Interim Monitoring Report for Blackwood Creek Restoration Phase I and II: Fish Ladder Removal and Barker Pass Road Crossing Replacement, Period of Record 2003-2008

USDA Forest Service

Lake Tahoe Basin Management Unit

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Executive Summary

In September of 2003, the U.S. Forest Service removed a concrete fish ladder in Blackwood Creek, and in 2006 replaced the stream crossing on Barker Pass Road. The stream channel was reconstructed at both of these sites as these structures were removed. These projects constitute Phase I and II of a three-phase project to restore physical processes that promote healthy aquatic ecosystems in Blackwood Creek.

The monitoring approach utilized by the LTBMU relied primarily on visual observations documented by photo points, and physical measurements of channel morphology. The monitoring questions related to the restoration goals are:

Goal 1: Remove in-channel structures, and create stable channel geomorphology, with improved aquatic habitat.

- Is channel form evolving from the constructed step/pool channel to a riffle/pool form, and is the channel horizontally and vertically stable while evolving into the desired form?
- Are constructed flood protection berms preventing headcutting and outflanking, and are grade control weirs maintaining their cross section shape, when exposed to high flows?

Goal 2: Promote recovery of stream bank and floodplain riparian vegetation, through channel design, including restoring connectivity of stream channel to the adjacent floodplain.

- Is riparian vegetation increasing along stream banks and the adjacent floodplain?

At the fish ladder site, longitudinal profile surveys and photos show that after early adjustments, the channel is now vertically stable. Photos show that cross-sectional shape is stable but will likely continue to experience minor adjustments. Sediment deposition from upstream transport suggests that the trend from step/pool toward riffle/pool channel forms may have started. At the bridge, thalweg profile and cross section stability are trending similar to what is occurring at the fish ladder.

In terms of vegetation colonization, the fish ladder site is underperforming because the new constructed channel does not have a large enough floodplain to allow flows to spread and reduce velocities which would result in sediment deposition. At the bridge site, it is too early to evaluate trends given the below-average flow conditions in 2007 and 2008. Because of the larger floodplain area present at the bridge site, conditions are expected to improve once higher flows occur.

Insufficient floodplain function and lack of sediment deposition post-removal of the fish ladder were factors that led to a Blackwood Creek Phase IIIB redesign; this phase is , scheduled for construction in 2010. While the photos and thalweg surveys do show that the step/pool design is maintaining grade and form, the current configuration does not

adequately promote depositional or hydro-geologic conditions to meet project goals. The Phase IIIB redesign will increase functional floodplain area, promoting better conditions for riparian vegetation colonization and increasing the rate at which this channel reach will evolve to the desired riffle/pool channel form.

I. INTRODUCTION

An important aspect of the Lake Tahoe Basin Management Unit's (LTBMU) project effectiveness monitoring program is to evaluate the success of U.S. Forest Service Restoration Projects. A framework has been established to monitor the status of the projects and to provide an ongoing assessmen of trends in condition over time. Interim monitoring updates are an opportunity to evaluate whether or not the project is meeting Forest management goals and objectives and if not, determine the course of action necessary to meet these goals and objectives. This report presents interim results of post-project monitoring conducted for the fish ladder removal and the Barker Pass Road stream channel crossing replacement on Blackwood Creek.

<u>Background</u>

In September 2003, the U.S. Forest Service removed a concrete fish ladder in Blackwood Creek, and in 2006 replaced the stream crossing on Barker Pass Road and reconstructed the stream channel at both sites. These projects constitute Phase 1 and II of a three-phase project to restore physical processes that promote healthy aquatic ecosystems in Blackwood Creek. Design drawings of plan view layout of these two phases of Blackwood Creek restoration are presented in Figures 1 and 2 later in the document.

From a channel-floodplain process perspective, both sites are located at or near important landscape features, which are transition points that induce changes in stream and valley form locally. The fish ladder was located at the head of the Blackwood Valley on the toe of a glacial / alluvial fan deposit. Early aerial photos show that at this location, stream form transitioned from a braided to single thread, alternate bar type channel. These channel forms are indicative of high bed load transport rates. Approximately 2,500 feet downstream of the fish ladder is the Barker Pass Road crossing. The crossing is located at the toe of a prehistoric, valley-wide landslide. The trace of this slide runs north to south, perpendicular to the fall line of the valley. At the time, this landslide formed a bed load trap upstream, preventing a significant portion of bed load sediment from moving downstream. This abrupt change in sediment transport character resulted in a shift in channel type. Upstream of the slide the creek was a single thread, pool - bar- riffle, Rosgen type C channel, and downstream of the slide the creek was characterized by a narrower, more sinuous channel with fewer sedimentary bars (Rosgen type C/E).

