

Kilpatrick Pond and Dam Restoration Feasibility Study - Final Report

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Prepared
By:

Gillilan Associates, Inc.
308 N. Bozeman, Bozeman, MT 59715
406.582.0660

In Association with:
Applied Geomorphology
Hoitsma Ecological
Oxbow, Inc.
DTM Consulting

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1 EXECUTIVE SUMMARY

This report details an investigation into restoration and enhancement alternatives for Kilpatrick Pond on Silver Creek. A comprehensive literature and data review was undertaken to assess historic conditions, trends and current conditions of Silver Creek on the Nature Conservancy Silver Creek Preserve and represents the bulk of this report. Our analysis of channel geomorphology necessarily extends upstream of the pond in order to identify an ideal channel template or reach. The Project Team also spent time on the project area with TNC personnel to gather additional data and observations.

Relative to likely historic and pristine conditions we believe that Silver Creek and at least some reaches of its tributaries are under-potential. The principal degradation is moderate to excessive siltation compounded by over-wide channel cross-sections and below potential riparian habitat. This degradation is manifested in non-equilibrium sediment transport (including the pond being identified as a sink for gravel), impacts to salmonid habitat including reduction in suitable spawning substrate, loss of water column depth cover, perhaps unusual winter turbidity related to aquatic macrophyte senescence and elevation of stream temperature.

While Silver Creek on the Preserve still supports a robust trout fishery, it is likely that the impairments are holding it below potential and perhaps exposing it to future declines related to a variety of negative environmental stressors. There is no current ability to compare the historic trout populations with current estimates though the ability to track future changes exists. One area of investigation that may warrant further exploration relates to the role of aquatic macrophytes in both creating and limiting habitat and whether these macrophytes are in fact increasing to a point where optimal trout habitat is being diminished both in the pond and upstream. This discussion is intrinsically woven into the synergistic relationship between the stream's sediment load, its role in vegetative establishment and sediment transport during full florescence and senescence.

The Project Team has concluded that the Kilpatrick Dam and impoundment impairs the ecological potential of Silver Creek, most significantly by disrupting natural sediment transport processes and by increasing summer water temperatures beyond background levels. Importantly, the maximum daily temperature is reached in the pond at least 6 hours before the rest of the stream, thereby affecting both the magnitude and duration of adverse temperatures. Given past examples of downstream fish kills due to high temperature and low dissolved oxygen content, we consider this to be a periodically significant impact.

Nine alternatives were developed to address identified ecological impairments ranging from full restoration measures to modest enhancement activities and no action. The alternatives were then subjected to a preliminary constraints and benefits analysis and three preferred alternatives were developed in greater

detail along with a cost:benefit analysis. While dam removal is the number one alternative from an ecological restoration perspective, it was not evaluated in detail due to the resistance of Picabo Livestock to this alternative. The next highest alternative is the modification of the dam to add a bottom release outlet structure (150 cfs capacity). The benefits of such a structure are cool water release (thermal benefits), hydraulic removal of pond sediments, improved sediment transport, improved angling by pond deepening, lowering of pond elevation to allow additional sediment removal and/or revegetation of exposed sediment. The downstream flushing of sediment would require careful consideration for the fate of the sediment such that downstream impacts are mitigated. This alternative would cost on the order of \$300,000. Cost:benefit considered to be good.

The third alternative considered is modification of the dam to lower the outlet elevation. Lowering the pond elevation would allow access to impounded sediments for mechanical removal or revegetation. Cost is anticipated to be on the order of \$65,000+. Ecological benefits of this alternative are considered to be limited. Cost:benefit considered neutral to fair.

The fourth alternative is the active/experimental revegetation of pond sediments during the non-irrigation season when pond is at low-pool stage. The cost for this type of effort is anticipated to be on the order of \$80,000/acre. The ability for the planted material to self-propagate after planting and expand coverage of the sediments is unknown. For this reason we have recommended that if this alternative is pursued that it be undertaken in a phased manner with observation of planting success and ability to self-propagate between planting years. We consider the ecological benefits of this approach to be neutral to potentially fair. The cost:benefit of this alternative is considered open to discussion.

Two additional discussions are included in this report -- one regarding an analysis of channel dimension and sediment transport capacity, and a second discussing the need for a systemic/holistic evaluation of the Silver Creek watershed trout habitat, riparian vegetation, and geomorphology. The sediment transport analysis concluded that the channel width:depth ratio of Silver Creek above and below the pond are not conducive to equilibrium sediment transport. The discussion of other management alternatives for addressing observed degradation on the Preserve suggests that TNC should also consider a more comprehensive aquatic assessment, prioritization and restoration program that encompasses the Silver Creek tributaries, mainstem and downstream of the Preserve.

2 INTRODUCTION

Gillilan Associates, Inc. and project partners Applied Geomorphology, Oxbow, Inc. and Hoitsma Ecological were hired by the Idaho chapter of The Nature Conservancy to assess historic and current channel conditions on Silver Creek and the ecological impacts of Kilpatrick Pond and dam, and make recommendations for addressing identified impacts. Over the course of the project the Project Team has interacted closely with TNC through conference calls, on-site meetings, email, and an interim report. We also undertook an extensive literature review, conducted interviews with key sources of knowledge, performed an on-site evaluation, and analyzed existing water and channel geometry data. This report summarizes the results of the investigation, beginning with a consensus statement of project goals and objectives developed in conjunction with TNC.

Defined Project Goals and Objectives

Goal : Develop conceptual alternatives and assess feasibility for restoring or enhancing natural riparian and stream habitat and processes through Kilpatrick Pond, the approximately one mile reach of Silver Creek spanning both Picabo Livestock and Nature Conservancy lands and downstream as warranted by any proposed activity on the project site.

Objectives:

- 1) Improve overall habitat diversity and ecological function which may include:
 - a. Achieving sediment transport continuity
 - b. Improving habitat connectivity
 - c. Maximizing riparian potential
 - d. Reducing thermal impacts of the dam
 - e. Improving existing fishing opportunities

- 2) Develop Cost/Benefit assessment for each considered alternative:
 - a. Provide costs and ecological benefits of selected alternatives from dam removal to no action.
 - b. Consider stakeholders needs and views and provide scientific and professional opinions supporting alternatives.

Summary of Pre-field Activities

Besides review of existing literature we began compiling data relative to the project on a GIS base map (Appendix A). A principal component of the map is a stream stationing system that provides a stream centerline distance measured from the point where Silver Creek crosses Hwy 20 (Station 0+00) so that past, current and future discussions of the area can use a common reference.

Summary of Field Activities

The Project Team met with TNC onsite January 10-12, 2007 during an unusually frigid period. Activities undertaken included:

- Visual observation of downstream reaches of Silver Creek (notably Point of Rocks and upstream).
- Observation of Stalker and Silver Creek via a canoe float from the Stalker Bridge downstream to Kilpatrick Bridge.
- Meeting with Nick Purdy of Picabo Livestock at the dam site.
- Collection of sediment samples upstream of Kilpatrick Pond.
- Observation of the TNC Stalker Creek enhancement project.
- Observation of Picabo Livestock's enhancement project downstream of the dam.
- Elevation survey of the Kilpatrick dam and ditch crest elevations.
- Meeting with TNC to vet the first series of project alternatives.

Additional Areas of Investigation

Based on observation of two stream alteration projects undertaken both above and below the project site that utilized a strategy of channel narrowing to improve channel dynamics, the Project Team concluded a general analysis of channel competence (ability to transport sediment at an equilibrium rate) would be helpful to inform future projects. This analysis will evaluate sediment transport ability relative to channel slope and cross-section and will point to a theoretical channel dimension (template).

3 PROJECT SITE HISTORY, DATA AND CONDITION

3.1. Geologic/Geomorphic Setting

Silver Creek and Kilpatrick Pond are located in Blaine County in central Idaho. The spring creek system is located in the upper Wood River Valley, which is more broadly located within what is referred to as the Bellevue Triangle (Figure 1). This topographic feature is a triangular shaped valley bounded by the Pioneer Mountains to the northeast, the Smokey Mountains to the northwest, and the Picabo Hills to the south. The uppermost part of the Bellevue triangle is near Hailey, where it is approximately 1 ½ miles wide. South of Bellevue, the valley widens to over 6 miles in an east-west direction. In this area, a series of river terraces are collectively known as Poverty Flats, where a drainage divide separates the Wood River system from that of Silver Creek. Whereas the Wood River flows to the southwest out of the Bellevue Triangle, Silver Creek flows south towards the Picabo Hills and then east past Picabo and onto the Snake River Plain (Figure 1) .

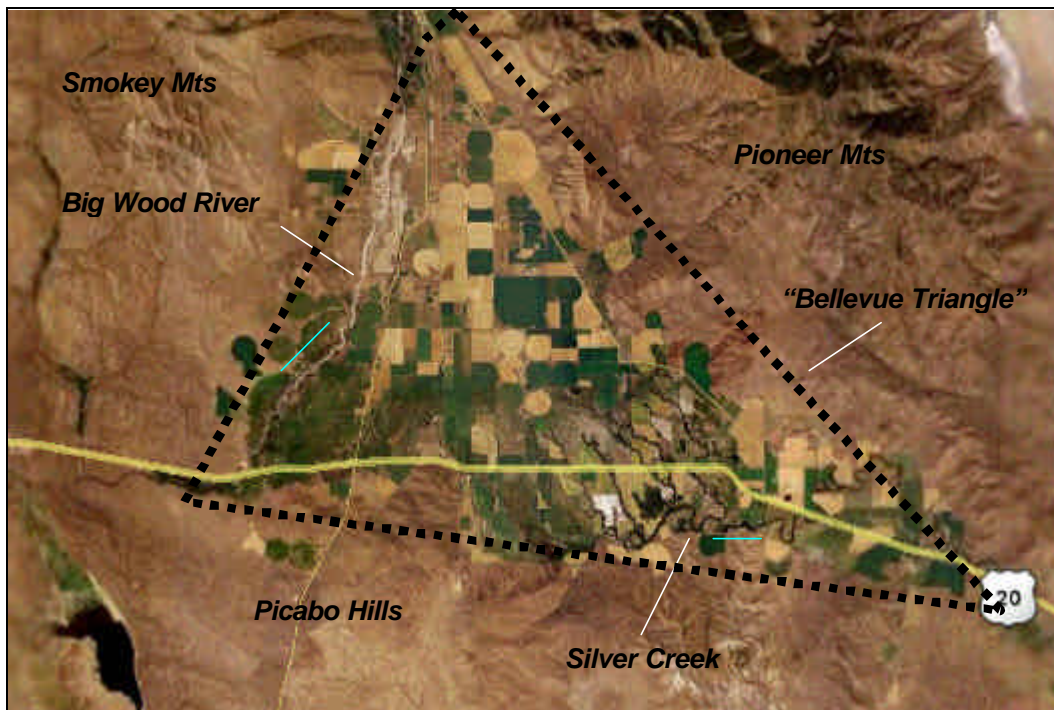


Figure 1. Satellite image of the “Bellevue Triangle”. Silver Creek spring creek system can be seen draining to southeast. Blue arrows note flow direction.

The Wood River Valley is underlain by Tertiary-age sedimentary rocks. These units were deposited by the ancestral Big Wood River, as it flowed southeastward across the valley, entering the valley through a deep canyon north of Bellevue, and exiting through the gap now occupied by Silver Creek south of Picabo. In early Pleistocene time, this gap was blocked by basalt flows which

dammed the Big Wood River. The formation of a lake over the valley floor resulted in deposition of coarse sediments in the northern portion of the valley where the river entered the lake, and finer sediments on the lake floor to the south (Moreland, 1977). When the lake filled to an elevation high enough to overtop a topographic gap on the western margin of the valley, the Big Wood River relocated to the west. This newly occupied gap was then blocked by another basalt flow, creating another lake and forcing the river back to the east. According to Moreland (1977), this process of basalt flows blocking the two exit points of the valley occurred multiple times, and each time the river deposited additional alluvium across the valley floor. Synchronous glaciation in the upper valley resulted in the delivery of large volumes of coarse sediment and runoff, further accelerating depositional rates in the area. The young, relatively permeable sediments in the valley coarsen from south to north and reach thicknesses of up to 500 feet (Moreland, 1977). These sediments are the primary source of groundwater in the area (Moreland, 1977), with the exception of the southern portion of the valley, where underlying fractured basalt flows comprise part of the aquifer system.

The geologic setting of the Bellevue Triangle is critical in understanding the geomorphology and hydrology of Silver Creek. Silver Creek is a spring fed system, and its flows are derived from groundwater that is sourced from irrigation activities, the Big Wood River aquifer, snowmelt, and precipitation. The naturally-derived water from Big Wood River recharge, snowmelt, and rainfall all provide water to the Silver Creek hydrologic system; this subsurface water generally flows southward along a topographic gradient across the Bellevue triangle towards the Picabo Hills. This groundwater is also augmented by irrigation water that is diverted eastward from the Big Wood River.

As the groundwater flows southward across the Bellevue Triangle towards the Picabo Hills, it encounters finer grained, sedimentary units that effectively drive the water to the surface. Moreland (1977) described these units as “virtually impermeable” relative to the overlying valley fill. This has resulted in the formation of a series of spring fed stream systems that typically begin to emerge about 3 miles north of the Picabo Hills, flowing southward. Near the northern flank of the Picabo Hills, the streams coalesce into Silver Creek, which flows eastward along the base of the Picabo Hills. The spring-fed tributaries that emerge from the valley floor include Stalker, Chaney, Mud, Grove, and Loving Creeks. As these streams coalesce to form Silver Creek, additional streamflow is contributed by upwelling along their courses.

3.2. [Historic Condition](#)

3.2.1. *Pre-settlement Condition*

Likely Riparian Condition

Little data is available on the historical condition of Silver Creek riparian zones though it may be reasonable to infer that a dense, and presumably beaver-dominated riparian zone existed prior to settlement. Reflecting on riparian conditions after the Oregon Trail era, a 1996 NRCS report noted significant riparian vegetation degradation and surmised that “the loss of riparian shrubs was probably a rapid event that culminated shortly after the first homesteaders and beaver trappers arrived in the area in the late 1800’s and early 1900’s.” The NRCS also noted that “some local landowners feel that there were never very many willows or other riparian plants along streams in the Silver Creek watershed. While this is possible, it is unlikely” (NRCS 1996).

Although there is a great deal of information about instream aquatic vegetation, almost no information exists about historic riparian vegetation. Fisheries population surveys have been tied to aquatic plants or channel substrate, with few links made to riparian cover.

Likely Channel Condition and Planform

The earliest description of the geomorphology of Silver Creek is from the diary of Winfield Scott Ebey, who recorded observations while traveling though on the Oregon Trail in 1854. On August 11, 1854, Ebey’s group left the Little Wood River and drove their wagons “over some low hills (Bradley Summit), to a camp on Silver Creek. Ebey noted that “This is a beautiful clear stream 25 ft wide, 2 ft deep and so full of trout that they can hardly swim”. It is not known exactly where on Silver Creek this 25 ft channel width was estimated so no inference can be made regarding historic channel top width though it is noted that today’s channel width commonly exceeds 100 ft in width.

It has been convincingly documented that agricultural land use impacts on Silver Creek have resulted in increased sediment loading, and hydrologic alteration due to changes in land cover types as well as irrigation practices. Without pre-settlement hydrologic or morphologic data, it is impossible to assess the actual geomorphic parameters of the stream for that time frame. However, the nature of these impacts typically include removal of riparian vegetation, bank erosion, channel widening, and loss of stream sinuosity.

The body of literature on channel changes due to land use is surprisingly absent with respect to low gradient spring creeks. It is also likely that there are few if any "pristine" low-gradient, broad valley spring creeks in the region that could be

utilized for functional reference points. However, our professional observation of spring creek systems in the Intermountain West suggests the following:

- In a pristine condition, (barring the effects of beaver dams), it can be assumed that channel width:depth relationships were created and maintained based on a balanced (equilibrium) sediment transport regime.
- Spring creek banks are particularly susceptible to obliteration through livestock trampling due in part to their typically fine-grained and frequently saturated soils. Repeated bank trampling leads to channel widening.
- Once widened, spring creeks display little propensity for natural process-driven re-narrowing even with a change in land management. This is largely associated with the absence of a hydrologic regime capable of significantly re-sorting in-channel sediments into lateral and point bars that become revegetated and form new channel banks.
- Once channel competence is compromised by channel over-widening, and combined with continued input of sediment into the stream, channel cross-section complexity decreases and frequently become plane bed with scour features limited to planform elements (outside bends) or in-channel roughness (roots, woody debris, emergent vegetation).

It is plausible that Silver Creek had a much narrower channel in non-beaver ponded reaches and that the current channel dimension has a wider cross section and straighter planform.

For the purposes of this project, postulated historic dimensions may not be useful in determining geomorphic restoration parameters for the channel. As the morphology of the stream is largely governed by sediment load, hydrology, vegetation, and slope, it is important to consider those parameters under current management practices. For restoration planning, appropriate channel geometry can be developed based on an assessment of existing sediment transport conditions within the preserve (Appendix B).

3.2.2. Post-settlement Changes to Project Reach

Agricultural Practices

Historic changes to Silver Creek following European settlement are considered to have degraded the geomorphic condition of the channel (Perrigo, 2006). Of primary concern is a trend of excess sedimentation in the spring creek system due to increased sediment loads and decreased transport competency.

Prior to the introduction of agriculture, the Silver Creek area was in a relatively pristine state (Perrigo,2006). With the onset of agriculture it is known that the natural vegetation was affected, and banks were destabilized due to grazing in

the riparian zones. Some riparian clearing occurred in the early 1900's in an effort to increase land area available for agriculture. The effects of these impacts would have been increased sediment loads and runoff, as well as reduced bank stability.

Manuel and others (1979) noted that land use changes that occurred around 1950 resulted in an increase in fine sediment loading to Silver Creek. Increases in fine sediment loading was likely in part due to several projects aimed at increasing drainage in the area for agricultural purposes. These projects include the Patton Drain (1952) which included channelization in the upper Stalker Creek drainage, Patterson Drain (1945), and Daly Ditch (1955), which augmented flows in Loving Creek. Manuel (1979) also referred to at least one time frame, the spring of 1974, when persistent winds during a dry spell resulted in "intolerable deposition" in Loving Creek, prompting the construction of a sediment basin upstream of the fish hatchery. This study concluded that in the late 1970's, the largest source of sediment to Silver Creek was fluvial transport from contributing tributaries. The results of that study indicated that Stalker Creek contributed 62% of the sediment in Silver Creek, whereas Grove Creek and Loving Creek contributed 23% and 15% respectively. Fairly coarse sediment (<4mm) dominated the bed on Silver Creek upstream of Sullivan Slough, but downstream, 75% of the bed material was less than 0.25 mm in diameter. Manuel measured the thickness of fine sediment accumulations and found that it ranged from 5 cm thick near Grove Creek to over 17 cm downstream of Loving Creek.

Manuel (1979) reported that where the Lower Patton Drain joined Stalker Creek, the water from the drain had much higher sediment concentrations than the creek (78 mg/l vs 22 mg/l). Furthermore, "large piles of dirt line the banks along the drain and constitute potential sources of sediment". Manuel concluded that "It is reasonable to assume that the combined effects of channelization and straightening of the stream, the network of drainage canals, and the extensive areas of exposed soil have resulted in the addition of significant amounts of silt to Stalker Creek. The hydrological regime of Stalker Creek has apparently been modified by the rapid draining of the adjacent fields, resulting in higher discharge rates, and for a brief period of time increases in the erosional and sediment carrying capacity of the stream".

Since the mid-1970's, management activities within the area have included native vegetation restoration, riparian fencing, and bioengineered bank stabilization. These efforts have improved the density of riparian vegetative cover and improved the integrity of the streambanks (Perrigo 2006). Flood irrigation practices have been replaced by sprinkler irrigation typically reduces sediment loading from fields.

Beaver Eradication

We have not yet encountered any definitive reports that document historic beaver populations on Silver Creek. However, our experience suggests that beaver in the Intermountain West inhabited virtually every perennial low gradient drainage with suitable food supplies (robust woody riparian vegetation). In its pristine condition, we assume that food supply was not an issue on Silver Creek and therefore find it highly likely that beaver played an important role in stream dynamics. The degree to which beaver may have affected the aquatic environment in Silver Creek is well illustrated in Figure 2.

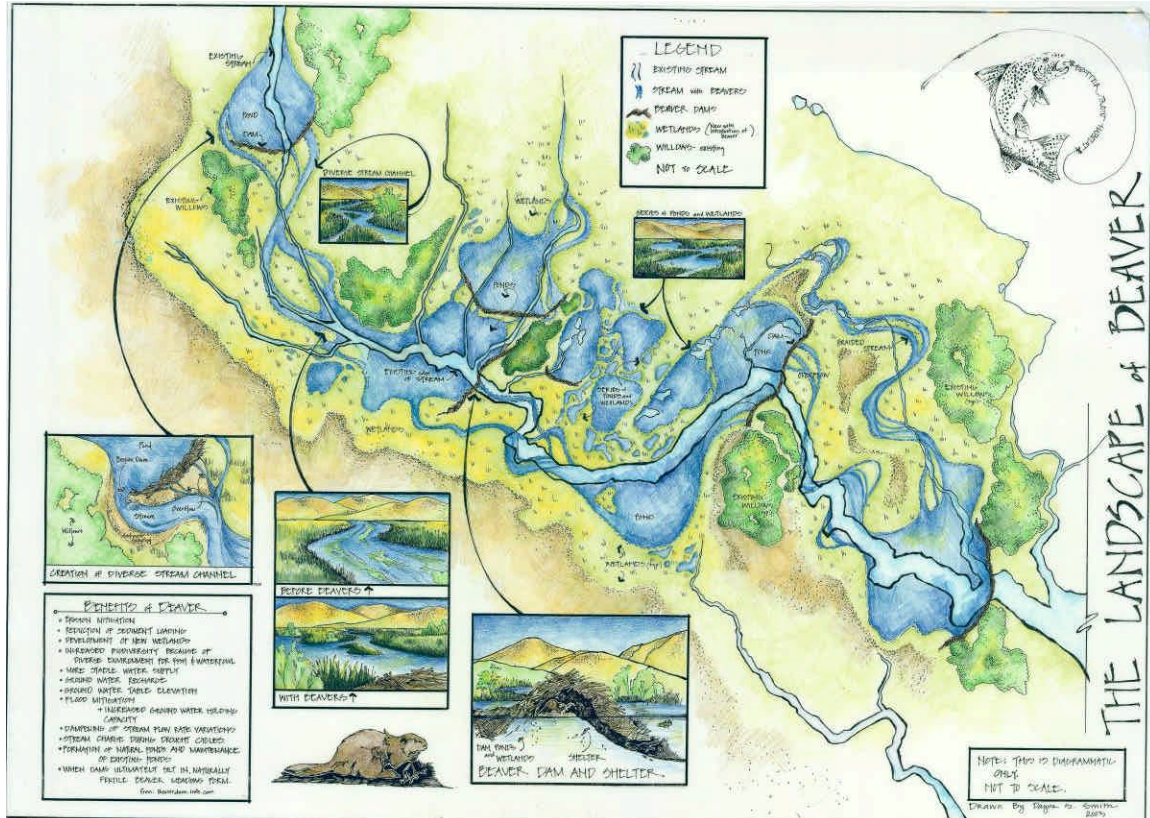


Figure 2. Possible historic influence of beaver in the Silver Creek drainage. The "current" channel is in light blue and the impounded condition represented by the darker blue. (Illustration courtesy of Dayna Smith).

Irrigation Diversion

The Purdy Dam was built in the late 1800's and constructed using railroad ties and rock. According to Nick Purdy the water right is for 40 cfs into the Kilpatrick ditch. The RR ranch also has a 10 cfs water right for a ditch on the north side of the Kilpatrick Pond.

3.3. Current Condition

3.3.1. Geomorphology

The results of the geomorphic assessment can be summarized as follows:

- Profile data indicate that Kilpatrick Pond backwatering extends upstream through the S turns during the irrigation season when the dam crest is at its maximum. This backwatering is most pronounced during high flows.
- During the irrigation off-season, the pond water surface is currently lowered approximately 2 feet. This reduces the backwatered area to below the S turns.
- From the lower Stalker Creek Bridge to Purdy Dam, Silver Creek can be divided into 4 reaches based on hydrology, channel dimensions, and channel slope.
- Existing cross section data indicate that Silver Creek is overwidened both in the pond area as well as in Reach 2, between the Loving Creek confluence and the Grove Creek confluence.
- The overwidening is coupled with shallow flow depths, resulting in anomalously high width to depth ratios at the pond and within Reach 2.
- Sediment gradations measured in Lower Stalker Creek indicate a D_{50} particle size of 11 mm to 18 mm, which is fine gravel.

The Kilpatrick Pond reach is obviously in an unnatural condition due to the dam and corresponding backwater that has created a 30-acre impounded area, with estimates of total sediment stored of 210,000 cubic yards with depths of silt ranging from 3 feet on the Preserve to up to 6 feet on Picabo Livestock (Confluence 1997). Relative to a natural condition, the channel is overwide and sediment laden (though it is noted that siltation is significant in many upstream reaches and Silver Creek tributaries and has been noted as such since at least 1947). Based on a comparison of topographic cross-sections across the pond from surveys in 1997 and 2003, which showed little net change in overall sediment storage, our preliminary assessment is that the pond has reached maximum sediment storage capacity. It is still unclear, if no changes to dam management are made, if further upstream aggradation (extension of a stored sediment wedge upstream) will occur.

The assessment of the existing geomorphic condition of Silver Creek from Purdy Dam to the Stalker Creek Bridge is based on existing survey data and flow measurements, as well as measured sediment gradations, and field observations collected by our team.

Reach Description

From Purdy Dam upstream to the Stalker Creek Bridge, the stream has been subdivided into four reaches (Table 1). The reaches are numbered to coincide with The Nature Conservancy Monitoring Cross Sections (T1, T2, and T3). The lowermost reach, referred to as “Kilpatrick Pond”, is wide and flat due to impoundment (Plate 1 and Plate 2). Just upstream, Reach 1 occupies the relatively sinuous “S-turn” section of Silver Creek. This reach is characterized by a single thread channel that is bound by very fine grained banks. The bank toe locally contains a high concentration of woody organic matter, suggesting historic beaver activity. Some recent bar deposition on the channel margin was observed within Reach 1 during the January 2007 field visit. Reach 1 appears to be at least seasonally backwatered by Kilpatrick Pond. From the Loving Creek confluence upstream to the Grove Creek confluence (Reach 2), the backwater effects of Kilpatrick Pond appear to be minimal. Within this reach, Silver Creek is moderately sinuous (1.28), and locally overwidened (Plate 4)). Extensive deposition on top of Chara beds occurred in this reach during the spring 2006 flood event (Plate 3). Upstream of Grove Creek (Reach 3), the channel is relatively small (Plate 5). This channel segment is referred to as lower Stalker Creek, however it is included in the assessment to help portray downstream trends in channel form through the preserve.

Table 1. Summary of project reach parameters, Purdy Dam to Stalker Creek Bridge.

