Slate River, Peanut Lake Reach

Assessment, Restoration, and Monitoring

To Protect Peanut Lake and Improve River and Wetland Function

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Above: The Slate River where it is almost breached into Peanut Lake (background). The sparsely vegetated gravel in the foreground is a constructed berm that runs along the left bank.

Below: Standing on the berm looking up the Slate River with Mt. Crested Butte in the background.

Contents

Introduction

Background

This study is one component in the Crested Butte Land Trust's (CBLT's) stewardship efforts within the Slate River Wetlands Preserve (SRWP). The SRWP was identified in the 1990s as a premier aquatic resource, and its preservation and restoration has been a cornerstone of the CBLT efforts for two decades.

A series of reports dating back to the early 1990s consistently identify the Peanut Lake Reach of the Slate River as a high concern for ecological impairment and a high priority for restoration. All of these past reports suggest that the reach is incised and geomorphically unstable, which has several consequences including the degradation of adjacent floodplain wetlands, poor stream function, increased erosion and sediment production, and an elevated risk that the river will breach into Peanut Lake, which would potentially drain the lake and release contaminated sediments into the watershed. This study provides a detailed assessment of this condition and a treatment design aimed at restoring stream and wetland function while protecting Peanut Lake and the contaminated sediments contained in it.

Objectives of this Study

1. To quantify functional condition of the Slate River and its associated riparian wetlands, with particular emphasis on geomorphic stability and floodplain connectivity.
2. To study options for maintaining separation between Peanut Lake and the Slate River to reduce the risk that the river will capture the lake.
3. To use this information to create a restoration plan for the Peanut Lake Reach.

This report is structured with a section devoted to each of these three objectives.

Report Structure and General Methods

Functional Assessment (Study Objective 1)

The river and its associated riparian wetlands function together as an integrated system but, by convention, the two habitat types are typically evaluated separately. In this study, we utilized a beta version of FACStream (Functional Condition of Colorado Streams - Beardsley and Johnson, in prep.) to assess the functional condition of the river, and FACWet version 3.2 (Functional Condition of Colorado Wetlands - Johnson, Beardsley, and Doran 2014) for riparian wetlands which also included a formal delineation of the present boundaries of wetland habitat.

Rather than attempting to rate the performance of any one particular river or wetland function, these methods consider the ability of the habitat to perform the entire suite of natural functions by assessing the condition of its natural infrastructure; that is, its health. Following an analysis of process domain, functional condition of the site is assessed by rating a set of state variables, each of which describes a key driver of stream or wetland health, and therefore its ability to function in a natural way. These variable scores are then combined into a composite score, called the FCI (functional capacity index) to represent the overall functional condition of the site.

Table 1: FACWet and FACStream variable scoring is numeric, from 50 to 100, corresponding to letter grades that represent different degrees of impairment.

90-100	**A**	**Negligible**
80-89	**B**	**Mild**
70-79	**C**	**Significant**
60-69	**D**	**Severe**
50-59	**F**	**Profound (or unsustainable)**

Variable and FCI ratings are numerical scores which correspond to letter grades according to the standard academic grading scale. Scores and grades represent the degree of impairment, or the level of departure from reference condition, and the meaning of each rating can be expressed as a concise narrative statement about the degree of impairment. 100/100 represents a perfectly natural site with no impairment, perfect health, and full functional capacity. The bottom of the scale is set at 50/100. In other words, 50 is the lowest score a site can receive if it is still recognizable as a stream or wetland. Sites that are so badly impaired that they are no longer a stream or wetland cannot be effectively evaluated by aquatic habitat assessment methods.

FACWet and FACStream variable assessments consist of two parts - the score and the rationale. The score is essentially a summary opinion on variable condition, and the rationale is the evidence upon which that opinion is based or justified. In this report, we present the reader first with a concise summary of each assessment (river and the wetland) in the form of a "report card" of variable scores along with a stressor matrix to analyze the causes of impairment. The details and rationale for each variable score are presented separately in Appendices 2 and 3, with any supporting data from detailed quantitative measurements and physical surveys. We organized the report like this to keep the structure simple and easy to navigate, and to avoid the pitfalls of "information overload." The reader may be selective in how much detail they wish to take in by simply deciding whether to read further in the supporting appendices. We hope that this format makes it easier for reviewers to follow the logical flow of the study without becoming bogged down in too much detail about each piece from the start.

For the purpose of this study, a rapid assessment is sufficient to score most variables with reasonable confidence, but for critical variables we incorporated more detailed quantitative techniques to provide greater certainty, as you will see. Detailed physical surveys were carried out, for example, to provide quantitative data that inform our assessment of stream morphology, floodplain connectivity, stability, and structure according to the US EPA WARSSS (Watershed Assessment of River Stability and Sediment Supply) Prediction Level Assessment (PLA) methods (Rosgen 2006) and methods prescribed in the US EPA Function-Based Framework (Harman and others 2012). Quantitative methods were also used in the assessment of hydrology, chemical condition, and vegetation structure. The important thing about the FACStream and FACWet frameworks is that they force the evaluator to consider all aspects of stream and wetlands health by scoring every variable in the assessment. This study is typical in that some of the variables have detailed quantitative supporting data while others are based on rapid assessment methods.

Peanut Lake Risk Assessment (Study Objective 2)

We use a standard risk assessment matrix to evaluate the risk of injury related to the breach of Peanut Lake by the Slate River which considers both the likelihood of a breach (exposure) and the potential consequences (hazard). The results, when applied to the matrix model, may be used to help decision-makers understand the relative urgency of the situation as well as identifying potential actions that can be taken to remove, prevent, or reduce risk. Our evaluation of the likelihood of a breach draws primarily from the assessment of river and lake shoreline stability. Our evaluation of the consequences of a breach relies heavily on previous studies that addressed chemical contamination in Peanut Lake, but we also consider overall ecological and societal benefits.

Restoration Plan (Study Objective 3)

The study culminates in a restoration plan that aims to reduce the risk of the Slate River breaching Peanut Lake while at the same time maximizing functional condition of the river and associated wetlands. To arrive at this plan, we first considered the various reasonable actions that could be taken to reduce risk at Peanut Lake. We then factored in approaches that could be taken to improve river and wetland function based on our river and wetlands assessments. The result is a plan that provides reasonable protection for Peanut Lake while also providing significant benefits to the river, 1.8 acres of wetlands reestablishment, and 5.3 acres of wetland rehabilitation. Each of these projected outcomes is quantified using functional assessment methods and a set of specific objectives with target success criteria that can be monitored over time to evaluate the effectiveness of the project. A specific monitoring plan is also described in this report.

In this main body of the report, we describe the general aspects of the restoration plan and a summary of the expected benefits and costs. Detailed descriptions of the restoration design are provided in a supporting appendix.

Functional Assessment

Site Setting

Assessment Area and Access

The assessment area for this study includes a segment of the Slate River and adjacent floodplain wetlands on CBLT property known as the Peanut Lake Parcel (Figure 1). The length of river in the assessment area is approximately 1500 ft with a valley length of 1300 ft. The floodplain area assessed east of the current river alignment includes about 7.3 acres of historic wetland area. Access to the site from the Slate River Road is along the river from the CBLT Rice Parcel, but this requires crossing through the neighboring McGill Property. Access from the Peanut Lake Road would require crossing Peanut Lake.

Process Domain Summary

The essential character of rivers and wetlands varies widely according to the climatic, geologic and ecologic setting. That is, riverine systems are not all created alike. It is therefore necessary to understand the site setting before delving into a site assessment. The climatic, geologic, and ecologic settings of the reach define a process domain, or the set of natural processes within which the riverine system evolved. These processes are what determine the type of river and

Figure 1: The study area includes a 1500 ft segment of river and 7.3 acres of floodplain area on the Peanut Lake Parcel northeast of Crested Butte.

wetlands that would naturally be present. Thus, the exercise of defining the process domain is extremely important for understanding the natural reference condition, or what the river and wetland system would be like in the absence of human disturbance.

This reach of the Slate River is a 3rd order perennial stream in an unconfined very low-gradient lacustrine valley with small gravel bed material. Hydrology is a mostly natural pattern of seasonal peaks caused by snowmelt runoff and occasional sub-peaks from rain events. Associated wetlands extend across the valley floor supported by riverine flows as well as groundwater, and beaver activity is important for maintaining water distribution and hydraulic head in the valley. The reference stream type is one that has a primary meandering channel and networks of anabranching distributary channels. A detailed description of the site setting and process domain is provided in Appendix 1.

River Assessment Summary

FACStream Summary

Functional condition of the Peanut Lake Reach of the Slate River was assessed using the FACStream framework (Beardsley and Johnson, in prep.). A summary of the results is provided here in the form of a "report card" with grades for each of the key components of stream health (Table 2). Details of the FACStream assessment including an explanation and justification for the variable scores are provided in Appendix 2.

Overall functional condition of the reach is given by the FACStream overall functional condition score which is compiled from the ten individual variable scores. The condition of the Peanut Lake Reach is rated 81/100, or B-, which indicates a moderately functional condition with a mild degree of impairment, bordering on significant impairment. This is not an especially "sick" or nonfunctional reach of river, but there is room for improvement, particularly in floodplain connectivity.

Individual variable scores provide an indication of which aspects of river health are most impacted. On this reach, we see significant impacts to chemical supply, riparian vegetation, morphology, floodplain connectivity, and biotic structure. Again, a thorough analysis of each state variable including the evidence and rationale for scoring is provided in Appendix 2.

Table 2: A report card of river functional condition organized by FACStream variable. The table lists the numerical score and associated letter grade for each variable and the FCI, along with its interpretation in degree of impairment. Confidence ratings indicate the level of confidence in variable assessment based on the amount and quality of supporting evidence (H = high, M = moderate, L = low).

Scale	Variable		Score	Grade	Degree of Impairment	Confidence
Watershed	V_{hyd}	Water Supply	94	A	Negligible	H
	V_{sed}	Sediment Supply	91	A-	Negligible	H
	V_{chem}	Chemical Supply	73	C	Significant	H
Riparian	V_{veg}	Riparian Vegetation	75	C	Significant	H
	V_{deb}	Debris Supply	87	B+	Mild	H
Reach	V_{morph}	Morphology	77	C	Significant	M
	V_{con}	Floodplain Connectivity	72	C-	Significant	H
	V_{stab}	Stability and Resilience	80	B-	Mild/Significant	M
	V_{str}	Physical Structure	86	B	Highly Functional	H
	V_{bio}	Biotic Structure	74	C-	Significant/severe	M
		Reach Condition Score	81	B-	Mild/Significant	H

Table 3: Ratings of functional capacity of the Peanut Lake Reach for the four EPA river functional categories.

Functional scores by EPA category		
Biology Functions	80	B-
Physicochemical Functions	79	C+
Geomorphology Functions	82	B-
Hydraulic Functions	82	B-

Recall that the FACStream score is an index of overall health, or condition, which is indicative of the reach's ability to perform its entire suite of natural functions. This index is more important from a conservation point of view, than is the maximization of any one particular function. It may be helpful, though, to consider how the reach rates in different functional categories. To meet this need, FACStream provides individual ratings for each of the functional categories recognized in the EPA's "Function-Based Framework" (Harman 2012). According to the scores given in Table 3, functional impairment is fairly evenly distributed across the various categories.

River Stressor Summary

Stressors are human impacts that are responsible for degradation of ecological function; they are the causes of impairment. Ultimately, these are the things that one could fix to improve or restore lost functions. A benefit of FACStream is that the important stressors are specifically identified and highlighted in the assessment. This makes it easy to account for the relative importance of each stressor to each variable, and ultimately to the overall functional condition of the river. Table 4 is a matrix that expresses the relative influence of each identified stressor to variable scores for the Peanut Lake Reach. It is essentially a tool to illustrate the linkage between cause (stressors) and effect (impairment).

Table 4: Stressor matrix for the Peanut Lake Reach. Significant stressors are listed on the left columns, organized by location (watershed, riparian area, or reach) and state variables are listed across the top. The degree of purple shading in the cells indicates the level of impact that each stressor has on each variable. No shading indicates no impact. The lightest shading indicates mild impact, and the darkest shades indicate the most significant impact.

		Watershed			Riparian		Reach				
Stressor Location	Stressor/Impact	Vhyd: Water Supply	Vsed: Sediment Supply	Vchem: Chemical Supply	Vveg: Riparian Vegetation	Vdeb: Debris Supply	Vmorph: Morphology	Vcon: Floodplain Connectivity	Vstab: Stability & Resilience	Vstr: Physical Structure	Vbio: Biotic Structure
Contributing Watershed	Water diversions										
	Wetlands loss										
	Watershed development (Roads, etc.)										
	Excessive channel erosion (in contrib. watershed)										
	Watershed veg cover (grazing, etc in watershed)										
	Stream crossings (bridges, constrictions)										
	Mine discharge (Point sources)										
Riparian Area	Constructed Berm (along left bank)										
	Vegetation clearing (shrub removal)										
	Ditches (in riparian area)										
	Grazing (in riparian area)										
Reach	Bed degradation (following in-channel excavation)										
	Managed fishery (stocking)										
	Non-native aquatic species										

From this analysis, it is clear that the constructed berm and discharge from mine waste are far and away the most important causes of impairment to this reach. The variables that are heavily affected by mine drainage are chemical supply (V_{chem}) and biotic structure (V_{bio}). The berm is a significant source of impairment to all of the riparian and reach-scale variables except, perhaps for debris supply (V_{deb}). It is extremely important to floodplain connectivity (V_{con}), riparian vegetation (V_{veg}) and stability/resilience (V_{stab}). The matrix also clearly shows that there are other stressors affecting the condition of the reach, but the effects of these other stressors are small compared to the impacts of mine drainage and the berm.

Opportunities for River Improvement

The stressor matrix (Table 4) makes it easy to see where the greatest functional gains can be met. By making it clear which stressors are associated with the most impairment, we now have a rational way of selecting which stressors would be good targets for treatment and a way to calculate functional gains that could be achieved by treating them. The matrix clearly identifies the berm and the mine drainage as the primary sources of impairment, so any effort to improve river function on the reach should focus first on these causes.

Mine drainage is an off-site stressor, meaning that the source of the stress is in the upper watershed, far away from the reach where it cannot be effectively treated in a site-specific restoration project. Ameliorating this stressor would surely result in significant functional gains on the Peanut Lake Reach, but fixing the problem will require work in the contributing watershed, particularly in Redwell Basin. According to the draft Watershed Plan for the Upper Slate (Bembeneck 2014), treating mine drainage is a very high priority in the Upper Slate, and the results of this study fully support this need.