The fish ladder site (toe of the glacial fan) supported a commercial gravel extraction operation in the 1960s. In addition to extensive channel diversions and excavation that occurred in the channel as part of this extraction operation, photos and records indicate the channel was also straightened through the 2,500 foot reach between the gravel pit and the Barker Pass low water crossing. Straightening increased channel slope and bed load transport capacity greatly, increasing the supply of bed load sediment to the channel downstream. Concurrent with pit operations was logging of large conifers off the floodplain. The removal of large trees eliminated an important grade control element critical for stream and valley stability. The combined effects of channel diversions, excavation in and straightening of the channel, logging on the valley floor, and clearing of channel debris (1970s), resulted in degraded channel and floodplain conditions throughout Blackwood Creek.

In the 1970s, a head cut was moving up through the gravel quarry site and would have likely continued up valley to the confluence of the main stem and North Fork tributary. A concrete and steel fish ladder was installed in 1980 to stop head cut erosion, and provide grade control and passage for spring-run fish migrating up from Lake Tahoe. Over the years, however, the baffles (steel plates anchored to the floor ladder that provided resting stations) wore out and significantly reduced the ladders' function as a fish passage feature.

The Barker Pass Road crossing was installed in the 1960s primarily to support commercial logging operations. This crossing impacted local stream hydraulics and sediment transport dynamics significantly. An 84-inch diameter culvert (500 cfs capacity) in the center of the crossing, funneled low and moderately sized snowmelt floods downstream. This caused pool scour and limited fish passage in the spring. Discharge levels during the larger floods exceeded culvert capacity and water cascaded over the road and on to the downstream face of the crossing, resulting in facial and toe scour. Additionally, a backwater effect occurred upstream of the crossing, reducing water surface slope and capacity to transport bed load sediment. Backwatering prevented much of the bed load sediment from moving past the crossing, resulting in sediment transport discontinuity downstream during large floods. Subsequent flood flows slowly eroded the channel and began eating away at the stream banks for at least several hundred feet downstream. Scour during an extreme rain–on-snow event in 1997 resulted in severe erosion, eroding a 100-foot wide swath of valley along a 200-yard section of the creek's left bank just downstream of the road. Erosion also formed a split channel downstream and a six-foot difference in streambed elevation above and below the crossing. This flood also undercut the base of the crossing, which then required significant maintenance to remain safe.

A watershed analysis in 2001-02 by Swanson Hydrology and Geomorphology formally identified the fish ladder and Barker Pass Road crossing as impediments to long-term ecosystem function. The Blackwood Creek Restoration Phase I and II projects removed these features and replaced them with a series of constructed boulder step pools to maintain a stable stream profile, while providing natural function in terms of coarse bed load sediment transport and fish passage (Figures 1 & 2). Swanson Hydrology and Geomorphology, the contractor selected to design the projects, based the restoration design primarily on natural analogues of step-pool channel segments found downstream in Blackwood Creek.