<i>Reach</i>	<i>Length (mi)</i>	<i>Slope (ft/ft)</i>	<i>Sinuosity</i>	<i>Mean Discharge</i>		<i>Comments</i>
				2005	2006	
Kilpatrick Pond	0.68	0*	1.09	100	150	Kilpatrick Pond: Inundated channel with no measurable gradient due to extensive infilling of pond. Minor remnant sinuosity; high wetted width
Reach 1	0.32	0.0007	1.41	100	150	Upstream end of Pond to Loving Creek: "S-turn" section, with increased sinuosity and relatively narrow measured cross section.
Reach 2	1.61	0.0007	1.28	80	120	Loving Creek to Grove Creek: Moderate sinuosity, with relatively wide surveyed wetted width
Reach 3	1.25	0.0007	1.6	30	45	Grove Creek to Stalker Creek Bridge: Sinuous reach with relatively small cross section area and mean discharge.



Plate 1. View upstream of Kilpatrick Pond from Purdy dam. Dam structure is on right edge of photo.



Plate 2. View downstream of upper end of Kilpatrick Pond. Ducks are decoys.



Plate 3. View upstream of overwidened section of Reach 2, Station 231+00.



Plate 4. View downstream of recent deposition on left channel margin in Reach 2. TNC personnel described flood-driven deposition on Chara beds in spring 2006.



Plate 5. View downstream of lower Stalker Creek (Reach 3), near TNC monitoring point T3.

Profile: Channel Slope

We assessed the morphology of Silver Creek using several existing datasets that include pond surveys, TNC discharge measurements, and a series of cross sections measured by Perrigo (2006; Table 2). The generation of a profile of Silver Creek required the compilation of the cross sections listed in Table 2 as well as additional survey points taken from the Purdy dam area during our field investigation. The surveys were not tied to a common datum, and therefore required some vertical adjustment based on best professional judgment. The results are therefore approximate, however it appears that correlating the surveys with the pond water surface elevation as well as a projected bed profile provides a relatively good overall picture of site conditions. The adjustments made to each dataset are summarized in Table 3.

Table 2. Data sources utilized on cross section/profile assessment, Silver Creek.

<i>Reach</i>	<i>Location</i>	<i>Station</i>	<i>Cross Sections</i>	<i>Date</i>	<i>Data Source</i>
Kilpatrick Pond	Upstream end Pond to Dam	11800- 15400	Pond B	1997, 2004	Galena Engineering Inc (2004)
			Pond D		
			Pond F		
			Pond H		
			Pond K		
			Pond M		
			Pond P		
			Pond R		
			Pond T		
Pond V					
1	Loving Creek to Pond	15400- 17100	T3	2003, 2005, 2006	TNC Monitoring
2	Grove Creek to Loving Creek	17100- 30100	J	2006 (May)	Perrigo (2006)
			K		Perrigo (2006)
			L		Perrigo (2006)
			M		Perrigo (2006)
			N		Perrigo (2006)
			T2	2003, 2005, 2006	TNC Monitoring
3	Mud Creek to Grove Creek	30100- 32200	C	2006 (May)	Perrigo (2006)
			I		Perrigo (2006)
			T3	2003, 2005, 2006	TNC Monitoring

Table 3. Vertical correlation of survey datasets, Silver Creek

<i>Data Source</i>	<i>Datum</i>	<i>Adjustment</i>
Galena (2004) Pond Survey	Local benchmark with assumed elevation	None
Perrigo (2006)	Local "reference points" with assumed elevation	Adjusted 4.5 feet vertically to match Galena profile
This Effort	High Water Mark at pond	Surveyed high water mark adjusted to match pond elevation in Galena Survey

The constructed bed profile for Silver Creek is shown in Figure 2. This profile reflects an upstream projection of the gravel bed surveyed by Galena (2004) to match the bed profile surveyed by Perrigo (2006). The resulting bed slopes are very similar, with a slope of the gravel bed at the pond at 0.0008 and a bed slope upstream from the Perrigo (2006) data of 0.0007. Because of this consistency in slope between the two surveys, it is assumed that the vertical adjustment made to the Perrigo (2006) provides an approximately equal datum for the two surveys. The composite profile is appropriate to assess the approximate effects of altered dam crest heights on pond extent, and the calculated slope of 0.0007 is used to

assess sediment transport conditions for existing and proposed restoration scenarios (Appendix B).

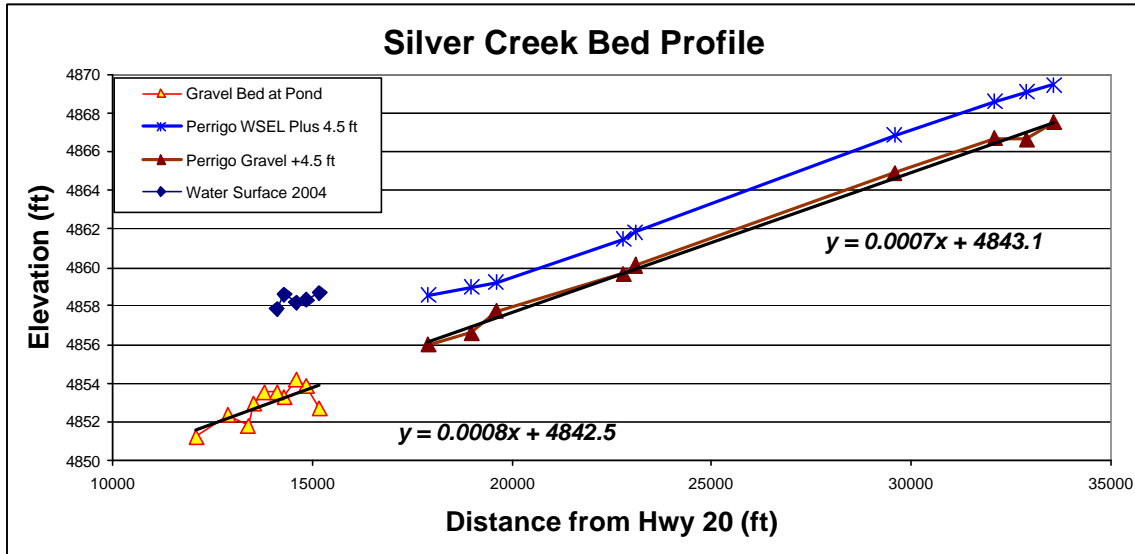


Figure 2. Constructed Silver Creek bed profile based on Galena (2004) pond survey and vertically adjusted Perrigo (2006) channel data.

The composite profile generated for Kilpatrick Pond and Silver Creek upstream allows an estimation of the extent of backwatering caused by the Purdy Dam under different dam management scenarios. The extension of the water surface elevation measured in 2004, when the pond was fully impounded indicates that the pond backwaters upstream to the vicinity of Loving Creek in an “all boards in” scenario (Figure 3).

During the field investigation of January 2007, several of the flashboards on Purdy Dam had been removed, to promote sediment flushing during the non-irrigation season. Under this scenario, the projected water surface profiles suggest that at a point of equilibrium, the pond will backwater upstream to approximately Station 155+00 (Figure 4). This coincides with the general upstream extent of the pond feature as visible on the aerial photography. However, when the boards are initially removed and sediment is exposed in the upstream portions of the pond, the pond extent will be somewhat shorter until the pond flushing results in downcutting and export of stored sediment.

It is unclear whether under current management scenarios enough sediment is flushed from the reservoir to achieve equilibrium ponding conditions upstream to Station 155+00. During the field investigation of January 2007, the boards were out of the dam, and it appeared that the majority of backwatering was below Kilpatrick Bridge. This suggests that the fine sediment flushing in the upper part of the pond is incomplete. It should be noted that even in the "boards out" condition, there is not enough channel slope/stream energy to mobilize gravels,

making the impoundment a sink for this portion of the total bedload (see Appendix B and following discussion on Substrate).

The 2006 flow measurement data from Monitoring Cross Section T1 help to identify the upstream extent of backwatering from the pond. If the measured water velocities at each site are compared seasonally, it is apparent that during irrigation season, velocities are relatively low at Cross Section T1 for a given discharge (Figure 5). This supports the contention that with the boards in, the backwatering effect extends up to near Loving Creek, and removal of the boards increases flow velocities in the S-turn area.

In the absence of the dam structure, and projection of the water surface profile to the January 2007 surveyed water surface elevation below the dam shows the complete removal of backwatering in the system (Figure 6).

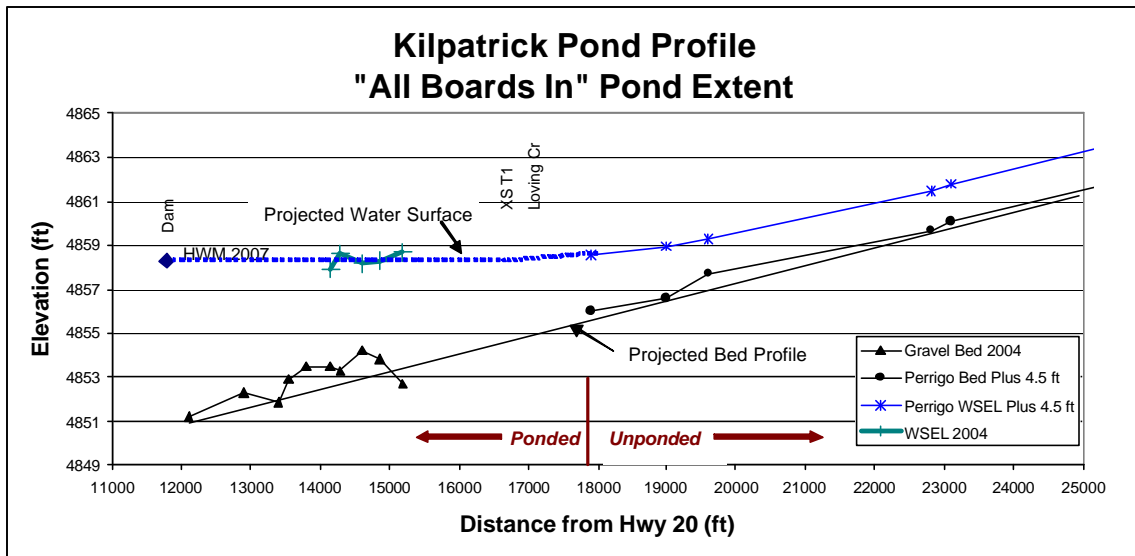


Figure 3. Projected water surface profile of Kilpatrick Pond showing backwatering to area around Loving Creek under “Boards In” scenario. “WSEL” refers to Water Surface Elevation; “HWM” is High Water Mark”.

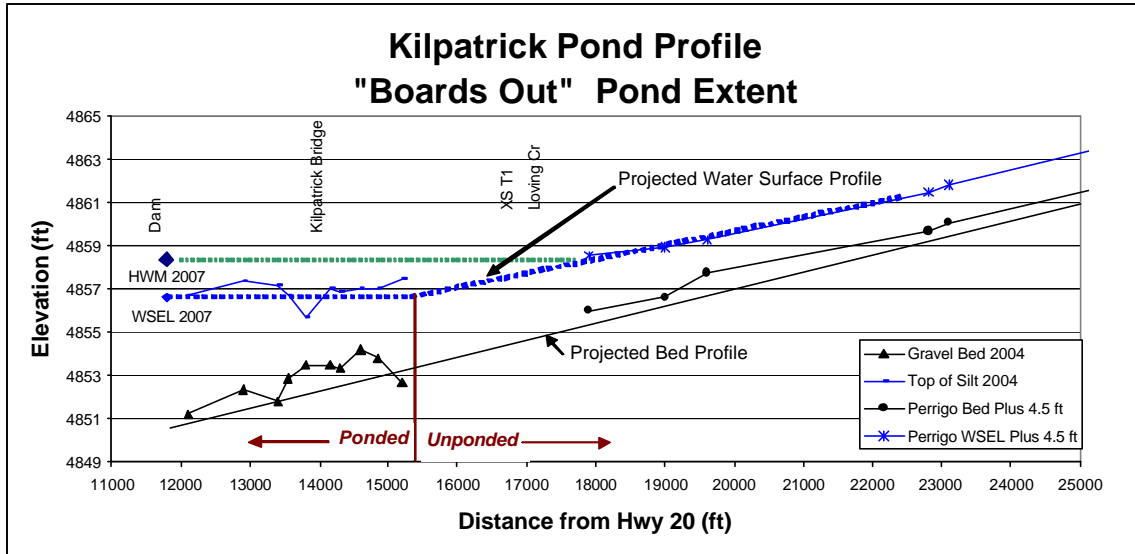


Figure 4. Projected water surface profiles of Kilpatrick Pond showing backwatering to area near Station 155+00 under current "Boards Out" scenario.

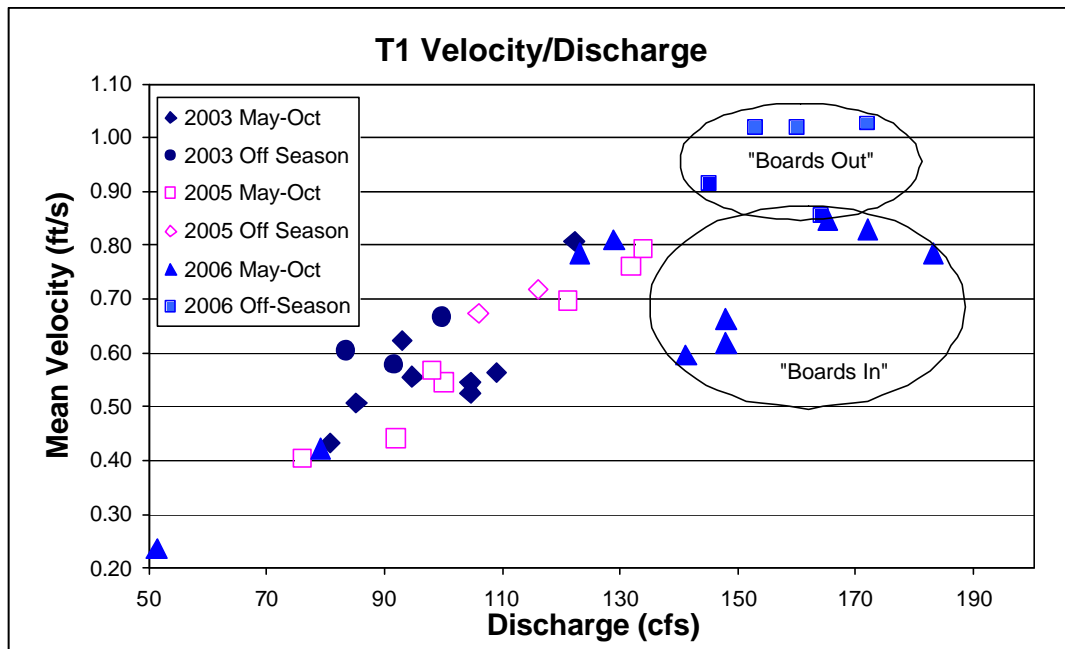


Figure 5. Comparison of discharge/velocity relationships at XS T1 showing relatively low velocities during the irrigation season of 2006 when the dam crest height is at its maximum.

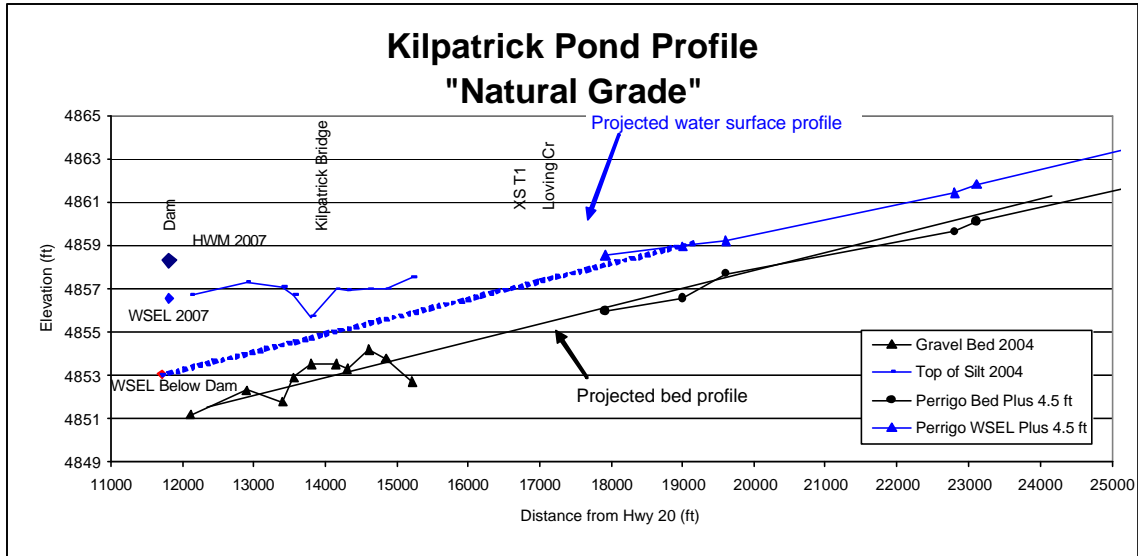


Figure 6. Projected water surface profiles of Kilpatrick Pond showing projected water surface profile in absence of dam.

Cross Section: Channel Morphology

A compilation of cross section data for Silver Creek allows a comparison of channel morphology by reach. All of the cross section measurements include documentation of the channel shape with reference to the water surface rather than the commonly-used bankfull elevation parameter. As such, the data presented here depict the range of wetted cross section measurements. However the dataset does allow a quantitative assessment of downstream trends in channel shape because of the following:

- the spring creek hydrology of Silver Creek supports relatively consistent flows through time;
- the time frame for the TNC measurements and Perrigo (2006) measurements overlap; and,
- the relatively high number of measurements (N value) document spatial and temporal variability of wetted cross section parameters (Table 4).

Table 4. Cross section data and associated N values used in morphologic assessment

<i>Data Source</i>	<i>Type of Data</i>	<i>Reach</i>	<i>N value</i>
Galena (2004)	Pond Survey	Kilpatrick Pond	8 (2004)
TNC Monitoring Point T1	Discharge Measurements	1	25 flow measurements 2005-2006
TNC Monitoring Point T2	Discharge Measurements	2	18 flow measurements 2005-2006
Perrigo (2006)	Channel Cross Section Survey	2	5 (May 2006)
TNC Monitoring Point T3	Discharge Measurements	3	19 flow measurements 2005-2006
Perrigo (2006)	Channel Cross Section Survey	3	2 (May 2006)

The range of discharges measured by TNC personnel in 2005-2006 are shown in Figure 7. These data include all seasons, and indicate a fairly low range of discharges at each site. The exception to this is a single measurement of over 450 cfs at Site T1 during the flood of April 2006.

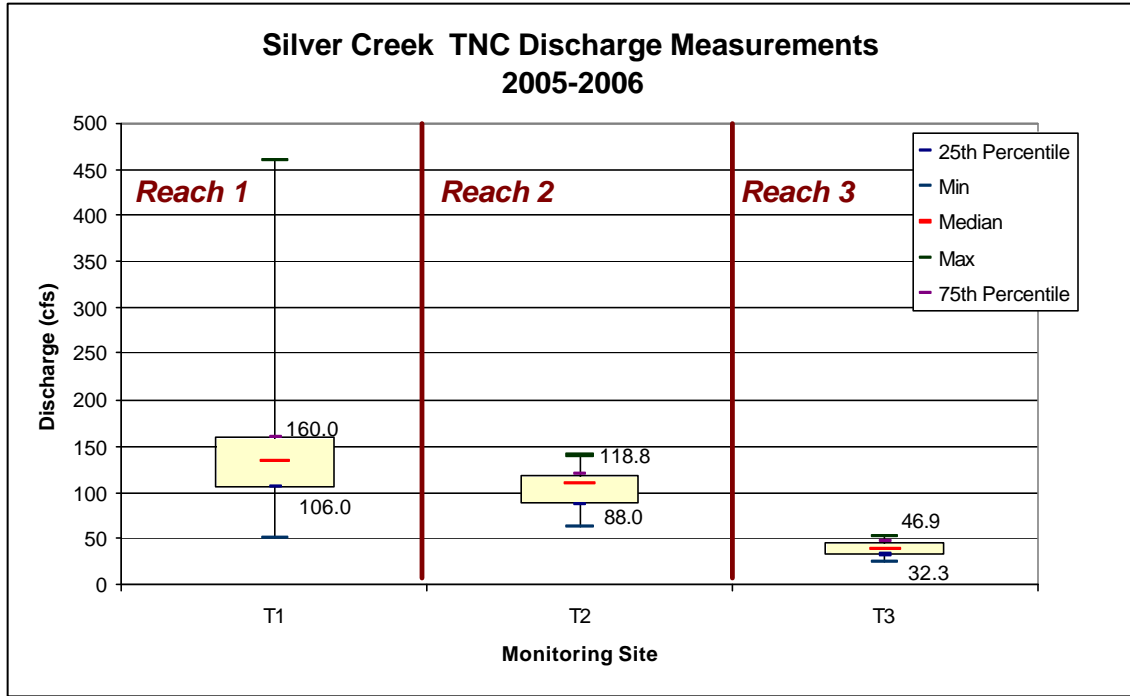


Figure 7. Box and Whisker Plot showing the range of discharges measured at TNC Monitoring Points from 2005-2006.

The variability in measured wetted widths for Kilpatrick Pond and Silver Creek is shown in Figure 8. These data show the anomalously high wetted top widths in the pond. Additionally, the five cross sections measured in Reach 2 are significantly wider than those of Monitoring Section T2, Reach 1, and Reach 3. These cross sections in Reach 2 also had relatively shallow water depths at the time of survey (Figure 9). It should be noted that for the Kilpatrick Pond cross sections, depth values reflect maximum water depth rather than mean water depth. This is because detailed pond survey data were not available to calculate mean depth. The width to depth ratios are anomalously high at Kilpatrick Pond and within Reach 2 (Figure 10).

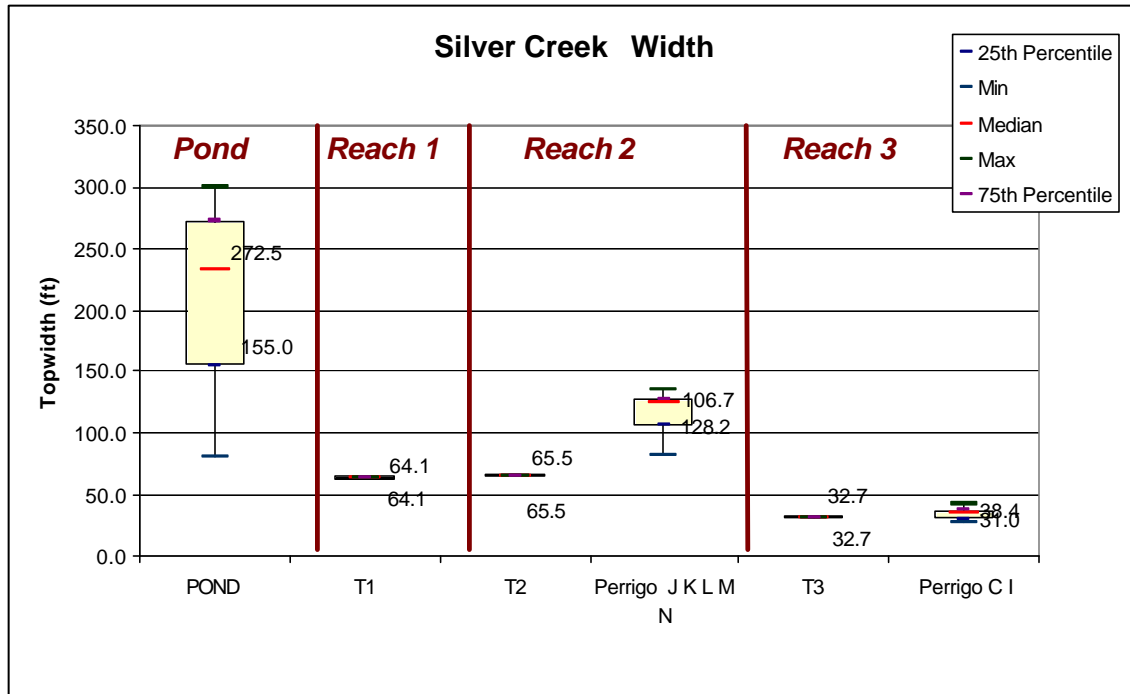


Figure 8. Measured wetted width values, Kilpatrick Pond and Silver Creek; 25th and 75th percentile values are labeled.

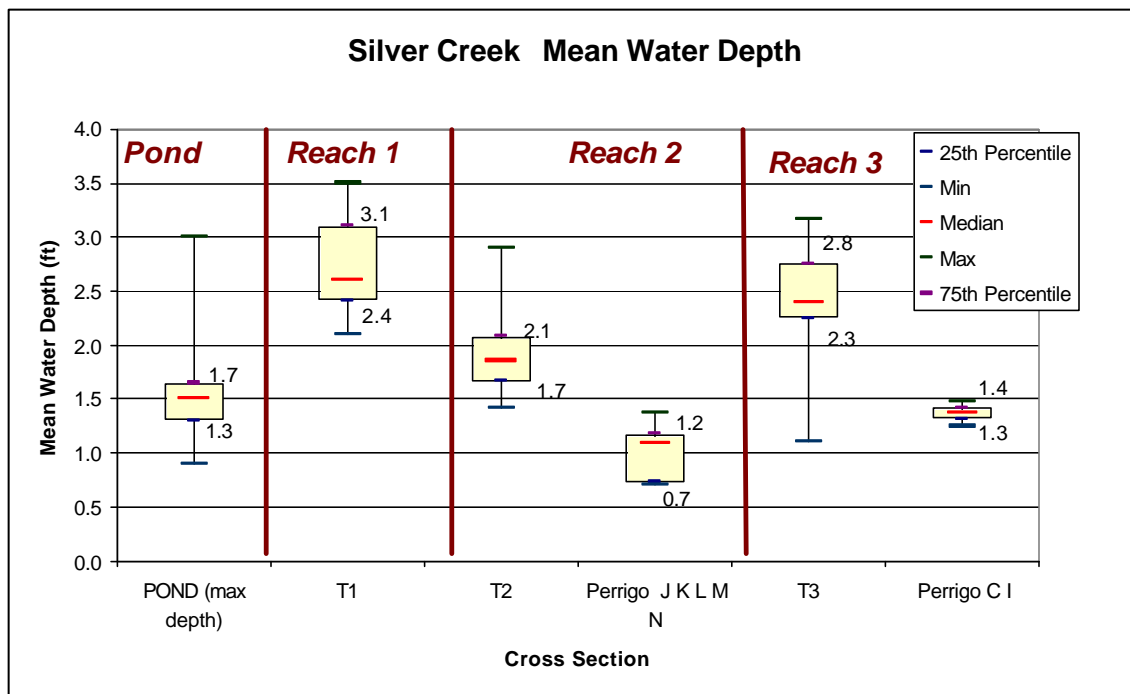


Figure 9. Mean water depth from cross section measurements ; 25th and 75th percentile values are labeled. Pond data depict maximum depth.