The berm, on the other hand, is a stressor that can easily be dealt with on a reach-scale restoration project. Eliminating the effects of the berm would result in major improvements to floodplain connectivity (V_{con}) as well as significant improvement to stability and resilience (V_{stab}) and streamside vegetation (V_{veg}). Physical structure (V_{str}) would benefit if the left bank can be stabilized with good vegetation and a proper bank height that could develop from the existing sloped cut bank to a more typical form.

Biotic structure (V_{bio}) would also benefit indirectly if biota respond to improved habitat structure. Improvements in these variables would be limited, however, because the V_{str} variable already has a high score and therefore not much room for improvement, and the V_{bio} variable is primarily limited by other stressors. A more thorough quantitative accounting of potential functional gains is made in the "Restoration Plan" section of this report.

Wetland Assessment

Wetland Delineation

A wetland delineation was performed on CBLT property along the Slate River (Figure 2). All of the riparian area west of the river to the edge of Peanut Lake is wetland. This area is presumed to be in very good functional condition due to the absence of identifiable stressors. Any restoration design on the property would do well to leave this functioning wetland area intact and undisturbed.

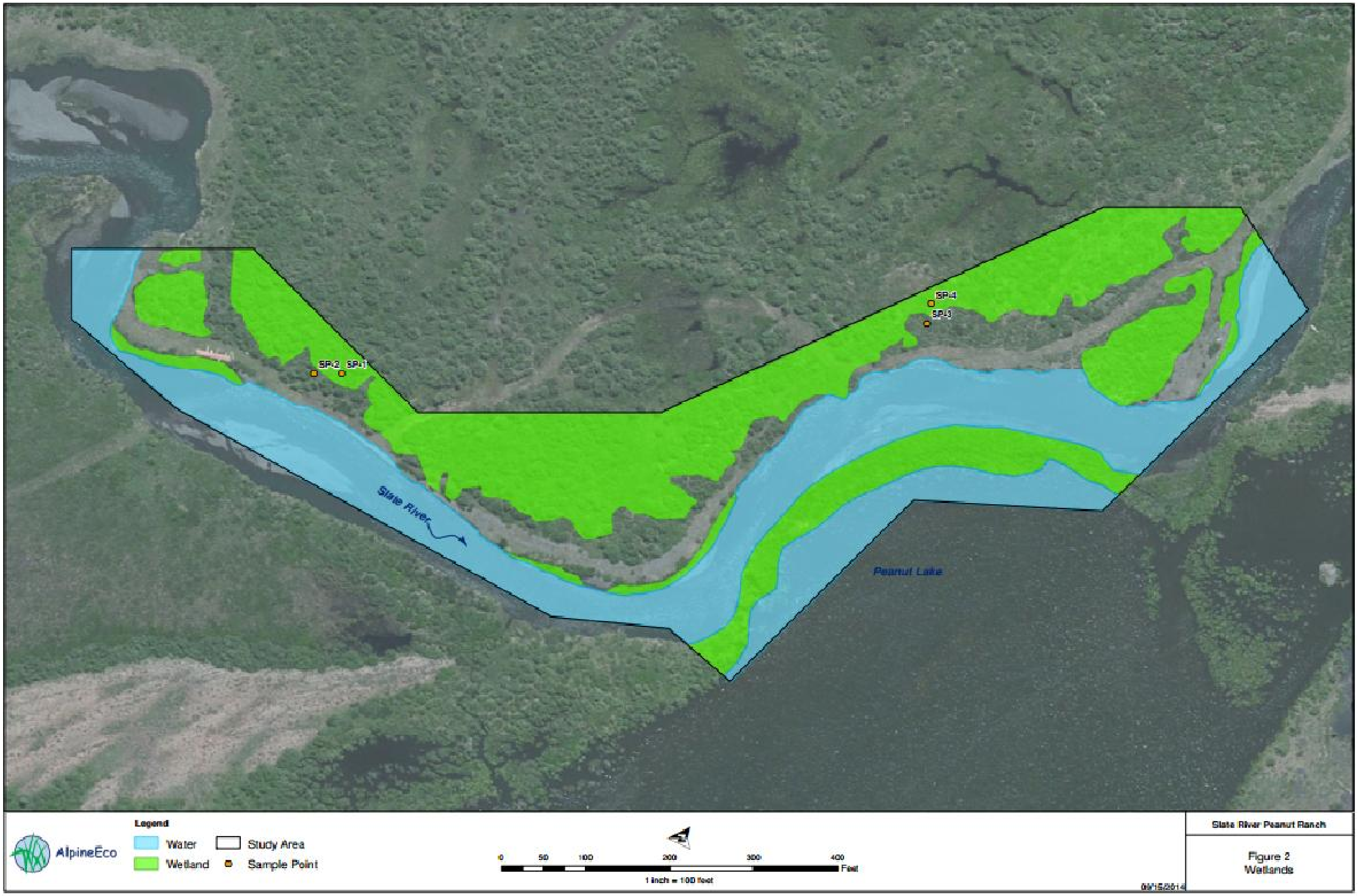


Figure 2: Wetlands delineation for the Peanut Lake Parcel. The land east (above) the river includes 5.3 acres of wetland (wetlands extend east, beyond the "study area" for delineation). 1.8 acres of wetland has been converted to upland along and adjacent to the berm.

East of the river, there is an area of about 1.8 acres within and adjacent to the berm that has been converted to upland. This area is no longer wetland, so it is assessed as nonfunctional. It presents an excellent opportunity for restoration or re-creation of wetlands if the berm can be removed. The remaining riparian area on CBLT property east of the river is still wetland, but its condition is somewhat diminished, which makes it a viable target for wetlands enhancement. This area includes about 0.2 acre of wetland adjacent to the river and west of the berm which is similar to the area west of the river and therefore assumed to be highly functioning. The remainder of the area is approximately 5.3 acres in size. We assessed this 5.3 acre wetland area using FACWet.

FACWet Summary

A summary of the FACWet assessment of the 5.3 acre area is provided here in the form of a "report card" that lists scores and grades for each of the key components of wetland health (Table 5). Details of the FACWet assessment including an explanation and justification for the variable scores is provided in appendix 3.

Table 5: A report card of wetland functional condition organized by FACWet variable. The table lists the numerical score and associated letter grade for each variable and the FCI, along with its interpretation in degree of impairment. Confidence ratings indicate the level of confidence in variable assessment based on the amount and quality of supporting evidence (H = high, M = moderate, L = low).

Attribute	Variable		Score	Grade	Degree of Impairment
Land-scape	Variable 1:	Habitat Connectivity (Connect)	91	A-	Negligible
	Variable 2:	Contributing Area (CA)	95	A	Negligible
Hydrology	Variable 3:	Water Source (Source)	72	C	Significant
	Variable 4:	Water Distribution (Dist)	72	C	Significant
	Variable 5:	Water Outflow (Outflow)	72	C	Significant
Abiotic and Biotic Habitat	Variable 6:	Geomorphology (Geom)	92	A	Negligible
	Variable 7:	Chemical Environment (Chem)	78	C+	Significant/Mild
	Variable 8:	Vegetation Structure (Veg)	83	B	Mild
		Condition Score	82	B	Mild

The 5.3 acres of remaining wetland area east of the river is moderately functioning with mild impairment. Coincidentally, the FCI score for this wetlands area is the same as that for the river which is approaching the "significant" category of impairment. Most of the stress and impairment is focused on hydrology factors and related to floodplain disconnect (*i.e.* lack of side channel connection and overbank flooding).

Table 6: FCI scores for each of the seven functional categories in FACWet for the wetland area east of the river on CBLT property. These scores are calculated from FACWet state variables.

Function 1 -- Support of Characteristic Wildlife Habitat	87	B-
Function 2 -- Support of Characteristic Fish/aquatic Habitat	75	C
Function 3 -- Flood Attenuation	78	C+
Function 4 -- Short- and Long-term Water Storage	75	C
Function 5 -- Nutrient/Toxicant Removal	84	B
Function 6 -- Sediment Retention/Shoreline Stabilization	89	B+
Function 7 -- Production Export/Food Chain Support	81	B-
Composite FCI	**81**	**B-**

Seven categories of functions are listed in FACWet to represent groups of functions that are often of interest and representative to the overall health of the system (Table 6). Not surprisingly, the "fish/aquatic habitat", "flood attenuation", and "water storage" categories are highlighted as the most impaired (C or C+), these being the closely tied to hydrology. A category of special interest in this watershed, "nutrient/toxicant removal" is graded B.

Wetlands Stressor Summary

As in the case for the river, we can use a stressor matrix to visualize the linkage between stressors (cause) and impairment (effect) for the wetland (Table 7). In this analysis, the riverside berm is once again highlighted as the most important stressor, with direct effects on the hydrology variables (Var. 3-5: Water Source, Distribution, and Outflow) as well as chemical environment (Var. 7) due to altered soil chemistry caused by desaturation. All of the other stressors have comparatively little impact. Grazing impacts refer to the effects of past livestock grazing.

Opportunities for Wetlands Improvement

There are definitely good opportunities for wetlands improvement on the property. The most obvious opportunity would be to restore the 1.8 acres of wetland that has been converted to upland by the berm. Removal of the berm and restoration of that area as wetland would also significantly improve the functional condition of the remaining 5.3 wetland acres by removing the primary cause of impairment. The positive effects would also be felt by adjacent wetland on the neighboring McGill property and others downstream, but these areas were not assessed in this study. A more thorough quantitative accounting of potential functional gains is made in the "Restoration Plan" section of this report.

Table 7: Stressor matrix for the 5.3 acres of wetland east of the river on the Peanut Lake Parcel. Significant stressors are listed on the left columns, organized by location (watershed, riparian area, or reach) and state variables are listed across the top. The degree of green shading in the cells indicates the level of impact that each stressor has on each variable. No shading indicates no impact. The lightest shading indicates mild impact, and the darkest shades indicate the most significant impact.

Stressor Location	Stressor/Impact	Landscape		Hydrology			Physicochemical		
		1. Connectivity	2. Contributing Area	3. Water source	4. Water distribution	5. Water outflow	6. Geomorphology	7. Chemical environment	8. Vegetation structure
Contributing Watershed	Water diversions								
	Wetlands loss								
	Watershed development (Roads, etc.)								
	Excessive channel erosion (in contrib. watershed)								
	Watershed veg cover (grazing, etc in watershed)								
	Stream crossings (bridges, constrictions)								
	Mine discharge (Point sources)								
Riparian Area	Constructed Berm (along left bank)								
	Vegetation clearing (shrub removal)								
	Ditches (in riparian area)								
	Grazing (in riparian area)								
Reach	Bed degradation (following in-channel excavation)								
	Managed fishery (stocking)								
	Non-native aquatic species								

Peanut Lake Risk Assessment

Peanut Lake Background

Figure 3: Peanut Lake viewed from the north with Mt. Crested Butte in the background.

Peanut Lake is about a 40 acre lake situated on the western edge of the Slate River Valley (Figure 3). At first glance, the origins of the lake are suspicious, and we initially expected to find that it is artificial or at least that it had been "enhanced" or enlarged. It is located in an area where there has been heavy mining activity dating back to the 1800s, and it has a 1200-ft long elevated "dam" that defines the southeast edge. There is also a typically "tell-tale" signature feature of artificial ponds and converted gravel pits in the singular island with one tree. For some reason, people seem to like to build an island when converting gravel pits to ponds (notice the McGill gravel pit pond just across the valley). Despite these suspicions, we can find no evidence that Peanut Lake is anything but natural, and other investigators seem to agree (Cooper 1993, Resource Engineering Inc (REI) 1996).

Peanut Lake sits in a trough between two bedrock ridges that run more or less parallel with the Slate River Valley, and the island appears to be the tip of another ridgeline between these two that just happens to daylight in the lake. The eastern ridge is obvious at the north end of the lake where it is elevated several feet above the surrounding ground level, but then moving south, it becomes submerged under alluvium in the area where the river is closest to the lake before resurfacing again as a rocky hill near the edge of the valley. It is probable Peanut Lake is formed by the capture of groundwater in the trough between these bedrock ridges, with the eastern ridge functioning as a natural dam blocking drainage of the lake to the valley (Figure 4).

We walked the length of the "dam" looking for any evidence of human construction, but found none. The construction of the dam is consistent with construction and long-term maintenance by beavers. Indeed it is only by the constant activity of beavers that the dam has not failed (Figure 5). The river and floodplain elevation drop from north to south, but the lake elevation is constant, so the dam is taller at its southern end where it reaches a maximum height of about 2.5 feet above the surrounding land.

Figure 4: Peanut Lake showing the prominent bedrock ridge. Areas where the ridge is exposed are shaded in yellow. The yellow arrows show where the bedrock is exposed in the banks and bed of the river. The river has crossed the ridge at these two locations and is now on the same side as Peanut Lake.

At the time of our survey, the elevation of the water surface in the lake was 3.8 feet higher than the water surface of the river which is also about 2.1 ft higher than the bankfull elevation of the river (See the plot of XS-8 in Appendix 5). It appears that beavers have effectively raised the level of Peanut Lake above the height of the geologic

Figure 5: The dam surrounding Peanut Lake is maintained by beavers. In this photo, a recent beaver dam in front of Andy is all that is preventing the lake (right) from draining into the river (left).

Figure 6: Slate River and Peanut Lake. The arrows indicate the two "close points".

bedrock dam by several feet over the course of centuries or millennia.

The Slate River runs right along the southeast end of Peanut Lake on this reach for about 700 feet, coming extremely close to the lake at two points. At the upstream "close point" the river is cutting into the Peanut Lake beaver dam and the river bank comes as close as 6 feet from the perimeter of the lake (Figure 7). At the lower point, the normal high water edge of the river is against the dam, and only 9 feet from the edge of water in the lake. Interestingly, historical aerials show that the river has been roughly in this position for at least 54 years.

Figure 7: At the upper "close point" the Slate River is actively eroding into the dam surrounding Peanut Lake. Here, the river and lake are less than 6 feet apart. A beaver dam is all that maintains separation.

This channel position is evident in the oldest available aerials for the site from 1958 (Figure 8). In that time, the channel has moved about 30-40 feet closer to the lake, but it has not yet breached.

