Final Report

Rosewood Creek Restoration, Area A

Brian Fitzgerald
Meghan Kelly
Domi Fellers
Rick Susfalk

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Prepared by
Nevada Tahoe Conservation District
400 Dorla Court
Zephyr Cove, NV 89448

Desert Research Institute
Division of Hydrologic Sciences
2215 Raggio Parkway
Reno, NV 89512

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LIST OF ACRONYMS

DRI	Desert Research Institute
EIP	Environmental Improvement Program
EMC	Event Mean Concentration
FEMA	Federal Emergency Management Agency
NDEP	Nevada Division of Environmental Protection
NDOT	Nevada Department of Transportation
NDOW	Nevada Department of Wildlife
NDSL	Nevada Division of State Lands
NTCD	Nevada Tahoe Conservation District
PSD	Particle Size Distribution
R^2	Correlation Coefficient
Reclamation	Bureau of Reclamation
RWC	Rosewood Creek
SC	Specific Conductance
SEZ	Stream Environment Zone
SR	State Route
TMDL	Total Maximum Daily Load
TRPA	Tahoe Regional Planning Agency
TSS	Total Suspended Solids
TTS	Turbidity Threshold Sampling
USACE	US Army Corps of Engineers

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INTRODUCTION

Incline Village, on the Nevada side of Lake Tahoe, experienced heavy development in the 1960s and 1970s that caused excessive sediment delivery to the lake (Glancy, 1988). Since that time period, urban development has slowed and sediment erosion rates have subsequently decreased (Rowe *et al.*, 2002). However, watersheds within Incline Village still have high rates of erosion and nutrient flux relative to background conditions. Research for the Lake Tahoe TMDL determined that the Third Creek watershed was the fifth highest contributor of fine sediment to Lake Tahoe (from perennial streams) and largest contributor on the Nevada side of the basin (Simon *et al.*, 2003; Simon, 2006; Lahontan and NDEP 2007).

Rosewood Creek is a small, urban tributary creek of Third Creek in Incline Village. The geomorphic status of Area A of middle Rosewood Creek was found to be unstable and actively degrading according to a 2005 Assessment by Mainstream Restoration, Inc. (NTCD, 2005). In an effort to improve the sensitive environmental zone and mitigate suspended sediment and nutrient delivery into Third Creek and ultimately into Lake Tahoe, the project to restore a 2,200 linear foot section of Rosewood Creek, "Area A," was constructed during a three year period between 2012 and 2014. In order to assess the success of the restoration, water quality monitoring was necessary and conducted both pre-and post-construction. The report that follows discusses both the construction and monitoring components of the Rosewood Creek Area A Stream Environment Zone Restoration Project.

PROJECT LOCATION

Rosewood Creek is a tributary branch of Third Creek, located in the Lake Tahoe Basin within Incline Village, Washoe County, Nevada. Figure 1 shows Rosewood Creek in relation to Lake Tahoe, along with displaying Rosewood Creek in its entirety, including the restoration projects referenced in this reprot. Figure 2 below details the Area A restoration location within the creek's watershed as well as the location of the monitoring stations. The creek's watershed encompasses 1.15 square miles with the headwaters located at an elevation of approximately 8,500 feet in the Carson Range. The middle reach of Rosewood Creek extends from State Route 431 to State Route 28 and ranges in elevation from 6,371 to 6,835 feet. The Area A project site (Figure 2) is a portion of the middle reach from State Route 28 upstream to 100 ft above Northwood Blvd.

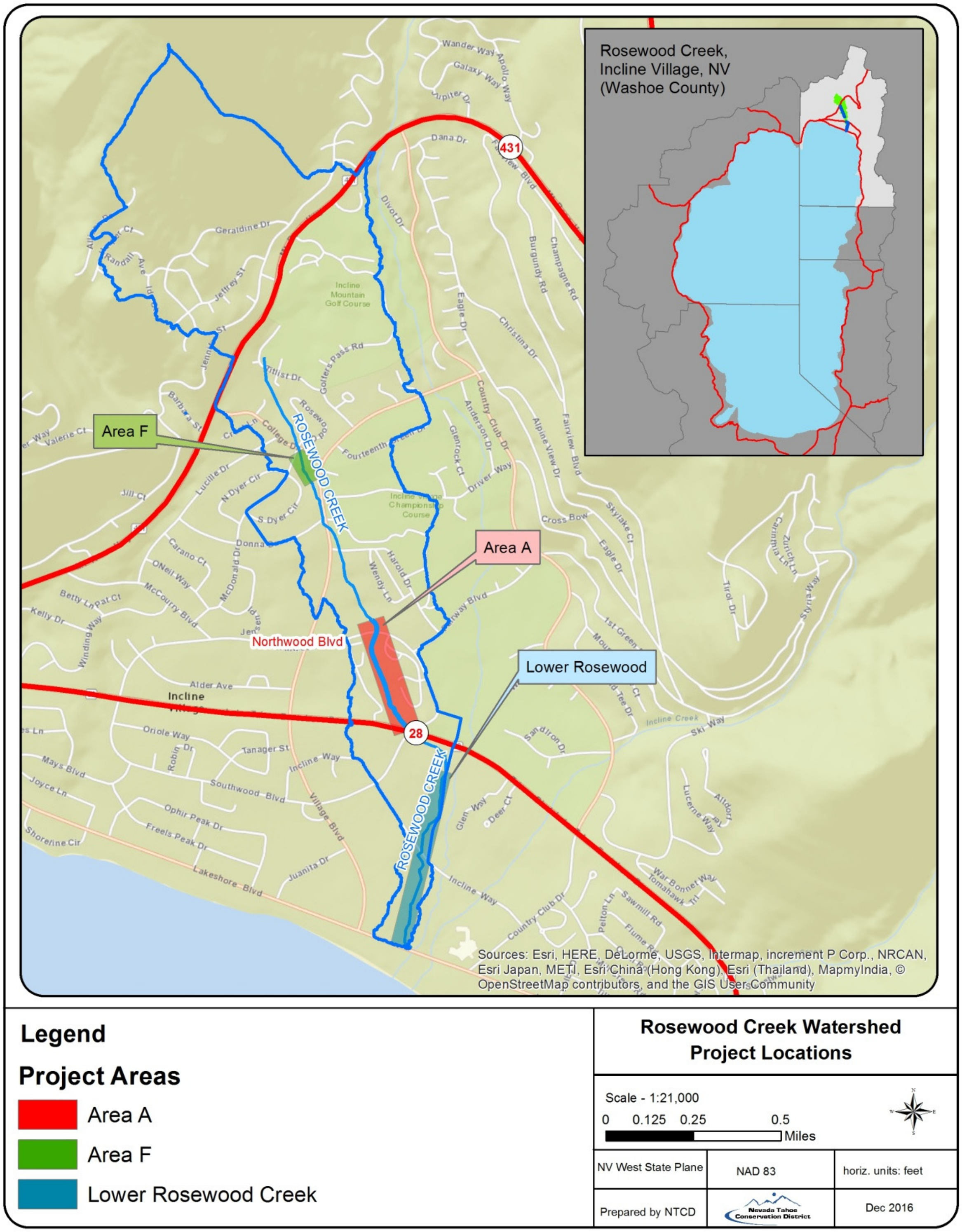

Figure 1. Project location of Area A within the Rosewood Creek watershed. Also shown is the location of 2 previous restoration projects on Rosewood Creek, Area F and the Lower Rosewood Creek Restoration.

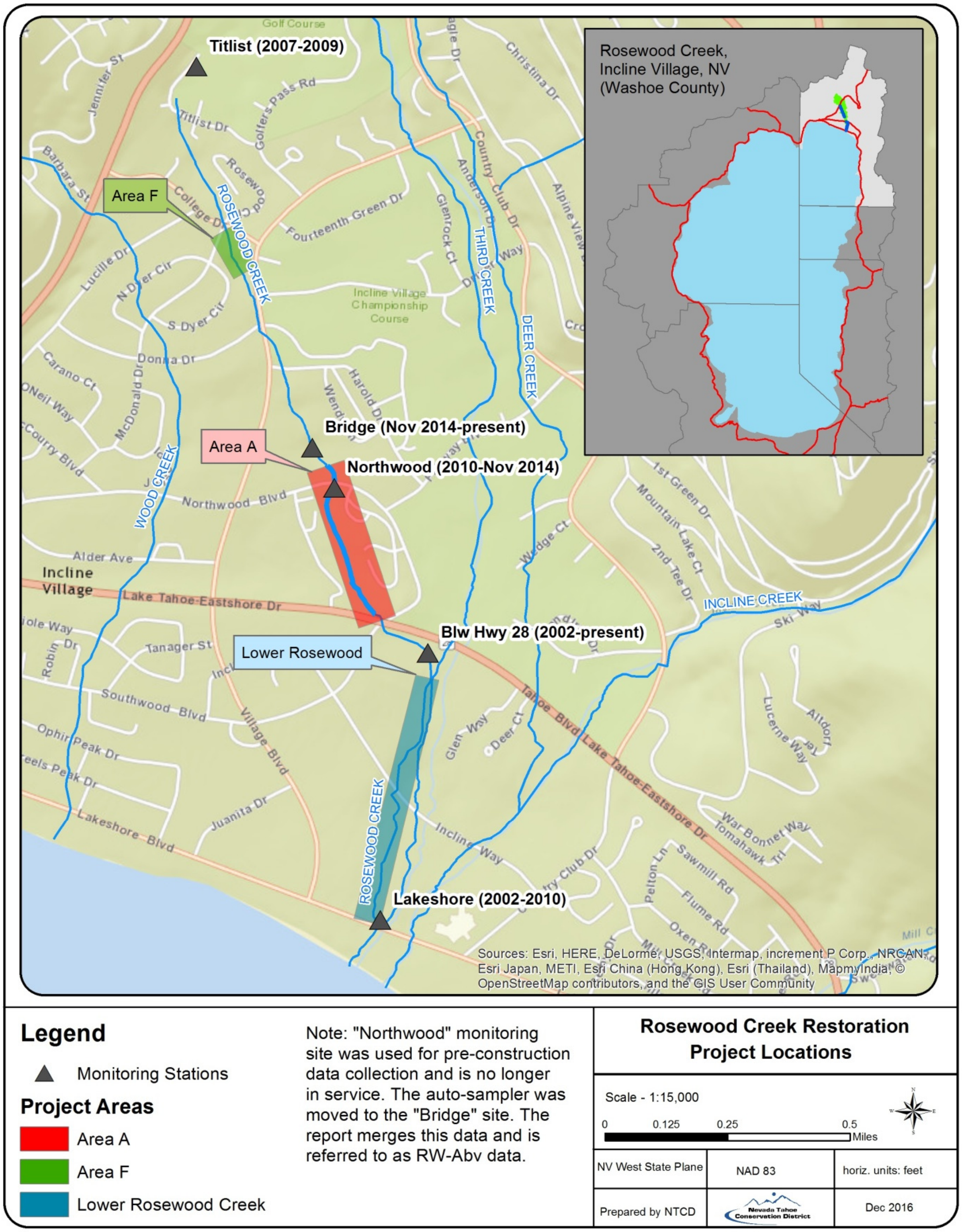

Figure 2. Rosewood Creek Restoration Project and Monitoring Locations. "Northwood" and "Bridge" are referred to as RW-Abv in this report. The station at "Blw Hwy 28" is referred to as RW-Blw in this report. Years in parentheses following the monitoring station names represent the station's operational dates.

PROJECT PURPOSE, GOALS AND OBJECTIVES

The goal of the project was to restore a 2,200 linear foot section, "Area A," of middle Rosewood Creek that was identified to be one of the most impaired sections in the 2005 assessment referenced above. The project is identified by TRPA's Environmental Improvement Program (EIP) as number 562.

The objectives of the restoration were as follows:

1. Water quality
    a. Reduce total sediment and fine sediment load to lower reaches of Rosewood Creek and Lake Tahoe.
    b. Improve the hydrologic connection between the stream and adjacent floodplain to allow some areas of net deposition within the reach. This change will promote a more healthy vegetation structure, reduce flood risk downstream, and prevent catastrophic stream bank failures.
2. Soil conservation
    a. Prevent the future loss of approximately 10,000 yd^3 of soil from the project area and restore soil moisture regimes through improved floodplain processes and groundwater support.
3. Vegetation
    a. Reduce the fuel load and risk of catastrophic wildfire in the project area. This will be obtained through the direct effects of clearing and improving density and age classes and structure of the vegetation. And also a more functional floodplain will improve vegetation recruitment and change on the active floodplain.
4. Fisheries
    a. Improve stability of stream banks and bed in the project area to provide a stable habitat for aquatic life.
    b. Construct and enhance pool/riffle, and step/pool physical habit within the project reach that would be sustained by natural processes without the historic degree of sedimentation and debris jam degradation.
    c. Improve resident fish movement by elimination of several large knickpoints and shallow, debris blockage areas, and potentially improve upstream and downstream fish passage at the Northwood culvert crossing, and permit access to habitat in adjacent stream reaches.
5. Wildlife habitat
    a. Improve the vegetation species, structure and age class distribution. Current large areas of even-age and same structure vegetation will be improved through selective removal and revegetation efforts. This will improve avian and mammal habitat, as well as reduce the risk of wildfire (as discussed above).

By completing the restoration, the following accomplishments were expected.

1. Decrease existing and future fine sediment load to Lake Tahoe and contribute to an improvement in lake clarity.
2. Continue the successful private/ government partnership demonstrated along Rosewood Creek to date.
3. Reduce risk of wild fire moving through the urban SEZ.
4. Improve aesthetics along the narrow creek corridor.
5. Provide high visibility evidence of commitment to multi-objective SEZ restoration and sediment source reduction.

In order to assess the success of many of the construction objectives, water quality monitoring was necessary. The overall objectives of the Rosewood Creek monitoring were to:

1. Evaluate the effectiveness of the restored section of Rosewood Creek at reducing sediment and nutrient loads to the Lake
2. Provide hydrology and hydraulics data to support the design of the Area A restoration project
3. Quantify the improvements to water quality resulting from Area A restoration.

These objectives were accomplished by utilizing pre-construction monitoring to assess the impact of Rosewood Creek suspended sediment and nutrient delivery from Area A and quantifying the ability of the restoration project to alter the mass and particle-size distribution of suspended sediment after construction. In-situ monitoring was conducted between August 2010 and November 2016; however, creek water was not introduced to the newly constructed channel for approximately one year (September 2014), in order to minimize sediment mobilization by allowing vegetation to take hold.

Data collected at each monitoring station included continuous measurements of water discharge, turbidity, specific conductance, and water temperature. Discrete water samples were collected by an automated vacuum sampler and were analyzed for total suspended solids (TSS), particle-size distribution (PSD), and nitrogen and phosphorus components. Particle-size distribution was used to assess the relative importance of suspended sediment loading as finer-sized particles remain entrained in stream flow and suspended in the nearshore regions of Lake Tahoe for a longer period of time, and are more likely to adsorb nutrients on their surface, compared to coarser-sized particles. Thus, fine sediment particles play a large role in decreasing Lake Tahoe's clarity and have been identified as the main pollutant of concern in the Lake Tahoe TMDL.

SITE HISTORY

Lake Tahoe has been designated an "Outstanding National Water Resource" under the federal Clean Water Act because of its ecological assets, aesthetic qualities and recreational appeal. Unfortunately, the optical clarity of Lake Tahoe has decreased 40 percent during the last five decades as a result of algal growth stimulated by nutrient input from atmospheric deposition, urban runoff, and the transport of sediment into the lake (Byron and Goldman, 1986; Jassby *et al*., 1999; Lahontan and NDEP, 2009). Once in the lake, suspended sediment can have a direct negative impact on visual water clarity (Jassby *et al*., 1999) and it can serve as a source of nutrients, particularly phosphorus, that stimulate algal growth (Goldman *et al*., 1993). The Lake Tahoe Clarity Model indicates that the loading of ultra-fine inorganic particles of <16 µm in diameter has the largest effect on lake clarity and that a 55 percent reduction in the loading rate of these particles is necessary to achieve historical clarity levels (Sahoo *et al*., 2010).

Twenty-seven percent of the fine sediment (<63 µm diameter) entering the Lake from all sources is from stream bank erosion (Lahontan and NDEP, 2009). However, low-elevation urban creeks, such as Rosewood Creek, also carry a significant load of stormwater runoff from the watershed during hydrologic events. Sediment delivery to the lake by streams from the Incline Village, NV area is particularly important as the Third and Incline Creek watersheds deliver the highest sediment and nutrient yields (load per watershed area) to the lake of the streams monitored by the Lake Tahoe Interagency Monitoring Program (Rowe *et al.*, 2002). Rosewood Creek, the largest tributary to Third Creek, has been previously identified as a low-elevation, urbanized stream whose excessive sediment erosion and suspended sediment loads are expected to respond to restoration and/or other management practices (Watershed Restoration Associates, 1999).

The Natural Resources Conservation Service conducted the first restoration project on Rosewood Creek in 1997 that was intended to reduce the sediment loads entering Rosewood Creek. This early project involved the installation of structural controls (rock lined inlets, oil separation vault and two detention basins) in the lower reach, but ultimately did not fully meet the desired performance criteria. A second restoration project for Lower Rosewood Creek (between State Route 28 and Lakeshore Blvd., Figure 1) was constructed in 2003 that re-routed Rosewood Creek into historical channels for approximately 3200 feet, and, moved its confluence with the upper reaches of Rosewood Creek from just south of State Route 28 to just north of Lakeshore Blvd. In addition to the added channel length, several flood spreading-basins were incorporated into the restored channel design in order to provide infiltration areas to reduce water velocity and drop sediment loads. The objectives of the 2003 project were to reduce sediment and nutrient loading to the Lake and create a functioning stream environment zone (SEZ). In 2008, the Nevada Tahoe Conservation District (NTCD) restored Area F, a 700 ft sub-reach from Village Blvd upstream to College Drive, by constructing six grade control structures in the creek, removing numerous creek-spanning logs, stabilizing creek banks, and installing a new stormwater treatment feature between College Drive and the creek with the objective of reducing sediment and nutrient loading to the Lake.

In 2011, NTCD received funding to restore Rosewood Creek Area A, incorporating a section from Northwood Blvd downstream to State Route 28, by constructing a new creek channel and filling in the highly degraded existing channel. The implementation of the Area A restoration project was expected to reduce pollutant loads and affect the particle size distribution of sediment entering the Lower Restoration Project and is the subject construction project of this report.

The 2003 Lower Rosewood Creek Restoration Project, the 2008 Rosewood Creek Middle Reach Area F, and the 2012 Rosewood Creek Middle Reach Area A are stream environment zone restoration projects, identified by TRPA's Environmental Improvement Program (EIP) Project 562. These projects are related to the following environmental thresholds: water quality of tributary discharge to Lake Tahoe (WQ-4), stormwater quality (WQ-5), and preservation of stream environment zones (SC-2).

PROJECT SUMMARY

The Rosewood Creek Area A SEZ Restoration Project involved design, engineering, acquiring permits and specific environmental documentation, construction, revegetation, and monitoring the reach of Rosewood Creek between State Route 28 and Northwood Boulevard in Incline Village. Restoration of this 2,200 ft reach was designed to prevent stream bed and bank material from being eroded, mobilized and transported to Lake Tahoe, to improve downstream water quality, and to reduce the load of TMDL pollutants as well as improve fish habitat, forest health, and riparian habitat. The project was a coordinated effort between the private land owners, including Club Tahoe Homeowners Association (HOA), Third Creek HOA, and Craig Robinson, and personnel from Tahoe Regional Planning Agency (TRPA), Nevada Division of State Lands (NDSL), Bureau of Reclamation (Reclamation), Nevada Department of Wildlife (NDOW), Nevada Department of Transportation (NDOT), Federal Emergency Management Agency (FEMA), US Army Corps of Engineers (USACE), Nevada Division of Environmental Protection (NDEP), and Washoe County. The project was funded by the Reclamation, NDSL, and Washoe County through the TRPA mitigation fund program.

Starting from State Route 28 and progressing upstream, the first 400 feet of Area A was incised over 12 feet deep and the width of incision was over 20 feet wide (Figures 3 and 4). It was estimated that 1,800 yd^3 of material have been moved from this area to the lower reach of Rosewood Creek, to Third Creek, and ultimately into Lake Tahoe. (NTCD, 2005).

The dramatic headcut described above was migrating upstream. The next upstream 200 feet of the Rosewood Creek channel was nearly 6 feet deep with vertical or undercut banks (Figure 5). The potential for additional incision and bank failure was high. If the headcut was allowed to migrate, it would affect a relatively stable upstream section of creek. The section of creek 600 feet to 880 feet above State Route 28 represented a potential model for restoration of the entire Area A of Rosewood Creek. However, the next 900 feet upstream to just downstream of Northwood Blvd "exhibits extreme, severe incision, generally reflecting the initial stages of rapid downcutting with vertical banks" (NTCD, 2005) (Figure 6). This section of the creek also appeared to have been relocated out of its original channel, west to a channel higher on the floodplain. Immediately upstream of Northwood Blvd, the creek was relatively stable.

As a result of the geomorphic assessment, the design team recommended filling the incised channel with adjacent material and restoring the active channel back to the now-abandoned terrace surface to re-establish a functional floodplain (Figure 7) along with stopping headcuts and re-wetting remnant channels. Due to the location of the project area on private property and the observation of previous levels of extreme erosion, the design incorporated resiliency by building a rock armored channel with subsurface channel and valley-wide grade controls. These grade controls were long sub-surface structures built of boulders and smaller rock designed to direct flow back to the constructed channel if flow were to ever exit the channel and begin forming a new channel. The goal of the grade controls was to prevent erosion from occurring in Area A like that evidenced in the head cuts prior to restoration.

An abbreviated set of design plans is included in Appendix F. A full set is available upon request or for download at ntcd.org.

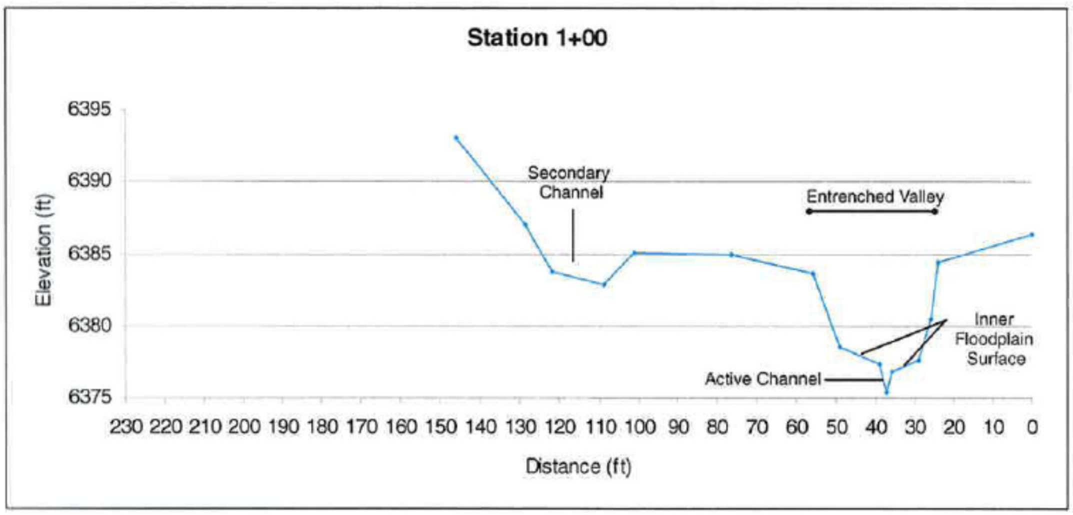

Figure 3. Cross-section of Rosewood Creek at Station 1+00 representing the condition of Area A for 400 feet upstream on State Route 28.

Figure 4. Photos of the large headcut near the crossing at State Route 28.

