0.00	0.00	0.00	11.3	31.8	59.2
	MTHB Glide	2011	119	0.18	0.11	0.00	0.03	0.00	8.6	22.0	65.2
	MTHB Riffle	2011	114	0.74	0.04	0.00	0.00	0.00	24.6	89.4	195.6
	MTHB All	----		**0.40**	**0.05**	**0.00**	**0.01**	**0.00**	**14.8**	**47.7**	**106.6**
	MTHR Pool	2011	--	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	MTHR Glide	2011	97	0.32	0.01	0.00	0.01	0.00	20.5	34.9	60.4
	MTHR Riffle	2011	115	0.65	0.01	0.00	0.01	0.00	17.2	81.8	195.7
	MTHR All			**0.49**	**0.01**	**0.00**	**0.01**	**0.00**	**18.9**	**58.4**	**128.0**
		Mean for pools		*0.52*	*0.05*	*0.00*	*0.00*	*0.00*	***26.53***	***111.00***	***347.96***
		Mean for glides		*0.30*	*0.08*	*0.00*	*0.01*	*0.00*	***13.31***	***32.46***	***84.91***
		Mean for riffles		*0.51*	*0.04*	*0.00*	*0.02*	*0.00*	***19.42***	***67.25***	***145.76***

Notes:

[1] *Size greater than 4 mm of the 10th, 16th, 50th, 84th, and 90th percentiles of material covering the bed.*
All particle sizes are for the intermediate ('b') axis, or about the size of sieve on which a particle of this size would be retained.

[2] *Surveys are typically conducted during the summer of the water year.*

[3] *Not measured in 2010*

[4] *Excluding Boulder Riffle for consistent comparison to 2010*

Table 3. Summary of particle-size measurements for 2014.

Stream	Site	Water Year [2]	Sample Size	Cobbles (>45mm)	Sand (<4mm)	Bedrock	Organics	Artifacts	D-16	D-50	D-84
				Proportion of bed area occupied by					*D-size [1]*		
Middle Truckee River	MTFC Pool	2014	106	0.44	0.20	0.00	0.02	0.00	11.0	62.2	278.8
	MTFC Glide	2014	88	0.38	0.11	0.00	0.00	0.00	10.0	36.8	86.7
	MTFC Riffle	2014	89	0.37	0.13	0.00	0.00	0.00	9.8	35.7	69.6
	MTFC Boulder Riffle [3]	2014	106	0.80	0.06	0.00	0.01	0.00	51.4	130.0	313.3
	MTFC All [4]			**0.40**	**0.15**	**0.00**	**0.01**	**0.00**	**10.3**	**44.9**	**145.0**
	MTHB Pool	2014	93	0.17	0.12	0.00	0.11	0.00	9.5	27.3	56.5
	MTHB Glide	2014	151	0.11	0.17	0.00	0.07	0.00	8.5	17.0	40.5
	MTHB Riffle	2014	276	0.47	0.13	0.00	0.03	0.00	11.2	51.8	125.9
	MTHB All			**0.25**	**0.14**	**0.00**	**0.07**	**0.00**	**9.7**	**32.0**	**74.3**
	MTHR Pool	2014	--	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	MTHR Glide	2014	101	0.16	0.21	0.00	0.13	0.00	8.2	23.8	56.9
	MTHR Riffle	2014	118	0.73	0.05	0.00	0.00	0.00	23.9	84.1	170.6
	MTHR All			**0.44**	**0.13**	**0.00**	**0.06**	**0.00**	**16.0**	**54.0**	**113.7**
		Mean for pools		*0.31*	*0.16*	*0.00*	*0.06*	*0.00*	***10.24***	***44.72***	***167.62***
		Mean for glides		*0.21*	*0.16*	*0.00*	*0.06*	*0.00*	***8.90***	***25.85***	***61.37***
		Mean for riffles		*0.52*	*0.11*	*0.00*	*0.01*	*0.00*	***14.95***	***57.21***	***122.01***

Notes:

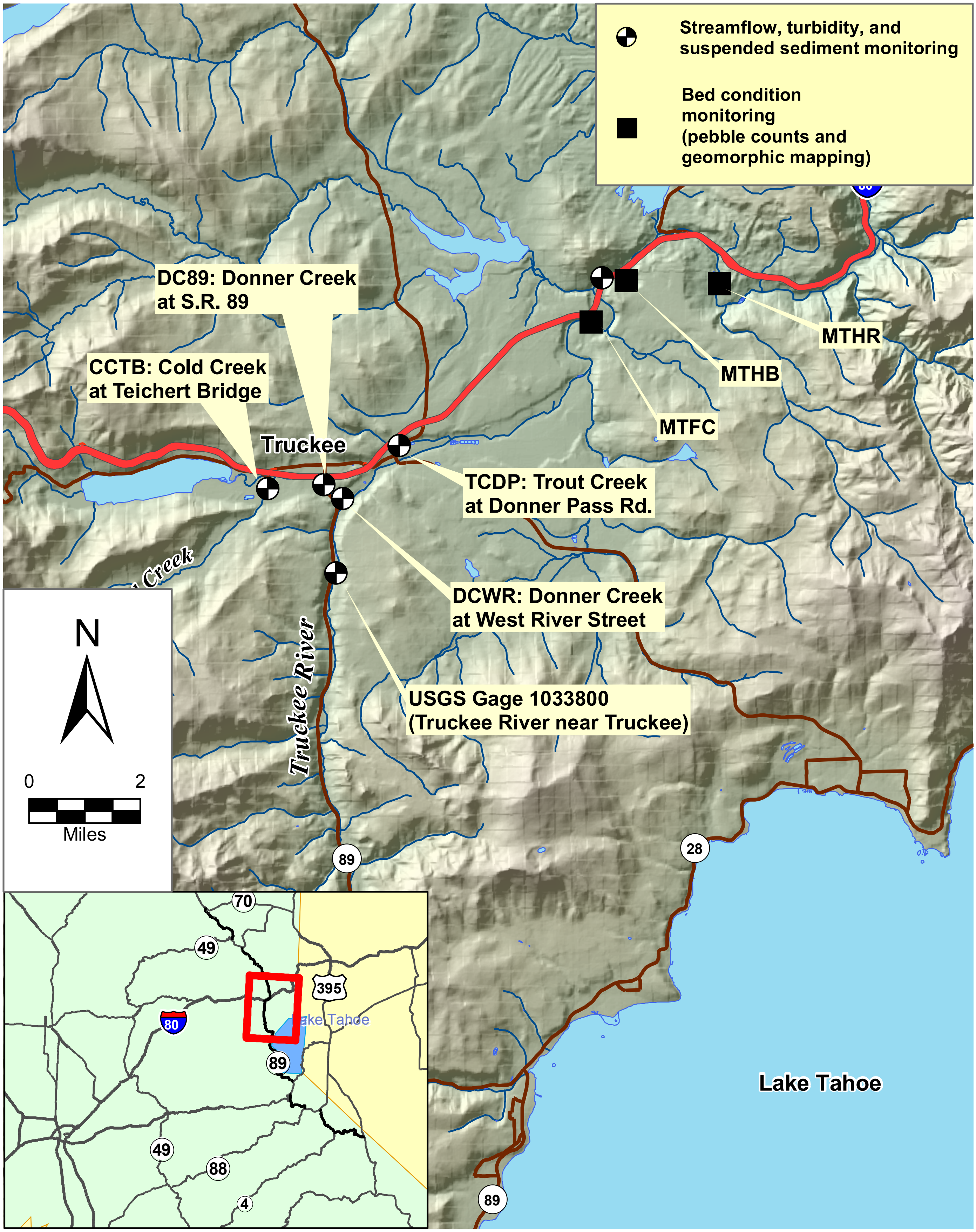
1 Size greater than 4 mm of the 10th, 16th, 50th, 84th, and 90th percentiles of material covering the bed.
All particle sizes are for the intermediate ('b') axis, or about the size of sieve on which a particle of this size would be retained.

2 Surveys are typically conducted during the summer of the water year.

3 Not measured in 2010

4 Excluding Boulder Riffle for consistent comparison to 2010

FIGURES



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210011 monitoring.mxd

Figure 1. Monitoring locations, Middle Truckee River TDML evaluation, Nevada County, California

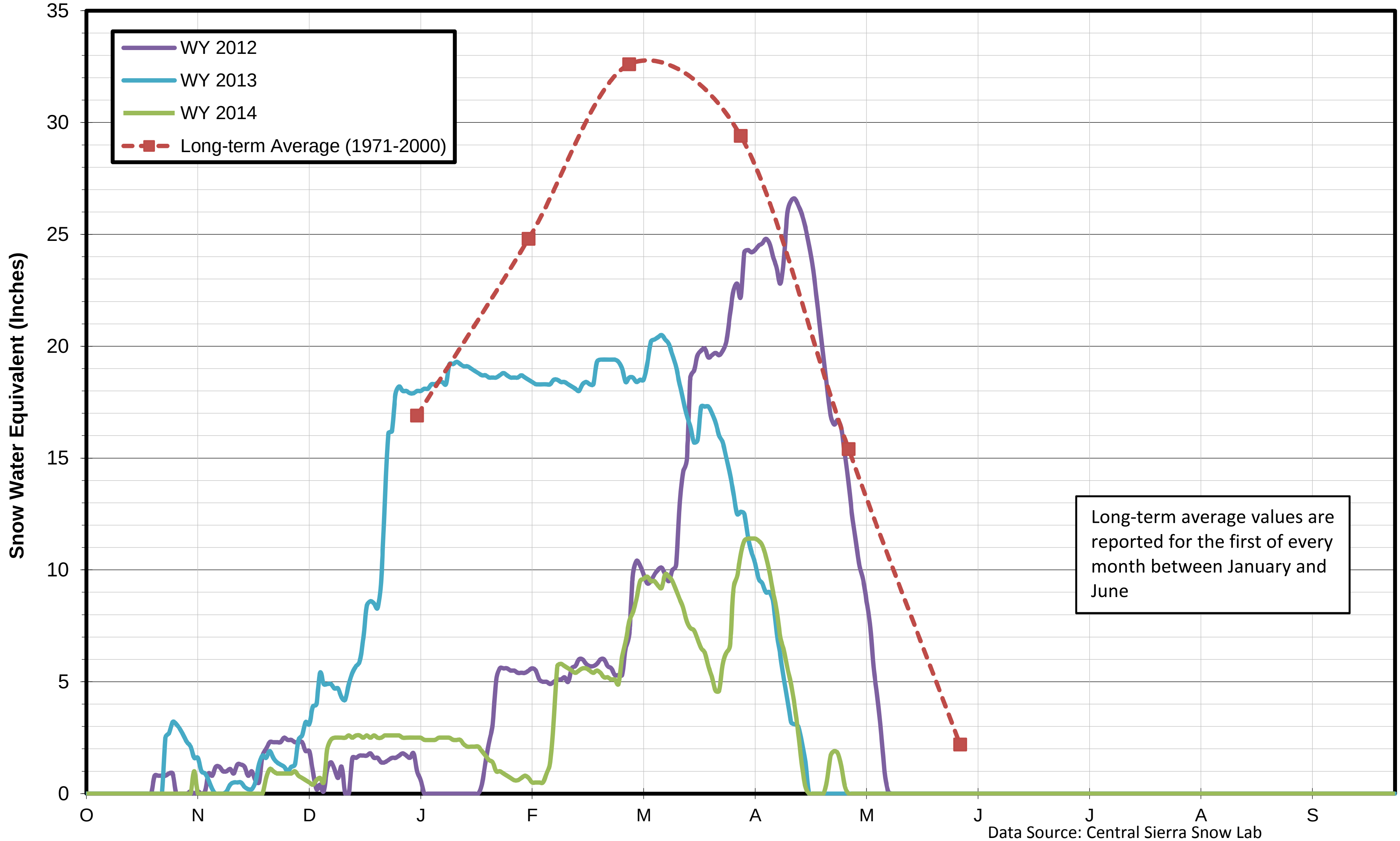

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Figure 2. **Snow-water equivalent snowpack, Central Sierra Snow Lab, Soda Springs, California, water years 2012, 2013, and 2014 as compared to long-term average.** The Snow Lab is located approximately 11 miles west of Truckee, California at 6,950 feet elevation.