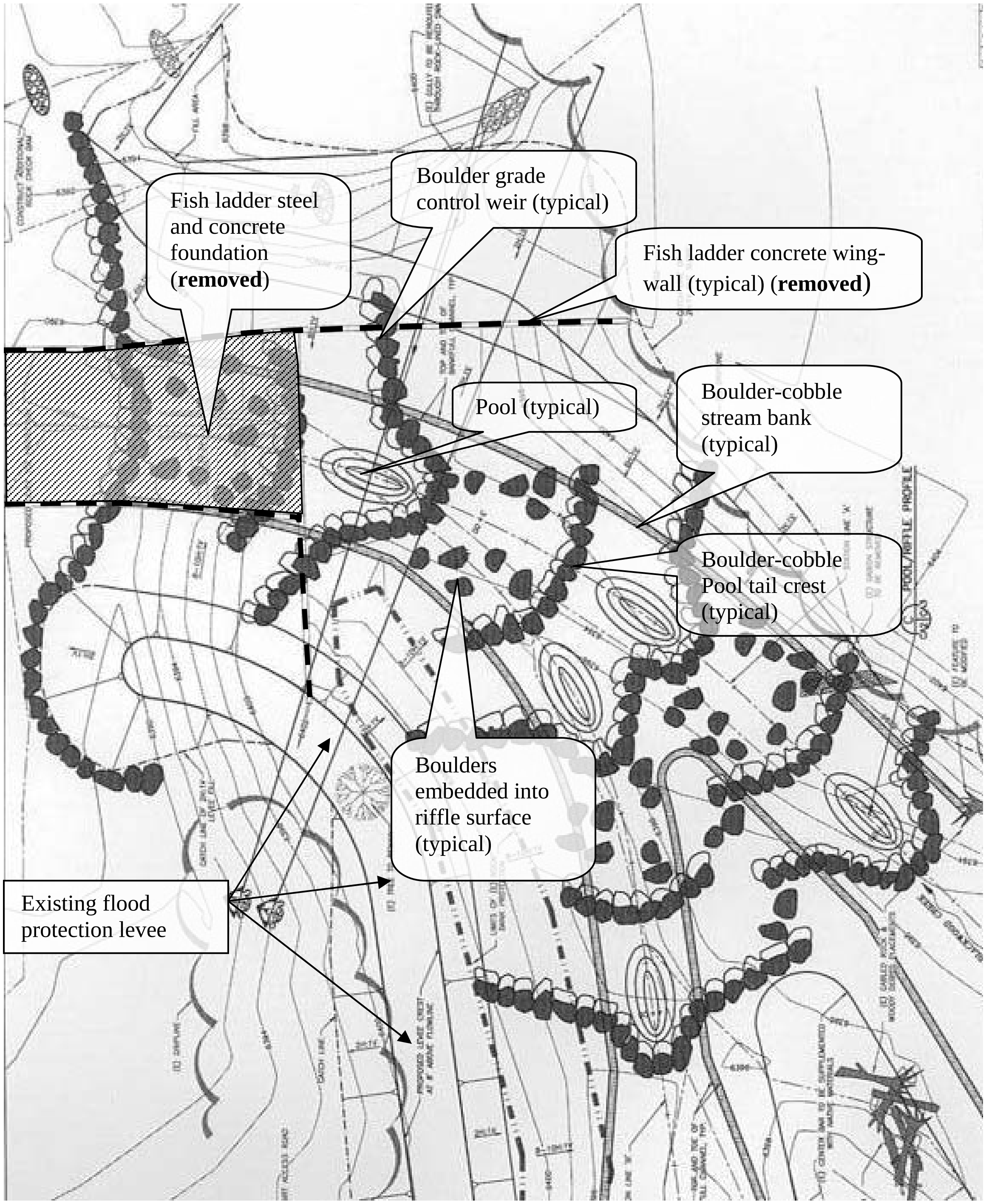

Figure 1 – Site Plan for Blackwood Phase I Fish Ladder removal project.