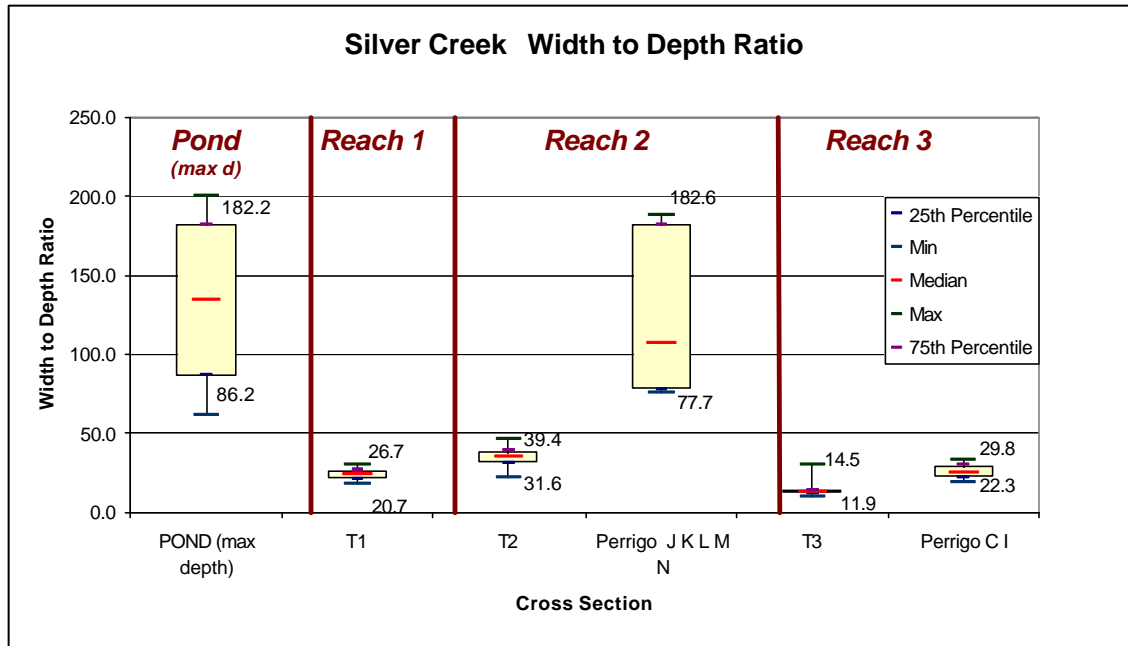


Figure 10. Measured wetted width to depth ratios, Kilpatrick Pond and Silver Creek; 25th and 75th percentile values are labeled. Pond data are based on maximum depth (versus mean depth for channel sections).

As documented by numerous investigators, (for example Hauck 1947, Perrigo 2006) the Silver Creek channel bed appears to have a relatively consistent gravel base overlaid by fine sediment accumulations. This is highly suggestive that Silver Creek once had a bed with a much greater bed surface expression of gravel with fines present but likely segregated in depositional bar forms and perhaps behind beaver dams versus the current fine deposition pattern which in many areas is universally distributed across the channel cross-section. The documented sediment accumulations indicate that the stream response to historic impacts has included a reduced capacity to transport the fine sediment delivered to the system. This reduction may be due to either an increased sediment load, a decreased transport capacity due to channel widening, or both.

The geomorphic assessment of Silver Creek morphology indicates that in Reach 2, which extends from the Loving Creek confluence upstream to the Grove Creek confluence, Silver Creek is significantly over-widened. As expected, this is also true at Kilpatrick Pond. The combination of wide channels and shallow depths in Reach 2 and the pond make these areas especially prone to thermal loading and fine sediment accumulations. Restoration scenarios for both areas should therefore consider means of reducing the width to depth ratios. Active bar deposition and channel narrowing during the April 2006 flood supports the contention that the cross section is overwidened and sediment transport capacities are insufficient to maintain channel equilibrium. The extent to which the cross sections should be narrowed is discussed in Appendix B.

Although actively reducing the width depth ratios of the overwidened sections may be appropriate, it is also important to consider the potential for natural narrowing under current land use scenarios. Perrigo (2006) compared air photos from 1951 and 2003 and found insignificant changes in planform or width during that time frame. As such, the change in management strategies since the mid-1970's has not resulted in substantial natural channel narrowing or increase in channel length. Natural channel narrowing commensurate with riparian land management is typically a slow process, as it requires sedimentation on the channel banks and progressive vegetative encroachment into the channel. In a spring creek system, the process is even slower due to the lack of high flow events that typically cause deposition on the channel margins.

Substrate

The substrate on Silver Creek consists of a predominantly gravel bed that is overlain by variable thicknesses of sand and finer material. Where gravel is exposed in the bed, it appears to be highly permeable and mobile. Three gravel samples were collected in Reach 3 during the field visit of January 2007. The sediment gradations of these three samples are shown in Figure 11. The gradations indicate a D50 particle size of 11mm to 18mm. These gradations are utilized in the sediment transport assessment of Appendix B.

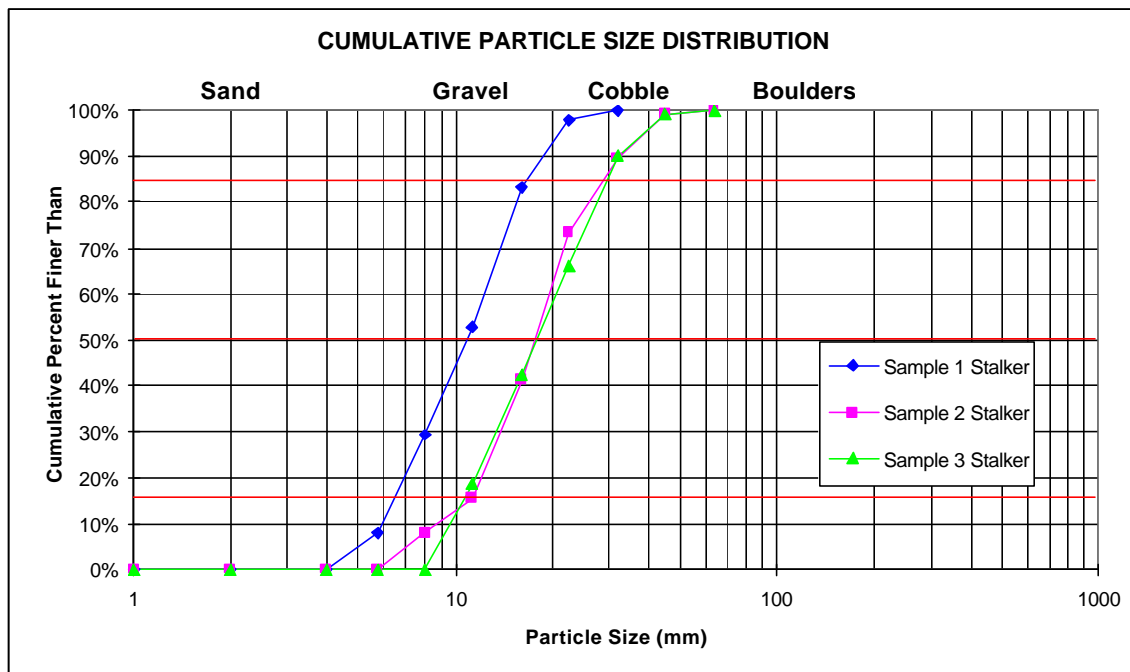


Figure 11. Pebble Count gradations for gravels collected on Lower Stalker Creek.

3.3.2. Hydrology

Existing Discharge Estimates

From 1921-1923 and 1936-1962 there was a USGS gauging station on Silver Creek located at Highway 20 one mile below Picabo. From 1963 to 1974 there were no continuous discharge measurements on Silver Creek. Since 1975, the USGS gauging station has been at Sportsman's Access (Sta 911+00). Figure 12 provides the annual peak streamflow in Silver Creek at the two different gauge sites for the period of record. It is interesting to note that the peaks at the Hwy 20 site hovered around 250 cfs, while the peak streamflow at the Sportsman's Access site has ranged from 150 to 560 cfs, with four out of the last 31 years achieving peak flows greater than 500 cfs. At this point we do not have a plausible explanation for what appears to be an increase in the annual peak discharge from 1980 forward.

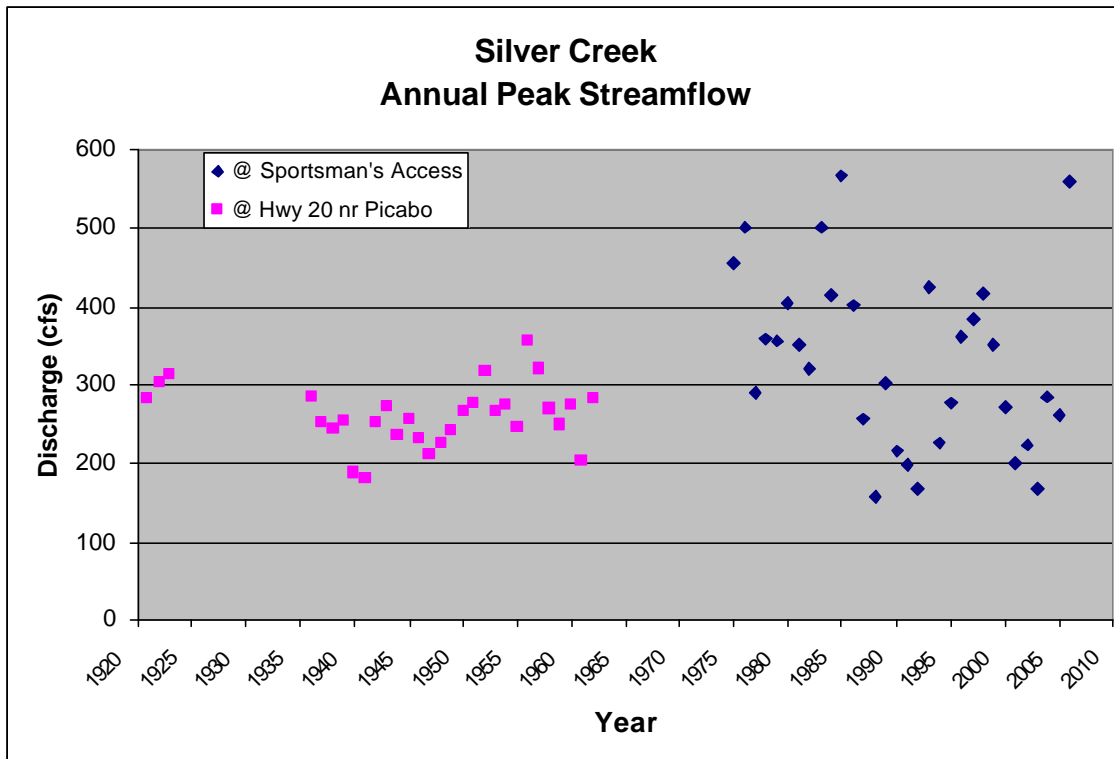


Figure 12. Peak streamflow measurements at USGS gaging sites on Silver Creek, Idaho

Maximum flow in Silver Creek generally takes place in March or April due to snowmelt and local runoff (Figure 13). Spring flows increase from August through November and then decrease from November through January or February.

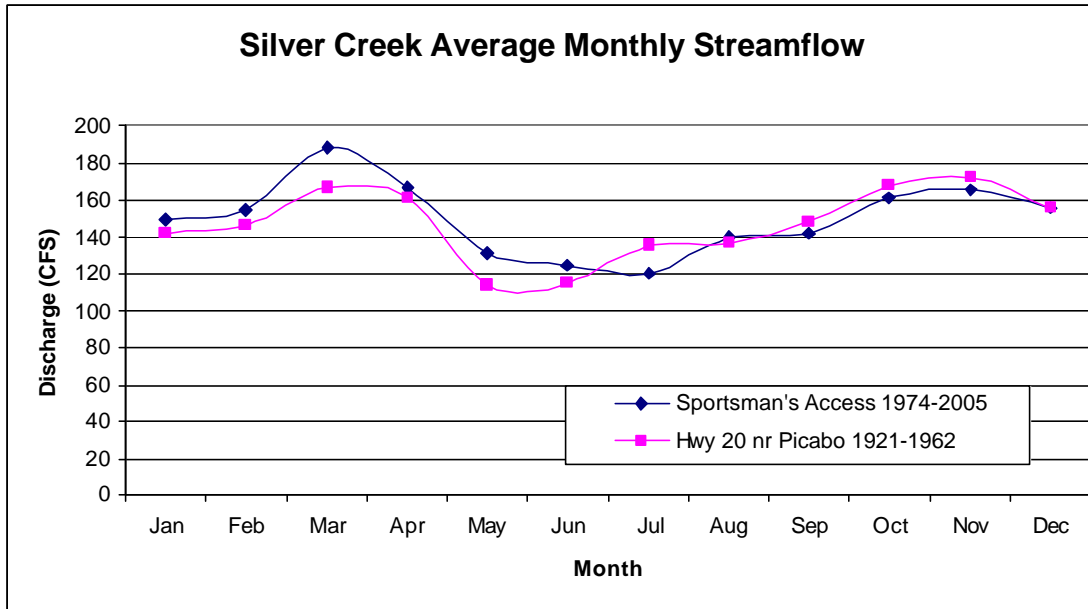


Figure 13. Monthly Mean Discharge on Silver Creek for the period of record at USGS gaging sites

Average annual flow in Silver Creek below Picabo after the 1930s was reasonably constant at about 160 cfs (Figure 14). Flow in the creek decreased markedly after 1987 and averaged below 120 cfs from 1988 through 1993 (Brockway and Kahlow 1994). Flows in the mid to late 1990's increased peaking in 1997 at 190 cfs. The period from 2001 to 2003 was another low flow period with annual discharges averaging around 110 cfs.

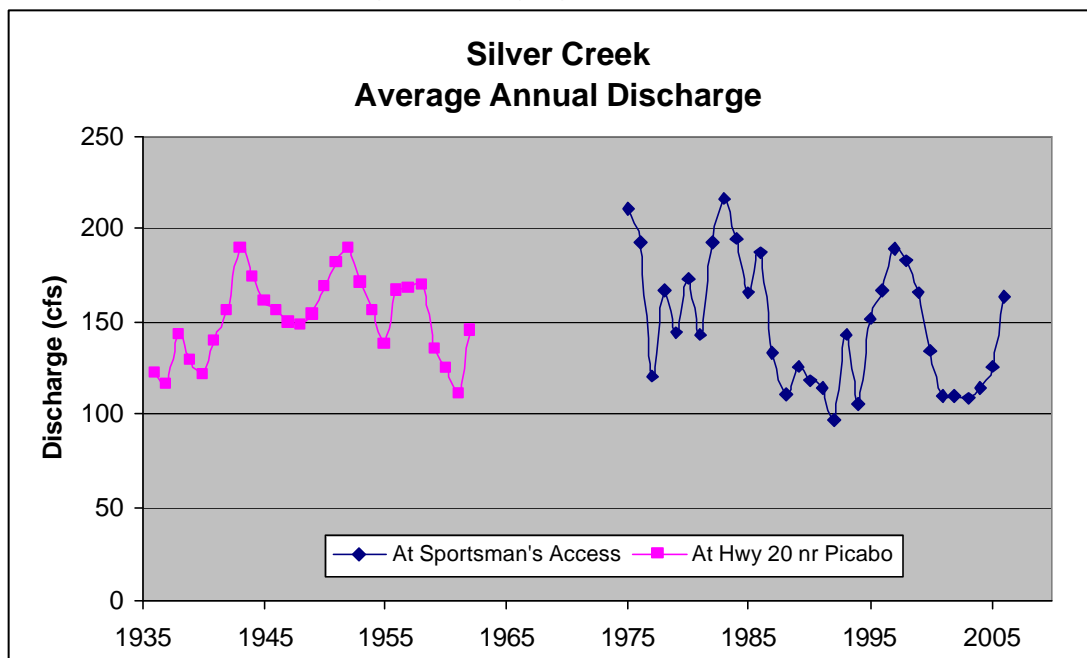


Figure 14. Average annual discharge for Silver Creek period of record at USGS gaging sites

TNC has conducted streamflow measuring at three locations on the preserve since 2001. The three sites are Transect 1 at the top of the S Turns (Sta. 170+00), Transect 2 below the visitor's Center (Sta 202+00), Transect 3 on Stalker Creek (Stalker Cr Sta 55+00 or if continue with Silver Creek stationing would be Sta. 257+00). The distance between the USGS Sportsmen's Access gage and the TNC measurements at the top of the S Turns is 3.9 mi. Between these two measuring sites, Purdy has a water rights to withdraw 59 cfs, 50 cfs above the Kilpatrick dam and 9 cfs below (Purdy, pers. Comm.).

Figure 15 shows the difference in discharge between the USGS gage and the TNC measurements at Transect 1. One would expect to see seasonal gains between the two sites during March/April when high flows occur. This was recorded in 2003 and 2006 with 2003 gains of 25-35 cfs and 2006 gains closer to 10 cfs. Losses due to irrigation withdrawals (up to 59 cfs) would be expected in the June through September period. In 2001 both gains (2-30 cfs) and losses (2 -12 cfs) were recorded. In 2003 discharge decreased in the downstream direction between 5 and 50 cfs during the irrigation season. In 2005 gains of 10 to 35 cfs were measured during the irrigation season except on July 13th when there was a 17 cfs loss. In the 2006 irrigation season, both gains (5-28 cfs) and losses (10 -35 cfs) were recorded. Reasons for the variability probably include irrigation management (turning off the irrigation during haying, increasing or decreasing irrigation in response to precipitation and temperature, or adjusting irrigation withdrawals depending on creek flows and fishery needs), dates on which measurements were taken, possible measurement error (TNC data is not verified), and precipitation events.

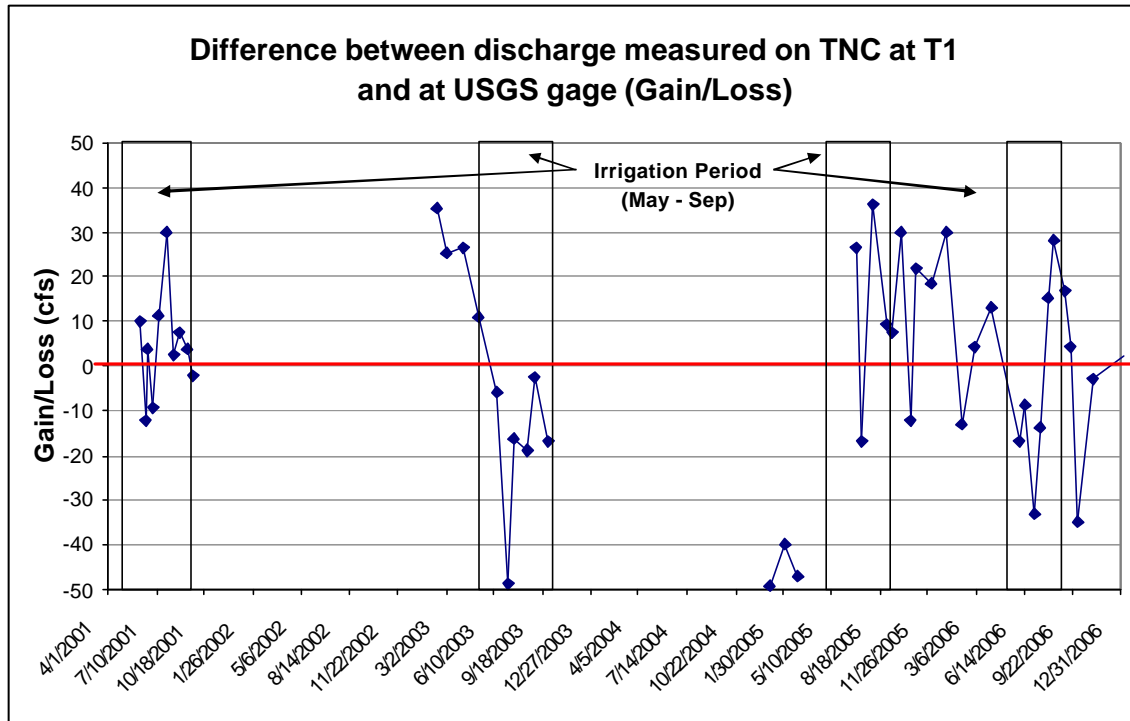


Figure 15. Difference between discharge measurements on TNC Silver Creek Preserve at Transect 1 and USGS gage. Yellow boxes denote irrigation period of May through September for 2001, 2003, 2005 and 2006.

Water Quality as Related to Project Reach

While a complete analysis of all water quality parameters related to the project is beyond the scope of this investigation we have reached some preliminary conclusions. First, the laws of physics suggest that the pond acts as a heat sink relative to sections of the creek with narrower cross-sections. As discussed in Section 3.3.3 below, identifying the total thermal gain due to the pond versus what would be the case in a naturalized condition is complicated by the fact that both warm water inflow from tributaries and cold water gain from upwelling groundwater results in a non-linear data set. Further, surface water temperatures in the pond may not reflect average temperatures in the entire water column due to stratification that may change on a seasonal or more frequent basis.

One observation made by the team related to an obvious discoloration of the stream that appeared to increase in the downstream direction from Stalker Creek to Point of Rocks. While turbidity measurements were not taken along this gradient, an ocular assessment near Point of Rocks suggested ratings approached at least 10-15 NTU's, in contrast to readings commonly below 5 NTUs in non-runoff periods. TNC's 2007 measurements of turbidity on the Preserve reached a high of 10.4 NTU's in January at monitoring section T1 (see Appendix A for map) and 7 NTU's at T2 and T1; these declined in February to 7

NTU, and 5 NTU respectively. TNC personnel and others have indicated that this is an annual phenomenon that corresponds in time with the die-back of submerged macrophytes. Theoretically, the observed turbidity could be the result of fine sediments being entrained when the previously stabilizing vegetation breaks loose. The Project Team has not observed this phenomenon in other spring creek systems and this phenomenon may be uniquely related to Silver Creek and the super-abundance of silt on the channel bed. Assessing the magnitude and duration of non-runoff season turbidity with a sampling program may help ascertain whether the winter turbidity is a "natural phenomenon" or simply an indication of overall impaired condition of Silver Creek.

3.3.3. *Stream Temperature*

The earliest reference we found regarding stream temperatures in Silver Creek noted that water temperatures increase in the downstream direction (Bell 1966). Efforts to-date to characterize summer stream temperatures in Silver Creek and the effects of the Kilpatrick pond in particular, suggest the pond is responsible for some heating beyond "background".

In 2004 TNC commissioned a Thermal Infrared (TIR) study of 14.2 miles of Silver Creek from the headwaters (where Grove and Stalker Creek join at river mile 25.9) to the Highway 20 bridge (river mile 11.6) (Watershed Sciences, 2005). The total warming measured over 14.2 miles was 5 °C (9 °F), or an average of 0.35 °C / mile (0.64 °F/mi). The study identified Kilpatrick Pond as having one of the highest gains in surface temperatures in the study area, with a maximum recorded gain of 2.7 F on August 21, 2004 (Figure 16). The pond temperature rise occurs abruptly within 0.1 mile upstream of the dam, indicating the backwatering effect of warm pond temperatures.

Over the last several years TNC has monitored temperatures along Silver Creek and some of its major tributaries by placing continuously recording temperature monitors (HOBOs) at nine locations (Figure 17). The temperature data collected by HOBO data loggers show that pond temperatures rise more quickly than stream temperatures and stay high for a longer period of time. In summer the pond achieves its daily maximum temperature by 12:30 pm and stays at the maximum until the 6:30 pm reading (Figure 18). In contrast, stream temperatures don't peak until 6:30 pm (although at a similar maximum) and then quickly drop. Thus the pond maintains warm temperatures for 6 hours in the middle of the day while the stream climbs to a maximum and then drops.

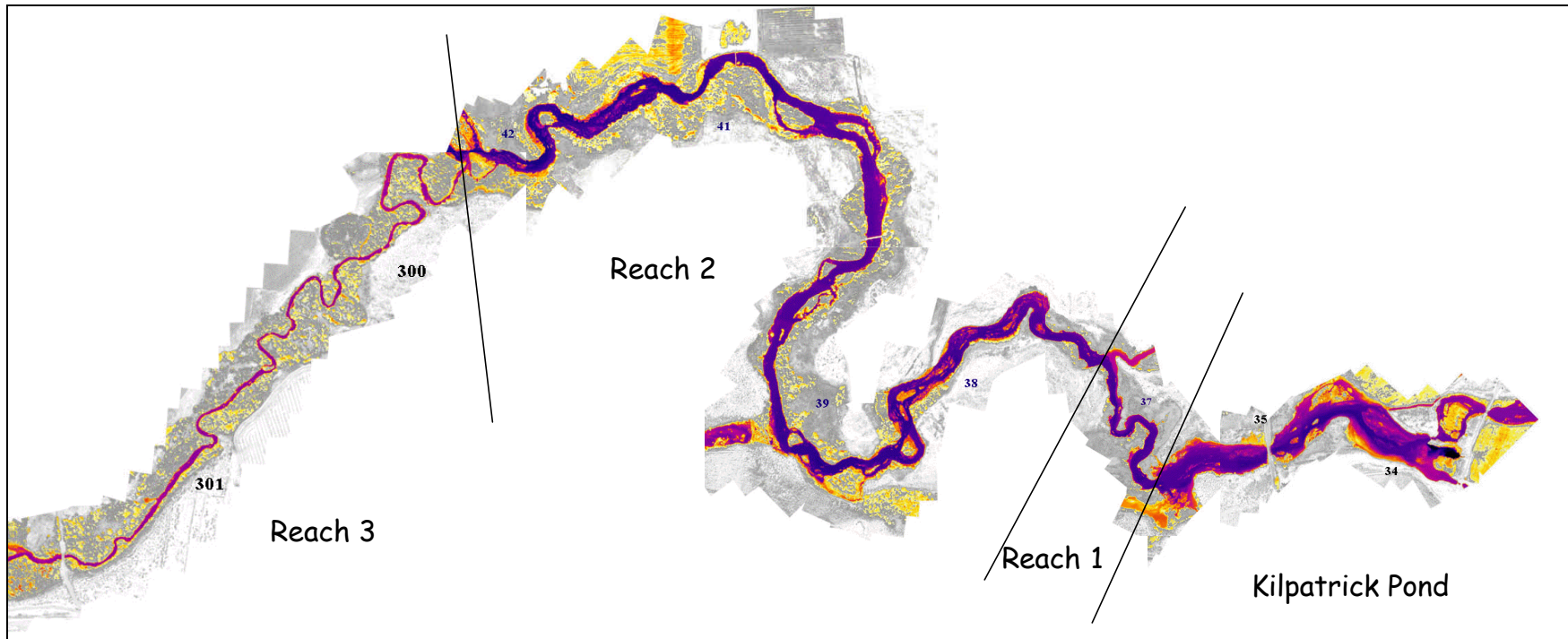


Figure 16. Composite map of TIR study area. Yellow and red represent warmer temperatures and blue/violet cooler temperatures.