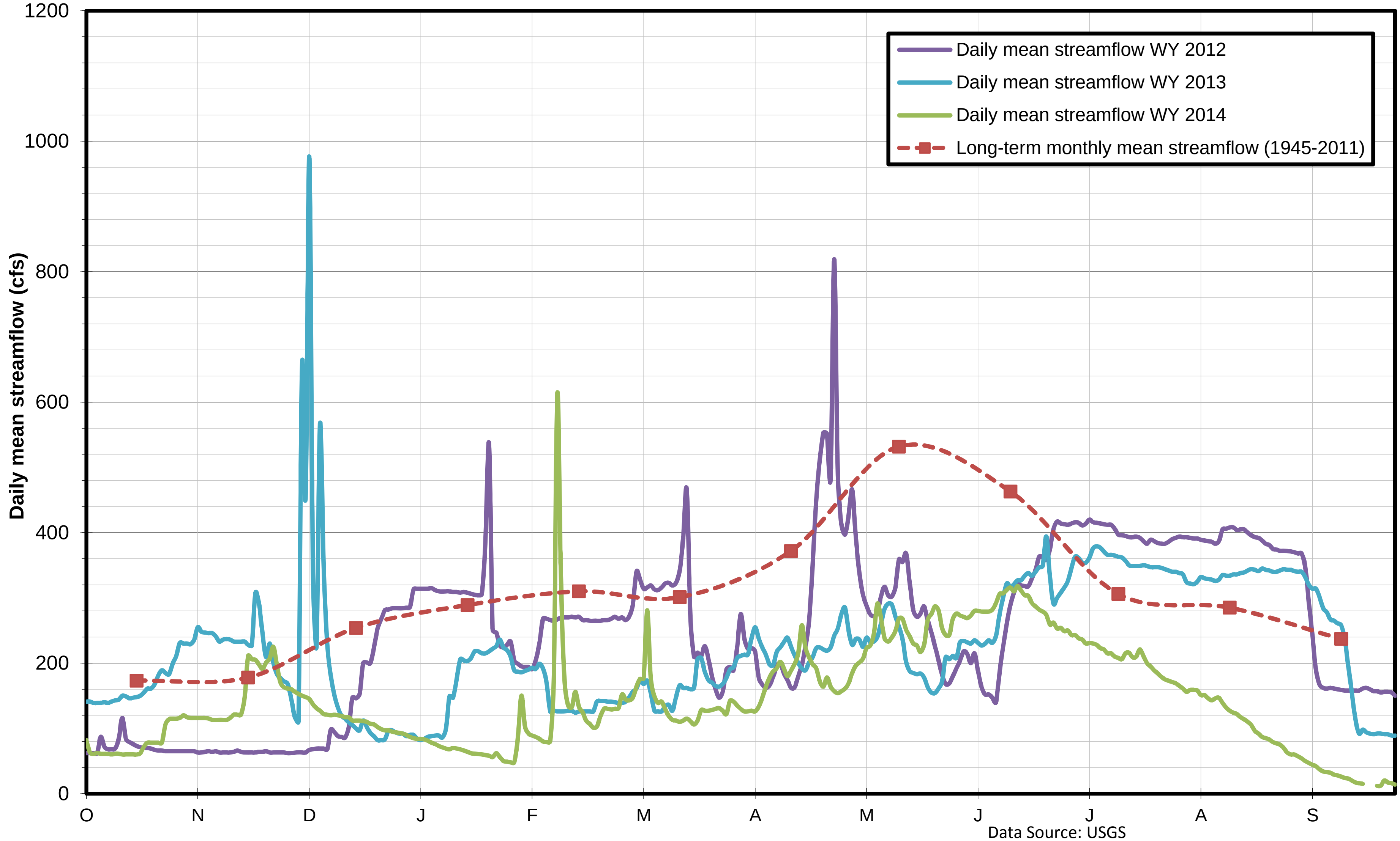

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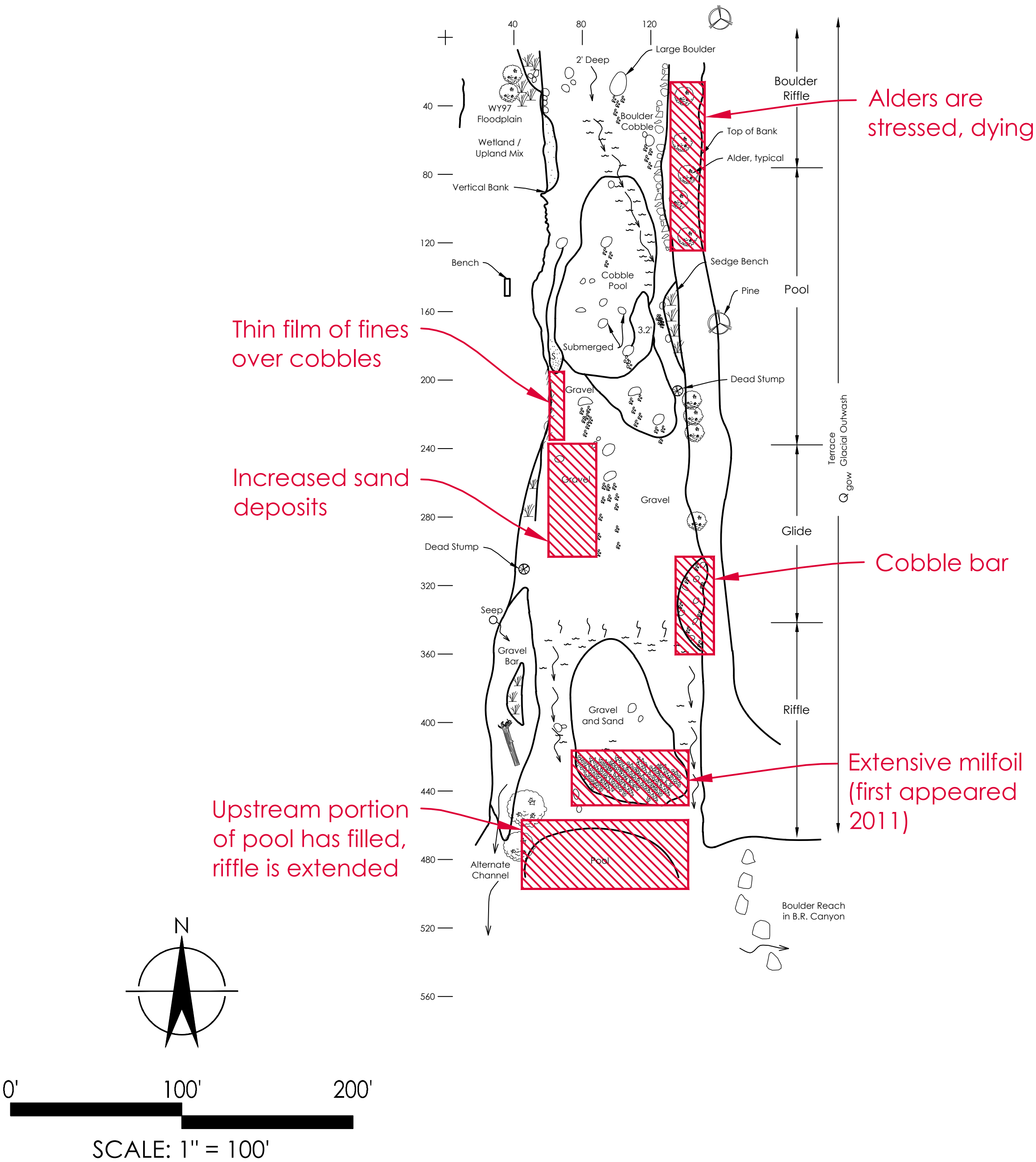
Figure 3. **Daily mean streamflow, USGS gage, Truckee River near Truckee (USGS 10338000). Water years 2012, 2013, and 2014 as compared to long-term monthly average.** The Truckee River near Truckee gage is located two miles south of Truckee, California, upstream of the confluence with Donner Creek.



Refer to monitoring report for Water Years 2010 and 2011 for areas of detected change between 2010 and 2011

Area of detected change between 2011 and 2014

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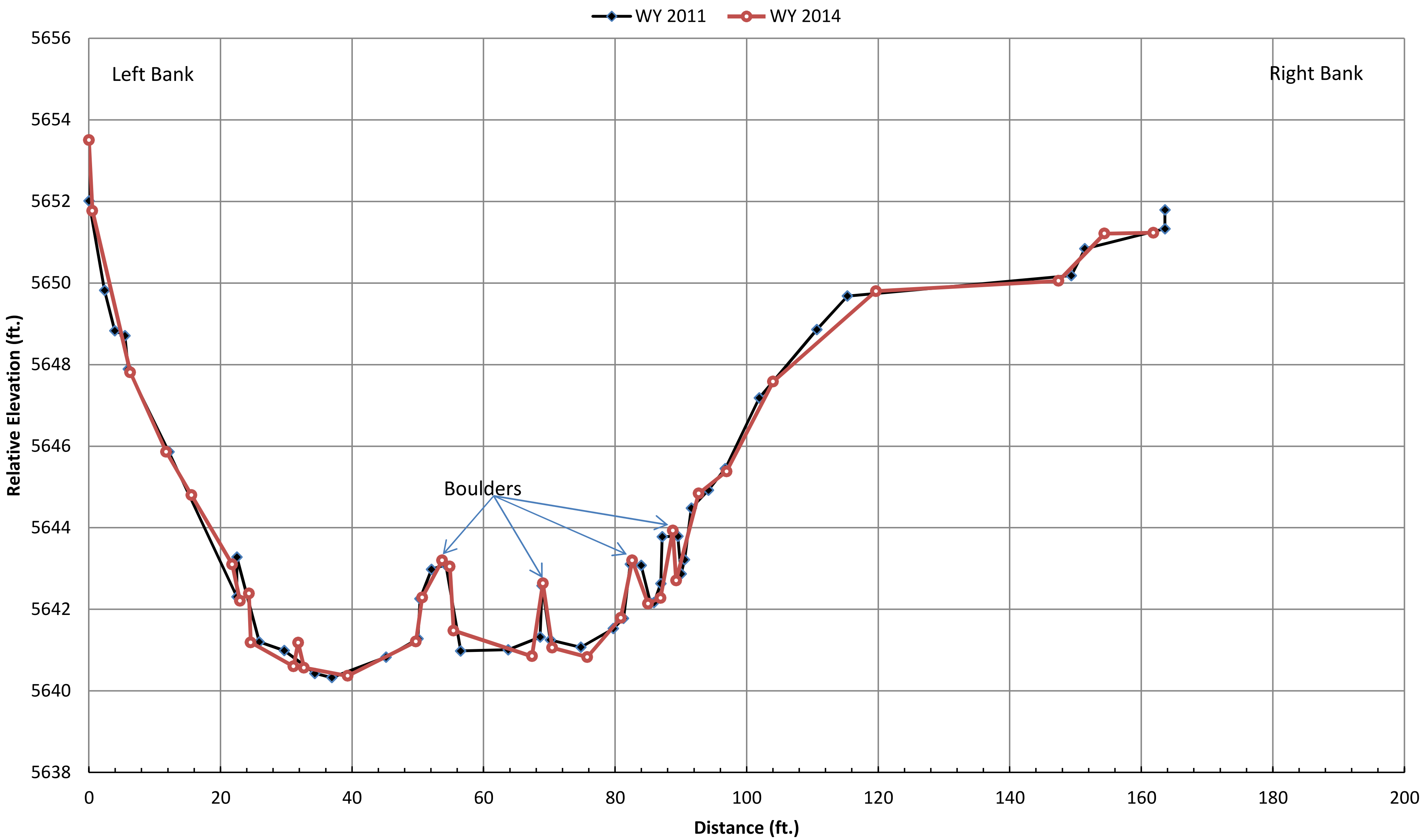
Bed conditions tracings.dwg

Figure 4. Digitized sketch map of summer 2014 conditions at San Francisco Fly Casting Club, Middle Truckee River, Nevada County, California.



Source: Balance Hydrologics Survey

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Figure 5. Cross-section 1 (Station 162) at the San Francisco Fly Casting Club (MTFC), Middle Truckee River, Nevada County, California.