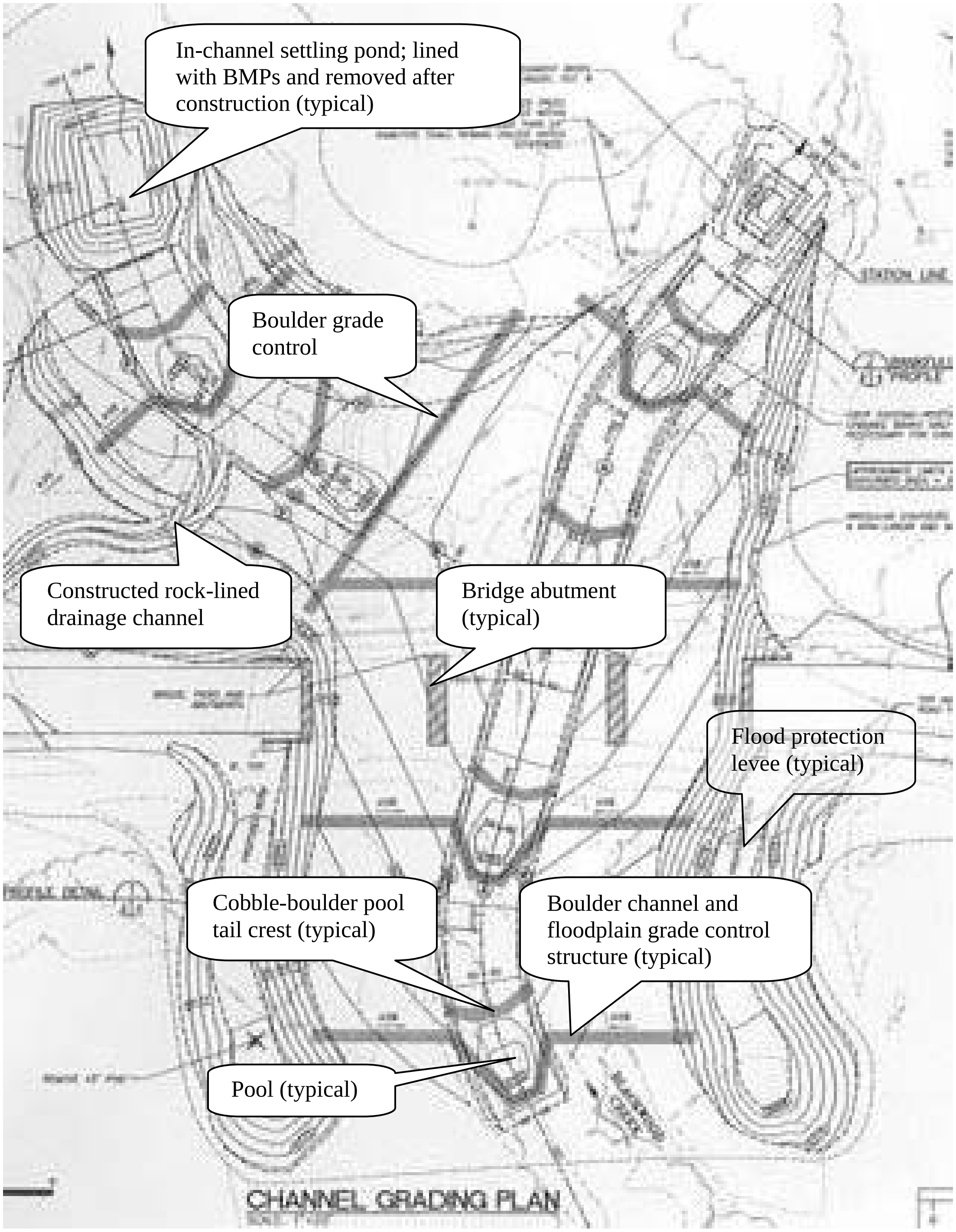

Figure 2 – Site Plan for Blackwood Phase II crossing replacement project

The goals of these projects were to:

1. Remove in-channel structures and put in place a stable step/pool channel form that will evolve over time, through natural erosion and sediment transport processes, from step/pool, to a riffle/pool channel form; that provides pool and resting habitat for anadromous and resident fish during spring runoff.
2. Create conditions (slack water and sediment deposition areas) that promote recovery of stream bank and floodplain riparian vegetation.

II. MONITORING APPROACH

The monitoring approach utilized by the LTBMU relies primarily on visual observations documented by photo points, and physical measurements of channel morphology. The monitoring questions related to the restoration goals described above are:

Goal 1: Remove in-channel structures, and create stable channel geomorphology with improved aquatic habitat.

- Is the channel form evolving from the constructed step/pool channel to a riffle/pool form, and is the channel horizontally and vertically stable while evolving into the desired form?
- Are constructed flood protection berms preventing headcutting and outflanking, and do grade control weirs maintain their cross section shape when exposed to high flows?

Goal 2: Promote recovery of stream bank and floodplain riparian vegetation, through channel design, including restoring connectivity of stream channel to adjacent floodplain.

- Is riparian vegetation increasing along stream banks and adjacent floodplain?

The monitoring parameters measured to answer the monitoring questions related to restoration goals include:

Goal 1:

- *Thalweg Longitudinal Profile Measurements*. Thalweg measurements are used to determine how the channel is evolving in terms of gradient and pool-bar-riffle formation. In 2003, the design consultant Swanson Hydrology conducted an as-built survey verifying that the construction contractor built the channel to within specifications (+/- 0.1 feet for channel width, pool tail depth, and pool head depth). Swanson repeated the topographic survey of the fish ladder site in 2007 as part of the redesign for Blackwood Creek Phase IIIB (scheduled for 2010). The Swanson 2007 survey was overlaid onto the 2003 as-built survey to compare changes in thalweg profile from 2003 to 2007 at this site. At the Barker Pass Road crossing, the LTBMU monitoring staff performed a survey of the thalweg profile in 2007 and 2008. These 2007 and 2008 thalweg surveys were overlaid

- *Cross Section Surveys*. In 2007, LTBMU hydrologists established four cross sections at the Barker Pass Road crossing to quantify the changes in cross section shape (scour and fill), and riparian vegetation colonization. Two cross sections were also established in 2003 at the fish ladder site; however, cross sections pins were lost and the locations were not well documented and so could not be re-established. This site will undergo significant changes as a result of future restoration actions (Phase IIIB), and so cross sections will be reestablished after the construction of that project. Because of the limited current data set, no analysis of cross section data is provided in this report.