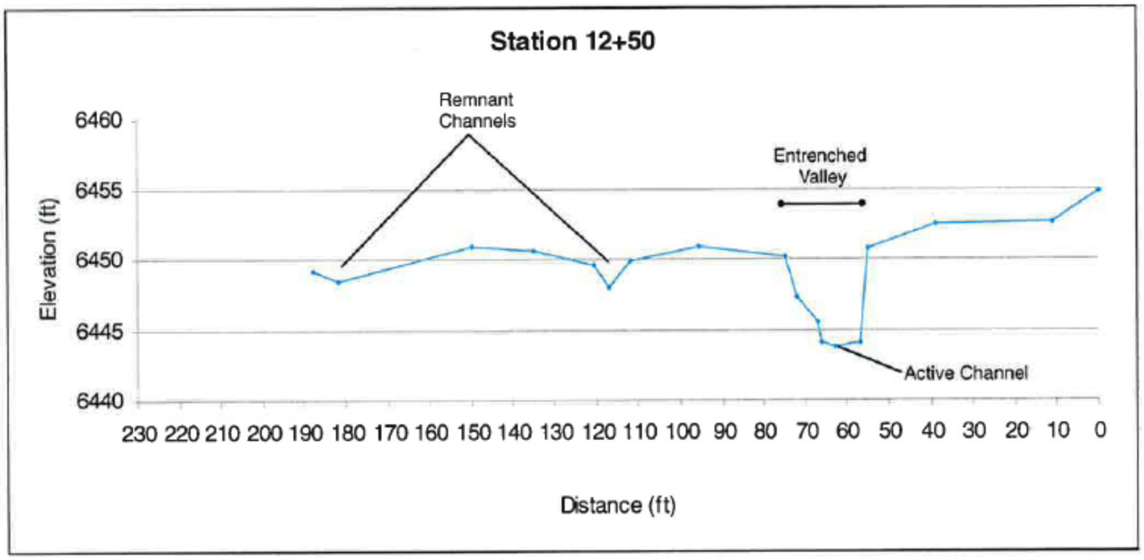

Figure 5. **Cross-section of Rosewood Creek at Station 12+50 representing the condition of Area A 400-600 feet upstream of State Route 28.**

Figure 6. **Photos of the large headcut near the crossing at Northwood Blvd.**

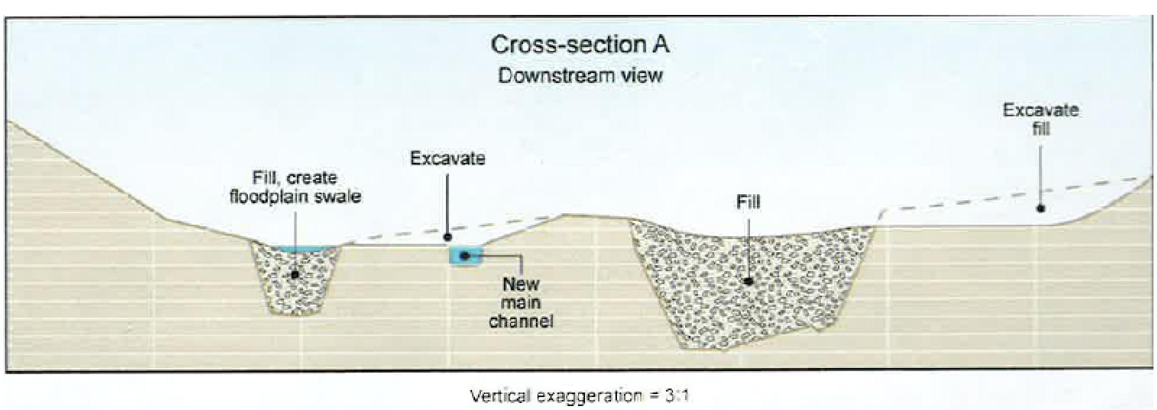

Figure 7. **Conceptual plan for the general design of the Area A restoration. A new main channel much smaller than the existing channel was constructed. Floodplain was graded adjacent to the new channel. Excess material was used to fill existing channels.**

RESTORATION CONSTRUCTION

The Rosewood Creek Area A Restoration Project was constructed in four phases over four years, which included two years of active construction. Phasing the project allowed for a majority of the new channel and floodplain to be constructed and remain inactive for a year while vegetation established and water remained in the existing creek. Once vegetation was deemed established, flow could be transferred over to the new channel and the old channel could be filled and decommissioned. A view of the new alignment versus the old alignment of the channel can be found in Figure 8.

Phase I occurred the summer of 2012 (Figure 9) and involved replacing and realigning the culvert under Northwood Blvd. (Figure 10) and creating a new channel, utilizing existing topography to the extent possible including an abandoned section of the creek, and sizing the channel such that flows move onto the surrounding floodplain approximately every 2 years on average. The new channel was constructed the length of the project area with the exception of three tie-ins to be constructed in Phase III. The floodplain was also constructed adjacent to the new channel leaving room for the creek to flow in its existing channel. Valley-wide and channel grade controls will also installed below the new channel and floodplain, stopping short of the existing channel. The remainder of these grade controls were installed in Phase III as to not conflict with the existing channel which remained active.

Phase II, summer of 2013, involved irrigating the new channel for a full growing season to establish vegetation before it became the active channel, removing invasive weeds, and visual inspections to ensure Rosewood Creek did not leave the old channel and enter the new channel during any significant precipitation events and that the banks of the new channel remained stable. The design of the new channel relied on the presence of mature vegetation with a rooting depth greater than 6 inches before water would be introduced for long term success and so it was imperative that the new channel remained inactive until vegetation was mature and established. During Phase II, July 9, 2013, a revegetation specialist surveyed the rooting depths of the vegetation in 15 locations along the new channel and found rooting depths to be on track for full maturity during Phase 3, but not mature or deep enough to forego Phase II or the seasoning phase. Results indicated rooting depths varying from 1 inch to 6.5 inches and root density was ranked as low to moderate (Wood Rodgers, 2013). Rooting depths of 6 inches or greater in all locations was the goal for bank and floodplain stability and so Phase II continued as an inactive channel and floodplain seasoning phase (Figure 11).

Phase III, constructed in 2014, consisted of building three key sections of new channel not constructed during Phase I in order to keep the existing channel active throughout Phase II. Building these “tie-ins” in the order that follows, a downstream one, one where the new channel crossed the old channel, and an upstream one, allowed water to be introduced to sections of the creek from downstream until water quality regulations were met (Figure 12). Water was introduced first to the lower section, pumping dirty water out downstream until the turbidity requirements of < 10 NTU difference from upstream were met. Once the middle “tie-in” was

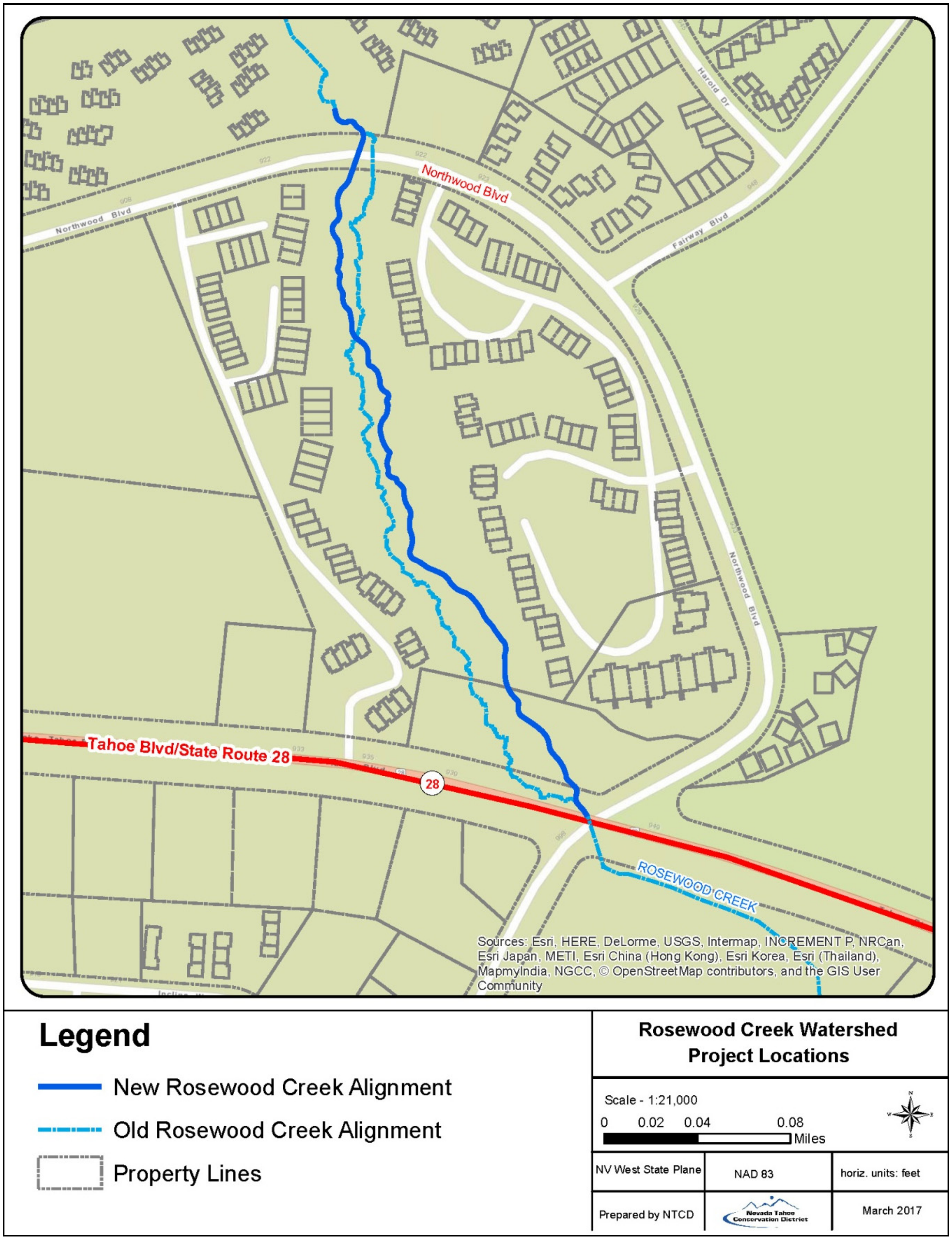

Figure 8. **The existing Rosewood Creek location is shown in light blue. The new alignment constructed during the Area A Restoration is shown in dark blue.**

Figure 9. Left: At the beginning of Phase I, an access road was built into the project area and numerous willows and alders were removed. Right: The construction of valley and channel wide grade control structures involved placing subsurface rock.

Figure 10. Left: Installation of the culvert presented difficulties as many existing utilities were present. Right: The construction of the channel immediately downstream of the newly installed culvert.

constructed, an additional section of new channel received water, pumping water out until the turbidity requirements were met. Finally, the upstream tie-in was constructed and water was introduced to the entire new channel (Figure 13). Once water flowed in the new channel, the old channel could be filled including the old culverts at Northwood and the old channel could be revegetated (Figure 14). Because the tie-ins would not have a year without possible flow, erosion control blankets were used to ensure floodplain and bank stability in the event high flows occurred. Phase IV occurred in 2015 and consisted of irrigating the old creek channel and the three newly constructed creek sections from Phase III, monitoring the vegetation growth throughout the project, removing the invasive weeds and monitoring Rosewood Creek for bank stability and channel movement, concluding the summer of 2015. Water quality monitoring was on-going throughout the project, including pre- and post-construction.

The majority of the design and engineering was sub-contracted to Valley and Mountain Consulting and Cardno, Inc (formerly known as Entrix). Burdick Excavating Co., Inc performed the construction and revegetation with Wood Rogers retained for assistance with permitting and environmental documentation, and revegetation input. The Desert Research Institute (DRI) was retained for water quality monitoring due to their expertise and prior monitoring experience on Rosewood Creek. The Nevada Tahoe Conservation District (NTCD) provided project management, construction oversight, and water quality monitoring support.

Figure 11. Left: Phase II, June 2013, vegetation showing remarkable success. Right: Phase II, July 2013, having an area at the bottom of the inactive channel for water to pond was essential for erosion prevention.

Figure 12. Left: Construction of the downstream tie-in occurred at the beginning of Phase III. Right: Filling the old channel commenced after the construction of the downstream tie-in.

Figure 13. **Left: Construction of the upstream tie-in. With the completion of this tie-in, the new Rosewood Creek channel could finally receive flow. Right: The new Rosewood Creek culvert receiving flow for the first time on September 11, 2014.**

Figure 14. **Left: With the water diverted from the old creek location to a pipe for the construction of Phase III, the monitoring station had to be moved upstream of Northwood. Right: The portion of the valley-wide grade controls that crossed the existing channel had to be constructed during Phase I and marked with a 2x4 so that the Phase III portions could be aligned.**

CONSTRUCTION LESSONS

Overall, the approach of a phased project allowed for greater project success. Vegetation on channel banks and throughout the floodplain was able to establish good root structure before receiving large flow events. The construction-related water quality impacts were minimized as work within an active flowing channel was avoided. However, a few changes during the design and permitting and to the construction methods and inspection protocol could have improved the overall construction of the project.

Design and Permitting

In 2011, after 90-percent of the design plans and specifications were completed, the board of the Third Creek HOA, the landowner than owned more than 60 percent of the project area, decided they would not enter a memorandum of understanding (MOU) to allow construction of the restoration project on their land. At this point, over $250,000 had been spent on studies, permitting, and design, and the project could have been halted without this landowner's participation. The primary objection of the Third Creek HOA was potential disruptions from the three-year construction period and visual changes from the removal of trees and vegetation. They were uncertain and concerned about how the changes in the landscape would affect their property value and way of life. It took nearly one year of meetings with board members and a regulatory push by the Tahoe Regional Planning Agency to move the project forward. The result of this process was additional costs to the project, spent on facilitation, and the loss of one year of post-construction monitoring data. Because of NTCD's failure to secure an MOU, they absorbed the actual facilitation costs. In order to avoid potential disruptions to stakeholders and contractors in the future, agreements with landowners must be signed earlier in the design process, preferably before considerable funding is expended. Furthermore, engineering plans are often difficult for non-engineers to visualize as a finished project. Restoration projects may benefit from having an artist's rendering prepared for presentations to stakeholders to help them envision a finished project. The "Area A" restoration has received only compliments from the same Third Creek HOA board members that were skeptical of the resulting landscape and hesitant to sign the MOU.

The design of the creek was based on numerous surveys and models; however, additional site visits prior to choosing the final channel alignment could have improved the alignment in a few locations and better utilized remnant channels. Near the proposed channel station of 300-400 feet upstream (Sheet P-1), the channel design aligned the creek bed up against a steep slope eliminating a floodplain on the left side of the channel. There was space to move the channel at this location and a small adjustment was made in the field, but a better design could have resulted in floodplain on both sides.

The design also called for underground buried protection (Sheets P-1 and P-2) to limit groundwater exchange between the new channel and the old channel in locations that were deemed to be vulnerable. These buried protections were likely unnecessary as the channel fill in the old channel was well compacted and unlikely to present any major issues in the long term. Furthermore, the short length of the designed buried protections was unlikely to stop the movement of groundwater as they could easily be flanked. Unfortunately there is no cost-effective way to monitor the impact of these buried dense soil layers.

Construction and Inspection

Construction of the project progressed relatively smoothly as the design plans and specifications contained considerable detail to guide both the inspectors (NTCD staff) and the contractor. However, lessons were learned from the construction efforts that may help future restoration projects.

As discussed above, the creek alignment was closer to a steep slope about 300 feet upstream from State Route 28. Had the inspectors and design team staked the project instead of a surveyor hired by the contractor, the alignment could have been altered more prior to construction. Alternatively, the specifications could have contained language that mandated the surveyor work closely with the inspector to stay ahead of the contractor and check the actual stake locations verses the plan locations. Measures have been integrated in to future restoration project planning to either stake the project internally or work closely with the hired survey in all future construction projects.

During Phase I an accident occurred during construction where an active water line was struck by equipment while excavating for the culvert installation. The ensuing water line break resulted in thousands of gallons of potable water filling the culvert excavation site, becoming sediment-laden, and spilling over into the existing Rosewood Creek. While teams were deployed quickly by the contractor to prevent downstream pollution, sediment did travel downstream to Lake Tahoe and a full day was spent cleaning up. Although the utility provider had been on site and identified the struck line as abandoned, it was clearly not the case. Agreements with utility providers in the project area should include clauses that describe the responsibility of the utility provider to accurately identify their own utilities in order to protect the project owner. Because an agreement like this was non-existent, this costly change order was split between the utility and the project owner (NTCD). Furthermore, NTCD staff has learned how to identify active and inactive water lines.

Willow and alder were to be transplanted as a way to revegetation the project using onsite materials. Because willows and alders seemed plentiful at the beginning of construction, the contractor did not take care to preserve root wads when clearing and grubbing despite warnings from the inspectors. The contractor was not able to locate enough willow root wads in Phase I to transplant the number matching the plans and therefore had to supplement with purchased willows. Additionally, transplanted willows were more successful than transplanted alders. Willow stakes were nearly 100 percent successful while alder root wads were only 80 percent successful.

The vegetation growth on the project was very successful and the specification has been emulated on future projects. In fact, the “Area A” project won a TRPA “Best in Basin” award in September 2016 and judges indicated that the revegetation was one of the most successful witnessed in the Tahoe Basin. A single layer of straw-coconut (30/70 percent ratio) erosion control blanket enabled plants to grow just as quickly and well as areas without blankets. The only impediment to vegetation establishment has on the periphery of the project was that mulch was applied over 1 inch thick in some locations.

The project was constructed during a 4-year drought period. Phase III occurred in the third year of the drought and while low flows made the creek diversion easier (smaller pumps and pipes), it was difficult to maintain water downstream when re-wetting the creek. As a result, when flow was first switched over to the new channel, Lower Rosewood Creek dried up for a short period of time as water could not exit the restoration area because it was filling up the rocky sub-grade and grade control structures. Fish were left stranded downstream and while staff members were deployed to rescue many of the fish, some fish could not be saved. With low flows and a rocky substrate, a contingency plan should have been employed to divert a nearby creek (Third Creek in this instance) to maintain fish flows downstream. Future projects will consider this possibility as newly built creeks often take time for void spaces to fill up and not flow sub-surface.

Photo point monitoring, which is discussed later in this report, gives a good overview of the project's success as well as the level of impact during construction.

MONITORING

MONITORING PLAN

To inform the restoration design, construction, and revegetation efforts, water quality monitoring was conducted by the DRI and NTCD. The monitoring equipment configuration (automated water sampler, turbidimeter, water level stage, specific conductance, and water temperature instruments) was used to collect data on Rosewood Creek for over six years. Approximately $246,000 was used to fund the operation of two autosamplers, one immediately above the project area and one immediately below, as well as the associated lab analyses, data analyses, and maintenance and operation for six years. Beginning in December 2010 and for the first year, monitoring was limited to continuous real-time data such as water discharge, turbidity, conductivity and water temperature to establish baseline data and rating curves. In August 2011 and for the next five years, continuous real-time data and water quality samples were collected.

The initial plan for water quality sampling was to collect and analyze up to nine events, annually: one baseflow, at least four rain/thunderstorm, and at most four snowmelt. However, sampling was restricted for the water years 2011, 2012, and 2013 to reserve a contingency for construction as the engineer's estimates and contractor's bid were higher than originally budgeted. There were three samples collected during the snowmelt period in each of the water years 2012 and 2013. Upon better gauging of the construction budget and the sampling and analytical costs, the sampling regime was increased to more than nine events per water year for 2014-2016. The event samples were analyzed for total phosphorus and nitrogen, total Kjeldahl nitrogen, dissolved inorganic phosphorus (Ortho-phosphate), nitrate, ammonia, total suspended sediment (TSS), and laser particle-size diameter analysis (PSD). The total nutrient analyses provide an overall indication of the loading delivery to the Lake. The nutrient species analyses

(Ortho-phosphate and nitrate) represent the most bio-available forms of these nutrients. Primary productivity of algae is limited by these species of nitrogen and phosphorus. Continuous flow, temperature, conductivity, and turbidity data were also collected. DRI provided the sampling equipment as an in-kind contribution to this project.

The goal of the monitoring was to evaluate the effectiveness of SEZ and creek restoration of an urban stream in the Lake Tahoe Basin. The supposition was that sediment and nutrient loads would decrease over time as the project was completed and vegetation becomes established. The objectives of the monitoring project were to: 1) evaluate the effectiveness of the restored lower reach of Rosewood Creek at reducing sediment and nutrient loads to the Lake, 2) provide hydrology and hydraulics data to support the design of selected areas in the middle reach, and 3) quantify the improvements to water quality resulting from middle reach restorations.

MONITORING STATIONS

For the duration of the project, Rosewood Creek Area A had two monitoring stations, one above and one below the project (Figure 1). The Northwood and Bridge monitoring stations represent the above project location (RW-Abv), while the Below State Route 28 monitoring station represents the below project location (RW-Blw). NTCD installed the Northwood monitoring station in August 2010 understanding the site would have to be moved prior to beginning Phase III of the project. Northwood was jointly moved by DRI and NTCD in August 2014 to the present location at “Bridge.” These monitoring stations automatically collect stream water based on a turbidity threshold. Event mean concentration (EMC) composite samples were analyzed for nutrients, TSS, and sediment particle size (using a laser particle-size analyzer). Data analysis efforts compare upstream data to data below the restoration site, including an assessment of the relationship between TSS and turbidity.

DRI began monitoring water quality data at the Below State Route 28 monitoring station in November 2002 for a NDSL funded project to assess the impact the Lower Rosewood Creek Restoration Project had on the loading and particle size of suspended sediment delivered by Rosewood Creek to Third Creek and ultimately Lake Tahoe. Funding for the Below Hwy 28 monitoring station continued through early 2010; the Lakeshore monitoring station was also active from November 2002 through early 2010 to capture the below-project data for the Lower Rosewood Creek Restoration. From 2007 through 2009, DRI and NTCD co-operated a Rosewood monitoring site near the upstream boundary of Rosewood Creek (Titlist Ct) in support of the Area F Middle Rosewood Creek Restoration Project (Susfalk, 2010).

MONITORING METHODS

Both the above (Northwood/Bridge) and below (Below State Route 28) project monitoring stations were equipped with an in-stream turbidimeter (DTS-12, Forest Technology Systems, British Columbia, CA), specific conductance (SC) and water temperature sensor (Campbell Scientific, Logan, UT), and pressure transducer (KPSI, Hampton, VA) to monitor stage. Data from these sensors were recorded every 10 minutes by a datalogger (Campbell Scientific). Automatic vacuum samplers (Teledyne ISCO 3700, Lincoln, NE) were used to collect water quality samples based on in-stream turbidity thresholds utilizing a modified turbidity threshold sampling (TTS) program (Redwood Sciences Laboratory, U.S. Forest Service, Arcata, CA) that runs on the datalogger.

Rating curves determined by manual stage-discharge measurements were used to estimate discharge from the 10-minute stage data at each monitoring station. Stage-discharge measurements must be taken at least every 3-4 weeks to account for unstable cross-sections and the buildup of debris that can obstruct the channel. Instantaneous discharge was calculated following standard USGS methodology using a Marsh-McBirney Inc. Flo-Mate model 2000 velocity meter (Hach Company, Loveland, CO).

Data Collection Design and Techniques

The base sampling approach that was used by the Area A project: (a) prior to the construction of Area A (August 2012) only ephemeral data (e.g. stage, turbidity, conductivity, and temperature) was collected; (b) during and after construction of Area A, water samples were collected with a goal of nine samples per year. After 2011, water quality samples were collected during baseflow (at least one sample/yr), rain/thunderstorm (at least four samples/yr), and snowmelt (as many as four samples/yr). Samples were composited into a flow-weighted event mean concentration (EMC) sample and analyzed for total phosphorus, total Kjeldahl nitrogen, soluble reactive phosphorus, nitrate, nitrite, ammonia, and total suspended sediment by the DRI Water Analysis Laboratory. Additionally, sediment samples were analyzed for particle size distribution (PSD) using a Saturn Digisizer at DRI's Soil Characterization Laboratory. To remain consistent with previous Rosewood Creek monitoring practices, multiple precipitation event water samples from RW-Abv (Northwood/Bridge) and RW-Blw (Below State Route 28) monitoring stations were analyzed for total suspended solids (TSS) and PSD to assess their changes through the various phases of the event hydrograph. Refer to Susfalk, 2010 for more detailed explanation of previous methods. Relationships between continuous turbidity measurements and TSS can then be developed to estimate suspended sediment loading on a continuous and an event basis.

Constituent results from both above and below monitoring sites were compared, including nutrient and sediment EMCs, EMC-based nutrient and sediment loads, turbidity surrogate based sediment loads, inherent changes to the turbidity-TSS relationship, and changes in the particle size distribution and loadings, to evaluate the effectiveness of the restoration project at reducing sediment and nutrient loads to the Lake.

MONITORING FINDINGS

Photo Point Monitoring

Photo point monitoring is an easy and inexpensive way to monitor vegetation and ecosystem change. It consists of repeat photography of an area of interest over time with photographs taken from the same location and with the same field of view as the original photograph. Photo monitoring was suggested as a proper and accepted form of assessing "the existing conditions and evaluate the impacts of proposed management actions" (LTIMP, 2002).

Photo points were set in 2012 at the end of Phase 1 of construction. Eleven points were chosen in an effort to represent the major changes in the project. The points were marked using a GPS and are shown are in the Figure 15. Photos were taken each spring and fall with the exception of the fall of 2015. The photos for all 11 of the photo points may be found in Appendix A. Overall the points show that the new channel was stable and that the floodplain vegetation is well established and thriving. The floodplain itself was stabilized as a result.

Pre-Project Monitoring

The Rosewood Creek watershed is a low-elevation, urbanized watershed that responds rapidly to low elevation/lake level snowmelt and storm events. The watershed is 2.9 km2 with 45 percent of the watershed below State Route 431 (at an elevation of 7160 ft). The objective of Area A pre-project monitoring was to establish background data for Rosewood Creek prior to construction. Prior to construction, the RW-Abv site was located just south of Northwood Blvd. This station was intentionally positioned within the intended construction area as a means of gathering data that was proximally relevant. Once flow was moved to the new channel, the RW-Abv station (Northwood) was moved upstream by approximately 300 feet. Monitoring continued at this new RW-Abv (Bridge) beginning on August 27, 2014.

Project construction of the restored channel was completed in October 2014. Water was released into the new channel at the diversion on September 11, 2014, but water flow was not detected at the bottom end of the new channel until September 21st. After reaching RW-Blw, the leading edge of the wetting front retreated upstream until a thunderstorm of September 26-28 resulted in sustained water discharge throughout the channel length. As the new Rosewood Creek channel and floodplain continued to be re-watered and voids spaces were filled, the discharge returned to normal with similar flow both above and below the project area.