Bed Surveys WY14

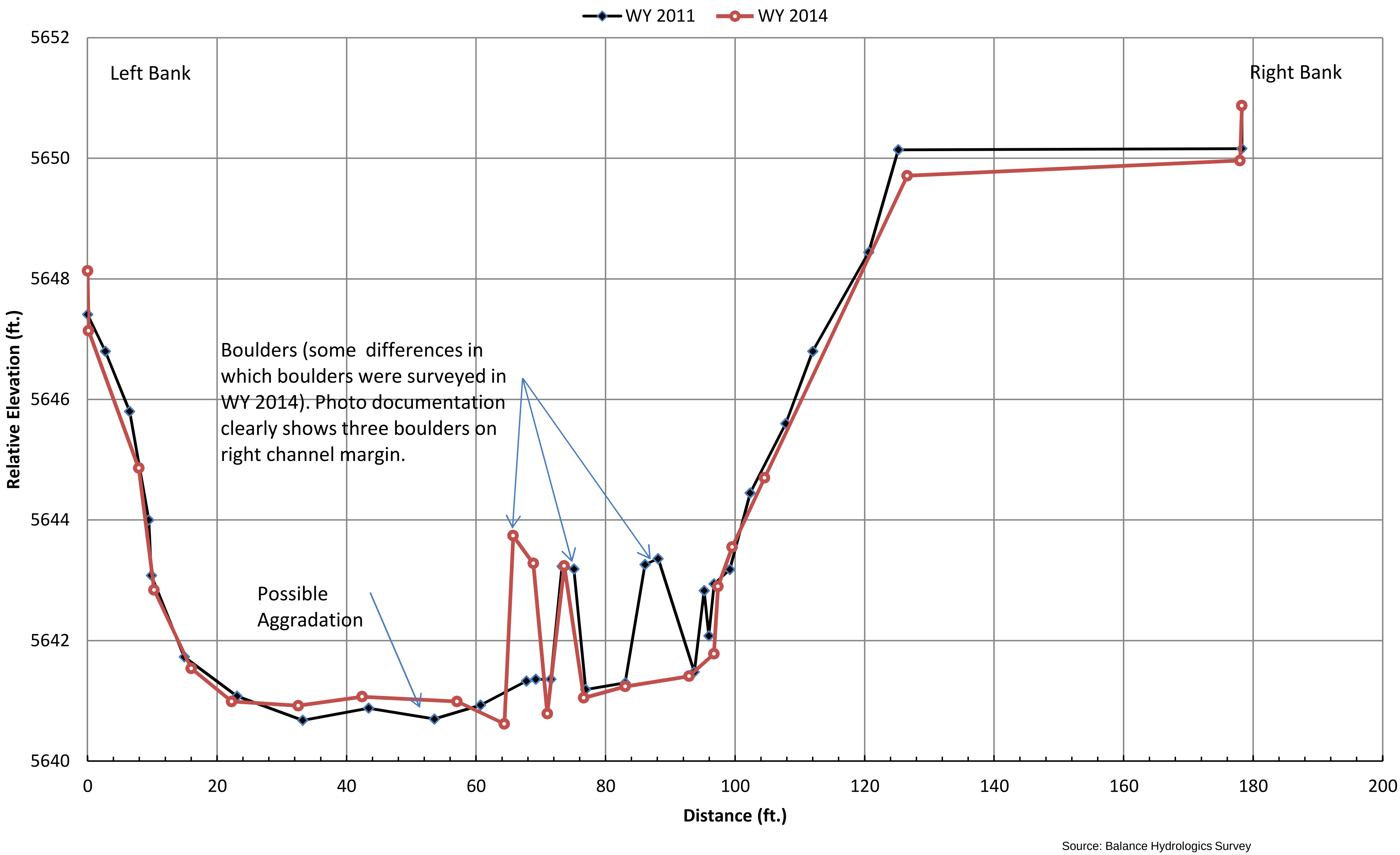

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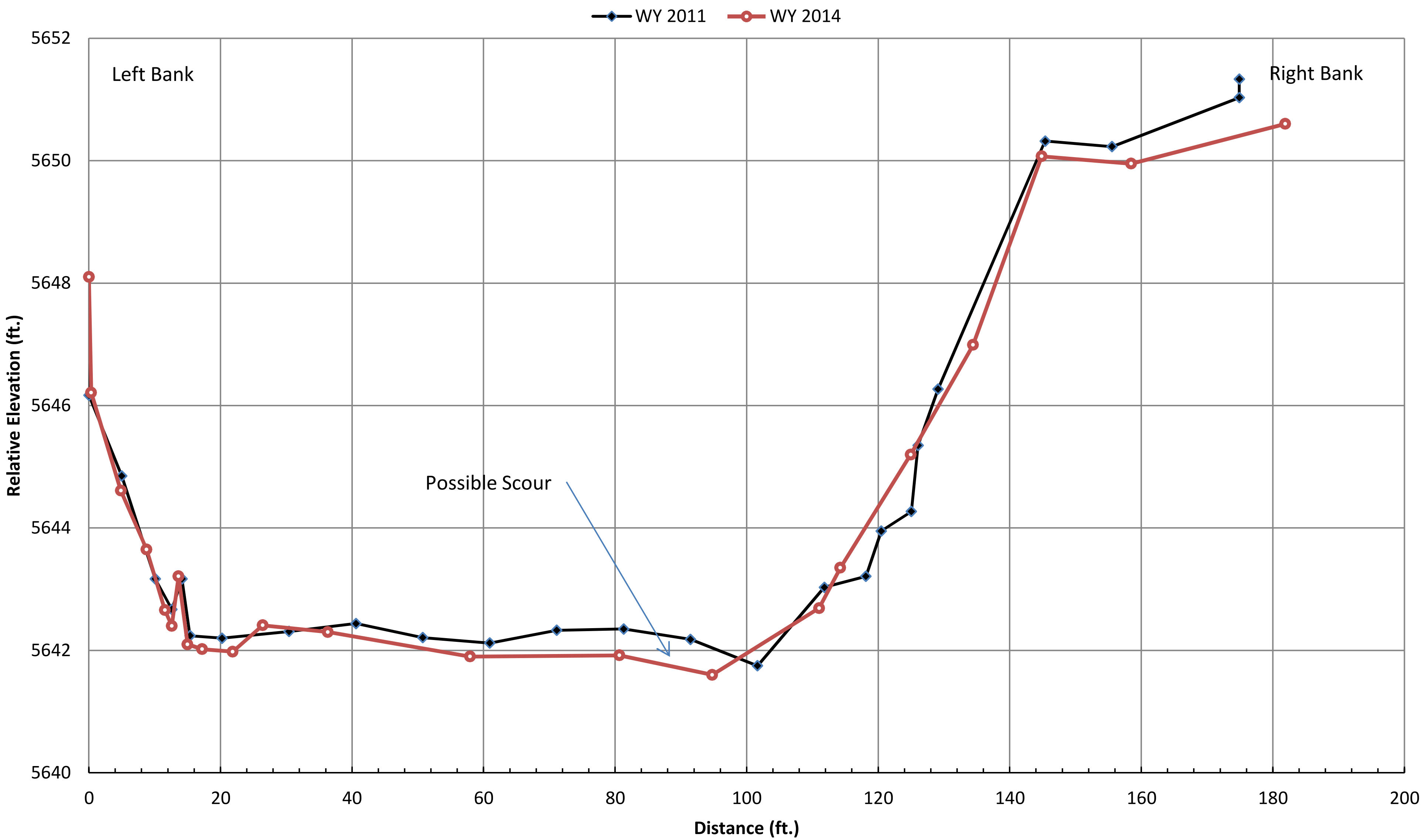
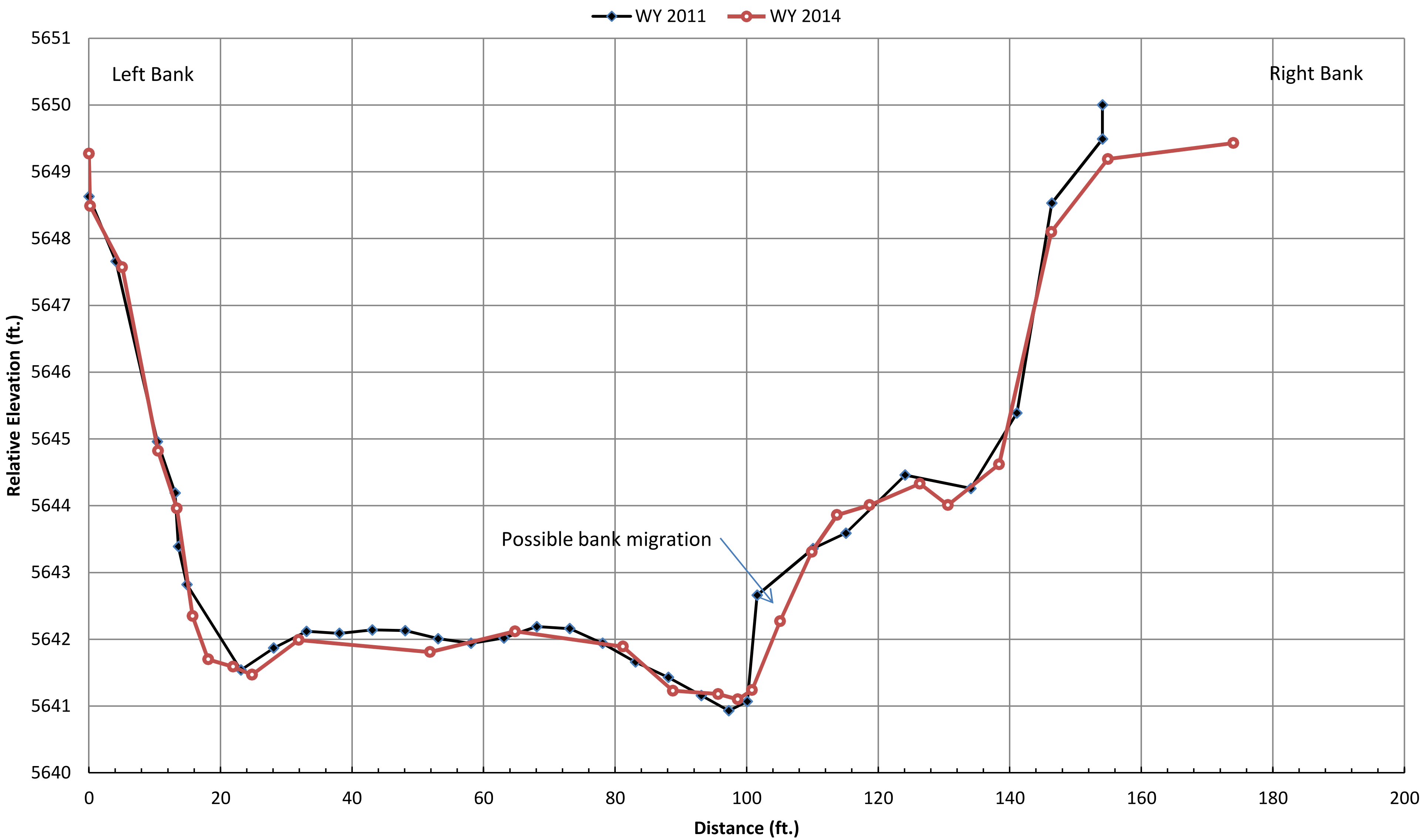
Figure 6. **Cross-section 2 (Station 234) at the San Francisco Fly Casting Club (MTFC), Middle Truckee River, Nevada County, California.**



Source: Balance Hydrologics Survey

Balance Hydrologics, Inc.

Figure 7. Cross-section 3 (Station 324) at the San Francisco Fly Casting Club (MTFC), Middle Truckee River, Nevada County, California.



Source: Balance Hydrologics Survey

Balance Hydrologics, Inc.

Figure 8. Cross-section 4 (Station 451) at the San Francisco Fly Casting Club (MTFC), Middle Truckee River, Nevada County, California.

Cross section 1 (Sta. 162)

Cross section 2 (Sta. 234)

Cross section 3 (Sta. 324)

Cross section 4 (Sta. 451)

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Figure 9. 2014 photo points at the San Francisco Fly Casting Club (MTFC) site, Middle Truckee River, Nevada County, California
Date of photos: October 7, 2014