Figure 17. Locations of temperature data loggers

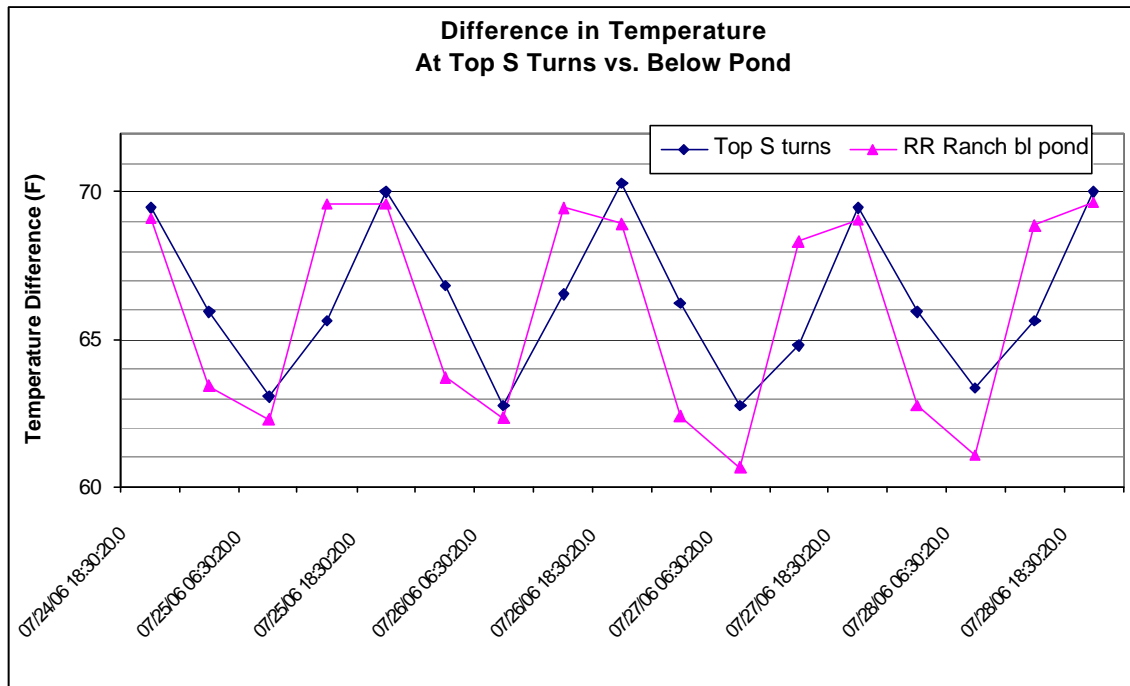


Figure 18. Temperature at the Top of the S Turns and below the Pond on 4 days in late July, 2006

Is diurnal warming in the pond higher than diurnal warming upstream?

2004 HOBO data indicates diurnal warming of 10-12 °F in the pond at Kilpatrick Bridge in July with the minimum occurring at 8 am and the maximum at 6 or 8 pm. This amount of diurnal fluctuation is not different from upstream (SC-1 Hi Silver Creek abv Loving Creek) where diurnal fluctuations of 9-13 °F were measured in July 2004. August diurnal warming is 8.5 - 9.5 °F, and September is 7-8.5 °F.

Is warming through the pond higher than warming in other reaches of Silver Creek?

The TIR study conducted on August 21, 2004 identified two areas with the greatest warming: (1) through the Kilpatrick pond (warming of 1.6 °C (2.7 °F) in 1 pm flight); and (2) Purdy section downstream of the Kilpatrick dam (warming of 1.2 °C (2.2 °F) in both 1 pm and 4:30 pm flights) (Figure 19). In the 1 pm TIR flight, temperatures at the Kilpatrick Bridge (0.3 mi upstream of the dam) were at the low point before the 2.7 °F rise. The temperature rise was very abrupt, occurring within 0.1 mi. upstream of the dam. (For best results in measuring temperature increases through the pond, data loggers should be placed at the downstream end of the pond close to the dam.) The fact that the pond did not show a rise in temperature in the 4:30 pm flight is explained by Figure 18 above. The pond achieves its maximum daily temperature by 12:30 pm and maintains it until about 6:30 pm when the creek achieves its maximum.

Both warming and cooling (due to tributary and groundwater inflow) occur along the length of Silver Creek. For example, Loving Creek’s temperature was measured 2.7 °C (4.9 °F) higher than Silver Creek above the confluence. Loving Creek has been identified as exceeding TMDLs for temperature.

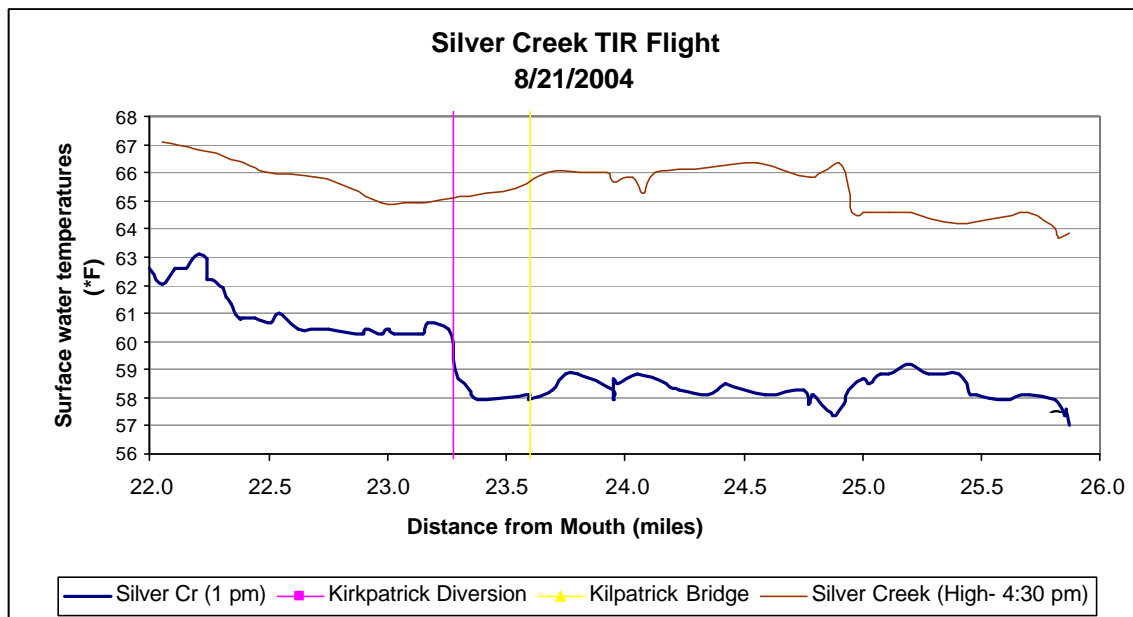


Figure 19. TIR temperatures at 1 pm and 4:30 pm August 21, 2004

To determine if more warming occurs in the pond than in other sections of Silver Creek we looked at temperature data collected on the HOBO data loggers at various locations along Silver Creek (Figure 17). By comparing the temperature at two loggers at the same time of day (within 30 minutes), we can see if the

warming through the pond is higher than elsewhere along the creek (Figure 20). This analysis proved to be inconclusive as the differences in temperatures among the tributaries created strong warming or cooling along Silver Creek not due to solar gain. For example in the most upstream section from the temperature logger at the bottom of Stalker Creek to the logger at the Visitor's Center the downstream logger was consistently 5-8 degrees F cooler than the upstream logger. This is because of the addition of the colder Grove Creek water between the loggers. Conversely there is a 5 -8 degree downstream increase in temperature between the Grove Creek HOB0 and the Visitor Center because of the input of warmer Stalker Creek water in this section. Likewise, the introduction of warmer Loving Creek water in Section 3 creates a warming of the water. None of these reflect solar gain. From the top of the S turns to the RR ranch below the pond, there is a consistent 3-6 F daily warming of the water. Some warm water enters from the slough on the south side of Silver Creek within this reach that contributes to temperature gains. However because the volume is small relative to the total volume in Silver Creek, this effect is likely minor, and the majority of the warming mostly due to solar gain.

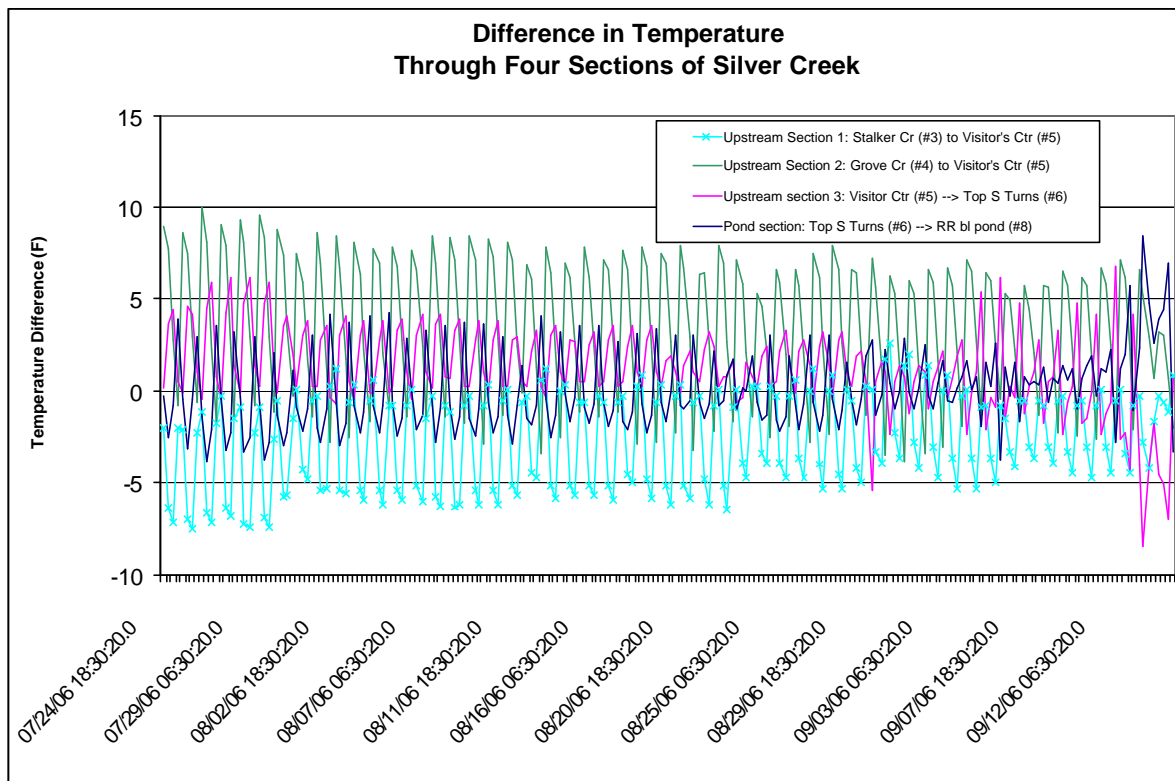


Figure 20. Temperature differences through 4 sections of Silver Creek

Are temperatures in the pond stratified (surface vs. depth)?

Two sets of data loggers were placed in the pond to record differences in temperature in the water column (one near the bottom and one near the water

surface). One pair was placed at the upstream end of the pond and one pair was placed at the Kilpatrick Bridge. Both recorded data from June 15, 2006 to July 20, 2006 when elevated temperatures occurred. Pond temperatures peaked above 73 F on July 16th and 17th. In August daily peaks were closer to 65 F. Pond temperatures were clearly stratified at the Bridge with surface temperatures up to 3 degrees F higher than bottom temperatures (Figure 21). Pond temperatures measured at the top of the pond showed only minor stratification with surface temperatures just 0.25 F higher than bottom temperatures. Since the Kilpatrick Bridge is about half way through the pond, it is likely that stratification is even more pronounced immediately upstream of the dam due to the longer residence period of water in the pond compared to the bridge (about the half way point of the pond).

This data indicates that the dam is responsible for beyond background thermal warming of Silver Creek. To further isolate the magnitude of this thermal gain, we recommend that a pair of temperature loggers be placed on the upstream side of the dam (away from the coldwater input) to measure the stratification at the downstream end of the pond.

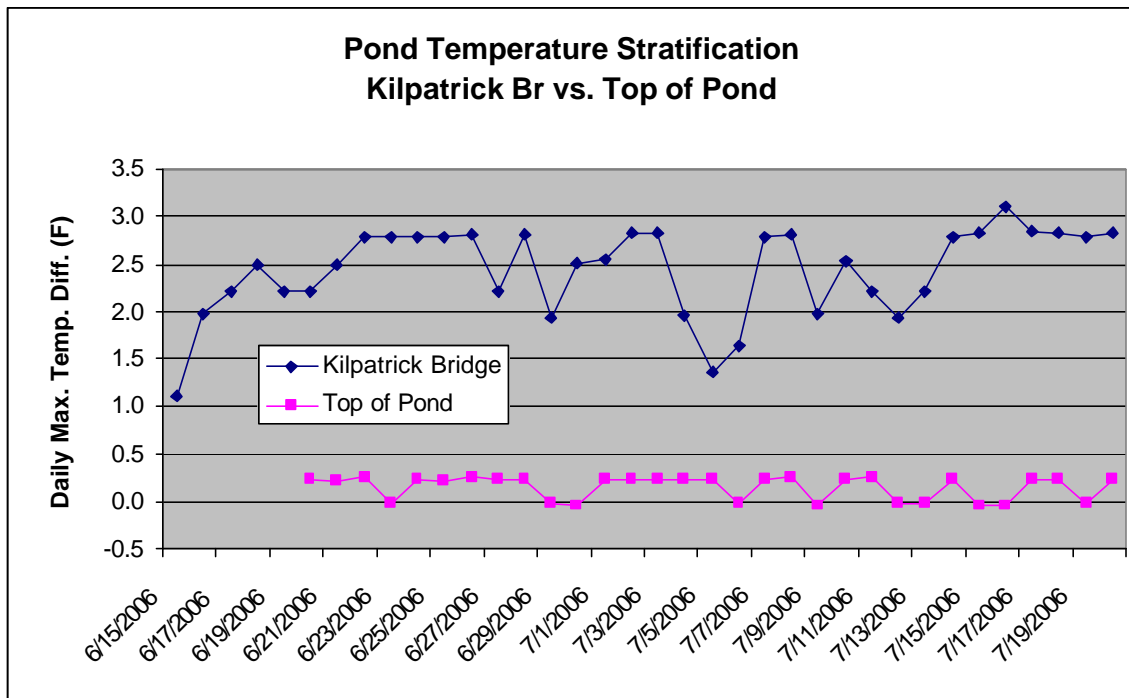


Figure 21. Temperature loggers at Kilpatrick Bridge

Is there a relationship between channel top width and thermal gain?

Thermal gain is in part related to both channel top width and water column depth in stream environments and there may be evidence of this relationship in Silver Creek. On a conceptual level, we have concluded that Silver Creek is overwide

compared to an equilibrium condition (see previous Channel Morphology - Cross Section discussion), and observation of width:depth ratios suggest a shallower water column than equilibrium. Therefore, it is reasonable to conclude that relative to an equilibrium condition the Silver Creek channel on the Preserve is more prone to experience thermal gain. This conclusion is also tentatively supported by the TIR study which showed the second largest temperature increase just downstream of the Purdy dam in what we qualitatively deem to be an overwide and shallow reach. While it is beyond the scope of this investigation, observations of downstream reaches to at least the Point of Rocks fishing access also suggest an over-widened and shallow channel cross-section. If these conclusions and observations are accurate, they suggest that thermal impairment of Silver Creek is systemic from the Preserve and well downstream.

3.3.4. Trout Fishery

Quantitative Information

Due to changes in methods for creating fish population estimates and the influences of past stocking efforts, it is not possible to make meaningful conclusions on historic or long-term trends in the Silver Creek fishery (Megargle pers. com). However, based on the electrofishing data reviewed by IDF&G over the last 6 years (at least two trout generations), there is no conclusive evidence of a decline in trout numbers in the project area. The most recent inventory (2004) in fact indicated an extremely robust brown and rainbow trout fishery. Brown trout appear to have been increasing in abundance for a number of years but not definitively so and it is open to speculation what if any effect this has had on the rainbow population. Based on rainbow redd counts conducted by TNC and combined with the electrofishing data TNC 2007 suggests that "rainbow trout are holding their own", though it is noted that the flood of 2006 may have obliterated a significant number of redds with possible future implications on rainbow trout numbers.

Whirling disease was documented in Silver Creek in 1995 though appears to be non-catastrophic and was not present in 2003-04 when tested by IDF&G (TNC 2007).

Qualitative Information on Populations

The earliest written report of the Silver Creek fishery is from 1854 when Oregon trail pioneers reported: " *This is a beautiful stream ..., & so full of Trout that they can hardly swim. We Caught as many as wanted of them.*" (Doyle and Dykes 1998). {Note that the trout observed by these pioneers were most likely redband rainbow trout, a species that is no longer present based on recent genetic testing (Clear Creek Genetics 1998)}. In 1947, Forrest Hauck, IDF&G noted that for the past 30 years Silver Creek was considered by sportsmen to be the most highly productive trout stream in the United States; (Wilkinson, 1996 documented the

highest recorded mixed-species trout biomass per mile of any stream in North America). Silver Creek has generally enjoyed a reputation as a "blue ribbon" fishery ever since despite what is generally acknowledged as degradation related to large inputs of fine sediment into the creek.

Even very healthy wild trout fisheries experience cyclical changes in population and catch rate, that result in angler concern, and Silver Creek has been no exception (Hauck 1947, Gebbards 1963, Bell 1966, Wiley 1977, TNC 2002). For example Wiley (1977) noted: *"By the early 1960's the slow decline in the heretofore unparalleled fishery on Silver Creek became more noticeable. While still a mecca for fly fisherman, it was the major tributary creeks - Stalker, Grove and Loving that provided the best fishing."*

A myriad of environmental factors in a watershed can affect recruitment and growth of trout in a single reach, much less an entire stream or river. For example, flooding or the lack thereof can greatly affect the quality of spawning habitat. Variations in catch rate can also be related to fish stocking which occurred at least as early as the late 1800's in Silver Creek with non-endemic and hatchery raised trout (Wiley 1977, TNC 2007) and fishing regulations have varied widely. For example Gebbard 1963 noted: *"Attempts to improve or sustain fishing on Silver creek by various regulations and stream improvement structures have been relatively ineffective ...and planting catchable size fish has been the only effective means to-date of artificially sustaining fishing on Silver Creek."* Hauck 1947 also refers to presence of fall spawning rainbows as evidence of surviving Hayspur Hatchery plants; TNC 2007 also suggests that McCloud River rainbow and other non-endemics have been planted in Silver Creek over the years.

Even when fish populations remain steady, the feeding behavior of trout can change daily, seasonally, and year to year based on variations in the abundance, duration and timing of nymph versus terrestrial life stages, and fishing pressure, all which in turn can affect catch rates.

According to Douglas Megargle, IDF&G (pers. com), anecdotal evidence suggests that catch rates and creel characteristics (notably size) experienced a decline 2-3 years ago (2003-04), particularly with rainbow trout. However, even during this period, many anglers reported "the best fishing ever during the same period others were complaining about poor fishing". This latter observation was also offered to the Project Team by a local fishing guide which suggests that while catch rates change year to year, they are non-uniform across the spectrum of anglers. Megargle also suggested that anglers doing better than others were fishing in "non-traditional" locations and that the aquatic macrophyte beds were forcing fish to utilize these non-traditional areas. At peak vegetative growth periods angling in the pond can be complicated both because of their effects on the distribution of fish as well as the difficulty in casting and retrievals as vegetation approaches or even extends above the water surface. If vegetation is

increasing and remains at this growth level, this angling issue may persist for some time.

Qualitative Information on Trout Habitat

To our knowledge there has not been a formal survey of fish habitat on Silver Creek to evaluate the quality of the habitat. According to IDF&G and IDEQ, there is not an existing habitat survey protocol relevant to low-gradient spring creeks. We are not aware of any in other regions or states. Until a formal survey method is developed and applied, observations on fish habitat in Silver Creek are qualitative.

Several studies have noted excess sediment in much of Silver Creek on the Preserve and downstream. Fine sediment accumulations can significantly impair spawning opportunities, and as a percentage of exposed substrate throughout Silver Creek, clean gravel appears greatly underrepresented. Wiley (1977) makes the argument that a significant period of sedimentation occurred in the early 1950's. This may be related to observations of declining angler success in the early 1960's (Gebbarde 1963, Bell 1966). Further, as noted by Griffith and Grunder 1982, fine sediments accumulated on the stream bed of Silver Creek also greatly reduce channel depth rendering the habitat unsuitable for either large trout or those reliant upon depth for cover. Further impairments related to high levels of fine sediment accumulations include: higher chemical oxygen demand, greater thermal gain, decreased diversity of macroinvertebrates and higher turbidity. The Project Team, visiting during a period of aquatic macrophyte senescence and relatively turbid conditions, noted significant amounts of sediment, shallow water column, and limited diversity of bedform and habitat type .

Silver Creek trout habitat is also unique in terms of the dramatic changes in complexity on a seasonal basis due to the presence or absence of submerged aquatic vegetation (see Section 3.3.5 Aquatic Flora and Fauna). When present (typically June through early fall) it provides abundant cover and structure, increases the depth of the water column and is related to creating localized scour channels in other wise unremarkable and non-complex channel habitat. When the vegetation reaches senescence and/or is naturally flushed from the system, in-channel habitat diversity is greatly reduced, particularly the cover component. This is true for Kilpatrick Pond and upstream and downstream reaches.

The preceding observations suggest that Silver Creek is under-potential with respect to trout populations primarily due to habitat impairments. In evaluating the overall stability of trout populations, it is important to note that system stressors can send a population into decline. Excess sediment and high temperatures increase the likelihood of a decline due to external stressors. For example, whirling disease, while not currently a problem in Silver Creek, is partially correlated with systems that have an abundance of fine sediments and

slightly elevated temperatures, as this habitat favors one phase of the infection cycle. There is also evidence that suggests full blown infections are resultant from repeated exposure to whirling disease and is therefore possible that Silver Creek is still at risk since water from the Big Wood River, a river with whirling disease, is routed into Silver Creek via irrigation diversions, providing a consistent exposure to Silver Creek trout.

Another stressor is extended drought (with consequent reductions in discharge) combined with a period of above average summer maximum daily air temperatures and abundant submerged aquatic vegetation. This combination of factors could easily result in lethal stream temperatures and depressed dissolved oxygen levels resulting in fish kills. New Zealand mudsnails also pose a risk to the long-term health of the trout fishery.

3.3.5. *Aquatic Flora and Fauna*

Macrophytes & Macroinvertebrates

Silver Creek is known for both its high densities of macroinvertebrates and macrophytes and has recorded the highest densities of aquatic macroinvertebrates in North America (Wikinson 1997) in what is likely a synergistic relationship. The populations of both of these, in terms of abundance and diversity, likely change through time.

While aquatic macrophytes play a large role in the stream ecology of the Preserve, this influence is neither steady-state nor well understood. For example, some recent observers suggest that the aquatic vegetation abundance has been steadily increasing over the last 5-6 years and has reduced the amount of available habitat for large trout. This is in contrast to an observation made in by the area biologist for Idaho Fish and Game in 1953 recommending closure of the fishery in June due to an abnormal absence of aquatic macrophytes (Irving 1953). Hauck (1947) suggested two seasonal or cyclical phenomenon related to presence or absence of aquatic vegetation: either removal of vegetation by cattle and ducks in the winter and early spring or; a period of successive years of plant build-up that results in the bed being "swept clean" by the "weight of the water". Bell 1966, Francis and Bjorn 1977 also note cyclical abundance of aquatic plants in the creek. Gebbards 1963 states succinctly: "*Seasonal abundance of vegetation may vary drastically from year to year.*" Factors that can influence these annual cycles include: nutrient supply, water temperatures, winter freezing conditions, animal foraging (currently waterfowl) and sediment dynamics.

Both aquatic plants and macroinvertebrates play an important role in nutrient cycling in aquatic systems and most certainly play a role in Kilpatrick Pond. An interesting question is whether Kilpatrick Pond is eutrofying. Conceptually, this process would be expected in any impoundment over time provided that annual accumulation of nutrients, sediment, and organics falls behind the rate of

through-put and flushing. At this stage of our investigation we can not provide a conclusion in this area but suggest it may be worth further discussion.

Submerged aquatic vegetation also plays a fairly complicated role in stream sediment transport and water quality in Sliver Creek. Thick growth of this vegetation is highly effective in immobilizing easily suspended sediment particles and its absence allows these to be entrained in the water column, even during non-runoff periods (Irving 1953), significantly increasing turbidity. This annual cycle is also noted by current stream managers.

A number of researchers (Griffith et. al 1982, Manuel-Faler 1982, others) note a close relationship between aquatic vegetation, sediment transport dynamics and channel bed conditions. Most observers suggest that sand sized and smaller particles are immobilized by thick growth but this can be mobilized during plant senescence periods. As far as bedload transport, observation also suggests that the vegetation is able to temporarily immobilize smaller sediment grain sizes (sands) that are also then made available for transport during plant senescence or absence. Numerous observers also have noted that large mats of vegetation create scour channels between them, exposing underlying gravel and providing preferred holding areas for trout, though sometimes the accumulations of vegetation are so thick that the creation of scour channels is inhibited. Besides the common observation relating to the role of the vegetation either influencing deposition or scour on the stream bed Manuel-Faler (1982) suggested that Chara may actually increase the total volume of instream sediment in the stream through the biological precipitation of calcium carbonate.

Nick Whittaker of University of Idaho (pers. com.) has been conducting macroinvertebrate sampling for the last two years at 10 sites on Silver Creek and its tributaries. His preliminary findings include:

- Utilizing the current IDEQ metric (BURP protocol) the diversity/assemblages of macroinvertebrates are Fair compared to free-stone creeks, with one site above Hwy 20 scoring as Poor.
- Using an adjusted metric that removes scoring related to macroinvertebrates normally associated with free-stone creeks and riffle habitat, the diversity scored as Good.
- Overall the tributaries of Silver Creek scored higher than Silver Creek proper.

Whittaker noted that there is not an established comparative metric for assessing macroinvertebrate populations in spring creek systems.

As for macroinvertebrates, the influence of the pond is unknown as it does not appear that macroinvertebrate sampling has occurred in the pond over a succession of years. One would expect to find macroinvertebrate populations more adapted to slower velocities, slightly elevated summer water temperatures

and silted substrates in the pond. It is plausible that aquatic macroinvertebrate populations rise and fall in relation to the density, growth stage, and shifting species composition of aquatic macrophytes, among other factors that include water temperature and water quality. That said, James and Moffit (2005) studied the non-endemic New Zealand mudsnail distribution in the Silver Creek drainage and speculated that distribution may be determined by minimum winter water temperatures, with significant populations not occurring in areas with winter temperatures below 0 degrees C. While the pond acts as a thermal sink during high summer temperatures, its high width:depth ratio also would be expected to promote colder winter temperatures, perhaps making the pond unsuitable for the mudsnails.

