Upper Truckee River Reach 5 Restoration Project

Effectiveness Monitoring Report

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<u>**Executive Summary**</u>

This report describes the monitoring results from short term effectiveness monitoring of the Upper Truckee River (UTR) Reach 5 Restoration Project. The Reach 5 project involved construction of approximately 7,340 feet of new river channel between 2013 and 2016. The overall goal of the project was to restore natural geomorphic and hydrologic function to the channel and adjacent meadow floodplain. The new channel has a smaller width and depth than the pre-existing channel with a bankfull capacity of 375 cfs, while the pre-existing channel required on average approximately 800 cfs flows to overbank and flood the adjacent floodplain (ENTRIX 2004). Therefore, the project results in more frequent overbank flood events, changing the return interval of overbank flooding from approximately every 5-7 years under the pre-project conditions to every 1-2 years after project completion.

Bank stability was monitored using several protocols for pre- and post-project comparisons. Pre-project results from 2 different protocols showed 46% and 59% stable banks, respectively. The post-project percent stable banks in the restoration project reach for both protocols is approximately 95%, well above the objective of 70% stable banks.

Based on our measurements at surveyed cross-sections, average bank height was decreased by 1.7 ft. This equates to approximately a 35% reduction in bank height resulting from the project. The post project width to depth ratios increased compared to pre-project values, and are more indicative of a functioning Rosgen C type stream channel. And pool-to-pool spacing decreased after project implementation, as intended.

An increase in groundwater table elevation was observed after the project was completed for all summer months monitored for all wells. In addition, all wells within the project area exhibited groundwater depths in July of 2018 within the range identified in the literature (2.5-3.3 ft) to provide sufficient water for wet meadow species, and none of the pre-project averages for July were within that range.

There was a dramatic improvement in the overall quality of the macroinvertebrates found in Reach 5 when comparing the pre-project and post-project sampling results. Based on the pre-project assessments, the observed/expected (O/E) score indicated a degraded condition (average O/E = 0.70). The O/E score for the post-project sampling was 1.05, indicating an excellent condition. This data suggests a jump in the overall biological health of the stream, even just 1 year after project completion.

As described above and in the body of this report, most of the monitoring metrics measured immediately and 1-year post-project indicate that the restoration project was successful at achieving its objectives. Not all monitoring metrics were measured for this report because more time is needed after project completion to expect measurable changes in various attributes. The remainder of the monitoring elements, and some of those monitored already will be completed approximately 5-10 years after project completion, and the results will be included in a subsequent monitoring report.

Introduction

This report describes the monitoring results from short term effectiveness monitoring of the Upper Truckee River (UTR) Reach 5 Restoration Project. The Reach 5 project involved construction of approximately 7,340 feet of new river channel with a smaller width and depth than the pre-existing channel. Project implementation began in 2012 with construction of an aggregate base pad at the Sunset Stables Staging Area, and continued in 2013, 2014, and 2016 with active channel construction. 2015 was an inactive seasoning and irrigation year. In 2017 and 2018 various adaptive management and stabilization measures were implemented in response to the large winter and spring experienced in 2016/2017 immediately following project completion. The new channel is expected to provide improved aquatic habitat, and better connection to the adjacent meadow floodplain. The approximate acreage of floodplain restored or re-activated as a result of this project is 120 acres.

The Reach 5 project included the strategic placement of 13 different types or variations of riffle bank treatments and 8 different pool bank structures along the newly constructed channel, including the use of logs, rocks, willows, erosion control fabric and/or sod. During project implementation, additional bank treatment variations were added to the design plans for several pool and riffle bank types to accommodate for the use of smaller logs and rootwads, and to provide an option for using coir fabric over sod or not, depending on sod quality and bank location. In addition, existing floodplain swales were reactivated where appropriate to dissipate flood energy on the floodplain, and log and/or willow roughness structures were also constructed at specific locations on the existing floodplain. These structures were located strategically for the purpose of increased floodplain roughness and flood energy dissipation, and to encourage sediment deposition and storage. Finally, the project graded and revegetated approximately 4.4 acres of existing floodplain near the downstream end of the project area. Less actual acres of inset floodplain creation resulted than originally planned to preserve large thickets of mature willows and reduce floodplain disturbance adjacent to the newly constructed channel.

The overall goal of the UTR Reach 5 Restoration Project was to restore natural geomorphic and hydrologic function to the channel and adjacent meadow floodplain. The project is expected to result in reduced streambank erosion, improved aquatic habitat, and enhanced floodplain connectivity over the long-term. Enhancing channel/floodplain connectivity is expected to reduce streamflow velocities and shear stress at high flows, trap fine sediments and enhance nutrient uptake, and increase the aerial extent and duration of groundwater retention to support diverse riparian vegetation. Improvement of these essential channel functions will have positive effects on pool and riffle formation, in-channel and floodplain sediment sorting and storage characteristics, groundwater retention, stream water quality, and the colonization of riparian vegetation along the channel and floodplain. The long-term result of restoring channel/floodplain function will be improved aquatic and riparian habitat and decreased suspended and fine sediment loading into Lake Tahoe.

The new channel was designed for a bankfull capacity of 375 cfs, while the pre-existing channel required on average approximately 800 cfs flows to overbank and flood the adjacent floodplain (ENTRIX 2004).

Therefore, the project results in more frequent overbank flood events, changing the return interval of overbank flooding from approximately every 5-7 years under the pre-existing conditions to every 1-2 years after project completion.

Project Effectiveness Monitoring

The Project Effectiveness Monitoring Plan (LTBMU, June 2013) described many monitoring protocols and metrics, some of which were required, and some of which were optional and dependent on the availability of funding. Also, many of the monitoring elements require several years after project completion before any change is expected, or before conclusions can be drawn from the monitoring results (e.g. vegetation monitoring on the floodplain and stream temperature monitoring). Therefore, this monitoring represents only a subset of the project effectiveness monitoring results for which funding was available and the metrics were ready for post-project monitoring. For a detailed list of all required monitoring elements from the Project Effectiveness Monitoring Plan and the 401 Certification for this project and the status of each, see Appendix A.

This report is organized in the following way:

1. Physical attributes
    a. As-built survey
        i. Longitudinal profile
            1. Residual pool depth
            2. Pool to pool spacing
    b. Stream Condition Inventory (SCI)
        i. Cross-sections
            1. Bank height
    c. Bank stability
    d. Groundwater monitoring
    e. Physical habitat attributes based on SWAMP protocol
2. Biological attributes
    a. Macroinvertebrate monitoring
    b. Western Pearlshell Mussel monitoring
    c. Bat monitoring
3. Photos and visual inspections
    a. Photo points and other representative photos
    b. Aerial photos
        i. Vegetation vigor based on NDVI
    c. Visual inspections during flood events
    d. Adaptive Management monitoring

Section 1: Physical Attributes

<u>a. As-built survey</u> – An as-built geomorphic survey was conducted immediately following construction to document the constructed channel and ensure that the channel and floodplain grading areas were

constructed as designed, in accordance with the surveying tolerances stated in the Technical Specifications. The As-built survey was completed in phases, with the segments of channel that were constructed in 2013 and 2014 surveyed in 2015, and the segments of channel constructed at tie-ins in 2016 surveyed immediately following construction in 2016. The post-project longitudinal profile was pulled from the as-built survey, and is compared to a longitudinal profile survey conducted along the pre-project channel in this reach in Appendix B. The protocol used for the pre-project 2013 longitudinal profile survey is from Stream Channel Reference Sites: An illustrated guide to field technique (Harrelson et al. 1994). This protocol requires the tape to be strung along the channel centerline. To pull the longitudinal profile from the as-built survey, a line was drawn between each thalweg survey point along the deepest part of the channel. Following the channel centerline results in a slightly shorter overall channel length than following the thalweg. Both the pre- and post-project surveys extended slightly upstream and downstream of the new channel construction to tie back into the pre-existing channel. In fact, the pre-project survey is slightly longer than the post-project surveyed channel length, 8,100 ft vs. 7,822.6 ft, or 277.4 ft difference. Although the difference in protocols for the longitudinal profile surveys from before and after project completion results in slight variations in overall channel length, the plots of the surveys as compared in Appendix B still show distinct changes to the channel bed form resulting from the project.

The as-built survey concluded that the channel through Reach 5 was constructed according to the design plans, resulting in overall channel capacity being decreased from an average of 800 cfs to an average of 375 cfs. Note: some aspects of the project were not constructed according to the original design plans, such as the former channel backfill. Some of the former channel in the upstream portion of the project area was only partially backfilled due to a shortage of fill material and running out of time in the final construction year. These changes are reflected in the red-line marked up plans, which are not included in this report.

The pre- and post-project longitudinal profile surveys were also used to measure channel bed elevations throughout the project reach, including average residual pool depth and pool to pool spacing, and the variability of these metrics. Greater pool depth and more frequent pools (i.e. less spacing between pools) are both indicators of improved aquatic habitat. The pre-project pool to pool spacing and residual pool depth measurements were taken from the plot of the longitudinal profile from 2013. These values were compared to measurements taken off the plot of the As-built longitudinal profile survey from 2015/2016. The average pool depth decreased after project implementation from 2.4 ft pre-project to 1.9 ft post-project. Given that the restored channel is much smaller than the pre-existing channel, this is not a surprise. This is not a good indicator of project success, given the large reduction in overall channel size resulting from restoring this reach of the channel, and the difficulty with increasing pool depth while decreasing overall channel size. Pool-to-pool spacing decreased after project implementation as intended, even though the channel length measurement was skewed as described above by running the tape along the channel centerline for the pre-project survey and along the thalweg for the post-project survey. Pre-project pool-to-pool spacing was on average 367 ft, with a range from 83 ft to 1,115 ft. The post-project pool-to-pool spacing was on average 342 ft, with a range from 142 ft to 667 ft.

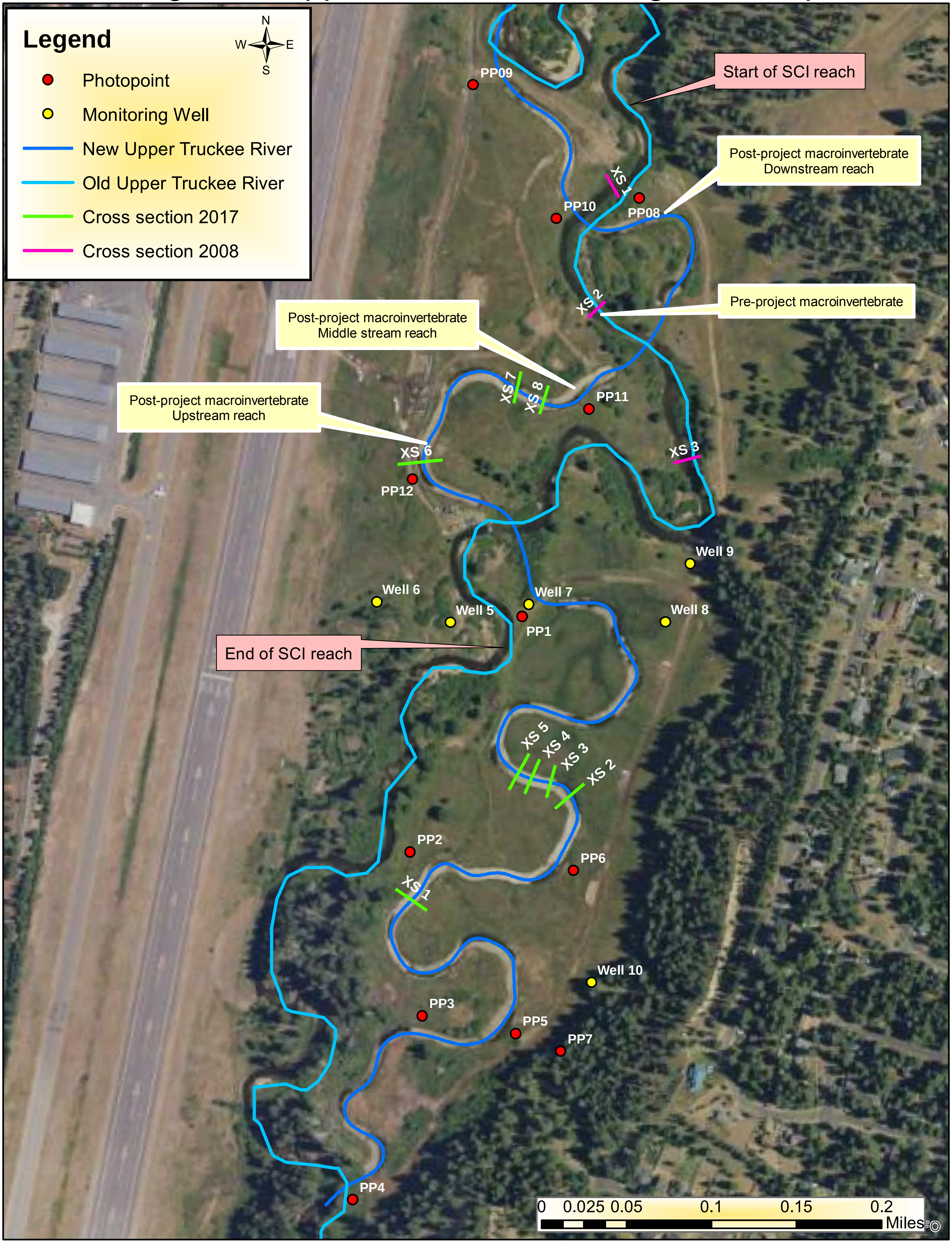
b. Stream condition inventory (SCI) monitoring – Some components of the Region 5 Stream Condition Inventory (SCI) Technical Guide (Frazier et al., 2005) were used to evaluate the channel conditions to track changes and trends in response to the project. SCI monitoring was conducted for the entire suite of SCI metrics in 2008 along a 1,000 m segment of Reach 5 before project implementation (Figure 1). Only a subset of the SCI metrics were repeated in the post project channel prior to this report, including cross sections, bank height, bank stability, and width-to-depth ratio.

Appendix C presents the cross-section plots from before and after project implementation. Because the existing channel was backfilled and a new channel constructed, new cross-sections were established in 2017 following the completion of restoration activities (Figure 1). These surveys were completed after the large flood events in the winter and spring of 2016/2017 because flows in the river were too high to safely complete cross-section surveys in 2016 after channel construction was complete. Three cross sections in riffles, 2 in runs, 1 in a glide, and 2 in pools were established with monuments for repeat surveys to track changes in these features over time. Because large flood events occurred prior to completing these cross-sections, the pools may have deepened compared to how they were originally constructed. Based on visual observations in the project area, riffle material was largely not altered by the large flood events, so the channel bed at riffles and runs are assumed to be very similar in these plots as they were when constructed. The SCI protocol only required cross-sections in fast water reaches of the channel, therefore, all the pre-project cross-sections were in riffles.

One of the project objectives was to decrease bank height by approximately 2 to 4 ft on average. Bank height was measured at the SCI cross sections. Based on the SCI cross-sections completed in 2008, the pre-existing average bank height at fast water reaches of the river (i.e. riffles and runs) was 4.8 ft, ranging from 3.7 to 6.7 ft. Bank height at fast water reaches decreased to an average of 3.1 ft, with a range from 2.4 to 4.0 ft after project implementation, according to the riffle and run cross-section geometry. Based on our measurements at surveyed cross-sections, average bank height was decreased by 1.7 ft. This equates to approximately a 35% reduction in bank height resulting from the project.

Channel width to depth ratio is also an important indicator of stream condition. Width to depth ratios were measured in 2008 for the pre-project conditions using the SCI protocol. For comparison, these dimensions were taken from surveyed cross-sections at fast water reaches for the post-project conditions. The pre-project width to depth ratios at cross sections 1, 2, and 3 were 7.19, 12.63 and 10.95, respectively. Width to depth ratios at the 5 cross sections measured in fast water reaches post project ranged from 13.1 to 15.13, with an average of 14.5. The low end of width to depth ratios for Rosgen C type channels (such as this reach of the UTR) is 12 (Rosgen, 1996). Channel dimension, pattern, profile, and corresponding stream types change when width to depth ratio is significantly altered (Rosgen, 1996). Pre-project width to depth ratios were low for a C type stream. The post project width to depth ratios increased compared to pre-project values, and are more indicative of a functioning C type stream channel.

Figure 1: Upper Truckee Monitoring Sites Map



c. Bank stability – Another project objective identified in the Project Effectiveness Monitoring Plan was to increase channel stability to approximately 70% stable banks. Bank stability measurements were taken during the 2008 SCI survey along the 1,000 m segment of Reach 5. The results indicated that the pre-project channel exhibited 46% stable banks (having more than 75% or more cover of living plants and/or stability components that are not easily eroded, and have no indicators of instability), 25% vulnerable banks (having 75% or more cover but with one or more instability indicators), and 29% unstable banks (having less than 75% cover and possibly also instability indicators). In addition, the TRPA conducted physical habitat monitoring as part of their benthic macroinvertebrate (BMI) monitoring in 2014 using SWAMP protocols. The pre-project bank stability monitoring from TRPA showed 36% eroded banks, 59% stable banks, and 5% vulnerable banks.

Post-project bank stability assessments were completed after the adaptive management and emergency stabilization measures were completed in 2017, effectively stabilizing several segments of eroded banks that resulted after the 2016/2017 winter and spring. For post-project comparison to the pre-project bank stability data, two metrics were used. The TRPA again collected physical habitat data using SWAMP protocols while completing the macro-invertebrate sampling in 2017 (described in detail below). Based on their results, the percent eroded banks decreased to 5% post project, stable banks increased to 95% post-project, and vulnerable banks decreased to 0% post-project. In addition, after adaptive management and emergency stabilization activities were completed in the fall of 2017, the entire restored Reach 5 channel was visually monitored for streambank stability, rather than only measuring this metric on a segment of the reach. Unstable banks identified during the post-project monitoring were photographed and their location along the channel profile was identified so that these areas can be tracked over time. The length of each eroding or vulnerable bank segment was noted. Based on the results of this assessment, 4% of the total restored channel bank length is eroding or vulnerable to erosion.