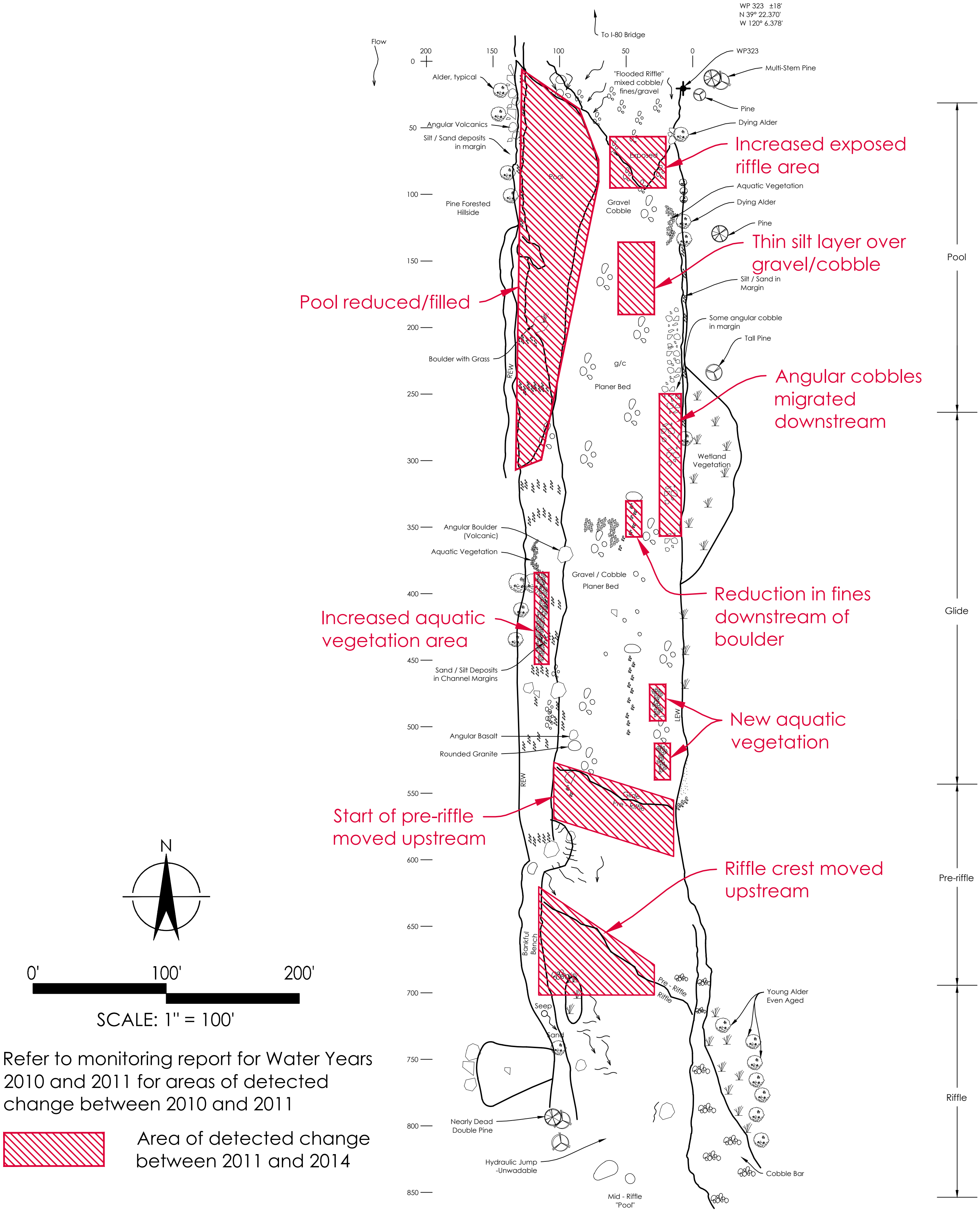

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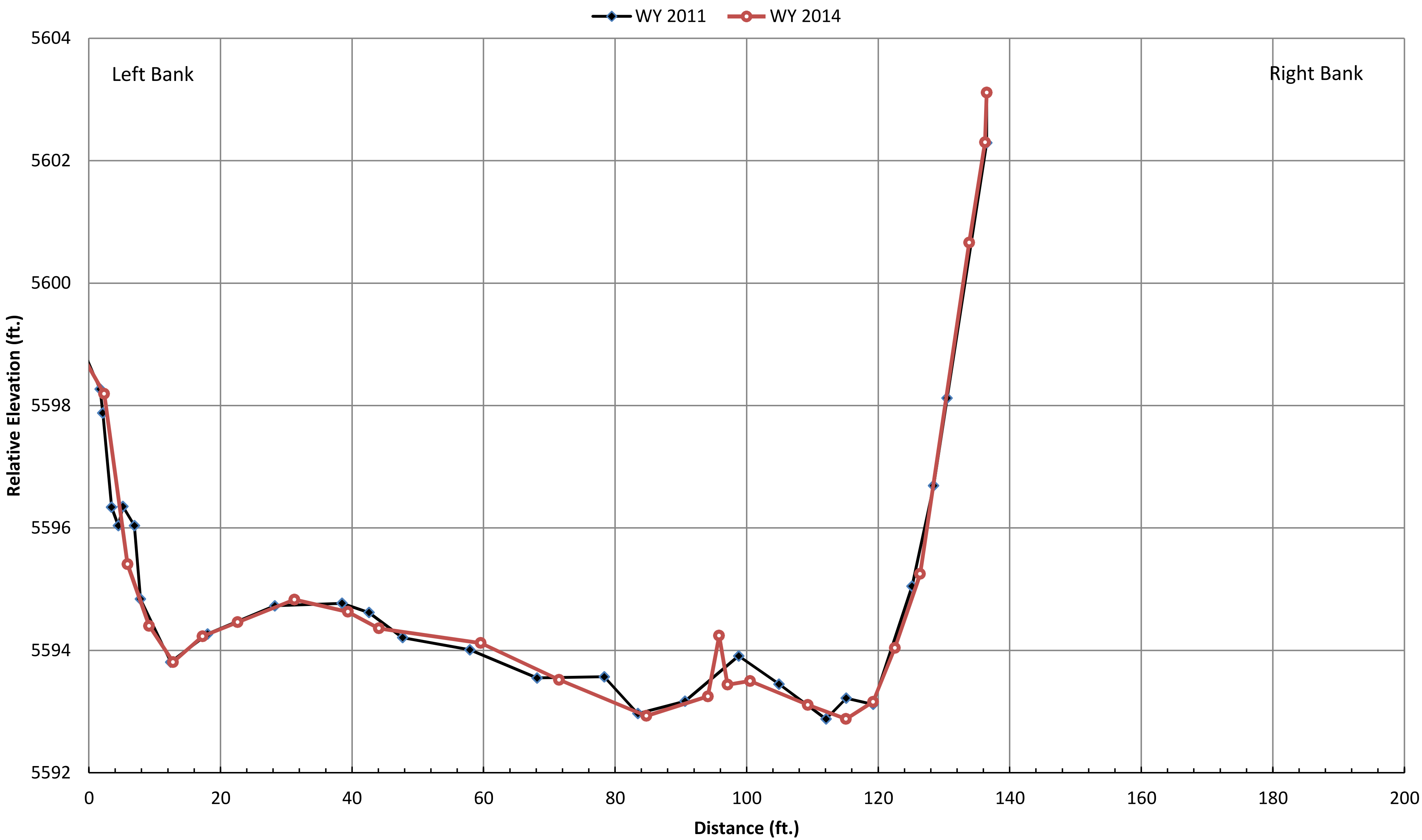
Figure 10. Digitized sketch map of summer 2014 conditions at Horseshoe Bend, Middle Truckee River, Nevada County, California.

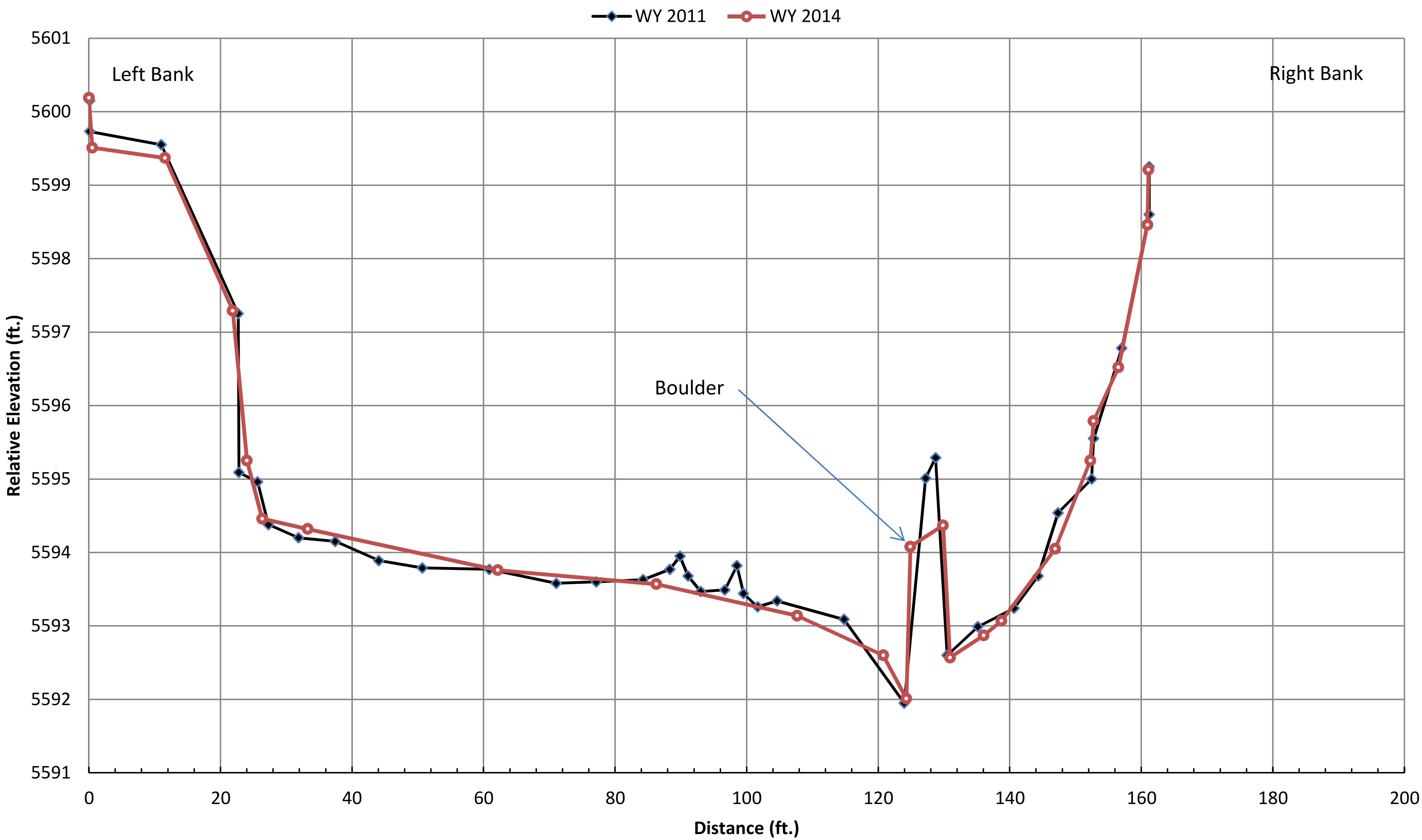
Bed conditions tracings.dwg



Source: Balance Hydrologics Survey

Balance Hydrologics, Inc.

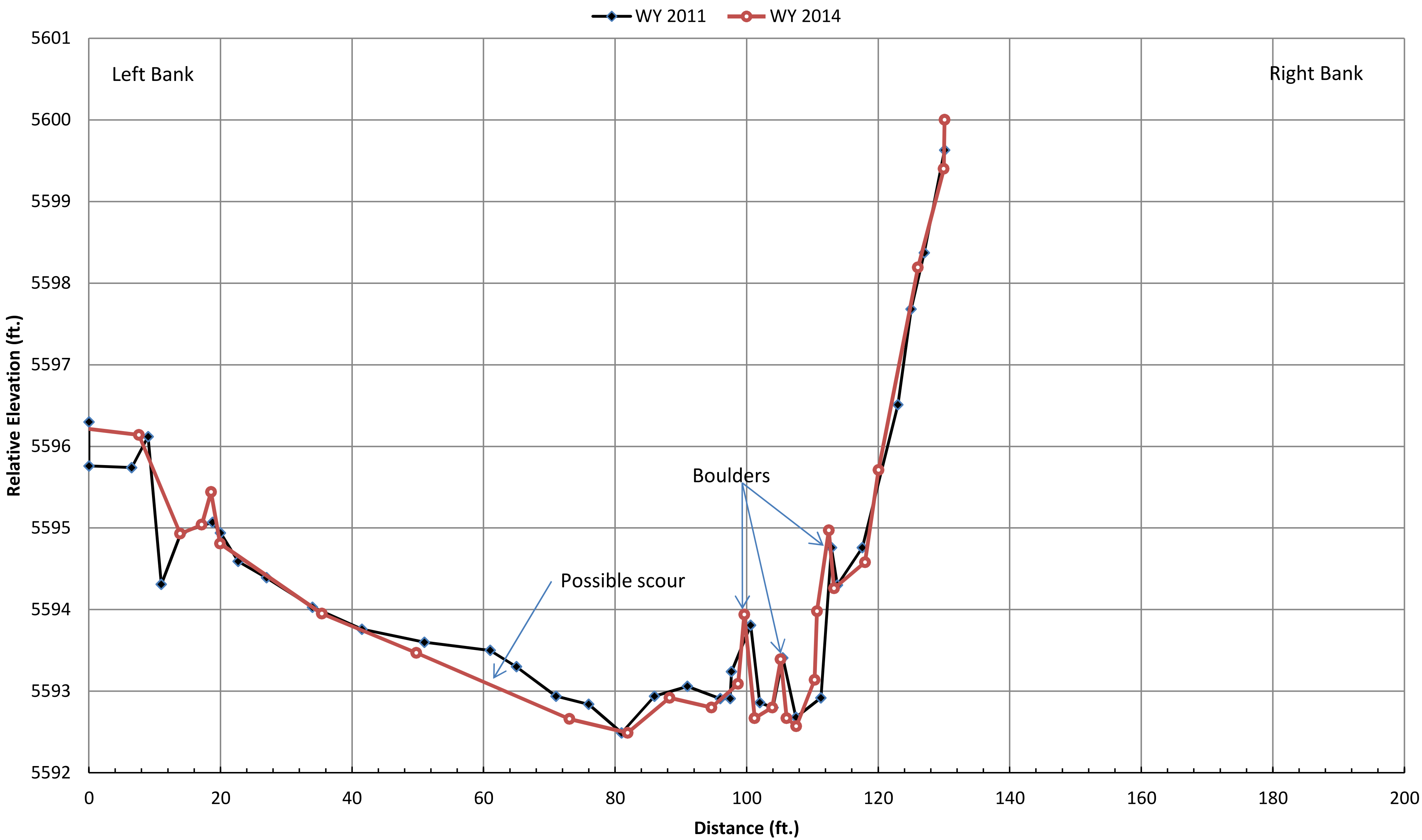
Figure 11. **Cross-section 1 (Station 55) at Horseshoe Bend (MTHB), Middle Truckee River, Nevada County, California.**



Source: Balance Hydrologics Survey

Balance Hydrologics, Inc.