Existing Riparian Conditions

Existing Information

The only known riparian inventory on Silver Creek and its tributaries was conducted by the NRCS in 1996. The NRCS used 1984 color-infrared photographs to evaluate riparian cover along 65 miles of stream. Stream segments with less than 50 percent riparian shrub cover were considered inadequate, while those with more than 50% were considered adequate. The 50% cutoff value was selected because “the actual pre-settlement riparian shrub cover may never be known” (NRCS 1996). Their results, shown in Table 5 indicated a “large deficiency in riparian shrub cover when compared to other streams of similar geomorphology, climate and water regime” with only 33% of the 40 miles of tributaries to Silver Creek having adequate riparian shrub cover, and only 10% of Silver Creek from its origin to where it enters the lava flow region just southeast of Picabo having adequate cover. Changes since 1984 are not known, though TNC and other landowners have engaged in restoration activities. A follow-up to this study is recommended.

Additional Information Derived From Project

The Project Team’s observation is that Silver Creek and its tributaries are dominated by dense and diverse assemblages of riparian plant communities. The overall quality and extent of native riparian vegetation within the TNC property is quite high, and contributes greatly to the aesthetic values and habitat of Silver Creek Preserve. Riparian health can be attributed to two primary factors: first, the relatively high summer ground water tables associated with a spring-creek hydrology and extensive in-channel aquatic vegetation, and second, land management strategies over the last 30+ years that has preserved riparian vegetation. In addition, over the last 25 years The Nature Conservancy has conducted numerous riparian plantings and erosion control efforts on degraded streambanks in riparian areas.

Table 5. Extent of adequate riparian shrub cover along streams within the Silver Creek watershed (based on ocular estimate of 1984 photographs). From NRCS 1996.

Stream	Segment	Total Length (ft)	Total Length (mi)	Adequate Riparian Shrub cover (ft)*	cover (mi)	% Adequate Cover
Stalker Cr	HW to Silver Cr	26,450	5.0	2,650	0.5	10%
Patton Cr	HW to Stalker Cr	25,160	4.8	5,030	1.0	20%
Cain Cr	HW to Stalker Cr	23,570	4.5	23,660	4.5	100%
Chaney Cr	HW to Cain Cr	11,600	2.2	2,320	0.4	20%
Unnamed #1	HW to Stalker Cr	2,790	0.5	840	0.2	30%
Unnamed #2	HW to Stalker Cr	2,030	0.4	200	0.0	10%
Mud Cr	HW to Stalker Cr	30,470	5.8	9,150	1.7	30%
Wilson Cr	HW to Silver Cr	14,570	2.8	4,370	0.8	30%
Grove Cr	HW to Wilson Cr	37,520	7.1	11,200	2.1	30%
Thompson Cr	HW to Grove Cr	6,230	1.2	1,870	0.4	30%
Loving Cr	HW to Silver Cr	29,620	5.6	8,900	1.7	30%
Butte Cr	HW to Loving Cr	2,000	0.4	600	0.1	30%
		212,010	40.2	70,790	13	33%
Silver Cr	Wilson Cr to Little Wood R.					
	Origin to SE of Picabo where enters lava flow region	113,860	21.6	11,390	2.2	10%
	SE of Picabo to Little Wood River	18,780	3.6	7,510	1.4	40%
		132,640	25	18,900	3.6	14%
	Total	344,650	65.3	89,690	17	26%

An unpublished 1989 plant species inventory at Silver Creek Preserve, which includes both riparian and upland species, totaled 43 grass species, 150 herbaceous species, and over 25 woody species. A total of 46 of these species are introduced (mostly non-native or “naturalized” grasses) which includes 2 noxious weed species -- Canada thistle (*Cirsium arvense*) and tansy ragwort (*Senecio jacobaea*). Interestingly this 1989 inventory did not list reed canarygrass (*Phalarus arundicae*), a problematic invasive species. TNC 2007 suggests that reed canarygrass might have been introduced by TNC managers two decades ago.

The preserve is dominated by numerous riparian plant communities. Perhaps the most common types are riparian mixed shrub/tree types, as characterized by varying amounts of willows (*Salix exigua* and *Salix lutea*), water birch (*Betula occidentalis*), and dogwood (*Cornus stolonifera*). Riparian shrubs that occur on slightly drier sites, or in lower densities within the floodplain zone include such species as currants (*Ribes* spp.), chokecherry (*Prunus virginiana*), and Woods rose, (*Rosa woodsii*), among others. Aspen (*Populus tremuloides*) stands are prominent, and showed excellent seedling regeneration. Narrow leaf cottonwood (*Populus angustifolia*) -- while common on the nearby Big Wood River, -- is limited to scattered individuals on the preserve, and is probably less suited to the spring creek hydrology than other riparian woody species. Riparian herbaceous communities are abundant along moist, low-lying streambanks, in backwater slough areas, and on recently deposited alluvial bars. Common species in these

areas include bulrush (*Scirpus spp.*), cattail (*Typha latifolia*), sedges (*Carex aquatalis* and others), and non-native Kentucky bluegrass (*Poa pratensis*).

Despite the overall value of riparian habitat there are several negative impacts to riparian vegetation of Silver Creek worth noting. One issue is trampling due to excessive foot traffic related to fishing access from the lower bridge. The TNC is currently monitoring these areas and has successfully relocated trails and posted signs to allow for passive recovery. A larger issue affecting riparian plant communities is the expansion of an aggressive non-native grass species, reed canarygrass. This species was the focus of a 2006 report (Intermountain Aquatics 2006) and is a problematic species that must be considered and/or managed in any proposed modifications or improvements to Silver Creek. Another issue that pre-dates the acquisition of the Silver Creek by TNC is the effect of the 100-year old Purdy dam, which backwaters Silver Creek upstream of the lower bridge. Specifically, this backwater creates more than 1/4 acre of poorly vegetated silts that could otherwise support valuable streambanks vegetated with dense riparian vegetation. This issue is discussed more specifically in subsequent sections of this document.

4 ALTERNATIVES FORMULATION AND FEASIBILITY DISCUSSION

4.1. Guiding Image Discussion – Team

Our conclusion is that the impoundment on Silver Creek has created an impaired condition relative to a fully functional channel reach in the following areas:

- Discontinuity of natural sediment transport/excessive accumulation of fine sediment.
- Channel geometry on the Preserve suggests a width:depth ratio unfavorable for equilibrium sediment transport
- Kilpatrick Pond is responsible for above background gains in water temperature discharging downstream
- The natural flow of biota, particularly trout up- and down-stream of the dam is altered by the dam.
- Chemical and biological nutrient processing is altered.

The concept of a guiding image for stream alteration projects to address impaired condition suggests that Project Sponsors and Stakeholders develop a clear vision of what ecological, physical and aesthetic condition (future endpoint) is desired before alternatives are fully developed and technical feasibility investigations are undertaken.

Due to possible constraints that include stakeholder participation downstream of the Preserve we felt it appropriate to consider two separate guiding images addressing identified impairments:

Guiding Image #1. Implement a project that fully restores natural channel attributes and functionality at least equivalent to higher functioning channel reaches either upstream or downstream of the pond. Consider restoration techniques and options that may result in improvement of ecological functionality as compared to the existing higher functioning reference channel reaches.

Guiding Image #2. Implement a project on Kilpatrick Pond that results in measurable improvement in ecological functionality that includes: a reduction in the rate of thermal gain through the pond and impacts to downstream warming; improvement in sediment transport continuity; improvement to connectivity of the impounded environment with downstream reaches (more natural flow of nutrients and biota).

The full range of alternatives available to TNC can be sub-grouped into "Full Restoration" approaches for Guiding Image 1, "Enhancement" projects for Guiding Image 2, and a third category for a "No Action" decision (Table 6). Based on our research and field investigation we have developed 9 alternatives,

8 of which if implemented should result in some positive ecological gains for the Kilpatrick Pond area and/or the downstream aquatic ecosystem (see Section 4.2 Strategies Considered).

Table 6. Alternatives within the continuum of ecological restoration activities

Full Restoration	Enhancement	No Action
Dam Removal and channel restoration	Pond bypass channel Dam alteration or operations changes Removal of sediment in pond Fish passage bypass Existing sediment revegetation	

4.1.1. Persistence of Desired Future Condition

Each of the alternative groups has built-in assumptions regarding a desired future condition. For example, under a Full Restoration approach an assumption is that the new condition will function on an equal or higher level as compared to the rest of the creek in perpetuity. With the Enhancement approaches there is disparity with respect to future endpoints. For example, installing a cold water release structure in the dam may be expected to result in a permanent reduction in the exported water temperatures (not necessarily a complete mitigation of thermal gain caused by the pond), while sediment removal or manipulation options may result in improvements that persist on the timescale of decades.

4.1.2. Possible Project Constraints

In the development of conceptual alternatives to achieve the project guiding image a number of physical and cultural constraints were identified that affect one or more alternatives. These include:

1. **Resistance to Dam Removal.** Picabo Livestock Company has expressed opposition toward removal of the dam and consequent loss of the pond.
2. **Irrigation Deliveries Need to Be Maintained.** Any adopted alternative must ensure that water is delivered to two ditches that currently are gravity fed off of the pond.
3. **No Unmitigated Habitat Impacts Downstream.** All considered alternatives must demonstrate they will have no short- or long-term impacts to downstream habitat or that they can be mitigated if they occur.
4. **Permitting.** All explored alternatives will require careful and extensive permit development and agency buy-in. In particular, IDEQ's regulations regarding the creation of turbidity during channel work will pose project challenges.

5. **Cultural.** Many stakeholders are satisfied with the existing condition while others have a single restoration/enhancement alternative they deem suitable.
6. **Financial.** Most considered alternatives will likely cost from the tens to hundreds of thousands of dollars.

4.2. Strategies Considered

4.2.1. *Field Alternatives Assessment*

Prior to the fieldwork we identified 13 possible project elements and then combined and expounded upon these with TNC personnel while onsite to arrive at 9 possible alternatives (see Appendix C. Kilpatrick Pond Project Alternative Assessments). A description of each alternative, anticipated benefits, and concerns/constraints are summarized in Table 7.

The alternatives discussed in Table 7 can be grouped into 2 overall groups: Dam and Pond in-Place and Dam Removal. These are briefly discussed below:

Dam and Pond Removal. A number of alternatives address either full or partial removal of the dam. With full removal options, the fate of the sediment behind the dam, and creating a channel through that area has a number of options that range from "natural channel scour" with revegetation of exposed mud flats to more active solutions that include full channel construction with sediment removal. Water deliveries to the two downstream ditches would either be accomplished by pumping or building new delivery ditches from diversion points further upstream.

Dam Alteration (Pond In-Place). Alteration alternatives explored include the addition of a cold water outlet and lowering of the full-pool elevation.

Sediment Removal Behind Dam (Pond in-Place). Alternatives under discussion for options which leave the dam in place but remove accumulated sediments include: dredging sediments from the impoundment; utilizing conventional excavation equipment for sediment removal with a temporarily reduced water surface elevation or; by utilizing the force of the existing flows to transport sediments from the impoundment. The latter option would require either a temporary lowering of the dam spillway or altering the dam by adding a bottom release structure.

Pond Bypass Channel (Pond In-Place). This alternative explores the feasibility of building a new channel that carries some portion of the total flow around the pond.

Fish Bypass Channel (Pond In-Place). If fish passage at the dam is impaired, an alternative includes the creation of a short fish bypass channel using a small portion of the total flows.

Revegetation of Sediment Deposits (Pond In-Place). Under this scenario the pond water surface elevation would be managed such that emergent vegetation could be planted and propagated on the impounded sediment.

No Action (Pond In-Place). This is self-explanatory.

Table 7. Summary of Alternatives

Alternative	Description	Anticipated Benefits	Concerns/Constraints	Comments
<p>1 Dam Removal and Active Channel Restoration</p>	<p>Dam is removed and new channel banks constructed w/ bioengineering techniques. Floodplain actively revegetated with native riparian vegetation. Sediment in channel alignment removed. A pump system would be required to maintain irrigation diversion.</p>	<p>Increased riparian cover (long-term). Restored sediment transport. Restored fish passage. Reduced water temps. Reduced maintenance costs. Natural live water fishing experience recovered.</p>	<p>Picabo Livestock likely does not want dam removal. Management of flushed sediments must be defined. Decrease in waterfowl habitat. Initial stability of new channel. Loss of ponded fishing experience.</p>	<p>Technical feasibility needs to be addressed. Mechanical removal of sediments while impounded (extensive coffer dam systems required). Likely the most expensive.</p>
<p>2 Dam Removal and Passive Channel Restoration</p>	<p>Dam removed to restore natural grade. Channel is self-formed by flow regime (impounded sediments transported downstream). A pump system would be required to maintain irrigation diversion. Revegetation of floodplain and banks either active or passive.</p>	<p>Increased riparian cover (long-term). Restored sediment transport. Restored fish passage. Reduced water temps. Reduced maintenance costs. Natural live water fishing experience created.</p>	<p>Picabo Livestock likely does not want dam removal. Management of flushed sediments must be defined. Decrease in waterfowl habitat. Initial stability of new channel. Loss of ponded fishing experience.</p>	<p>Fate of sediments flushed downstream further addressed. Initial stability of a self-formed channel needs to be considered. Natural revegetation would likely favor canarygrass. Less expensive than Alternative 1.</p>
<p>3 Bypass Channel Around Pond</p>	<p>Pond would remain in place though a significant portion of total stream flows would be routed around pond in a newly constructed channel. Pond would have a minimum flow-through discharge necessary for irrigation and maintenance of fish habitat.</p>	<p>Increased riparian cover (long-term). Restored sediment transport. Restored fish passage. Reduced water temps. Reduced maintenance costs. Natural live water fishing experience created.</p>	<p>Quality of remaining pond fishery due to lower flowthrough rate is uncertain. Ponded area still will contribute to water temperature increases. Requires buy-in from Picabo Livestock.</p>	<p>Technical feasibility is good as construction not related to excavating in the impoundment environment. No net increase in sediment downstream. A new bridge will be needed on the new channel. Probably less expensive than Alternative 1.</p>
<p>4 Modify Dam/Add Bottom Release Outlet</p>	<p>A separate bottom release structure installed in dam (leaving historical Purdy weir in place) so that pond sediments can be periodically flushed from the impoundment and a deeper channel naturally formed. During irrigation season, some proportion of flows can be released from the bottom structure versus over the current dam weir (may reduce discharged water temperatures if stratification does occur). Also provides opportunity to manipulate pond sediments exposed at drawdown with mechanical equipment.</p>	<p>Long-term ability to regulate sediment movement downstream. Pond maintenance/ enhancement activities easier. Possible reduction in water temps. Pond angling opportunities improved.</p>	<p>Fate of downstream sediment transport needs to be addressed. No fish passage improvement. Sediment transport continuity improved but not restored. Requires buy-in from Picabo Livestock.</p>	<p>Technical feasibility initially good though analysis of the existing dam would need to be undertaken to determine whether an alternative installed without increasing chance of option would allow maximum flexibility in managing impounded pond sediments upstream, mechanical manipulation of these sediment growing surfaces (islands, pond edges). Fate of sediments flushed downstream further addressed (work with downstream landowners).</p>

Table 7. (continued)

Alternative	Description	Anticipated Benefits	Concerns/Constraints	Comments
5 Modify Dam/Lower Minimum Weir Elevation	Reconfigure existing dam weir elevation so minimum pool elevation can be reduced by 1.5 - 2.0 feet during non-irrigation season. Revegetate exposed bars.	Ability to expose more pond sediments for revegetation. Ability to periodically flush some accumulated sediment downstream. Pond angling opportunities may be improved during irrigation season.	Requires on-going maintenance as pond refills with sediment. Pond smaller and shallower degrading angling experience when lowered. No fish passage improvement. Thermal gain issue not fully addressed. Sediment transport continuity not addressed.	Technical feasibility of lowering exist clear given integrity and materials use One option would be to build another elsewhere in the dam.
6 Dredge Pond	Channels dredged through the existing pond and islands created with dredge spoils (see Confluence 1997).	Creation of more attractive angling water less affected by aquatic vegetation. Reduction in total surface area of pond and possible decrease in thermal gain. Increase in riparian vegetation area.	Thermal gain issue not fully addressed. Fish passage/aquatic connectivity not addressed. Lifespan of effort unclear. Cost/benefit unclear. Extended period of mechanical activity. Sediment transport continuity not addressed.	This alternative was comprehensively earlier report. While considered to be feasible management of dredge spoils further analysis and design. Overall impairments caused by the pond.
7 Fish Bypass Channel Near Dam	Construct a short bypass channel near the dam carrying a small portion of the total flow so that fishery connectivity is improved.	Fish passage improved.	Majority of impairments not addressed. Requires Picabo Livestock buy-in.	Technically very feasible and relative be combined with any of the alternatives leaving the dam in-place.
8 Vegetation Enhancement	Revegetate exposed bars and shallows with perennial vegetation (emergents and woodies) at lowest possible water level under current dam operations.	May decrease some thermal gain over time.	Area exposed for suitable planting may not be significant. Majority of impairments not addressed.	Lowest risk of all alternatives though are limited. Cost would be relatively to alternatives above. Competition with reedgrass needs to be addressed.
9 No Action	Maintain current dam operations and enhancement activities.	N/A	No impairments addressed.	The Silver Creek fishery is currently though likely under potential.

4.3. Preferred Alternatives

The following alternatives are ranked based on their potential to achieve the largest ecological benefits. In the spectrum of channel improvement projects, only dam removal and channel reconstruction alternatives are considered to be true restoration projects while the other projects are considered enhancement projects since they only partially address identified system impairments. The Project Team identified an additional alternative, watershed restoration, (see Appendix D), that addresses larger system impairments both above and below Kilpatrick Pond, but is not discussed here as it does not address the scope of work for this project.

4.3.1. Preferred Alternatives 1&2 - Dam Removal

Alternatives 1&2 address all identified ecological impairments and therefore have the highest potential ecological gains and would constitute true restoration projects. However, the constraints imposed by Picabo Livestock (opposed to dam removal) are considered to be significant.

Besides the concern regarding the support of the downstream landowner, other concerns that go with this alternative include: a reduction in total amount of water fowl habitat and expense, which would be significant.

Due to the unlikelihood of Picabo Livestock participating in this alternative further feasibility and cost benefit analysis was not undertaken.

4.3.2. Preferred Alternative 4 - Modification of Dam, Add Bottom Release Outlet

This alternative addresses Picabo Livestock's desire for the dam and pond to remain in-place and will provide some ecological benefits that include: reductions in water temperature delivered below the dam; improved sediment transport dynamics and; reduced area of thermal gain on revegetated sediment deposits. Additional benefits would be realized in creating conditions more beneficial for tube/float fishing in the pond.

This alternative would add a second release structure in the dam separate from the existing spillway so that both could be used either in tandem or separately, depending on desired pool management. The new structure would have an on grade bottom release structure capable of handling a minimum discharge of about 150 cfs, controlled by headgates and with an energy dissipating outlet that ultimately discharged into Silver Creek below the dam.

Under this alternative, a bottom release structure would be added to the dam that would provide:

- Cooler water released downstream during the heat of the summer;
- Ability to hydraulically remove existing sediment stored in the pond, improving angling opportunities and the sediment budget;
- Ability to significantly lower the pool elevation for access to impounded sediments for either removal using conventional excavation equipment or revegetation efforts.

The following discussion first describes the potential benefits of this alternative, then potential drawbacks or impacts of the alternative and finally a cost:benefit analysis.

Discussion of Potential Benefits

Reduction in Discharged Water Temperatures

Data reviewed in Section 3.3.3 demonstrates thermal stratification of pond temperatures during the warmest periods of approximately 2.5 degrees F (surface temperature minus subsurface temperature). (Note that this data is based on a somewhat limited number of observations and measured at the Kilpatrick Bridge. It would be expected that this degree of stratification increases in the downstream direction to the dam due to an additional 15 acres of ponded surface area available for elevated thermal gain).

Controlled Flushing of Impounded Sediments and Improved Sediment Transport

Provided the dam is operated to create ponded conditions for a significant period of every year, the dam will always be a sink for fine sediments and gravel. Current activities underway on Picabo Livestock include pond dredging/excavation and island building to create deeper water channels to improve fishing opportunities. TNC has considered this alternative as well. With an appropriately sized bottom releasing outlet (see Technical Design Elements section below), the capability would exist to remove impounded pond sediments. The removal process would effectively be achieved by releasing enough water through the bottom outlet that a headcut would be initiated in the accumulated sediments and these sediments would be discharged downstream. Based on the substrate profiles in the pond we expect that the vast majority of sediment removed in this manner would be the fine fraction sediments with only some gravel based on the energy needed to transport gravels versus the easily mobilized fines.

The fate of sediments flushed from behind the dam under this alternative needs to be carefully considered. For example, there may be advantages to either a short duration large sediment release or a gradual and long duration release, and both of these options may be optimally timed to the flow regime, such as during the annual peak discharge or alternatively during a base flow period. Both considerations relate to potential impacts to downstream stream reaches which need to be mitigated or predicted to be insignificant.

During the sediment removal period we expect scour channels to develop behind the dam to a point near the end of the pond backwater. Assuming that the scour depth will be limited to the underlying gravel layer these channels may approach 5-6 feet deep. Based on pooling following flushing, these channels would be expected to backfill through time if a periodic flushing regime was not maintained. Periodic flushing would ultimately improve the sediment balance between pond inputs and outputs.

Ability to Lower Pond Pool Elevation for Sediment Removal/Revegetation

A bottom release structure would also allow the pond pool elevation to be dropped by approximately 5-6 feet and expose impounded sediments outside the scour channels. This would provide the opportunity to either utilize conventional excavation equipment to remove sediment, build deeper channels and islands and/or revegetate pond fringes with emergent vegetation.

Potential Drawbacks/Impacts of Alternative 4

Evaluating the fate of stored sediment discharged downstream is paramount if an active flushing alternative is considered as this alternative is not considered viable if there would be significant downstream impacts.

Are Impacts Likely From A Sediment Release?

While a "first reaction" to the concept of downstream flushing is that there most certainly would be impacts, we are not convinced at this time that if there are measurable impacts that these would be long-term. Most literature regarding the release of a sediment pulse from a dam is based on complete dam removal. In such cases, it is critical to carefully develop a sediment management strategy to limit negative impacts downstream. That strategy may include dredging of pond sediment, staged removal of the dam to gradually release sediment downstream, or rapid removal followed by a relatively short-term sediment pulse.

Possible impacts of a dam sediment release include:

- Pool/run infilling and decrease in depth
- Degradation/burying of spawning gravels
- System "stress" during the highly turbid release period that could include: reduced fish foraging opportunity; increase in BOD and COD due to

entrainment and release of both nutrients and anaerobic sediments;
impacts to macroinvertebrates

One consideration relating to potential impacts is the quality of the existing habitat downstream. While only cursory on our part, our initial impression is that the downstream reaches are already over-wide and sediment laden, raising the question as to whether more sediment deposition would in fact result in net degradation of the habitat. Further, an ideal flushing scenario would be one where the sediment carrying discharge was high enough that differential sediment entrainment and settling would occur that resulted in the formation of new lateral, mid-channel and point bars in what are currently over-wide channel cross-sections. Sediments captured in bar forms may be an important mechanism for re-establishing equilibrium channel cross-sections in over-wide reaches.

Can These Potential Impacts Be Mitigated?

We have considered potential impacts and feel that there are several means to mitigate potential impacts that include:

1. Immediately following the sediment release engage in a comprehensive in-channel restoration program in affected reaches. (See Appendix D for possible techniques that would mitigate undesirable sediment deposition).
2. As part of 1), above, prior to sediment release install in-channel structure such as sod/earth barbs or other elements that encourage desirable scour and deposition patterns for the entrained sediment.
3. Active and adaptive management of the actual sediment release. Under this scenario, the downstream aquatic conditions would be real-time monitored to assess impacts to stream biota and the release of sediment metered with the control structure to stay below identified thresholds. Monitoring could include placement of sentinel fish in cages, DO, total suspended load and turbidity. (Note that short-term turbidity and suspended load is not well correlated with long-term impacts to fisheries though they would still have value in an overall threshold-monitoring plan).
4. Long duration - low intensity sediment releases. Under this scenario the sediment release program could occur over a longer time frame than a "single event" sediment release that could approach months in duration. A monitoring program could be adopted similar to that described in 3), above, with different thresholds for measured parameters.

There is also the opportunity to combine pre-release activities and post-release restoration measures with either single-event or long duration event releases.

Not listed above as a mitigative measure is the concept of a sediment trap or series of traps below the dam to limit the downstream dispersion of sediments. This is because that over the course of 20 years of performing in-channel work

that generates significant short-term turbidity and suspended loads we have found no effective method for trapping entrained sediment, though many have been tested.

Technical Design Elements

Outlet Sizing and Management and Sediment Transport

Typical patterns of reservoir accumulations suggest that the sediment closest to the dam will be fines, and coarse accumulations will be concentrated in the upstream portion of the pond. If this is the case, the initial pulse of sediment discharged from a bottom release will be primarily fine grained. As the pond sediment is naturally excavated from upstream reaches, however, increasing amounts of gravel will be delivered downstream and rates of bottom discharge will have to be reduced to prevent excessive bed aggradation downstream.

The achievement of long-term sediment continuity through the pond will be best achieved if at least seasonally, the majority of flows exit the pond through the bottom release. An evaluation of mean daily flows from the gage at Hwy 20 indicates that this will typically require releases on the order of 150 cfs (Figure 22). Preliminarily, then for the passage of the mean daily flow, an outlet sized to discharge 150 cfs would be appropriate.

Achieving gravel transport through the pond and downstream will require discharges greater than about 190 cfs, based on an analysis of critical grain size calculations for the cross section depicted in Figure 22, surveyed on the Picabo Ranch prior to restoration work. If gravel transport is desired, the sediment release could be timed with the annual peak discharge, which since 1980 exceeds 300 cfs approximately 50% of the years. One could potentially increase the size of the bottom release structure to capture larger discharges or harness both the bottom release discharge with that flowing over the existing spillway for transport of gravel released from the pond.

Managing bottom releases at the pond will require monitoring and adaptive management. In general, however, we recommend that an initial ramping occur with a goal of trapping fine sediment on the channel margins at the peak of the release, followed by gradually reduced discharges that sort sediment transported out of the pond.

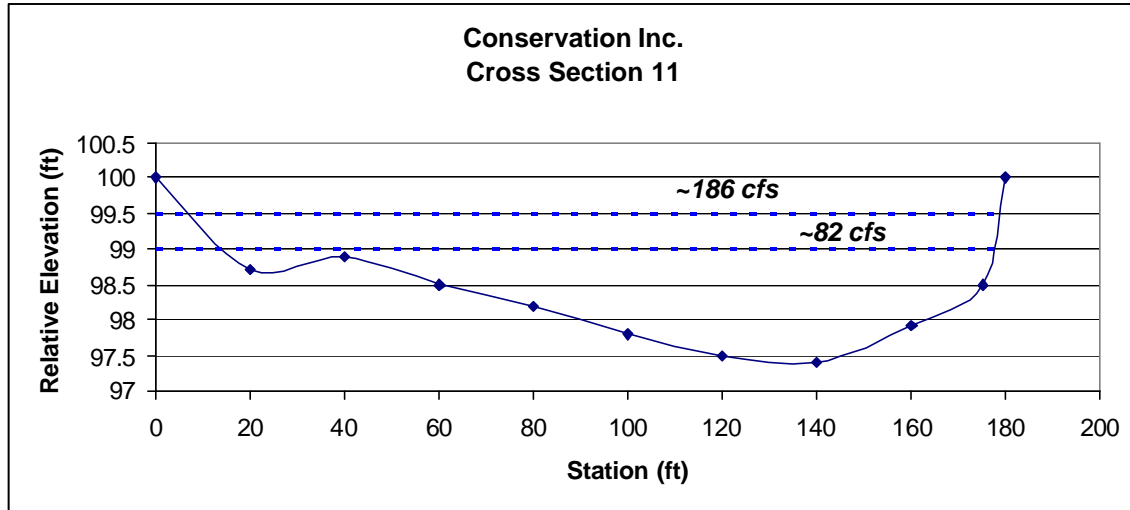


Figure 22. Estimated water depths and inundation extent at selected discharges for an overwidened cross section downstream of Kilpatrick Pond.