Based on both the TRPA bank stability measurements on a segment of the restored channel and those conducted by the LTBMU tracking all segments of eroding or vulnerable banks, the post-project percent stable banks in the restoration project reach is approximately 95%, well above the objective of 70% stable banks.

d. Groundwater monitoring – Groundwater elevation was measured at 4 monitoring well locations within the Reach 5 meadow installed in the project area in 2005 (Figure 1, wells labeled 5-8). Four additional wells were installed in Reach 6 and monitored since 2005, but are not discussed in this report because they are outside of the project area. New channel construction eliminated well #7, so monitoring at this site was discontinued. Several years of pre-project data have been collected at these sites, and these wells continue to be maintained now that the Reach 5 Restoration project is complete. In addition, two other groundwater wells exist in the Reach 5 meadow and are shown in Figure 1 (Wells 9 and 10), which were monitored starting in 2013. Due to extremely low groundwater table elevations at site #10, monitoring was discontinued at this site in 2015. However, starting in 2019, this site will be monitored again to track post-project groundwater table elevations.

For this report, the 3 original wells established in 2005 that still remain in the project area (well #5, 6, and 8), and one additional well that has been monitored since 2013 (well #9) are included for analysis and discussion. The graphs of groundwater elevation at each of these 4 wells for the duration of the monitoring record are presented in Appendix D.

Monitoring occurs monthly throughout most of the year to track groundwater table elevations in the represented portions of the project area. Under pre-project conditions, the groundwater table was between 5 and 7 ft below the meadow surface during summer months (approx. July-Sept), and more than 2 ft deep by approximately June 1st each year. The data indicates high variability based on water year, and also some variability between individual monitoring wells. Groundwater needs to remain within 0.75 to 1 meter (approximately 2.5-3.3 ft) of the surface of the meadow during June and July in order to provide sufficient water for wet meadow species (Micheli and Kirchner 2002, Loheide and Gorelick 2007). Therefore, after project completion, the target for late season groundwater table was to increase groundwater elevation by approximately 2 ft, so that it is approximately 2 to 3 ft below the meadow surface during summer months.

Because 2017 was an anomalously large water year, and no similar water year exists in the pre-project groundwater monitoring record, it was left out of this comparison. There was a dataset for pre-project conditions (9 years for wells 5, 6, and 8, and 4 years for well 9) which allowed the pre-project data for each summer month to be averaged for all pre-project years and compared to the data collected in 2018 (which was approximately an average water year for the area). It's worth noting that several years in the pre-project data record were drought years, including 2007-2009 and 2012-2016. Unfortunately, groundwater monitoring was not conducted in June of 2018, and since 2017 was an anomalously wet year and couldn't be used for direct comparisons, at this time no determination can be made about the project's effect on June water table elevations. Groundwater elevations will be monitored beginning in early June for the next several years.

The summary of groundwater monitoring results for these 4 wells for the summer months is provided in Table 1 below. Data is provided in measurements of feet below ground surface (ft bgs).

Table 1: Summary of groundwater data for summer months.

Well #	**Sampling Month**	**Pre-project average (ft bgs)**	**2018 value (ft bgs)**	**Difference (ft)**
5	July	4.52	2.99	1.53
	August	5	4.76	0.24
	September	4.99	4.17	0.82
6	July	4.52	2.83	1.69
	August	4.82	3.97	0.85
	September	4.83	4.26	0.57
8	July	3.97	2.7	1.27
	August	4.88	3.15	1.73
	September	6.42	3.18	3.24
9	July	4.86	2.86	2
	August	5.47	3.84	1.63

	September	5.75	4.31	1.44

As shown in Table 1, for all summer months monitored for all wells, an increase in groundwater table elevation was observed after the project was completed. However, only well number 9 exhibited a 2 ft increase in groundwater table elevation in July of 2018 compared to the pre-project average for that month. Nonetheless, all four of the wells within the project area exhibited groundwater depths in July of 2018 within the range identified in the literature cited above (2.5-3.3 ft) to provide sufficient water for wet meadow species, and none of the pre-project averages for July were within that range.

Because only 1 post-project monitoring year is included in this comparison, the project effects on groundwater table elevations should be revisited in the next project monitoring report when a larger post-project dataset representing a variety of water years is available.

e. Physical Habitat using SWAMP – Although this metric was not identified in the Project Effectiveness Monitoring Plan, physical habitat data was collected by the TRPA using SWAMP protocols at the Reach 5 project macroinvertebrate sampling site (Figure 1). Based on this data, there was a marked improvement in bank erosion (detailed above), substrate type, and overall fish cover shown in the data. Several of the changes noted between the 2014 pre-project monitoring and the 2017 post-project monitoring include: an increase in percent cobble from 1% to 7%, an increase in percent coarse gravel from 10% to 22%, a decrease in percent fines from 7% to 0%, and a decrease in percent hardpan from 31% to 5%. The median particle size (d50) increased from 1.03 mm to 3 mm from 2014 to 2017. And, natural shelter cover increased from 10.9% to 22.4% as a result of the project. These are all indicators of improved aquatic habitat in the project area resulting from project implementation.

Section 2: Biological Attributes

a. Macroinvertebrate monitoring – Macroinvertebrates have been used as biological indicators of water quality and habitat conditions in both California and Nevada (Harrington 2000). Macroinvertebrate species abundance and the diversity of benthic macroinvertebrate (BMI) communities are expected to be maintained or improved as physical conditions within the stream channel are restored to a pre-disturbance condition (Gerard and Hellethal 2003). The TRPA has a macroinvertebrate sampling site within this reach of the UTR. This monitoring site is a trend site, which will be monitored every other year in even years. Based on the 2012 and 2014 assessments at the site located within Reach 5, the observed/expected (O/E) score indicated a degraded condition (O/E = 0.73 and 0.66, respectively).

Because the river was relocated as part of this restoration project, the long-term trend site also needed to be relocated into the new channel. The LTBMU worked with TRPA to ensure that this site was re-established in the new channel, and that continued macroinvertebrate monitoring will continue to be conducted at this site now that the project has been completed. Macroinvertebrate sampling followed the SWAMP protocol, as described in the Project Effectiveness Monitoring Plan. There was a dramatic improvement in the overall quality of the bugs found in Reach 5 when comparing the pre-project and post-project sampling results, with much more EPT (mayflies, stoneflies, and caddisflies) and fewer pollution-tolerant species. The post-project sampling was completed in 2017, and the O/E score for the site at that time was 1.05, indicating an excellent condition. According to the TRPA, any score near 1 is good, indicating that the BMI found in the stream are what would be expected in a healthy "reference" stream. This data suggests a jump in the overall biological health of the stream, even just 1 year after project completion.

b. Western Pearlshell Mussel monitoring – Western Pearlshell mussels are known to occur in the Upper Truckee River. Pre-project snorkel surveys estimated a total mussel population of approximately 10,440 individual mussels within the Reach 5 project area. In order to improve the success of large scale relocation efforts and because little information was available about relocation criteria, a pilot relocation study was conducted in 2014 and 2015. During the pilot study, approximately 10% of the total mussel population in Reach 5 was weighed, measured, tagged and relocated to study plots in the UTR, Trout Creek, Cold Creek and the Truckee River. These plots were monitored for several years to evaluate relocation success and impacts of relocation on the mussel population, to determine important habitat variables for mussel survival, and to compare the findings to control plots within Reach 5. The findings from the pilot relocation study are not discussed in detail in this report, but are available in Appendix E.

Between 2015 and 2016, project-wide mussel relocation efforts took place in Reach 5 as guided by the pilot study results, and a total of 25,409 mussels were relocated. All mussels were relocated to other known locations of mussels or areas thought to provide suitable habitat prior to dewatering and backfilling the former channel in the final implementation year. Relocation sites were located on Cold Creek, Trout Creek, other reaches of the UTR, and on the Truckee River. Mussel relocation success was monitored using snorkel surveys in the vicinity of the relocation sites to count the total number of mussels present in 2017. Approximately 1,000 mussels from the poorest performing relocation sites were moved back into the newly constructed Reach 5 channel in 2017, after the aquatics staff at the LTBMU determined that the restored Reach 5 channel exhibited the habitat characteristics needed to support them.

Snorkel surveys took place between August 7th and October 5th of 2017 to monitor the success of relocating the mussels. These surveys were conducted starting 100 ft downstream of the first reach of every site, continued through adjacent reaches and ended 100 ft upstream of the last reach. This survey area was intended to include the natural movement of mussels. However, in the pilot relocation study, it was determined that the maximum distance travelled by mussels in the downstream direction was 165 meters (over 540 ft). This was likely due to the very high water year in 2016/2017 carrying mussels downstream with the river current.

During the post-project snorkel surveys, a total of 12,820 mussels were rediscovered out of the 25,409 mussels that were relocated from Reach 5 in 2015 and 2016. Therefore, a total of 50% of the relocated mussels were rediscovered during snorkel surveys in the 2017 field season. While only 50% were detected during the 2017 monitoring efforts, this does not necessarily equate to the survival rate of all relocated mussels. Only about 41% of the mussels that were present within the Reach 5 channel before project implementation were identified during pre-project snorkel surveys. It is likely that more than 50% of the relocated mussels are alive, but that they were not found during snorkel surveys because they moved outside of the survey area, or burrowed into the ground making detection of them more difficult. Based on the large distance travelled by mussels in the pilot relocation study, the post-project snorkel survey area may have been too small to detect all the relocated mussels. Snorkel surveys, while the most cost-effective way to monitor presence of this species, is not the most effective way to detect all individuals in a given site. What these findings can tell us is that at least 50% of the mussels survived the relocation one or two years post relocation.

Bat monitoring – Because the extent and duration of meadow wetness has increased as a result of the project, potential foraging habitat for bats is also likely to increase. A Before/After/Control/Impact (BACI) monitoring design was used for the bat surveys. Bat surveys were conducted using the protocol presented in the Project Effectiveness Monitoring Plan to assess the project effects on bat species richness and frequency.

Desired condition bat species for the Upper Truckee River Restoration are:

- Spotted bat (*Euderma maculatum*)
- Townsend's big-eared bat (*Corynorhinus townsendii*)
- Long-eared myotis (*Myotis evotis*)
- Fringed myotis (*Myotis thysanodes*)
- Yuma myotis (*Myotis yumanensis*)

Two of these species, Townsend's big-eared bat and fringed myotis, as well as pallid bat *(Antrozous pallidus)*, are also designated US Forest Service Region 5 Sensitive species.

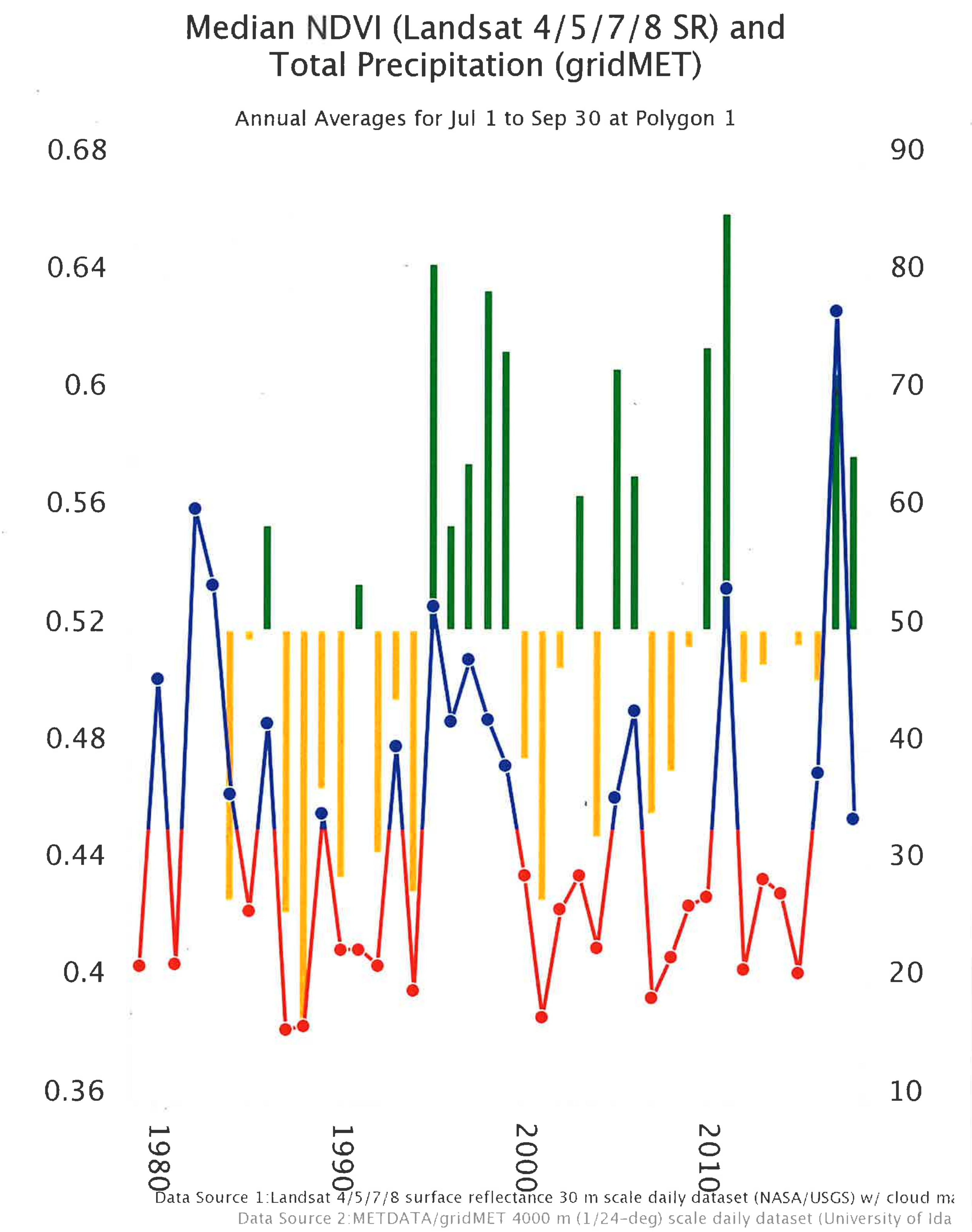
The control site designated for monitoring purposes was the Truckee-Trout Marsh. The Truckee-Trout Marsh control site and the Upper Truckee River restoration site were monitored for pre-project bat conditions in 2006 and post-project bat conditions in 2017. A total of four species were detected at the control site in 2006, while the same four species plus two additional species were found at the restoration site. In 2017, seven species were found at the control site and eight species were found at the restoration site. Therefore, species richness increased at both the control and the restoration site from pre-restoration to post-restoration. There was not a definitive increase or decrease in species richness that could be attributed to the restoration project. Detection frequency could not be calculated for the pre-restoration data. Therefore, even though the post-restoration detection frequency was significant, there was nothing to compare it to in order to determine if the restoration project had an effect.

Section 3: Photos, Inspections, and Adaptive Management

a. Photo points and other representative photos – Photo points were established throughout the project area to monitor whether a stable channel alignment and vegetation on the banks is maintained. Photos will also be used to monitor the extent and vigor of meadow and riparian vegetation over time. Twelve long-term photo points were established at strategic locations prior to project implementation to document existing conditions and to characterize new channel construction, floodplain grading, and tree removal areas and changes to these areas over time (Figure 1). Photo point locations were determined prior to project construction, and were identified with GPS coordinates and monumented in the field for repeatability. Subsequent post project photos were taken to document channel stability over time and/or changes in channel morphology, and vegetation establishment and vigor. Representative photos from pre, during and post-project time periods for several of the monumented photo points and other locations within the project area are presented in Appendix F.

b. Aerial imagery – Google Earth images were compared from pre-project conditions and post-project. The Google Earth platform provides sharper, less pixelated images than NAIP, and provides the ability for geo-referencing. These comparisons will be particularly useful in tracking revegetation of disturbed areas, and tracking meadow greenness over the long-term. In addition, project specific aerial photos were collected in December of 2016 and May of 2017 by a private entity immediately following flood events, and were shared with the LTBMU staff. Aerial imagery analyzed in series can provide useful information about project wide changes to channel sinuosity, total channel length, vegetation communities, meadow wetness during certain times of the year, and presence and extent of ponded water on the meadow surface (depending on the timing of collected images). See Appendix G for a few examples of the aerial images collected in 2016 and 2017 immediately following flood events in the project area.

A method called normalized difference vegetation index (NDVI) has been used in the recent past to compare Landsat images of a given project area over time. This method compares images at the same time of year from before and after a project or event, and looks at vegetation color indices to determine whether vegetation vigor and cover has changed because of that project or event. It plots the NDVI results against total precipitation amounts for each year. In addition to the monitoring described in the project monitoring plan, NDVI image comparison for the UTR Reach 5 project has been completed, and the resulting graph is presented in Figure 2. Because only 2 years have passed since project completion, and no drought years have been experienced during that time frame, the results are not yet conclusive. But, NDVI scores for each post-project year have been above the median value. Similar precipitation years to 2018 from before the project was implemented correspond to similar NDVI scores in some cases (e.g. 2005), and below median NDVI scores in other cases (e.g. 1989). This tool is particularly useful when several years have passed after completing a restoration project, representing the full range of precipitation scenarios. The LTBMU intends on repeating this metric in another 5-10 years, and including this in future monitoring reports.