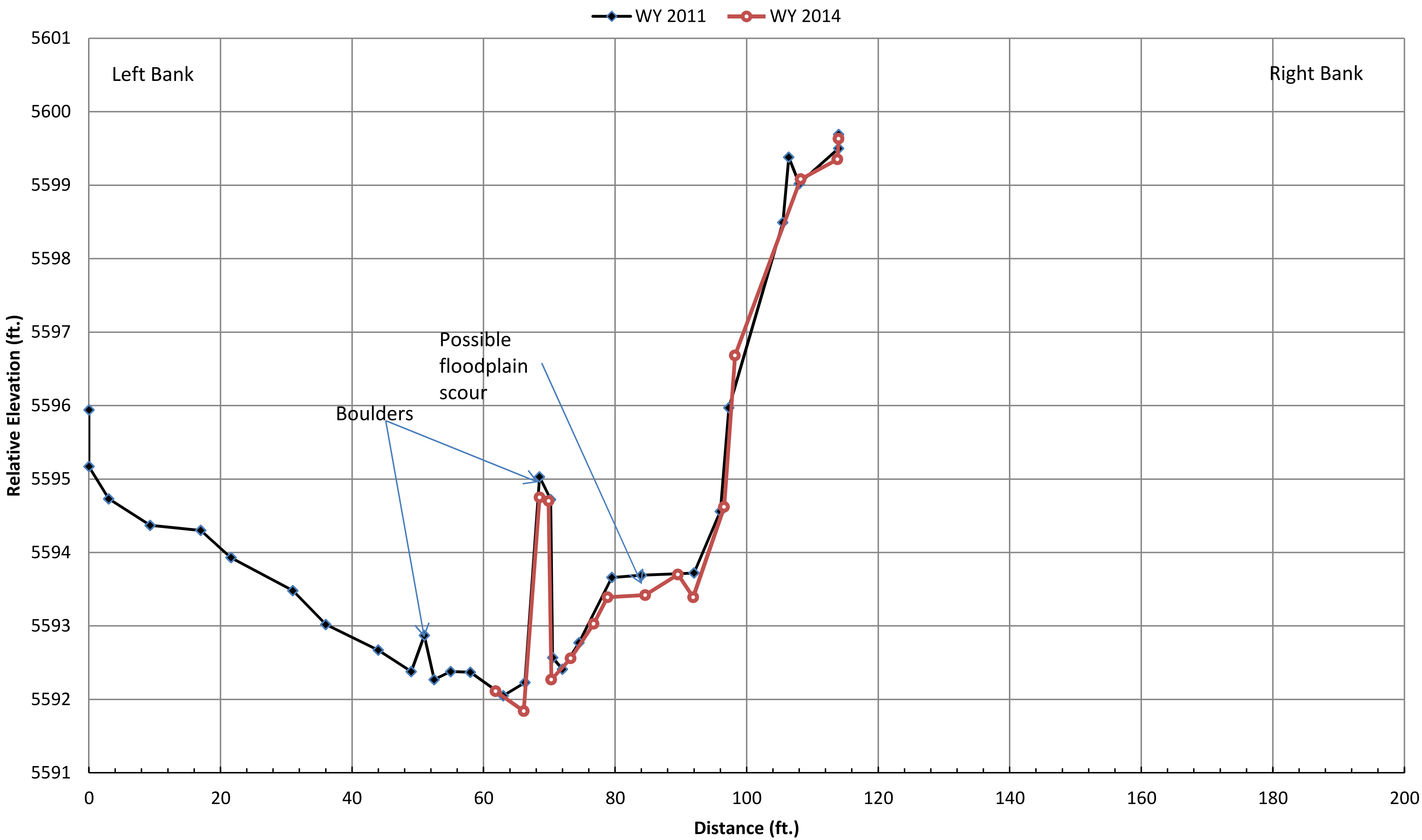
Figure 12. Cross-section 2 (Station 402) at Horseshoe Bend (MTHB), Middle Truckee River, Nevada County, California.



Source: Balance Hydrologics Survey

Balance Hydrologics, Inc.

Figure 13. Cross-section 3 (Station 667) at Horseshoe Bend (MTHB), Middle Truckee River, Nevada County, California.

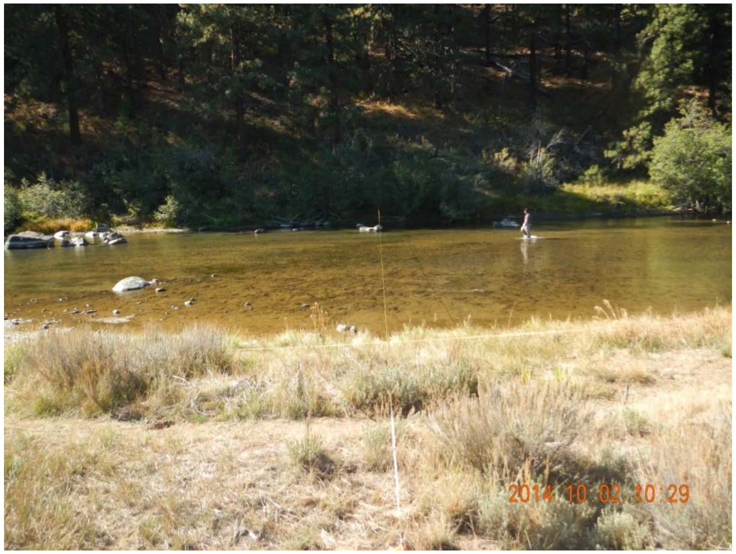


Source: Balance Hydrologics Survey

Balance Hydrologics, Inc.

Figure 14. **Cross-section 4 (Station 769) at Horseshoe Bend (MTHB), Middle Truckee River, Nevada County, California.**

Cross section 1 (Sta. 55)



Cross section 2 (Sta. 402)

Cross section 3 (Sta. 667)

Cross section 4 (Sta. 769)

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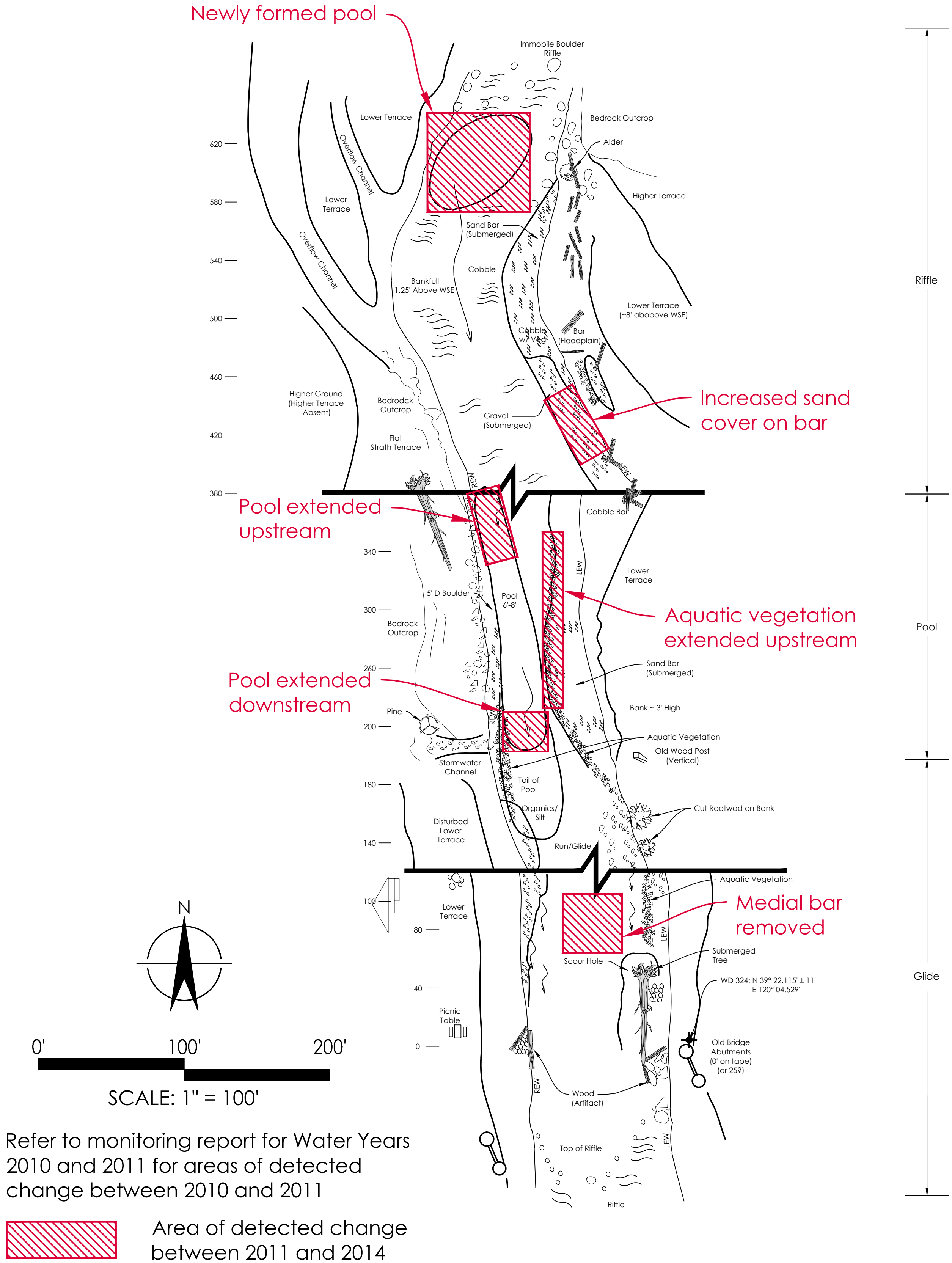
Figure 15. 2014 photo points at the Horseshoe Bend (MTHB) site, Middle Truckee River, Nevada County, California
Date of photos: October 2, 2014



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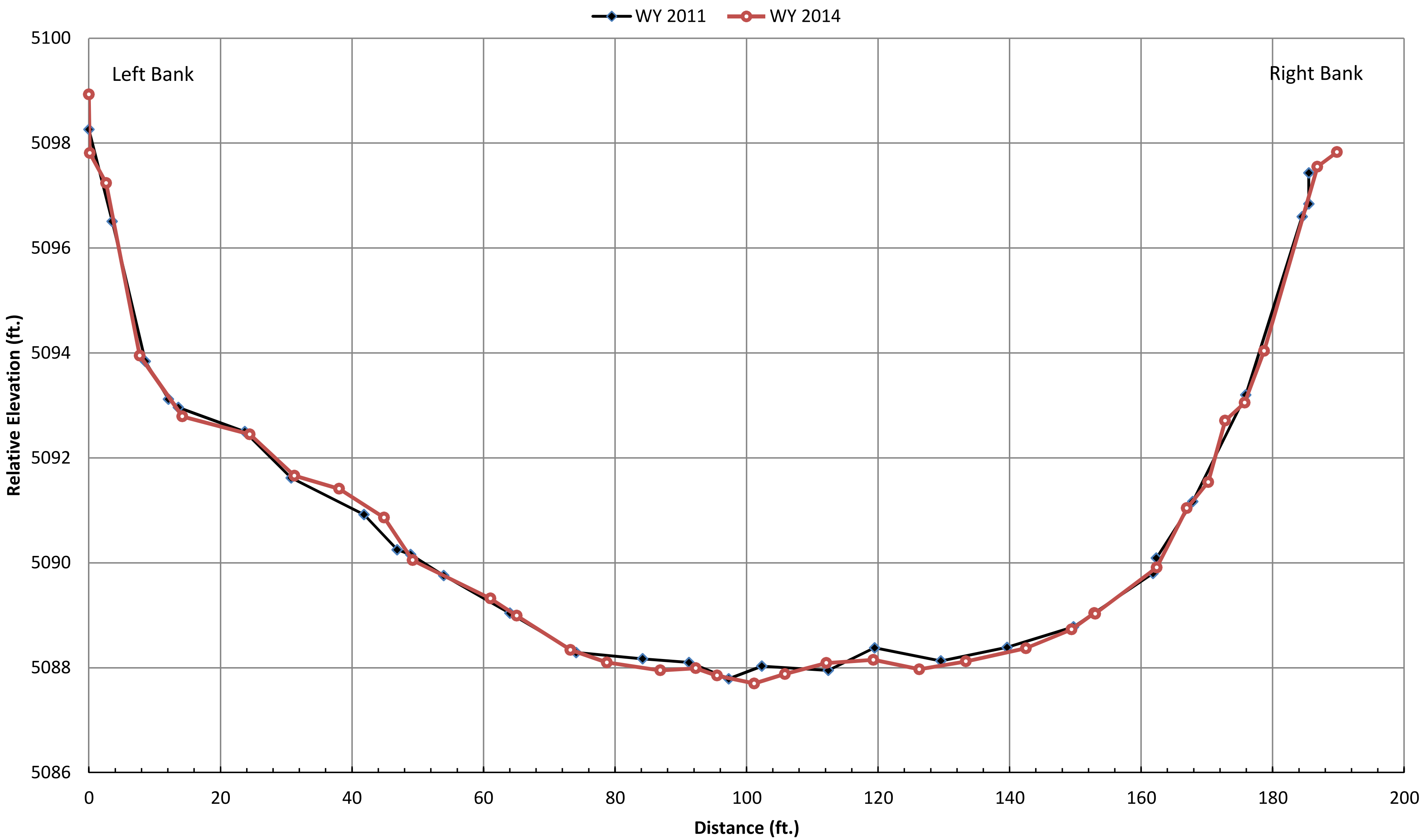
Bed conditions tracings.dwg

Figure 16. Digitized sketch map of summer 2014 conditions at Hirschdale Road, Middle Truckee River, Nevada County, California. Note that Hirschdale Road Reach was sketched on three separate sheets. Long profile distances have been correlated, but the separate sketches not shifted and rotated. Sketches are separated by dividing lines.