Outlet Design and Installation

A geotechnical evaluation will be required to assess the existing condition of the dam, integrity and composition of the dam where the new outlet would be installed, and composition of pond sediments in the vicinity of the dam. This would involve coring the dam and sediments.

Assuming the dam posed no geotechnical risks, a sheet-pile coffer dam would be required to exclude ponded water from the upstream face of the dam where the outlet was installed. This "dry" work area would require 24-hour pumping to keep the site free of saturation. The installation of the outlet works would then proceed with conventional approaches.

An energy dissipation system will likely be required for the discharge end of the outlet. The designs for these come in many forms and it is assumed that the selected design would strive for as natural and aesthetic an appearance as possible.

Potential Costs for Alternative 4

Our preliminary investigation suggests that the total cost for installing a new release structure in the dam would break down as follows:

Task 1. Geotechnical evaluation of existing dam and sediments	\$30,000
Task 2. Civil Engineering - Dam survey and outlet design	\$35,000
Task 3. Permitting, Installation and Materials	\$220,000*

Task 4. Implementation Monitoring

\$20,000**

* Assumes an outlet structure capable for 150 cfs

** Costs could be less depending on the involvement of both agency and TNC staff participation.

Note that the above cost estimate is only a preliminary estimate and the development of a more precise one could be discerned through letting of an RFP to qualified professionals.

Cost:Benefit Analysis for Alternative 4

This alternative ranks second in terms of potential for ecological improvements on the Preserve related to the pond. However, due to an absence of temperature data we cannot confidently quantify expected benefits from a bottom release structure in terms of reducing the temperature of discharged water (though it appears that up to 3 degrees F or more cooling is possible). Another benefit to the bottom release structure is the ability to improve total sediment transport rates through the pond and/or actively remove or revegetate sediments with conventional approaches. This benefit is not immediately quantifiable though qualitatively it appears to be a sound benefit.

Given the total project cost would be expected to cost at least \$300,000, we conclude that the cost:benefit of this approach is fair. If one also places a benefit on improved angling conditions in the pond through the creation of deeper water channels we consider the cost:benefit to be good.

4.3.3. Preferred Alternative 5 - Modification of Dam, Lower Minimum Outlet Elevation

With this alternative the dam's existing spillway would be modified so that the minimum pool elevation could be lowered. The benefit of lowering the minimum elevation of the spillway weir would be to access impounded sediments for either mechanical removal or revegetation of exposed sediments (see Alternative 8 below). The total control of pool elevation is envisioned to be at least 2 feet below the current "boards out" elevation.

Discussion of Potential Benefits

The principal benefit of this alternative is the ability to manipulate impounded sediments utilizing conventional excavation equipment rather than a suction dredge (which other investigations and this one have concluded that the cost versus benefits is not favorable). Added to Alternative 8, below, a significantly greater surface area of impounded sediments would be exposed if the minimum pool elevation could be lowered even an additional 2 feet.

Potential Drawbacks/Concerns with Alternative 5

While we feel that modifying the existing weir is ultimately technically feasible it will require careful engineering design so that a new weir structure can be installed while the full flow of the creek is discharging over the weir. (This is in contrast to Alternative 4 where the existing weir is fully functional while the new bottom release outlet is installed elsewhere in the dam in the "dry" utilizing sheet piling to build a coffer on the pool side of the dam). Additionally, there may be some risk of destabilizing the existing outlet structure during modification.

An additional potential concern is that lowering the pool elevation by 2 feet will also release sediment downstream (similar to Alternative 4 but with less total load discharging). However, this impact would not likely be any more than was experienced several years ago when the flashboards were removed from the dam in the post irrigation period.

Potential Costs for Alternative 5

Task 1. Geotechnical evaluation of dam outlet	\$10,000
Task 2. Civil Engineering - Survey and outlet design	\$15,000
Task 3. Permitting, Installation and Materials	\$40,000
Task 4. Implementation Monitoring	\$Unknown*

*This depends on whether sediment discharged downstream is considered a potential impact that needs to be monitored.

Cost:Benefit Analysis for Alternative 5

The ecological benefits of this alternative are unclear; it's principal benefit would be to make removal of pond sediments with conventional equipment easier and/or revegetating the exposed pond sediments. At a minimum cost of \$65,000 weighed against the anticipated benefits we consider the cost:benefit to be neutral. If angling is ultimately improved by subsequent projects to remove pond sediments this ratio is considered to be slightly better than neutral. Should revegetation of pond sediments (Alternative 8, below) provides an ecological benefit than the ratio is considered neutral to fair.

4.3.4. Preferred Alternative 8 - Active/Experimental Re-Vegetation of Pond Sediments.

Alternative 8 is likely to be the cheapest and least difficult to permit and execute and involves actively planting exposed sediment bars (or very shallow inundation areas) when the pond is in the "boards out" or low-pool stage. It can work in

concert with Alternative 4 and Alternative 6. The targeted revegetation species would be bulrush (*Scirpus spp.*) and cattail (*Typha latifolia*) due to their native status and emergent nature that allows for periodic inundation.

While we generally advocate passive restoration and revegetation when possible, the lack of naturally colonizing emergent species on the sediment bars suggests that an active approach (e.g. planting) would be required, at least initially, to provide a jump start for subsequent vegetative colonization.

However, establishment of these species might be challenging due to such factors as inundation during most of the growing season. Therefore it is best to approach this strategy experimentally by comparing different plant material types, elevational zones, soils, and installation dates. With one year of limited planting trials, a much better understanding of planting success and planting methods could be developed, and if successful, emergent area revegetation could be implemented on a broader scale. It will also be important the natural propagation of planted species through rhizomatous colonization over a period of years so that the rate of natural colonization can be weighed against the cost of planting additional acreage.

Decisions with regard to plant layout (a continuous revegetated bankline vs. "island"), and site preparation (e.g. using existing bars, selective backfilling, or creating roughness to encourage deposition) could be considered as data on planting methods is evaluated.

Discussion of Potential Benefits

Reduction of Thermal Gain In Pond

Conceptually, if a significant pond area was revegetated with emergent vegetation (50% or better) one would expect the total thermal gain would be reduced by some corresponding fraction. Unfortunately, we do not see a way to predict or quantify this reduction with any precision.

Improved Angling Habitat

Provided again a significant colonization of emergents, (in clusters or on pond fringes), there is a possibility that these will be more resistant to flow and create localized scour similar to what a "hard" island would do. This affect may increase over time if the vegetation also encourages deposition of fine sediments and coalesce into islands. Scour associated with these feature may create deeper water channels where angling is improved.

Improved Waterfowl Habitat

While the pond is certainly a waterfowl resource for foraging and loafing, it lacks emergent vegetation that can be used for escape cover, hiding and nesting.

Nutrient Stabilization

Both bulrush and cattail can immobilize nutrients derived from sediments and the water column. We cannot speculate at this time on whether this is a measurable benefit to the ecosystem.

Aesthetics

Emergent vegetation would clearly improve the aesthetics upstream of the bridge, especially during periods of low flow when the pond margins become shallow mud flats. During summer months when flow is higher the aesthetic benefit may or may not be as great and it should be noted that there would be some loss in shallow, open water habitat.

Potential Drawbacks/Concerns with Alternative 8

Concerns with this approach include potentially limited impact on thermal gain issues in the pond and it would not be expected to dramatically improve sediment continuity. While perhaps a lower cost alternative than others considered, the area that would need to be planted to perhaps address thermal gain issues and improvement in angling opportunities is not insignificant.

Potential Project Costs

Costs for such revegetation projects are a function of the acreage of the planting area, planting density, and installed per plant cost. With so much uncertainty about these components at this point, anything but ballpark cost per acre are risky. Given these uncertainties a very approximate cost is \$20,000 per 0.25 acre or \$80,000/acre. This assumes an *average* planting density of one wetland plug per square feet and an installed cost of \$2.00 per plant (utilizing some volunteer labor). The total project cost will be dependent on the acreage planted. If the plantings are successful the species planted will theoretically have the ability to increase through rhizomatous propagation and/or by seeding provided that the pond water elevations can be managed for seed reproduction. It is also assumed that planting even on half or one third of the total unvegetated area would provide many benefits, and allow for natural colonization over time.

Cost:Benefit Analysis for Alternative 5

Despite the fact that many of the benefits of sediment revegetation to habitat, thermal gain, and nutrient stabilization are hard to quantify, we believe this approach seems to offer a fair value if it is approached incrementally and done in

phases to ensure both feasibility and success and the planted species subsequently self-propagated. However, if one were to contemplate planting upwards of 10 acres, the per-acre cost would make this a very expensive project. It is noted that the design costs are relatively low for a project like this and limited mostly to the first year's experimental studies and data collection; thus most of the money spent goes towards on-the-ground implementation. An additional benefit is that if a successful planting approach can be developed, such a project could engage volunteers and the local community and result in a tangible product visible to visitors and local residents.

4.3.5. No Action

A No Action alternative is still considered to be valid given likely costs of implementing projects that have either true restoration or significant enhancement outcomes. This is coupled with the realization that the Silver Creek fishery, one of the principal values the community associates with the Preserve, is still robust.

The potential risk of a no action alternative is that in hindsight TNC may be perceived to have overlooked the possibility that the creek biota were at risk to significant system stressors due to the impacts of the pond and dam. (Note again we are not predicting a future and widespread degradation of biotic integrity; rather that the system resiliency to future stress may not be high based on the current level of habitat impairment). If a no action alternative is pursued for the immediate future, we recommend that the scientific and management staff of TNC independently conclude that existing condition of the pond and dam do not constitute a need for active intervention.

4.3.6. Discussion of Non-Selection of other Alternatives

Alternative 3 - Pond Bypass Channel was not selected due to the possibility that it would negatively impact the quality of the ponded fishery. With the majority of the creek routed through the new by-pass channel, the remaining pond would be subject to increased thermal gain due to a reduction in volume of cooler flow-through water while still maintaining a large top width.

Alternative 7- Dredge Pond was not selected due to what would be a very expensive project with a benefit narrowly centered on improving angling opportunities in the impoundment. Cost estimates from 1997 ranged between \$600,000 for the preferred outcome and \$300,000 for a minimalist approach and it would be expected that these costs would be at least 20% greater in 2007 dollars. Further, even in the most scaled-down scenario the aesthetic impact of a dredging operation on the pond for 100-300 days is considered to be a significant project drawback. Additional concerns include the longevity of the project (rate of infilling not known), and potential impacts to other Preserve values during an extended dredging project.

5 SUMMARY DISCUSSION

This report describes the findings of the Project Team in their investigation of the past and existing ecological condition of Silver Creek on the Preserve with a focus on the Kilpatrick Pond reach. We have provided additional thoughts and observations regarding the larger Silver Creek watershed. Our over-arching conclusion is that Silver Creek, on the Preserve and downstream, is ecologically under-potential. The principal degradation is related to a historic input of fine sediments, riparian vegetation removal and the combined impacts of all human uses and natural processes that have resulted in an over-wide and shallow channel cross-section that is prone to solar thermal gain. The Kilpatrick Pond is without question resulting in increases in maximum daily water temperature in the summer months and disrupting natural sediment transport. Of these disruptions to natural channel condition we consider the pond's role in thermal gain during the height of the summer to be significant while the lack of sediment transport continuity is more difficult to qualify as a problem beyond noting the obvious alteration to natural channel bed characteristics in the pond.

Quantifying the degradation of the habitat in the larger study area (up- and downstream of the pond) is difficult since there are no accepted standard habitat metrics for large, low-gradient spring creeks which are distinctly different than higher gradient free-stone creeks in the Intermountain west. However, the Project Team strongly feels, based on their professional experience with aquatic resource inventory, assessment and restoration of other spring creeks and systems, that the degradation is both real and significant. This has lead us to consider the resiliency of the aquatic system and trout fishery in particular in the face of new system stresses that might include extended and deepened drought, whirling disease and non-native invasive species such as the New Zealand Mud Snail. We recommend that TNC and partners further refine their monitoring protocols in an effort to capture possible trends in keystone habitat indicators. We also encourage TNC to continue to expand the amount of academic research undertaken on Silver Creek, perhaps specifically addressing ecosystem resiliency and quantifiable habitat mapping and trend monitoring.

This project will conclude with a presentation of these report findings to TNC and selected stakeholders on April 3, 2007. It is anticipated that the discussions from this presentation will highlight the most desirable set of next steps for pro-active restoration and enhancement work, or alternatively, the reasons for not doing so.

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APPENDIX A: PROJECT AREA MAP

APPENDIX B: SEDIMENT TRANSPORT CONSIDERATIONS IN RESTORATION DESIGN

The main objectives of this sediment transport assessment are to evaluate existing sediment transport conditions on Silver Creek, and to use that data to help define appropriate channel dimensions to support future restoration planning/design efforts. The results of this assessment may be summarized as follows:

- Survey data from both Kilpatrick Pond and the Silver Creek channel upstream of the pond indicate that the channel is overwidened, especially in Reach 2 between Grove Creek and Loving Creek;
- A cursory hydraulic/sediment transport assessment of the overwidened sections indicates that these reaches have relatively poor sediment transport capacities; and narrowing of these overwidened sections from over 100 ft topwidths to approximately 65 ft topwidths would greatly improve the sediment transport condition within the project area; and,
- If base level at the dam can be lowered, there are opportunities to modify the channel cross section and substantially improve sediment transport conditions through what is now the upper pond area. Effective sediment transport through the upper pond area would require construction of a channel with a width to depth ratio typical of a Rosgen (1996) E channel type (<12).

Mapped locations of the cross sections surveyed in the project reach are contained in Appendix A.

Based on the pond survey (Galena, 2004) and surveyed channel cross sections (Perrigo, 2006), it is clear that the width-to-depth ratios for Silver Creek are anomalously high (overwidened) in Reach 2 and at Kilpatrick Pond (see Section 3.3.1 Geomorphology). However, all of the TNC monitoring sections, including Monitoring Cross Section T2 in Reach 2 have relatively low W:D ratios. We presume that these sites were intentionally selected are relatively narrow cross sections to facilitate the collection of accurate flow measurements.

Consequently, the TNC monitoring sites provide information regarding the channel morphologies where the channel is markedly narrower than the remainder of the reach. Preliminary field observations indicate that in the vicinity of these monitoring cross sections, overwidening is minimal and sediment transport capacities are relatively high, such that fine sediment infilling is not a chronic problem (an exception to this may be XS T1 at the upper end of Kilpatrick Pond, which is affected by backwater during the irrigation season). These existing relatively narrow channels that are associated with relatively high sediment transport competencies have been assessed as a potential “sediment transport reference condition”. These reaches can be used to help define

modifications necessary in overwidened reaches to replicate their sediment transport competencies.

The methodologies applied in the sediment transport assessment are twofold. First, incipient mobility calculations for typical discharges within each reach have been made for both reference and overwidened cross sections. This methodology identifies the range of particle sizes that will be mobile under a given flow scenario. The second methodology concentrates on assessing only the movement of sand and finer material, and uses sediment discharge rating curves to describe the volume of fine sediment transport as a function of discharge. ***It is critical to note that this effort does not consist of a detailed hydraulic/sediment transport study. Such a study is extremely time intensive and is well beyond the scope of this project. The tools used herein to describe sediment transport conditions are limited in terms of their accuracy and precision, but they are effective tools with regard to the demonstration of relative difference in transport competencies and assistance in conceptual restoration planning.***

A software utility called WinXSPRO was used to assess the hydraulic conditions and bedload discharge rates associated with each evaluated cross section. WinXSPRO is a software package designed to analyze stream channel cross section data for geometric, hydraulic, and sediment transport parameters. However, the program was developed for use in relatively steep streams, as it does not incorporate the effects of backwater in its calculations. In a low gradient stream such as Silver Creek, the program is likely to overestimate transport rates, as backwatering through the system reduces transport competencies. This will be most significant where the pond backwaters the channel. However, although the specific volumes of sediment movement may be overestimated, the program is still useful in depicting the relative differences in transport between sections, and cross section modifications required in one area to mimic sediment transport conditions in another. WinXSPRO was developed by the U.S. Forest Service.

For the incipient mobility assessment, it is necessary to select one or a series of flow conditions for which sediment mobility will be determined. Commonly, bankfull discharge is used in this assessment. In this case, however, bankfull data are not available; instead, a series of flow measurements were used to define “average” flow conditions within each reach. The flows used for this assessment are the average measured 2005 and 2006 discharges for each reach. This insures that tributary inputs are addressed in the sediment transport assessment. In Reach 3 on lower Stalker Creek, mean flows in 2005 were about 30 cfs, whereas below Loving Creek in Reach 1, mean discharges were approximately 100cfs (Table 8).

Table 8. Flow values used in incipient mobility assessment.

<i>Reach</i>	<i>Average Discharge (cfs)</i>		<i>Cross Sections</i>	<i>Width to Depth Ratio</i>
	<i>2005</i>	<i>2006</i>		
Pond	100	150	H	133
1	100	150	T1	25
2	80	120	T2	35
			J	187
			L	183
3	30	45	T3	14
			I	19

The WinXSPRO package was utilized to assess the hydraulic conditions at the flows of interest at each site. An important input parameter into the package is “Manning’s n”, which is a descriptor of bed roughness. On Silver Creek, measured flow data show that roughness values increase during summer and early fall when aquatic macrophytes flourish on the channel bed. This results in an increased stage for a given discharge during the summer. The growth of macrophytes on the bed is also correlated to very clear water. Hence it appears that sediment transport rates are reduced by the vegetation stabilizing the channel bed. To avoid the complexities of aquatic vegetation on sediment transport, the model roughness values were calibrated to winter flow measurements. The results of the analysis therefore describe winter transport conditions.

The cross sections evaluated are highly variable in terms of wetted width to depth ratios (Table 8; Figure 23). They were selected to illustrate the difference in transport capacities as a function of channel width. Also developed was a modified Cross Section L, which was narrowed substantially to assess the effects of channel narrowing on sediment transport (Figure 24). Results of the WinXSPRO hydraulic analysis are summarized in Table 9. The results consist of the stage (water depth) at which the estimated discharge approximates the flows listed in Table 8. The last column to the right, Critical Grain Size, was calculated separately using the Shields Parameter for Incipient Motion (Shields 1936). The critical grain size is that particle size that can be mobilized by the shear stress generated on the channel bed at that discharge.

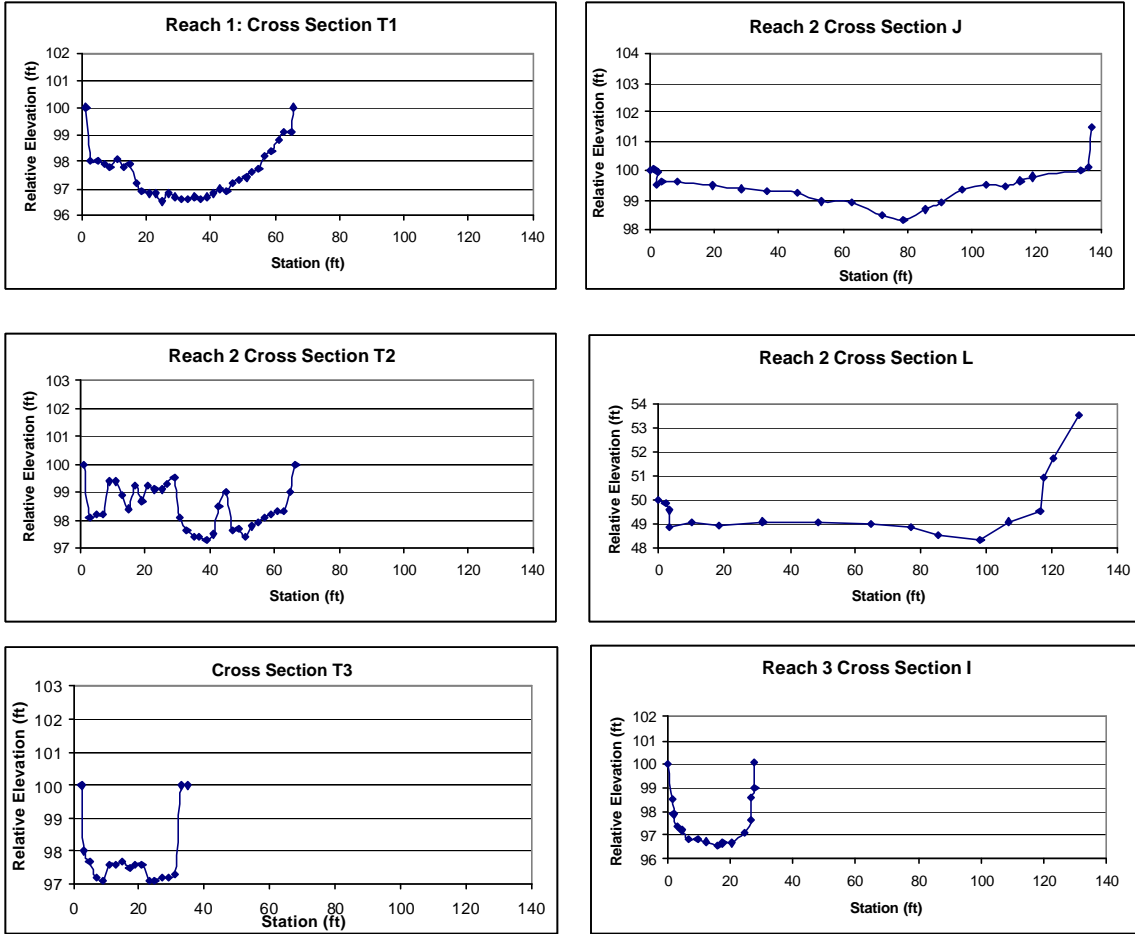


Figure 23. Cross sections used in sediment transport assessment

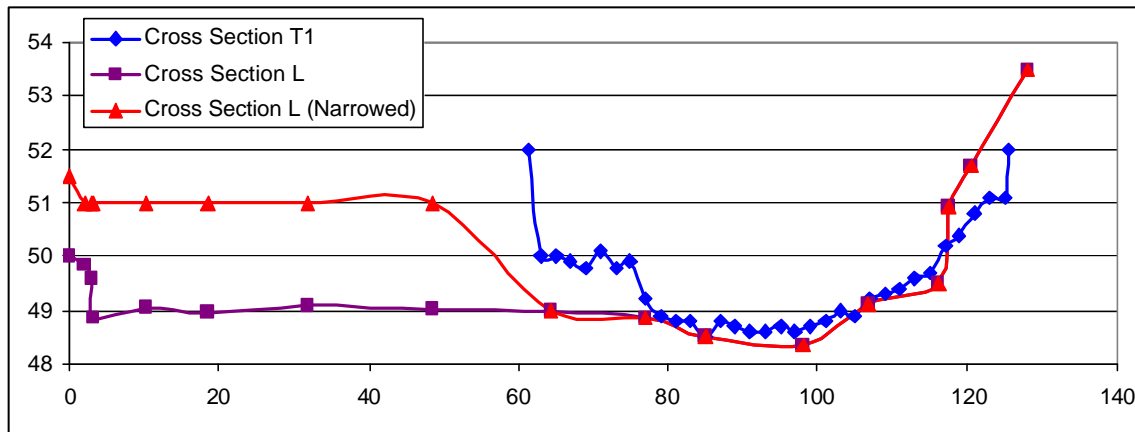


Figure 24. Modified (narrowed) Cross Section L, shown in comparison to existing Cross Sections L and T1.

Table 9. WinXSPRO output for selected cross sections

Cross Section	Stage (ft)	Area (sq ft)	Wetted Perimeter (ft)	Width (ft)	Slope (ft/ft)	Manning's n	Mean Velocity (psf)	Discharge (cfs)	Shear Stress (psf)	Critical Grain Size (mm)
T1	2.6	99.7	57.4	56.5	0.0007	0.054	1.06	105.3	0.08	7.9
T2	2.4	84.0	65.8	62.7	0.0007	0.05	0.92	77.7	0.06	3.8
J	1.9	120.3	127.9	127.8	0.0007	0.054	0.69	83.6	0.04	2.5
L	1.6	117.4	116.6	115.7	0.0007	0.059	0.67	78.8	0.04	2.5
T3	1.7	37.2	28.9	27.4	0.0007	0.056	0.83	30.9	0.06	3.8
I	1.7	34.7	26.4	25.3	0.0007	0.056	0.84	29.2	0.06	3.8
L (narrowed)	2	84.6	56.4	55.6	0.0007	0.056	0.92	78.0	0.07	4.4
T1	3	122.4	58.3	56.9	0.0007	0.051	1.26	153.8	0.09	5.7
T2	2.7	103.0	66.8	63.5	0.0007	0.048	1.11	113.8	0.07	4.4
J	2.1	145.9	128.2	127.9	0.0007	0.053	0.81	118.8	0.05	3.1
L	1.9	152.4	118.0	116.7	0.0007	0.057	0.82	125.5	0.06	3.8
T3	2	45.5	29.6	27.7	0.0007	0.054	0.98	44.5	0.07	4.4
I	2.1	44.9	27.5	25.8	0.0007	0.053	1.04	46.6	0.07	4.4
L (narrowed)	2.4	107.1	57.9	56.9	0.0007	0.053	1.12	119.9	0.08	5.0

Incipient Motion: What Particle Size is Mobile at a Given Flow?

Results of the incipient mobility assessment indicates that in general, Cross Sections T1, T2, T3, and I all mobilize a particle size of ~4.5mm under conditions typical of 2006. In contrast, Cross Sections J and L mobilize particles of smaller diameter. Also note that the narrowed Cross Section L shows as much mobility as Cross Section T2, which is considered a potential transport reference.