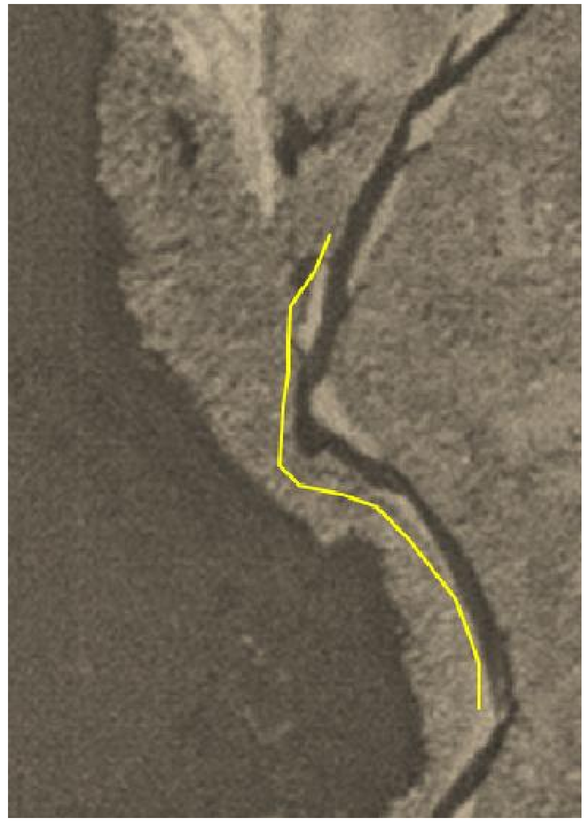


Figure 8: 1958 aerial showing the relatively similar alignment of the Slate River relative to Peanut Lake. The yellow line is an overlay of the right bank position in 2012 showing that the river has migrated 30-40 feet closer to the lake in 54 years.

Despite the proximity of Peanut Lake to adjacent mines and the fact that these mines drain directly into it, water quality in the lake is reported to be excellent. Cooper (1993) and REI (1996) both report that the only water quality concern in the lake is elevated manganese, which may sometimes exceed standards for aquatic life and potentially limit a fishery in the lake. The REI report also analyzed lake sediments and found these to be very high in many trace metals. According to their report, the water in Peanut Lake is alkaline which causes most introduced metal contaminants to precipitate out of solution where they become integrated with lake sediment. In this state, the metals are relatively harmless to most forms of aquatic life.

The purpose of this section of the study is to assess the risk of a breach between the Slate River and Peanut Lake. Assessing risk requires an understanding of two different factors: likelihood of an event occurring (exposure) and the consequences of that event (hazard). After discussing each of these factors, we apply the findings to a risk matrix which allows decision makers the ability to view them together to help determine the need for action.

Likelihood of a Breach (Risk Exposure)

There are two mechanisms of failure that could cause a breach between the lake and the river: (1) the river could migrate into the area of the lake by eroding through the dam, or (2) the dam could fail at a particular location and erode as lake water evacuates through that opening. It is easy to imagine either one of these things happening at any time. Notwithstanding the fact that neither of these failures have happened during the 50-plus year history when the river was alongside the lake, vulnerability of a lake breach is obvious.

Quantifying the likelihood of a breach is difficult because the events leading up to a breach are episodic and not gradual. While the river is moving slowly towards the lake, over decades, in at least two locations, it is not doing so at any regular rate, and it is not clear whether this migration will continue in the future. The question is more complex than simple extrapolation of a constant river migration rate. Areas of significant or rapid bank erosion on this relatively straight reach tend to be associated with scour caused by hard objects such as debris jams, sediment bars, or bedrock, especially where these occur along the banks of outside bends.

This situation is set up perfectly at the upstream "close point" where the river has migrated to the Peanut lake side of the bedrock ridge. The bedrock is forming a scour point that concentrates energy along the right bank which is already eroding into the dam (Figure 9). This condition is also clearly seen on XS surveys (see appendix 5).

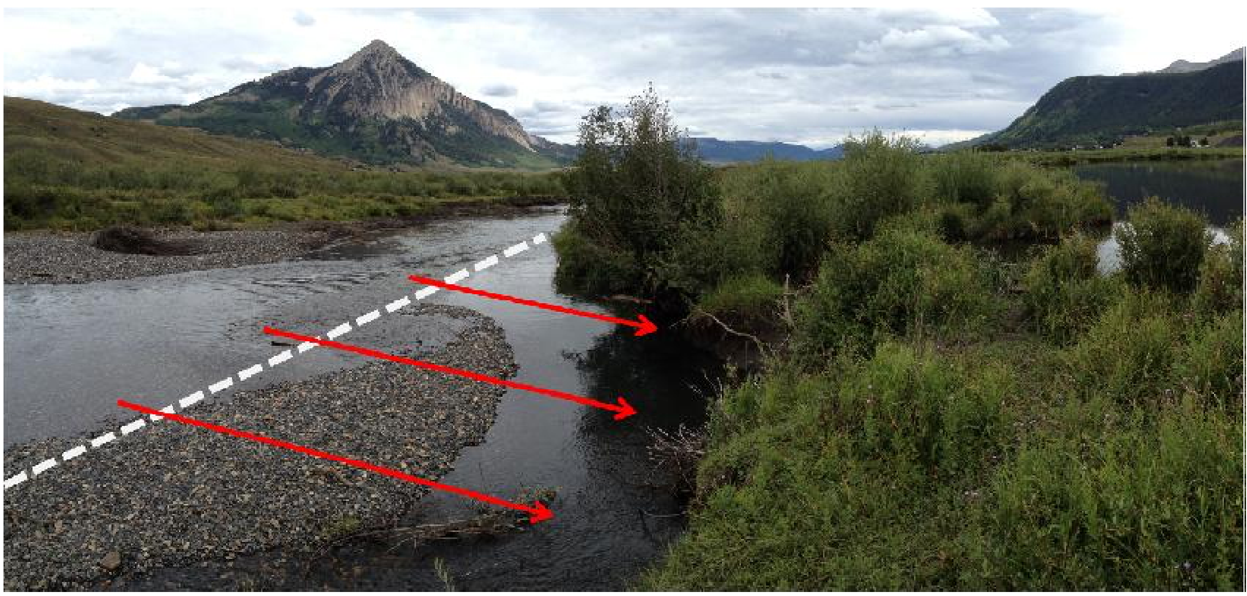


Figure 9: Concentrated energy along the back side of the bedrock ridge (dashed line) is increasing scour of the bed and banks on the right side of the channel causing accelerated migration towards Peanut Lake (right).

The right bank will continue to erode to the west, towards Peanut Lake. The width of the land between the river and the lake at this point is only 6-10 feet, an amount that could easily be eroded in a single high flow event, especially if scour were increased further by the chance deposition of a log jam, debris jam , or failing beaver dam.

Beavers complicate the issue. It is certainly true that the lake dam would have failed long ago were it not for the constant maintenance by beavers, but the presence of the animals also brings certain risks. These beavers build dens along the banks of the river and the lake. The dam around Peanut Lake and the banks along the Slate River are lined with hollowed out beaver dens, and for better or worse, the narrow spit of land separating the lake from the river

Figure 10: Beaver dams and debris are common on this reach, and this adds to the episodic nature of bank erosion.

at the upper "close point" appears to be a favorite location. In this area, a lot of the dam material has been hollowed out by denning beavers, making it even more susceptible to erosion.

Finally, there is the issue of beaver dams in the river channel (Figure 10). Beavers routinely build dams on this section of the Slate, and these structures are critically important for maintaining many basic ecological functions. They also introduce another element of dynamicity or stochasticity to river geomorphology. These dams regularly get blown out during peak flows in the spring, and when this happens, near one bank or the other, there is often a great deal of bank erosion as the river works its way around the dam. These are perfectly natural processes that actually have value in the system. But it is also another factor to consider in assessing the likelihood of a Peanut Lake breach since it is a mechanism for rapid bank erosion. An ideal solution for protecting Peanut Lake would allow for these natural processes to continue to occur.

We mentioned earlier that beavers are critical for maintaining the natural dam and banks of Peanut Lake. This has to do with the second potential mechanism of failure leading to a breach which is the failure of the dam and subsequent erosion caused by evacuation of the lake. Water continually flows over and through the dam from the lake to the river in multiple spots, including the two "close points." Should this flow ever become concentrated into a channel through the dam, it could easily erode the dam and cause a large breach in a very short order of time (days). By constantly surveilling the dam and patching small areas that concentrate flow, beavers are naturally wired to prevent this from occurring. Loss of beavers from the site, by disease or trapping or whatever means, would greatly increase the vulnerability of the lake.

Consequences of a Breach (Risk Hazard)

The most important consequences of a breach include (1) the release of contaminated lake sediments to the river system, (2) the impacts of erosion and sediment production caused by a breach, and (3) the shrinkage of Peanut Lake that would happen if the natural dam is broken.

The previously cited REI (1996) report was undertaken specifically to evaluate the water quality consequences of a lake breach. By comparing Peanut Lake to Nicholson Lake as a control, they verified that the Peanut sediment does indeed contain elevated amounts of potentially toxic trace metals such as aluminum, cadmium, chromium, and Zinc.

They did, however, explain that these metals were bound as solids that would not become released into solution unless pH of the water drastically dropped (became more acidic). That is, release of the metals into a toxic form would require severe acidification, which they concluded is highly unlikely. They concluded that the mine drainage into Peanut Lake was not significantly acidic and that the buffering capacity of Peanut Lake was sufficient to resist a major shift in pH. They also looked at the pH of waters downstream from Peanut Lake on the Slate and East Rivers and found them to be generally alkaline, which means that metals should remain bound to sediments even if they are released to the river system (Table 8). The conclusion of this report is that the release of water and sediment from Peanut Lake to the river following a breach would probably not have drastic consequences to water quality downstream.

Analyte	Peanut subject	Nicholson control	% increase
Al	19000	1400	1357%
Cd	1.2	<0.4	>300%
Cr	8.4	2.8	300%
Cu	10.8	4.8	225%
Mn	63	55	115%
Mo	0.7	0.4	175%
Zn	137	10	1370%

Table 8: Metal concentrations in Peanut Lake sediment (subject) compared to those in Nicholson Lake (control) as reported in REI 1996.

Another consequence of a breach is the geomorphic impacts that would occur if a large amount of sediment was released to the river system. A lake breach would probably be a catastrophic failure in the sense that once the breach started, it would likely proceed all at once. A large volume of sediment, on the order of tens or hundreds of cubic yards, would be produced from the erosion of the dam in addition to the release of lake sediments, and sudden release of that volume into the river system may have consequences such as filling pools and beaver pond habitat, aggrading or embedding the streambed, and exacerbating bank erosion on reaches downstream. The magnitude of these effects is difficult to predict. We suspect that there would be temporary impacts (range of 1-5 years), but that we would not likely see serious long-term effects (>10years).

Finally, and probably most importantly, are the ecological and societal values of Peanut Lake as it is. A breach would result in shrinkage of the lake as water levels drop to match the elevation of the river. Our data show a difference of up to 3.8 feet in the height of the lake and water surface of the stream at low flow. A full breach would cause the level of the lake to drop by about that much. REI (1996) report that the average depth of Peanut Lake is 3-4 feet, so a breach would mean a substantial decrease in size of the lake and conversion of much of the lake area from open water to wetland or upland habitat. Beyond the lake itself, this water level drop would significantly impact neighboring wetlands dependent on Peanut Lake as a water source. Surprisingly, there does not appear to be a minimum lake level water right associated with Peanut Lake, so there may not be a legal imperative to save the lake from a water rights standpoint, but the ecological and societal values of a full lake are a strong incentive. Natural lakes are rare in this region, so the loss of any amount of natural lake habitat is noteworthy from an ecological point of view. The societal value of Peanut Lake is also very high, particularly for the scenic and recreation values. Threats to these values are probably the greatest consequences that would result from a breach.

Risk Assessment Summary

We can now apply these analyses to a basic risk matrix (Table 9) to help stakeholders make a rational and informed decision about whether or how to proceed with the protection of Peanut Lake by reducing risk of a breach. This decision is largely an exercise in applying the analyses of likelihood and consequences to understand our relative position in the matrix.

The categories for likelihood and consequences are very subjective, and ultimately the stakeholders will have to define these categories in terms that make most sense to them. For starters, we suggest that the consequences of a breach are in the moderate category. It seems that none of the effects of a breach would result in widespread long term habitat destruction, water quality issues, or property loss. There would be some negative impacts to the river, but probably nothing that would qualify as "major". On the other hand, partial loss or severe shrinkage of Peanut Lake would be a major loss of societal value in addition to the loss of rare and valuable natural lake habitat. Certainly these push the consequences beyond the "minor" category.

Likelihood	**Consequences**		
	Minor	Moderate	Major
Likely	(yellow)	(red)	(red)
Possible	(green)	(yellow)	(red)
Unlikely	(green)	(green)	(yellow)

Intolerable Risk. Immediate action required.
Moderate Risk. Take action to reduce risk as practical.
Acceptable Risk. Normal precautions, monitoring

Table 9: Risk matrix linking likelihood (exposure) and consequence (hazard) to determine the need for action.

Assessing likelihood in this case is largely a matter of defining the time scale of interest. It is unlikely that a breach will occur in the next month, but almost certain that it will happen in the next 100 years if nothing is done to protect it. It is possible that the breach will occur in one year, and likely that it will happen in 20. Given the CBLT mission to protect and preserve resources of their properties in perpetuity, or at least over generational time scales, we suggest a longer time frame. Assuming a time frame of 50 years, we would place the likelihood of a breach at the extreme end of the "likely" category. This places us in the top row and center column of the matrix, in the "red zone" which indicates a level of intolerable risk and a recommendation for immediate action (Table 9).

Options for Risk Removal, Prevention, and Reduction.

When making recommendations about taking action to limit or manage risk, professionals describe options in terms of removal, prevention, and reduction. These options are considered sequentially starting with removal. Removal of risk implies actions that can remove the risk altogether, and we can see no realistic measures that could be taken to do this short of totally moving the river off of the property, which is impractical.

Prevention implies measures that can be taken to reduce the likelihood of a breach, and there are several practical prevention measures that could be considered. One could take an engineering or structural approach to prevention by reinforcing the dam and stabilizing the river to keep it from moving. This would reduce the likelihood of a breach by eliminating the reliance on beavers to maintain the dam and by decreasing the chance that the river will migrate towards the lake. This solution would be very expensive and contrary to the conservation mission of CBLT which seeks to protect natural ecological processes. It is therefore not a practical or desirable solution.