Source: Balance Hydrologics Survey

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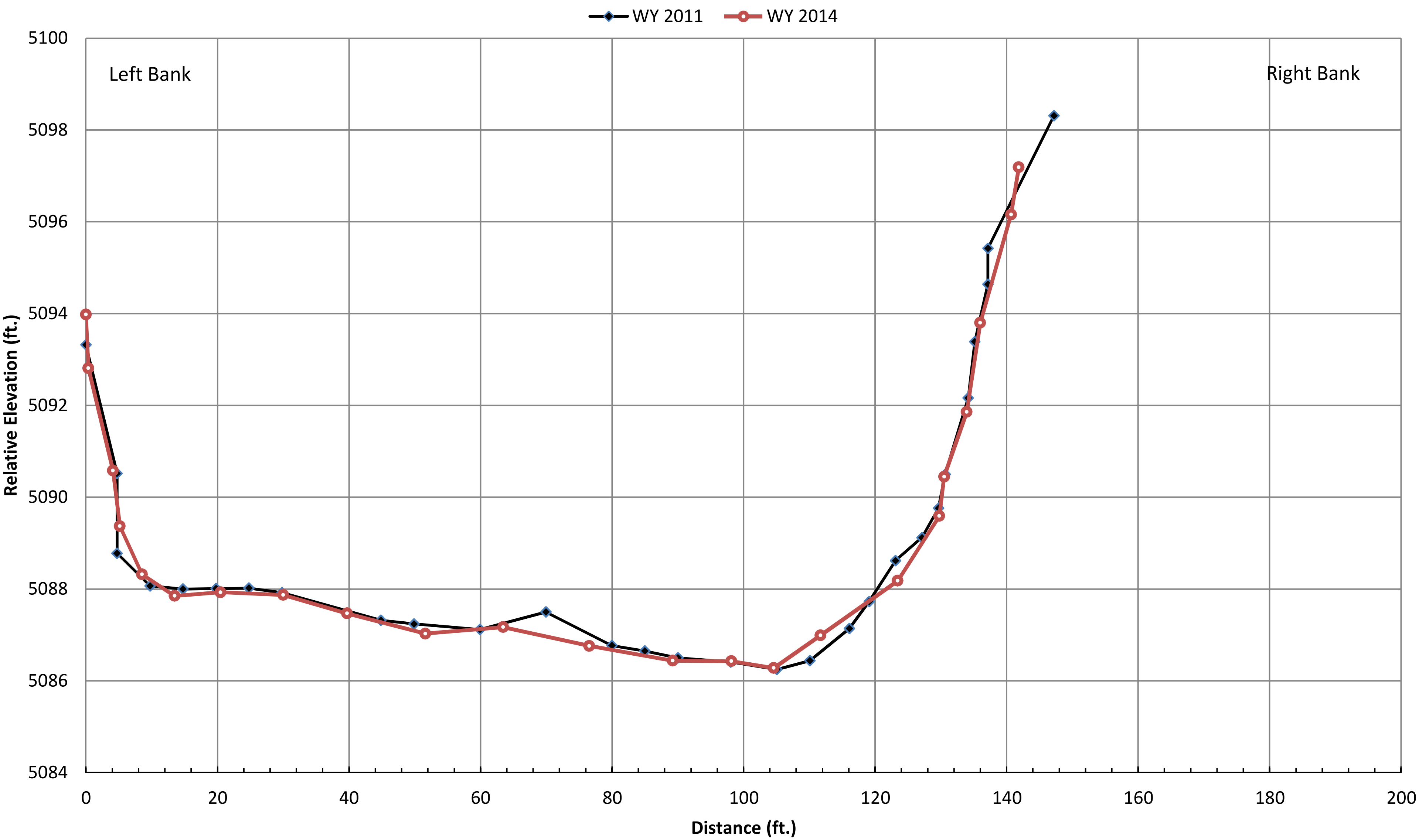
Figure 17. Cross-section 1 (Station 499) at Hirschdale Road (MTHR), Middle Truckee River, Nevada County, California.



Source: Balance Hydrologics Survey

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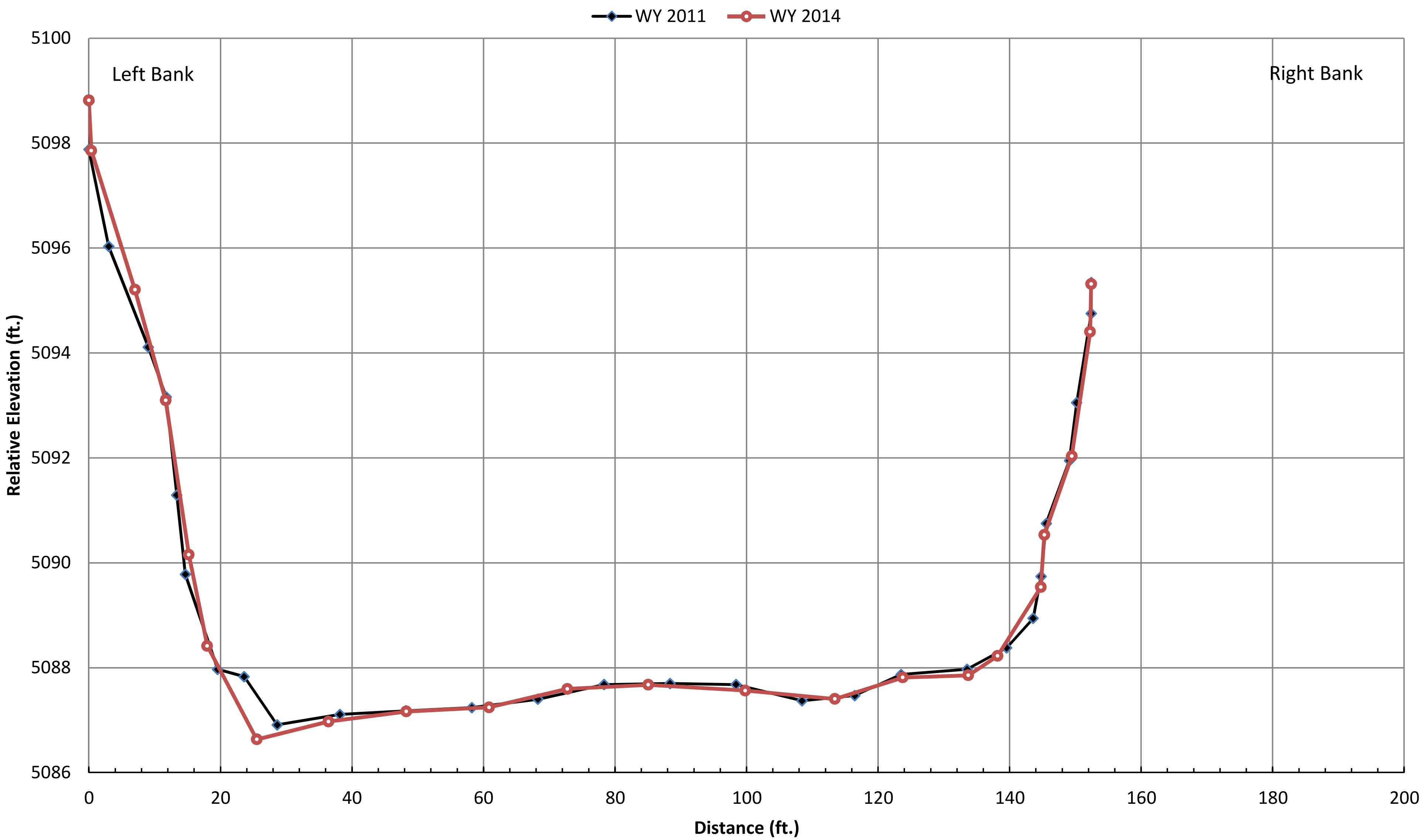
Figure 18. **Cross-section 2 (Station 130) at Hirschdale Road (MTHR), Middle Truckee River, Nevada County, California.**



Source: Balance Hydrologics Survey

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Figure 19. **Cross-section 3 (Station 50) at Hirschdale Road (MTHR), Middle Truckee River, Nevada County, California.**

Cross section 1 (Sta. 499)

Cross section 2 (Sta. 130)

Cross section 3 (Sta. 50)

Balance Hydrologics, Inc.

Figure 20. 2014 photo points at the Hirschdale Road (MTHR) site, Middle Truckee River, Nevada County, California
Date of photos: October 9, 2014

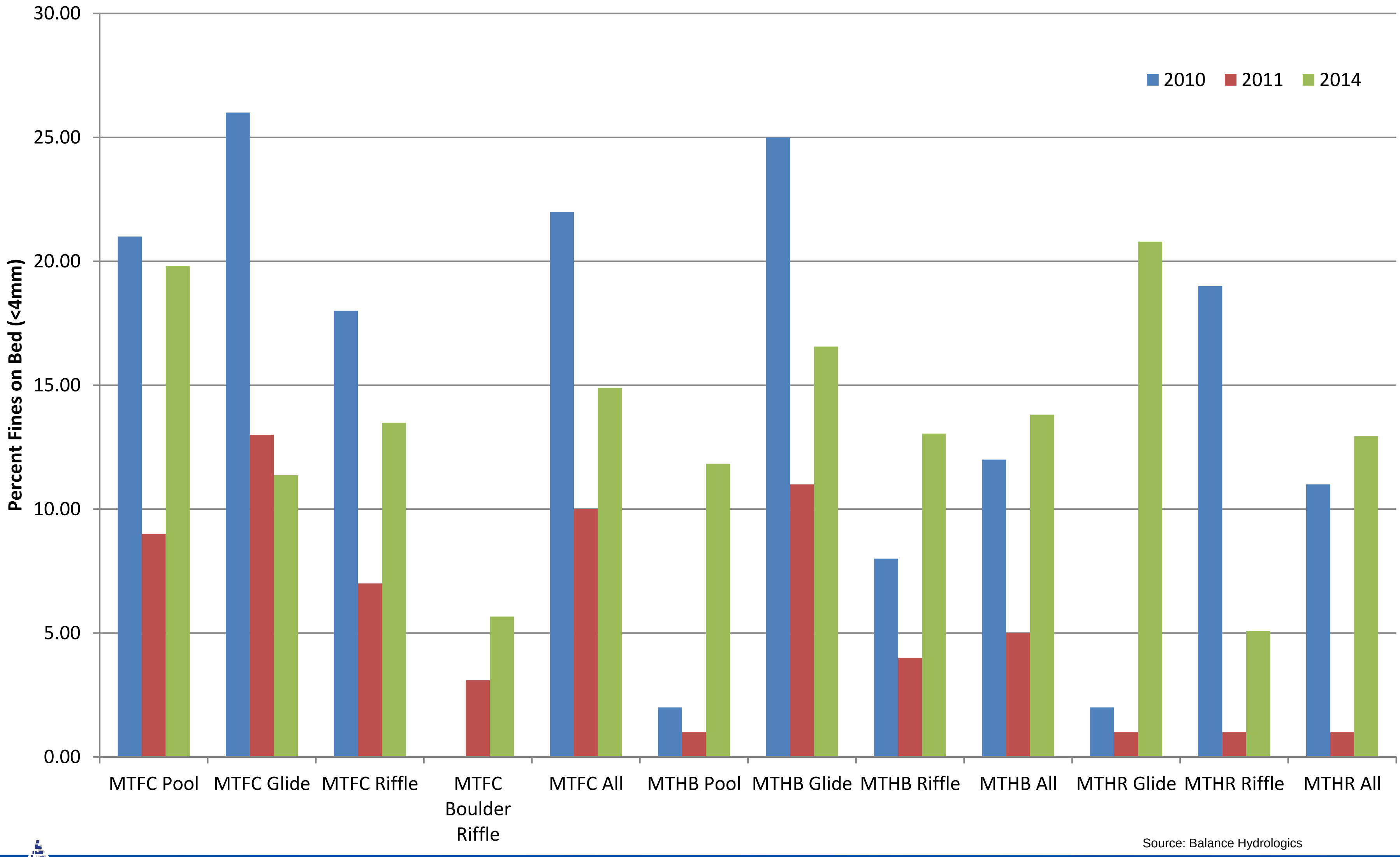

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Figure 21. Comparison of percent fines on the bed (<4mm) between past and 2014 bed surveys. Middle Truckee River TMDL, Truckee River, Nevada County California. Note that more fines were observed on the bed at every unit except one within all three reaches during the 2014 pebble counts compared to past (2010 and 2011) pebble counts.