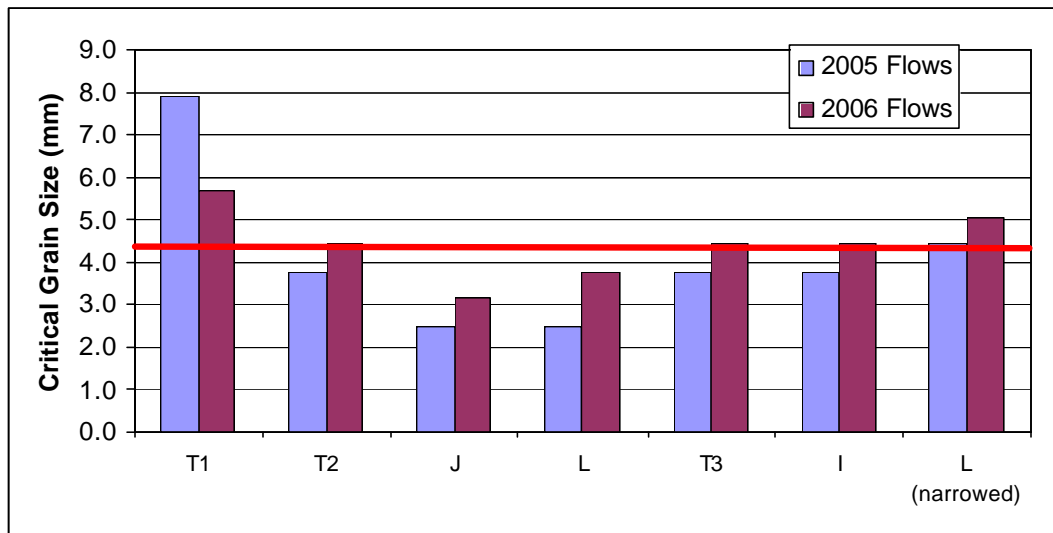


Figure 25. Incipient mobility results by cross section.

Sediment Discharge Rating Curves

To assess the mobility of relatively fine sediment over a range of discharges, a sediment transport relationship was used that calculates a bed material load (bedload plus suspended load) rating curve for each cross section (Ackers and White, 1973). This bed material load was developed for a sediment gradation with a D50 (50% finer by weight) size of 2mm. The results therefore reflect the relative fine grained sediment transport competency at each cross section. Plotted results for all of the cross sections are shown in Figure 26. Cross sections of Reach 3 tend to have the highest transport rates, even though the discharges used in that reach were relatively small. This accentuates the importance of width to depth ratio in sediment transport; these two cross sections have the lowest W:D of any cross sections analyzed (Table 8). The lowest transport capacities are in Cross Sections J and L of Reach 2, both of which have very high width to depth ratios.

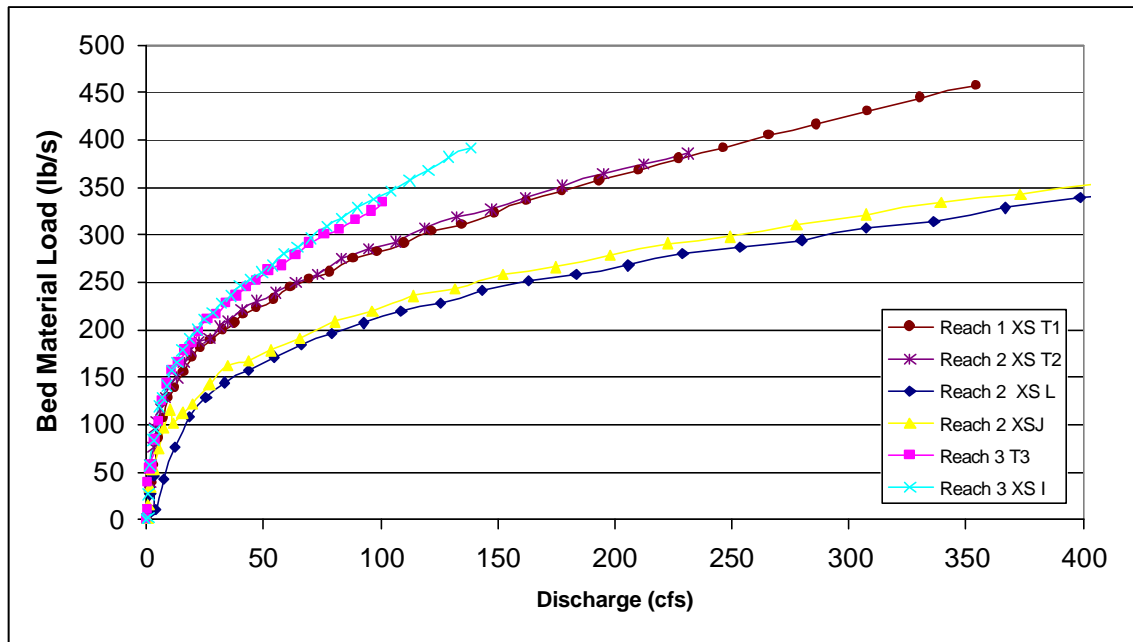


Figure 26. Bedload discharge rating curves for all cross sections.

Implications for Design: Channel Narrowing in Reach 2

The example design cross section, which consists of cross section J narrowed from a topwidth of 125 feet to 65 feet, shows marked improvement in transport competency relative to the existing cross section (Figure 27). The curve generated by the narrowed example design section is close to that of Cross Sections T1 and T2. Thus, if T2 can be utilized as a sediment transport reference, narrowing channels of Reach 2 to a topwidth of 60 to 65 feet would greatly facilitate the flushing of fines through the system. Incipient mobility

results indicate that this level of narrowing should not mobilize gravels to a greater extent than is already experienced in adjacent reaches (ie result in channel destabilization and downcutting).

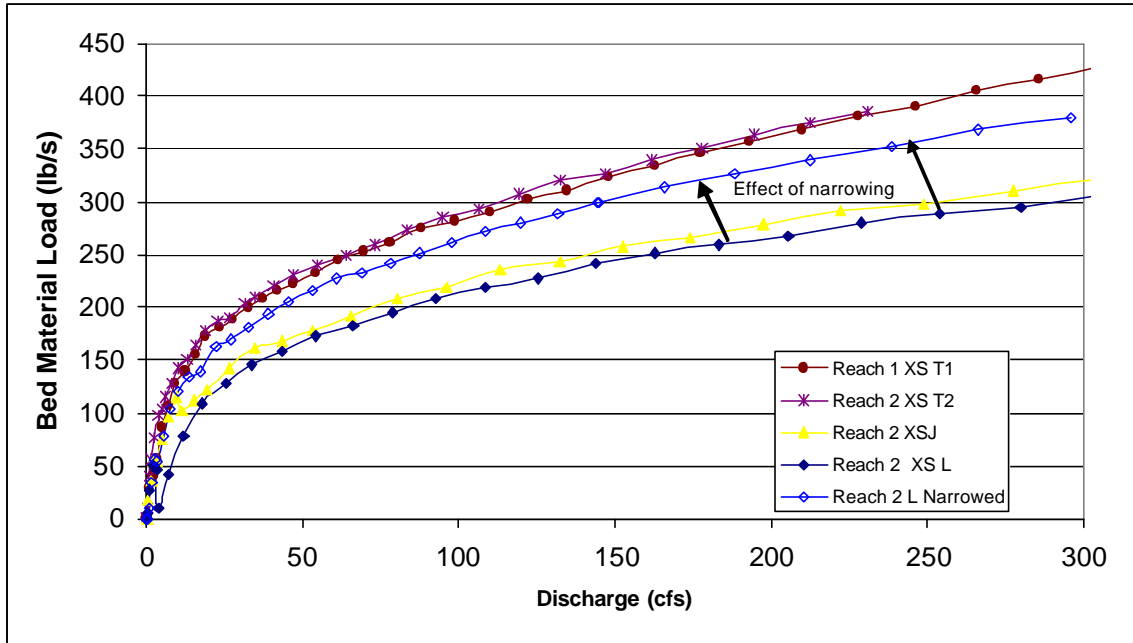


Figure 27. Bedload discharge rating curves showing effects of Cross Section L narrowing on transport competency.

Implications for Design: Channel Narrowing in Upper Portion of Pond

In order to estimate how sediment transport capacity in the pond might be increased by stream channel reconfiguration, it was necessary to estimate the anticipated equilibrium slope condition through the pond under a given management scenario. A potential restoration scenario is the alteration of channel cross section parameters to facilitate sediment transport when the flashboards are pulled in the irrigation off-season. To demonstrate potential channel dimensions in this scenario, a base level elevation was assigned to the dam at 4851 feet. This places the **base level** generated by the porous rock structure approximately 2.8 feet below the water surface elevation measured at the dam with several of the boards out, and approximately 2 feet above the gravel bed elevation (pre-dam channel). This is not meant to define the top of the rocks, but the elevation of the base level provided by the structure. Due to the porous nature of the dam, the base level control is somewhat lower than the top of the highest rock. However, this is an estimation based on limited field observations, and thus must be considered appropriate only for conceptual level design.

The resulting equilibrium bed profile (Figure 28) depicts an equilibrium bed slope of 0.0005, versus a slope of 0.0007 in the natural channel. Also note from Figure

28 that the schematic profile does not quite reach the gravel bed under the silts accumulated in the lower end of the pond, but exposure of the gravels is likely in the upper portions of the pond above Kilpatrick Bridge. At cross section H, the anticipated bed elevation is approximately 3 ft below the top of the silts as surveyed in 2004 (Figure 29).

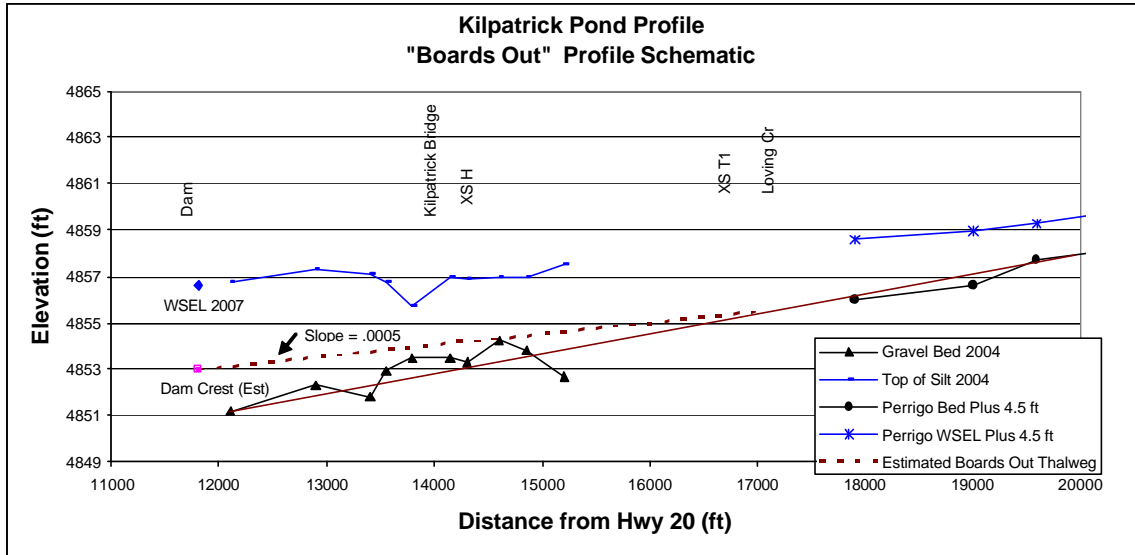


Figure 28. Estimated equilibrium bed profile through dam with flashboards removed. Slope of profile is .0005 versus .0007 for natural channel.

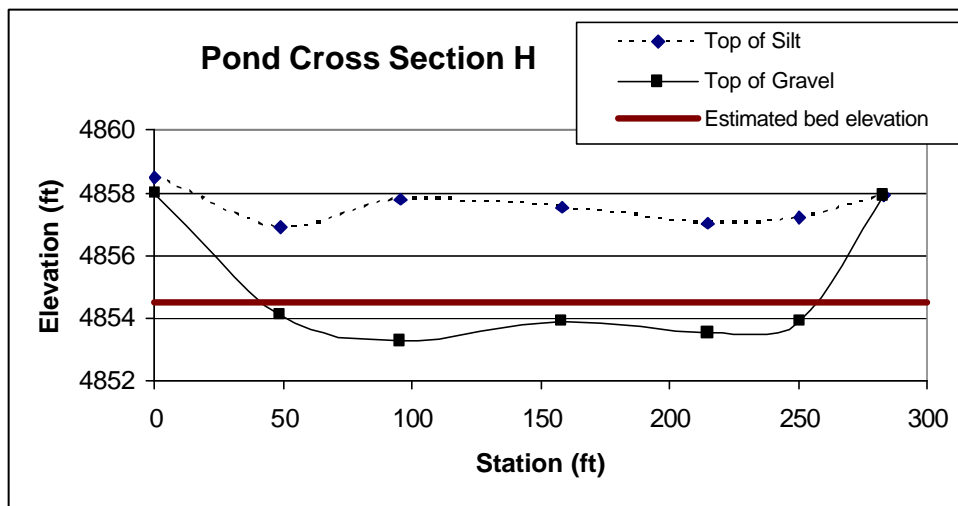


Figure 29. Plot of Cross Section H showing estimated equilibrium bed elevation under "boards out" scenario.

Two example modified cross sections were assessed at Cross Section H, which was surveyed in the pond approximately 350 ft upstream of Kilpatrick Bridge in 2004 (Figure 30). These cross sections are intended to be schematic in nature and to conceptually demonstrate the effects of narrowing on sediment transport.

They are not implicitly intended to provide design dimensions for restoration purposes, but can be used to develop conceptual approaches to restoration planning.

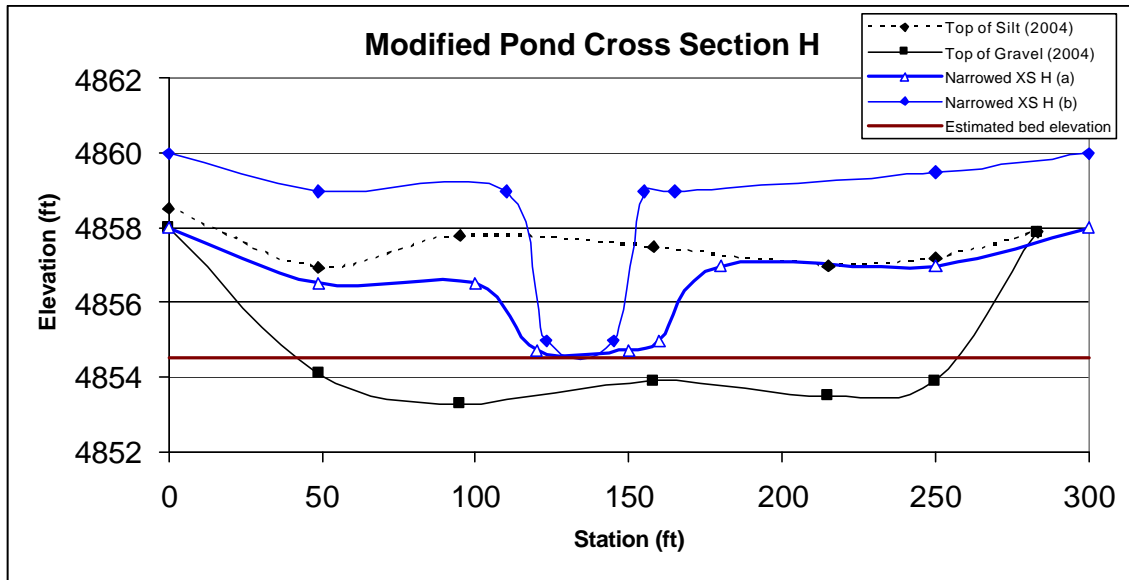


Figure 30. Plotted cross sections for existing and two narrowed configurations, Cross Section H in Kilpatrick Pond.

The cross sections evaluated in the pond include the existing Cross Section H (Galena, 2004), as well as two narrowing scenarios. The existing cross section (2004 conditions) has a width to depth ratio of 133 (Table 10). This section was narrowed to a width to depth ratio of 44 in “Narrowed XSH (a)”. Note that for this cross section, the change from existing conditions consists purely of excavation into the silts surveyed in 2004 (Figure 30). For the cross section referred to as “Narrowed XS H (b)”, the margins of the pond as surveyed in 2004 are raised approximately 2 feet above the silt surface to further reduce the width to depth ratio within the channel. The width to depth ratio of this cross section is 10.5.

Because of the base level control provided by the dam, any channel excavated below the equilibrium bed elevation will be prone to sedimentation and loss of cross section area. Thus there is a limit to how low of a thalweg elevation any restored channel segment can sustain. That estimated limit is at elevation 4854.5 ft at Cross Section H (Figure 30).

Table 10. Cross section and slope parameters for existing and narrowed cross sections, Cross Section H.

Cross Section	Width	Depth	Width/Depth	Slope
Existing XS H	280	2.1	133	.0005*
Narrowed XS H (a)	80	1.8	44	.0005

Narrowed XS H (b)	42	4.0	10.5	.0005
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* Existing XS H evaluated at anticipated equilibrium slope; 2004 slope is zero.

The bed material discharge rating curves developed for the existing and narrowed cross section show the poor transport condition associated with the cross section surveyed in 2004 (Figure 31). Because the boards at the dam have been seasonally removed since that survey, it is likely that the cross section has changed due to sediment flushing, and that transport competencies have increased somewhat since 2004. The two narrowed scenarios show progressive improvement of transport competencies. Cross section “Narrowed XS H (b)”, which has a width to depth ratio of 10.5 displays a sediment transport rating curve that is approaching that of Cross Section T1, which is located upstream of the pond in Reach 1.

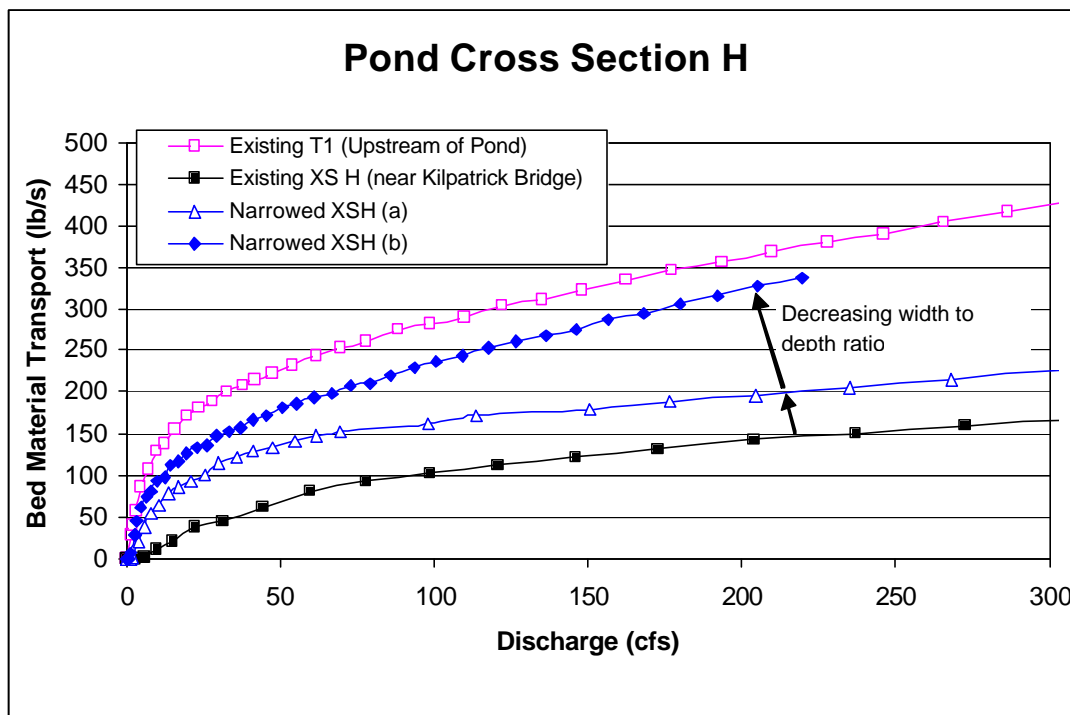


Figure 31. Bed material load rating curves for existing and narrowed XS H, and existing XS T1 located upstream of pond.

The sediment transport assessment provided above uses sediment transport algorithms developed for stream systems rather than impounded waters. As such, the results are only applicable to areas upstream of impoundment. The most fundamental results of this assessment indicate that if it is possible to reduce the upstream extent of impoundment by lowering base level at the dam, there are opportunities to modify the channel cross section and substantially improve sediment transport conditions through what is now the upper pond area on the TNC preserve. Furthermore, the results show that the best way to achieve this cross section will likely be to build banks and floodplain on top of the

existing silt horizon to reduce width to depth ratios as portrayed in the “Narrowed XS H (b)” example.

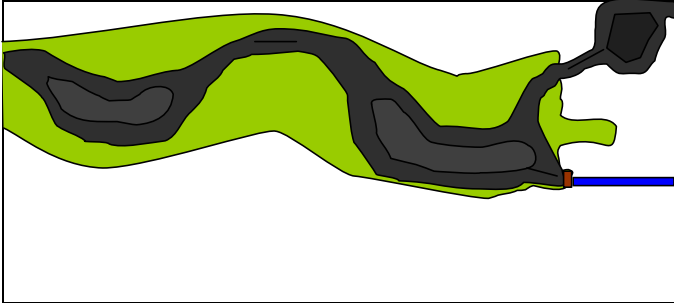
The low slope and low width to depth ratio of the “Narrowed XS H (b)” configuration renders it an “E channel” type in the Rosgen Classification scheme (Rosgen, 1996). E channels are common in low gradient systems with fine grained cohesive banks and extensive floodplain access, and they are relatively efficient at transporting fine sediment. As such, this configuration may provide a sound “guiding image” for modified cross section configurations in the pond in the event that modified management practices or altered structural configurations at the dam result in a lowered base level and a consequent increase in bed slope relative to 2004 conditions.

APPENDIX C: ALTERNATIVE DEVELOPMENT SHEETS

Kilpatrick Pond Restoration Alternatives Assessment

Field Team: SG, KB, TH, MK	1/11/2007
Alternative (check one)	
<i>Page 1/2</i>	
<input checked="" type="checkbox"/> 1. Full dam removal/channel reconstruction (staged drawdown, gradual sediment release)	
<input checked="" type="checkbox"/> 2. Full dam removal/channel reconstruction (instantaneous drawdown, immediate sediment release)	
<input type="checkbox"/> 3. Partial dam removal/drawdown with revegetation of exposed deposits	
<input type="checkbox"/> 4. Cold water dam release structure/periodic pond drainage and maintenance	
<input type="checkbox"/> 5. Seasonal lowering of pond using flashboards	
<input type="checkbox"/> 6. Active sediment removal: dredging under drawdown or drainage scenario	
<input type="checkbox"/> 7. Vegetation only: vegetating banks/bars with no modifications to dam	
<input type="checkbox"/> 8. Pond reconfiguration: Narrow/deepen/shorten pond (partial dam removal with pond narrowing)	
<input type="checkbox"/> 9. Relocation of point of diversion or reconfigure headgate	
<input type="checkbox"/> 10. Bypass channel around pond (pond left as-is or reconfigured)	
<input type="checkbox"/> 11. Fish bypass channel around dam	
<input type="checkbox"/> 12. NO ACTION	
<input type="checkbox"/> Other:	

Alternative Schematic



Basic Description of Alternative

Remove Purdy Dam completely and return Silver Creek to free-flowing spring creek through this section, eliminating the pond. This could be done either with a staged drawdown and gradual sediment release, or instantaneously with one large sediment release. Deliver irrigation water to Kilpatrick Ditch by installing a pump to lift water into canal (wtr rt = 40 cfs).

Alternatives: 1&2

Page 2/2

Restoration Design Elements

<p>Channel Allow thalweg to re-establish naturally with drawdown, flushing of sediment, and emergence of islands. Subsequent "dig & pitch" to stabilize islands and better define channel within design parameters.</p>	<p>Infrastructure Pump for irrigation water or change of POD</p>
<p>Vegetation Revegetate exposed bars to create stable islands. May require use of structure (coir mats/logs, other) to create form for island. Actively revegetate new shoreline banks with woodies to increase shading.</p>	<p>Other</p>

Anticipated Benefits

<p>Riparian Active revegetation will eventually provide increased shading, structure and habitat.</p>	<p>Sediment Transport Improved transport with channel narrowed, grade restored to stream.</p>
<p>Fisheries Habitat/Connectivity Fish able to move freely throughout the system up into headwater areas for spawning/cooler water in summer heat.</p>	<p>Temperature Lower residence time, reduced surface area, deeper channel should reduce temperature through existing pond section.</p>
<p>Other (eg waterfowl, angling, access...) Fishing will be stream vs. stillwater/pond experience. Fishing anticipated to still be excellent. Waterfowl habitat reduced.</p>	

Concerns/Constraints

<p>Relative Cost</p>	<p>Constructability/ Logistics/ Access</p>
<p>Permitting</p>	<p>Other Purdy's are very attached to existing dam structure as historical and beautiful element of their property. (Note use picture of dam on letterhead and wine label.)</p>

Potential Risk/Liability Elements

Downstream pulse of sediment may impact fish habitat downstream. Would require careful analysis of sediment transport, depositional patterns and possible creation of sediment trapping areas (roughness elements??) for managing. If excavate some of sediment in pond in island and bank development, this sediment would not be entrained downstream.

Monitoring Approach

Monitor ecological impacts -- fish, macroinvertebrates, habitat (sediment). Establish cross-sections up and downstream to monitor rate of sediment released, impacts to habitat. Fishing impact should also be monitored.

Comments (data needs, general concerns, etc...)

At this time this alternative is not realistic as the Purdy's will not consider removing the dam. However, explanations about the ecological benefits of pond removal should be explained for educational purposes

Kilpatrick Pond Restoration Alternatives Assessment	
Field Team: SG, KB, TH, MK	1/11/2007
Alternative (check one) Page 1/2	
<input type="checkbox"/> 1. Full dam removal/channel reconstruction (staged drawdown, gradual sediment release)	
<input type="checkbox"/> 2. Full dam removal/channel reconstruction (instantaneous drawdown, immediate sediment release)	
<input checked="" type="checkbox"/> 3. Partial dam removal/drawdown with revegetation of exposed deposits	
<input type="checkbox"/> 4. Cold water dam release structure/periodic pond drainage and maintenance	
<input checked="" type="checkbox"/> 5. Seasonal lowering of pond using flashboards	
<input type="checkbox"/> 6. Active sediment removal: dredging under drawdown or drainage scenario	
<input type="checkbox"/> 7. Vegetation only: vegetating banks/bars with no modifications to dam	
<input checked="" type="checkbox"/> 8. Pond reconfiguration: Narrow/deepen/shorten pond (partial dam removal with pond narrowing)	
<input type="checkbox"/> 9. Relocation of point of diversion or reconfigure headgate	
<input type="checkbox"/> 10. Bypass channel around pond (pond left as-is or reconfigured)	
<input type="checkbox"/> 11. Fish bypass channel around dam	
<input type="checkbox"/> 12. NO ACTION	
<input type="checkbox"/> Other:	
Alternative Schematic	
Basic Description of Alternative	
<p>Drawdown pond elevation seasonally by removing all boards in existing Purdy dam. (Note: how much will we lower pond beyond what Purdy currently getting if remove other 2- 10' boards?) Revegetate exposed bars, and build some bars up so that vegetation persists during inundated period. Dredge or excavate sediment to build up bars/islands and deepen channel through pond.</p>	
Alternatives: 3, 5 & 8 Page 2/2	
Restoration Design Elements	
Channel Allow thalweg to re-establish naturally with drawdown, flushing of sediment, and emergence of islands. Subsequent dredging/excavation to stabilize islands and deepen channel.	Infrastructure Possible to lower existing dam crest?
Vegetation Revegetate exposed bars to create stable islands. May require use of structure (coir mats/logs, other) to create form for island. Actively revegetate with woodyies to increase shading.	Other
Anticipated Benefits	
Riparian Active revegetation will eventually provide increased shading, structure and habitat.	Sediment Transport Island establishment will narrow channel, but natural grade not restored and sediment deposition will continue until pond is "full", thus requiring periodic maintenance.
Fisheries Habitat/Connectivity No change.	Temperature Lower residence time, reduced surface area, deeper channel should reduce temperature through pond.
Other (eg waterfowl, angling, access...) Fishing not significantly changed. Minimal reduction of waterfowl habitat.	
Concerns/Constraints	
Relative Cost	Constructability/ Logistics/ Access Removing boards easy. Lowering of existing dam crest poses structural problems, liability, \$\$\$ -- most likely not feasible.
Permitting	Other Downstream sediment pulse, impact to fish habitat.
Potential Risk/Liability Elements	
Downstream pulse of sediment may impact fish habitat downstream. Would require some analysis of sediment transport, depositional patterns and possible creation of sediment trapping areas (barbs, roughness elements?). Dredging sediment to build islands reduces downstream transport.	
Monitoring Approach	
Monitor ecological impacts -- fish, macroinvertebrates, habitat (sediment). Establish cross-sections up and downstream to monitor fate of sediment released, impacts to habitat. Fishing impact should also be monitored.	
Comments (data needs, general concerns, etc...)	
This alternative extends what Purdy is currently doing with building islands upstream onto TNC part of pond. What does removal of last 2 boards get us? Wrt discussion of sediment, mention "brown drake hatch" and it's importance in the fishery (key on sediment?).	