Lists of Samples and Events

The events and samples for this project can be found in Appendices B and C, respectively. Table B1 has a list of hydrologic events during the study period of record. There were 81 total events monitored over the study period, with 18 snowmelt events, 44 rain events, and 19 rain-on-snow events. Table C1 contains a list of sample times and locations. For RW-Abv, there were 34 nutrient samples and 73 sediment samples. For RW-Blw, there were 34 nutrient samples and 86 sediment samples. Summary statistics for the monitored constituents for each of the 81 events can be found in Appendix D, Table D1 for RW-Abv and Table D2 for RW-Blw.

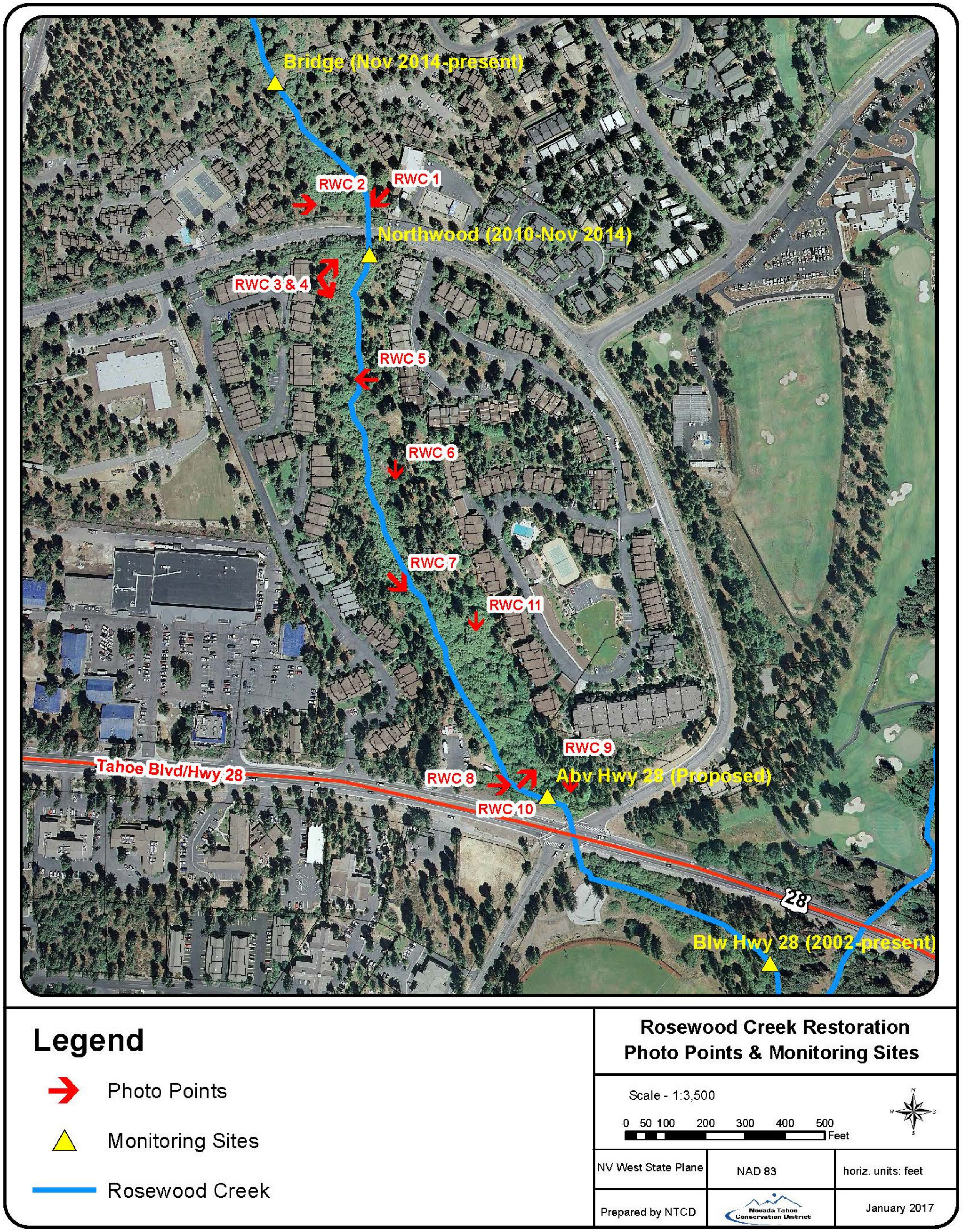

Figure 15. Photo point locations.

Suspended Sediment Results

Suspended sediment delivery by Rosewood Creek was flashy, characterized by a high peak loading (7000 kg/hour, 1450 NTU) and a quick return to near base line levels. These peak levels were both found during an unusually high-intensity storm in September of 2012, before the restoration was in effect, but reflect the potential for large suspended sediment load deliveries. Suspended sediment less than 16 μm in diameter comprised nearly 33 percent of the samples collected at RW-Abv. The particle size distribution of RW-Abv and RW-Blw suspended sediment samples are shown on a sample basis in Figure 16. The particle size distribution of RW-Abv samples was slightly finer near peak suspended sediment loading, and was consistent with the particle size distribution observed in other events. It must be noted that these TSS statistics do not describe the average value for a given site, as sampling was purposefully biased towards the collection of samples during elevated suspended sediment conditions. In general, the particle size distribution was consistent and heavier at RW-Abv regardless of event type. Early post-construction variations in the particle size distribution at RW-Blw were attributed to the delivery of coarser, unconsolidated sediment left within the channel. Beginning at Event 40 at RW-Blw, the percent fractionation increases in the 16-125 um fraction but decreases above and below those fraction bin sizes. The very heavy events at RW-Abv (Events 63, 68, 69) were likely the result of a sampling artifact where the sample intake orifice was located too low within the water column, biasing the sample with larger particles. Suspended sediment results from these events should be considered suspect. For suspended sediment loading calculations, the TSS versus turbidity relationship was used to generate per-unit concentrations.

The regression models take either a linear or polynomial form:

$$TSS = b \times Turbidity + c \tag{1}$$

$$TSS = a \times Turbidity^2 + b \times Turbidity + c \tag{2}$$

where a and b were the first and second order regression coefficients, and c was the intercept. The original objective was to develop a single site-specific regression model by aggregating all the samples collected at a given site. To support this, the sampling scheme was tuned to the collection of fewer elevated turbidity samples per event, relying on the aggregated population built over time. The correlation coefficients of the regression models using this approach was 0.562 at RW-Abv, but was less than 0.781 at RW-Blw (1st DTS-12) and 0.818 (2nd DTS-12) (Figure 17). The low predictive ability of the model at RW-Blw was a result of the temporal changes that occurred within the project as the creek and adjacent riparian zone recovered from the disturbance of construction and the planted vegetation matured over time (Susfalk, 2008). The two turbidimeters used at RW-Blw did not allow for the aggregation of all samples. The biofouling wiper mechanism on the first turbidimeter failed in spring of 2015 and was replaced soon thereafter. The turbidity values were not compromised, as manual cleaning of the sensor

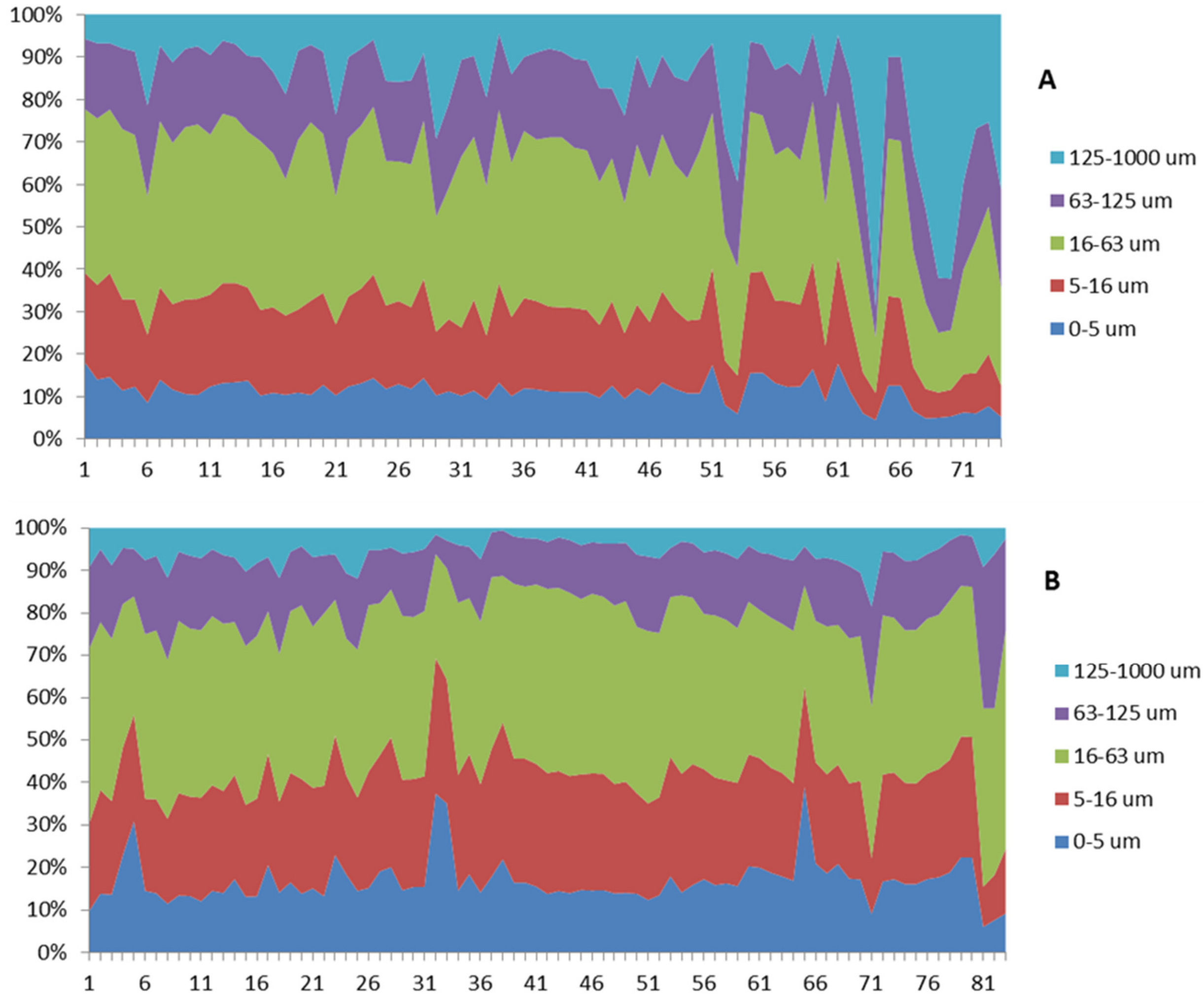

Figure 16. Particle size distribution of suspended sediment samples by site, RW-Abv is (A), RW-Blw is (B). The x-axis denotes the sample number collected at each site. Particle size fractionation is denoted by different colors for different size fractions. Pre-construction samples are #1-20 at RW-Abv (A) and #1-21 at RW-Blw (B).

face occurred in the interim before replacement. But, the calibrations of the two sensors were quite different. At RW-Abv, the relationship was largely determined by the unstable side-cut walls of the creek located above Area A.

Collected data indicates that an event-based approach was not suitable for a small creek like Rosewood, whose sediment sources appeared to be variable and highly responsive to urban runoff. Urban road runoff may have especially confounded the results due to the section of creek below State Route 28 inputs and above RW-Blw, as potentially significant contributions to suspended sediment from the road occurring below any treatment by Area A. For future work, a new monitoring station should be placed at the exact bottom of the Area A restoration and above the contribution of State Route 28 road runoff.

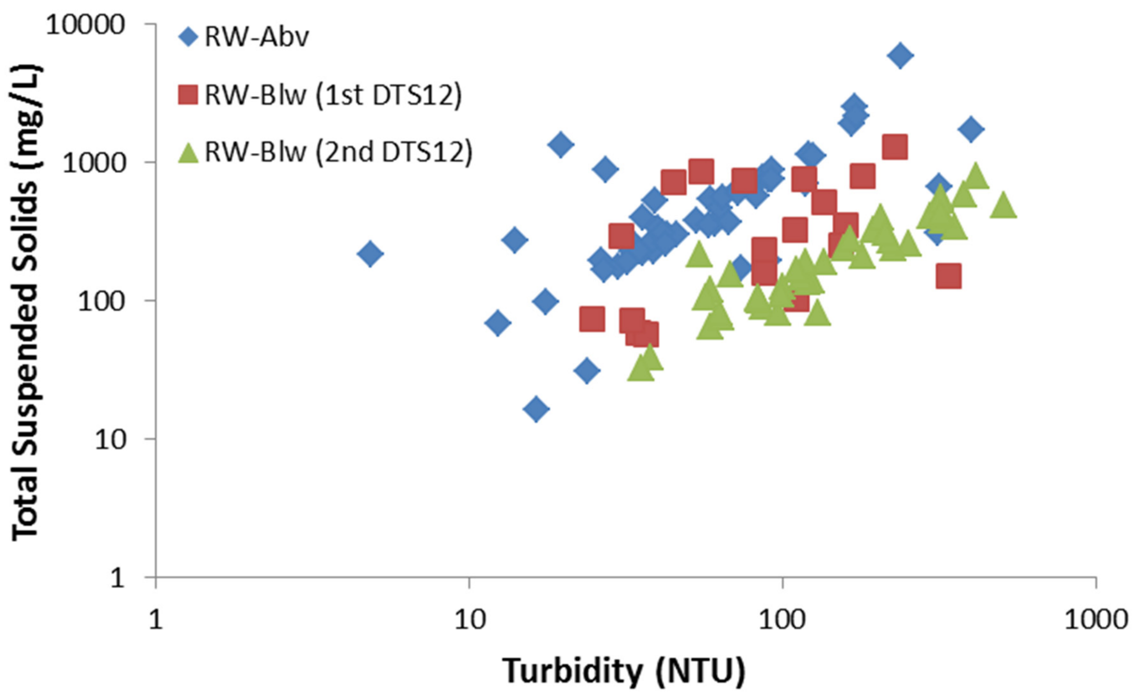

Figure 17. Comparison of TSS from discrete water samples and in-stream turbidity for RW-Abv (Northwood/Bridge) and RW-Blw (H28). The turbidimeter was replaced at RW-Blw in July of 2015.

Aggregate models failed to capture the change in relationship between turbidity and TSS over time for both RW-Abv and RW-Blw and were also potentially influenced by how the turbidity sensors themselves perceived temporal changes in water composition and particle sediment size and shape. Another influence confounding the aggregated regression models was the change in water quality entering the restoration project, as there were very few high intensity precipitation events in WYs 2013-2015. One explanation for the trend in lower-impact events was the construction of treatment projects higher in the watershed that affected the volume, timing, and sediment loads delivered by urban runoff to the creek. Three examples that directly impacted Rosewood Creek were the installation of a detention basin near Harold Drive in 2013, the installation of curb and gutter and cartridge filters on State Route 431 in 2012, and an infiltration basin installed along State Route 28 in 2014. As a result of these factors, the sampling scheme was optimized to collect additional samples from a given event in order to facilitate the better estimation of loads on an event basis and to better assess how the relationship between turbidity and TSS changes over time. The TSS-Turbidity relationship should become stronger over time.

Loadings and Errors

The turbidity versus suspended sediment regression (TSS) has an inherent associated error. This error is best represented by the correlation coefficient (R^2), which is a measure of the discrepancy between the two parameters when compared against each other; the closer R^2 is to 1, the less divergence. The power of the relationship is described by the p-value of the regression. It can reasonably be said that the correlation between two parameters is causal when the p-value is below 0.001, i.e.—is considered significant. The most highly-correlated regression forms for the in situ relationship between TSS and turbidity for the period of record date range at the two sites is shown in Table 1. Many permutations of independent variables and type of regressions were performed apart from those presented here. For example, water temperature and/or specific conductivity were considered in addition to turbidity as part of multiple linear regressions but did not improve the predictive power of the equation. Log transformation of the dependent and/or the independent variables did not improve the correlation coefficient. The strength of the TSS versus turbidity regressions may translate into small or large disparities in the resultant predicted event loads.

The results of loading calculations are presented in Appendix D, Table D1 and D2. Both sediment loads and water loads for all 81 events are shown for RW-Abv and RW-Blw. For some of the events, water and sediment loadings can be orders of higher than others. For example, the total snowmelt (Event 1) water and sediment loads, 477 10^6L and 80009 kg respectively, are much larger than those of the rain event on September 12, 2011, which were 0.41 10^6L and 196 kg. More in-depth discussion of the event loadings can be found in sections “Cumulative Loads” and “Sediment and Water Loads Comparison”.

Discharge Results

Water loads for each water year snowmelt period are presented in Figure 18. As expected, the largest snowmelt volumes were observed in WY 2011 and 2016. Drought conditions for the water years 2012-2015 become particularly striking compared to the larger 2011 and 2016 water loads. The timeframe of the graph x-axis covers a 5-month period because some of the snowmelt periods begin much earlier than would normally be expected. Researchers of climate change impacts on Sierra Nevada snowmelt timing and intensity have suggested that snowpacks may melt earlier in the year and with less intensity than historically (Huntington, 2012). Some of the drought years shown in Figure 18 may reflect these climate forcings.

Table 1. Regression equations for the TSS-turbidity relationship. TSS is the dependent variable.

Site		Coefficient	Intercept	R^2	p-value
RW-Abv		7.292	0	0.562	<0.001
RW-Blw	1st	5.058	0	0.786	<0.001
RW-Blw	2nd	1.363	0	0.818	<0.001

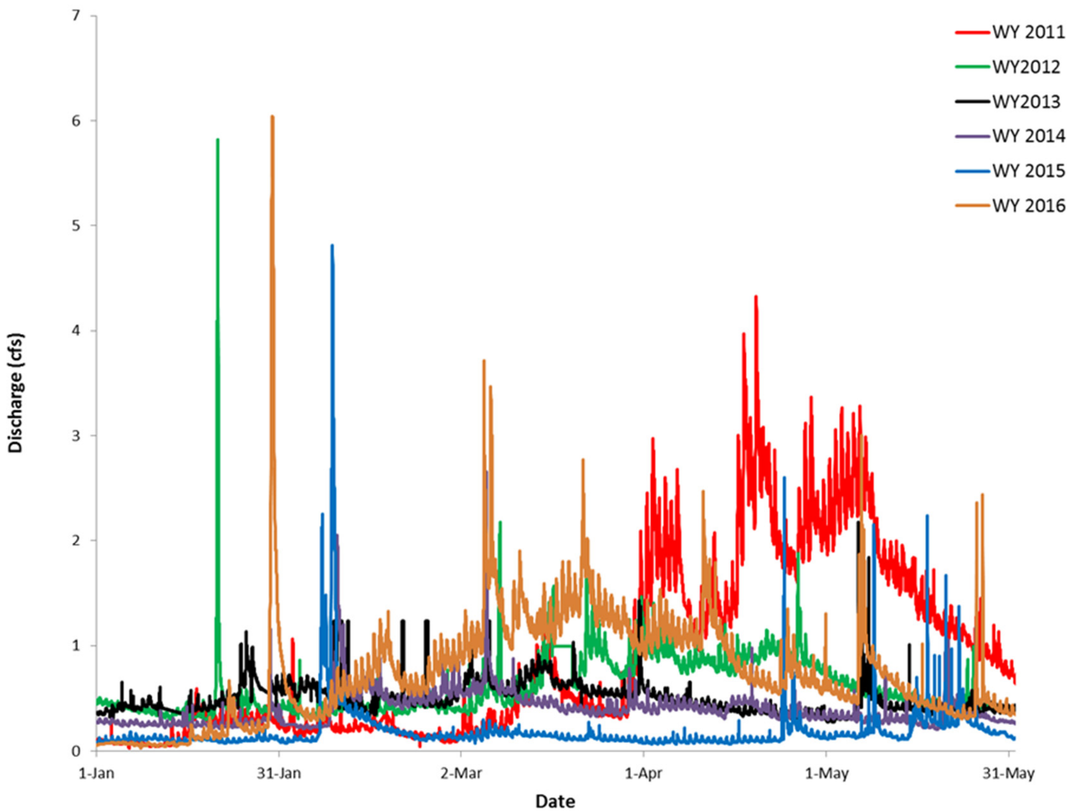

Figure 18. Comparison between water years of average hourly discharge during the snowmelt period at RW-Blw.

After construction of the Area A restoration, visual inspection revealed a seep midway through stream environment zone. The seep may have been the result of a poorly constructed clay barrier at a low-point bend in the creek. Rosewood Creek takes a moderate left turn halfway through the construction, where a clay barrier was intended to deflect hyporheic flow in the same direction. After full wetting of the in summer 2015, water began seeping out of the ground approximately 40 feet downstream of the bend in the creek. The difference in flow between RW-Abv and RW-Blw as a result of the seep may have been modest, but no attempt was made to quantify this water load. Any loss of flow, in velocity and/or load, as a result of the seep may have served to enhance function of restoration, intended or not.

Hysteresis curves can be used to observe trends in suspended sediment within and between different events. In this context, hysteresis describes the phenomenon whereby a given parameter (TSS) is observed to have a different relationship with discharge during the rising limb of an event hydrograph compared to the falling limb. Hysteresis curves are presented for the entire period of record in Figure 19. The greater "stacking" of the lines parallel to the x-axis at RW-Blw indicates that hysteresis was more prevalent at this site. Sites having greater hysteresis will have a poorer relationship between discharge and TSS, suggesting the inclusion of a factor to account for hysteresis in the construction of loading regressions. Unfortunately, the addition of a hysteresis factor did not statistically improve the regressions for RW-Blw.

Hysteresis curves also provide insight as to sediment sources (Figures 19 A and B). The ability of a stream to carry suspended sediment depends on the energy of the water (e.g. velocity) and on the availability of a sediment source. When both energy and a sediment source are present, TSS will be elevated. However, if the sediment source becomes depleted, then TSS will decrease even with elevated discharge. To complicate matters, not only may there be several different sediment sources, but some sediment sources may not become active until a certain energy level or a specific stage is exceeded. Figure 19 A and B shows that elevated TSS had a wide-range distribution at RW-Abv, as TSS was elevated at varying discharge levels. In contrast, calculated TSS at RW-Blw had much lower peak TSS across all discharge levels, except for the event of September 26, 2012.

Coarser sediments appeared to become depleted or deposited, as the mean particle diameter decreased in samples collected after March 16, 2014, despite discharge remaining elevated (Figure 16). If this coarse sediment source was from residual sediment left over from project construction or deposited by the large rain-on-snow, Event 53, it should not be observed in subsequent years. The largest water and sediment load events occurred on June 5-7, 2011 (Event 4) and September 26, 2012 (Event 17). The rain event of June 2011 was a long and intense storm over multiple days. The September 2012 event was a very short-lived and high intensity rain storm after a long period of warm, dry weather. This likely created the conditions under which RW-Abv saw discharge above 16 cfs and RW-Blw recorded TSS above 9000 mg/L.

RESULTS FOR EVENTS

Precipitation Events

The 22,520 kg of suspended sediment delivered by Rosewood Creek during low elevation snowmelt comprised 37 percent of that delivered by the watershed during snowmelt, a total of 60,435 kg. Water and sediment load results for all 81 events can be found in Appendix E. Total water loads for Rosewood Creek prior to restoration (January 1, 2011-August 12, 2014) were 3.1 times greater than the 452 x 10^6 L of water from Rosewood Creek Area A post-construction (August 13, 2014- September 30, 2016). This water load resulted in an event average TSS concentration of 112 mg/Land loadings of 315 kg/day for Rosewood Creek.