210011 2010 Middle Truckee pebble counts

APPENDICES

APPENDIX A

2014 Geomorphic Hand Sketches

Balance Hydrologics, Inc.

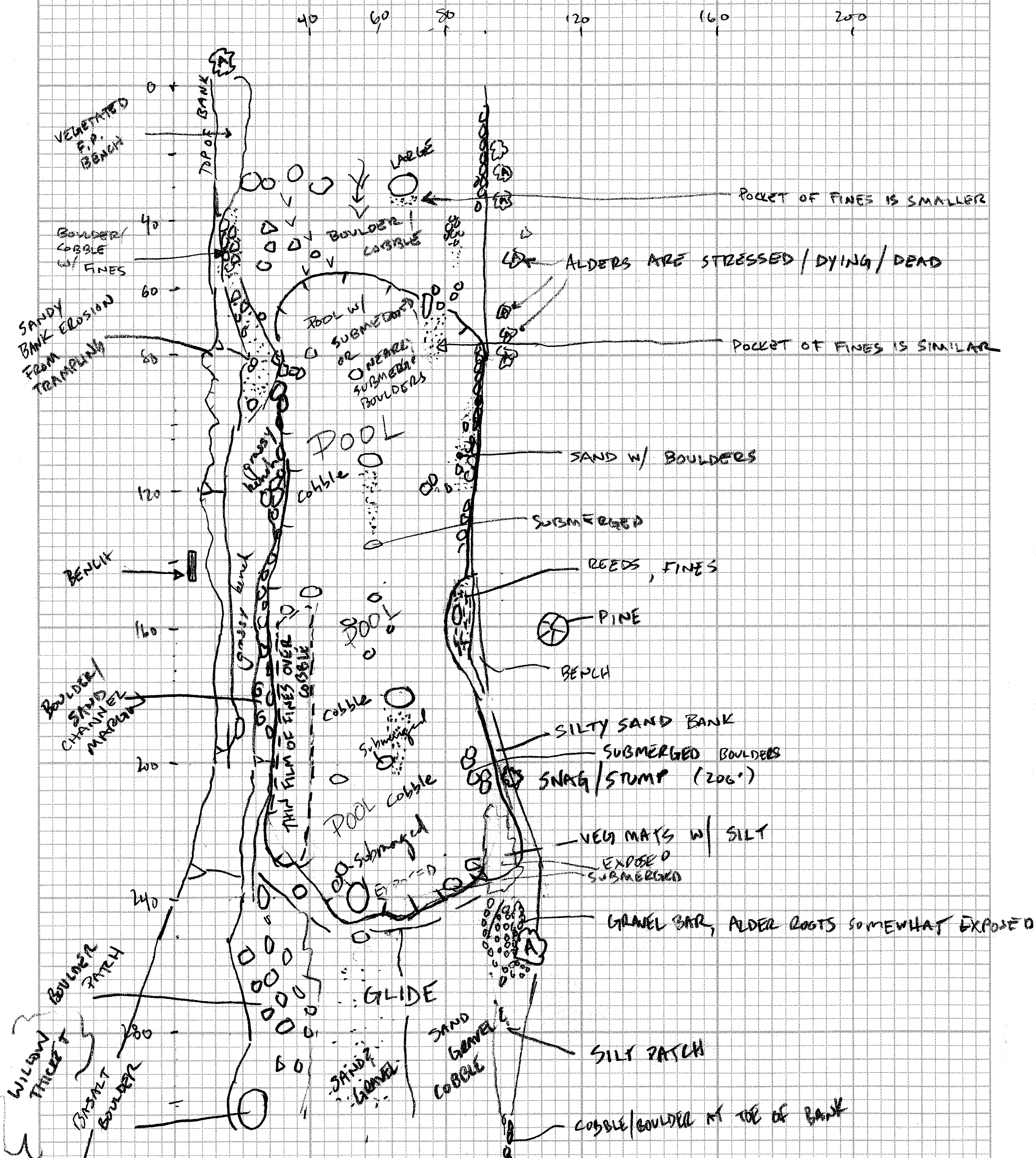
SHEET 1 OF 2

PROJECT 210011 BED CONDITIONS PROJECT NO.

SUBJECT TMDL

BY DS / PK DATE 10/7/14

REVIEWED BY DATE



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SHEET 2 OF 2

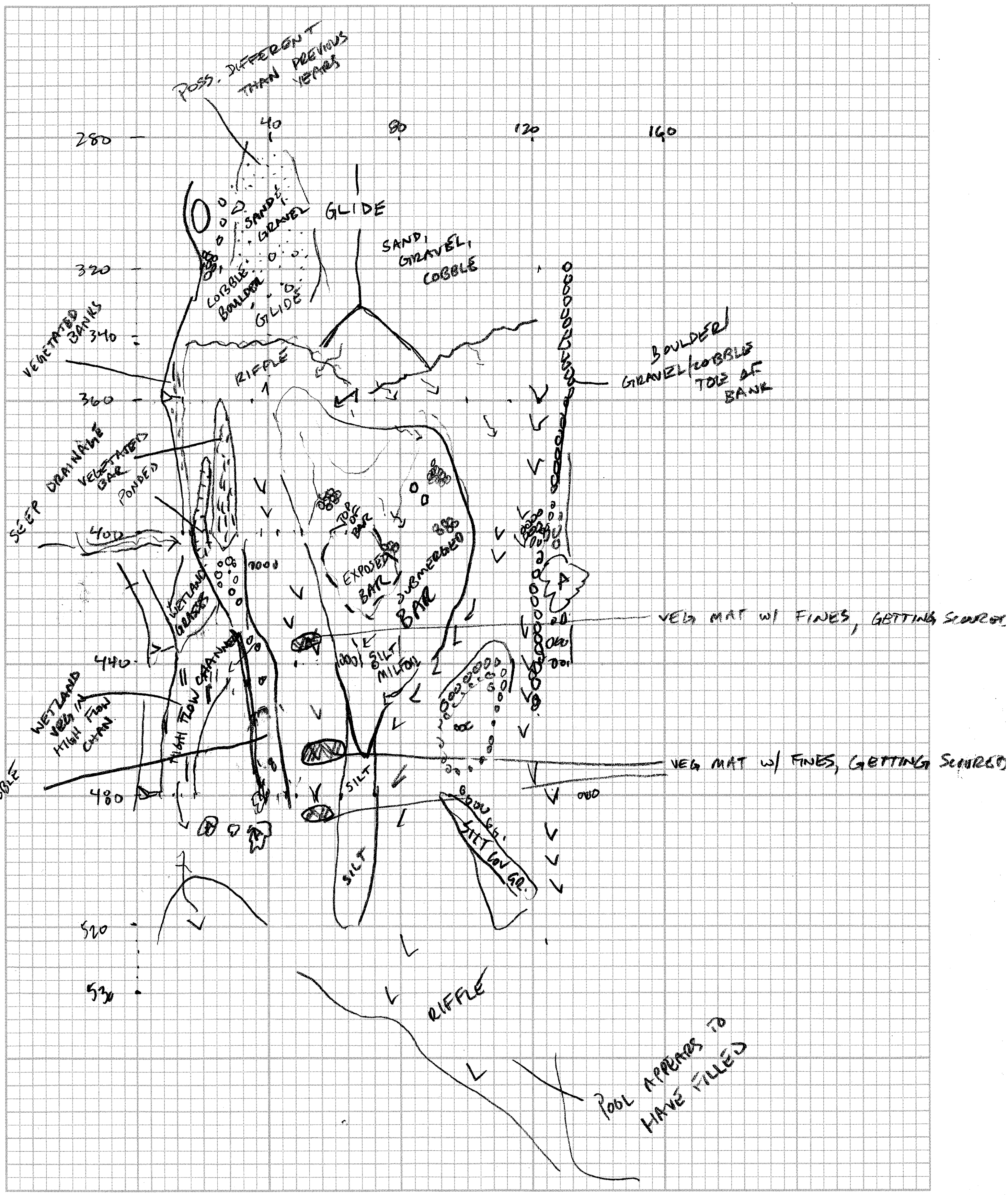
Balance Hydrologics, Inc.

PROJECT ______ PROJECT NO. 210011

SUBJECT TMDL BED CONDITIONS, SFFCC

BY DS, PK DATE 10/7/14

REVIEWED BY ______ DATE ______



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SHEET 1 OF 3

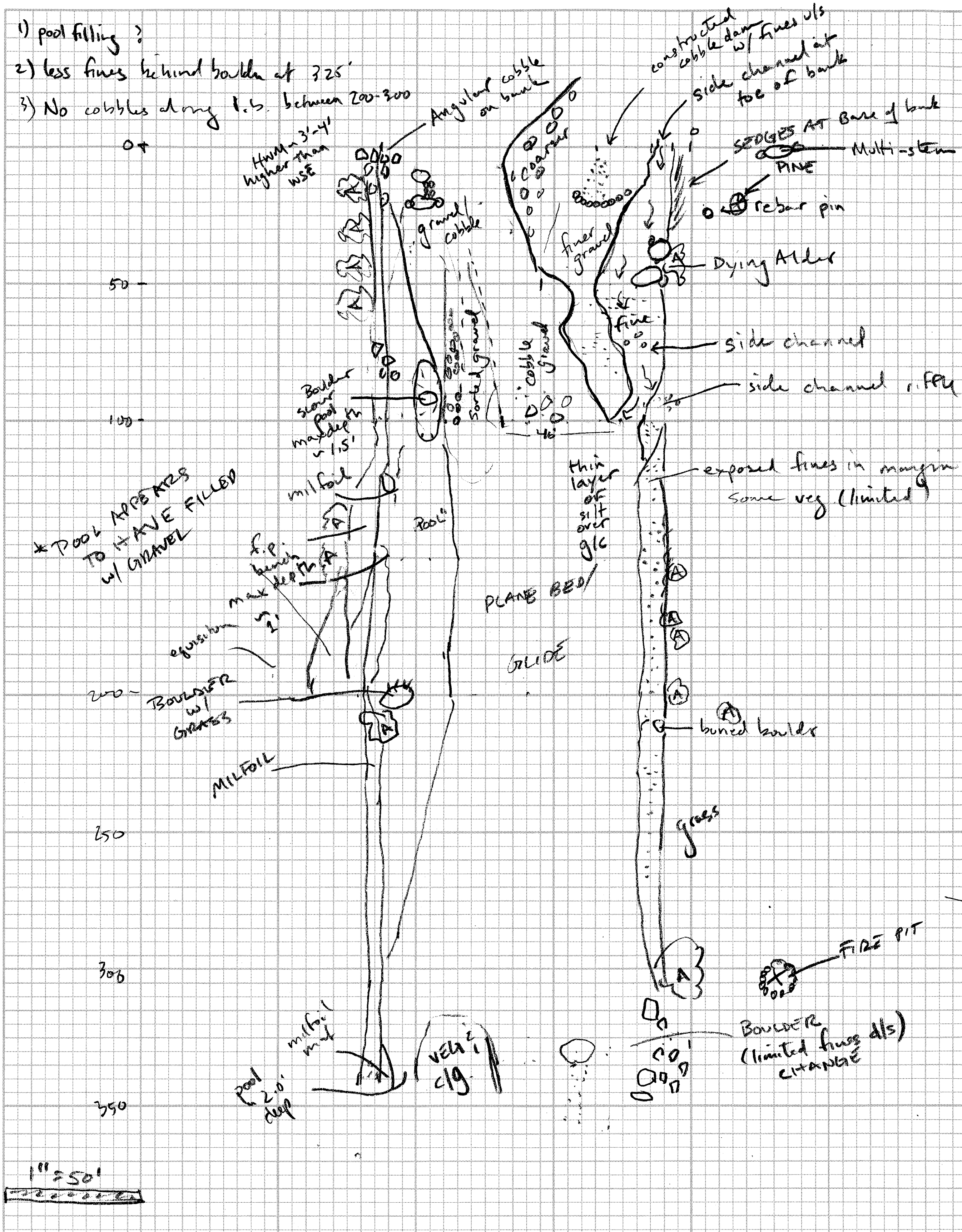
PROJECT 210011 MIDDLE TRUCKEE PROJECT NO.