Median NDVI (Landsat 4/5/7/8 SR) and
Total Precipitation (gridMET)
Annual Averages for Jul 1 to Sep 30 at Polygon 1
0.68
0.64
0.6
0.56
0.52
0.48
0.44
0.4
0.36
90
80
70
60
50
40
30
20
10
1980
1990
2000
2010
Data Source 1:Landsat 4/5/7/8 surface reflectance 30 m scale daily dataset (NASA/USGS) w/ cloud ma
Data Source 2:METDATA/gridMET 4000 m (1/24-deg) scale daily dataset (University of Ida

c. Visual inspections during flood events – Visual observations were made during various flood flow conditions over the 375 cfs design flow (based on USGS gage 10336610) to determine the actual flow needed to overbank the new channel in this reach. The areas where overbank flow was and was not occurring, and the approximate flows needed to overbank the entire constructed channel were noted. Although access to the monumented photo points was not always available during flood events, photos were taken during these inspections to document the extent of flooding at various flows. Some examples of floodplain inundation at various flows are presented in Appendix H.

One of the objectives of the project was to decrease channel capacity from an average of approximately 800 cfs to approximately 375 cfs and increase floodplain inundation frequency and duration. Based on visual observations and photo documentation at various flows, the restored channel is confirmed to overbank at approximately 375 cfs on average. There are several locations where overbanking occurs at lower flows (275-325 cfs), and several locations that require larger flows to experience overbanking, as detailed in the modeling report prepared for the LTBMU (AECOM 2018). However, in most of the project area the floodplain is activated at approximately 375 cfs, as designed.

d. Adaptive management – Lake Tahoe Basin Management Unit staff have visited the site each year since construction with permitting and partner agencies (primarily during and after spring high flow conditions) and conducted visual observations of the channel bed and banks and floodplain areas to determine whether any adaptive management actions are needed. In addition, a small group of agency representatives that are actively involved in UTR restoration efforts have formed an Adaptive Management Group to collectively determine whether or not, and if so when additional actions may be needed in each of the UTR restoration project areas. This group, which is comprised of staff members from the LTBMU, California Tahoe Conservancy, California State Parks, and the City of South Lake Tahoe have agreed to participate in one field walk and one office meeting per year (as needed) for at least 5 years after completing project construction for each restoration reach. These groups have conducted visual observations each year since Reach 5 project completion, and collectively identified signs of bank erosion, bare soil areas vulnerable to erosion or flooding impacts, or other indicators of the potential for future resource damage. These field visits, rather than the results of the monitoring described above, have been used to determine if additional actions are warranted to prevent a chronic or worsening trend in erosion or channel instability.

Due to the large water year experienced in 2016/2017, field visits were conducted immediately following construction completion in late 2016 after large flood events occurred in the project area, and the spring/early summer 2017 following construction completion after flood flows were experienced throughout most of the project area for the entire duration of the winter. Based on observations made during these field visits, the LTBMU with Lahontan and the CTC identified adaptive management and emergency stabilization measures needed in the project area. These measures were implemented in 2017 and 2018, and effectively stabilized several vulnerable or eroding segments of newly constructed channel banks, in addition to stabilizing the partially backfilled former channel and improving revegetation of temporary disturbance areas. Refer to the Short-term Corrective Action Plan (December 2016), Adaptive Management Plan (August 2017), Emergency Stabilization Plan (August 2017), and the Long-term Corrective Action Plan (July 2018) for more details about the actions that were taken.

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Appendix A: Detailed list of all required monitoring elements and their status

The required monitoring elements from the Project Effectiveness Monitoring Plan and the 401 Certification are listed below. Next to each monitoring element is the status of that monitoring.

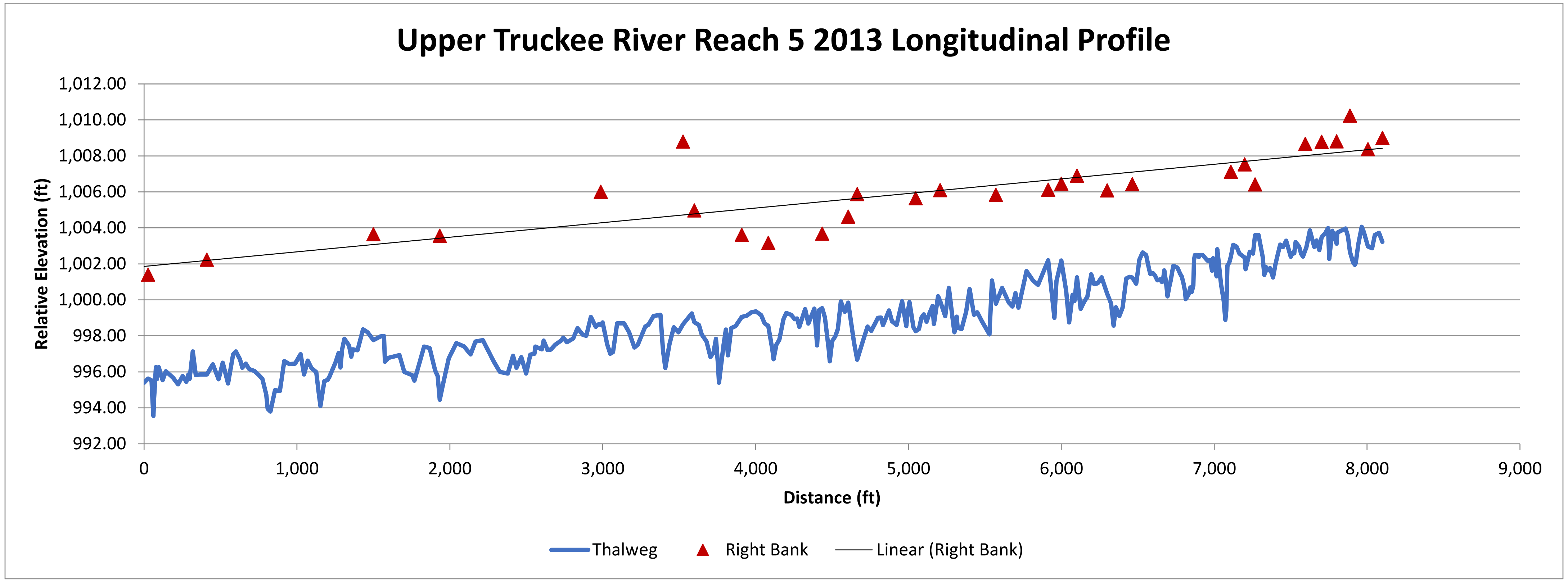
The Project Effectiveness Monitoring Plan for the UTR Reach 5 Restoration project identified the following monitoring elements as being required:

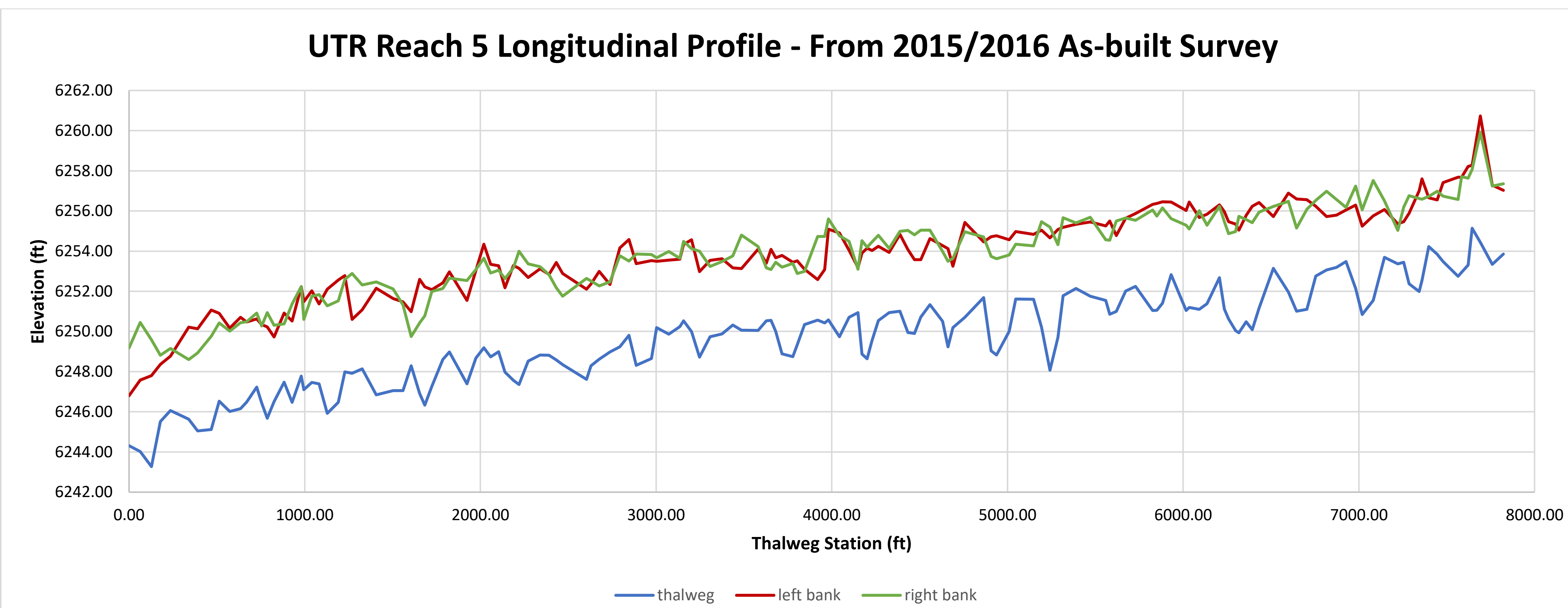
- As-built survey – Completed in 2016 and 2017.
- Photo-point monitoring – Completed July 2018
- Stream Condition Inventory (SCI) monitoring
  - Particle size distribution – LTBMU proposes that this is not necessary given that the particles installed as part of this project are largely those still found in the project reach. This will be completed 5-10 years after project completion.
  - Large woody debris – None of the installed wood meets the requirement to be counted as LWD in the SCI protocol. Not necessary to complete this monitoring at this time. This will be completed 5-10 years after project completion.
  - Cross-sections – Completed in 2017
  - Width-to-depth ratio – Completed in 2017 using surveyed cross-sections.
  - Entrenchment ratio – Completed in 2017 using surveyed cross-sections.
  - Bank stability – Completed in 2017
  - Number of pools – Completed, taken from longitudinal profile
  - Residual pool depth – Completed, taken from longitudinal profile
- Aerial Imagery – Completed and ongoing
- Visual Inspections during >375 cfs flows – Completed and ongoing
- Macroinvertebrate monitoring – Completed by TRPA
- Groundwater monitoring – Completed and ongoing
- Monitor relocation success for Western Pearlshell Mussels – Completed
- Stream temperature monitoring – Completed and ongoing
- Adaptive Management – Completed and ongoing

The following additional monitoring elements that were not identified as required monitoring elements in the project Effectiveness Monitoring Plan, were added to the required monitoring in the 401 Certification:

- Longitudinal profile survey – Completed
- Measure bank height using Rosgen methods – Completed using surveyed cross-sections
- Monitor bank stability using Rosgen method of Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) – LTBMU took photos, measured length and noted station of all segments of eroding or unstable banks. Rosgen bank stability, including BEHI and NBS will be completed 5-10 years after project completion.

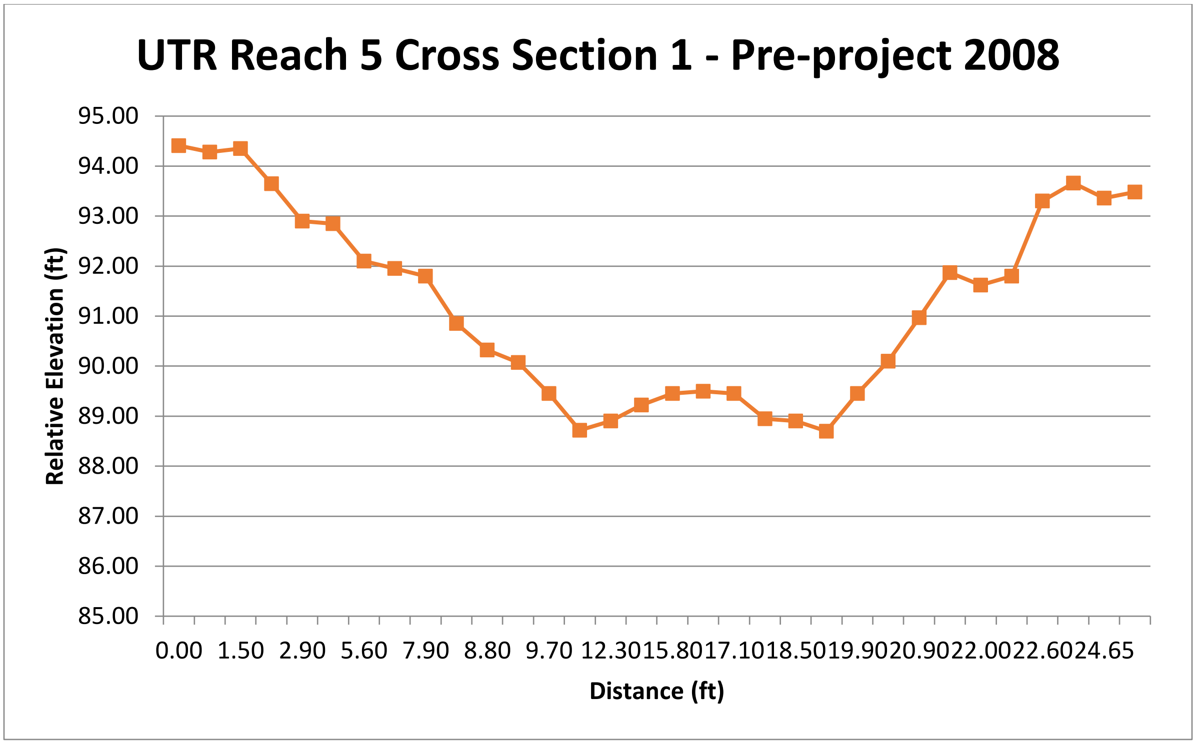
Appendix B: Pre- and Post-Project Longitudinal Profile Plots