An ecologically preferable prevention measure would be to relocate a short segment of the river and move it slightly to the east to create a wetland floodplain buffer between the lake and the river. The design presented in this report is based on this strategy. It is a practical solution that also meets the desires of CBLT to improve river and wetland functions while reducing the most imminent threat of a breach, which is erosion of the dam by the river. Obviously, there is still some exposure to a breach that would occur if the beaver dam fails catastrophically, but so long as the beaver population is present and active, the chances of this happening are slim. On this front, we recommend that CBLT engage citizens to monitor the extent and health of the beaver population in and around Peanut Lake to serve as a sort of "warning system."

Finally, we may consider options for reducing the severity of the consequences of a breach. Reduction measures are often taken as an alternative to prevention when the level of risk is deemed acceptable, but it can also be done alongside prevention when there is still some likelihood that the harmful event could happen. One thing that could be done to reduce water quality impacts of a breach would be to monitor pH of the lake to provide a warning if the waters begin showing signs of increasing acidity. If it is found that the lake is becoming acidic, then remediation steps can be taken to buffer it so that metals will remain chemically bound to sediment.

Restoration Plan

Goals

This section describes a restoration plan for the Peanut Lake Reach on CBLT property that aims to meet the following goals:

1. Reduce the likelihood that the river will breach Peanut Lake
2. Improve functional condition of the Slate River on the Peanut Lake reach
3. Restore 1.8 acres of riparian wetland
4. Improve functional condition of 5.3 acres of riparian wetland

Key Features of the Plan

The plan (Figure 11) is to relocate a short segment of the river to create a riparian wetland bench between the river and Peanut Lake. Most of the berm on the left side of the river will be removed and restored to wetland habitat. In this section, we describe some of the key features of the plan and accounting to evaluate costs and benefits. Details of the restoration design are outlined in Appendix 4.

River Realignment

Morphological design criteria for the new channel was taken from the neighboring reference reach (see Appendix 2) according to the principles of natural channel design (NCD). Because the reference reach and the project reach share similar hydrology, the morphological parameters of the reference reach can be directly applied to the project reach without scaling to a new effective discharge or hydrologic regime. Channel morphology design parameters and reference reach values are described in Appendix 4. The proposed channel realignment involves excavating a new channel through existing wetland and upland areas (Figure 11). Approximately 0.6 acre of wetland will be relocated from the proposed channel area to the existing channel area in this process.

Temporary Stabilization Measures

This design requires very little specialized bank or channel stabilization. The planned alignment is such that all of the banks along outside bends are set against areas with appropriate floodplain elevation and dense riparian vegetation. That is, we will be moving the channel to areas where bank strength is already optimal. Furthermore, the gentle meanders planned for the reach have very high radius of curvature in order to minimize the amount of lateral scour. A further preventative measure will be taken by shaping the channel so that the thalweg is towards the center of the channel, at least 20 feet away from the bank on the outside bend.

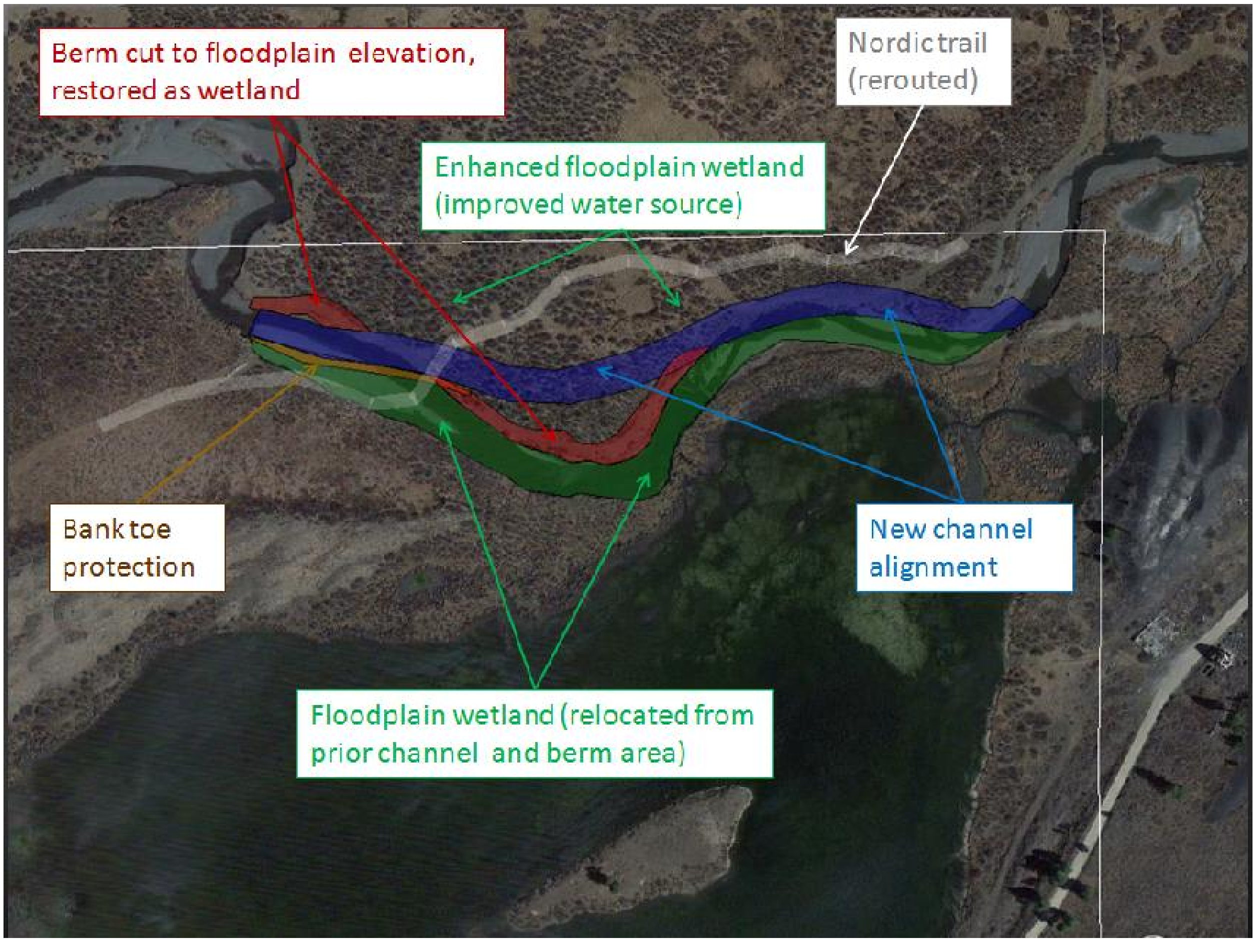


Figure 11: Restoration design for the Peanut Lake Reach involves realignment of the river with a short segment of bank toe protection, removal of the berm, restoration of floodplain wetlands including vegetation plantings, and realignment of the Nordic ski trail on the property.

The channel bed shape will adjust naturally within a few seasons, but this will allow for at least one season of minimal stress against new banks.

There is one 400-foot long bank segment that will require temporary bank stabilization where the new channel originates. At this location, the right bank of the new channel will be set against sod fill material within the existing channel area, so a treatment is needed to protect that new fill for at least 2 seasons. This will give the vegetation time to become established and anchor itself. Along this segment, we will armor the toe of the new sod bank using either large woody debris or native cobble-sized rock. If a local source of wood is available, the wood toe would be the preferred option. The design goal for this treatment is to protect the new bank from excess scour for 2-3 seasons without introducing any permanent structures or materials that the river cannot transport over time.

Berm Removal

One of the main objectives of this project is to remove the berm which is the source of most of the impairment to the reach and adjacent wetlands. A major focus of this design is to do this in a practical and cost-effective way that leaves us with a functioning river reach and wetland area. Simply excavating the berm material to grade and hauling the material away is not a viable option for several reasons. First, hauling this material off site would be very expensive and difficult, requiring the construction of temporary haul roads and access through neighboring properties for dozens of loaded haul trucks. Second, berm removal is more than simply taking off the high material to match grade. Restoring wetland to the area requires over-excavating 1-2 feet to reestablish a characteristic soil horizon and appropriate vegetation. Our solution is to use the excess berm material on-site to facilitate channel realignment. The upper (northern) portion of the berm area will be restored as part of the riparian wetland. The lower (southern) portion will be converted to channel area under the proposed new alignment.

Floodplain Restoration

Another major feature of the plan is to create a fully functioning floodplain area on the right side of the river to serve as a buffer between the river and the lake. Moving the river to gain this width requires excavating the new channel through 0.6 acre of existing wetland, but we intend to recreate the same amount of wetland within the existing channel and in the footprint of the berm by transplanting excavated wetland soil and vegetation as very large intact sod lifts. In addition to the excavation and placement of sod, the plan calls for planting additional vegetation including approximately 1000 small containerized willows and about 2500 containerized sod plugs to enhance vegetation cover on gravel bar areas and along the toe-protected sod bank. The net effect will be an increase in both the amount and functional condition of wetlands which is outlined in the next section.

Nordic Ski Trail Realignment

River and wetlands restoration requires relocation of the Nordic ski trail from its present location. We identified a new alignment for the trail that makes use of existing grass patches to minimize the amount of impact to shrubs. Some parts of the new alignment will require trimming willow shrubs.

Quantifying Benefits

The aim of this section is to account for the benefits of restoration in terms of ecological function and reduced risk of a Peanut Lake breach.

Reduced Risk of a Peanut Lake Breach

This project would reduce the risk of a breach by significantly decreasing the *likelihood* that a breach will happen. The project will significantly lessen the level of exposure by creating a natural riparian floodplain buffer between the river and Peanut Lake. The plan increases the distance between lake and river from 6 feet to 180 feet at the critical location, with a minimum distance of 115 feet between the lake and the bank of any outside bend. In addition to the added buffer width, the rate of bank migration towards the lake will also be significantly decreased since the causes of erosion along the right bank will be significantly lessened. Specifically, the banks of the new channel will be lower relative to bankfull since the channel will no longer be adjacent to the elevated lake dam and also because the new channel will not be incised. Bank stress will also be decreased by opening up floodplain connectivity on the left bank, allowing high flows to spread rather than build up increasing stream power within a confined channel. Finally, by moving the river back to the opposite side of the bedrock ridge, accelerated erosion that is presently caused by scour caused by that ridge will be eliminated.

At present, it is very likely that a breach will occur within the next few years because the river has come so close to the lake and because it is obviously actively eroding the natural dam surrounding the lake. Using the terminology from the risk matrix (Table 9), it is almost certain that a breach will occur in the next 50 years if nothing is done. If the project is successfully implemented as planned, the likelihood of a breach within the next few years will be extremely low, and the likelihood of it occurring within the next 50 years would be significantly reduced.

Reducing the risk of a breach is a clear benefit, and one that we assume is worth the costs of the project. Additional ecological benefits, described below, may be viewed as extra gains.

Ecological Benefits: Functions

As a restoration community, one of the biggest criticisms we get is that we rarely quantify the benefits of a project in any meaningful way. It is a valid critique since, more often than not, the value of any particular project is described in vague terms rather than measureable results. This makes it difficult for stakeholders to evaluate the relative value of different projects and approaches. Our aim in this section of the report is to describe the expected ecological benefits of the Peanut Lake project in quantitative terms using the tools that are being developed for the federal compensatory mitigation of aquatic resources program in Colorado. The terms and methods of these tools should also be familiar to the permitting agencies, such as the US Army Corps of Engineers, that will ultimately have to evaluate this project from a regulatory standpoint.

Ecological benefits (ecological lift) may be quantified in terms of increased ecological function which can be made by improving the amount or the quality of habitat. Quantifying benefits using a functional assessment method provides a rational and transparent justification for how functional improvements will be made as well as a way to quantify those functional gains. This analysis is valuable so that stakeholders and decision-makers can have figures upon which to base decisions and cost-benefit analysis, rather than relying on vague concepts of "ecological improvement." Also, by specifically outlining how functional gains are made, the method provides a guideline for establishing success criteria and a monitoring protocol that can be used to validate functional improvement over time. A detailed monitoring plan designed to test the effectiveness of the project is described in the next section of this report.

Functions are the physical, chemical, and biological processes that occur in ecosystems[1], in this case streams and wetlands. Conserving aquatic resource functions is the primary objective of §404 of the Federal Clean Water Act and the reason for stream and wetland regulation. Though this project is a *voluntary* aquatic resource improvement effort, the tools used in quantifying functions for *compensatory* mitigation can be applied as an accepted measure of improvement. The FACStream and FACWet functional assessment methods that are used in this study were specifically designed to quantify aquatic resource functions in the federal compensatory mitigation program.

Stream Functional Units (SFU)

The currency used in accounting for functional impacts or improvements is functional units. which is the product of the amount of habitat and its relative ability to function. For streams it is Stream Functional Units (SFU).

For rivers and streams, the amount of habitat is quantified as the valley length of the reach (L), and this is measured as the distance along the centerline of the valley or the belt width of a meandering stream through a site. For this project, the value is 1300 feet (Figure 12).   Quality is quantified by a term called the Functional Capacity Index (FCI).

$$SFU = L(FCI)$$

Equation 1: The general equation for stream functional units (SFU) is length (L) times functional capacity index (FCI)

which is calculated directly from the condition score in FACStream to represent the overall functionality of the reach (from 0-100%) using Equation 2.

$$FCI = -\left(\frac{Condition\ Score}{50} - 1\right).$$

Equation 2: General equation for converting FACStream

Figure 12: Valley length is used to calculate functional units for stream habitat, shown as the yellow line which measures 1300 ft.

[1] This is the definition used in the Federal Register 40 CFR Part 230, 2008, Final Rule on Compensatory Mitigation for Losses of Aquatic Resources.

condition score to FCI.

The FACStream condition score for the Peanut Lake Reach is 81 (B-), giving an FCI score of 0.62. Thus:

$$= \; = (1300\ )(0.62) = \; 806$$

Equation 3: SFU calculated for the present condition of the Peanut Lake Reach.