SUBJECT GEOMORPH MAP / PEBBLE COUNT

BY DS w/ PK DATE 10/1/14

REVIEWED BY DATE

1) pool filling ?
2) less fines behind boulder at 325'
3) No cobbles along l.s. between 200-300



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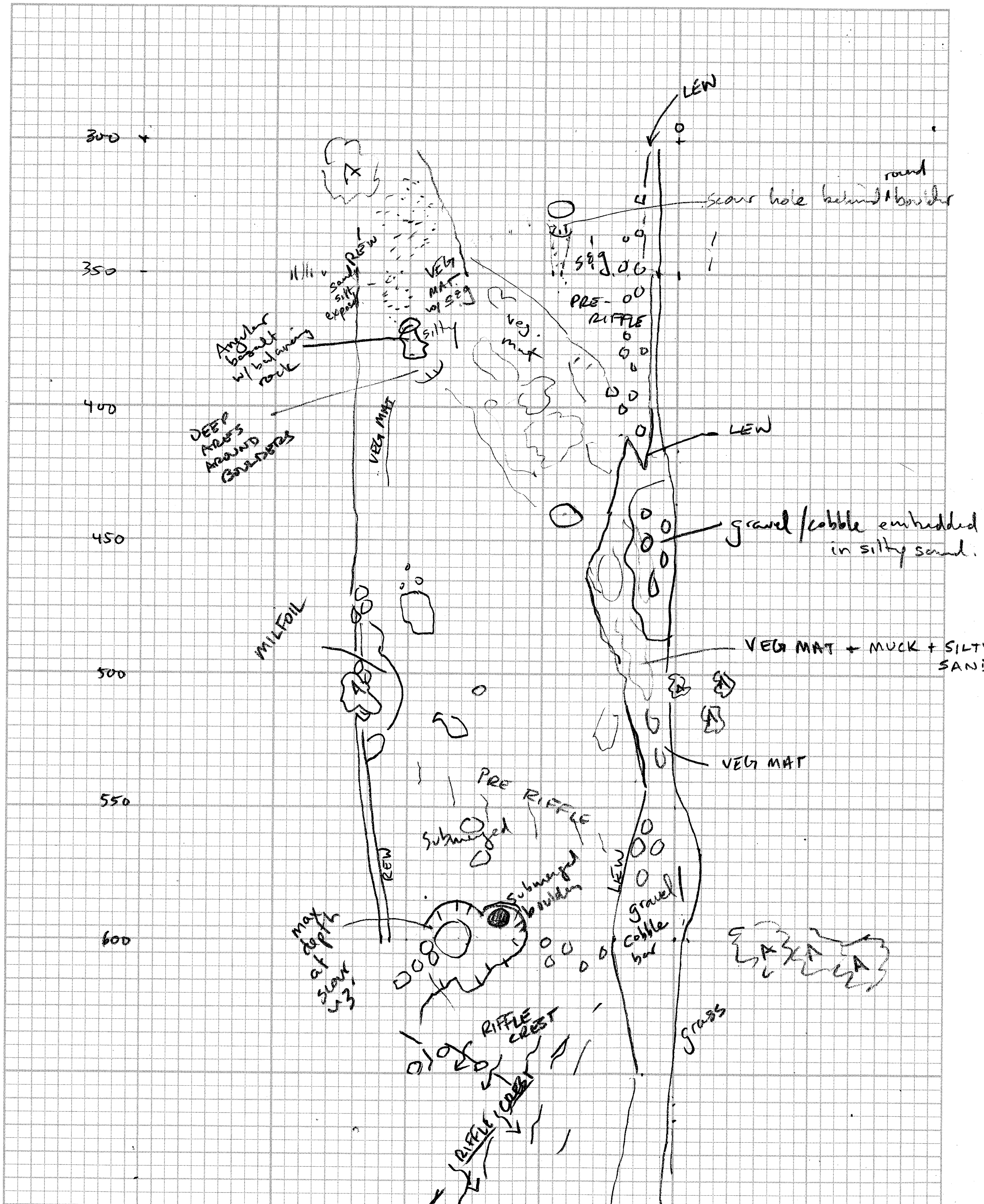
SHEET 2 OF 3

PROJECT 210011 MIDDLE TRUCKEE PROJECT NO. TMDL

SUBJECT HORSESHOE BEND

BY DS + PK DATE 10/1/14

REVIEWED BY ______ DATE ______



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Balance Hydrologics, Inc.

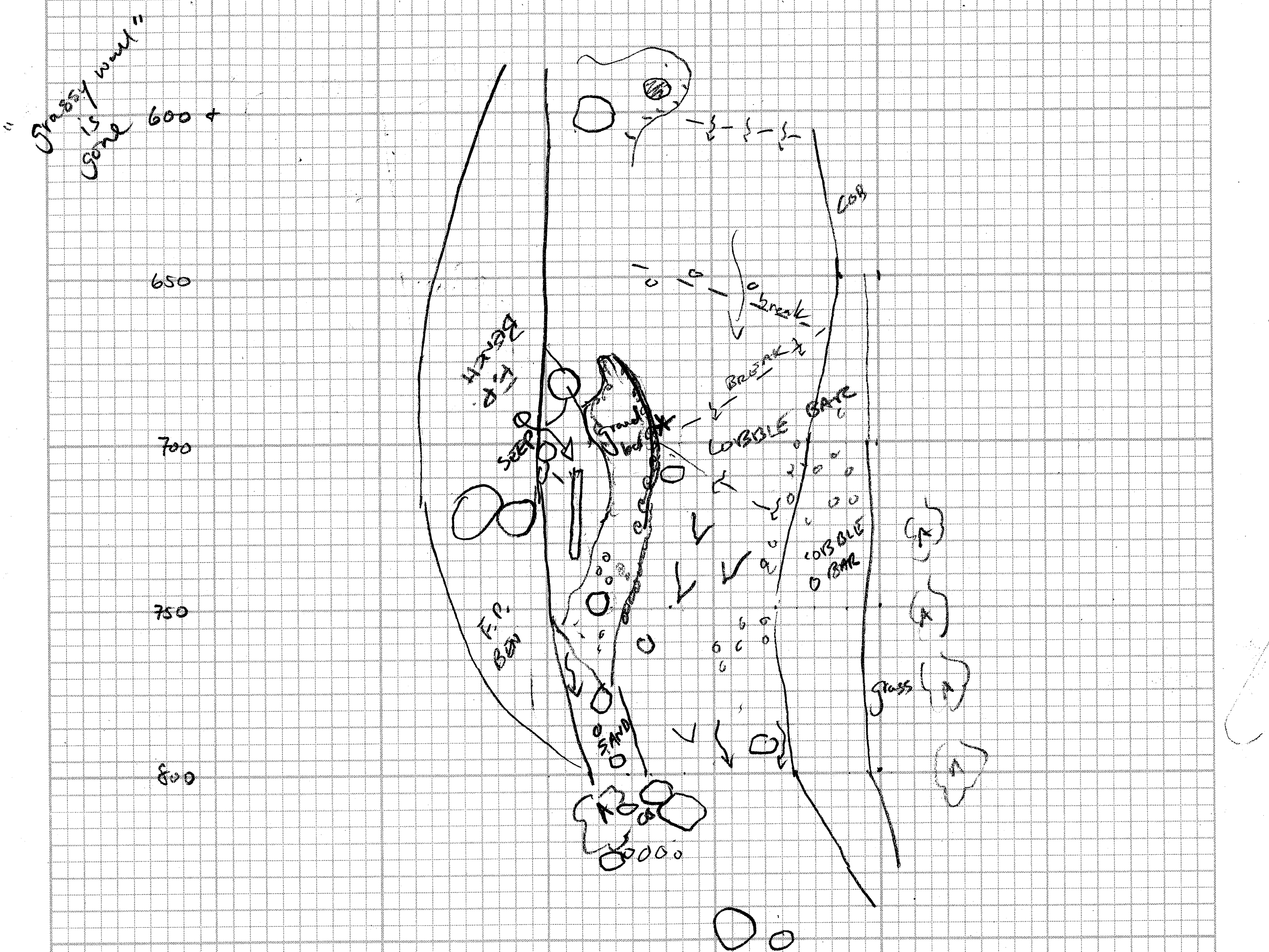
SHEET 3 OF 3

PROJECT 210011 Truckee R TMDL PROJECT NO.

SUBJECT Horseshoe Bend

BY DS + PK DATE 10/1/14

REVIEWED BY DATE



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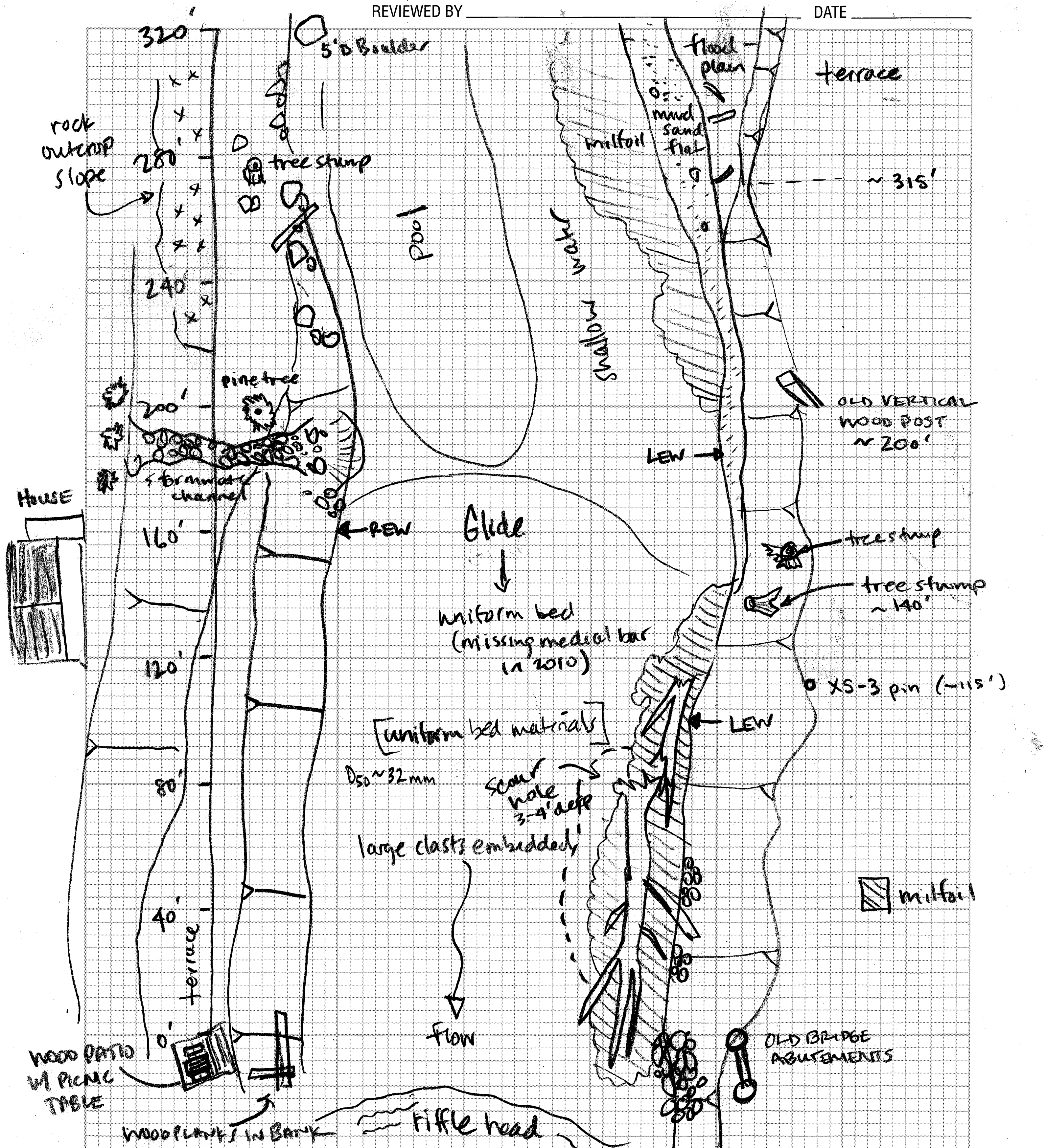
SHEET 1 OF ____

PROJECT TMDL — Middle Truckee R. PROJECT NO. 210011

SUBJECT Bed Conditions – Hirschdale Bridge

BY BKH DATE 10/9/14

REVIEWED BY ____ DATE ____



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SHEET 2 OF

Balance Hydrologics, Inc.

PROJECT TMDL – Middle Truckee R. PROJECT NO. 210011

SUBJECT Bed Conditions – Hirschdale Bridge

BY BFH DATE 10/9/14

REVIEWED BY DATE