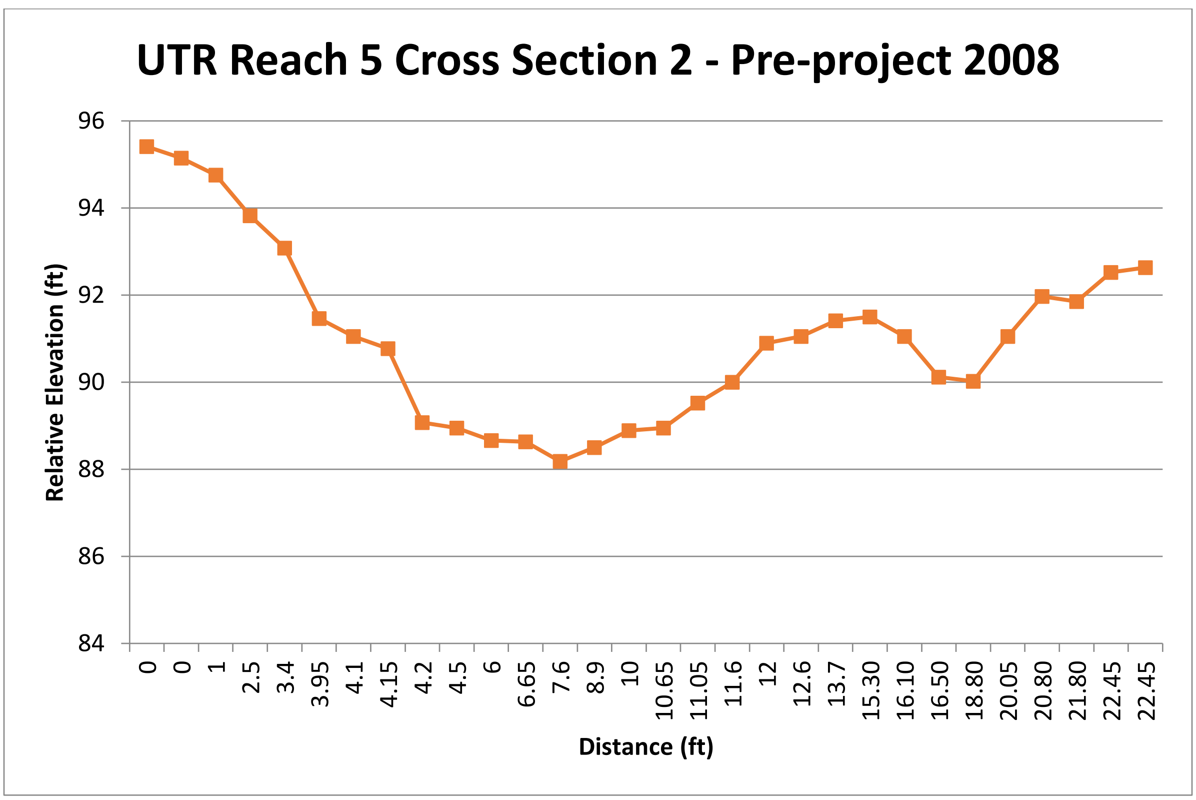


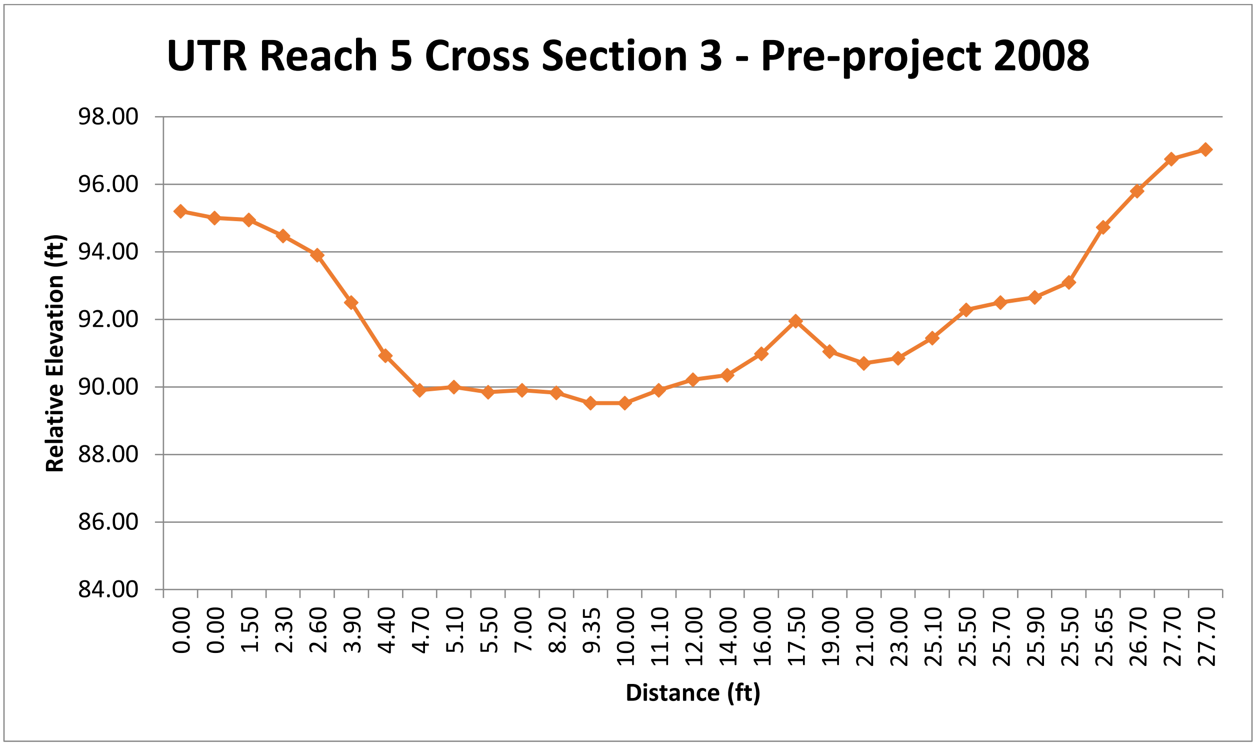


Appendix C: Pre- and Post-Project Cross-section Graphs

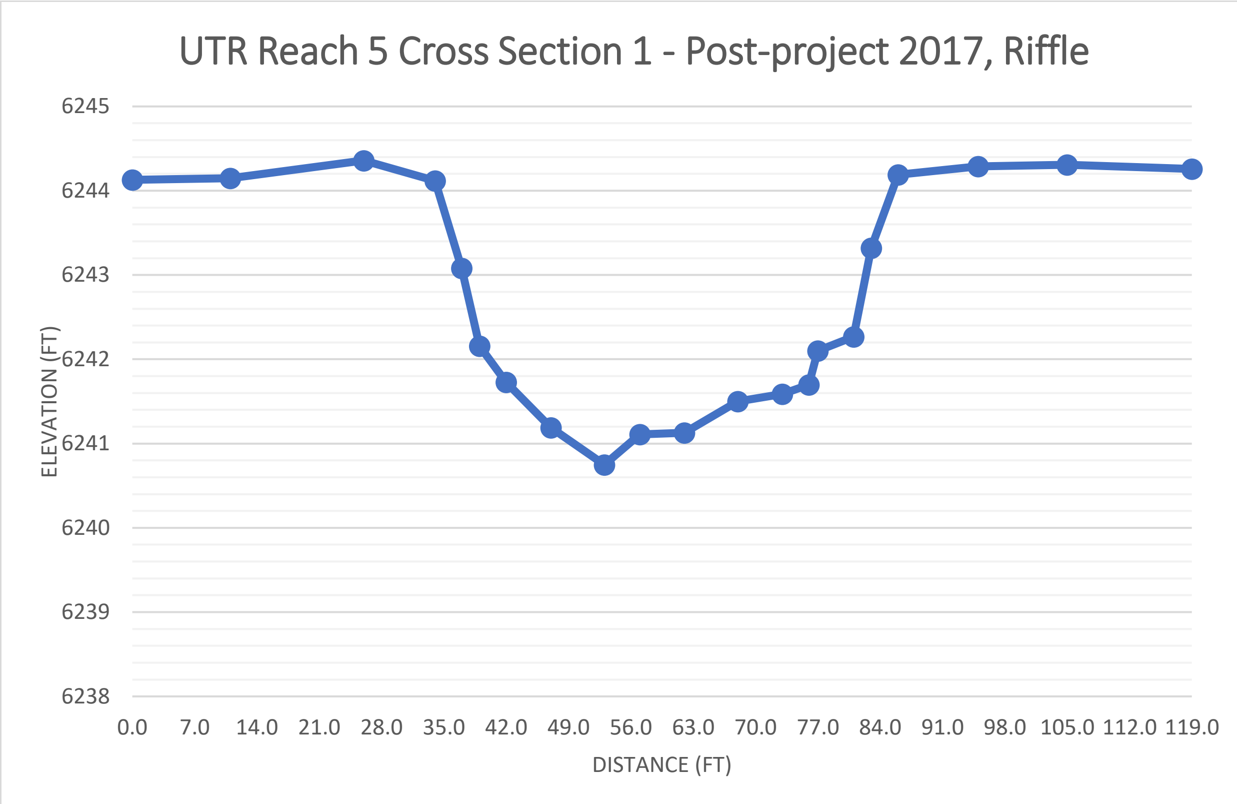
Pre-project cross-sections

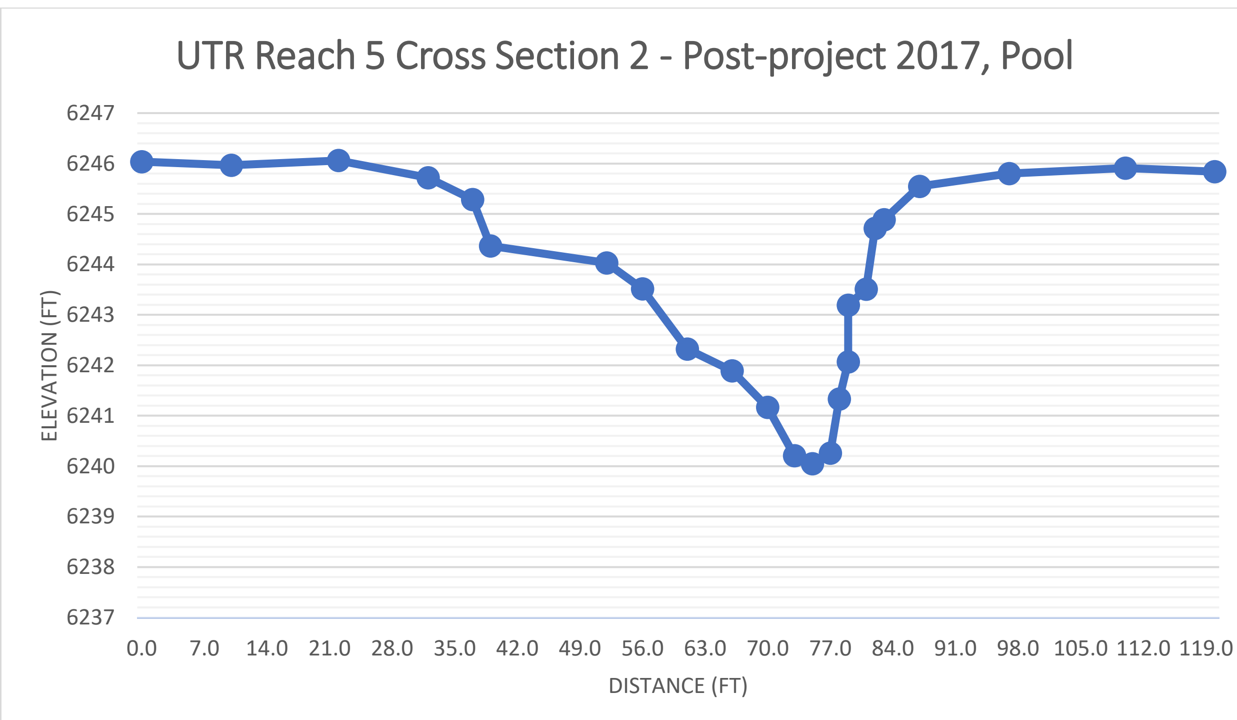


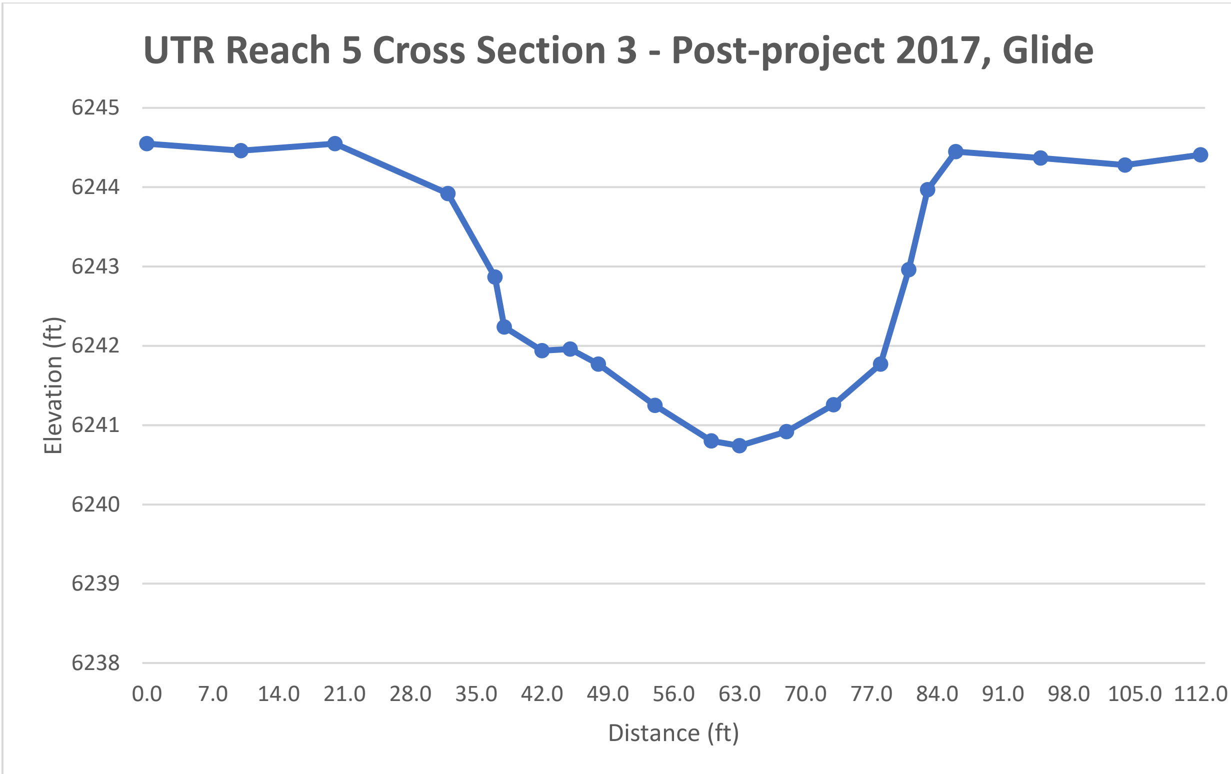


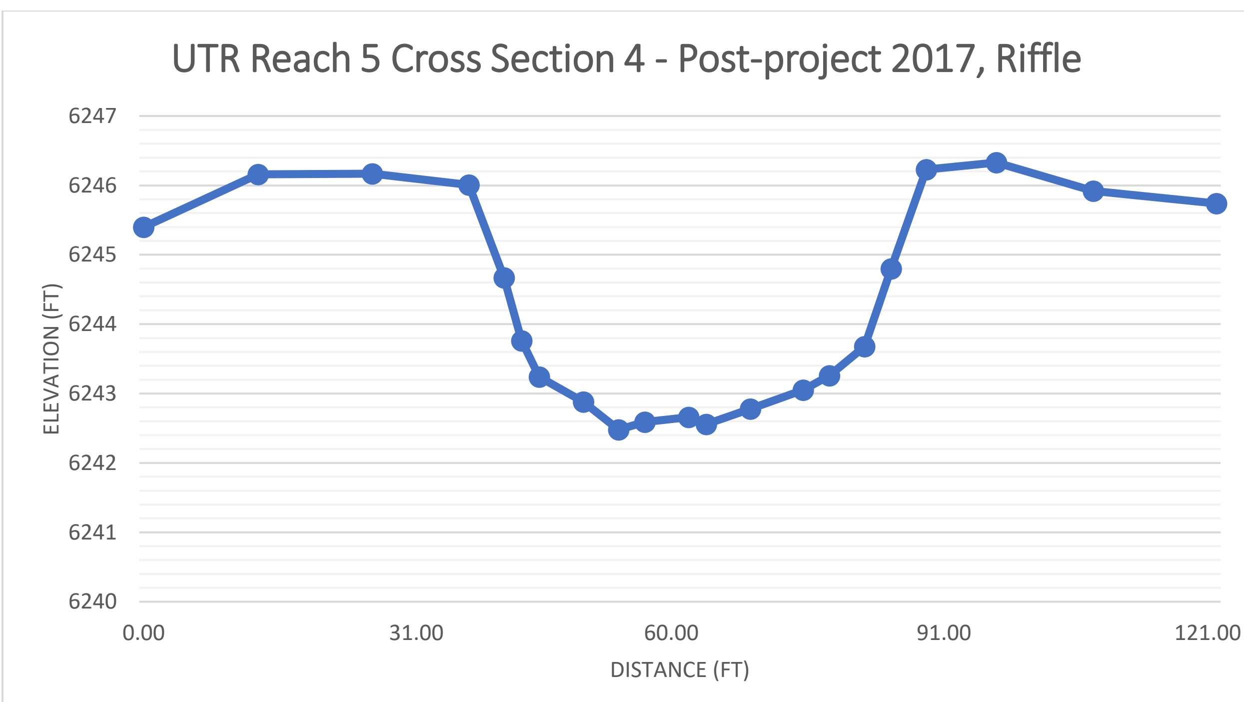

UTR Reach 5 Cross Section 3 - Pre-project 2008
Relative Elevation (ft)
98.00
96.00
94.00
92.00
90.00
88.00
86.00
84.00
0.00
0.00
1.50
2.30
2.60
3.90
4.40
4.70
5.10
5.50
7.00
8.20
9.35
10.00
11.10
12.00
14.00
16.00
17.50
19.00
21.00
23.00
25.10
25.50
25.70
25.90
25.50
25.65
26.70
27.70
27.70
Distance (ft)