Synoptic Sampling

In order to better assess the function of the restoration area, synoptic samples were collected on two occasions in the spring of 2016. Synoptic samples act as a snapshot of water quality for a particular water body. The synoptic samples were collected through the length of Area A and were analyzed for a suite of nutrients consistent with the rest of the project samples. It was intended that a similar “slug” of water will be sampled as we proceed down the length of the creek while sampling. The timing of synoptic sampling was chosen to be during low-flow conditions, so as to not be influenced by the external forcing of a significant precipitation event. The goal was to determine whether a reduction in nutrients from passing through the restoration

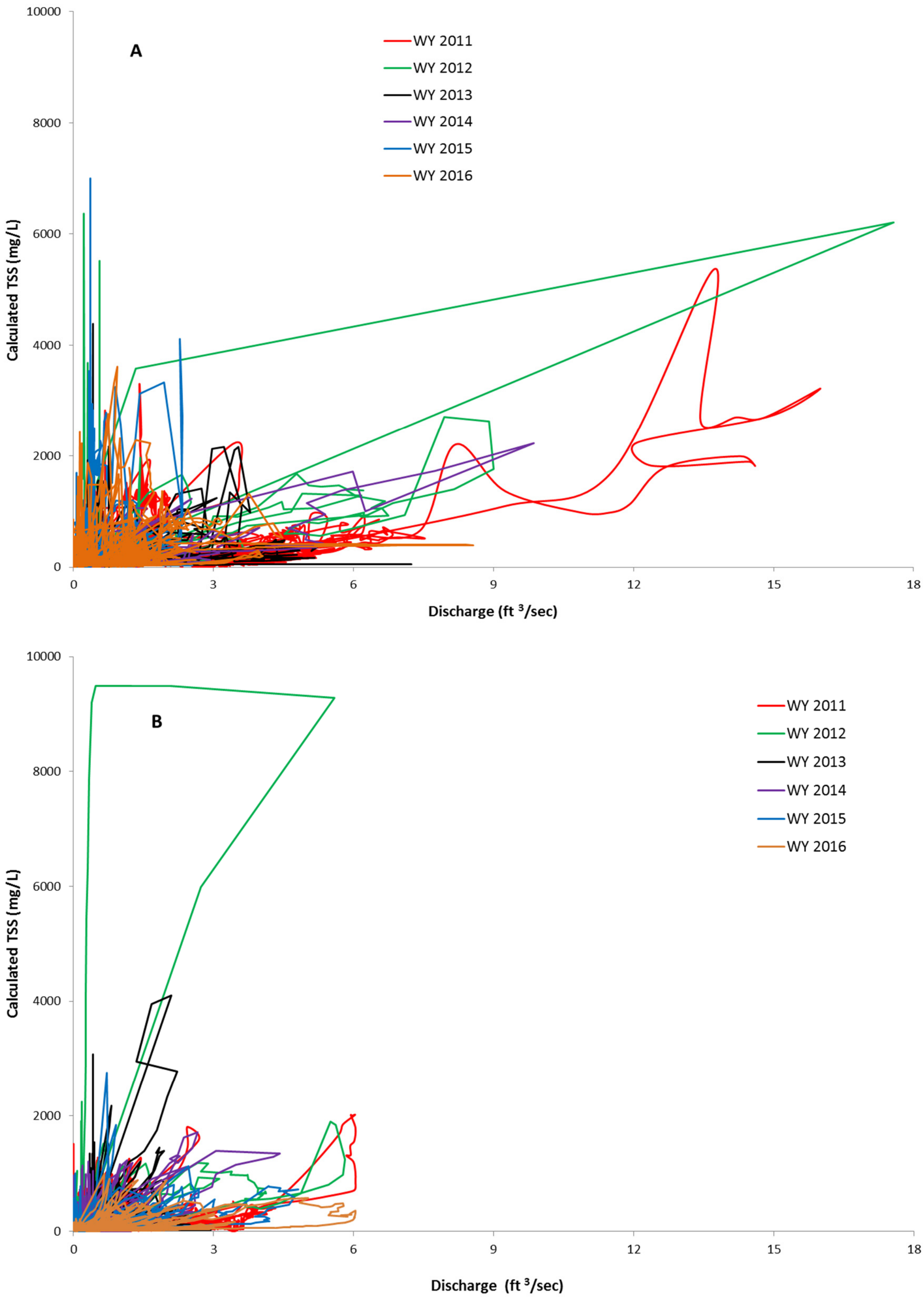

Figure 19. Hysteresis relationship at both Rosewood Creek sites between RW-Abv (A) and RW-Blw (B). The data in this graph uses lines rather than points in order to show changes through time.

project could be ascertained during baseline conditions. The locations for the first sampling, which occurred on February 21, 2016, were the RW-Abv (Bridge), RW-Blw (H28), and the outlet or bottom of the restoration just before the creek goes under State Route 28, called "Outlet". For the second of the synoptic sampling event on March 22, 2016, five locations were sampled: the same 3 sites from the first sampling plus a site at the top of the construction area, "Entrance" and another in the approximate middle of the restoration, "Middle" (Table 2).

Results of the synoptic sampling show some improvement in the treatment of nitrate/nitrite. During both sampling events, nitrate/nitrite and ortho-phosphate were moderately diminished over the length of Area A. The other analytes did not show a decrease. It should be noted that these results are not statistically significant. The sampling locations were meant as a precursor to establish better sampling procedures in the future. The three stations within the restoration, Entrance, Middle, and Outlet, were logical places to look for differentiation. In any future monitoring, sampling of flow, sediment, and nutrients should occur within the restoration area to better assess the beneficial function of the restoration. The same five sites should be sampled in a synoptic fashion, for baseline and precipitation-based events, in order to better discover whether trends over time can be ascertained.

Table 2. Results of synoptic sampling during the spring of 2016. Nutrient analyses were conducted for nitrate/nitrite (NO3-N+NO2-N), ammonia (NH3-N), total Kjieldahl nitrogen (TKN), Ortho-phosphate (OPO4-P), total phosphorus (TP), total suspended solids (TSS), and turbidity.

Sample Datetime	Sample Location	NO3-N+NO2-N (mg/L)	NH3-N (mg/L)	TKN (mg/L)	OPO4-P (mg/L)	TP (mg/L)	TSS (mg/L)	Turbidity (NTU)
2/27/16 5:00 PM	Bridge	0.090	0.018	0.27	0.006	0.035	13.8	8.60
2/27/16 5:45 PM	Outlet	0.079	0.012	0.26	0.004	0.034	7.8	9.61
2/27/16 5:35 PM	H28	0.078	0.017	0.29	0.003	0.035	11.5	10.6
3/22/16 11:30 AM	Bridge	0.073	0.005	0.23	0.010	0.026	8.8	6.29
3/22/16 11:47 AM	Entrance	0.066	0.005	0.24	0.009	0.025	7.9	5.55
3/22/16 11:55 AM	Middle	0.063	0.007	0.25	0.009	0.029	10.8	8.21
3/22/16 12:45 PM	Outlet	0.054	0.010	0.21	0.008	0.027	8.1	6.63
3/22/16 1:15 PM	H28	0.056	0.011	0.23	0.008	0.031	9.7	8.88

COMPARATIVE LOADINGS AND RESTORATION EFFICIENCY

Suspended sediment loading from Rosewood Creek can have a major impact on the amount of suspended sediment delivered from Third Creek into Lake Tahoe. During the period of record, Rosewood Creek was the source of between 4,221kg and 46,358 kg of total suspended sediment load, per water year, entering the lake (Figure 25). The magnitude and timing of water loading was an important control on the delivery of suspended sediment. The slope of the cumulative suspended sediment load during snowmelt from RW-Abv was typically greater than that from RW-Blw and occurred later in the season. The steeper slope indicates a much more intense delivery of suspended sediment from RW-Abv than that from RW-Blw. The temporal offset was the result of snowmelt being sourced from the lower elevation Rosewood Creek watershed before that of the higher elevation Rosewood Creek watershed.

The delivery of suspended sediment from Rosewood Creek at RW-Blw was primarily dependent on the volume of water (Figure 20). One rain-on-snow event delivered the highest relative suspended sediment loads and water volumes, that of June 5-7, 2011 (Event 44). Two rain-on-snow events (Events 9 & 40) and a rain event (Event 4) had substantially higher sediment loads for a given water load. These events appeared to be of a shorter duration, less than 2.3 days, indicating a precipitation rate of higher than normal intensity.

Direct Comparison of Samples

Discrete and composite samples were compared between above and below the restoration, and before and after the restoration. The samples considered for this comparison were those that were analyzed for the general chemistry nutrient suite. The discrete samples that were compared include only those that are "paired" – they were sampled within a one-hour period of each other at RW-Abv and RW-Blw. While these paired discrete samples do not carry the weight of a composite sample, a direct comparison of one-liter samples may still reveal trends over time. For this analysis, samples taken during non-precipitation baseline events were not included for loading calculations. The background samples may be more statistically relevant in a direct comparison of discrete one-liter sample volumes.

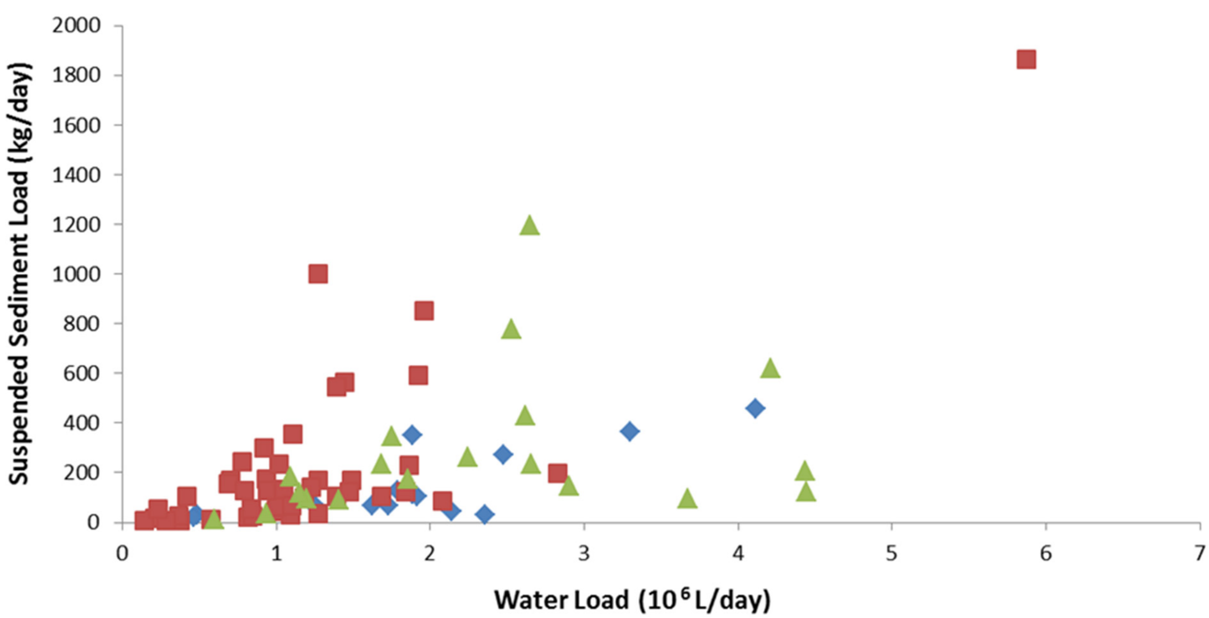

Figure 20. Water and suspended sediment loads from RW-Blw by event. Red squares are rain events, green triangles are rain-on-snow events, blue diamonds are snowmelt events.

The above versus below, before restoration comparison of samples (Figure 21 A and B) indicates that there was a removal of nutrients from the water column within Area A. The results from after the restoration (Figure 22 A and B) indicate that nitrate and ammonia were removed from the water column more effectively after the restoration, especially at the higher concentrations. The slope of the regression line for nitrate before the restoration was 1.00, while after the restoration was 0.32.

Before the restoration ammonia was mitigated while moving through Area A with a slope of 0.92, whereas after the restoration ammonia was removed very well at the higher concentrations with a regression slope of 0.52. The other nutrients were not reduced as effectively as nitrate and ammonia. To show a reduction in concentration, the points on the graph comparing above versus below, before versus after would fall beneath the 1:1 ratio line. This would mean that each of the nutrients was mitigated while moving through the Area A restoration. At lower concentrations, both before and after the construction, most nutrients are increased within Area A. Ammonia and nitrate loads appear to be diminished after the construction of Area A, but there are insufficient sample event-loads to make a determinative assessment. This type of calculation appears to be a good representation of nutrient loads, and efforts should be made to conduct better sampling efficiency in the future.

Figure 23 shows the loadings for TSS and the suite of nutrients for before and after the restoration. This is another means of examining the discrete samples, but includes the calculation for an entire event loading. It would have been desirable to obtain more samples that allow for this type of calculation over the course of the period of record, but for a multitude of reasons the direct

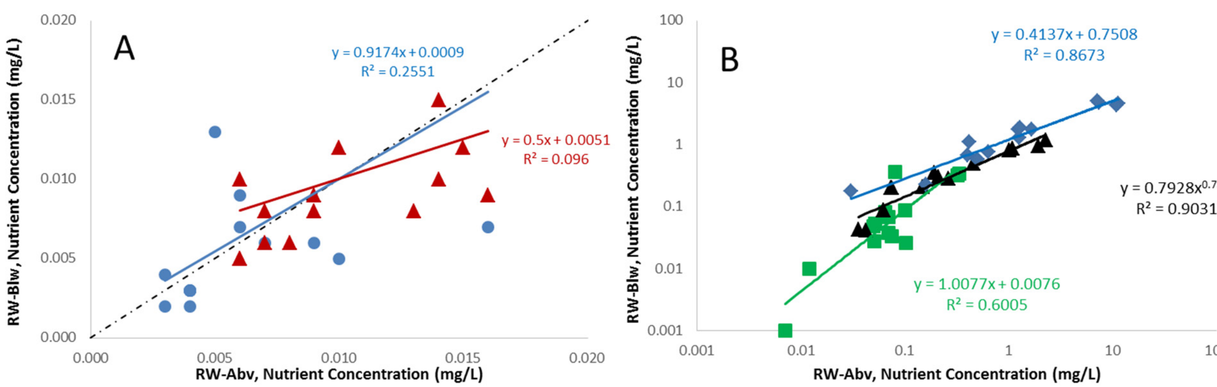

Figure 21. Comparison of discrete and composite water samples between the upper site, RW-Abv, and the lower site, RW-Blw, before the restoration. In (A) the nutrients ammonia (blue circle, blue regression eq., blue line) and ortho-phosphate (red triangle, red regression eq., red line) are shown. In (B), the axes are log-log scale, and the nutrients total kjieldahl nitrogen (blue diamonds, blue regression eq., blue line), total phosphorus (black triangles, black regression eq., black line), and nitrate (green squares, green regression eq., green line) are shown. Dashed line is 1:1.

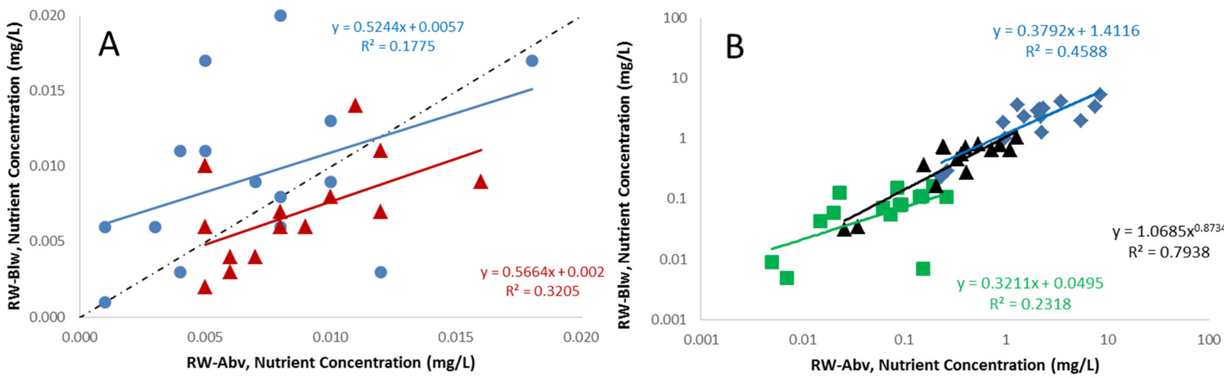

Figure 22. Comparison of discrete and composite water samples between the upper site, RW-Abv, and the lower site, RW-Blw, after the restoration. In (A) the nutrients ammonia (blue circle, blue regression eq., blue line) and ortho-phosphate (red triangle, red regression eq., red line) are shown. In (B)), the axes are log-log scale, and the nutrients total kjieldahl nitrogen (blue diamonds, blue regression eq., blue line), total phosphorus (black triangles, black regression eq., black line), and nitrate (green squares, green regression eq., green line) are shown. Dashed line is 1:1.

comparison of loadings was not possible in this manner. Some of the issues that occurred included the failure of the autosampler during an event at one of the stations, the failure of the datalogger battery during an event at one of the stations, and not collecting enough volume to conduct laboratory analyses for both nutrients and particle-size diameter. The results of this analysis show that total Kjeldahl nitrogen was reduced through Area for the event of May 5, 2016.

As discussed previously, the particle size fraction that is less than 16 µm in diameter is of particular concern for the Lake Tahoe watershed. For Rosewood Creek, the percentage of particle distribution in the ultra-fine fraction may or may not decrease as the restoration becomes stabilized. The measure of effectiveness for the restoration will be whether the load of the ultra-fine fraction is diminished. Figure 24 represents the percent and load of the sub-16µm fraction at both RW-Abv and RW-Blw. While the trendlines of both percent and load of ultra-fine sediment indicates a decrease over time at RW-Abv, only the load decreases at RW-Blw. This analysis could be more informative if drought conditions had not persisted over many years, as to deliver little energy to the system. The lack of high energy rain events and the decrease in <16 um mg/L entering the project made the results difficult to interpret.

Cumulative Loads

Suspended sediment loading from Rosewood Creek can have a major impact on the amount of suspended sediment delivered from Third Creek into Lake Tahoe. During the period of record, Rosewood Creek was the source of 112,603 kg of suspended sediment entering Third Creek, and then ultimately, Lake Tahoe (Figure 25). The magnitude and timing of water loading was an important control on the delivery of suspended sediment.

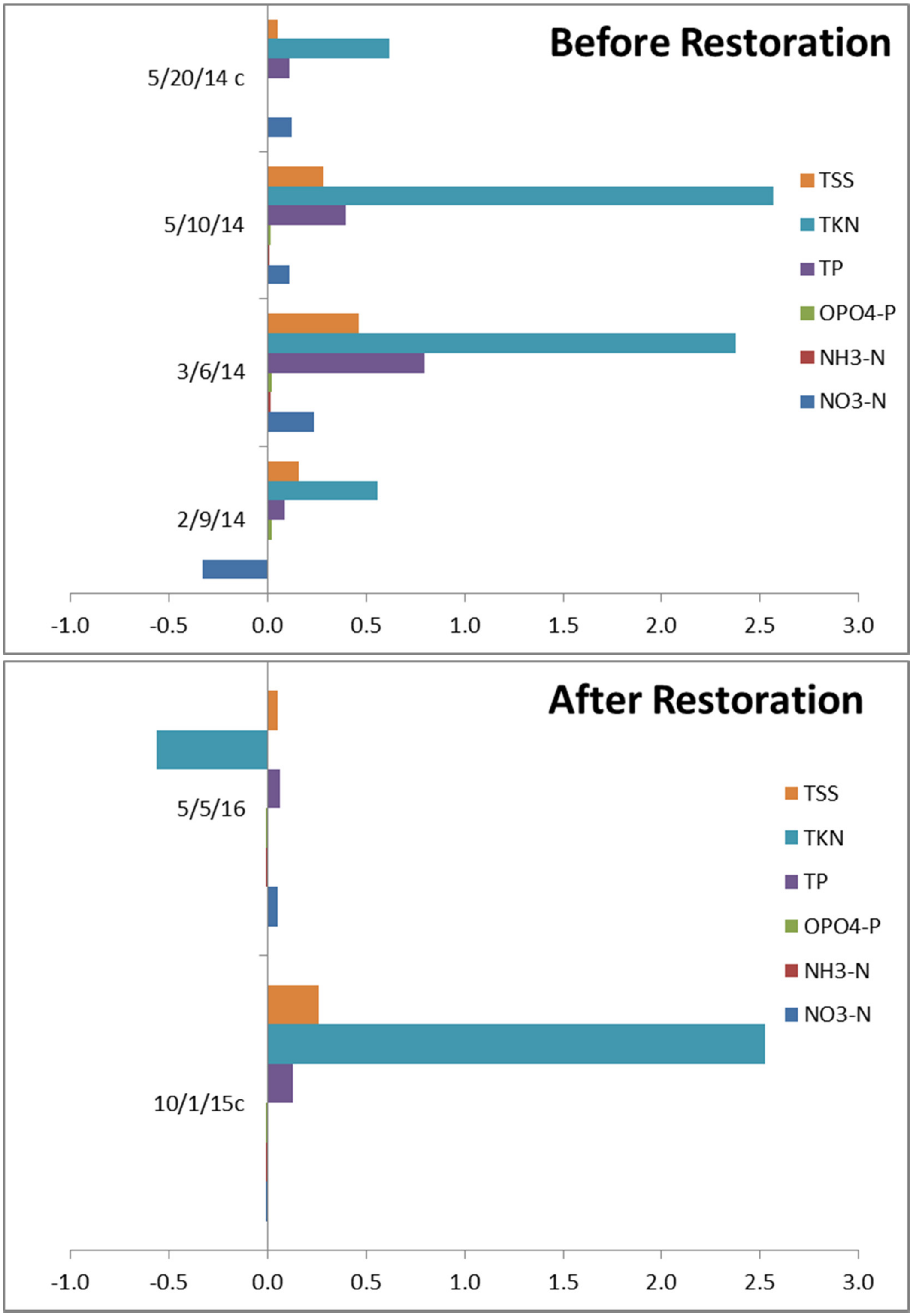

Figure 23. Cumulative difference in nutrient and sediment between RW-Abv and RW-Blw for events before and after restoration. These are event mean concentration samples, nutrients in units of Event Load (kg) per day. TSS in kg1000 per day. (Most normalized units possible, over time and over water volume or intensity).

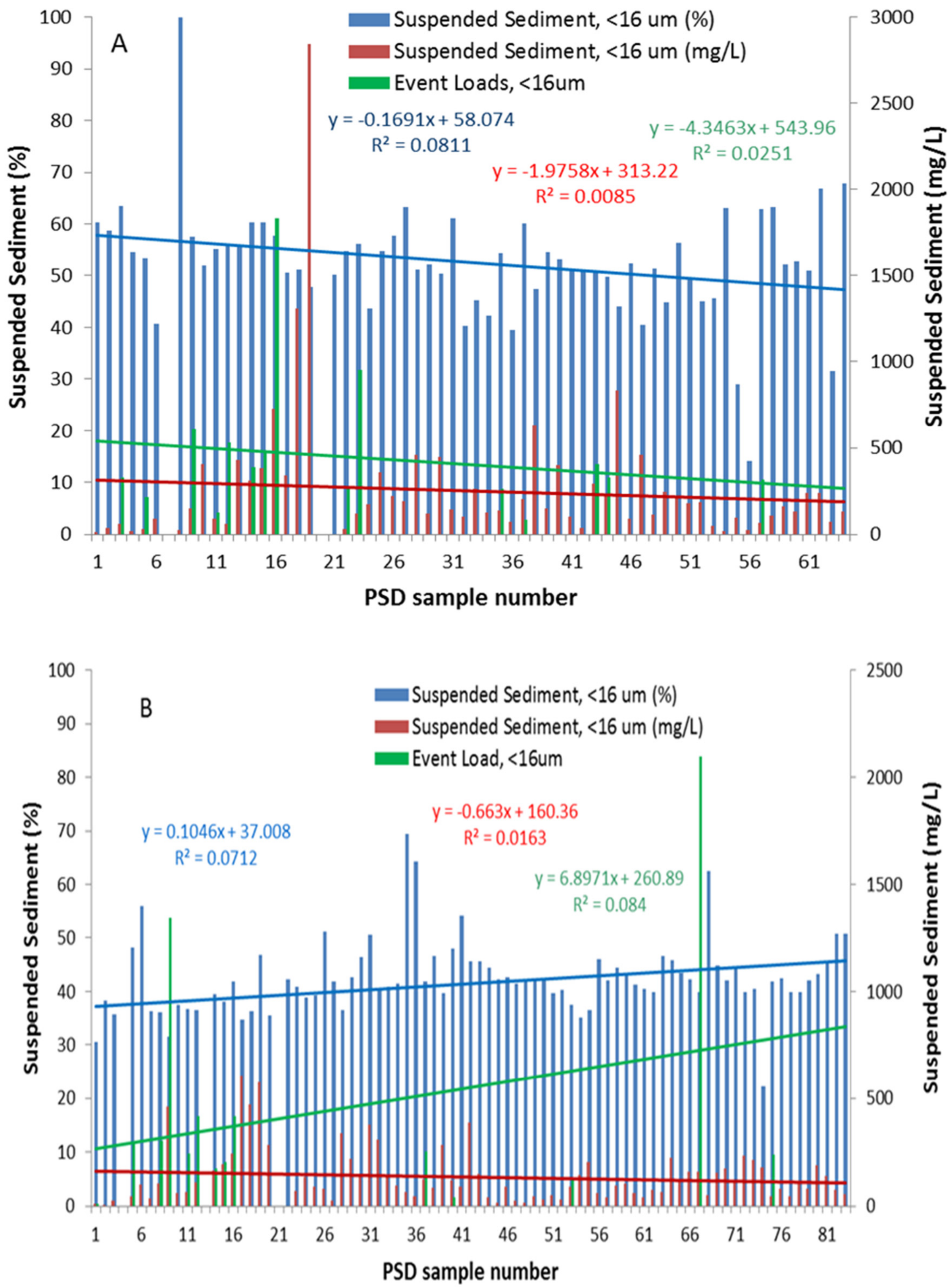

Figure 24. **Particle size sample analysis for the ultra-fine fraction (under 16µm) over time at RW-Abv (A) and RW-Blw (B) for events before and after restoration. Water enters the restored channel at Sample 21 for RW-Abv and at Sample 22 for RW-Blw. Included are both event mean concentration and discrete samples.**

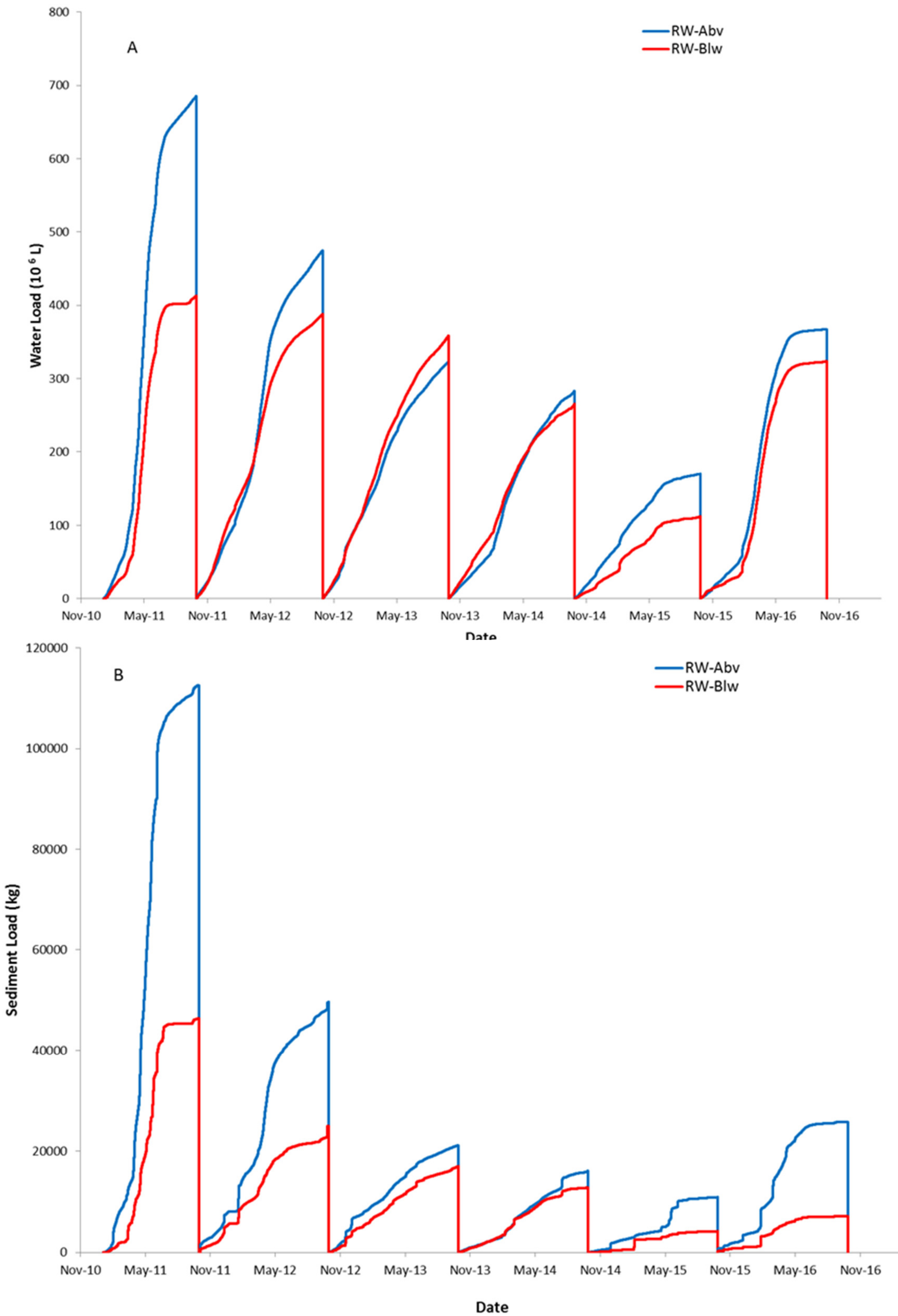

Figure 25. Cumulative water (A) and sediment (B) loads for the period of record, by water year.