The functional improvement, or ecological lift, provided by a project is the difference in the amount of functioning on the reach before and after the project is completed, measured as the difference in SFUs (Δ SFU) (Equation 3).

$$\approx \Delta = \; -$$

Equation 4: General equation for ecological lift of a project using SFU.

When planning a project, as we are doing now, the actual number of functional units for the "after" condition obviously cannot be measured directly, so we have to rely on predictions for these values. Valley length does not change, but in our case the FCI should be increased from the before to the after condition. Predicting FCI for the "after" condition is a matter of applying the expected affects of project treatments to each of the individual FACStream variable scores and then calculating the resultant condition score and the FCI. Table 10 shows the results of this analysis for the proposed project according to the restoration plan.

Using the "after" condition score from this table, we can calculate the FCI_{after} to predict the number of functional units for the reach after the project. The predicted value for FCI_{after} is 0.78, therefore:

$$= \; = (1300\ )(0.78) = \; 1014$$

Equation 5: SFU calculated for the predicted post-project condition of the Peanut Lake Reach.

The expected amount of stream functional lift for this project is the difference in SFUs between the before and after condition.

$$\approx \; - \; = 1014 - 806 = 208$$

Equation 6: Expected stream ecological lift for this proposed project, in SFU.

If the project meets success criteria, we predict an increase of 208 SFUs (stream functional feet). That is, functional improvement is equal to the amount provided by 208 feet of fully functional river.

Table 10: Accounting for the predicted effects of restoration on individual FACStream variable scores and composite FCI for the proposed project on the Peanut Lake Reach. Post-restoration variable scores reflect the expected result of treatments based on removal of stressors.

			Existing condition		Post-restoration		Net change
Scale	Variable		Score	Grade	Score	Grade	Score
Watershed	V_{hyd}	Water Supply	94	A	94	A	0
	V_{sed}	Sediment Supply	91	A-	91	A-	0
	V_{chem}	Chemical Supply	73	C	73	C	0
Riparian	V_{veg}	Riparian Vegetation	75	C	88	B+	13
	V_{deb}	Debris Supply	87	B+	92	A-	5
Reach	V_{morph}	Morphology	77	C	90	A-	13
	V_{con}	Floodplain Connectivity	72	C-	93	A	21
	V_{stab}	Stability and Resilience	80	B-	93	A	13
	V_{str}	Physical Structure	86	B	93	A	7
	V_{bio}	Biotic Structure	74	C	76	C	2
		Condition Score	81	B-	89	B+	8

It is important to recognize that the calculation of ecological lift is based directly on the difference in FACStream variable scores before and after the project. The variable scores in our predicted FACStream assessment of the "after" condition must reflect actual effects of treatments which can be expressed as the documented relief from stressors (Level 2 - rapid assessment) or predicted change to specific metrics or indicators (Level 3 - quantitative assessment). Note that these predicted "after" scores also represent target values, or success criteria, that can monitored after the project is complete to validate compliance, which is the subject of the next section of this report.

Wetland Functional Units (WFU)

A similar analysis may be made for wetlands using wetlands functional units (WFU), but first to eliminate any confusion, stream and wetlands functional units are different and not interchangeable. For wetlands the "amount" factor is a measure of area, expressed in acres, and the "quality" factor is the FCI score calculated by FACWet. Our study site presently contains 7.3 acres of potential or historic wetland area including 0.2 acres that we assumed to be in an unimpaired condition (FACWet score of 95, A), 5.3 acres in mildly impaired condition (FACWet score of 81, B-, determined in previous section), and 1.8 acres that is now upland (FACWet score of 50, F). After restoration, the area will contain 7.3 acres of wetland of relatively homogenous quality (FACWet score of 91, A-). Thus, the "before" condition requires a separate FCI score for each of the three categories, while the "after" condition can be effectively represented with a singular FCI. The predicted FCI value of 91 for the "after" condition of the 7.3 acres of floodplain wetlands comes from the expected condition of FACWet variables summarized in Table 11.

Table 11: FACWet variable and FCI scores for the predicted post-restoration condition of the 7.3 acres of floodplain wetlands.

Attribute	Variable		Score	Grade	Degree of Impairment
Land-scape	Variable 1:	Habitat Connectivity (Connect)	92	A	Negligible
	Variable 2:	Contributing Area (CA)	95	A	Negligible
Hydrology	Variable 3:	Water Source (Source)	92	A	Negligible
	Variable 4:	Water Distribution (Dist)	92	A	Negligible
	Variable 5:	Water Outflow (Outflow)	82	B	Mild
Abiotic and Biotic Habitat	Variable 6:	Geomorphology (Geom)	92	A	Negligible
	Variable 7:	Chemical Environment (Chem)	88	B+	Mild/Negligible
	Variable 8:	Vegetation Structure (Veg)	92	A	Negligible
		Condition Score	91	A-	Negligible/Mild

A calculation of functional units for the "before" and "after" condition is given in Table 12. To be conservative in estimating gains, we assumed reference condition and score of 95 for the 0.2 acres of wetland west of the berm and a condition score of 50 for the 1.8 acres of berm area that has been converted to upland. The score of 81 for the 5.3 acres of wetland east of the berm is the result of the FACWet assessment described earlier in this report. The predicted "after" value is from table 11.

Table 12: Summary accounting for the predicted effects of the project on wetland functional units. The total number of functional units in the "before" condition is the sum of units for the three assessment areas. The final row displays net change, or "ecological lift".

Wetland Functional Units	Area (acres)	FACWet Condition Score	FCI	WFU
Wetland area between berm and river	0.2	95	0.90	0.2
Wetland area east of berm	5.3	81	0.62	3.3
Berm area (presently upland)	1.8	50	0.00	0.0
Total (Before)	**7.3**	**N/A**	**N/A**	**3.5**
Total (Predicted After)	**7.3**	**91**	**0.82**	**6.0**
Net change	**0.0**	**N/A**	**N/A**	**2.5**

If the project meets success criteria, we predict an increase of 2.5 WFUs (wetland functional acres). That is, functional improvement is equal to the amount provided by 2.5 acres of fully functional wetland. As in the case of calculating stream functional units using FACStream, these predicted FACWet variable scores represent target values for the wetlands, and may therefore be used as success criteria to evaluate project success.

Diffuse Benefits

This analysis was focused just on the lands within CBLT property east of the river. But obviously, functional improvements do not stop at property boundaries. This project would improve condition of wetlands on adjacent properties, particularly McGill, by improving water source (Variable 3) and distribution (Variable 4). Nearby wetland areas would also benefit from improved habitat connectivity (Variable 1) following the restoration of wetlands on the site. Improvements to wetland hydrology would not extend down valley from the McGill property, however, due to the presence of a large cross-valley drainage ditch. We did not specifically calculate these diffuse effects, but it is worth acknowledging them.

Temporary Impacts

We are also obliged to mention the temporary impacts that would result from this project. Certainly, there would be a deficit in functioning for the short time while construction was underway (approximately 10-14 days). It is also true that the full benefits of the project may take several seasons to develop because it takes time for the vegetation to recover. In this project, most of the vegetation is transplanted whole, in large mats of intact soil, so the lag between construction and full benefit will be much shorter than it would be by relocating the wetlands areas using other methods. We have had experienced very rapid recovery of riparian wetlands relocated by these methods on several past projects.

Another temporary impact would be increased turbidity in river during construction. Our plan would minimize this by separating construction from river for most of the process. Nearly all of the construction can take place "in the dry." Nevertheless, there are several steps that will cause increased turbidity, particularly the stage when the river is turned into the newly constructed channel. In all, we anticipate less than 8 days of increased turbidity from construction activities. Typical river construction BMPs will also be used (Appendix 4).

Quantifying Costs

Project costs can easily be estimated from the restoration plan. Table 13 is a draft budget for completing the project according to the plan. All of the tasks would be completed by AlpineEco, EcoMetrics, and their subcontractors so cost estimates reflect our experience in other projects of similar type and scope. Site assessment and restoration design were completed as part of this study, so no additional costs are necessary for these tasks.

Permitting, construction, oversight, and vegetation costs are all directly associated with implementation of the restoration plan. The monitoring budget covers costs for field work and data analysis to complete the monitoring study described in the next section of this report. The reporting budget covers costs of completing an as-built report after construction, and annual reports to summarize results of the monitoring study and appraisal of project effectiveness. The budget does not cover any additional expenses related to administration.

Table 13: Budget estimate for project costs.

Task	**Estimated Cost**
Site Assessment	Complete
Restoration Design	Complete
Construction (excavation and labor)	$ 45,000
Oversight/direction	$ 15,000
Vegetation (material and planting)	$ 10,000
Monitoring (5 years)	$ 30,000
Reporting	$ 20,000
Total	**$ 120,000**

Monitoring Plan

We are confident that this project will result in the protection of Peanut Lake and the functional improvement of both river and wetland habitats on the property, and that these benefits can be demonstrated in a measureable results monitoring program. The following plan is developed as an objective and scientific means by which project success can be tested by monitoring the site over a five-year period.

Monitoring Goal 1: Reducing the risk of a breach

Measureable results are difficult to define precisely for this goal, at least in terms of physical deterministic parameters that can effectively represent reduced exposure or hazard (see the "Peanut Lake Risk Assessment" section of this report). For the purpose of evaluating success towards this goal in particular, however, we suggest the following criteria. If, over five years, the primary channel is not migrating towards the lake at a rate that exceeds 2.0 ft/yr at any point, and the channel shows no obvious signs of instability such as a clear trend in aggradation, down-cutting, or avulsion then it is assumed that by moving the active channel away from the lake, we have effectively reduced the risk of a breach.

Monitoring Goals 2-4: Improving ecological function of aquatic habitat

This plan includes a detailed scientific monitoring protocol to evaluate whether project goals are met. For each goal, we set a number of specific objectives that can be tested as hypotheses by comparing measureable parameters to pre-determined objective success criteria. Improvements to the stream and wetland conditions are quantified in FACStream and FACWet, as described in the Restoration Plan "quantifying benefits" section of this report (Tables 10-12). These sections describe how the ecological benefits are quantified as functional stream and wetlands units (functional feet and functional acres, respectively) from the difference in before (pre-project) and after (predicted) variable scores.

Each variable that is expected to change more than one full category (greater than 10 points) is written as an explicit objective with a very specific measure of success that is quantified in the target variable score. It is important to understand that FACStream and FACWet variables each represent complex systems or characteristics of the habitat, and thus they require some level of subjective interpretation or inference to score accurately. In general, the more precise a parameter is, the more restricted is its scope. Rarely can all of the important aspects of a whole FACStream or FACWet variable score be summed up in one physical parameter. Nevertheless, it is valuable to use very precise and repeatable physical measurements as indicators of the relevant change. For the most important objectives in this study, we define one or more physical parameters to monitored over time. For each of the ecological function goals (2, 3, and 4), the explicit objectives, physical parameters, and monitoring methods are outlined in tabular form (Tables 12, 13, and 14), along with the baseline and target FACStream or FACWet variable and FCI scores. Future analyses and monitoring reports will be organized according to these outlines.

Monitoring activities

Monitoring activities are listed below, along with a brief description

- XS surveys - There are presently 9 monumented XS (cross section) transects spanning the primary channel, and these were surveyed in 2014. XS surveys will be repeated for the as-built condition and then annually for four more years to show channel geometry changes that occur year to year. For locations where the channel is relocated off of existing transects, new transects will be set up and monumented. All of the NCD dimension parameters can be directly calculated from XS data for comparison to design criteria.
- Longitudinal profile survey - A detailed longitudinal profile was completed in 2014. Another profile survey of similar detail will be completed on the as-built channel and repeated once again after 4 years. All of the NCD profile parameters (including Bank Height Ratio - BHR) can be directly calculated from longitudinal profile data for comparison to design criteria.
- Planform parameters - Planform parameters are best measured using aerial photography. Measurement of planform
- Vegetation monitoring - vegetation will be quantified along greenlines and transects according to functional guilds. These surveys will be completed annually on the project reach and after 4 years on the reference reach to facilitate a direct comparison for both the as-built condition.
- Test banks - Approximately 15 test banks will be set up to monitor annual rates of accretion (bank migration) using bank profiles or bank pins. Accretion rates will be measured annually following construction.
- Site visits to observe high flow stage - direct observation of water distribution during runoff peak flows is the best indicator of proper function for many variables and an important step for calibrating dimension, pattern, and profile parameters to "bankfull discharge". Annual site visits will be timed to observe runoff flows on the reach, and conditions will be documented with photos and video.

Table 14: An outline of the explicit objectives, parameters, and monitoring methods for the goal of increasing river function via rehabilitation of the reach. Success criteria are derived directly from the expected change in FACStream variable scores that will occur if the project effectively ameliorates stressors.

Stream Restoration: Rehabilitation objectives, Success criteria, and Monitoring activities					
FACStream Variable	Before (baseline)	After (target)	Objective	Parameter (Success Criteria)	Monitoring
V_{hyd}	94 (A)	94 (A)	The project will have no significant affect on the condition of contributing watershed	N/A	N/A
V_{sed}	91 (A-)	91 (A-)		N/A	N/A
V_{chem}	73 (C)	73 (C)		N/A	N/A
V_{veg}	75 (C)	88 (B+)	Reduce impairment from significant to mild/negligible by restoring wetland (veg) on berm area, relocating bank to area of good vegetation	1. Cover values for veg. strata 2. Cover values for weeds, non-natives, impervious surface	Greenline and veg. transects surveys, wetland test plots
V_{deb}	87 (B)	92 (A)	Reduce impairment from mild to negligible by increasing deciduous shrub cover on left bank	1. Cover values for shrub strata 2. Cover values for weeds, non-natives, impervious surface	Greenline survey, left bank
V_{morph}	77 (C)	90 (A-)	Reduce impairment from significant to negligible/mild by re-establishing planform, channel dimension and profile to reference range	1. NCD Planform parameters 2. NCD Dimension parameters 3. NCD Profile parameters (parameters defined in appendix 4)	Planform surveys, XS surveys, Longitudinal profile, observation, photopoints
V_{con}	72 (C)	93 (A)	Reduce impairment from significant to mild by re-establishing connection to distributary channels and overbank flow, and establishing channel dimension	$Q_{overbank}$, XS-Area, BHR, distrib. activation, saturation duration	Planform surveys, XS surveys, Longitudinal profile, monitoring wells, observation, photopoints
V_{stab}	92 (A)	93 (A)	Maintain negligible impairment by restoring channel to reference geometry and condition	Minimal improvement expected	WARSSS PLA, Planform surveys, XS surveys, longitudinal profile, test banks, observation, photopoints
V_{str}	86 (B)	93 (A)	Reduce impairment from mild to negligible by establishing native vegetation and bank morphology on left bank	1.Channel dimension (shape, D/Dmax) 2. Bank profile (height, angle)	XS surveys, bank profiles
V_{bio}	74 (C)	76 (C)	Reduce impairment from mild to negligible by planting native vegetation on berm area re-establishing natural saturation regime	Minimal improvement expected	Analyze biological data as available
Condition Score	81 (B-)	89 (B+)	Goal: Increase stream function on site by rehabilitating a 1300 foot reach of the Slate River, primarily improving the conditions of riparian vegetation, morphology, and connectivity.		