Goal 1 and 2:

- *Photo point documentation*. LTBMU hydrology staff maintained four photo points at the fish ladder (2003-2007) and three photo points at the Barker Pass Road crossing (2006-2007). The photos are a qualitative tool used to evaluate project success in terms of geomorphic stability and riparian vegetation colonization overall. Photo points are presented in Appendix A.
- *Vegetation Transects*. In 2007, LTBMU botany staff established four transects (at the same location as channel cross sections) at the Barker Pass Road crossing site to quantify the changes in riparian vegetation colonization. Because of the limited current data set, no analysis of transect data is provided in this report

The LTBMU will continue performing the above measurements and photo points every five years, or after major flood events that result in significant movement of bed load. The next scheduled monitoring will occur no later than 2012, with the next monitoring report produced in 2013. In 2013, the monitoring report will also include results from Forest Service fisheries surveys, and an analysis of the water quality data collected at the Blackwood Creek water quality station (maintained by USGS) located near the mouth of the watershed.

III. MONITORING RESULTS

<u>Background Hydrology</u>
Flow volumes that occur within a stream with a 1.5 year flood frequency are on average the hydrologic events that many river scientists believe transport the most sediment, and do most of the work in terms of channel forming and shaping. This is also referred to as "bank-full" flow, the point where water fills the channel to capacity and begins to spill out onto the floodplain. The Swanson study, however, revealed that the significant channel and floodplain-shaping flow in this creek appears to occur every three to five years, which is a flow level for a large snowmelt or small rain-on-snow event. They based this hypothesis on coarse woody debris influence on local hydraulics and sediment transport within a functional section of Blackwood Creek, in terms of channel-floodplain connectivity. Aerial photos show that this section of channel, with its coarse woody structures, has changed little since 1939. Cross-section measurements combined with

hydraulic and incipient particle motion analysis were used to determine when significant channel and floodplain shaping occurs. Analysis showed that structural overtopping, floodplain sedimentation and channel shaping tend to occur at flows associated with the three to five year flood frequency. This, however, does not imply that the 1.5-year flows have no influence, or that the channel is contained within its banks in the 1.5 to 3 year flows; it just indicates that widespread channel and floodplain shaping tends to occur at slightly higher flows.

Based on this hypothesis, only two channel-shaping flows occurred during this period of evaluation. The most significant channel-shaping event occurred on December 31, 2005, (WY 2006) during a rainstorm that partially melted the snow pack and triggered a relatively large flood. USGS gauge records downstream suggest the flood was one with a 20 to 25 year recurrence interval. All other high flows during this period occurred during the annual spring snowmelt runoff. Peak flows during these events are displayed in Table 1 below. These flows had reoccurrence intervals that ranged between one and three years and had little or no sculpting capacity. After late spring peak flows, surface flow typically ceased from about mid-summer on, and did not reemerge until late fall during storm recharge.

Water year	Event type	Peak discharge at USGS 10336660	Peak discharge at fish ladder	Peak discharge at bridge	Flood Return Interval
2004	SM	372	245		1.5-2
2005	SM	765	504		3-5
2006	RS	404	266		2
2006	SM	2260	1491		20-25
2007	SM	178	117	123	<1.5
2008	SM	312	200	215	1.5-2

SM = snowmelt RS= rain-on-snow

Goal 1: Create stable channel geomorphology, and improve aquatic habitat.

Phase I-Fish Ladder

As expected, flows in 2004 through 2008 washed out much of the finer fraction (2-305mm diameter) of channel substrate along the lower two-thirds of the fish ladder site, a process known as "winnowing." Some of this finer substrate fraction is still present in the channel (located on the downstream end of large boulders) and was placed during construction; some of this finer substrate probably represents some incoming bed load sediment. However, photo evidence suggests that, since construction, this portion of the channel has experienced an increase in the median grain diameter overall, a process known as "coarsening." The photo sequence from photo point #1 (2003-2007) in Appendix A, shows this coarsening occurring over time. In 2004, a minor downward shift (a drop of about one foot at the downstream end) in the thalweg profile elevation was observed. This shift represents settling at boulder weirs 1 and 2 following construction. Settling along the lower two-thirds of the constructed channel has not occurred since. Some minor erosion occurred along a 30-foot section of terrace above the right bank of the bank-full channel at the downstream end of the project. This erosion was a product of the December 2005 flood and no floodplain erosion has occurred since.