The higher cumulative suspended sediment loading from RW-Blw during the 2013 snowmelt season (Figure 25) was primarily driven by consistent, moderately elevated discharge at RW-Blw throughout the entire season rather than significantly elevated sediment levels. In WY 2015 and 2016, cumulative loadings suggested that the restoration project reduced sediment loads, primarily during mixed rain/rain-on-snow events that occurred during late spring and summer (Events 54-63 and 76-80).

Sediment and Water Loads Comparison

The ability of the restoration project to alter water volumes or sediment loads was also dependent on the type of event (Figure 26). In this graph, points in the lower left quadrant (III) reflect events where water volumes and suspended sediment loads were lower at the bottom of the restoration project (RW-Blw) than at the top (RW-Abv). Points in the upper two quadrants (I and II) represent events that had significant contributions of surface or urban runoff water volume that entered the creek within the project area. In a majority of the cases, this augmentation of water was associated with a decrease in suspended sediment loads (upper left quadrant, I). However, there were several events where increased water volumes also resulted in increased sediment loadings (upper right quadrant, II).

This indicates that a substantially greater decrease in water volume is needed to affect a reduction per unit of sediment load compared to the water volume needed to increase sediment loading by the same mass. However, the fact that there was a relationship in the bottom left quadrant (III) suggests that the restoration project did, under certain events, reduce suspended sediment and water loading. Events in this quadrant only included events that occurred during the 2013 and 2014 snowmelt seasons, the two lowest water years studied. Rain events appeared to fall on a single line whereas there was no trend with rain-on-snow events. The two rain events (Events 50 and 52) in the bottom left quadrant had a 28-30 percent decrease in suspended sediment loading.

For most events, the efficiency of the restoration zone to reduce suspended sediment yields could not be directly assessed as a result of the creek accepting significant water volumes within the restoration project (upper right quadrant II in Figure 26). When water load was added and sediment load is diminished (quadrant I), Area A was functioning as designed to sequester sediment. Many of the precipitation events, regardless of type, were found to be in quadrant I. The project was still likely affecting sediment reductions; however, they could not be parsed from total loadings without knowledge of the sediment concentration, volume, and location of inputs to the creek. Therefore, the most likely events to be able to estimate project efficiency were when the majority of water load entered the project area through the creek at RW-Abv. Examples of these events included rain events where precipitation was predominately in the middle and upper reaches of the Rosewood Creek watershed or during the middle to later periods of snowmelt when the creek is devoid from higher elevation snowmelt. Carefully parsing cumulative water loads and assessing those time periods that have no clear surface water inputs could obtain additional effectiveness estimates. The source of water load was difficult to ascertain with our two monitoring stations.

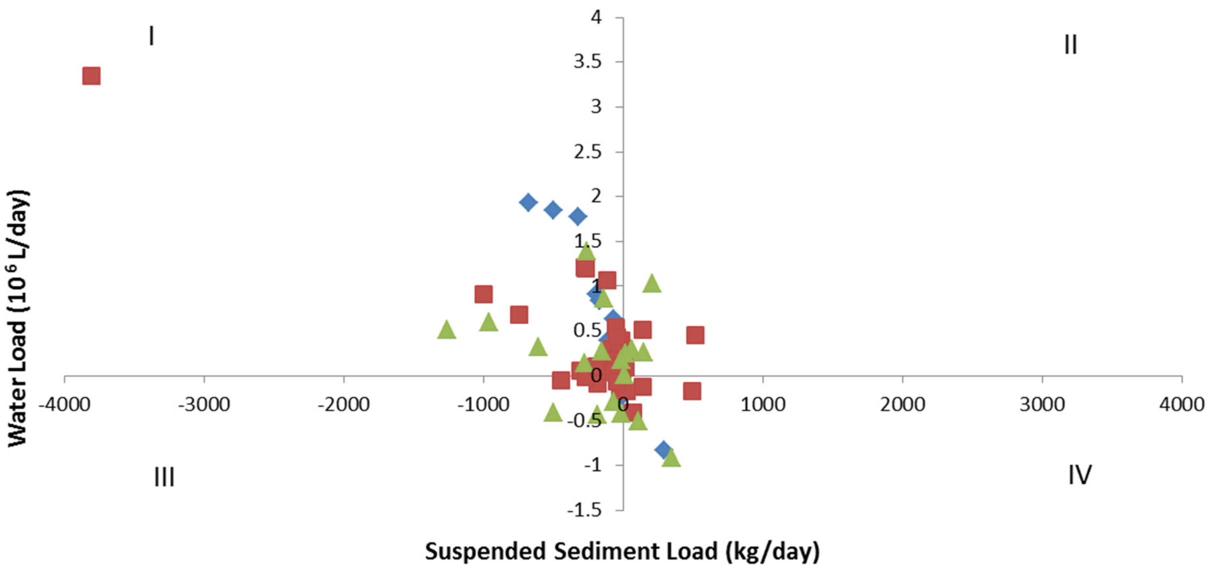

Figure 26. Reduction of suspended sediment load compared against reduction in water load from the restoration zone. Values were calculated by subtracting loads at RW-Blw from RW-Abv. Event loads are normalized by their duration, in days. Red squares are rain events, green triangles are rain-on-snow events, blue diamonds are snowmelt events.

PROJECT ACCOMPLISHMENTS

Water and sediment loadings were provided for 81 events on Rosewood Creek based on monitoring conducted from January 2011 through October 2016. Events included an intense summer thunderstorm on June 5-7, 2011 (Event 4), an intense rain-on-snow event on January 20-22, 2012 (Event 9), as well as seasonal snowmelt events (Events 1, 10, 25, 35, 50, and 69) over six years.

Pre-project monitoring indicated that Rosewood Creek could contribute significant suspended sediment loads to Third Creek and ultimately to Lake Tahoe. The relative contribution of suspended sediment by Rosewood Creek was the greatest during lake-level snowmelt and rainstorms that impacted low elevation watersheds, when high elevation water and sediment sources were dormant. During these events, Rosewood Creek can become highly turbid whereas adjacent Third Creek can remain relatively clear, indicating a perceived sediment problem on Rosewood Creek.

The actual load of suspended sediment from Rosewood Creek was also important during some precipitation events, such as a fall thunderstorm in 2012 (Event 8), where suspended sediment load was mitigated by 852 kg between RW-Abv and RW-Blw. Despite its small surface area, the Rosewood Creek watershed did respond rapidly to storm events. Of the rain events before the wetting of the new channel during WYs 2011 through 2013, the mean of event suspended sediment load was 586 kg/event for RW-Blw. For rain events during WYs 2014 through 2016, the mean of event suspended sediment load decreased to 146 kg/event for RW-Blw. Though, the decrease could largely be determined by drought conditions. Nearly the entire length of Rosewood Creek Area A flows within an urbanized watershed, so it was very susceptible to contributions from urban runoff. Surface runoff that entered Rosewood Creek had an immediate impact on stream flow, given that the average daily discharge for WYs 2011 through 2016 was only 0.7 cfs.

The delivery of suspended sediment from and through Area A of Rosewood Creek was altered after construction of the project. Rather than delivering its load downstream to Third Creek and Lake Tahoe, water and sediment load delivery was reduced within Area A for many flow regimes, or varying durations and quantities of flow. In addition to the newly constructed channel, three other factors could also affect the delivery of suspended sediment as the restoration matures. First, the incorporation of increased floodplain area into the restored channel should cause the creek to exit its banks under higher water conditions, providing an opportunity to slow water velocities and drop suspended sediment. Second, the slope of the channel in the restored section was more even and shallower than the channel slope in the upper reaches of the watershed. Shallower channel slopes result in lower water velocities and a decrease in the potential to mobilize or retain suspended sediment in the water column. Hysteresis curves developed during the first year of post-construction monitoring show that less water energy was needed to transport sediment into the restoration zone than out of it (Figure 19 a and b), primarily as a result of the differences in slope. Third, the maturation of vegetation and its velocity-decreasing potential will sequester sediment and nutrients. The net result is that the restoration project can act as a sediment sink until higher flows and water energies become available to transport the sediment further downstream.

A fully quantitative and statistically significant comparison of how the restoration project affected sediment loads was not possible because of the inherent variability and error associated with comparing environmental measurements. The error was compounded by the need to subtract external, uncontrollable inputs from the RW-Abv and RW-Blw sites that were separated by 2,200 feet in order to produce an estimate of suspended sediment loading. There is error associated in the measurement of turbidity, the collection and analysis of TSS samples, the derivation of the turbidity surrogate relationship, and the estimation of flow. Of these, the greatest sources of error are the two components that constitute a sediment load: estimation of suspended sediment concentrations through the turbidity surrogate and the estimation of flow to a lesser degree. To compound this problem, the drought conditions observed within Rosewood Creek that affected the turbidity/TSS surrogate relationship made it difficult to separate individual years of data. This was particularly important for RW-Blw whose surrogate model changed from year to year as the Area A restoration project matured. Therefore, in order to provide the best estimate, period of record surrogate models were chosen to estimate sediment loading, increasing the number of points contributing to each model, and decreasing the importance that sparsely measured, high turbidity values contributed to the overall error estimates. As a result, the original cost-effective sampling design that relied on the power of an aggregated surrogate model based on fewer event samples, but collected over a longer multi-year period was shown to be ineffective. The drought conditions just before and just after water was diverted to the new channel minimized the potential for a wide range of energy delivered by hydrologic events. Starting in WY 2016, the sampling design has been changed to the collection of a greater number of samples for an individual event to support the calculation of event-based turbidity/TSS surrogate models, and seasonal and/or yearly models having a greater number and distribution of points throughout the observed turbidity range. Data and interpretations found from this report will be reviewed for its applicability in the development of future surrogate models.

Future relationships between TSS and turbidity will likely change based on: new residential and commercial construction, the restoration of Rosewood Creek between State Route 28 and the diversion splitter box in 2018, and the maturity of the lower Rosewood and Area A restorations. These relationships are expected to change modestly based on the magnitude of a particular water year and the types of events driving the majority of the sediment mobilization. Turbidity measurements have an inherent error based on interference from inorganic particles, particle size, the shape of the particle, and the type of light being employed. Therefore, changes in the TSS versus turbidity relationship over time on Rosewood Creek will likely be driven by these parameters as the various restoration projects mature. The energy and water level stage of a particular hydrologic event will dictate the amount, size fraction, source, and mobility of the sediment load. The equilibrium of the Area A restoration will affect the lower restoration areas.

The weight of evidence that this dataset provides relates to the trends and changes observed as the restoration project matured. During the first two post-construction years, the delivery of suspended sediment from the restoration project was variable and difficult to estimate using a turbidity surrogate. Equilibrium of the Area A restoration may not have occurred within the first two years post-construction. As with the previous restoration-monitoring efforts on Rosewood Creek, the maturation of vegetation and full-function of sediment sequestration structures can take many years (Susfalk, 2010). A major confounding factor in our determination of the effectiveness of the Area A restoration was the drought period (WY2012-2015) in the years immediately before and after the re-watering of the new construction. Further monitoring of Area A would be necessary for unequivocal determinations.

Key Findings:

- Due to potential for limited or no access to the project site following the installation of the restoration for repairs or maintenance, an emphasis was placed on installing a project that would be resilient to large events. Construction for this type of project was intensive and the effects of disturbance likely had a longer impact than a softer approach would have had. The project has flourished 2 years after construction and the natural appearance continues to improve while the form and function is maintained and the project objectives of reducing soil erosion and improving riparian and forest health continue to be met. It is desirable that future projects that construct entire channels and the adjacent floodplains consider monitoring periods longer than 2 years post construction in order to observe expected longer term results.

- The success of the vegetation growth as well as the presence of primarily riparian vegetation in the floodplain indicates full achievement of the objective to increase the use of the floodplain and improve forest health. Additional years of flow monitoring may add supporting evidence.
- The objective to improve fish habitat could not be quantified or measured during the project period with the exemption of no observed fish passage barriers now exist within Area A. It was observed that the creek was still flowing subsurface in some areas post-construction for a full year following the completion of Phase III which would present fish habitat barriers. Following the winter of 2015-2016, the creek no longer had regions of subsurface flow and this condition was maintained throughout the drier periods of 2016. In October 2016, visual observations indicated fish were present in the restored reach and newly installed culvert within 2 years of the end of construction; however, additional monitoring would be needed to determine whether suitable habitat increased. It is recommended that future monitoring include a fish visual encounter survey and a benthic macroinvertebrate (BMI) survey. A pre-construction BMI survey by others does existing and NTCD will be obtaining the results in an effort to conduct a comparable survey.
- Monitoring stations placed above/below the restoration area were able to quantify water, nutrient, and sediment loadings. Data collection would be enhanced by targeted sampling at specific locations within Area A. Water load determinations would be enhanced with shallow groundwater level monitoring, however, without pre-project data, a comparison of pre- and post-project conditions would not be possible.
- The drought period of water years 2013-2015 severely limited determinative findings. There was not enough water volume in the post-construction period WY2014-2016 to make definitive statements about restoration effectiveness across all hydrologic flow regimes—need additional study.
- Initial results indicate modest improved performance in mitigating total sediment loads and nitrate to Third Creek, and thereby Lake Tahoe. But, fine ($<63\mu m$) and ultra-fine ($<16\mu m$) suspended sediment particle-size fractions were found to not be mitigated at RW-Blw in the two post-construction water years. Fine particles were 78%, by volume, both before and after the restoration. Ultra-fine particles were 42%, by volume, both before and after the restoration. Since total loads were reduced, the total fine sediment load was also reduced which is beneficial for Lake clarity as identified in the TMDL. Nitrate was mitigated moderately in WY 2016, two years after the completion of the restoration, possibly due to full vegetation establishment and diminishing negative effects from construction in conjunction with the drought subsiding.

- Water flow was mitigated at RW-Blw after construction and after full-restoration wetting, in WY2016. These results suggest a trend toward reduced water loads in future years, but one year of data cannot support a trend.
- In order to fully understand the benefits of the project, additional funding and years of monitoring data are needed. Due to uncertainties like drought, bids on construction, and private landowners, contingency funds are needed for projects in Tahoe and it is difficult to imagine a more cost-effective way to monitor the water quality. One way to reduce costs could be to observe relationships between data and use them to eliminate testing for a certain component (i.e. understand if the relationship between turbidity and FSP is staying consistent and refrain from spending additional funds using LPSA to determine the particle size distribution).

Future Work:

- Construct new restoration between Area A and lower reach of Rosewood Creek to further mitigate sediment and nutrient contributions from upper and middle reaches and from State Route 28 and decrease the number of fish passage barriers.
- Install a new monitoring station at the immediate bottom of Rosewood Creek Area A (just above State Route 28) to help account for measurement discrepancies at RW-Blw associated with road runoff from State Route 28.
- Compare channel cross-sections and reach-long profiles to evaluate long-term stability of the channel armoring and sediment sequestration within the restored reach of Area A.
- Continued flow, sediment load, and nutrient monitoring at RW-Blw, RW-Abv, and the new station to understand the longer term effects of restoration.
- Obtain aesthetic video and photographic evidence of the success of the project to use for stakeholder engagement in future projects.

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APPENDIX A: ROSEWOOD CREEK AREA A SEZ RESTORATION –PHOTOGRAPHS

Photo Point 1: Upstream of existing culvert at upstream tie-in. This point looks at the area restored just upstream of the Northwood Culvert and though willow and alder obscure the view, the point shows that the vegetation on the slope above the culvert and the floodplain is vigorous and established on the slope around the culvert by May 2016. The work in this area was completed in October 2014.

Photo Point 1- October 16, 2012

Photo Point 1- June 12, 2013

Photo Point 1 – October 1, 2013

Photo Point 1 – May 8, 2014

Photo Point 1 – October 18, 2014

Photo Point 1 – May 28, 2015

Photo Point 1 – May 12, 2016

Photo Point 1 – Oct 5, 2016

Photo Point 2: Staging area at Northwood Blvd to become wetland in Phase 3. This point looks at an area of historic fill that was removed during the project and converted back to a more natural slope. The area was also used for staging throughout the project. The photo point missed the main area of change which is best shown in the October 16, 2014 photo where the grade has been leveled and more riparian vegetation now occupies the point. The area also now has a swale to convey road runoff to a flat vegetated treatment area before entering the creek.

Photo Point 2 – October 16, 2012

Photo Point 2 – June 12, 2013

Photo Point 2 – October 1, 2013

Photo Point 2 – May 8, 2014

Photo Point 2 – October 16, 2014	Photo Point 2 – May 28, 2015

Photo Point 2 – May 12, 2016	Photo Point 2 – Oct 5, 2016

Photo Point 3: This point shows the downstream end of the newly installed culvert at Northwood Blvd. Vegetation was well established within 8 months of the completion of Phase 1 and vegetation continues to flourish after the creek occupied its new channel in September 2014 and irrigation was turned off. Nearby ferns have migrated into the area as they were not planted from seed.

Photo Point 3- October 16, 2012

Photo Point 3- June 4, 2013

Photo Point 3 – October 1, 2013

Photo Point 3 – May 8, 2014

Photo Point 3 – October 18, 2014

Photo Point 3 – May 28, 2015

Photo Point 3 – May 12, 2016

Photo Point 3 – Oct 5, 2016

Photo Point 4: This point shows the new floodplain upstream of the tie in location. Vegetation was establishing well within 8 months after Phase 1 was completed and continued to flourish after irrigation was turned off in October 2014.

Photo Point 4- October 16, 2012

Photo Point 4- June 4, 2013

Photo Point 4 – October 1, 2013

Photo Point 4 – May 8, 2014

Photo Point 4 – October 18, 2014

Photo Point 4 – May 28, 2015

Photo Point 4 – May 12, 2016

Photo Point 4 – Oct 5, 2016

Photo Point 5: This photo is looking upstream from mid-channel tie-in – an area where the new channel crossed the old channel. The photos through May 2014 show the old channel as a wide (over 12’ wide) and deep hole. After Phase 3 was completed in October 2014, vegetation started to grow. The new vegetation was well established by May 2015 and continues to flourish. The HOA installed a walking path and removable bridge in the summer of 2016 which they place each June and remove each October depending on the weather. The design and size of their bridges necessitates removal or the bridges would be washed downstream and destroyed.

Photo Point 5- October 16, 2012

Photo Point 5- June 12, 2013

Photo Point 5 – October 1, 2013

Photo Point 5 – May 8, 2014

Photo Point 5 – October 18, 2014

Photo Point 5 – May 28, 2015

Photo Point 5 – May 12, 2016

Photo Point 5 – Oct 5, 2016

Photo Point 6: This point shows the new floodplain downstream of the tie in location. Vegetation was just starting to establish 8 months after Phase 1 and was well established a year and a half later. Vegetation continued to flourish after irrigation was turned off in October 2014.

Photo Point 6- October 16, 2012

Photo Point 6- June 4, 2013

Photo Point 6 – October 1, 2013

Photo Point 6 – May 8, 2014

Photo Point 6 – October 16, 2014

Photo Point 6 – May 28, 2015

Photo Point 6 – May 12, 2016

Photo Point 6 – Oct 5, 2016

Photo Point 7: This point shows a wet area that was the least steep portion of the valley. Because of the wetness, vegetation took a bit longer to initially establish but was well established within a year and a half of the completion of Phase 1. The photo from October 6, 2016 shows that the floodplain was recently inundated in this area due to a rain storm and the vegetation offered floodplain roughness for overland flow.

Photo Point 7- October 16, 2012

Photo Point 7- June 4, 2013

Photo Point 7 – October 1, 2013

Photo Point 7 – May 8, 2014

Photo Point 7 – October 18, 2014

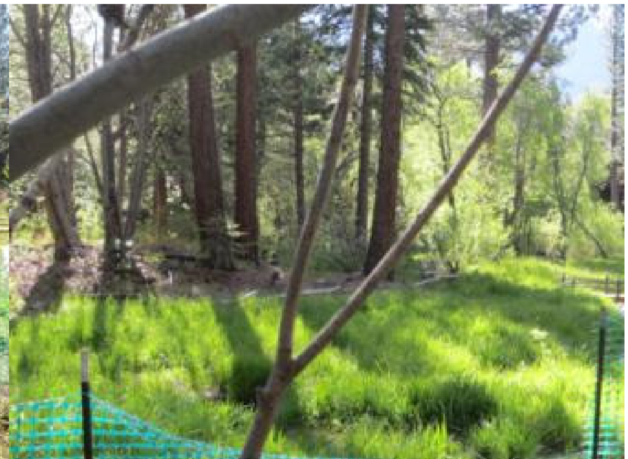


Photo Point 7 – May 28, 2015

Photo Point 7 – May 12, 2016

Photo Point 7 – Oct 6, 2016

Photo Point 8: This point shows the location of the invasive weed such as common teasel on the banks of the old channel. The teasel was removed as part of the project and the channel was filled in this location. The weed was removed in Phase 1 (October 2012) and the channel filled during Phase 3 (October 2014). Vegetation was well established a year and a half later and the teasel did not return.

Photo Point 8- October 16, 2012

Photo Point 8- June 4, 2013

Photo Point 8 – October 1, 2013

Photo Point 8 – May 8, 2014

Photo Point 8 – October 16, 2014

Photo Point 8 – May 28, 2015

Photo Point 8 – May 12, 2016

Photo Point 8 – Oct 6, 2016

Photo Point 9: This point shows the most downstream area of the restoration project – the downstream tie-in at State Route 28. Before construction of the tie-in, at the end of Phase 1, the area was temporarily stabilized by placing multiple sediment logs in the flow path in the event that runoff from the construction site upstream would accumulate and flow to the existing creek. These construction best management practices stayed in place throughout Phase 2 and the area essentially turned into a small wetland by October 2013. The tie in was constructed in Phase 3 which started in August 2014 and was completed in October 2014. Vegetation was well established 8 months later and wetland vegetation began to thrive about one year later.

Photo Point 9- October 16, 2012

Photo Point 9- June 4, 2013

Photo Point 9 – October 1, 2013

Photo Point 9 – May 8, 2014

Photo Point 9 – October 18, 2014	Photo Point 9 – May 28, 2015

Photo Point 9 – May 12, 2016	Photo Point 9 – Oct 5, 2016

Photo Point 10: This point shows a steep slope that was treated with erosion control blanket near the downstream end of the restoration. Erosion control blanket was used here and on one other steep slope in Phase 1 above the installed culvert. Erosion control blanket was also used in Phase 3 for the tie-in areas as they would not have a channel seasoning period before the introduction of flow. The area receiving blanket treatment appeared to have similar vegetation success as the area that did not receive blanket which was unexpected as typically blankets have been observed to slow the establishment of vegetation. The blanket was a fully biodegradable 30/70% coconut/straw mixture and due to the success here, we used this same blanket design on other revegetation projects.