Table 15: An outline of the explicit objectives, parameters, and monitoring methods for the goal of increasing wetland function via rehabilitation of 5.3 acres of existing wetland on the property. Success criteria are derived directly from the expected change in FACWet variable scores that will occur if the project effectively ameliorates stressors.

Wetlands Restoration: Rehabilitation objectives, Success criteria, and Monitoring activities					
FACWet Variable	Before (baseline)	After (target)	Objective	Parameter (Success Criteria)	Monitoring
Connectivity	85 (A)	92 (A)	Reduce impairment from mild to negligible by res-establishing 1.8 acres of adjacent wetland	Delineated wetland area on site increased by 1.8 acres	Delineation (verified with test plots)
Contributing Area	95 (A)	95 (A)	Maintain negligible impairment by not introducing any new impacts	No significant improvement expected	Observation, photopoints.
Water Source	72 (A)	92 (A)	Reduce impairment from significant to negligible by increasing floodplain connectivity with Slate River (berm removal, channel restoration)	Same as FACStream V_{con} ($Q_{overbank}$, XS-Area, BHR, distrib. activation, saturation duration)	Planform surveys, XS surveys, Longitudinal profile, monitoring wells, observation, photopoints
Water Distribution	72 (A)	92 (A)	Reduce impairment from significant to negligible by re-establishing water source and reconnecting overflow channel distributary network	1. Active distributary network 2. Water table depth < 1.0 ft for >20 days in growing season	Monitoring wells, observation, photopoints
Water Outflow	72 (A)	82 (A)	Reduce impairment from significant to mild by re-establishing water source and distribution (impairment related to drainage ditches not treated)	Minimal improvement expected	Monitoring wells, observation during high flows, photopoints
Geo-morphology	92 (A)	92 (A)	Maintain negligible impairment by not introducing any new long term impacts, reclaiming any temporary impacts	No significant improvement expected	Observation, photopoints.
Physicochemical Environment	76 (A)	88 (A)	Reduce impairment from significant to mild by re-establishing natural saturation regime (water distribution)	1.Water table depth < 1.0 ft for >20 days in growing season 2. WQ parameters as available	Monitoring wells, observation during high flows, photopoints, analyze WQ data as available
Vegetation Structure and Complexity	83 (A)	92 (A)	Reduce impairment from mild to negligible by planting native vegetaion on berm area re-establishing natural saturation regime	1. Cover values for veg. strata 2. Cover values for weeds, non-natives, impervious surface	Greenline and veg. transects surveys, wetland test plots
Condition Score	81 (B-)	91 (A-)	Goal: Increase wetland function on site by rehabilitating 5.3 acres of existing wetland, improving condition of connectivity; water source, distribution, and outflow; physicochemical environment, and vegetation.		

Table 16 An outline of the explicit objectives, parameters, and monitoring methods for the goal of increasing wetland function via re-establishment of 1.8 acres of wetland on the property. Success criteria are derived directly from the expected change in FACWet variable scores that will occur if the project effectively ameliorates stressors.

Wetlands Restoration: Re-establishment objectives, Success criteria, and Monitoring activities					
FACWet Variable	**Before (baseline)**	**After (target)**	**Objective**	**Parameter (Success Criteria)**	**Monitoring**
Connectivity	50 (F)	92 (A)	Re-establish 1.8 acres of wetland with specific condition values for FACWet variables (see target values column to left).	Delineated wetland area on site increased by 1.8 acres	Delineation (verified with test plots)
Contributing Area		95 (A)		N/A	Observation, photopoints.
Water Source		92 (A)		Same as FACStream V_{con} ($Q_{overbank}$, XS-Area, BHR, distrib. activation, saturation duration)	Planform surveys, XS surveys, Longitudinal profile, monitoring wells, observation, photopoints
Water Distribution		92 (A)		1. Active distributary network 2. Water table depth < 1.0 ft for >20 days in growing season	Monitoring wells, observation, photopoints
Water Outflow		82 (A)		N/A	Monitoring wells, observation, photopoints
Geo-morphology		92 (A)		N/A	Observation, photopoints.
Physicochemical Environment		88 (A)		1.Water table depth < 1.0 ft for >20 days in growing season 2. WQ parameters as available	Monitoring wells, observation during high flows, photopoints, analyze WQ data as available
Vegetation Structure and Complexity		92 (A)		1. Cover values for veg. strata 2. Cover values for weeds, non-natives, impervious surface	Greenline and veg. transects surveys, wetland test plots
Condition Score	50 (F)	91 (A-)	Goal: Increase wetland function on site by re-establishing 1.8 acres of wetland on areas that were previously converted to uplands by removing berm, recreating a new soil profile and re-vegetation.		

- Monitoring wells - 1-m deep monitoring wells will be installed at 4 representative locations on the re-established and rehabilitated floodplain wetlands to track the depth of the water table through the growing season. Each well will be equipped with a data-logger that is programmed to read depth to water approximately once every 6 hours from May through October.
- Delineation - a formal delineation will be repeated at the end of the monitoring period to document the extent of wetlands on the site. Test plots will be completed as necessary to perform the delineation.
- Photopoints - approximately 12 monumented photopoints will be set prior to construction, and photos from these locations will be repeated twice annually, preferably during peak flow and during the peak of growing season.
- Annual monitoring reports will be completed in a form that is acceptable to the US Army Corps of Engineers for the purpose of evaluating project success and compliance with any additional permit requirements. Additional reports and summaries may be completed for specific stakeholder needs.

Conclusion

The Slate River is adjacent to Peanut Lake and has begun eroding through the beaver-maintained dam which separates the two water bodies, making the probability of breach likely. A breach would cause shrinkage of the lake as water levels drop by several feet, and sediment from the lake bottom would be released to the river. Though the lake sediment contains high levels of several metals, it is not likely that widespread water quality issues would occur since these metals are bound in insoluble forms. Nevertheless, Peanut Lake provides rare open-water lake habitat and it is highly valued by the community. These are the major values at stake considering the breach of the lake. The likelihood of a breach is high and the consequences would be significant, so we recommend taking action to reduce risk.

This property is part of the Slate River Wetlands Preserve, and the Crested Butte Land Trust's overarching goal on it is to preserve river and wetland functioning. We completed functional assessments for river and wetland resources on the property to quantify the existing condition and to identify opportunities for improvement. The 1300-foot segment of the Slate River that runs through the study area is mildly impaired (condition score 81/100, B-) with the primary impacts being a constructed berm along the left bank and water quality issues related to mine drainage. We also assessed the wetlands east of the river and found three different categories of condition present including 0.2 acres in reference condition with negligible impairment, 5.3 acres with mild impairment (condition score 81/100, B-), and 1.8 acres that was converted to upland in the footprint of the constructed berm.

We crafted a restoration plan with the goals of reducing the risk of a breach while also increasing river and wetland functioning. Key features of the plan include realignment of a short segment of the Slate River with temporary stabilization, removal of the artificial berm, floodplain restoration, and realignment of the Nordic trail on the property. These treatments will decrease the risk of a breach by creating a wide riparian floodplain buffer between the lake and the river and reducing the erosive capacity of the river. River and wetland functioning will be increased primarily by opening up floodplain connectivity when the confining berm is removed and by vegetation treatments.

We used the framework and tools proposed for federal compensatory mitigation in Colorado as a way to quantify the functional improvements expected from the project, predicting an increase in functions equal to 208 feet of river and 2.5 acres of wetland. These predictions are based on expected increases to several key functional assessment variables. The plan includes a detailed monitoring plan that uses several quantitative indicators to evaluate whether the project meets target criteria for these key variables.

Appendix 1: Site Setting and Process Domain Details

Climatic Setting

The site and all of its contributing watershed exhibit a climate regime typical of Colorado's Central Mountains where the bulk of precipitation falls as snow in winter that is released during melt-off during spring into summer, with peak flows typically occurring in June. The amount of snowfall across the drainage varies with elevation and orographics, but in general the contributing Elk Range is a particularly wet area, by Colorado standards, with mean annual snow water equivalent ranging from around 30 inches near Gothic to about 15 inches in Crested Butte. The area is also prone to summer monsoonal patterns that can bring significant amounts of rain that sometimes last well into autumn. In years with especially strong monsoons, the Slate may exhibit secondary peaks on the river hydrograph and a corresponding elevated groundwater table, but even in big monsoon years, such as 2013, these summer/fall peaks tend to be much lower than the normal snowmelt peaks. Convective thunderstorms throughout the season are very common, and these often activate small tributary drainages to bankfull discharge or higher. The effects of individual thunderstorms on hydrology in the main Slate River valley, though, are largely attenuated, and the hydrograph spikes related to these events are generally minimal on the Peanut Lake Parcel reach.

Geologic Setting

The system is a 3rd order perennial stream in an unconfined very low-gradient lacustrine valley with small gravel bed material. The valley bottom and flood-prone area width is nearly 3000 ft, and valley slope is a mere 0.3%. This exceptionally flat, broad valley condition is the result of a terminal moraine that was left by glaciers after the last ice age just downstream from the present-day location of the Gothic Bridge. The moraine is a natural geologic valley grade control point that maintains deep alluvial or lacustrine deposits upstream. Cooper (1993) suggests that some of these deposits are up to 300 feet thick, forming a very deep alluvial aquifer. Indeed, abundant groundwater discharge is a very important water source in this valley, particularly on the valley margins where groundwater commonly daylights in springs. Peanut Lake, for instance, is supported almost entirely by groundwater discharge. Cooper's report provides additional detail on the geologic history of the valley. The main points for our assessment is that the valley is especially wide and flat, with a deep alluvial aquifer of lacustrine deposit, and that it is supported by a large amount of groundwater discharge in addition to the surface flows in the river.

Above the site, upstream from about Nicholson Lake, the Slate River valley is of a much different character. Above the influence of the terminal moraine by the Gothic Bridge, the upstream valley is a steep-walled glacial trough. In its upper reaches, the valley varies from unconfined (wide meadows) to very confined (narrow canyon). The geologic features of the contributing watershed that are most germane to our assessment include the naturally high amounts of sediment and debris (wood), along with the dynamic nature by which these are supplied to the river. Our geomorphic assessment of the watershed (AlpineEco/EcoMetrics 2012) explains these processes in more detail, including the natural geologic disturbance regimes such as large avalanches and mass erosion events like landslides and debris flows that frequent the domain.

Ecologic Setting

Cooper (1993) described the broad ecological setting succinctly: The vegetation of the Crested Butte area is dominated by big mountain sagebrush on summer dry Mancos Shale uplands. Forests occur only on steeper hillsides and coarser textured rock. Aspen and lodgepole pine forests are common where past disturbance from fire or logging has occurred, and at higher elevations engelmann spruce and subalpine fir forests dominate. The steep left (southwest)side of the valley is dense forest grading to aspen and eventually grass and shrub-land at the valley bottom. The more gradual right (northeast) side is grass and sage lands with small stands of aspen.

Riparian vegetation expands the entire width of this flat lacustrine valley and is dominated by a variety of large woody shrub species including several species of willow, birch and some spruce. In some areas, the shrub layer has been removed by people to convert wetland areas to pasture; but for the most part, the riparian vegetation in the valley is still remarkably intact, especially near the project area. Beavers are an extremely important ecological agent in these wood-dominated riparian systems, as is the dense woody riparian vegetation. Large woody debris (LWD) is common on river systems in this setting, typically transported to the river from surrounding forested hillslopes via large snow avalanches.

Natural ecological disturbance regimes include forest fire, disease, and parasites. The pine beetle is an example of the latter, which can drastically alter forest composition in a short time. Tuleremia and other mammalian disease are examples of other types of natural disturbance. Diseases that cause population crashes in beaver, for instance, may have drastic short-term consequences on the river and wetland conditions, but these systems typically recover quickly when beaver populations rebound. Fire ecology in the surrounding forests is well-understood, and the effects these have on the river and wetlands tend to be manifest in temporarily altered sediment regime and LWD supply. The importance of fire in wooded (shrubby) riparian areas is much less understood.

Reference condition

In the setting thus described, we should expect to find a natural riverine system with broad wetland area spanning the entire valley bottom. HGM classification of the wetlands is complicated by the fact that they are intimately tied, to varying degrees across the valley, to the river and/or groundwater as the water source. Purely groundwater wetlands are called "slope wetlands" while those along rivers classify as "riverine". The wetlands on this site are really a hybrid of both. Some wetland professionals use the term "sliverine" for this hybrid wetland type. At some level, the distinction may be mostly semantic since the groundwater and surface water in the alluvial system are more or less interconnected.

The typical river type in this process domain is an anastomosed (branching) channel system that is tightly connected to the floodplain with little or no entrenchment. Beavers are a key driving factor in reference streams of this type. By building dams and digging channels, beavers impound water and divert it throughout the floodplain. On similar but smaller systems, this type of beaver activity may be so complete that there is no main river channel at all, but rather a broad system of small anabranching channels and ponds. On a river the size of the Slate, however, there does generally tend to be one main river channel. Beaver dams that span this main channel are regularly "blown out" during peak flows; nevertheless, beavers are still very effective at diverting flows from the main channel and across the floodplain season-long by activating broad networks of distributary channels. As a result, the floodplain in these types of systems is typically saturated all year, and widespread wetland conditions persist. Given the naturally high sediment bedload supply from the contributing watershed, and the episodic nature of its delivery, a typically wide, even braided morphology is expected along the main channel.