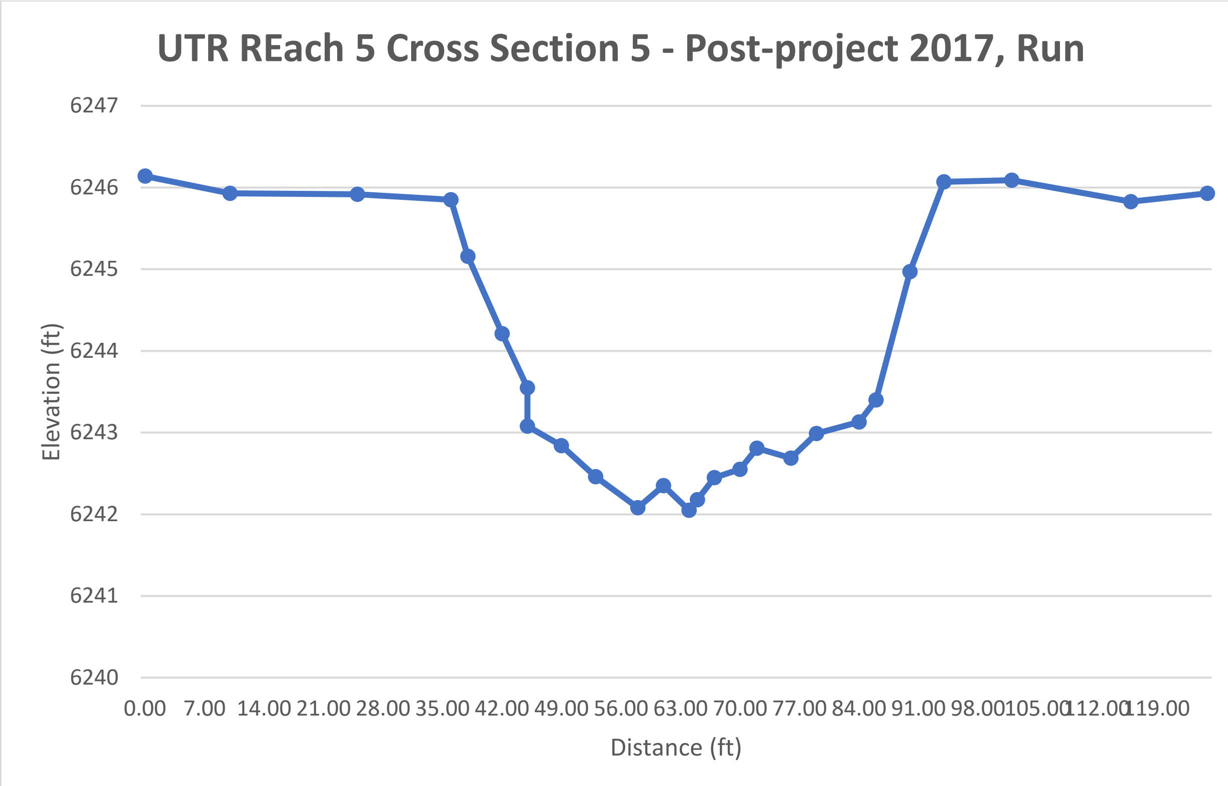
Post-project cross-sections

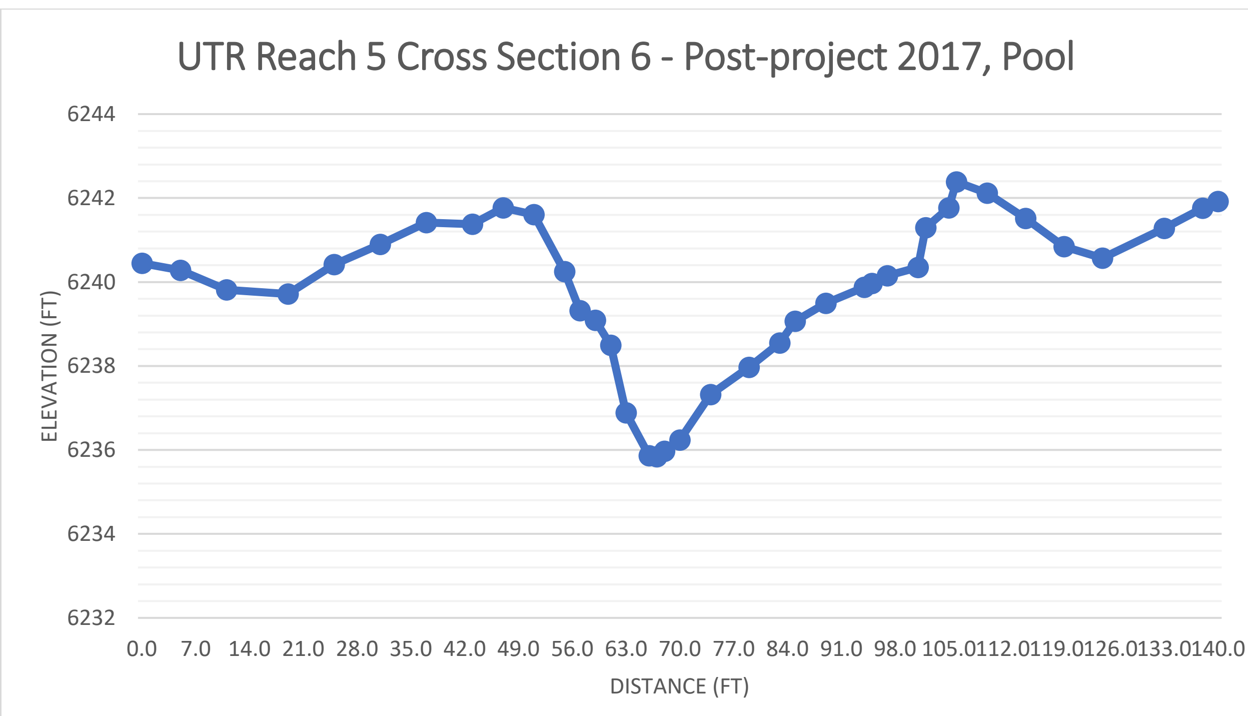


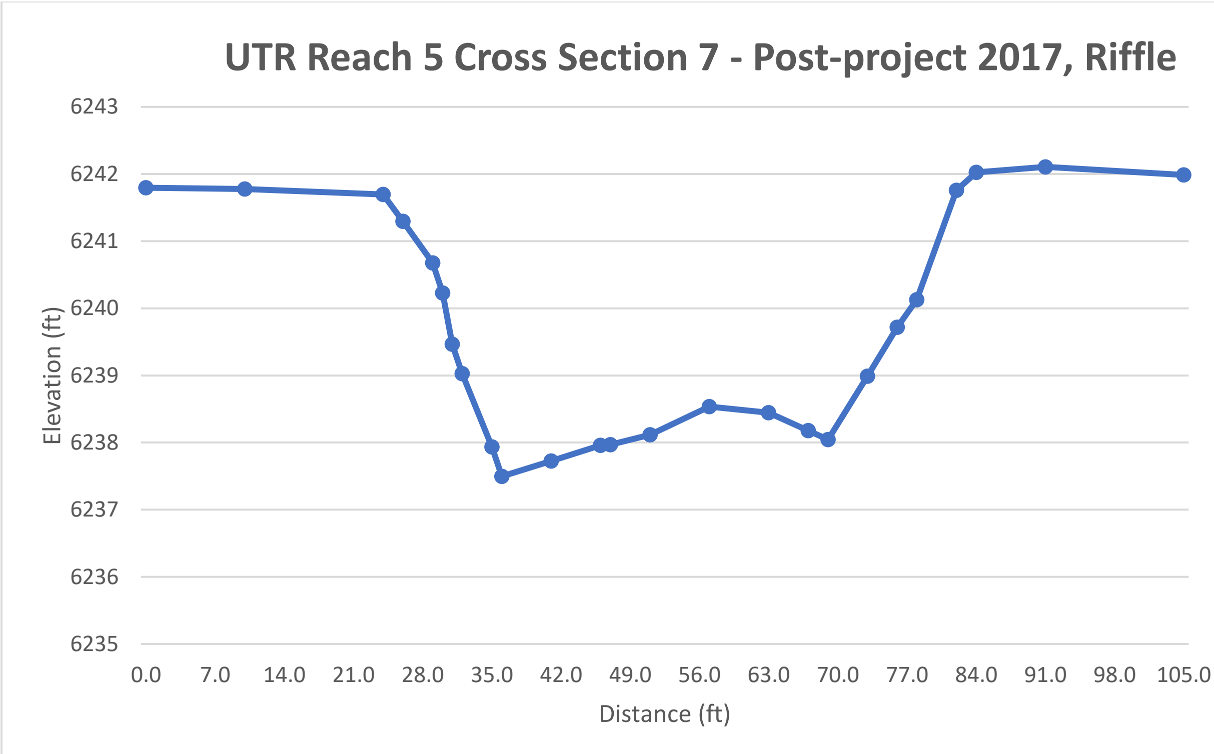


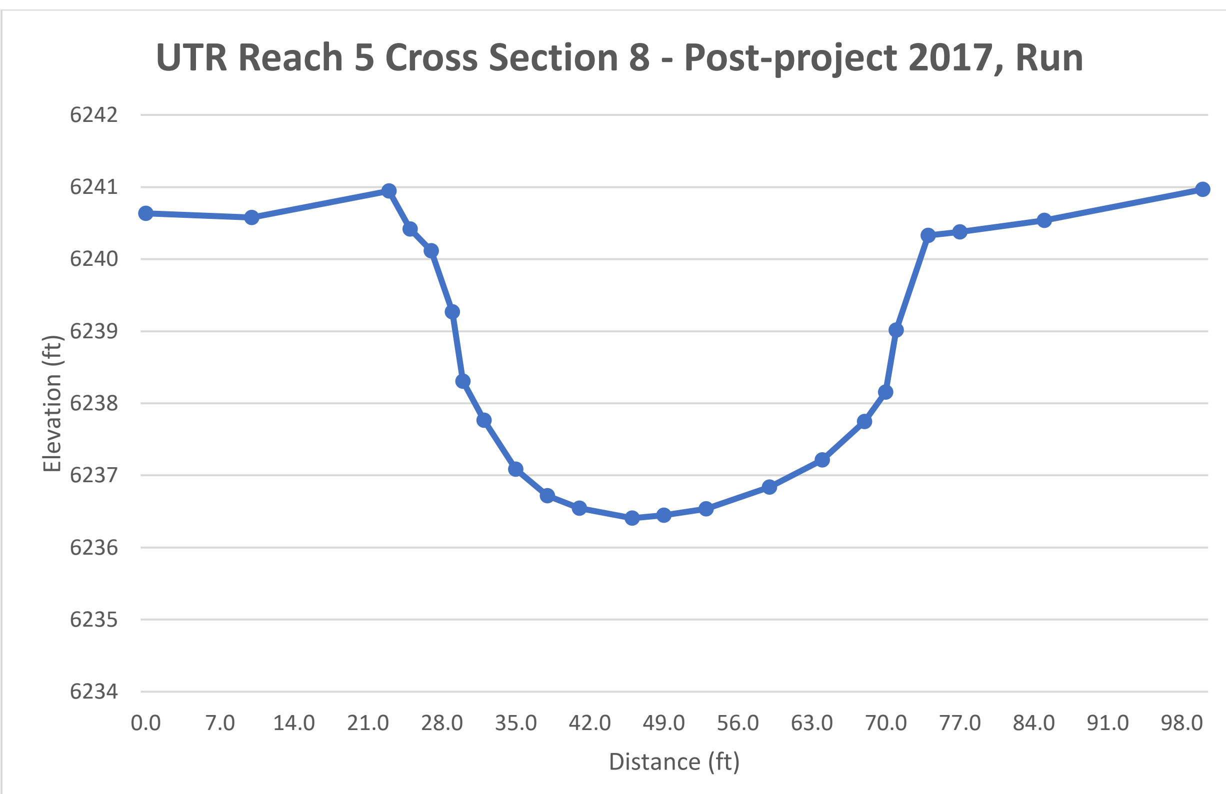

UTR Reach 5 Cross Section 3 - Post-project 2017, Glide
Elevation (ft)
6245
6244
6243
6242
6241
6240
6239
6238
0.0
7.0
14.0
21.0
28.0
35.0
42.0
49.0
56.0
63.0
70.0
77.0
84.0
91.0
98.0
105.0
112.0
Distance (ft)


UTR Reach 5 Cross Section 4 - Post-project 2017, Riffle
ELEVATION (FT)
6247
6246
6245
6244
6243
6242
6241
6240
0.00
31.00
60.00
91.00
121.00
DISTANCE (FT)

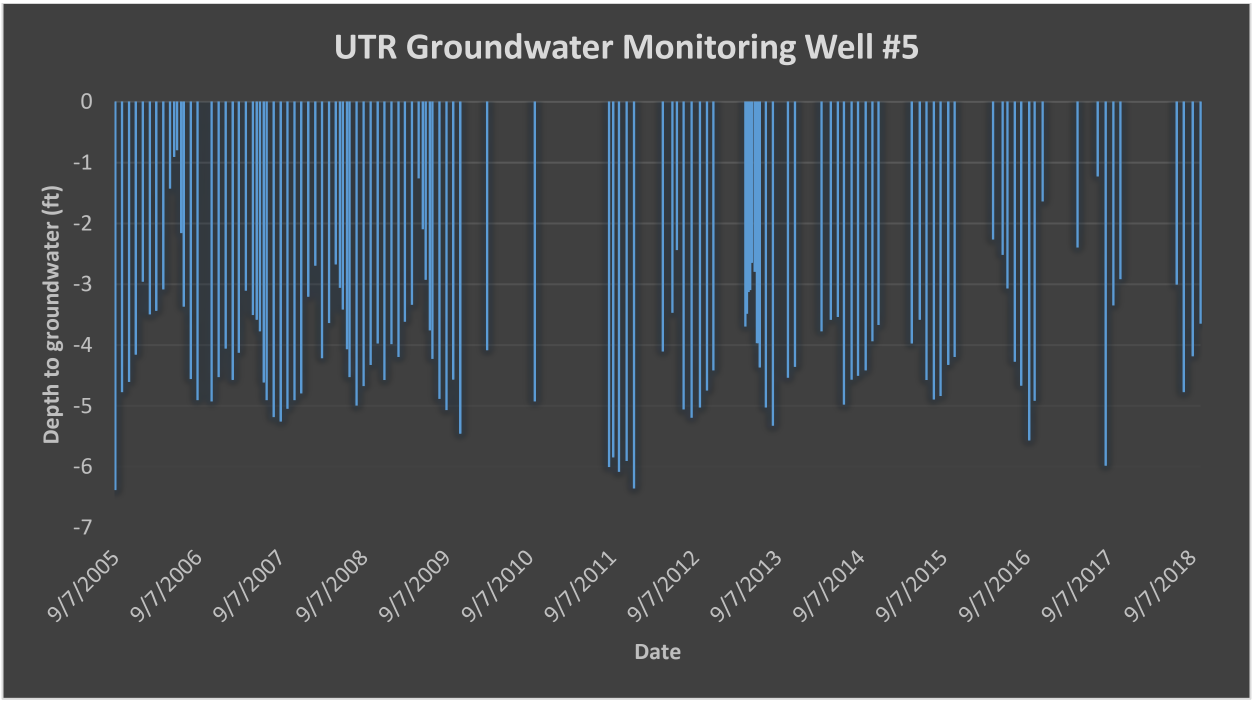

UTR REach 5 Cross Section 5 - Post-project 2017, Run
6247
6246
6245
6244
6243
6242
6241
6240
Elevation (ft)
0.00 7.00 14.00 21.00 28.00 35.00 42.00 49.00 56.00 63.00 70.00 77.00 84.00 91.00 98.00 105.00 112.00 119.00
Distance (ft)

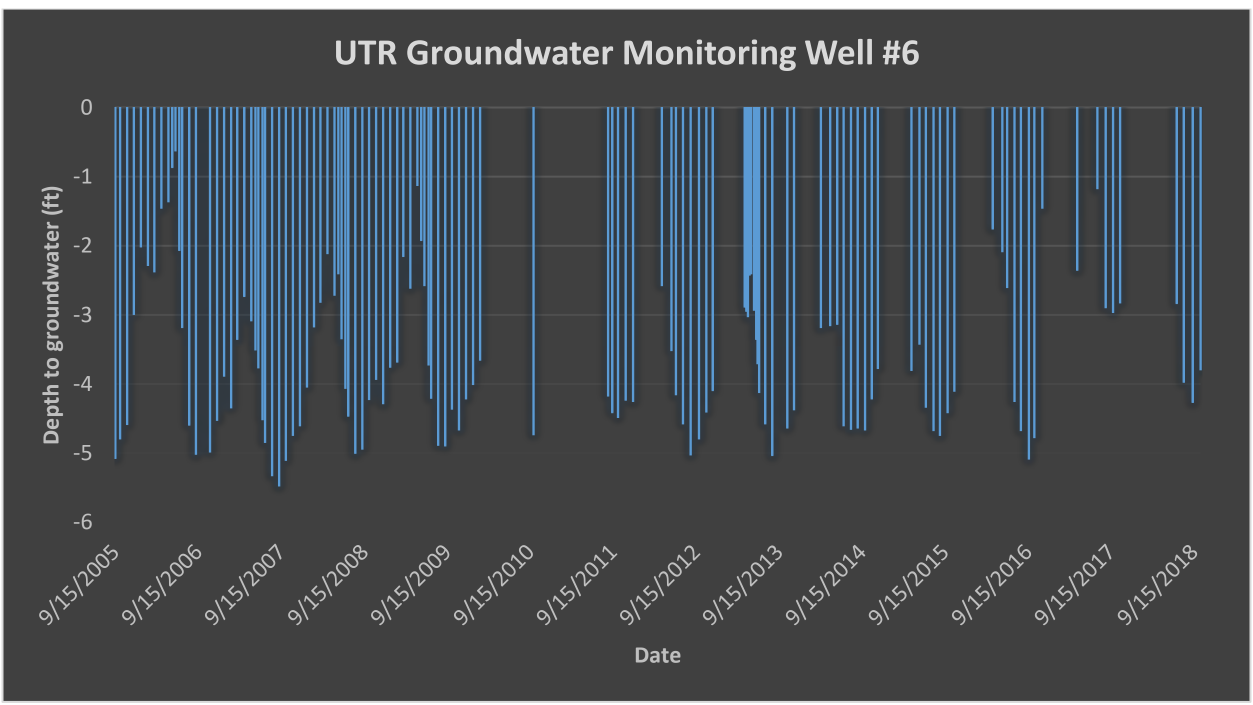

UTR Reach 5 Cross Section 6 - Post-project 2017, Pool
6244
6242
6240
6238
6236
6234
6232
ELEVATION (FT)
0.0 7.0 14.0 21.0 28.0 35.0 42.0 49.0 56.0 63.0 70.0 77.0 84.0 91.0 98.0 105.0 112.0 119.0 126.0 133.0 140.0
DISTANCE (FT)

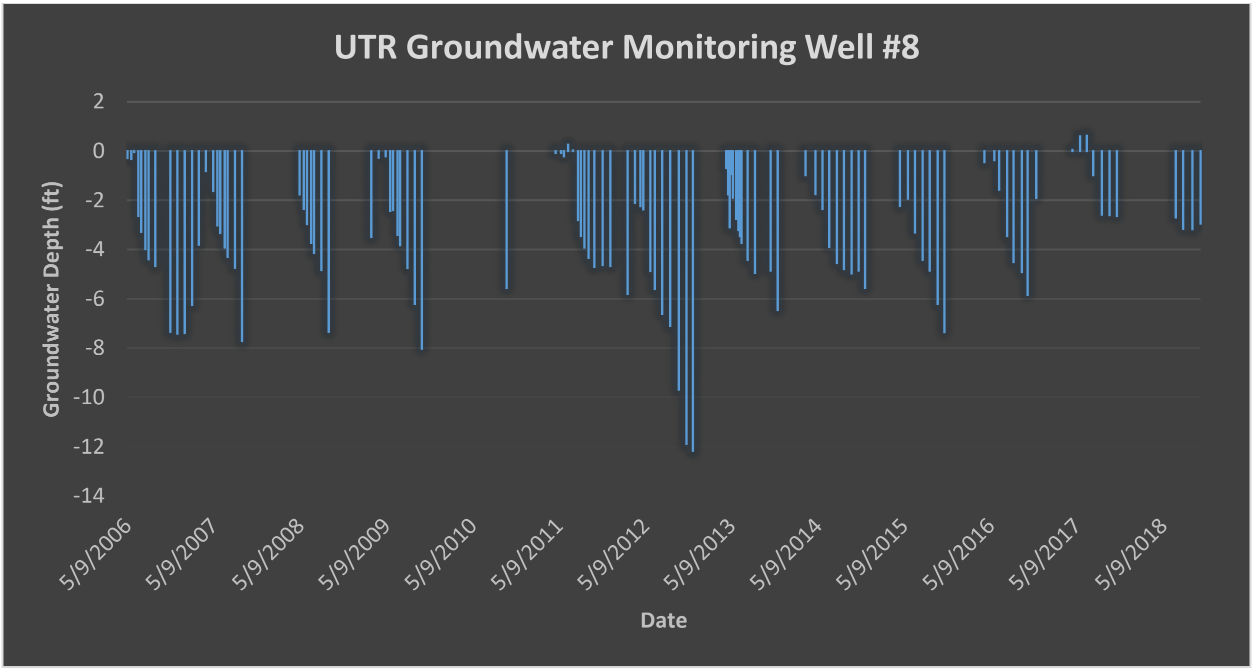

UTR Reach 5 Cross Section 7 - Post-project 2017, Riffle
Elevation (ft)
6243
6242
6241
6240
6239
6238
6237
6236
6235
0.0
7.0
14.0
21.0
28.0
35.0
42.0
49.0
56.0
63.0
70.0
77.0
84.0
91.0
98.0
105.0
Distance (ft)