Photo Point 10 – October 16, 2012

Photo Point 10 – June 4, 2013

Photo Point 10 – October 1, 2013

Photo Point 10 – May 8, 2014

Photo Point 10 – October 18, 2014

Photo Point 10 – May 28, 2015

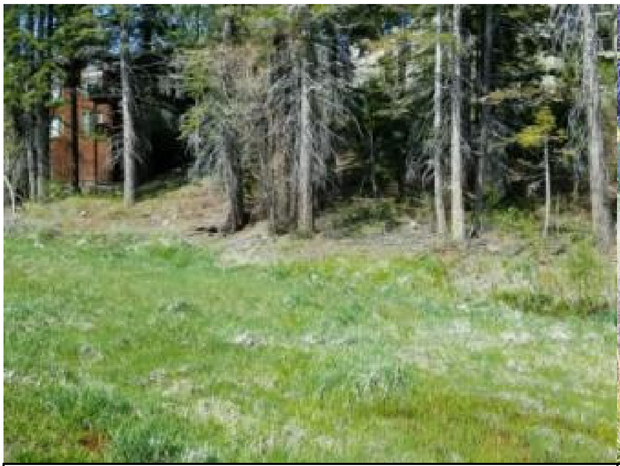


Photo Point 10 – May 12, 2016

Photo Point 10 – Oct 5, 2016

Photo Point 11: This point shows the downstream floodplain and transplanted willows root wads. Transplanted willow and alder root wads were only used on the steepest parts of the new channel in order to limit floodplain roughness to areas that could pass enough flow to not increase the boundary or the 1% and 0.2% floods per FEMA regulations. From the photo it is difficult to see the amount of growth on the relocated tree clumps, but only about 25% of the transplanted willow and alder showed unsuccessful growth within 2 years of relocation. The transplanted willows were more successful than the alder.

Photo Point 11- October 16, 2012

Photo Point 11- June 4, 2013

Photo Point 11 – October 1, 2013

Photo Point 11 – May 8, 2014

Photo Point 11 – October 18, 2014

Photo Point 11 – May 28, 2015

Photo Point 11 – May 12, 2016

Photo Point 11 – Oct 5, 2016

APPENDIX B: HYDROLOGIC EVENTS DURING THE STUDY PERIOD OF RECORD

Table B1. List of Hydrologic Events during the study period of record.

Event Number	Event Start	Event End	Event Type	Duration (days)
1	3/4/2011 9:00	6/5/2011 1:30	Total Snowmelt	92.7
2	3/4/2011 9:00	4/19/2011 15:30	Rising Limb Snowmelt[1]	46.3
3	4/19/2011 15:30	6/5/2011 1:30	Falling Limb Snowmelt[2]	46.4
4	6/5/11 1:30	6/7/11 7:30	Rain	2.3
5	6/28/11 20:40	6/29/11 20:40	Rain	1.0
6	9/12/11 11:40	9/12/11 21:30	Rain	0.4
7	9/14/11 15:40	9/15/11 16:20	Rain	1.0
8	10/4/11 22:10	10/6/11 1:20	Rain	1.1
9	1/20/12 9:50	1/22/12 12:30	Rain on Snow	2.1
10	3/2/2012 13:00	5/22/2012 12:40	Total Snowmelt	81.0
11	3/2/2012 13:00	3/21/2012 20:00	Rising Limb Snowmelt	19.3
12	3/21/2012 20:00	5/22/2012 12:40	Falling Limb Snowmelt	61.7
13	4/25/12 23:10	4/27/12 6:50	Rain on Snow	1.3
14	5/25/12 12:00	5/27/12 3:30	Rain	1.7
15	6/4/12 13:10	6/5/12 2:00	Rain	0.5
16	9/5/12 11:40	9/6/12 15:40	Rain	1.2
17	9/26/12 11:40	9/26/12 17:30	Rain	0.3
18	10/12/12 3:30	10/12/12 18:00	Rain	0.6
19	11/16/12 18:40	11/19/12 8:00	Rain	2.6
20	11/20/12 22:20	11/22/12 7:10	Rain	1.4
21	11/28/12 10:50	11/29/12 17:50	Rain	1.3
22	11/29/12 23:20	12/4/12 5:40	Rain	4.3
23	12/5/12 0:50	12/6/12 21:40	Rain	1.9
24	1/24/13 15:00	1/25/13 13:00	Rain on Snow	0.9
25	2/27/2013 3:30	5/5/2013 13:40	Total Snowmelt	67.4
26	2/27/2013 3:30	3/20/2013 14:50	Rising Limb Snowmelt	21.5
27	3/20/2013 14:50	5/5/2013 13:40	Falling Limb Snowmelt	46.0
28	3/3/13 9:00	3/4/13 8:00	Rain on Snow	1.0
29	3/31/13 2:00	4/1/13 9:00	Rain on Snow	1.3
30	5/6/13 2:00	5/7/13 8:00	Rain	1.3
31	5/7/13 17:20	5/8/13 10:30	Rain	0.7
32	5/24/13 3:00	5/24/13 20:30	Rain	0.7
33	6/4/13 16:30	6/5/13 12:00	Rain	0.8
34	6/24/13 23:30	6/26/13 4:30	Rain	1.2
35	1/29/2014 6:40	5/19/2014 21:40	Total Snowmelt	110.6
36	1/29/2014 6:40	3/6/2014 2:40	Rising Limb Snowmelt	35.8
37	3/6/2014 2:40	5/19/2014 21:40	Falling Limb Snowmelt	74.8

Table B1. List of Hydrologic Events during the study period of record (continued).

Event Number	Event Start	Event End	Event Type	Duration (days)
38	1/29/14 12:00	1/30/14 6:00	Rain on Snow	0.8
39	2/8/14 5:30	2/11/14 2:00	Rain on Snow	2.9
40	3/5/14 21:00	3/7/14 0:30	Rain on Snow	1.2
41	3/29/14 3:00	3/30/14 0:30	Rain on Snow	0.9
42	4/18/14 15:30	4/19/14 9:30	Rain on Snow	0.8
43	5/20/14 4:30	5/23/14 10:30	Rain	3.3
44	7/16/14 16:30	7/18/14 4:00	Rain	1.5
45	7/20/14 13:00	7/21/14 10:00	Rain	0.9
46	8/4/14 7:30	8/5/14 0:00	Rain	0.7
47	11/22/14 4:00	11/23/14 6:30	Rain	1.1
48	11/29/14 4:30	12/2/14 3:30	Rain on Snow	3.0
49	12/2/14 12:00	12/5/14 5:30	Rain on Snow	2.7
50	2/6/2015 5:20	4/23/2015 11:00	Total Snowmelt	76.2
51	2/6/2015 5:20	2/7/2015 17:00	Rising Limb Snowmelt	1.5
52	2/7/2015 17:00	4/23/2015 11:00	Falling Limb Snowmelt	74.8
53	2/6/15 17:00	2/11/15 8:00	Rain on Snow	4.6
54	4/23/15 17:00	4/24/15 21:30	Rain	1.2
55	4/24/15 23:00	4/26/15 9:00	Rain	1.4
56	5/7/15 18:00	5/8/15 7:30	Rain	0.6
57	5/8/15 17:00	5/10/15 6:00	Rain	1.5
58	5/14/15 17:00	5/24/15 12:00	Rain	9.8
59	5/25/15 12:00	5/25/15 19:30	Rain	0.3
60	6/6/15 17:00	6/7/15 19:00	Rain	1.1
61	6/9/15 18:00	6/11/15 16:30	Rain	1.9
62	7/2/15 17:00	7/3/15 18:00	Rain	1.0
63	7/8/15 12:00	7/9/15 6:00	Rain	0.8
64	9/30/15 17:00	10/2/15 18:40	Rain	2.1
65	10/17/15 5:00	10/18/15 22:30	Rain	1.7
66	10/28/15 6:00	10/29/15 7:00	Rain	1.0
67	11/1/15 15:30	11/3/15 9:00	Rain	1.7
68	11/9/15 16:00	11/11/15 7:00	Rain	1.6
69	1/22/2016 13:00	5/24/2016 9:00	Total Snowmelt	122.8
70	1/22/2016 13:00	3/4/2016 19:50	Rising Limb Snowmelt	42.3
71	3/4/2016 19:50	5/24/2016 9:00	Falling Limb Snowmelt	80.6
72	1/22/16 13:30	1/24/16 5:30	Rain on Snow	1.7
73	1/29/16 6:30	2/1/16 8:30	Rain on Snow	3.1
74	3/4/16 13:00	3/7/16 9:30	Rain on Snow	2.9
75	3/20/16 11:00	3/21/16 13:30	Rain on Snow	1.1
76	4/9/16 11:30	4/11/16 10:00	Rain on Snow	1.9

Table B1. List of Hydrologic Events during the study period of record (continued).

Event Number	Event Start	Event End	Event Type	Duration (days)
77	5/5/16 4:00	5/7/16 0:30	Rain on Snow	1.9
78	5/15/16 16:30	5/16/16 0:00	Rain	0.3
79	5/24/16 9:00	5/25/16 4:30	Rain	0.8
80	5/25/16 14:20	5/26/16 3:30	Rain	0.6
81	8/22/16 13:30	8/23/16 5:30	Rain	0.7

1 Rising Limb Snowmelt is the portion of the hydrograph where the flow quantity is increasing or rising.

2 Falling Limb Snowmelt is the portion of the hydrograph where the flow quantity is decreasing or falling.

APPENDIX C: SAMPLE TIMES AND LOCATIONS

Table C1. List of sample times and locations. See Figure 1 for monitoring station locations.

Location	Sample Datetime	Sample Analyses	Location	Sample Datetime	Sample Analyses
RW-Abv, Northwood	1/24/14 2:00 PM	Gchem	RW-Blw, H28	3/16/12 1:30 AM	LPSA
RW-Abv, Northwood	2/9/14 EMC	LPSA	RW-Blw, H28	3/16/12 5:00 AM	LPSA
RW-Abv, Northwood	2/9/14 7:05 AM	LPSA	RW-Blw, H28	6/4/12 EMC	LPSA
RW-Abv, Northwood	2/28/14 EMC	Gchem	RW-Blw, H28	3/20/13 EMC	LPSA
RW-Abv, Northwood	2/28/14 EMC	LPSA	RW-Blw, H28	3/20/13 EMC	Gchem
RW-Abv, Northwood	3/6/14 EMC	Gchem	RW-Blw, H28	1/24/14 2:30 PM	Gchem
RW-Abv, Northwood	3/6/14 EMC	LPSA	RW-Blw, H28	2/8/14 EMC	LPSA
RW-Abv, Northwood	3/6/14 1:48 AM	LPSA	RW-Blw, H28	2/8/14 10:20 AM	LPSA
RW-Abv, Northwood	3/6/14 2:30 AM	LPSA	RW-Blw, H28	2/26/14 EMC	Gchem
RW-Abv, Northwood	4/21/14 12:45 PM	Gchem	RW-Blw, H28	2/26/14 EMC	LPSA
RW-Abv, Northwood	4/21/14 12:45 PM	LPSA	RW-Blw, H28	3/6/14 EMC	Gchem
RW-Abv, Northwood	5/10/14 EMC	Gchem	RW-Blw, H28	3/6/14 EMC	LPSA
RW-Abv, Northwood	5/10/14 EMC	LPSA	RW-Blw, H28	3/6/14 3:00 AM	LPSA
RW-Abv, Northwood	5/20/14 EMC	Gchem	RW-Blw, H28	4/21/14 1:35 PM	Gchem
RW-Abv, Northwood	5/20/14 EMC	LPSA	RW-Blw, H28	4/21/14 1:35 PM	LPSA
RW-Abv, Northwood	5/20/14 10:52 AM	Gchem	RW-Blw, H28	5/10/14 EMC	Gchem
RW-Abv, Northwood	7/16/14 EMC	Gchem	RW-Blw, H28	5/10/14 EMC	LPSA
RW-Abv, Northwood	7/16/14 EMC	LPSA	RW-Blw, H28	5/20/14 EMC	Gchem
RW-Abv, Northwood	7/16/14 9:06 PM	LPSA	RW-Blw, H28	5/20/14 EMC	LPSA
RW-Abv, Northwood	7/17/14 EMC	Gchem	RW-Blw, H28	5/20/14 10:40 AM	Gchem
RW-Abv, Northwood	7/17/14 EMC	LPSA	RW-Blw, H28	5/20/14 1:30 PM	LPSA
RW-Abv, Northwood	7/17/14 2:54 PM	LPSA	RW-Blw, H28	7/16/14 EMC	Gchem
RW-Abv, Northwood	7/20/14 EMC	Gchem	RW-Blw, H28	7/16/14 EMC	LPSA
RW-Abv, Northwood	7/20/14 EMC	LPSA	RW-Blw, H28	7/16/14 9:50 PM	LPSA
RW-Abv, Northwood	7/20/14 3:04 PM	LPSA	RW-Blw, H28	7/17/14 EMC	Gchem
RW-Abv, Northwood	7/20/14 3:16 PM	Gchem	RW-Blw, H28	7/17/14 EMC	LPSA

Table C1. List of sample times and locations (continued).

Location	Sample Datetime	Sample Analyses
RW-Abv, Bridge	12/3/14 EMC	LPSA
RW-Abv, Bridge	2/6/15 EMC	Gchem
RW-Abv, Bridge	2/6/15 EMC	LPSA
RW-Abv, Bridge	2/8/15 EMC	Gchem
RW-Abv, Bridge	2/8/15 EMC	LPSA
RW-Abv, Bridge	2/8/15 5:10 PM	LPSA
RW-Abv, Bridge	4/23/15 5:20 PM	LPSA
RW-Abv, Bridge	4/23/15 5:30 PM	LPSA
RW-Abv, Bridge	4/24/15 12:16 AM	LPSA
RW-Abv, Bridge	4/24/15 12:52 AM	LPSA
RW-Abv, Bridge	5/8/15 7:06 PM	LPSA
RW-Abv, Bridge	5/8/15 7:18 PM	LPSA
RW-Abv, Bridge	5/8/15 8:14 PM	LPSA
RW-Abv, Bridge	5/17/15 1:14 PM	LPSA
RW-Abv, Bridge	5/17/15 1:46 PM	LPSA
RW-Abv, Bridge	5/17/15 2:22 PM	LPSA
RW-Abv, Bridge	6/9/15 11:58 PM	Gchem
RW-Abv, Bridge	6/10/15 EMC	Gchem
RW-Abv, Bridge	6/10/15 EMC	LPSA
RW-Abv, Bridge	6/10/15 12:16 AM	LPSA
RW-Abv, Bridge	7/2/15 6:00 PM	LPSA
RW-Abv, Bridge	7/8/15 EMC	Gchem
RW-Abv, Bridge	7/8/15 EMC	LPSA
RW-Abv, Bridge	7/8/15 1:56 PM	LPSA
RW-Abv, Bridge	7/8/15 2:20 PM	Gchem
RW-Abv, Bridge	7/8/15 2:30 PM	LPSA
RW-Abv, Bridge	8/7/15 6:16 PM	LPSA
RW-Blw, H28	7/17/14 3:40 PM	LPSA
RW-Blw, H28	7/20/14 EMC	Gchem
RW-Blw, H28	7/20/14 EMC	LPSA
RW-Blw, H28	7/20/14 3:00 PM	LPSA
RW-Blw, H28	7/20/14 3:10 PM	Gchem
RW-Blw, H28	7/20/14 5:00 PM	LPSA
RW-Blw, H28	12/3/14 EMC	LPSA
RW-Blw, H28	2/6/15 EMC	Gchem
RW-Blw, H28	2/6/15 EMC	LPSA
RW-Blw, H28	2/6/15 9:20 PM	LPSA
RW-Blw, H28	2/7/15 2:20 AM	LPSA
RW-Blw, H28	2/8/15 EMC	Gchem
RW-Blw, H28	2/8/15 EMC	LPSA
RW-Blw, H28	2/8/15 2:50 PM	LPSA
RW-Blw, H28	2/8/15 7:40 PM	LPSA
RW-Blw, H28	4/24/15 12:10 AM	LPSA
RW-Blw, H28	4/24/15 12:40 AM	LPSA
RW-Blw, H28	5/8/15 6:20 PM	LPSA
RW-Blw, H28	5/8/15 7:50 PM	LPSA
RW-Blw, H28	5/8/15 8:10 PM	LPSA
RW-Blw, H28	5/8/15 8:30 PM	LPSA
RW-Blw, H28	5/17/15 12:50 PM	LPSA
RW-Blw, H28	5/20/15 1:20 PM	LPSA
RW-Blw, H28	6/9/15 9:40 PM	Gchem
RW-Blw, H28	6/10/15 EMC	Gchem
RW-Blw, H28	6/10/15 EMC	LPSA
RW-Blw, H28	6/10/15 12:40 AM	LPSA

Table C1. List of sample times and locations (continued).

Location	Sample Datetime	Sample Analyses	Location	Sample Datetime	Sample Analyses
RW-Abv, Bridge	8/7/15 6:38 PM	LPSA	RW-Blw, H28	6/10/15 5:10 AM	LPSA
RW-Abv, Bridge	9/30/15 EMC	Gchem	RW-Blw, H28	7/8/15 EMC	Gchem
RW-Abv, Bridge	9/30/15 EMC	LPSA	RW-Blw, H28	7/8/15 EMC	LPSA
RW-Abv, Bridge	9/30/15 6:56 PM	LPSA	RW-Blw, H28	7/8/15 1:20 PM	Gchem
RW-Abv, Bridge	9/30/15 8:54 PM	Gchem	RW-Blw, H28	7/8/15 1:30 PM	LPSA
RW-Abv, Bridge	10/1/15 EMC	Gchem	RW-Blw, H28	7/8/15 2:40 PM	LPSA
RW-Abv, Bridge	10/1/15 EMC	LPSA	RW-Blw, H28	8/6/15 5:40 AM	LPSA
RW-Abv, Bridge	10/1/15 6:30 AM	LPSA	RW-Blw, H28	8/6/15 6:30 AM	LPSA
RW-Abv, Bridge	10/1/15 8:32 AM	Gchem	RW-Blw, H28	8/6/15 8:30 AM	LPSA
RW-Abv, Bridge	10/1/15 3:42 PM	LPSA	RW-Blw, H28	8/7/15 5:30 AM	LPSA
RW-Abv, Bridge	10/17/15 8:00 AM	LPSA	RW-Blw, H28	8/7/15 6:10 AM	LPSA
RW-Abv, Bridge	10/17/15 9:46 AM	LPSA	RW-Blw, H28	8/7/15 8:20 AM	LPSA
RW-Abv, Bridge	10/17/15 10:36 AM	LPSA	RW-Blw, H28	8/7/15 7:10 PM	LPSA
RW-Abv, Bridge	10/18/15 3:32 AM	LPSA	RW-Blw, H28	8/7/15 7:20 PM	LPSA
RW-Abv, Bridge	11/1/15 8:24 PM	LPSA	RW-Blw, H28	8/13/15 3:00 PM	LPSA
RW-Abv, Bridge	11/1/15 8:46 PM	LPSA	RW-Blw, H28	8/14/15 12:30 PM	LPSA
RW-Abv, Bridge	1/29/16 1:24 PM	Gchem	RW-Blw, H28	10/1/15 EMC	Gchem
RW-Abv, Bridge	1/29/16 4:16 PM	LPSA	RW-Blw, H28	10/1/15 EMC	LPSA
RW-Abv, Bridge	1/29/16 7:08 PM	Gchem	RW-Blw, H28	10/1/15 12:00 PM	LPSA
RW-Abv, Bridge	1/31/16 1:00 AM	LPSA	RW-Blw, H28	10/1/15 2:50 PM	LPSA
RW-Abv, Bridge	2/27/16 5:00 PM	Gchem	RW-Blw, H28	10/1/15 4:00 PM	Gchem
RW-Abv, Bridge	2/27/16 5:05 PM	Gchem	RW-Blw, H28	10/1/15 4:20 PM	LPSA
RW-Abv, Bridge	3/21/16 11:24 PM	LPSA	RW-Blw, H28	10/11/15 12:50 PM	LPSA
RW-Abv, Bridge	3/21/16 11:34 PM	Gchem	RW-Blw, H28	10/14/15 10:10 AM	LPSA
RW-Abv, Bridge	3/22/16 11:30 AM	Gchem	RW-Blw, H28	11/1/15 9:10 PM	LPSA
RW-Abv, Bridge	3/22/16 11:30 AM	LPSA	RW-Blw, H28	11/1/15 9:20 PM	LPSA
RW-Abv, Bridge	5/5/16 EMC	Gchem	RW-Blw, H28	11/1/15 10:10 PM	LPSA
RW-Abv, Bridge	5/5/16 EMC	LPSA	RW-Blw, H28	11/2/15 1:30 AM	LPSA

Table C1. List of sample times and locations (continued).

Location	Sample Datetime	Sample Analyses
RW-Abv, Bridge	5/5/16 7:08 AM	Gchem
RW-Abv, Bridge	5/5/16 7:38 AM	LPSA
RW-Abv, Bridge	5/5/16 6:04 PM	Gchem
RW-Abv, Bridge	5/5/16 6:30 PM	LPSA
RW-Abv, Bridge	5/5/16 6:36 PM	LPSA
RW-Abv, Bridge	5/24/16 3:12 PM	LPSA
RW-Abv, Bridge	5/24/16 3:46 PM	LPSA
RW-Abv, Bridge	5/25/16 4:22 PM	LPSA
RW-Abv, Bridge	5/25/16 4:48 PM	LPSA
RW-Abv, Bridge	8/22/16 2:10 PM	LPSA
RW-Abv, Bridge	8/22/16 2:48 PM	LPSA
RW-Abv, Bridge	8/22/16 3:52 PM	LPSA
RW-Abv, Bridge	10/14/16 2:54 PM	Gchem
RW-Abv, Bridge	10/14/16 4:16 PM	LPSA
RW-Abv, Bridge	10/14/16 4:38 PM	LPSA
RW-Abv, Bridge	10/14/16 5:26 PM	LPSA
RW-Abv, Bridge	10/14/16 6:30 PM	LPSA
RW-Abv, Bridge	10/15/16 5:50 PM	Gchem
RW-Abv, Bridge	10/15/16 6:26 PM	LPSA
RW-Abv, Bridge	10/15/16 7:54 PM	LPSA
RW-Abv, Bridge	10/15/16 8:00 PM	LPSA
RW-Abv, Bridge	10/15/16 8:40 PM	LPSA
RW-Abv, Bridge	10/14/2016 EMC	Gchem
RW-Abv, Bridge	10/14/2016 EMC	LPSA
RW-Abv, Bridge	10/15/2016 EMC	Gchem
RW-Abv, Bridge	10/15/2016 EMC	LPSA

Location	Sample Datetime	Sample Analyses
RW-Blw, H28	12/10/2015 EMC	Gchem
RW-Blw, H28	12/10/2015 EMC	LPSA
RW-Blw, H28	12/10/15 6:10 AM	Gchem
RW-Blw, H28	12/10/15 6:40 AM	LPSA
RW-Blw, H28	12/10/15 7:00 AM	LPSA
RW-Blw, H28	12/10/15 7:30 AM	LPSA
RW-Blw, H28	12/10/15 8:30 AM	Gchem
RW-Blw, H28	1/29/16 EMC	Gchem
RW-Blw, H28	1/29/16 EMC	LPSA
RW-Blw, H28	1/29/16 9:40 AM	LPSA
RW-Blw, H28	1/29/16 11:10 AM	LPSA
RW-Blw, H28	1/29/16 1:10 PM	Gchem
RW-Blw, H28	1/29/16 2:30 PM	LPSA
RW-Blw, H28	1/29/16 4:00 PM	LPSA
RW-Blw, H28	1/29/16 4:50 PM	LPSA
RW-Blw, H28	1/29/16 5:50 PM	Gchem
RW-Blw, H28	1/29/16 7:10 PM	LPSA
RW-Blw, H28	1/29/16 7:40 PM	LPSA
RW-Blw, H28	1/29/16 9:50 PM	Gchem
RW-Blw, H28	2/27/16 5:35 PM	Gchem
RW-Blw, H28	3/21/16 EMC	Gchem
RW-Blw, H28	3/21/16 EMC	LPSA
RW-Blw, H28	3/21/16 11:50 PM	LPSA
RW-Blw, H28	3/22/16 12:10 AM	Gchem
RW-Blw, H28	3/22/16 1:15 PM	Gchem
RW-Blw, H28	3/22/16 1:15 PM	LPSA
RW-Blw, H28	5/5/16 EMC	Gchem
RW-Blw, H28	5/5/16 EMC	LPSA

Table C1. List of sample times and locations (continued).

Location	Sample Datetime	Sample Analyses

Location	Sample Datetime	Sample Analyses
RW-Blw, H28	5/5/16 7:30 AM	Gchem
RW-Blw, H28	5/5/16 8:30 AM	LPSA
RW-Blw, H28	5/5/16 6:30 PM	LPSA
RW-Blw, H28	5/5/16 6:50 PM	Gchem
RW-Blw, H28	5/5/16 7:10 PM	LPSA
RW-Blw, H28	5/5/16 7:30 PM	LPSA
RW-Blw, H28	5/24/16 3:40 PM	LPSA
RW-Blw, H28	5/24/16 4:00 PM	LPSA
RW-Blw, H28	5/24/16 4:50 PM	LPSA
RW-Blw, H28	5/24/16 5:10 PM	LPSA
RW-Blw, H28	10/2/16 6:00 PM	LPSA
RW-Blw, H28	10/2/16 6:30 PM	LPSA
RW-Blw, H28	10/2/16 6:50 PM	LPSA

APPENDIX D: RW-ABV/BLW SUMMARY STATISTICS FOR EVENTS

Table D1. RW-Abv summary statistics for each of the 81 events.