Reference Stream Morphology - Rosgen Classification

Many practitioners would classify this stream type (the one just described above) as C4 in the Rosgen classification system owing to the wide meandering primary channel. To wit, a previous assessment (HRS 1995) strictly used a standard C4 reference for the reach. However, the C4 classification assumes a single-thread meandering pool-riffle form that does not take into account the importance of numerous secondary channels and branching. Technically, the presence of these channels is indicative of the D_A (anastomosed) stream morphology, according to the Rosgen classification system, even when there is one large primary channel with smaller secondary branching channels. Furthermore, we must also recognize the fact that these systems often exhibit a braided bed form in the primary channel as opposed to the pool-riffle form that is characteristic of the C type. This would suggest the D class as a potential reference stream morphology. Hence, our river system would seem to have characteristics from three separate classes, which is a bit confounding. This type of confusion is common in river classification because complex river systems often do not fit neatly into simple discrete categories. In any event, for the purpose of this assessment we stuck with a strict interpretation of Rosgen's delineative criteria and selected D_A as the appropriate reference morphology due to the critical importance of distributary channels. We are also not surprised to find braided bed forms in the primary channel in place of the standard C-type pool-riffle sequences.

Reference Stream Morphology - SEM and Montgomery-Buffington Classification

Classification in the Stream Evolution Model (SEM) is a bit more straightforward. In this model, the reference condition is clearly a stage 0 anastomosed system that is intimately connected to the floodplain. The Montgomery-Buffington system classifies rivers simply by bed form. In this system, the braided form is the most appropriate reference condition.

Reference Reach

We are fortunate to have a relatively unimpacted valley segment just upstream of the study area where the reference condition appears to be fully expressed. The reach from Nicholson Lake down to just upstream of the Wildbird Bridge serves as a perfect reference for both the river and wetland condition (Figures 12 and 13). We used morphology data from this reach throughout the assessment as a standard for comparison, and the reach later serves as an analog for stream and wetland morphology in our restoration design.

Figure A1-1 Aerial photo showing the location of the reference reach (yellow rectangle) relative to the peanut Lake reach (yellow rectangle) and the Wildbird Bridge (white arrow).

Figure A1-2: Closer views of the reference reach (left) and Peanut Lake Reach (right) show the very different condition of floodplain wetlands. As Cooper described in his 1993 report, the floodplains wetlands differ markedly upstream and downstream of the Wildbird Bridge. At the reference reach, the distributary channel network is still very much intact with hydrology supplied by overbank flows and groundwater. Floodplain conditions are much dryer on the project reach, with a disconnected distributary network, owing largely to the berm. The geometry of the primary channel is remarkably similar between the reference and project reaches.

Appendix 2: River Assessment Details

Table A2-1: FACStream summary.

Slate River	River/Stream	Date	2014-09
Peanut Lake Reach	Site/Reach ID:	Evaluators	Mark Beardsley, Jessica Doran, Dave Sutherland, Andy Herb
CBLT Slate River Peanut Lake Project	Project ID:		
1250	Reach length (Valley length in feet)	Affiliation	EcoMetrics

Score	Variable	Sub-score	Sub-variable
94	V_{hyd}	96	$V_{hyd}1$: Total Volume
H	Confidence	96	$V_{hyd}2$: Peak Flows
		93	$V_{hyd}3$: Base Flows
91	V_{sed}	94	$V_{sed}1$: Land Erosion
H	Confidence	89	$V_{hyd}2$: Channel Erosion
		97	$V_{hyd}3$: Delivery
73	V_{chem}	95	$V_{chem}1$: Temperature
H	Confidence	95	$V_{chem}2$: Organics/Nutrients
		62	$V_{chem}3$: Water Quality
75	V_{veg}	93	$V_{veg}1$: Riparian Veg.
H	Confidence	66	$V_{veg}2$: Streamside Veg.
87	V_{deb}	86	$V_{deb}1$: LWD
H	Confidence	91	$V_{deb}2$: Detritus
77	V_{morph}	88	$V_{morph}1$: Stream Evolution
M	Confidence	74	$V_{morph}2$: Planform
		72	$V_{morph}3$: Dimension
		92	$V_{morph}4$: Profile
72	V_{con}	71	$V_{con}1$: FP Access
H	Confidence	71	$V_{con}2$: FP Extent
		78	$V_{con}3$: Saturation Duration
80	V_{stab}	78	$V_{stab}1$: Dynamic Eq.
M	Confidence	86	$V_{stab}2$: Resilience
86	V_{str}	84	$V_{str}1$: Coarse Structure
H	Confidence	93	$V_{str}2$: Fine Structure
74	V_{bio}	75	$V_{bio}1$: Microbes
M	Confidence	85	$V_{bio}2$: Macrophytes
		68	$V_{bio}3$: Macroinvertebrates
		75	$V_{bio}4$: Fish/Amphibians
		95	$V_{bio}5$: Other Animals
81	Reach Condition Score		

Process Domain

Confinement	UC
Valley Slope	VL
Stream Order	3
Physographic Region	Rockies
Ecosystem	Mountains
Riparian Reference	Scrub-Shrub

Morphology

Stream Type	Rosgen	SEM
Existing	C	1
Reference	C	0

Functional scores by EPA category

Biology Functions	80
Physicochemical Functions	79
Geomorphology Functions	82
Hydraulic Functions	82

Watershed-scale Variables

V_{hyd}: Water Supply

The water supply variable rates the degree of impact to the natural amount and timing of water supply to the reach, and there are no indications that these factors are significantly altered. The watershed is undeveloped and there are no major diversions or reservoirs. The slightly depressed score (94/100, A) reflects the few operational ditch diversions present upstream of the reach and the relatively minor amounts of localized wetland loss in the upper watershed (primarily near Pittsburg). These are very minor impacts, and the water source generally appears to exhibit a natural hydrologic regime.

We estimate bankfull discharge at this site to be about 550 cfs using a regional linear relationship we developed in previous hydrologic studies in the watershed. Drainage area for the Peanut Lake reach is 37.0 mi^2, and the linear conversion is 14.9 cfs/mi^2 giving 551 cfs. This value is corroborated by hydraulic models we applied on riffle cross sections on the reach (Table A2-2). These data provide further evidence that water source is relatively unimpaired.

Table A2-2: Summary of the hydraulic methods for estimating bankfull discharge recommended for WARSSS PLA (Rosgen 2006). The valid methods show good agreement for the value of 550 cfs.

Peanut Reach. Velocity and discharge estimates for stage that match field bankfull indicators			**Velocity**		**Discharge**	
Friction Factor/Relative Roughness		$u = [2.83 + 5.66 \text{ Log } (R/D84)]U^*$	4.16	ft/s	605	CFS
Roughness Coefficient: Manning's n =	0.024	Mannings n from R/D84 (Limerino's curve) $u = (1.4895 \cdot R^{.667} \cdot S^{.5})/n$	4.25	ft/s	618	CFS
Roughness Coefficient: Manning's n =	0.027	Mannings n from R/D84 (Rosgen West curve) $u = (1.4895 \cdot R^{.667} \cdot S^{.5})/n$	3.78	ft/s	549	CFS
Roughness Coefficient: Manning's n =	0.036	Mannings n from Jarrett $n = 0.39 \cdot S^{.38} \cdot R^{-.16}$ $u = (1.4895 \cdot R^{.667} \cdot S^{.5})/n$	2.86	ft/s	417	CFS
Darcy-Weisbach f =	0.070	Factor f from R/D84 $u = \sqrt{(8gRS/f)}$	3.80	ft/s	552	CFS
Gauge Analysis DA=	37.0	Q_{BKF} @ Gauge 1100; DA @ Gauge 73.4	3.81	ft/s	554	CFS

Chosen estimation method	Gauge, Rosgen West, D-W friction factor
Reason	Values agree Q_{BKF} is approximately 555 cfs. Values agree with regional relationship of 15.0 cfs/mi^2 of drainage area

V_{sed}: Sediment Supply

The sediment supply variable was also scored high (91/100, A-) owing to the lack of identifiable stressors in the watershed. Low-intensity grazing throughout the watershed and low road density present negligible contributions of sediment via land erosion. Lateral instability and channel erosion on some segments of the Slate River within the contributing watershed is high, particularly in areas near Pittsburg and Poverty Gulch, The OBJ Campground, and the Rice Parcel just upstream. Insofar as this instability is exacerbated by human causes (as it certainly is at least at Pittsburg and the Rice Parcel) the increased erosion presents some increase to sediment budget throughout the system. When viewed against the huge amount of natural sediment that annually moves through this system, these contributions are minimal if not insignificant. Tributary systems are all more or less unimpacted as well, with few signs of artificial entrenchment or gully formation.

We also noted that impacts to sediment transport/continuity through the watershed are negligible. Several stream crossings and artificial constrictions such as the Gunsight and Wild bird Bridges may slightly alter sediment transport efficiency through these segments, but there is no indication that these constrictions significantly impede large fractions of bedload or suspended sediment. They are essentially like full sediment traps. Overall, the sediment regime on the Peanut Lake reach appears to be more or less natural.

V_{chem}: Chemical Supply

The chemical condition of waters on the reach are assessed by considering three subvariables: (1) temperature, (2) organics/nutrients, and (3) inorganics. The temperature and organic/nutrient subvariables were both scored in the highest category (95/100 - A+) indicating no impairment, or reference condition. The only small impacts in these categories are a slightly diminished amount of shading and perhaps some lack of groundwater exchange affecting temperature, and some small increase in nutrient source from livestock. These stressors are minor, however, and overall impact is negligible.

The third subvariable considers water quality related to inorganic compounds like metals. Here, there are some definite problems that stem from mine contamination. This reach of the Slate and its tributaries are on the state 303d list as a high priority for elevated Zinc and Cadmium. Oh Be Joyful Creek, is a high priority for Zinc, Cadmium, Lead, and Copper, with pH also listed as a concern in Redwell Creek. According to the most recent draft of the Upper Slate River Watershed Plan (Bembeneck, in prep), mine drainage from Redwell Basin is the source of 85% of this contamination. These facts support a score of 62/100, or D-, for this subvariable reflecting severe impairment.

In FACStream, the overall score for the variable is calculated from these three subvariable scores to give a final rating for the V_{chem} variable of significant impairment (73/100, C), and in this case, the overwhelming cause of impairment appears to be quite clearly indicated as the mine drainage from Redwell Basin.

Riparian-scale Variables

V_{veg}: Riparian Vegetation

Riparian vegetation is remarkably intact throughout most of the Slate River valley. In the Colorado Mountains, there are few other wide, low-gradient river valleys like this that have escaped the pattern of widespread willow (shrub) removal and the conversion of riparian area to grassy pastureland the way the Slate has. Nevertheless, the valley does contain some acute areas of vegetation impact, and unfortunately one of those areas is focused along the left bank of the Peanut Lake Reach where a 20-ft wide berm and road were constructed alongside the river. The elevation of the berm is high enough above the river and the surrounding water table, that hydrophytic plants are have not established. The nature of the fill material (mostly compacted fine gravel) is also not conducive to plant growth. As a result, the vegetation on the berm is sparse and mostly xeric. (Figure A2-1)

Figure A2-1: The berm is constructed mostly of compacted gravel and is about 1.5-2.5 higher than surrounding floodplain area, making it difficult or impossible for riparian vegetation to establish. As a result, the vegetation on the berm is sparse and mostly xeric. Vegetation to the right of the berm and on the other side of the river is more typical of a healthy riparian area.

The berm also has the effect of limiting water transport from the river to the adjacent floodplain. The dryer conditions on the back side of the berm is causing a subtle shift in species composition and plant condition in this area which became evident during the wetland delineation. There is a distinct gradation of plant types as one goes from the greater floodplain to the areas near the berm reflecting the dryer and more disturbed conditions there.

The berm (fill material) is far and away the most significant stressor to riparian vegetation due to the direct effect of fill and surface disturbance and its impact on decreasing floodplain connectivity, but the effect of drying may be exacerbated by channel incision. Previous studies suggested that this reach had down-cut as much as a few feet leaving the channel deeply incised. Our geomorphic data, however, do not indicate a high degree of incision due to bed cutting (see later sections), so any additional stress due to this factor on vegetation is probably minimal.

A few additional stressors to riparian vegetation are the direct affects from livestock grazing and clearing/brush-cutting to accommodate the nordic ski trail that passes through the riparian area. The nordic trail impacts amount to a 15- to 20-ft wide band that is cleared of shrubs. Grazing impacts are reflected in a subtle shift in species composition across the site. It appears that grazing pressure is presently light, and has been for at least several years. We estimated that about 15% of the herbaceous layer was made up of non-native or invasive species, with a few occurrences of noxious weeds. These are relatively minor stressors that do not cause a great deal of impairment to riparian vegetation condition compared to the major stressors described above.

The condition of vegetation across the entire riparian area is scored (93/100, A) owing to the fact that cover values for the three vegetation layers (herbaceous, shrub, and tree) are very similar to reference condition. However, when focused on the streamside vegetation, the score is much lower (66/100, D) due to the acute impacts of the berm. The overall rating for the riparian vegetation comes out to 75/100, C, indicating is significant impairment.

V_{deb}: Debris Supply

Large woody debris (LWD) is an important structural component of the Slate River system. Wood deposits and log jams are responsible for a good portion of the pool habitat, structural diversity, and channel dynamics on the Slate. LWD is regularly delivered to the river from surrounding hillslopes via snow avalanches and other processes, and these materials are transported across riparian areas and downstream during peak flows and floods. The watershed is generally only sparsely forested so the volume of LWD is not particularly high compared to systems in densely forested areas, but this appears to be the natural condition. That is, there is no indication that logging or other deforestation land uses limit the amount of large wood available. The only significant impacts to LWD supply we observed are the artificial obstructions to LWD transport such as the Gunsight and Wildbird bridges, and the physical removal of wood from the river for maintenance which was observed at OBJ campground and is probably necessary at the bridge constrictions and road crossings. Based on these minor stressors, LWD source is rated as mildly impaired (86, B).

The primary importance of detritus on the Slate River is in energetics. Detritus is the energy source that forms the base of the food chain, but it also plays a role in the formation of fine structure such as leaf packs and brush deposits. Riparian vegetation condition is generally good within the fetch area and throughout the watershed except along the left bank from the Rice Parcel down, and in particular deciduous tree and shrub cover is good which is most important source of detritus. Another important factor is that beavers are present and active since these animals are important in facilitating the delivery of detritus material from riparian areas to the river. Detritus source is rated as unimpaired (91/100, A). Debris source is therefore rated as mildly impaired (87/100, B).