Along the upper 1/3 of constructed channel illustrated in photo point #4 (2003-2007) in Appendix A, some winnowing occurred early (2004 and 2005), followed by deposition of gravel-cobble size bed load invading from upstream (2006 through 2008). A lateral bar has formed upstream of weir 4 as the channel upstream of the project area aggrades. A slight increase in thalweg elevation occurred along weirs 3 & 4 and supports the observations of bed load invasion and deposition from sources upstream.

A graph of the thalweg profile in Figure 3 verifies photo evidence and observations showing the winnowing and settling of weirs 1 and 2, and aggrading along weirs 3 and 4.

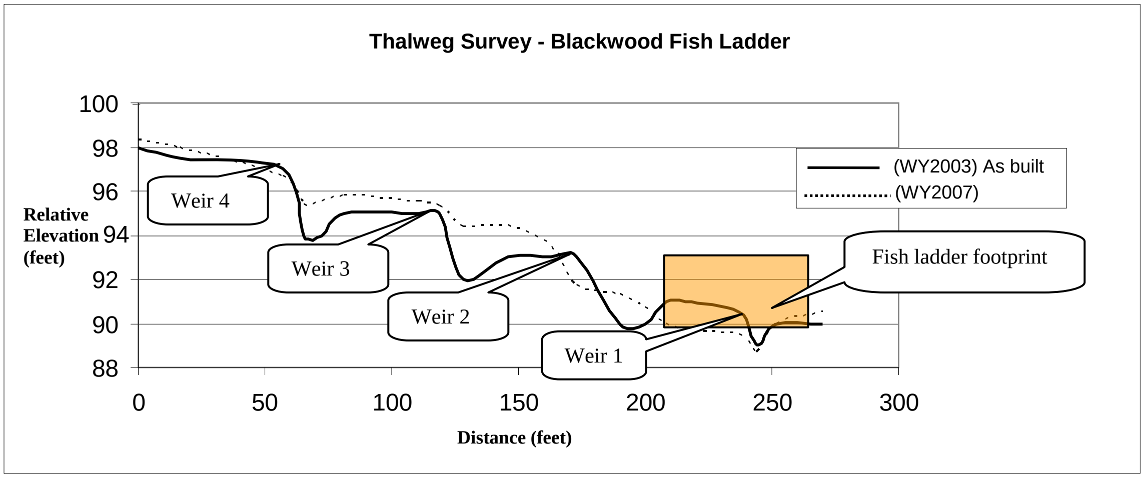

Figure 3. Fish ladder thalweg profile

Phase II -Bridge Crossing

As expected, spring snowmelt flood flows in 2007 winnowed much of the finer fraction (2-305mm) of substrate from constructed riffles upstream of the bridge as illustrated in the photo points. This snowmelt flood, however, was not sufficient in magnitude or duration to transport this material any further than the pool and riffle just downstream of the bridge (Figure 4).

Figure 4. Bed sediment deposit in the channel downstream of bridge

In 2008, spring flows continued to move that sediment downstream, sorting the sediment into a series of lateral bars downstream of the constructed channel (Figure 5). Winnowing continued in the riffles upstream of the bridge; however, bed load sediment has also begun to invade the upper end of the constructed channel, similar to what is occurring at the fish ladder site.

Figure 5. Lateral bar formation downstream of bridge

A graph of the thalweg in Figure 6 above verifies photo point evidence and observations showing channel fill below the bridge, scour above, and lateral bar formation below the constructed channel.