UTR Reach 5 Cross Section 8 - Post-project 2017, Run
Elevation (ft)
6242
6241
6240
6239
6238
6237
6236
6235
6234
0.0
7.0
14.0
21.0
28.0
35.0
42.0
49.0
56.0
63.0
70.0
77.0
84.0
91.0
98.0
Distance (ft)

Appendix C: Groundwater Well Monitoring Graphs






UTR Groundwater Monitoring Well #8
Groundwater Depth (ft)
2
0
-2
-4
-6
-8
-10
-12
-14
5/9/2006
5/9/2007
5/9/2008
5/9/2009
5/9/2010
5/9/2011
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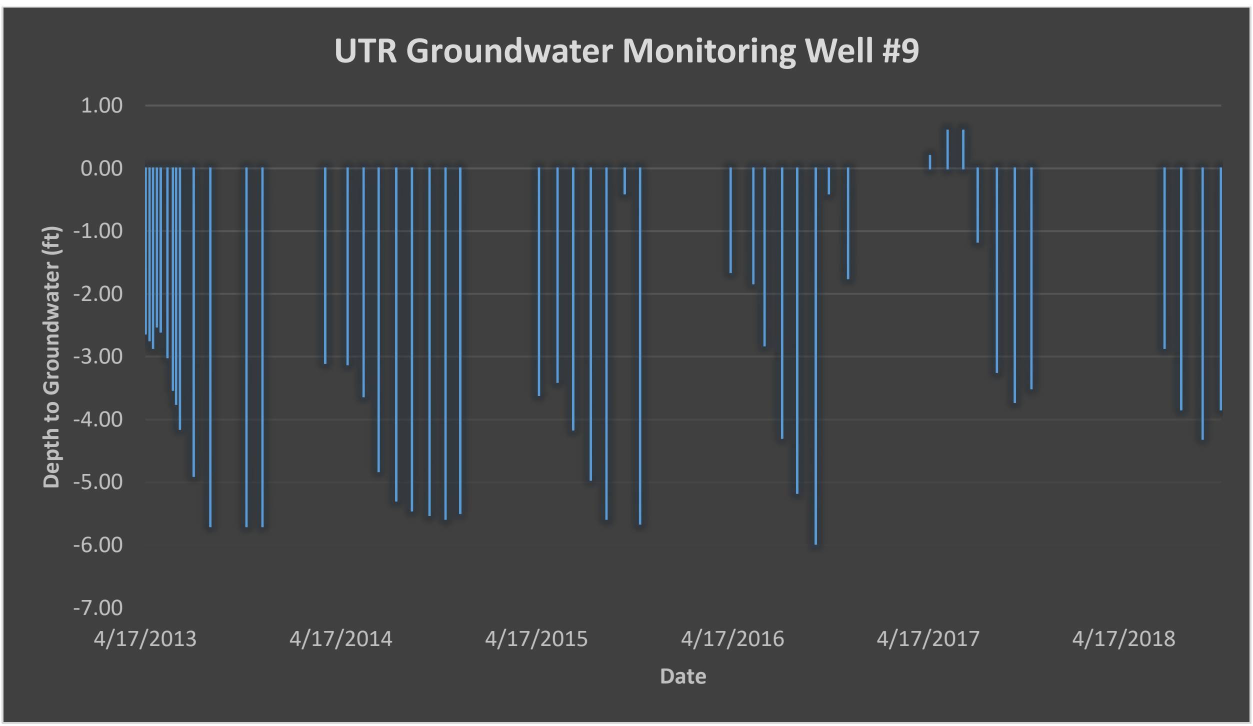
5/9/2015
5/9/2016
5/9/2017
5/9/2018
Date


UTR Groundwater Monitoring Well #9
Depth to Groundwater (ft)
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
4/17/2013
4/17/2014
4/17/2015
4/17/2016
4/17/2017
4/17/2018
Date

Appendix E: Western Pearlshell Mussel Pilot Relocation Study Summary Report

Western Pearlshell Mussel (*Margaritifera falcata*) Relocation Study SNPLMA Report

Shana Gross, Central Sierra Province Associate Ecologist, USDA Forest Service Pacific Southwest Region 5
Erin Miller, Aquatic Biologist, USDA Forest Service Lake Tahoe Basin Management Unit

1 Contents

2 Introduction

The western pearlshell (*Margaritifera falcata*) is a freshwater mussel belonging to the family Margaritiferidae. *M. falcata* has been documented widely throughout western North America, and ranges from Alaska south to central California and east to Nevada, Wyoming, Utah and Montana (Hovingh 2004, Jepsen et al. 2010). The species inhabits cold creeks and rivers with clean water and host salmonids, where they have an average lifespan of 60 to 70 years (Nedeau et al 2005). Threats to populations of this species include anthropogenic impacts on watersheds such as chemical pollution, impoundments, channel modification (including restoration activities), siltation, introduction of exotic species, and the decline of host fish (Jepsen et al. 2010, Nedeau et al. 2005).

Many historic populations have been drastically reduced in size from dense beds to a few isolated individuals (Vannote and Minshall 1982, Hovingh 2004, Strayer et al. 2004, Howard 2008, 2010). There is still, however, a lack of historical abundance data for this species, making it difficult to document the level of decline across its range (Jepsen et al. 2010). Taylor (1981) hypothesized that *M. falcata* had been eradicated from much of its native range in California, and Hovingh (2004) concluded that the species had been extirpated from Nevada. *M. falcata* was once numerous in the Truckee watershed with 20,000 individuals identified in 1942 (Murphy) but only 120 found in 2007 (Howard 2008). Today populations of the western pearlshell mussel are found in both the Upper Truckee River (UTR) and the Truckee River, and are the only known historic populations of *M. falcata* in the Lake Tahoe Basin.

In August 2011, an effort was made to relocate over 5,000 mussels from Reach 4 of the Upper Truckee River prior to dewatering for stream channel restoration. The purpose of the 2011 relocation effort was to preserve one of the last remaining populations of *M. falcata* in the Lake Tahoe Basin, collect sufficient information regarding the number and sizes of rescued mussels to characterize the population, and adequately document specific relocation habitat locations and conditions to enable future monitoring of relocated mussels (Howard 2013). Unfortunately, a qualitative resurvey of the relocated mussels demonstrated that 25% of the relocated individuals were persisting (Howard 2013).

The Upper Truckee River Reach 5 Restoration Project (hereby referred to as Reach 5) dewatered and filled a 7,400 ft reach that contained approximately 26,000 *M. falcata*. Due to the poor success of the Reach 4 relocation effort it was imperative that plans be made to successfully relocate the mussels to suitable new habitat. This required careful planning, execution, and follow up monitoring to ensure that *M. falcata* endures in the Lake Tahoe Basin. This was completed through a pilot relocation effort that relocated no more than 10% of the larger population in order to evaluate success prior to moving the remaining 90% of the mussels.

2.1 Study Goals and Questions

The goal of the study was to evaluate the success of mussel relocation in order to identify suitable relocation methods and site habitat characteristics that would successfully support the translocation of 26,000 mussels from Reach 5. We developed the following questions to achieve this goal:

1. Is survival influenced by relocating individuals to sites with existing mussel beds?
2. What stream/habitat characteristics influence survival of relocated mussels?
3. Does mussel size influence success, defined as survivorship and persistence?
4. Do actions associated with relocation (e.g. marking and measuring) influence relocation success?

3 Methods

3.1 Study site selection

Suitable sites for the pilot relocation study were identified on Trout Creek, Cold Creek, the Upper Truckee River, and the Truckee River. These waterbodies were selected based on their proximity to the host population or were areas with historically known populations. A suitable site was a site that had the following (not all study sites met each criterion):

- velocities 0.25-0.30 m/s (Stone et al. 2004)
- depth 0.2-0.6 m (Stone et al. 2004)
- low gradient (<4%) (Howard and Cuffey 2003, Stone et al. 2004)
- low shear stress in all flow conditions (Howard and Cuffey 2003, Stone et al. 2004)
- will not dewater
- clean, coarse sand, gravel, cobble, and boulders (no fine sediment) (Vannote and Minshall 1982, Howard and Cuffey 2003, Stone et al. 2004)
- sheltered microhabitats protected from scouring flows and sediment deposition
- high riparian canopy density (Stone et al. 2004)

Other factors that were important were proximity to the project area, accessibility, and future plans for stream channel restoration.

The following locations were chosen based on the above criteria (Figure 1):

- Upper Truckee River reaches 4 and 6
- Upper Truckee River in Christmas Valley between Han St and Egret Way
- Trout Creek upstream and downstream of Martin Ave
- Trout Creek downstream of Powerline Rd
- Cold Creek upstream of Pioneer Trail
- Cold Creek downstream of High Meadow
- Truckee River at San Francisco Fly Fishing Club
- Truckee River at Silver Creek Campground

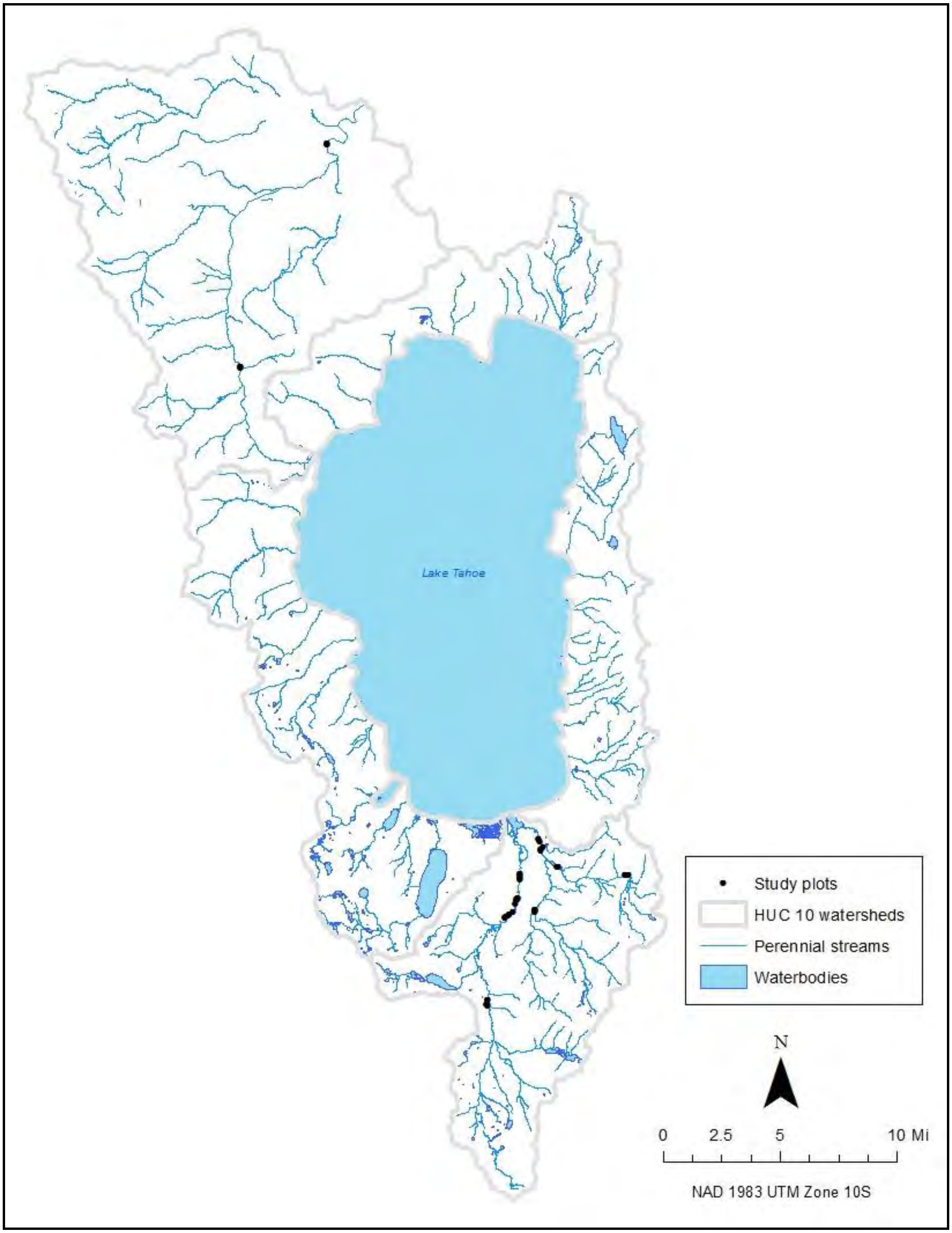


Figure 1. Study plot locations

3.2 Study plot setup and study plot data attributes

One m^2 quadrats were used as translocation study plots. Plots were established by marking each corner with a white plastic survey stake (Plastake® Survey Stakes) (Figure 2). Due to high recreational use in the streams, plastic was used for safety concerns. A 1 m^2 PVC quadrat frame was used during establishment and follow-up visits.

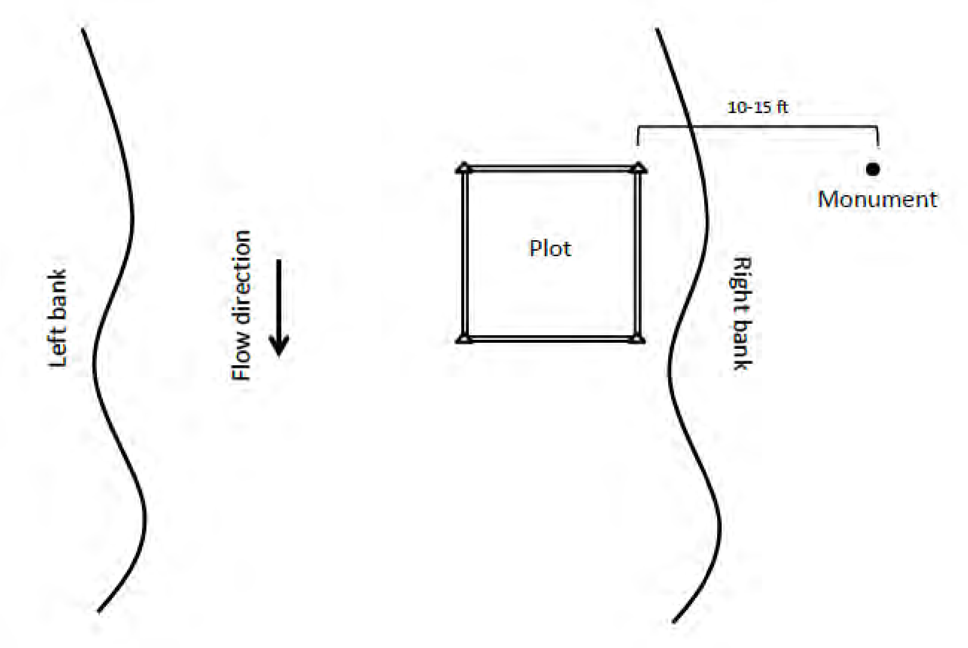


Figure 2. Plot setup

Each plot was also marked on the streambank with a yellow capped rebar monument flush to the ground. Monuments were placed between 10 and 15 ft from the upstream corner of the plot on the bank closest to the plot. If vegetation and visibility favored placing the monument on the opposite bank this was noted in the data.

At each study plot, UTMs were recorded at the monument and at the center of the plot in NAD 1983 using a Trimble GeoExplorer 6000. The azimuth from the monument to the upstream bank-side plot corner was taken with a compass, and the distance from the monument to the upstream bank-side plot corner was measured with an open reel measuring tape to the nearest 0.01 ft. In the event that the plastic stakes were scoured from the streambed, these measurements were used to relocate plots during monitoring. Photographs were taken were taken from the following locations: 5 feet behind monument looking towards monument and plot, 10 feet downstream of plot looking upstream, and 10 feet upstream of plot looking downstream.

The study had 38 translocation plots and 5 control plots for a total of 43 plots (Table 1). Control plots are where mussels were removed, marked, measured and placed into roughly their same location within their respective plot. All control plots were within the restoration reach, Reach 5.

Reach 6 contained 3 plots with existing mussels and 3 plots without existing mussels. This was the only location comparing plots with and without existing mussels, because this is the only site where mussels were relocated to where existing mussels were already present. “No mussel” plots were placed a minimum of 25 m from existing mussels. This is based on Fernandez (2013), who found that *M. falcata* moved up to 102 m over a four year study, and we therefore assumed mussels can move up to 25 m in one year.

Study plots on the Upper Truckee River, Truckee River, and Trout Creek were established in August and September 2014. Plots on Cold Creek were established in September 2015.