Event Number	Turbidity (NTU)		Water Temp (^{0}C)		EC (µS/cm)		Stage (ft)	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
1	21.7	22.7	3.8	1.7	154.6	43.1	0.88	0.09
2	15.0	11.4	2.7	0.9	183.5	42.3	0.85	0.09
3	28.4	28.4	4.9	1.6	125.9	16.2	0.91	0.08
4	42.7	73.8	5.6	1.6	112.9	13.0	0.99	0.11
5	17.0	10.8	9.5	0.5	165.7	10.7	0.79	0.04
6	38.0	44.9	11.6	0.3	135.3	33.4	0.68	0.05
7	26.2	39.0	11.4	0.9	125.7	43.3	0.67	0.06
8	31.6	46.4	5.9	0.8	161.3	3.0	0.73	0.11
9	55.6	61.9	1.7	1.1	126.1	23.6	0.78	0.14
10	13.1	7.2	5.2	3.0	137.3	19.4	0.80	0.05
11	11.1	5.0	2.8	1.2	137.4	22.1	0.78	0.04
12	13.8	7.6	6.0	2.9	137.3	18.8	0.80	0.05
13	14.7	9.8	5.4	1.3	139.1	4.3	0.85	0.04
14	13.5	7.4	5.4	0.7	141.3	7.2	0.74	0.03
15	21.9	15.5	7.0	1.1	128.4	10.3	0.75	0.05
16	19.5	9.8	11.4	0.5	106.6	6.1	0.64	0.03
17	111.0	148.8	12.0	1.5	78.6	13.4	0.64	0.15
18	27.3	37.4	9.2	0.7	70.7	0.8	0.66	0.02
19	19.4	35.8	4.8	0.6	67.7	5.5	0.77	0.09
20	6.6	2.4	4.8	1.1	63.8	1.4	0.70	0.02
21	6.6	0.0	4.7	0.5	79.6	28.2	0.71	0.04
22	9.7	13.9	4.0	0.7	85.8	22.3	0.80	0.09
23	10.8	12.0	4.6	0.7	151.7	37.5	0.84	0.09
24	12.1	11.3	3.5	0.3	240.7	64.6	0.70	0.02

Table D1. RW-Abv summary statistics for each of the 81 events (continued).

Event Number	Turbidity (NTU)		Water Temp (^0C)		EC (µS/cm)		Stage (ft)	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
25	7.6	4.0	5.3	2.5	150.6	32.4	0.71	0.03
26	7.6	4.1	3.8	1.6	170.1	18.7	0.72	0.02
27	7.6	4.0	6.1	2.5	140.2	33.4	0.70	0.03
28	16.1	12.9	3.2	0.6	179.7	27.3	0.72	0.02
29	11.6	7.7	4.9	1.0	165.7	9.8	0.76	0.03
30	17.4	19.2	6.0	0.8	119.2	13.6	0.75	0.06
31	10.6	5.1	6.0	0.3	136.9	10.3	0.76	0.04
32	11.9	16.1	4.1	1.3			0.67	0.01
33	26.9	37.1	11.4	1.5	108.5	19.6	0.68	0.07
34	10.2	7.2	9.8	0.4	94.9	15.4	0.69	0.04
35	6.5	4.0	4.8	2.9	152.0	18.3	0.71	0.04
36	6.5	5.3	2.7	1.6	151.3	22.0	0.72	0.05
37	6.5	3.3	5.8	2.8	152.4	16.2	0.70	0.03
38	19.0	16.4	4.7	0.9	162.5	42.8	0.75	0.06
39	8.5	6.9	1.2	1.1	164.3	14.8	0.78	0.07
40	14.9	18.4	4.4	0.8	164.9	8.7	0.83	0.06
41	6.6	2.2	3.5	0.9	173.3	30.7	0.73	0.03
42	11.3	7.4	7.8	1.5	152.5	9.1	0.70	0.02
43	9.4	3.9	6.9	2.1	190.2	59.7	0.72	0.05
44	17.4	24.6	14.8	1.0	119.5	4.9	0.66	0.05
45	24.9	48.2	14.1	1.3	110.5	12.5	0.75	0.14
46	10.1	7.6	13.0	0.4	108.8	6.9	0.71	0.05
47	3.8	4.5	5.9	0.9	181.1	2.9	0.67	0.01
48	4.9	2.4	5.8	2.0	196.9	9.9	0.69	0.02
49	20.9	38.3	5.1	0.5	212.1	3.5	0.76	0.06
50	3.4	1.6	6.0	2.5	168.9	22.4	0.67	0.03

Table D1. RW-Abv summary statistics for each of the 81 events (continued).

Event Number	Turbidity (NTU)		Water Temp (^{0}C)		EC (µS/cm)		Stage (ft)	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
51	6.4	2.8	5.0	1.1	148.0	22.5	0.71	0.07
52	3.3	1.5	6.0	2.5	169.1	22.3	0.67	0.03
53	6.0	2.4	4.6	1.2	219.3	28.8	0.77	0.05
54	21.3	53.5	8.5	1.2	162.5	16.0	0.71	0.07
55	18.4	26.6	5.6	0.9	166.0	5.4	0.71	0.03
56	3.8	1.0	6.2	0.4	158.7	3.1	0.66	0.02
57	11.6	11.7	7.8	1.6	166.6	7.1	0.70	0.07
58	46.1	76.4	7.8	1.2	177.0	16.7	0.70	0.03
59	5.2	1.6	11.3	0.1	190.1	0.8	0.68	0.01
60	8.9	6.6	12.5	1.6	157.5	7.2	0.67	0.02
61	47.4	98.2	10.1	4.1	139.5	9.5	0.71	0.06
62	8.8	8.6	16.5	0.8	159.9	4.7	0.63	0.03
63	12.0	19.4	13.2	1.0	130.5	7.2	0.66	0.05
64	52.4	66.9	13.9	1.1	130.4	19.1	0.67	0.07
65	22.8	28.1			82.2	13.5	0.69	0.07
66	23.2	33.9			101.4	15.1	0.66	0.04
67	14.1	22.5			104.6	14.0	0.72	0.07
68	8.7	7.6			126.2	3.1	0.68	0.02
69	7.8	11.2			198.7	36.3	0.81	0.07
70	7.9	13.6			193.2	53.5	0.80	0.07
71	7.7	9.7			201.1	25.2	0.82	0.06
72	19.5	24.6			263.2	66.7	0.73	0.02
73	29.5	31.1			180.6	42.4	0.92	0.14
74	28.0	41.6			216.6	13.6	0.96	0.05
75	6.1	2.9			224.6	7.8	0.92	0.03
76	24.8	12.5			197.4	10.6	0.87	0.03

Table D1. RW-Abv summary statistics for each of the 81 events (continued).

Event Number	Turbidity (NTU)		Water Temp (^{0}C)		EC (µS/cm)		Stage (ft)	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
77	15.7	15.4			184.5	17.9	0.82	0.05
78	8.7	4.1			187.4	7.7	0.75	0.02
79	11.6	14.7			171.1	18.4	0.76	0.04
80	10.5	7.5			173.1	20.6	0.78	0.05
81	65.5	63.0			280.7	153.2	0.63	0.04

Table D2. RW-Blw summary statistics for each of the 81 events.

Event Number	Turbidity (NTU)		Water Temp (^0C)		EC (µS/cm)		Stage (ft)	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
1	24.7	34.8	3.9	2.0	174.4	37.8	0.60	0.11
2	22.8	32.8	2.8	1.4	195.7	33.9	0.55	0.11
3	26.5	36.6	5.1	1.8	153.2	28.5	0.65	0.09
4	39.0	64.9	5.7	1.7	126.8	21.6	0.75	0.17
5	11.5	9.2	9.4	0.5	170.3	11.7	0.48	0.04
6	29.4	48.8	11.4	0.1	169.1	18.8	0.44	0.05
7	18.2	52.3	11.3	1.2	200.2	50.7	0.46	0.07
8	31.6	46.4	5.9	0.8	105.5	13.7	0.48	0.10
9	50.4	60.2	1.4	0.9	110.0	22.9	0.56	0.16
10	11.0	6.5	5.2	3.1	137.8	39.2	0.52	0.04
11	12.7	6.8	2.6	1.3	126.1	19.7	0.51	0.04
12	10.4	6.3	6.0	3.1	139.7	41.2	0.52	0.03
13	15.4	10.3	5.6	1.2	129.2	27.9	0.57	0.03
14	21.2	26.2	5.2	0.7	123.8	13.0	0.48	0.02
15	53.6	56.9	7.1	1.1	149.2	24.1	0.48	0.04
16	44.6	53.1	11.5	0.6	136.4	6.2	0.43	0.03
17	560.0	698.2	13.6	1.7	128.8	6.6	0.46	0.15
18	28.0	38.3	9.2	0.7	114.3	3.8	0.45	0.02
19	39.3	53.5	4.9	0.4	129.8	26.3	0.52	0.06
20	8.6	2.2	4.7	1.1	113.1	8.2	0.46	0.02
21	5.5	0.0	4.4	0.4	146.9	49.6	0.46	0.03
22	8.8	14.4	4.0	0.6	111.7	8.9	0.53	0.07
23	10.8	12.0	4.6	0.7			0.58	0.07
24	24.2	28.4	3.0	0.3	208.5	41.3	0.51	0.02
25	8.3	8.5	5.3	2.6	151.8	13.6	0.48	0.03
26	7.7	5.9	3.7	1.7	150.8	13.2	0.50	0.02

Table D2. RW-Blw summary statistics for each of the 81 events (continued).

Event Number	Turbidity (NTU)		Water Temp (^{0}C)		EC (µS/cm)		Stage (ft)	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
27	8.5	9.5	6.1	2.6	152.4	13.8	0.46	0.02
28	16.5	12.6	3.1	0.7	167.7	14.0	0.52	0.02
29	30.3	36.6	4.9	1.0	154.6	8.4	0.51	0.03
30	17.4	19.2	6.1	0.8	131.8	17.0	0.52	0.07
31	10.3	5.0	6.1	0.5	150.6	13.2	0.51	0.04
32	11.9	16.1	4.1	1.3	141.4	7.1	0.46	0.01
33	63.1	138.0	11.5	1.4	146.4	14.7	0.47	0.06
34	17.1	21.4	9.8	0.4	125.8	8.7	0.49	0.04
35	9.3	11.4	4.8	3.0	152.6	22.6	0.46	0.03
36	9.1	13.2	2.7	1.9	152.8	28.8	0.47	0.04
37	9.4	10.7	5.8	2.9	152.4	18.9	0.45	0.02
38	18.2	44.9	6.9	2.0	156.4	16.1	0.46	0.03
39	21.5	21.0	1.9	2.3	158.9	14.3	0.54	0.06
40	37.1	63.1	4.6	0.9	173.7	24.8	0.56	0.06
41	14.0	14.5	3.5	0.9	160.4	41.1	0.47	0.02
42	17.9	17.9	8.0	1.8	159.7	12.0	0.47	0.02
43	14.7	13.0	6.9	2.1	173.6	32.5	0.47	0.03
44	22.9	38.9	14.6	1.0	157.4	14.9	0.43	0.04
45	28.4	57.7	14.0	1.2	135.5	63.1	0.51	0.13
46	16.2	17.9	13.0	0.2	115.4	10.1	0.47	0.04
47	2.4	4.5	5.1	1.2	241.2	11.9	0.39	0.03
48	3.5	2.4	4.0	0.6	201.5	23.1	0.42	0.02
49	7.6	28.6	4.5	0.7	143.5	20.3	0.48	0.07
50	2.1	7.5	5.1	2.5	171.9	20.5	0.40	0.05
51	21.4	25.3	3.7	1.2	153.8	35.9	0.51	0.10
52	1.8	6.1	5.1	2.5	172.3	19.9	0.40	0.05

Table D2. RW-Blw summary statistics for each of the 81 events (continued).

Event Number	Turbidity (NTU)		Water Temp (^{0}C)		EC (µS/cm)		Stage (ft)	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
53	16.4	26.1	4.0	1.5	165.9	37.4	0.56	0.13
54	14.7	30.1	7.3	1.5	163.5	42.3	0.45	0.08
55	4.5	4.3	4.4	1.2	150.2	14.3	0.44	0.04
56	3.2	3.4	5.5	0.5	168.0	18.4	0.41	0.02
57	9.0	23.5	7.3	2.5	161.3	36.5	0.44	0.07
58	3.4	6.4	7.0	1.3	175.2	19.1	0.44	0.03
59	7.3	14.1	10.8	0.6	218.4	10.5	0.44	0.03
60	8.4	21.8	11.5	2.4	211.1	22.0	0.37	0.03
61	11.8	17.3	9.4	3.6	176.2	34.9	0.45	0.06
62	5.6	9.7	15.9	1.5	241.4	22.7	0.36	0.02
63	16.8	33.0	12.3	1.2	191.5	19.8	0.39	0.04
64	68.2	134.1	10.6	1.1	168.3	21.4	0.42	0.06
65	44.1	89.1	10.1	0.9	161.4	13.8	0.43	0.06
66	21.7	38.3	7.2	1.0	155.9	9.1	0.39	0.03
67	26.3	36.2	6.3	1.1	126.4	5.7	0.45	0.07
68	9.8	7.7	1.5	1.1	126.6	14.9	0.38	0.03
69	10.1	20.7	5.0	2.8	261.1	25.8	0.53	0.08
70	13.2	32.7	3.0	1.5	262.7	25.8	0.50	0.09
71	8.4	9.2	6.0	2.7	260.2	25.8	0.55	0.06
72	25.6	23.7	2.4	0.3	261.5	33.7	0.45	0.02
73	60.7	99.3	1.8	0.9	249.7	45.9	0.65	0.21
74	26.1	44.7	3.7	1.2	240.8	25.8	0.67	0.06
75	18.8	15.0	5.0	1.0	269.3	16.1	0.67	0.04
76	16.7	22.2	5.5	1.0	239.3	21.4	0.63	0.04
77	28.2	33.8	8.0	2.6	236.6	49.5	0.58	0.06
78	17.2	16.7	8.7	0.5	256.5	10.1	0.48	0.02

Table D2. RW-Blw summary statistics for each of the 81 events (continued).

Event Number	Turbidity (NTU)		Water Temp (^{0}C)		EC (µS/cm)		Stage (ft)	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
79	32.2	55.0	6.9	0.6	214.1	26.1	0.49	0.05
80	29.0	37.4	7.9	0.9	219.8	28.8	0.51	0.06
81	57.5	97.8	13.2	1.3	384.7	114.6	0.37	0.03

APPENDIX E: RESULTS OF HYDROLOGIC EVENTS DURING THE STUDY PERIOD

Table E1. Results of Hydrologic Events during the study period of record for water loads and sediment loads at both RW-Abv and RW-Blw.

Event Number	Event Start	Event End	Event Type	Water Load (10^6L/event)		Suspended Sediment Load (kg/event)	
				RW-Abv	RW-Blw	RW-Abv	RW-Blw
1	3/4/2011 9:00	6/5/2011 1:30	Total Snowmelt	477.15	305.74	80009.74	33754.07
2	3/4/2011 9:00	4/19/2011 15:30	Rising Limb SM	196.75	114.68	27379.55	12475.80
3	4/19/2011 15:30	6/5/2011 1:30	Falling Limb SM	280.51	191.13	52686.14	21305.88
4	6/5/11 1:30	6/7/11 7:30	Rain	20.80	13.25	12799.29	4201.92
5	6/28/11 20:40	6/29/11 20:40	Rain	2.62	1.40	385.24	105.51
6	9/12/11 11:40	9/12/11 21:30	Rain	0.41	0.38	196.46	124.32
7	9/14/11 15:40	9/15/11 16:20	Rain	1.06	1.15	554.89	365.41
8	10/4/11 22:10	10/6/11 1:20	Rain	2.43	1.65	1494.87	643.37
9	1/20/12 9:50	1/22/12 12:30	Rain On Snow	6.72	5.62	5197.82	2532.73
10	3/2/2012 13:00	5/22/2012 12:40	Total Snowmelt	220.75	148.28	22295.20	8776.73
11	3/2/2012 13:00	3/21/2012 20:00	Rising Limb SM	46.76	34.51	3858.02	2502.70
12	3/21/2012 20:00	5/22/2012 12:40	Falling Limb SM	174.02	113.80	18439.40	6274.99
13	4/25/12 23:10	4/27/12 6:50	Rain On Snow	5.36	3.08	655.81	269.47
14	5/25/12 12:00	5/27/12 3:30	Rain	2.75	2.08	307.42	280.10
15	6/4/12 13:10	6/5/12 2:00	Rain	1.03	0.75	217.07	294.44
16	9/5/12 11:40	9/6/12 15:40	Rain	0.77	0.90	126.13	283.94
17	9/26/12 11:40	9/26/12 17:30	Rain	0.44	0.33	2004.14	2133.85
18	10/12/12 3:30	10/12/12 18:00	Rain	0.46	0.54	120.35	101.49
19	11/16/12 18:40	11/19/12 8:00	Rain	6.32	3.00	1660.79	924.21
20	11/20/12 22:20	11/22/12 7:10	Rain	1.55	1.31	79.32	58.71
21	11/28/12 10:50	11/29/12 17:50	Rain	1.66	1.41	78.48	39.50
22	11/29/12 23:20	12/4/12 5:40	Rain	13.45	8.46	845.05	351.39
23	12/5/12 0:50	12/6/12 21:40	Rain	7.56	5.31	875.10	372.07

Table E1. Results of Hydrologic Events during the study period of record for water loads and sediment loads at both RW-Abv and RW-Blw (continued).

Event Number	Event Start	Event End	Event Type	Water Load (10^6L/event)		Suspended Sediment Load (kg/event)	
				RW-Abv	RW-Blw	RW-Abv	RW-Blw
24	1/24/13 15:00	1/25/13 13:00	Rain On Snow	1.09	1.55	113.46	218.06
25	2/27/2013 3:30	5/5/2013 13:40	Total Snowmelt	81.20	85.38	4622.34	3846.91
26	2/27/2013 3:30	3/20/2013 14:50	Rising Limb SM	29.55	34.83	1695.65	1453.94
27	3/20/2013 14:50	5/5/2013 13:40	Falling Limb SM	51.67	50.57	2929.86	2394.95
28	3/3/13 9:00	3/4/13 8:00	Rain On Snow	1.38	1.79	180.92	166.62
29	3/31/13 2:00	4/1/13 9:00	Rain On Snow	2.61	2.27	251.55	448.10
30	5/6/13 2:00	5/7/13 8:00	Rain	2.47	2.34	479.09	286.46
31	5/7/13 17:20	5/8/13 10:30	Rain	1.43	1.22	131.16	74.12
32	5/24/13 3:00	5/24/13 20:30	Rain	0.61	0.74	54.26	46.01
33	6/4/13 16:30	6/5/13 12:00	Rain	0.91	1.04	415.27	819.13
34	6/24/13 23:30	6/26/13 4:30	Rain	1.31	1.81	119.75	207.20
35	1/29/2014 6:40	5/19/2014 21:40	Total Snowmelt	141.00	117.51	7261.15	6415.45
36	1/29/2014 6:40	3/6/2014 2:40	Rising Limb SM	54.31	44.44	3071.48	2654.12
37	3/6/2014 2:40	5/19/2014 21:40	Falling Limb SM	86.77	73.11	4237.95	3806.16
38	1/29/14 12:00	1/30/14 6:00	Rain On Snow	1.48	0.83	243.36	139.94
39	2/8/14 5:30	2/11/14 2:00	Rain On Snow	7.26	6.43	565.16	753.50
40	3/5/14 21:00	3/7/14 0:30	Rain On Snow	4.10	2.92	652.98	898.90
41	3/29/14 3:00	3/30/14 0:30	Rain On Snow	1.31	1.08	66.62	84.24
42	4/18/14 15:30	4/19/14 9:30	Rain On Snow	0.88	0.87	84.95	89.56
43	5/20/14 4:30	5/23/14 10:30	Rain	4.86	3.85	383.80	326.14
44	7/16/14 16:30	7/18/14 4:00	Rain	1.25	1.05	319.64	249.07
45	7/20/14 13:00	7/21/14 10:00	Rain	2.53	1.73	1636.46	753.00
46	8/4/14 7:30	8/5/14 0:00	Rain	0.92	0.85	87.45	96.92
47	11/22/14 4:00	11/23/14 6:30	Rain	0.63	0.42	18.96	7.74
48	11/29/14 4:30	12/2/14 3:30	Rain On Snow	2.30	1.79	86.26	36.90

Table E1. Results of Hydrologic Events during the study period of record for water loads and sediment loads at both RW-Abv and RW-Blw (continued).

Event Number	Event Start	Event End	Event Type	Water Load (10^6L/event)		Suspended Sediment Load (kg/event)	
				RW-Abv	RW-Blw	RW-Abv	RW-Blw
49	12/2/14 12:00	12/5/14 5:30	Rain On Snow	4.22	3.85	996.56	244.07
50	2/6/2015 5:20	4/23/2015 11:00	Total Snowmelt	49.04	37.35	1307.38	2140.59
51	2/6/2015 5:20	2/7/2015 17:00	Rising Limb SM	1.57	2.82	86.33	520.79
52	2/7/2015 17:00	4/23/2015 11:00	Falling Limb SM	47.50	34.55	1222.99	1621.83
53	2/6/15 17:00	2/11/15 8:00	Rain On Snow	7.88	12.13	358.69	1987.92
54	4/23/15 17:00	4/24/15 21:30	Rain	1.34	1.22	520.02	278.38
55	4/24/15 23:00	4/26/15 9:00	Rain	1.31	1.16	171.46	31.46
56	5/7/15 18:00	5/8/15 7:30	Rain	0.28	0.33	8.16	6.64
57	5/8/15 17:00	5/10/15 6:00	Rain	1.42	1.46	206.44	201.29
58	5/14/15 17:00	5/24/15 12:00	Rain	8.84	8.28	3229.70	263.91
59	5/25/15 12:00	5/25/15 19:30	Rain	0.21	0.27	7.98	16.83
60	6/6/15 17:00	6/7/15 19:00	Rain	0.62	0.23	50.55	15.65
61	6/9/15 18:00	6/11/15 16:30	Rain	1.93	2.04	1120.73	256.11
62	7/2/15 17:00	7/3/15 18:00	Rain	0.31	0.15	30.05	8.71
63	7/8/15 12:00	7/9/15 6:00	Rain	0.42	0.32	94.46	77.35
64	9/30/15 17:00	10/2/15 18:40	Rain	1.39	1.43	873.50	322.15
65	10/17/15 5:00	10/18/15 22:30	Rain	1.47	1.38	411.97	224.46
66	10/28/15 6:00	10/29/15 7:00	Rain	0.58	0.39	95.55	26.20
67	11/1/15 15:30	11/3/15 9:00	Rain	2.04	1.92	187.45	119.34
68	11/9/15 16:00	11/11/15 7:00	Rain	1.17	0.46	79.23	8.51
69	1/22/2016 13:00	5/24/2016 9:00	Total Snowmelt	281.51	262.73	19582.08	5502.16
70	1/22/2016 13:00	3/4/2016 19:50	Rising Limb SM	89.96	73.10	7441.46	2912.73
71	3/4/2016 19:50	5/24/2016 9:00	Falling Limb SM	191.59	189.67	12163.62	2591.63
72	1/22/16 13:30	1/24/16 5:30	Rain On Snow	2.01	1.56	321.10	60.87
73	1/29/16 6:30	2/1/16 8:30	Rain On Snow	14.03	13.02	3785.35	1918.97

Table E1. Results of Hydrologic Events during the study period of record for water loads and sediment loads at both RW-Abv and RW-Blw (continued).