Kilpatrick Pond Restoration Alternatives Assessment	
Field Team: SG, KB, TH, MK	1/11/2007
Alternative (check one)	Page 1/2
<input type="checkbox"/> 1. Full dam removal/channel reconstruction (staged drawdown, gradual sediment release)	
<input type="checkbox"/> 2. Full dam removal/channel reconstruction (instantaneous drawdown, immediate sediment release)	
<input type="checkbox"/> 3. Partial dam removal/drawdown with revegetation of exposed deposits	
<input checked="" type="checkbox"/> 4. Cold water dam release structure/periodic pond drainage and maintenance	
<input type="checkbox"/> 5. Seasonal lowering of pond using flashboards	
<input type="checkbox"/> 6. Active sediment removal: dredging under drawdown or drainage scenario	
<input type="checkbox"/> 7. Vegetation only: vegetating banks/bars with no modifications to dam	
<input type="checkbox"/> 8. Pond reconfiguration: Narrow/deepen/shorten pond (partial dam removal with pond narrowing)	
<input type="checkbox"/> 9. Relocation of point of diversion or reconfigure headgate	
<input type="checkbox"/> 10. Bypass channel around pond (pond left as-is or reconfigured)	
<input type="checkbox"/> 11. Fish bypass channel around dam	
<input type="checkbox"/> 12. NO ACTION	
<input type="checkbox"/> Other:	
Alternative Schematic	
Basic Description of Alternative	
<p>Drawdown pond elevation seasonally by removing all boards in existing Purdy dam and releasing water through new cold water release structure. (Cold water could also be released in summer to help with downstream temperature issues.) Size and construct release such that sediment will move through structure allowing spawning gravel replenishment downstream. (NOTE: to move sediment, need open pipe through, not AgriDrain type control structure (below)) Vegetate exposed bars creating permanent islands. Deepen channels through pond by excavating or dredging sediment and using it to build bar/new bank height up.</p>	
Alternatives: 4	
Page 2/2	
Restoration Design Elements	
<p>Channel Allow thalweg to re-establish naturally with drawdown, flushing of sediment, and emergence of islands. Subsequent dredging/excavation to stabilize islands and deepen channel.</p>	<p>Infrastructure Cold water release structure designed for flow amount that will achieve drawdown, pass sediment, and release water downstream into channel without "fire hose" effect.</p>
<p>Vegetation Revegetate exposed bars to create stable islands. May require use of structure (coir mats/logs, other) to create form for island. Actively revegetate with woodies to increase shading.</p>	<p>Other</p>
Anticipated Benefits	
<p>Riparian Active revegetation will eventually provide increased shading, structure and habitat.</p>	<p>Sediment Transport Gravel moved downstream. Island establishment will narrow channel, but natural grade not restored. Sediment deposition will occur during irrigation season, then flush each fall with drawdown. May create impacts on downstream fish habitat.</p>
<p>Fisheries Habitat/Connectivity No change</p>	<p>Temperature Lower residence time, reduced surface area, deeper channel should reduce temperature through pond.</p>
<p>Other (eg waterfowl, angling, access...) Fishing not significantly changed. Reduction of waterfowl habitat when drawn down.</p>	
Concerns/Constraints	
<p>Relative Cost</p>	<p>Constructability/ Logistics/ Access Downstream cold water outlet will be a "fire hose". How large would pipe have to be to achieve drawdown?</p>
<p>Permitting</p>	<p>Other Downstream sediment pulse, impact to fish habitat.</p>
Potential Risk/Liability Elements	
<p>Downstream pulse of sediment may impact fish habitat downstream. Would require analysis of sediment transport, depositional patterns and possible creation of sediment trapping areas (barbs, roughness elements??) on downstream properties. Dredging sediment to build islands will reduce sediment pulse in first year, but each year will get pulse when open release.</p>	
Monitoring Approach	
<p>Monitor ecological impacts – fish, macroinvertebrates, habitat (sediment). Establish cross-sections up and downstream to monitor fate of sediment released, impacts to habitat. Fishing impact should also be monitored.</p>	
Comments (data needs, general concerns, etc...)	
<p>This alternative ability to further drawdown the pond without removing historic dam feature.</p>	

Kilpatrick Pond Restoration Alternatives Assessment	
Field Team: SG, KB, TH, MK	
1/11/2007	
Alternative (check one) Page 1/2	
<input type="checkbox"/> 1. Full dam removal/channel reconstruction (staged drawdown, gradual sediment release)	
<input type="checkbox"/> 2. Full dam removal/channel reconstruction (instantaneous drawdown, immediate sediment release)	
<input type="checkbox"/> 3. Partial dam removal/drawdown with revegetation of exposed deposits	
<input type="checkbox"/> 4. Cold water dam release structure/periodic pond drainage and maintenance	
<input type="checkbox"/> 5. Seasonal lowering of pond using flashboards	
<input checked="" type="checkbox"/> 6. Active sediment removal: dredging under drawdown or drainage scenario	
<input type="checkbox"/> 7. Vegetation only: vegetating banks/bars with no modifications to dam	
<input type="checkbox"/> 8. Pond reconfiguration: Narrow/deepen/shorten pond (partial dam removal with pond narrowing)	
<input type="checkbox"/> 9. Relocation of point of diversion or reconfigure headgate	
<input type="checkbox"/> 10. Bypass channel around pond (pond left as-is or reconfigured)	
<input type="checkbox"/> 11. Fish bypass channel around dam	
<input type="checkbox"/> 12. NO ACTION	
<input type="checkbox"/> Other:	
Alternative Schematic	
Basic Description of Alternative	
Dredge or excavate sediment. Create islands. See Confluence 1997 report for this scenario.	
Alternatives: 6 Page 2/2	
Restoration Design Elements	
Channel Dredge/excavate to stabilize islands and deepen channel.	Infrastructure
Vegetation Revegetate exposed bars to create stable islands. May require use of structure (coir mats/logs, other) to create form for island. Actively revegetate with woodies to increase shading.	Other
Anticipated Benefits	
Riparian Active revegetation will eventually provide increased shading, structure and habitat.	Sediment Transport Island establishment will narrow channel, but natural grade not restored and sediment deposition will continue, require regular maintenance. Gravel removed from system.
Fisheries Habitat/Connectivity No change	Temperature Lower residence time, reduced surface area, deeper channel should reduce temperature through pond.
Other (eg waterfowl, angling, access...) Fishing not significantly changed. Minimal reduction of waterfowl habitat.	
Concerns/Constraints	
Relative Cost	Constructability/ Logistics/ Access
Permitting	Other On-going maintenance required.
Potential Risk/Liability Elements	
Monitoring Approach	
Comments (data needs, general concerns, etc...)	

Kilpatrick Pond Restoration Alternatives Assessment	
Field Team: SG, KB, TH, MK	
1/11/2007	
Alternative (check one) Page 1/2	
<input type="checkbox"/> 1. Full dam removal/channel reconstruction (staged drawdown, gradual sediment release)	
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<input type="checkbox"/> 11. Fish bypass channel around dam	
<input type="checkbox"/> 12. NO ACTION	
<input type="checkbox"/> Other:	
Alternative Schematic	
Basic Description of Alternative	
Add scirpus (or other species) clumps or thick sod mats (sedge etc) onto exposed bars/islands when boards out of irrigation diversion. Species will depend on inundation depth.	
Alternatives: 7 Page 2/2	
Restoration Design Elements	
Channel	Infrastructure
Vegetation Revegetate exposed bars to create stable islands/banks. May require use of structure (coir mats/logs, other) to create form for island. Actively revegetate with woodies to increase shading.	Other
Anticipated Benefits	
Riparian Active revegetation will eventually provide increased shading, structure and habitat.	Sediment Transport Improved if can effectively narrow channel
Fisheries Habitat/Connectivity No change	Temperature If narrowing achieved reduced surface area, and lower residence time should reduce temperature through pond.
Other (eg waterfowl, angling, access...) Fishing not significantly changed.	
Concerns/Constraints	
Relative Cost	Constructability/ Logistics/ Access Timing of planting in spring is just before pond raised for irrigation. Is there time for plants to establish well before inundation? Are bars stable enough and high enough for sod mats, or need to be raised?
Permitting	Other
Potential Risk/Liability Elements	
Monitoring Approach	
Comments (data needs, general concerns, etc...)	

Kilpatrick Pond Restoration Alternatives Assessment

Field Team: SG, KB, TH, MK	1/11/2007
Alternative (check one)	
<i>Page 1/2</i>	
<input type="checkbox"/> 1. Full dam removal/channel reconstruction (staged drawdown, gradual sediment release)	
<input type="checkbox"/> 2. Full dam removal/channel reconstruction (instantaneous drawdown, immediate sediment release)	
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<input checked="" type="checkbox"/> 9. Relocation of point of diversion or reconfigure headgate	
<input type="checkbox"/> 10. Bypass channel around pond (pond left as-is or reconfigured)	
<input type="checkbox"/> 11. Fish bypass channel around dam	
<input type="checkbox"/> 12. NO ACTION	
<input type="checkbox"/> Other:	

Alternative Schematic



Basic Description of Alternative

- 1) Move POD for Kilpatrick ditch upstream. This will allow a lower pond surface elevation required to divert irrigation water and reduce pond size (backwater of pond stops at bridge...). TNC then re-naturalize channel on their property. Lower dam crest. (NOTE: at what location is there enough elevation gain to make a difference?).

- 2) Reconfigure existing diversion structure to lower necessary crest height. The floor of the box of the existing headgate structure is 1.2 feet higher than the ditch invert. Thus, if this headgate were reconfigured to lower the invert, could we lower the required ht of water on dam to deliver irrigation water to ditch?

Alternative: 9		<i>Page 2/2</i>
Restoration Design Elements		
Channel Silver Creek channel on TNC property narrowed and returned to more natural stream state.	Infrastructure New irrigation headgate structure. Lower crest of existing dam?	
Vegetation Revegetate banks, and exposed islands.	Other	
Anticipated Benefits		
Riparian	Sediment Transport Improved on TNC property. Little change through pond as grade is not restored.	
Fisheries Habitat/Connectivity	Temperature Improved because pond surface area is smaller.	
Other (eg waterfowl, angling, access...)		
Concerns/Constraints		
Relative Cost	Constructability/ Logistics/ Access Need to evaluate where POD would have to be to get 40 cfs into channel. Would still probably need a dam of sorts to push water into ditch.	
Permitting	Other Not supported by Nick Purdy, so not feasible alternative.	
Potential Risk/Liability Elements		
Moving POD means more maintenance and hassle for Purdy. May not be feasible with elevations		
Monitoring Approach		
Comments (data needs, general concerns, etc...)		
Option 1) moving POD a non-starter with Purdy. Option 2) reconfigure headgate needs investigation to determine benefits.		

Kilpatrick Pond Restoration Alternatives Assessment	
Field Team: SG, KB, TH, MK	1/11/2007
Alternative (check one) Page 1/2	
<input type="checkbox"/> 1. Full dam removal/channel reconstruction (staged drawdown, gradual sediment release)	
<input type="checkbox"/> 2. Full dam removal/channel reconstruction (instantaneous drawdown, immediate sediment release)	
<input type="checkbox"/> 3. Partial dam removal/drawdown with revegetation of exposed deposits	
<input type="checkbox"/> 4. Cold water dam release structure/periodic pond drainage and maintenance	
<input type="checkbox"/> 5. Seasonal lowering of pond using flashboards	
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<input type="checkbox"/> 9. Relocation of point of diversion or reconfigure headgate	
<input checked="" type="checkbox"/> 10. Bypass channel around pond (pond left as-is or reconfigured)	
<input type="checkbox"/> 11. Fish bypass channel around dam	
<input type="checkbox"/> 12. NO ACTION	
<input type="checkbox"/> Other:	
Alternative Schematic	
Basic Description of Alternative	
Build new Silver Creek channel on North side of existing pond/channel. Allow 40 cfs to remain in pond for irrigation right and to maintain pond for stillwater fishing, waterfowl habitat and activities (hunting)...	
Alternative: 9 Page 2/2	
Restoration Design Elements	
Channel Build new channel for Silver Creek according to design w/d.	Infrastructure Control structure to divert 40 cfs to Purdy.
Vegetation Vegetate new channel for shading and bank stability	Other
Anticipated Benefits	
Riparian Narrow channel with well vegetated banks.	Sediment Transport Excellent. Grade fully restored through this section of channel. Channel narrowed to appropriate w/d for sed transport.
Fisheries Habitat/Connectivity Excellent.	Temperature Greatly improved in creek. Worse in pond due to smaller volume of water & longer residence time. However, cold water input will have more impact b/c lower volume.
Other (eg waterfowl, angling, access...) Waterfowl habitat excellent. Angling experience in pond may decrease significantly as macroinvertebrate production affected, temperatures may be too hot for trout. Better angling in new creek. Downstream section may benefit from lower temps, improved sed transport.	
Concerns/Constraints	
Relative Cost VERY expensive	Constructability/ Logistics/ Access On Purdy land. Requires significant buy-in not only from Purdy, but from entire community as this is major work on Silver Creek.
Permitting	Other
Potential Risk/Liability Elements	
Monitoring Approach	
Fish, temps, macroinvertebrates, sediment...	
Comments (data needs, general concerns, etc...)	

Kilpatrick Pond Restoration Alternatives Assessment	
Field Team: SG, KB, TH, MK	1/11/2007
Alternative (check one) Page 1/2	
<input type="checkbox"/> 1. Full dam removal/channel reconstruction (staged drawdown, gradual sediment release)	
<input type="checkbox"/> 2. Full dam removal/channel reconstruction (instantaneous drawdown, immediate sediment release)	
<input type="checkbox"/> 3. Partial dam removal/drawdown with revegetation of exposed deposits	
<input type="checkbox"/> 4. Cold water dam release structure/periodic pond drainage and maintenance	
<input type="checkbox"/> 5. Seasonal lowering of pond using flashboards	
<input type="checkbox"/> 6. Active sediment removal: dredging under drawdown or drainage scenario	
<input type="checkbox"/> 7. Vegetation only: vegetating banks/bars with no modifications to dam	
<input type="checkbox"/> 8. Pond reconfiguration: Narrow/deepen/shorten pond (partial dam removal with pond narrowing)	
<input type="checkbox"/> 9. Relocation of point of diversion or reconfigure headgate	
<input type="checkbox"/> 10. Bypass channel around pond (pond left as-is or reconfigured)	
<input checked="" type="checkbox"/> 11. Fish bypass channel around dam or make existing structure more fish friendly	
<input type="checkbox"/> 12. NO ACTION	
<input type="checkbox"/> Other:	
Alternative Schematic	
Basic Description of Alternative	
Build fish by-pass channel around dam or make existing structure passable with boulder/plunge pool series below dam.	
Alternative: 9 Page 2/2	
Restoration Design Elements	
Channel Build small (5 cfs?) fish bypass channel. Consider different pond stage elevations in design.	Infrastructure Possible control at entrance to new channel to have open only seasonally.
Vegetation Heavily vegetate new channel for shading and protection of migrating fish (fishable??)	Other Consider building boulder/plunge pool series below dam to allow fish passage through current structure.
Anticipated Benefits	
Riparian Narrow channel with well vegetated banks.	Sediment Transport Small channel will not significantly affect sediment transport.
Fisheries Habitat/Connectivity Significantly improved.	Temperature No change.
Other (eg waterfowl, angling, access...) No change	
Concerns/Constraints	
Relative Cost	Constructability/Logistics/ Access
Permitting	Other
Potential Risk/Liability Elements	
Monitoring Approach	
Fish monitoring.	
Comments (data needs, general concerns, etc...)	
Is current configuration a fish barrier? Need measurements of velocity, jump height, etc. under current configuration and with boards in.	

APPENDIX D: SYSTEMIC RESTORATION ALTERNATIVE

While the objective of this project was to assess the ecological impacts of Kilpatrick Pond and Dam and provide restoration and enhancement alternatives to mitigate these, it is difficult to evaluate ecological health looking at one small segment of a large system. For example, with respect to the fishery and available spawning habitat, looking only at Silver Creek on TNC one would conclude that spawning habitat is limited and below potential. However, there may be an abundance of spawning habitat on upstream tributary sections that are more than adequate to maintain the fishery. Without assessing the distribution and abundance of a variety of habitat types, it is difficult to draw conclusions about where Silver Creek falls relative to its potential, and what measures are most needed to address impacts.

Our brief field reconnaissance suggested that the physical impairments identified on Silver Creek within the TNC Preserve (see main report) are in evidence downstream, specifically: under-potential riparian conditions; high channel width:depth ratios; poor sediment transport competence; and thermal degradation. Therefore we have outlined a fourth alternative for TNC consideration which would be to conduct a comprehensive evaluation of in-stream habitat, riparian vegetation, and geomorphology and provide recommendations for priority restoration efforts. The scope and logistics of such an effort are described below.

Potential Project Scale

The scale for a comprehensive restoration effort for Silver Creek would encompass the tributaries down to Point of Rocks, although the best downstream ending point should be discussed. The total length of the tributaries Stalker Creek, Loving Creek, Wilson Creek, Grove Creek, Mud Creek and Chaney Creek is approximately 82,000 feet (15.5 miles).

Table 11. Silver Creek tributary reach lengths.

<i>Tributary</i>	<i>Reach</i>	<i>Length</i>
Stalker Creek	Confluence w/ Silver Creek to Chaney Cr.	13,000 feet
Chaney Creek	Stalker Cr to Hwy 12	9,000 feet
Grove Creek	Confluence w/ Silver Cr. to headwaters	20,000 feet
Wilson Creek	Confluence w/ Grove Cr. to headwaters	11,000 feet

Loving Creek	Confluence w/ Silver Creek to Hayspur Hatchery	14,500 feet
Mud Creek	Confluence w/Stalker Creek to Hwy 20	15,000 feet

Silver Creek can be broken into the following reaches:

Table 12. Silver Creek reaches and length.

<i>Reach</i>	<i>Length</i>
Kikpatrick Bridge to confluence w/ Grove and Stalker Creeks	11,600 feet
Hwy 20 to Kilpatrick Bridge	13,900 feet
Eastern Point of Rocks access boundary to Hwy 20 (1st crossing).	15,500 feet
2nd Hwy 20 Crossing to Eastern Point of Rocks access boundary.	34,200 feet

Based on significant rounding of reach lengths, a project area that included Silver Creek from the eastern most Hwy 20 crossing to the confluence with Grove and Stalker Creeks would include 75,200 feet (14.2 miles) of channel. Adding tributaries to the project area would add an additional 82,000 feet (15.5 miles), for a total of about 30 miles of channel.

Project Implementation

Since any large scale effort would involve the cooperation of numerous landowners, forming a watershed group might be considered. Funding for watershed groups is readily available, and could be applied for to support a large scale evaluation. One caution to this approach is that we have observed some watershed groups become bogged down with internal disputes and cumbersome processes that make them less nimble in the assessment and execution of projects. An alternative to the formation of a formal watershed group would be garnering the support of key landowners and directing an effort through TNC.

Conduct Habitat/Riparian/Geomorphic Assessment

Evaluating stream conditions on over 30 miles of channel is a large scale effort. Therefore, a rapid assessment protocol based on existing protocols and modified to address a low-gradient spring creek system would need to be developed first. Our research into existing protocols suggests that not one is perfectly suited to evaluating a low-gradient spring creek system; however, a protocol could be rapidly developed utilizing elements of various existing protocols, as well as the

input of fisheries scientists, geomorphologists, and riparian ecologists familiar with spring creeks.

Expand Existing Monitoring Protocols

Every habitat inventory benefits greatly from monitoring data collected prior to the survey. This information is also extremely valuable in evaluating restoration activities. Monitoring elements needed for a thorough evaluation in the Silver Creek watershed include:

- **Water Temperature Monitoring.** While the FLIR study has an abundance of good data over stream reaches beyond the Preserve, longer-term data sets from the tributaries and particularly downstream of the dam and Highway 20 would be very helpful for any future thermal modeling.
- **Spawning Surveys.** Currently knowledge of the principal spawning areas is somewhat anecdotal beyond the sites being monitored by TNC. It does not appear that an assessment has been made of spawning resources in the tributaries nor the extent of spawning activity below Kilpatrick Pond.
- **Quantify Trends In Aquatic Vegetation.** Terry Merat of the USGS (pers. com) suggested that gathering more data on the seasonal and annual trends of submerged aquatic vegetation abundance is important for understanding ecological trends in Silver Creek and we agree. Fitzgerald (2006) outlines an approach using aerial photograph interpretation that would suit Silver Creek well.
- **Macroinvertebrate Monitoring.** Extend the number of sample areas to all areas in the watershed.

Prioritize Restoration Reaches and Restoration Activities

Prioritization of restoration reaches following a survey can become complicated and ultimately rely on professional judgments. For example, the overall restoration need may prove to be high on miles of stream -- does one approach the most degraded sections first, or is it most appropriate to work from the top of the watershed downstream, addressing all impairments despite their ranking? While we conceptually recommend the top-down approach, the realities of funding for projects often dictates that the most critical reaches are addressed first, particularly if there is concern that degradation in these reaches could have systemic effects if left untreated. Kilpatrick Pond may be a good example of this dilemma.

Develop Feasibility/Restoration Plan and Costs

The development of a restoration plan with anticipated costs is typically necessary for acquisition of funding from agencies, and is the natural outgrowth of the assessment and prioritization process. In fact, the initial assessment, prioritization and feasibility/restoration plan are best approached as single staged

task versus broken out as separate tasks undertaken by a number of different entities.

Solicit Funding

Given Silver Creek's storied history and cachet, obtaining funding for a well-designed restoration program would face far fewer hurdles than many other projects. Silver Creek and TNC also have the unique opportunity to attract and raise private (non-federal or state) funds that can be used to match government grants.

Conceptual Restoration Implementation Issues

Restoration activities would be driven by the findings of the assessment. Outside of Kilpatrick Pond, we anticipate that the principal restoration needs will be fairly straight-forward and the techniques for restoring spring creek systems well-developed. Based on our observations to-date activities might broadly include riparian revegetation (including experimental reedgrass control) and adjustments to channel geometry that result in specific in-channel habitat types with an emphasis on improving sediment transport continuity.

While the techniques for riparian revegetation have become quite advanced to meet a range of planting opportunities, control of reedgrass in restoration is considered experimental. Riparian restoration will need to balance the cost:benefit of reedgrass control efforts.

Unlike most freestone creeks with upland hydrology runoff regimes, it is generally accepted that spring creeks do not re-establish equilibrium channel geometry simply by changing management practices in the watershed. This is partly attributable to the fact that spring creeks typically do not experience frequent flooding regimes that actively re-sort in-stream sediments into bars that are then stabilized by naturally encroaching vegetation. While not documented in the literature, it is our observation that once a spring creek experiences a channel-widening episode (almost always concurrent with an influx of sediment), the channel width-depth ratio does not change at rates observable on decade level periods.

When changes in land management do not or cannot favorably alter channel geometry, restoration practice turns to active manipulation of channel cross-section. Where width:depth ratios are high (channel is overly wide and shallow), narrowing the channel can promote "equilibrium" channel transport that maintains pools and sorts sediments on lateral and point bars. The guidelines for defining appropriate channel geometry can be patterned after replicating reference reach channel characteristics, if available, or sediment transport approaches such as those utilized in Appendix B, (approaches that we have utilized with great success in spring creek environments).

Recent projects on the Preserve on Stalker Creek and on Silver Creek on Picabo Livestock property provide examples of different approaches to narrowing channel cross-sections and utilizing instream sediment to build new lateral and point bars that are then revegetated to create new channel banks. The Stalker Creek project relied on a small capacity dredge pumping sediment/waste water into cells defined by coir rolls staked to the channel bed and while sound in principal, was ultimately not completed due to underperformance of the dredge for moving sediment and the cost of coir rolls. The Picabo project avoided the use of a dredge to build new banks by utilizing an excavator operating from the bank to backfill the coir roll-defined bank margins.

While both projects were sound in principal we do have additional recommendations should this type work proceed. First, as outlined in Appendix B there are project-tested design methodologies (and others not described in Appendix B) that can calculate or estimate the desired channel top width in an over-widened cross-section to achieve equilibrium sediment transport conditions. To be effective, re-configured channel geometry needs to be effectively continuous through a reach rather than intermittent narrowing with intervening over-wide cross-sections.

Further, we do not believe the specific methods utilized in the two projects are ultimately cost-effective when compared to other projects we are intimate with that rely upon a hydraulic excavator that operates from either the banks or within the channel that works in a downstream direction shaping the channel bed, building new lateral, point bars and barbs with the sediment, and stabilizing these surfaces with donor sod or other methods. It should be noted that the practice of using dredges and avoiding in-channel excavation has been largely driven by various Idaho permitting agency requirements relating ultimately to discharge of turbid water downstream of the work. Our recent experience with Fox Creek, a 25 cfs spring creek near Driggs, ID, suggests that permitting agencies are amenable to more aggressive approaches (and ones that create temporary downstream turbidity) provided they are made partners in the process at an early stage of design and permitting and rational reasons are identified for the recommended methods. Addressing the fate of sediment in the holistic evaluation of Silver Creek would go a long way in addressing these concerns.

Conceptual Restoration Program Costs

The following estimates are to be considered to be very "broad brush" and not a comprehensive and detailed program budget. They are offered for consideration so that they can be weighed against other discussed alternatives and for planning purposes if such an effort is contemplated.

Watershed Assessment /Preliminary Restoration Alts	\$60-70,000
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Restoration Design and Permitting	\$40-80,000*
Tributaries Channel and Riparian Restoration	\$15-20/ft (\$79K - 105K/mile)
Silver Creek Mainstem Channel and Riparian Restoration	\$20-40/ft (\$105K - 211K/mile)

* This figure is completely dependent on the linear scale of the project