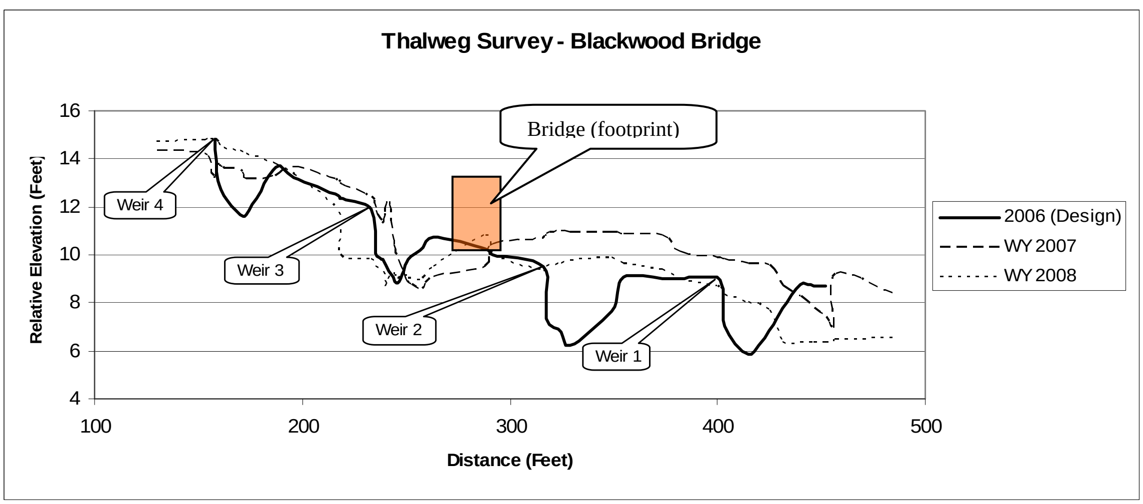

Figure 6. Thalweg profile of channel at Barker Pass Road crossing

Upstream of the constructed channel, photo point #3 (2007-2008) in Appendix A illustrates that the thalweg appears to be shifting laterally as it adjusts to the new conditions. These types of shifts will occur as the system begins to equilibrate.

Though no formal surveys of fish passage performance were conducted, visual observations suggest that the new step pools are providing some resting habitat for large lake run fish. In the spring of 2004, we observed several large rainbow trout (estimated 2-5 lbs) resting in the step pools as well as spawning in the channel just upstream of weir 4 at the fish ladder site. The size of these fish suggests that they are resident fish of Lake Tahoe that migrated up channel to spawn that spring. From 2004 thru 2007, resting habitat remains adequate; however, the pools are filling in from sediment deposition. No fish were observed in the new channel at the bridge crossing site during the period of observation.

<u>Goal 2: Promote recovery of stream bank and floodplain riparian vegetation.</u>

Phase 1- Fish Ladder
The photo points at the fish ladder site presented in Appendix A illustrate that virtually no desired riparian species have colonized on stream banks or adjacent floodplain benches during the period of observations at either the fish ladder or bridge crossing restoration sites. There are three reasons for this response. First, the substrate left in the channel after construction was very coarse, with minimal water holding capacity for riparian plants to establish roots. Second, the flood protection berm along the left bank , left in place to prevent out flanking and head cut erosion**,** is likely funneling higher flows through at a rate that is prohibiting the desired fine (2mm and finer) sediment deposition needed for riparian plant colonization. Third, the ground water gradient is steep and so water drains out easily, lowering the local ground water table early in the growing season. All these factors create conditions that do not support riparian plant colonization.

Phase II-Bridge Crossing
Flows in 2007 and 2008 were not sufficiently high for depositing floodplain sediment or to supply enough ground water for a period sufficient to promote vegetation colonization on the stream banks or floodplain. Unlike the fish ladder site, conditions at the bridge crossing site are expected to improve when higher water years are experienced because this site contains a larger floodplain area that will help spread and reduce the velocity of higher flows.

IV. CONCLUSIONS AND RECOMENDATIONS

The two goals of these projects were 1) removal of in-stream structures and creation of a stable step/pool channel form that evolves over time to a riffle/pool channel form, and 2) promotion of the establishment of riparian vegetation on channel banks and adjacent floodplains. At the fish ladder, longitudinal profile surveys and photos show that after early adjustments, the channel is now vertically stable. Photos show that the cross-sectional shape is also stable but will likely continue to experience minor adjustments. Sediment deposition from upstream transport suggests that the trend from step-pool toward alternate bar formation (the first stage of riffle/pool channel forms) may have started. At the bridge, thalweg profile and cross-section stability are trending similar to what is occurring at the fish ladder; alternate bar formation downstream of the bridge and sediment deposition from upstream are signs of desired channel evolution to a riffle/pool channel form.

In terms of fish passage performance, sediment deposition has caused a transformation of pools to high gradient riffles below weirs 3 and 4 four at the fish ladder, which may have reduced pool habitat temporarily. However, the channel bed in these areas is very coarse and there are large boulders that fish can still hide behind, so fish passage performance overall is likely to be adequate. In terms of fish passage in the channel at the Barker Pass Road crossing, no conclusions can be drawn; however, pool and riffle habitat is forming. The site should be observed in the future during spring snowmelt and evaluated for fish passage performance.