Table 1. Study plot locations

Reach name	Abbreviation	Plot number	Existing mussels?	Year established
Trout Creek downstream of Powerline Trail	TCP	1	N	2014
Trout Creek downstream of Powerline Trail	TCP	2	N	2014
Trout Creek downstream of Powerline Trail	TCP	3	N	2014
Trout Creek downstream of Powerline Trail	TCP	4	N	2014
Trout Creek downstream of Powerline Trail	TCP	5	N	2014
Trout Creek up and downstream of Martin Ave	TCM	6	N	2014
Trout Creek up and downstream of Martin Ave	TCM	7	N	2014
Trout Creek up and downstream of Martin Ave	TCM	8	N	2014
Trout Creek up and downstream of Martin Ave	TCM	9	N	2014
Trout Creek up and downstream of Martin Ave	TCM	10	N	2014
Upper Truckee River in Christmas Valley between Han St and Egret Way	UTC	11	N	2014
Upper Truckee River in Christmas Valley between Han St and Egret Way	UTC	12	N	2014
Upper Truckee River in Christmas Valley between Han St and Egret Way	UTC	13	N	2014
Upper Truckee River in Christmas Valley between Han St and Egret Way	UTC	14	N	2014
Upper Truckee River in Christmas Valley between Han St and Egret Way	UTC	15	N	2014
Upper Truckee River Reach 4	UT4	16	N	2014
Upper Truckee River Reach 4	UT4	17	N	2014
Upper Truckee River Reach 4	UT4	18	N	2014
Upper Truckee River Reach 4	UT4	19	N	2014
Upper Truckee River Reach 4	UT4	20	N	2014
Upper Truckee River Reach 6	UT6	21	Y	2014
Upper Truckee River Reach 6	UT6	22	Y	2014
Upper Truckee River Reach 6	UT6	23	N	2014
Upper Truckee River Reach 6	UT6	24	N	2014
Upper Truckee River Reach 6	UT6	25	Y	2014
Upper Truckee River Reach 6	UT6	26	N	2014
Truckee River at San Francisco Fly Fishing Club	TSF	27	N	2014
Truckee River at San Francisco Fly Fishing Club	TSF	28	N	2014
Truckee River at San Francisco Fly Fishing Club	TSF	29	N	2014
Truckee River at Silver Creek Campground	TSC	30	N	2014
Truckee River at Silver Creek Campground	TSC	31	N	2014
Truckee River at Silver Creek Campground	TSC	32	N	2014

Upper Truckee River Reach 5	UT5	33	Y	2014
Upper Truckee River Reach 5	UT5	34	Y	2014
Upper Truckee River Reach 5	UT5	35	Y	2014
Upper Truckee River Reach 5	UT5	36	Y	2014
Upper Truckee River Reach 5	UT5	37	Y	2014
Cold Creek upstream of Pioneer Trail	CCP	38	N	2015
Cold Creek upstream of Pioneer Trail	CCP	39	N	2015
Cold Creek upstream of Pioneer Trail	CCP	40	N	2015
Cold Creek downstream of High Meadow	CCH	41	N	2015
Cold Creek downstream of High Meadow	CCH	42	N	2015
Cold Creek downstream of High Meadow	CCH	43	N	2015

3.3 Habitat data attributes

Habitat data was collected at each study plot prior to translocation and during each monitoring effort. Bankfull depth was measured using an open reel measuring tape and stadia rod to the nearest 0.01 ft. Channel unit type was evaluated according to Hawkins et al. 1993. Any beaver activity having an apparent influence on hydrology or geomorphology at each plot was noted. Both left and right bank angles were measured directly adjacent to each plot using a stadia rod and clinometer. The stadia rod was extended to full length to create a flat surface that represented the average slope of the bank, and the clinometer was used to measure the representative bank angle. Minimum and maximum water depth within each plot were measured using a stadia rod and recorded to the nearest 0.01 ft. The percent of each plot covered by aquatic vegetation and algae was recorded to the nearest 5% using visual estimation during snorkeling. A Solar Pathfinder™ was used to measure percent shade at one foot above the water surface at the center of each plot. Calcium hardness (mg/L) was measured at each plot using a total calcium test kit (Hach Model HA-4P-MG-L). A modified Wolman pebble count was used to evaluate dominant substrates. Each plot quadrat was divided into a grid of one hundred 10 cm squares and the substrate was sampled once in each square. Velocities (ft/s) were measured at the bed surface, 20%, 60%, and 80% of water depth in the center of the plot and the center of the upstream and downstream edges using a Marsh McBirney Flow Mate 2000. A “substrate finger test” was conducted to evaluate the effects of flow on the substrate. Just downstream of the plot toward the outside edge of the plot, a small trench was scraped perpendicular to the direction of flow (~2-4 inches long, 1 inch deep). The largest particle size moved by the current was noted (using a pebble-o-meter). This was conducted three times: left edge of plot, center of plot, and right edge of plot. Velocities and substrate finger test data were only collected at plot establishment, because these tests would disturb mussels. Underwater photographs were taken from the downstream edge of the plot looking upstream to the plot. One photo was taken immediately prior to relocation and one was taken immediately post-relocation.

3.4 Mussel translocation

Mussels were captured, measured, marked, and transported following a specific protocol.

Mussels were collected from the surrounding area of each of the 5 control plots (UT5), no more than 50 m upstream and downstream from each plot. The distance upstream and downstream that field crews needed to snorkel to find enough mussels for translocation depended on the density of mussels surrounding the control plots. Control plots were a minimum of 100 m from each other. Mussels were removed from the substrate by trained personnel who were snorkeling or wading, and placed in 8" x 12" mesh bags to be brought to the shore for marking and measuring. Mesh bags were kept in the stream before and after marking and measuring.

Mussels were affixed with a unique numbered tag (Floy tag, Inc., Seattle, WA) using a cyanoacrylate adhesive on the right valve, at the dorsal side of the posterior end. A heavy duty scouring pad was used to clean algae, silt and external organisms off the mussel prior to affixing the tag.

Length and weight of mussels was measured prior to translocation. Mussels were measured from the anterior to posterior sides at the greatest length to the nearest 0.01 mm using Mitutuyo Digimatic calipers. Mussels were patted dry with a cotton towel and weighed to nearest 0.01 g using an Ohaus Scout Pro Portable Electronic Balance. Each mussel was exposed to air for no more than 5 minutes.

After each mussel was tagged, weighed, and measured, each individual was placed in one of 5 mesh bags. Each bag represented a control plot area, so as mussels were processed they were placed in the appropriately labelled bag. To set up the control plots, mussels were removed directly from control plots, tagged, weighed, measured, and placed back into their respective plot.

No more than 20 mussels were placed in any mesh bag. Mesh bags were kept in the river until they were ready for transport. During transport mesh bags containing mussels were placed in plastic coolers filled with stream water, and covered with a clean cotton towel wetted with stream water. Enough river water was used to completely cover the mussels by at least 2 inches. Bags of mussels were arranged in the coolers to avoid overcrowding. A layer of 4 oz Nalgene bottles filled with frozen stream water was placed on top of the towel, which floated at the top of the water. The towel was used to ensure that frozen bottles did not come into direct contact with mussels.

The length of time mussels were in a cooler was recorded in minutes. Water temperature was recorded in degrees Celsius using a Traceable® Waterproof Mini Thermometer at each plot prior to translocation.

After transporting to the translocation study plot, mesh bags of mussels were immediately transferred from coolers to the stream. At each plot, mussels were placed in the center of the plot next to each other, with the anterior end partially buried in the substrate and the ventral side facing toward the flow. This method was used to be sure that the valves from which the foot extends were buried down and the incurrent and excurrent siphons were exposed at the surface. Burial was done carefully by digging a small depression in the substrate before placing the mussel to avoid damaging internal tissues. Vannote & Minshall (1982) found that mussels over 10 cm are unable to migrate vertically within the sediment, and are also unable to regain an upright position after falling on their sides. Therefore, care was taken to ensure that all mussels were placed in an upright position in the substrate.

At each study plot, five mussels were translocated from each control plot bag for a total of 25 mussels translocated into each plot. This method was employed to ensure that the location mussels were collected from would not influence overall survivorship and persistence of the plot as a whole. For each mussel placed in each plot, tag number and control site translocated from were recorded, as well as the initial length and weight of each mussel. Presence of existing mussels in the plot was also noted.

3.5 MONITORING

Study plots were monitored in the summer and fall of 2015 and 2016, and the fall of 2017. Two-thousand seventeen was an above average water year, and field crews were unable to safely snorkel until September (Figure 3).

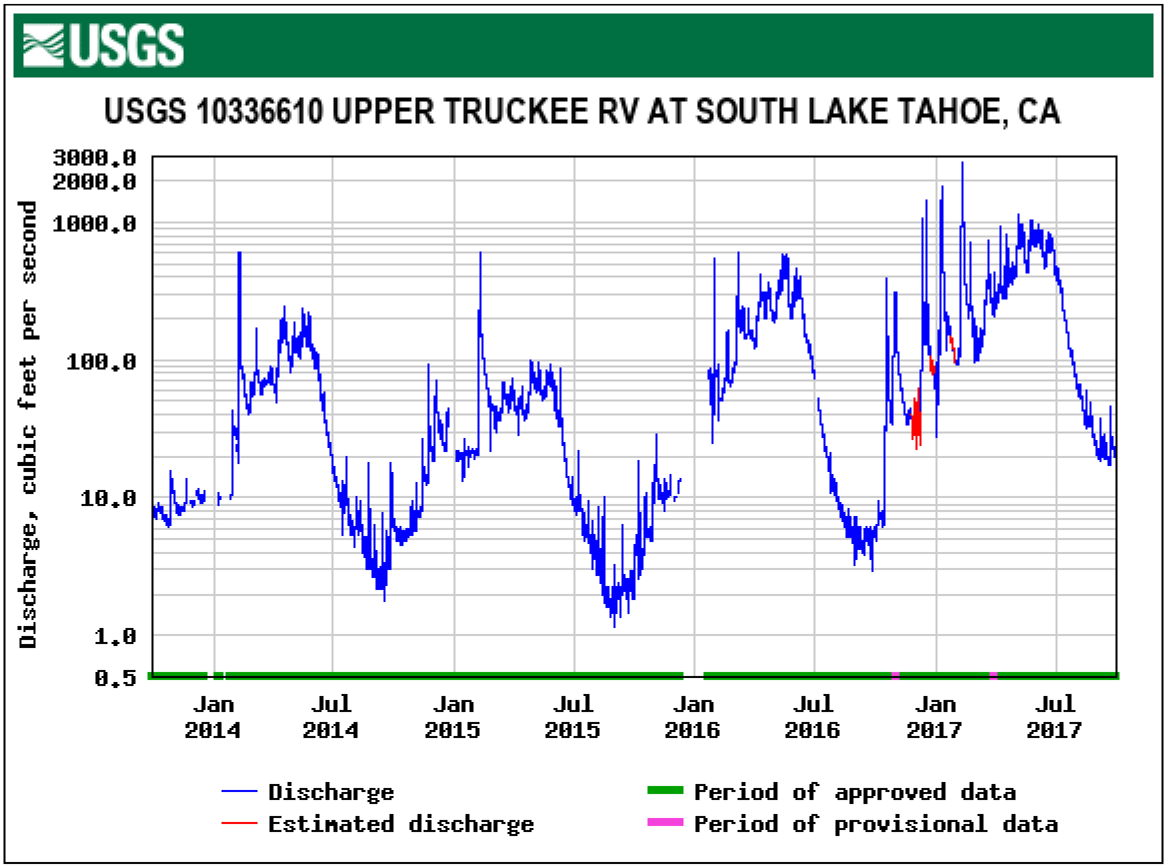


Figure 3. USGS discharge data at gage 10336610 for water years 2014-2017

The number of mussels in each plot was recorded by either snorkeling or wading using a viewing bucket (Top Shelf Marine Products Battlewagon Bucket™ Reef Scope™). Both tagged and untagged mussels were counted. The area 25 m upstream, downstream, and the area surrounding the plot was searched at each monitoring effort in order to locate mussels that travelled. For each mussel located in and nearby each plot, tag number and length and weight of each mussel were measured. During monitoring, mussels were exposed to air for no more than 5 minutes. After each mussel was weighed and measured, it was returned to where it had been found. The status of each tagged mussel was recorded, which was either live (present in the plot), dead, missing, or travelled outside the plot. For mussels that had travelled outside the plot, distance was measured as the shortest distance from the mussel to the outside edge of the plot quadrat. Distance was measured using an open reel measuring tape to the nearest 0.01 m. Additionally, for travelled mussels the direction travelled was recorded as the azimuth from the edge of the plot to the mussel, and whether the mussel moved upstream, downstream, or to the side of the plot.

All habitat data attributes were also measured and recorded at each monitoring effort, with the exception of velocities and the substrate finger test.

3.6 STATISTICAL ANALYSIS

4 RESULTS

General Summary (and Q1)

One year post relocation 72% of the mussels were relocated, however by three years post relocation (and following a high water year) only 34% of the mussels were relocated (Table 2). The average size of the mussels did not significantly change over the study period and therefore did not explain the success in relocation. During relocation the average length of mussels was 80.25 mm (±9.63, range from 34.33 mm to 104.73 mm) and the average weight of mussels was 46.42 (±14.16, range from 3.8 g to 89.49 g) (Table 3).

Table 2. The percentage of mussels by year that were found in the plot (live), outside of the plot (travelled), were not relocated (missing), or were confirmed dead.

Number of Years Post Relocation	Year	Live	Travelled	Missing	Dead
1	2015	50.3	21.6	28.0	0.1
2	2016	45.0	20.6	34.0	0.4
3	2017	19.6	14.6	65.0	0.8

Table 3. Summary information for the size of the mussels (length and weight).

		Length (mm)			Weight (g)		
Number of Years Post Relocation	Year	Mean	Standard Deviation	Standard Error	Mean	Standard Deviation	Standard Error
0	2014	80.25	9.63	0.32	46.42	14.16	0.47
1	2015	81.11	8.82	0.31	48.22	13.61	0.48
2	2016	80.55	9.43	0.34	47.26	13.73	0.50
3	2017	80.45	8.46	0.47	46.93	13.17	0.73

Mussels travelled during the study. They moved upstream, to the side of the plots and downstream. The average distance travelled downstream was 4.2 meters with a maximum of 165 meters, upstream was 2.2 m with a maximum of 18.8 m, and to the side was 0.7 m with a maximum of 14.7 m (Figure 4).

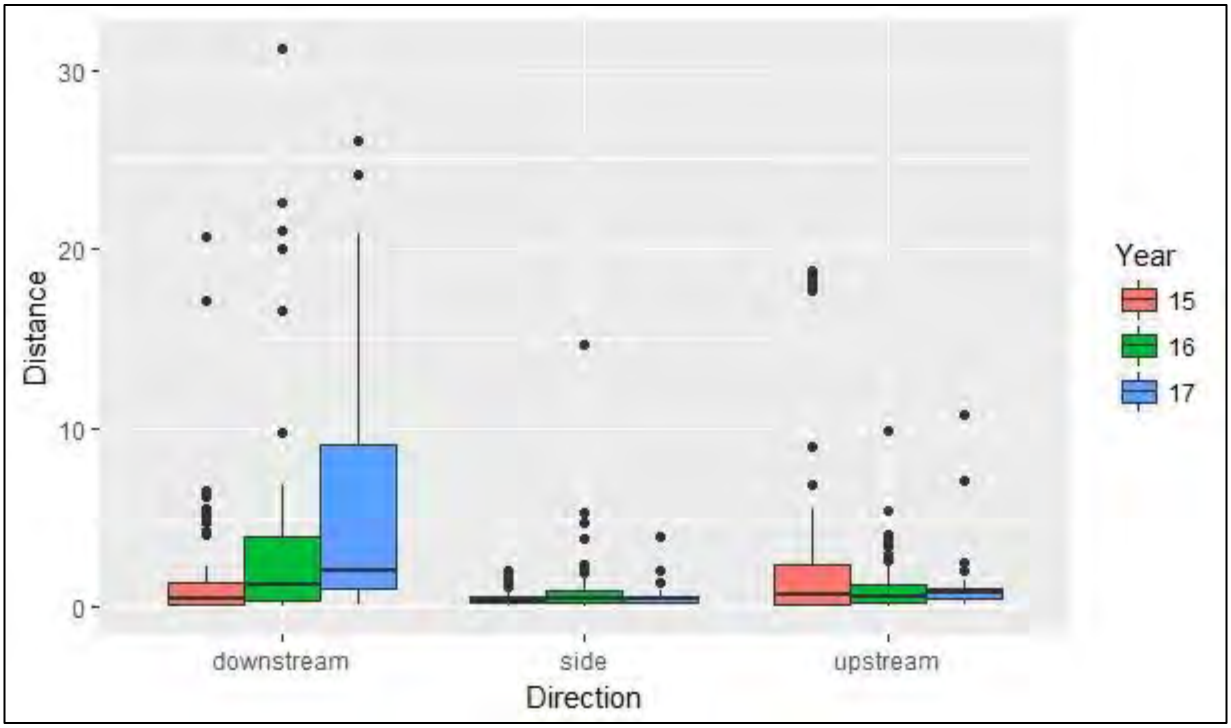


Figure 4. Bar graph of distance (meters) mussels travelled in 2015 (red), 2016 (green), and 2017 (blue) and the direction they travelled (downstream, side, upstream). Note one data point was excluded from the figure for scale issues – 2017 mussel travelled 165 m downstream.