Event Number	Event Start	Event End	Event Type	Water Load (10^6L/event)		Suspended Sediment Load (kg/event)	
				RW-Abv	RW-Blw	RW-Abv	RW-Blw
74	3/4/16 13:00	3/7/16 9:30	Rain On Snow	14.40	12.69	3326.55	587.51
75	3/20/16 11:00	3/21/16 13:30	Rain On Snow	4.62	4.94	212.99	138.83
76	4/9/16 11:30	4/11/16 10:00	Rain On Snow	6.34	7.14	1158.14	185.67
77	5/5/16 4:00	5/7/16 0:30	Rain On Snow	4.60	5.40	619.00	273.95
78	5/15/16 16:30	5/16/16 0:00	Rain	0.44	0.41	29.71	11.56
79	5/24/16 9:00	5/25/16 4:30	Rain	1.25	1.21	155.75	102.47
80	5/25/16 14:20	5/26/16 3:30	Rain	0.98	1.02	95.60	68.91
81	8/22/16 13:30	8/23/16 5:30	Rain	0.23	0.16	163.45	37.54

APPENDIX F: ABBREVIATED DESIGN PLANS (FOR FULL PLAN SET VISIT HTTP://NTCD.ORG)

Control Points			
Point #	Elevation	Northing	Easting
1		14767363.48	2239106.26
2		14769146.43	2238546.39
400	6394.27	14767522.96	2238947.26
408	6395.86	14767662.08	2238972.06
421	6402.48	14767740.12	2239101.26
423	6405.08	14767805.52	2238944.07
426	6416.02	14767926.73	2238847.62
429	6429.64	14768081.85	2238717.35
430	6432.31	14768146.90	2238699.41
433	6450.41	14768450.40	2238643.03
434	6458.52	14768569.40	2238575.66
437	6470.05	14768746.26	2238704.20
438	6464.88	14768723.42	2238642.23

Control Points			
Point #	Elevation	Northing	Easting
439	6450.53	14768500.00	2238750.39
441	6475.68	14768859.41	2238580.33
442	6489.15	14768923.57	2238695.51
443	6490.34	14768972.43	2238699.58
444	6485.21	14769034.06	2238665.44
447	6431.75	14768180.90	2238835.12
449	6411.53	14767939.27	2238968.26
450	6411.64	14767871.14	2239058.20
452	6392.59	14767677.84	2239099.73
453	6379.13	14767472.54	2239234.30
454	6376.25	14767383.38	2239243.28
456	6381.00	14767523.99	2239159.62
550	6492.02	14768961.96	2238600.17

Control Points			
Point #	Elevation	Northing	Easting
7002	6386.57	14767426.30	2239036.02

Line Table: Alignments		
Line #	Length	Direction
L2	27.651	S57° 23' 41.15"E
L3	13.103	S69° 30' 16.04"E
L4	51.101	S44° 55' 41.94"E
L5	82.345	S25° 19' 54.00"E
L6	139.650	S2° 49' 26.35"W
L7	15.194	S0° 15' 19.73"E
L8	268.740	S0° 15' 19.73"E
L9	16.780	S8° 05' 05.66"E
L10	383.270	S8° 05' 05.66"E
L11	22.507	S18° 46' 22.52"E

Line Table: Alignments		
Line #	Length	Direction
L12	261.793	S18° 46' 22.52"E
L13	16.075	S14° 43' 52.03"E
L14	91.599	S14° 43' 52.03"E
L15	23.882	S17° 06' 08.76"E
L16	265.272	S17° 06' 08.76"E
L17	98.415	S43° 32' 38.34"E
L18	26.068	S43° 32' 38.34"E
L19	20.756	S43° 32' 38.34"E

HORIZONTAL AND VERTICAL CONTROL/PROJECTION

VERTICAL CONTROL IS NGVD 29; HORIZONTAL CONTROL IS NEVADA STATE PLANE WEST, NAD 83 (FEET).

REVISIONS		
MARK	DATE	BY

GRAPHIC SCALE
SCALE IN FEET
60 30 0 60

PROFESSIONAL ENGINEER - STATE OF NEVADA
STEPHEN H. PECK
Exp. 12/31/13
CIVIL
No. 16993

SEAL OF WASHOE COUNTY
STATE OF NEVADA

Nevada Tahoe Conservation District

WOOD RODGERS

Cardno ENTRIX
295 Hwy 50, Suite 1
P.O. Box 1533
Zephyr Cove, NV 89448
(775) 775-9069 Main

Valley & Mountain Consulting

MIDDLE ROSEWOOD CREEK AREA "A" SEZ RESTORATION

INDEX & SURVEY CONTROL SHEET

DATE
6/2012

SHEET
iii

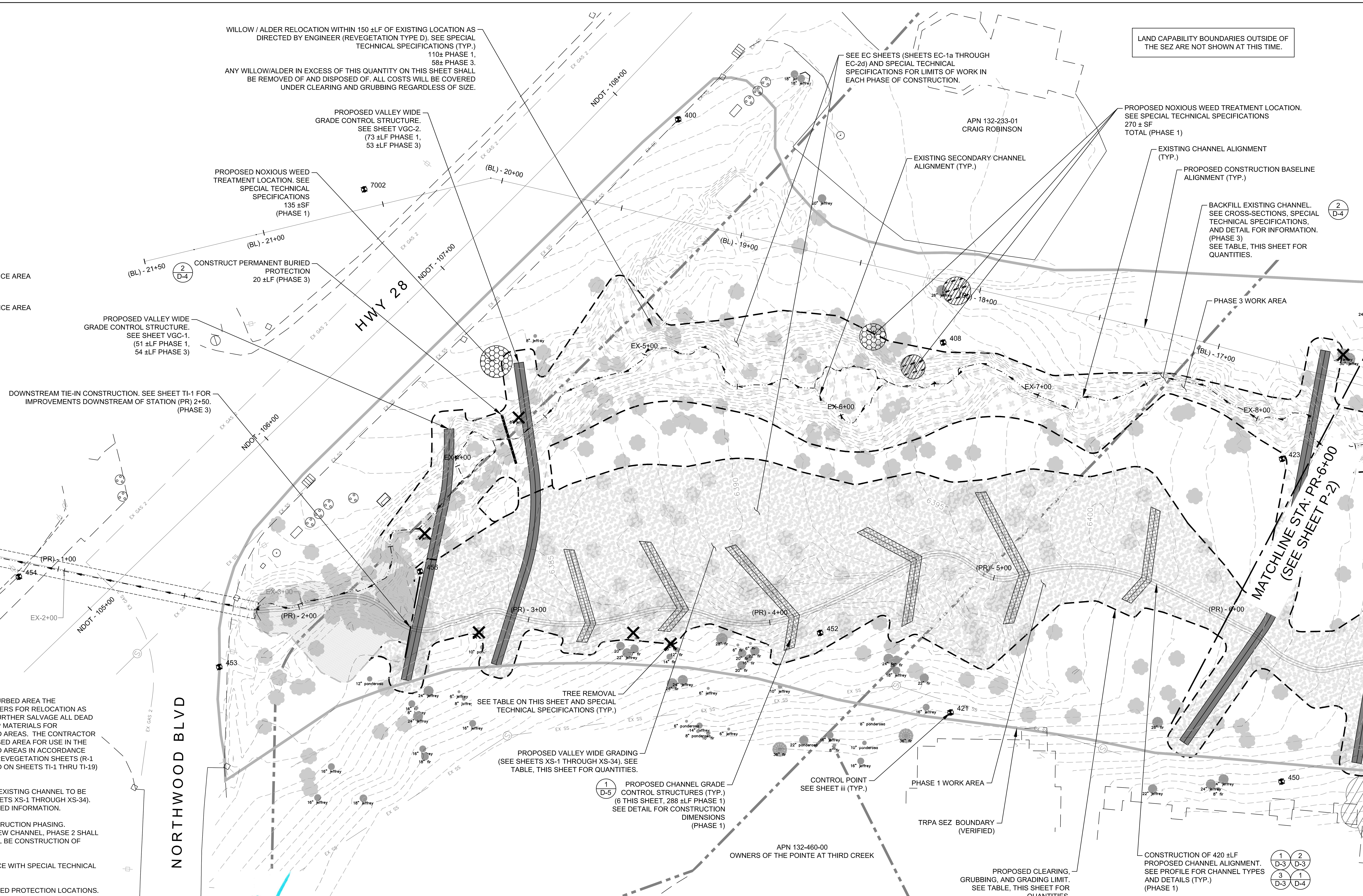
CONIFER TREE REMOVAL TABLE (THIS SHEET ONLY TYP.)	
TREE D.B.H.	NO. OF TREES
6" - 12"	3
13" - 24"	2
25" - 36"	1
> 36"	0

DISTURBANCE AREAS (THIS SHEET ONLY TYP.)	
CLEARING & GRUBBING 1	20,755 ±SF
CLEARING & GRUBBING 3	14,650 ±SF
PHASE 1 CUT	1,242 ±CY
PHASE 1 FILL	240 ±CY
PHASE 3 CUT	6 ±CY
PHASE 3 FILL	1,930 ±CY

LEGEND

PROPOSED PHASE 1 DISTURBANCE AREA

PROPOSED PHASE 3 DISTURBANCE AREA



NOTES:

1. PRIOR TO ANY CLEARING AND GRUBBING IN THE DISTURBED AREA THE CONTRACTOR SHALL SALVAGE ALL WILLOWS AND ALDERS FOR RELOCATION AS DIRECTED BY ENGINEER. THE CONTRACTOR SHALL FURTHER SALVAGE ALL DEAD AND DOWNED WOODY DEBRIS FOR USE IN WOOD CHIP MATERIALS FOR RESTORATION AND REVEGETATION OF ALL DISTURBED AREAS. THE CONTRACTOR SHALL FINALLY SALVAGE ALL TOPSOIL IN THE DISTURBED AREA FOR USE IN THE RESTORATION AND REVEGETATION OF ALL DISTURBED AREAS IN ACCORDANCE WITH THE SPECIAL TECHNICAL SPECIFICATIONS AND REVEGETATION SHEETS (R-1 THRU R-4 AND REVEGETAION TREATMENTS IDENTIFIED ON SHEETS TI-1 THRU TI-19) FOR THE PROJECT.
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5. SEE SHEETS EC-1a THRU EC-1d FOR TEMPORARY BURIED PROTECTION LOCATIONS.

REVISIONS			
MARK	DATE	BY	

GRAPHIC SCALE
SCALE IN FEET
20 10 0 20

PROFESSIONAL ENGINEER STATE OF NEVADA
STEPHEN H. PECK
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No. 16993

SEAL OF WASHOE COUNTY STATE OF NEVADA

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WOOD RODGERS

Cardno ENTRIX
295 Hwy 50, Suite 1
P.O. Box 1533
Zephyr Cove, NV 89448
(775) 775-9069 Main

VALLEY & MOUNTAIN CONSULTING

MIDDLE ROSEWOOD CREEK AREA "A" SEZ RESTORATION

PLAN VIEW
STATION: PR-0+00 TO PR-6+00

DATE
6/2012

SHEET
P-1

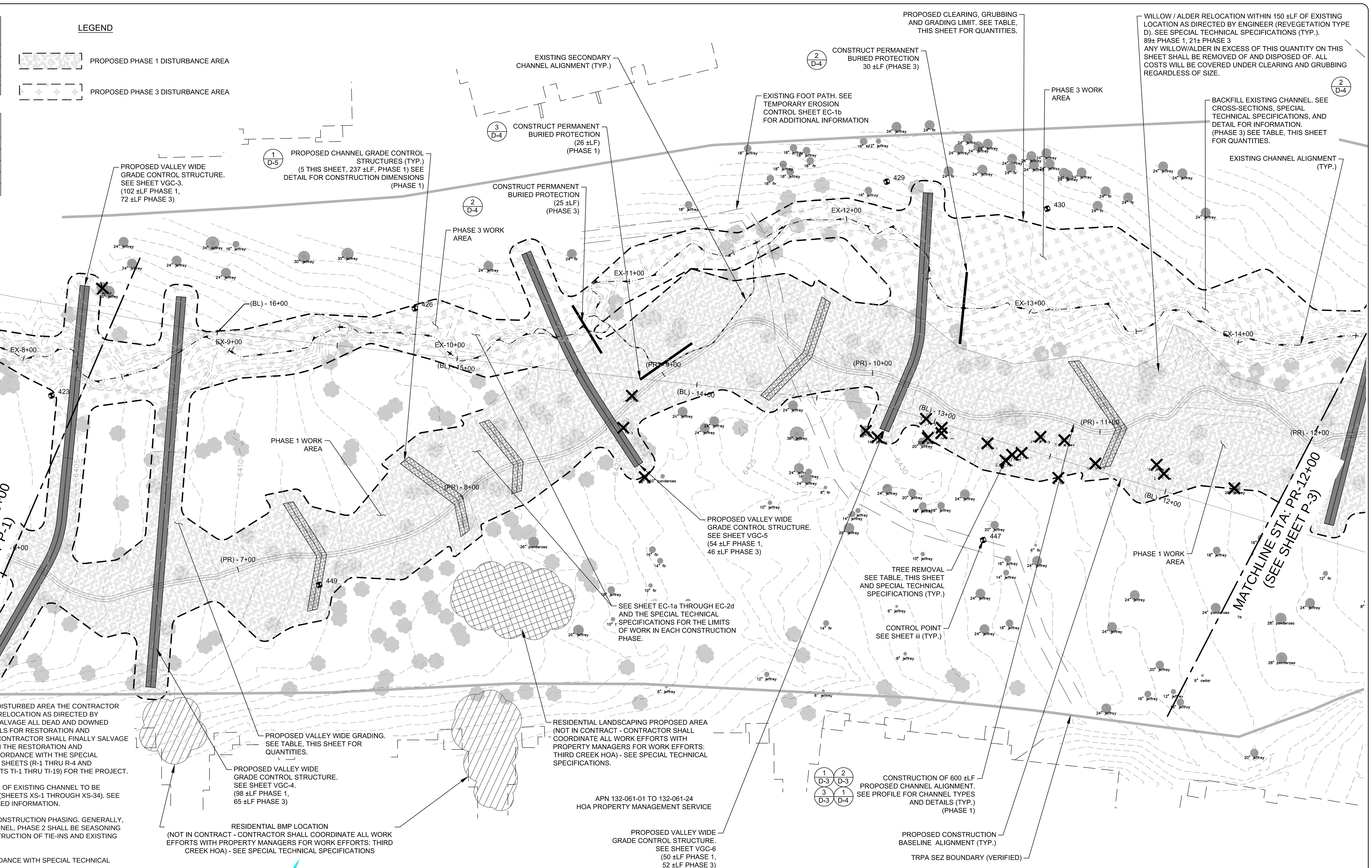
CONIFER TREE REMOVAL TABLE (THIS SHEET ONLY TYP.)	
TREE D.B.H.	NO. OF TREES
6" - 12"	3
13" - 24"	13
25" - 36"	4
> 36"	0

DISTURBANCE AREAS (THIS SHEET ONLY TYP.)	
CLEARING & GRUBBING 1	26,975 ±SF
CLEARING & GRUBBING 3	17,230 ±SF
PHASE 1 CUT	986 ±CY
PHASE 1 FILL	23 ±CY
PHASE 3 FILL	1,222 ±CY

LEGEND

PROPOSED PHASE 1 DISTURBANCE AREA

PROPOSED PHASE 3 DISTURBANCE AREA



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REVISIONS

MARK	DATE	BY	

GRAPHIC SCALE
SCALE IN FEET
20 10 0 20

PROFESSIONAL ENGINEER - STATE OF NEVADA
STEPHEN H. PECK
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SEAL OF WASHOE COUNTY
STATE OF NEVADA

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WOOD RODGERS

Cardno ENTRIX
295 Hwy 50, Suite 1
P.O. Box 1533
Zephyr Cove, NV 89448
(775) 775-9069 Main

Valley & Mountain Consulting

MIDDLE ROSEWOOD CREEK AREA "A" SEZ RESTORATION

PLAN VIEW

STATION: PR-6+00 TO PR-12+00

DATE 6/2012

SHEET P-2

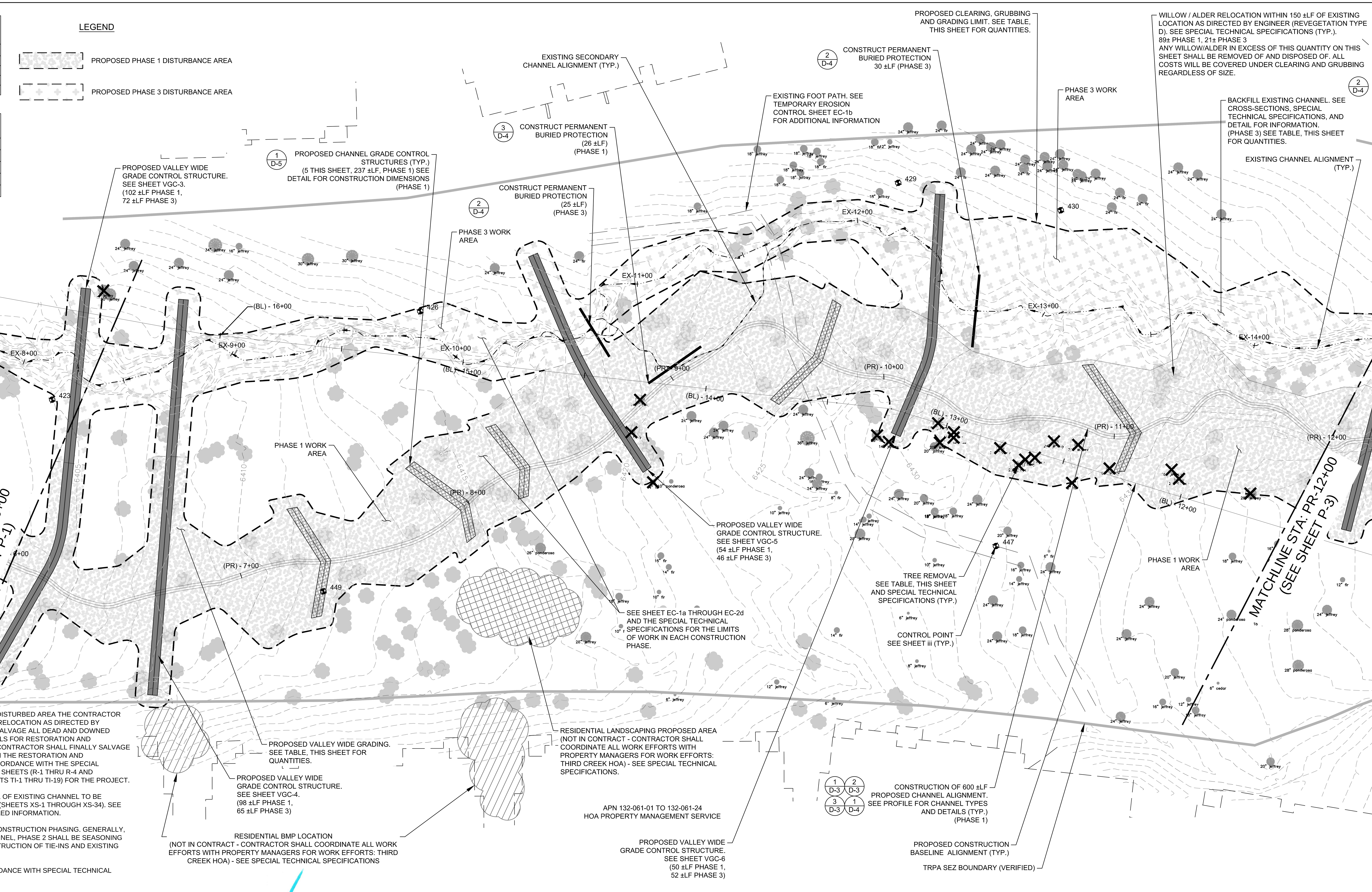
CONIFER TREE REMOVAL TABLE (THIS SHEET ONLY TYP.)	
TREE D.B.H.	NO. OF TREES
6" - 12"	3
13" - 24"	13
25" - 36"	4
> 36"	0

DISTURBANCE AREAS (THIS SHEET ONLY TYP.)	
CLEARING & GRUBBING 1	26,975 ±SF
CLEARING & GRUBBING 3	17,230 ±SF
PHASE 1 CUT	986 ±CY
PHASE 1 FILL	23 ±CY
PHASE 3 FILL	1,222 ±CY

LEGEND

PROPOSED PHASE 1 DISTURBANCE AREA

PROPOSED PHASE 3 DISTURBANCE AREA



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REVISIONS

MARK	DATE	BY	

GRAPHIC SCALE
SCALE IN FEET
20 10 0 20

PROFESSIONAL ENGINEER - STATE OF NEVADA
STEPHEN H. PECK
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CIVIL
No. 16993

SEAL OF WASHOE COUNTY STATE OF NEVADA

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WOOD RODGERS

Cardno ENTRIX
295 Hwy 50, Suite 1
P.O. Box 1533
Zephyr Cove, NV 89448
(775) 775-9069 Main

Valley & Mountain Consulting

MIDDLE ROSEWOOD CREEK AREA "A" SEZ RESTORATION

PLAN VIEW

STATION: PR-6+00 TO PR-12+00

DATE 6/2012

SHEET P-2

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DISTURBANCE AREAS (THIS SHEET ONLY TYP.)	
CLEARING & GRUBBING 1	22,975 ±SF
CLEARING & GRUBBING 3	16,175 ±SF
PHASE 1 CUT	706 ±CY
PHASE 1 FILL	69 ±CY
PHASE 3 FILL	2,584 ±CY

CONIFER TREE REMOVAL TABLE (THIS SHEET ONLY TYP.)

TREE D.B.H.	NO. OF TREES
6" - 12"	6
13" - 24"	1
25" - 36"	3
> 36"	0

REVISIONS		
MARK	DATE	BY

GRAPHIC SCALE
SCALE IN FEET
20 10 0 20

PROFESSIONAL ENGINEER STATE OF NEVADA STEPHEN H. PECK Exp. 12/31/13 CIVIL No. 16993

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295 Hwy 50, Suite 1
P.O. Box 1533
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(775) 775-9069 Main

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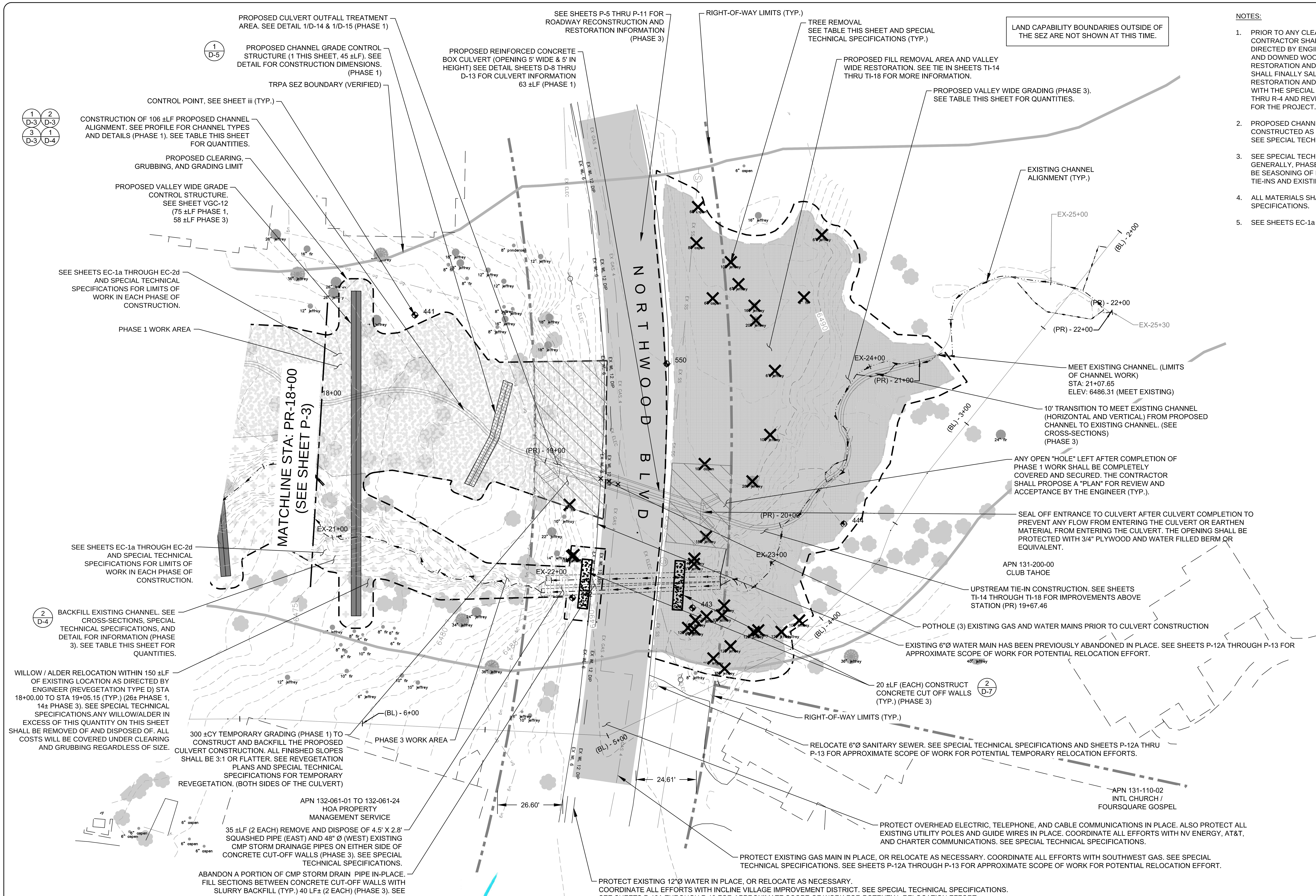
MIDDLE ROSEWOOD CREEK AREA "A" SEZ RESTORATION

PLAN VIEW
STATION: PR-12+00 TO PR-18+00

DATE 6/2012

SHEET P-3



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DISTURBANCE AREAS (THIS SHEET ONLY TYP.)	
CLEARING & GRUBBING 1	7,130 ±SF
CLEARING & GRUBBING 3	3,295 ±SF
PHASE 1 CUT	104 ±CY
PHASE 1 FILL	33 ±CY
PHASE 3 FILL	165 ±CY

CONIFER TREE REMOVAL TABLE (THIS SHEET ONLY TYP.)	
TREE D.B.H.	NO. OF TREES
6" - 12"	20
13" - 24"	7
25" - 36"	1
> 36"	0

LEGEND

PROPOSED PHASE 1 DISTURBANCE AREA

PROPOSED PHASE 3 DISTURBANCE AREA

REVISIONS			
MARK	DATE	BY	

GRAPHIC SCALE
SCALE IN FEET
20 10 0 20

PROFESSIONAL ENGINEER - STATE OF NEVADA
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MIDDLE ROSEWOOD CREEK AREA "A" SEZ RESTORATION

PLAN VIEW

STATION: PR-18+00 TO PR-22+19

DATE
6/2012

SHEET
P-4