In terms of lateral stability, the flood plain benches and berm at the fish ladder survived a 20-25 year flood in 2006 with no significant scour or outflanking. It is, however, too early to tell whether or not lateral stability could be maintained during a larger (50-100 year) flood event. We can draw no conclusions regarding lateral stability for the channel and floodplain at the Barker Pass Road crossing because no high flows have occurred since construction.

In terms of vegetation colonization, the fish ladder site is underperforming because the new constructed channel does not have a large enough floodplain to allow flows to spread and reduce velocities, which would result in sediment deposition. At the bridge site, it is too early to evaluate trends given the below-average flow conditions in 2007 and 2008. Because of the larger floodplain area present at the bridge site, conditions are expected to improve once higher flows occur.

Fish Ladder Redesign (Blackwood Phase IIIB)

The observations of insufficient floodplain function and lack of sediment deposition post-removal of the fish ladder were factors that led to a Blackwood Creek Phase IIIB redesign, scheduled for construction in 2010. While the photos and thalweg profile surveys do show that the step/pool design is maintaining grade and form, the current configuration does not adequately promote depositional or hydro-geologic conditions to meet project goals.

The Phase IIIB redesign of this site includes removing the left bank flood berm and extending the grade control weirs cross-valley so that the channel will be free to adjust laterally or form flood and side channels**.** This new configuration is more reminiscent of a pre-disturbance condition, where channel position shifts are part of the natural process of valley-stream evolution typical of glacial / alluvial fan environments. Removal of the flood berm would allow flood flows to spread out laterally, reducing flood flow velocities; these conditions would encourage deposition of finer grain sediment as well as the storage and burial of coarse woody debris. The Phase IIIB redesign will increase functional floodplain area, promoting better conditions for riparian vegetation colonization, and increase the rate at which this channel reach will evolve to the desired riffle/pool channel form.

Blackwood Creek TMDL Targets

The Blackwood Creek TMDL was developed to document the recovery of certain stream and floodplain geomorphic components, which are indirect measures of a reduction in fine sediment (particles 2mm and finer) delivered to Lake Tahoe. This TMDL was designed so that trends in ecosystem recovery and reductions in fine sediment loading could be tracked simultaneously. The long-term TMDL targets for Blackwood Creek are that:

1. 80% of stream banks are vegetated and stable
2. 50% of active floodplain areas are colonized with riparian vegetation
3. sinuosity has increased so that it is at or near a pre-disturbance level

Phases I and II of the Blackwood Creek Restoration plan were specifically designed to function as stable sediment transport reaches (step-pool channels), expected to evolve into sediment storage areas (pool-riffle channels), characterized by higher sinuosity, over the long term. This may take 20 years to achieve, given that large floods need to occur in order to achieve the desired state.

At the fish ladder site, five years of observations suggest the channel continues to function as a stable transport reach with some signs (in-filling and channel bar formation at the upper end of the project) of the system evolving into its desired form. The stream banks, thalweg profile, and narrow floodplain benches are stable. However, the lack of riparian plant colonization suggests that the flow environment is too energetic to encourage fine sediment deposition on the banks and benches. The redesign of this reach as part of Blackwood Phase IIIB, will reduce flow forces and encourage riparian plant colonization. This would then set up a positive feedback loop in that increased riparian vegetation encourages fine sediment storage leading to thalweg profile adjustments necessary to evolve back into the desired form with increased sinuosity.

At the bridge site, two years of observations suggest that this site may be on a faster evolutionary trajectory. The quick formation of alternate bars at the downstream end, with in-filling starting to occur at the uppermost end, is suggestive of the desired transformation. Increases in riparian vegetation were not expected at this site during the short time since construction, given the lack of adequate water supply needed for plants to become established.

APPENDIX A – PHOTO POINTS

PHASE I –Fish Ladder Removal

Photo Series at Photo Point #1. Photo taken on right bank looking down stream at grade control weirs #1 & #2. Compass Bearing (15^0 declination in the Tahoe Basin): 5^0

September 2003

June 2004

July 2006

August 2007

PHASE I –Fish Ladder Removal

Photo Series at Photo Point #4. Photo taken on right bank looking downstream at grade control weirs #3 & #4. Compass Bearing (15^0 declination in the Tahoe Basin): 29^0

September 2003

June 2004

July 2006

June 2007

PHASE II- Bridge Removal

Photo Series at Photo Point #4. Photo taken in center of channel, atop a large immobile boulder (no monument), upstream of project. Compass Bearing (15^0 declination in the Tahoe Basin): 55^0

August 2006

July 2007