<u>Presence of Live Mussels (Q2, Q3, Q4)</u>

In 2016, following three dry years, mussels were more likely to be found when there were not beaver in the area and when there was lower aquatic vegetation cover (Figure 5). Following the wet winter of 2017, mussels were more likely to be found in areas where other mussels occurred naturally and in non-turbulent runs (FNRN) when compared to mussels found in mid channel (SSMC), in riffles (FTRF), and in lateral scour (SSLS) areas (Figure 6).

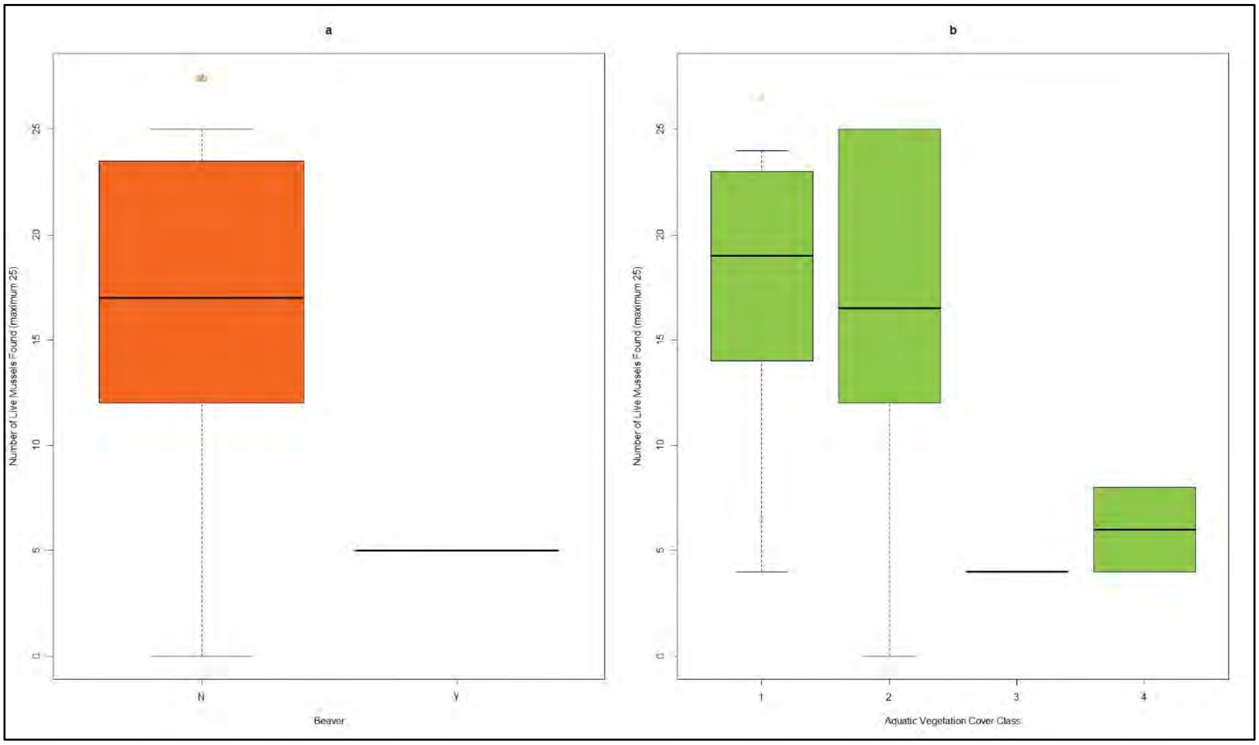


Figure 5: Box plots mussels relocated alive in 2016 (maximum of 25) showing the third quartile (Q3) and first quartile (Q1) range of the data and data outliers summarized by significant model habitat variables.

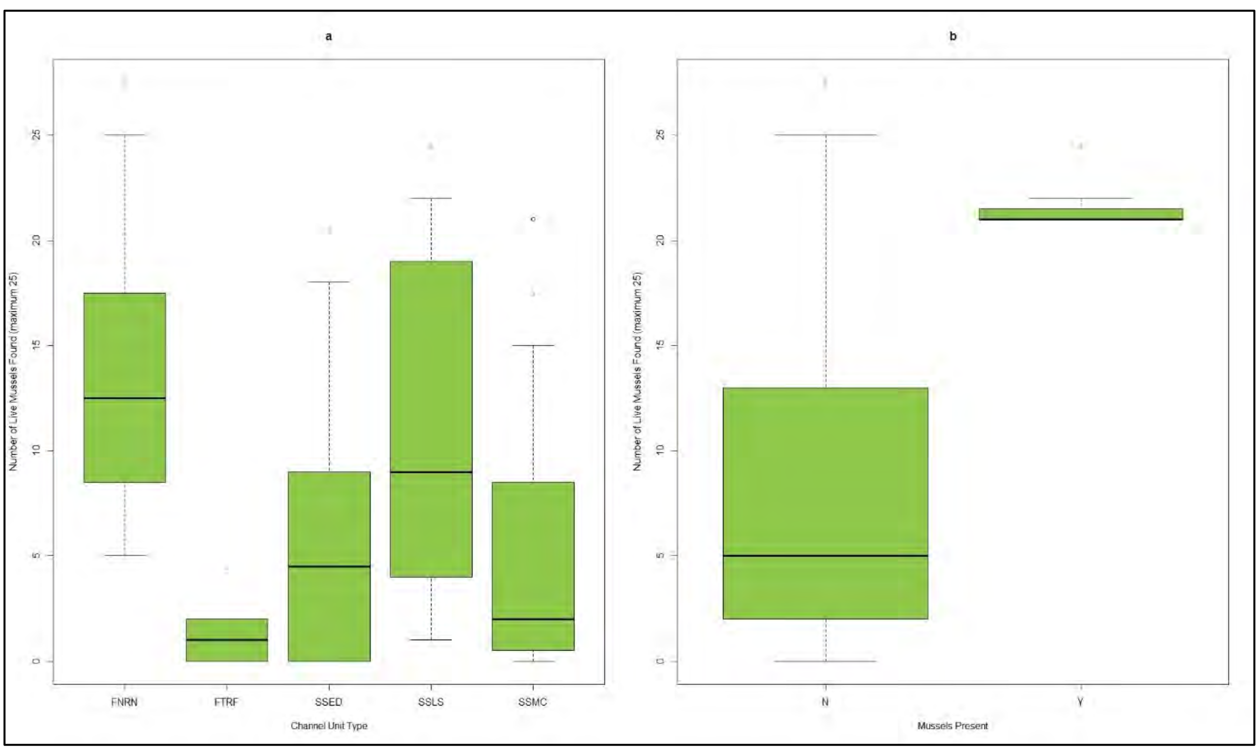


Figure 6: Box plots mussels relocated alive in 2017 (maximum of 25) showing the third quartile (Q3) and first quartile (Q1) range of the data and data outliers summarized by significant model habitat variables.

Mussel condition as measured by Fulton's K (Q2, Q3)

When mussels were relocated to areas where mussels already occurred they had a better change in condition compared to locations without mussels. Mussels had the best change in condition in the Upper Truckee River, which had the greatest number of known mussels. While the Upper Truckee River had the best change in condition, when separated by reach, mussel condition increased in the two reaches where mussels were known to occur (UT4 and UT6) and decreased in the reach where mussels were not previously known to occur (UTC).

Mussels found in mid-channel (SSMC) and non-turbulent runs (FNRN) had a better change in condition compared to mussels found in slow water scour eddies (SSED) where mussels had a decrease in condition. When sand was the dominant substrate, mussels had a poorer change in condition. When the largest particle size moved was silt, mussels had a better change in condition.

Mussels had an increase in condition in areas with higher cover of algae and were slightly better in areas where beaver were present. Mussels in streams with calcium less than 20 mg/L had better condition compared to streams with calcium amounts of 40 mg/L.

Reaches

There were more mussels found in reaches associated with the Upper Truckee River where mussels previously occurred (UT4, UT6). In areas where mussels were not previously found, two reaches in Trout Creek (TCM, TCP) that are at a similar elevation with UT4 and UT6 plots did the best. While mussels were previously found in Truckee River, these reaches did the worst (TSC, TSF) (Figure 7). Mussels relocated to the Upper Truckee River reaches UT4 and UT6 also had the best condition (Figure 8).

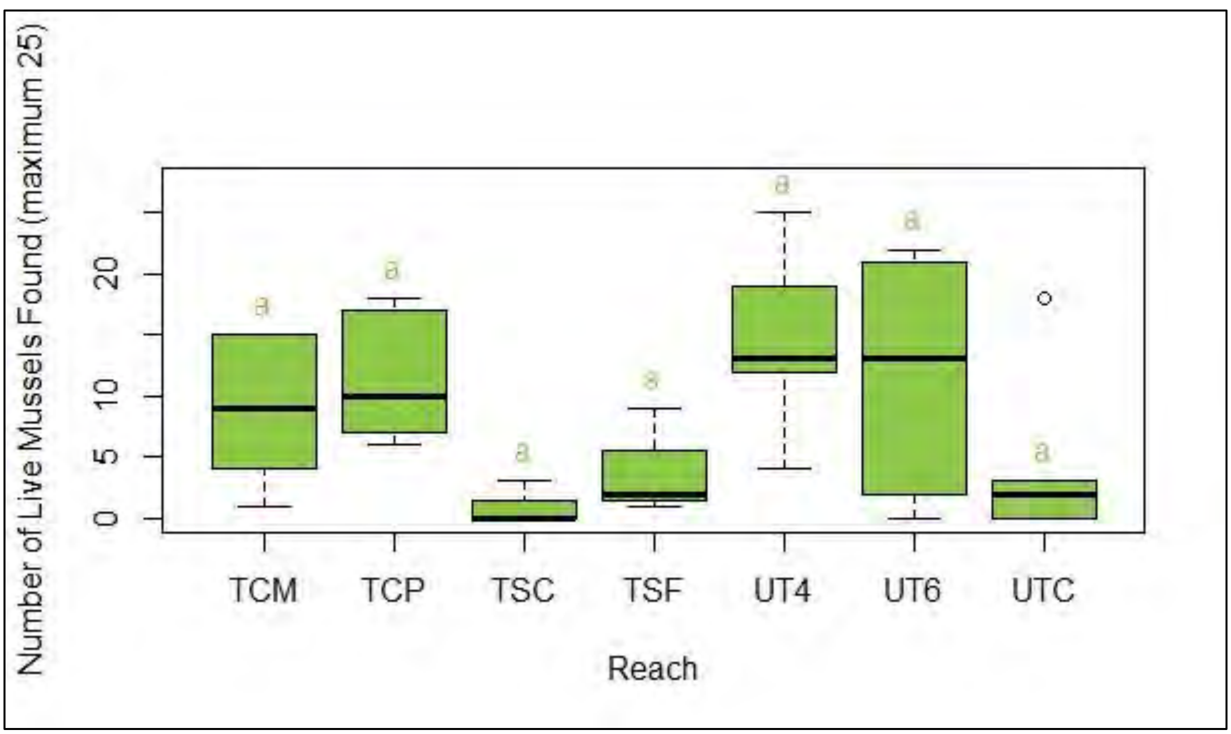


Figure 7: Box plots of number of mussels relocated alive in 2017 (maximum of 25) showing the third quartile (Q3) and first quartile (Q1) range of the data and data outliers summarized by reach.

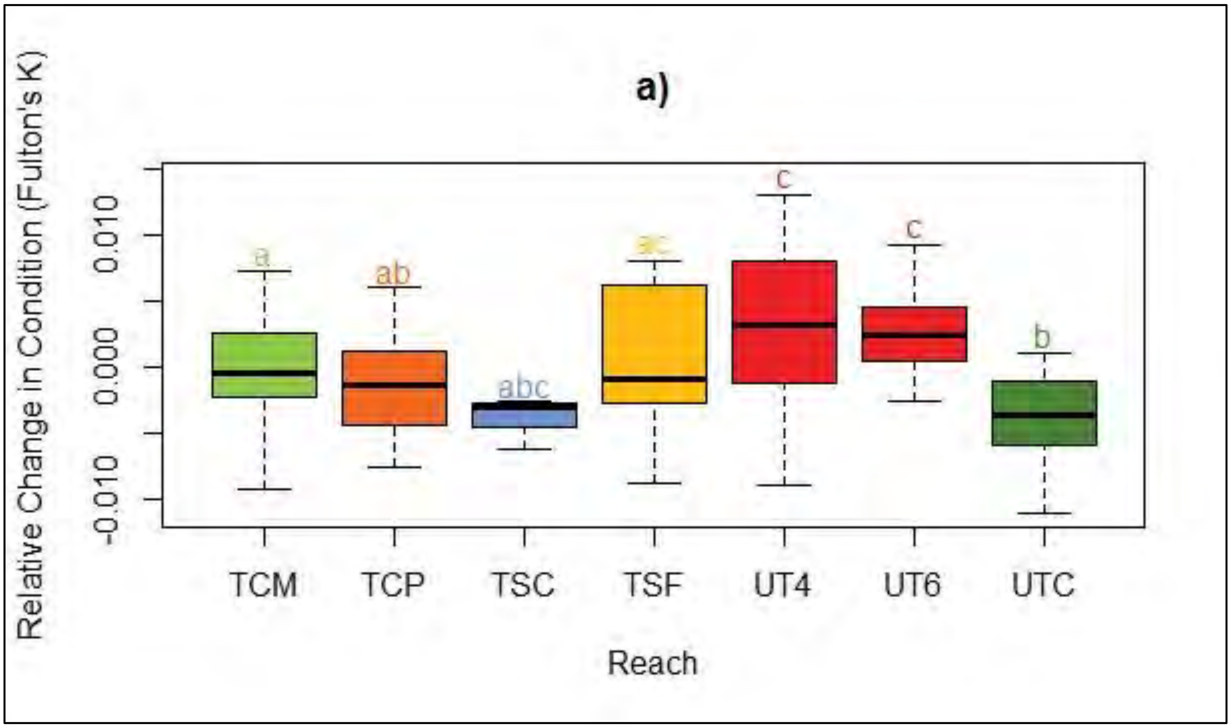


Figure 8: Box plots of change in mussel condition (change in mussel condition based on Fulton's K from 2014 to 2017) showing the third quartile (Q3) and first quartile (Q1) range of the data and data outliers summarized by reach.

5 Discussion

In 2015, an interim report was completed to help identify reaches to relocate mussels during the large translocation efforts of 2015 and 2016. Since the study plots had only one year of data post relocation, we recognized that additional information would be gained by tracking the study mussels over a longer time period and following high flows. This information can be used during future restoration efforts, as well as for consideration in moving some of the mussels that were relocated in 2015 and 2016.

In 2015, one year after relocation, 72% of the mussels were alive, 22% of which travelled outside of the plot. In 2017, 3 years after relocation and following a large water year (Figure 3), 34% of the mussels were alive, 15% of which travelled outside of the plot. While the number of mussels that were found was low, less than 1% of the mussels were actually confirmed dead and therefore likely more than 34% of the mussels are alive but were not found during monitoring surveys. During the initial survey prior to relocation efforts it was estimated that 10,440 mussels had to be relocated. However, during relocation efforts 25,409 mussels were relocated – this means that only 41% of the mussels were identified during snorkel surveys. Therefore we can say at least 34% of the mussels survived the pilot study relocation effort three years post. It is challenging to find mussels, especially when they travel. This study has shown that mussels can travel upstream, downstream, or to the side. The study design only planned for searching for mussels 25 m on all sides of the plot. While survey efforts often continued past 25 meters these efforts decreased past 25 m. Yet the results show that by 2017, while the average distance travelled was 4.2 m, one mussel had travelled 165 m downstream, likely due to the large flow events. If future studies are conducted it would be important to use electronic pit tags rather than rely on snorkel techniques. While snorkel techniques are more affordable, there is uncertainty in the results when a mussel is not found.

The 2015 draft interim report identified the percent cover of algae and to a lesser extent the bankfull height as potential habitat variables that were tied to translocation success, however neither of these were significant. In 2016, mussels were more likely to be found in areas with less aquatic vegetation and where beaver were not present. While these were significant variables, they may be linked more to survey ability than habitat since mussels would be easier to see in areas with less vegetation or in shallower water that was not ponded due to beaver dams. In 2017, following the large flow events mussels were more likely to be found in areas where other mussels had previously been present and in non-turbulent runs. Non-turbulent runs and areas where mussels were previously known to occur were also areas where mussels had increased condition. Other variables that were associated with increased mussel condition included, food supply (an increase in algae, and presence of beaver at some point in the study), mid-channel areas, and areas where the largest substrate moved in 2014 using the finger substrate test was silt. This suggests that velocity is a key indicator for mussel condition, which we knew was an important factor for mussels but were unable to measure due to safety concerns during high water years.

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Appendix F: Representative Photos from Pre-, During and Post-Project From Photopoints and Other Locations

Photo point 3 – Looking across the meadow/channel

Photo point 4 – Trees converted to meadow

Before construction

During construction

After construction

Photo point 8 – Looking across the meadow/channel

Before construction

During construction

After construction

Photo point 12 – Looking downstream

Photos from immediately following construction and 2 years post-project from northern lookout

Photos of rootwad revetment pool bank treatment during construction and 2 years post-project

Photos of northern inset floodplain and former channel backfill during construction and 2 years post-project

Appendix G: Examples of Aerial Images of Reach 5 Project Area During Flood Events

Aerial photos from 12/17/2016, approximate 350 cfs flow

Aerial photos of Reach 5 project area from 5/28/2017, approximate 775 cfs flow

Appendix H: Photos of Reach 5 Project Area During Flood Events

Overlook of Reach 5 project meadow from April 11, 2018 at approximately 400 cfs flows (above) and from June 1, 2017 at approximately 800 cfs flows (below)

Looking downstream from left bank near upstream end of project area on July 5, 2017 at approximately 400 cfs flow.

Looking north into meadow near downstream end of project area from right bank forested terrace on June 1, 2017 at approximately 800 cfs.