Reach-scale Variables

V_{morph}: Stream morphology

Stream morphology on the Peanut Lake Reach is best described as a slightly entrenched, single-thread, high W/D ratio C-type channel with very low sinuosity that is in fact almost straight. The bed form is planar tending towards braided, with large elongated bars, and few small pools that exist only at scour points. Direct physical impacts are the primary stressors affecting morphology, with past in-channel mining, construction of a berm and road on the left bank, and consolidation of higher-than-bankfull flows into a single channel being of the greatest influence. Loss of bank strength due to impaired riparian vegetation on the left bank also causes lateral instability and accelerated bank erosion which may be a cause of channel widening and enlargement. Moderate decrease in LWD supply is another mild stressor.

The channel does not appear to be in an active state of evolution, or drastic change. Historical aerial analysis going back to 1955 and comparison of the channel condition to that in photos from 1995 show it to be relatively stable. The reference morphological state is described as a slightly incised C-type channel with a tightly connected network of distributary channels in stage 0 of the Stream Evolution Model (SEM). Whereas, the existing condition is a similar channel type without the connected distributary system. This makes scoring this subvariable difficult. FACStream scoring guidelines indicate a score in the 70s for a shift from stage 0 to 1, which is reasonable, yet the change in this case does not appear to be the result of an evolving or changing channel but one that was caused by direct physical manipulation by people. For this reason, we scored the evolution subvariable as mildly impaired (88/100, B). The slightly depressed score represents the moderate degree of incision observed on stream cross section surveys which is presumably the result of channel adjustments following the in-channel bed excavations for gravel mining that occurred in the past. The relevant morphological changes that accompanied the directly manipulated shift from stage 0 to 1 are accounted for in other subvariables that follow.

The greatest impairment to planform is the loss of connected side channels and overflow swales. An essential characteristic of the reference condition (which is also readily observed on the applied reference reach) is the presence of a broad network of side channels and distributaries connected to the main channel. We classified the reference condition as a C-type channel because in the Rosgen classification there is not an easy way to account for the importance of anabranching channels. When there is one dominant channel, as in this case, most practitioners default to the single-thread channel description (C or E) rather than classifying the stream as anastomosed (D_A or D_B). However, the presence or absence of anabranching side channels is critically important river function, and an equally valid classification of this stream type could be D_B (anastomosed with biotic control). These issues are largely semantics of classification. The salient point is that the network of distributary channels present in the reference condition is absent on the Peanut Lake reach (Figure 11). This is best understood as a shift from stage 0 to 1 in the SEM.

If we turn our attention to the primary channel only now, we see that the planform morphology of the study reach is not much different from reference. Reference reaches show a remarkable range of variability for all planform variables, and the values for the Peanut Lake Reach fall within these ranges in all cases. (See Table A4-1 in Appendix 4). Planform morphology is rated as significantly impaired (74/100, C). By and large the source of impairment to planform lies in the loss of a distributary side channel network. Otherwise, the primary channel exhibits a characteristic pattern.

Dimension is also significantly impaired (72/100, C-) reflecting the artificial entrenchment of the channel on this reach, which is evident in the elevated bank height ratios (BHRs) measured here. In this regard, our assessment agrees with previous studies (Cooper 1993 and HRS 1995), but our XS surveys show that the main cause of entrenchment is the constructed berm rather than degradation of the river bed. Entrenchment ratio (ER) is not a good indicator of entrenchment in this case, since it is only sensitive to gross changes in entrenchment that exceed a certain (very high) threshold that is (fortunately) not met on this reach. Values for other dimension parameters such as width (W), width-depth ratio (W/D), and area (A) are not significantly different from reference reaches. (See Table A4-1 in Appendix 4).

River profile is only mildly impacted on the reach (92/100, A). We identified a few potential stressors that could affect localized bed slope and features such as the marginally diminished LWD supply, but we have no quantitative evidence to support any significant impairment of profile.

These subvariable scores combine to give an overall assessment of significant impairment (77/100, C) for morphology of the reach. The almost singular cause for this impairment is the constricted berm along the left bank which effectively cuts off any distributary side channels (planform impairment) and forces an entrenched channel condition (dimension impairment).

V_{con}: Floodplain Connectivity

Floodplain connectivity is significantly impaired on this reach (72/100, C-). The variable assesses how well water communicates between the river channels and the floodplain by considering stressors acting on floodplain access, width, and saturation duration. The primary stressor is, again, the berm along the left bank which cuts off any distributary side channels that would convey flows to and from the primary channel. It also raises the left bank height by as much as two feet which inhibits high flows from spilling out over the bank and onto the floodplain. Only extreme floods in excess of about 2000 cfs would be high enough to overtop the berm on this reach, compared to reference reaches which overbank at around 500 cfs.

For all practical purposes, the berm effectively prevents surface water access to most of the floodplain and keeps it contained within an enlarged channel, which, by the way, was probably the intent of the berm and the reason for its construction in the first place. Nevertheless, this floodplain decoupling has many negative consequences. Additionally, even though we observed only a small amount of bed degradation on this reach, any drop in bed elevation serves to exacerbate the problem of access of water from the channel to the floodplain by increasing bank heights. Floodplain access is rated as significantly impaired, bordering on severe (71/100, C-).

The net result of these confining features is that they limit the width of the effective floodplain to an area between the berm and the natural beaver dam that surrounds Peanut Lake. In some places, the width of floodplain accessible by normal bankfull flows has been reduced to less than 10% of its natural extent. This shouldn't be confused with the floodplain that activates during extreme events like the 100-year flood. The low frequency (high magnitude) floodplain still probably extends across the entire valley bottom, though it may be impacted by fills across the valley, particularly the elevated Wildbird road and fills along the left bank on the Rice and McGill properties just upstream. Floodplain width is rated similarly to floodplain access as significantly impaired, bordering on severe (71/100, C-).

The floodplain constrictions and limited access of flood flows from the channel results in an overall drying of the floodplain area. It is easy to see this by comparing aerial views of the project reach to the reference reach upstream (Figure 12). While the magnitude and duration of floodplain saturation is significantly diminished by these impacts, it appears to be somewhat offset by diffuse groundwater flow that maintains some level of hydration. The groundwater source must be quite strong because even multiple large drainage ditches on the neighboring McGill property have been unable to completely dry the floodplain, and as our delineation shows, some wetlands still persist. Because of this, the rating for the floodplain saturation duration subvariable is marginally higher than would be suggested by the severity of stressors. It is significantly impaired (78/100, C).

V_{stab}: Geomorphic Stability and Resilience

River stability on this reach is especially important since a goal of the project is to protect Peanut Lake which is largely a question of keeping the river from breaching it. This variable is rated as mildly impaired, bordering on significant (80/100, B-).

This variable considers two aspects to stability. The first component is the classic interpretation of stability the way it is used by Rosgen and others in WARSSS which is the ability of the reach to maintain a characteristic shape and size, over time, without aggrading or degrading. This aspect is commonly defined as the balance of sediment source to transport as symbolized in Lane's Balance. We refer to this aspect of stability as dynamic equilibrium.

Our assessment of the dynamic equilibrium aspect of stability on this reach is aided by the application of a WARSSS PLA analysis. A detailed report on the PLA results is beyond the scope of this report, but a summary of results is given in Table A2-3 below.

Table A2-3: WARSSS PLA Stability Assessment Summary.

Stability Summary	Rating	Score	Scale	Notes
Pfankuch Stability	Fair Stability	98	38-152	Stability rated as fair for a C4 channel, Poor for a D_A4
PLA Lateral Stability	Unstable	13	4-24	Primary contributing factors are bank erosion and confinement caused by the berm, plus sediment deposition.
PLA Vertical Stability	Stable	N/A	N/A	Bank heights (BHR) and entrenchment are concerns.
PLA Enlargement	Slight Increase	11	6-16	Primary contributing factors are bank erosion and confinement caused by the berm.
PLA Sediment Supply	Moderate	8	4-16	Sediment supply from bank erosion, primarily on left bank adjacent to berm.

These WARSSS results present a more moderate assessment of stability than the evaluation given by HRS in 1995, and an analysis of historical aerial photos confirms the moderate stability rating for this reach. Lateral migration is certainly evident over the past several decades, and it is clear that bank erosion is especially high along the constructed berm where there is no root density to bind bank material (Figure A2-2). Nevertheless, lateral stability and migration rates do not appear to be much different from that seen on reference reaches. Rivers of this type and landscape position are expected to move and migrate laterally, so observing this tendency is not necessarily a reflection of serious impairment. Nearly the entire amount of impairment we did note on this reach, which is significant (78, C+), can be attributed to the berm and the secondary effects caused by it such as diminished vegetation, weakened banks, and floodplain disconnect.

Figure A2-2: Bank erosion is accelerated along the left bank due to increased bank height and poor vegetation caused by the berm.

The second aspect of stability is resilience. Resilience is the capacity of the system to recover following a major disturbance, and it is critically important to consider resilience in assessing river stability since the processes that cause rivers to change happen episodically rather than gradually. That is, the accumulation of changes that take place year to year on an adjusting reach are typically small compared to the drastic changes that occur after large-scale events, or disturbances, such as major floods, forest fires, landslides, and so on.

Primary factors of resilience include the ability of the river to move and adjust, so riparian vegetation and floodplain connectivity are key, along with stressors such as channel hardening and floodplain encroachment. In this case, we have relatively good riparian vegetation across the floodplain except for near the channel edge and berm (the $V_{veg}1$ score is 93), there is excellent vegetation and floodplain connectivity upstream, and the large scale low-frequency floodplain is still relatively undeveloped. resilience is rated as mildly impaired (86/100, B).

V_{str}: Physical Structure

The primary channel on this reach is more or less a straight, plane-bed form. Most of the diversity in coarse structure is caused by beavers (their dams, ponds, caches and channels) and by scour related to LWD, strong riparian vegetation, and other natural hard points such as clay deposits or bedrock. These features are still present on the reach. The relatively homogenous plane-bed structure appears to be a mostly natural condition. Bank structure on the left side of the river is impaired because the berm erodes into a sloped bank rather than the normal condition which is a complex overhanging structure supported by vegetation. The score of 84/100, B, for coarse structure reflects the impairment caused by the berm, which inhibits the formation of scour pools and complex bank structure on that side of the river.

Fine structure is generally loose, unconsolidated, highly mobile gravel particles with almost no embeddedness. Accumulations of organic debris such as leaf packs, accumulations of small woody debris, and beaver dams are common as well. Impairment to fine structure is therefore rated as negligible (93/100, A) giving an overall score of 86/100, B, for the variable.

V_{bio}: Biotic Structure

Biotic structure can be very difficult to assess because direct observations of community structure cannot be made without rigorous sampling and analysis over multiple seasons. But characteristic native biota and trophic structure are still extremely important to many primary river functions, even though it is difficult to measure or directly observe. At the level of this assessment, our best estimate of biotic structure comes from the documentation of indirect factors such as impacts to physical and chemical habitat as well as direct impacts to specific biotic components such as game management, extirpations, invasions, etc. The primary and most obvious stressor to aquatic life on this reach is chemical contamination from mine waste (see the V_{chem} variable), and to a much lesser extent, the impairment of physical structure on the reach (V_{str}).

Other factors include the presence of aquatic invasives such as didymo, an invasive diatom, which has apparently been found in the watershed (Bembeneck 2014) but was not directly observed on the reach, and active management of game fish including the introduction and ultimate take-over of the reach by nonnative fish, stocking, and harvest. ratings for the different taxonomic groups within the V_{bio} variable are shown in Table A2-4. These scores represent the different degrees to which the various groups of organisms would respond to the identified stressors, especially water quality impairment.

Table A2-4: FACStream V_{bio} subvariable scores.

75	V_{bio}1: Microbes
85	V_{bio}2: Macrophytes
68	V_{bio}3: Macroinverts
75	V_{bio}4: Fish/amphibians
95	V_{bio}5: Other Animals
74	**V_{bio}: Biotic Structure**

Appendix 3: Wetland Assessment Details

FACWet Score Card

VARIABLE SCORE TABLE

Land-scape	Variable 1:	Habitat Connectivity (Connect)	85
	Variable 2:	Contributing Area (CA)	95
Hydrology	Variable 3:	Water Source (Source)	72
	Variable 4:	Water Distribution (Dist)	72
	Variable 5:	Water Outflow (Outflow)	72
Abiotic and Biotic Habitat	Variable 6:	Geomorphology (Geom)	92
	Variable 7:	Chemical Environment (Chem)	78
	Variable 8:	Vegetation Structure and Complexity (Veg)	83

Functional Capacity Indices

Function	Terms	Values	Total Functional Points	Divisor	FCI
Function 1 -- Support of Characteristic Wildlife Habitat	$V1_{connect}$ + $V2_{CA}$ + $(2 \times V8_{veg})$	85 + 95 + 167	346.52	÷ 4	87
Function 2 -- Support of Characteristic Fish/aquatic Habitat	$(3 \times V3_{source})$ + $(2 \times V4_{dist})$ + $(2 \times V5_{outflow})$ + $V6_{geom}$ + $V7_{chem}$	216 + 144 + 144 + 92 + 78	674.00	÷ 9	75
Function 3 -- Flood Attenuation	$V2_{CA}$ + $(2 \times V3_{source})$ + $(2 \times V4_{dist})$ + $(2 \times V5_{outflow})$ + $V6_{geom}$ + $V8_{veg}$	95 + 144 + 144 + 144 + 92 + 83	702.26	÷ 9	78
Function 4 -- Short- and Long-term Water Storage	$V3_{source}$ + $(2 \times V4_{dist})$ + $(2 \times V5_{outflow})$ $V6_{geom}$	72 + 144 + 144 + 92	452.00	÷ 6	75
Function 5 -- Nutrient/Toxicant Removal	$(2 \times V2_{CA})$ + $(2 \times V4_{dist})$ + $V6_{geom}$ $V7_{chem}$	190 + 144 + 92 + 78	504.00	÷ 6	84
Function 6 -- Sediment Retention/Shoreline Stabilization	$V2_{CA}$ + $(2 \times V6_{geom})$ + $(2 \times V8_{veg})$	95 + 184 + 167	445.52	÷ 5	89
Function 7 -- Production Export/Food Chain Support	$V1_{connect}$ + $(2 \times V5_{outflow})$ + $V6_{geom}$ + $V7_{chem}$ + $(2 \times V8_{veg})$	85 + 144 + 92 + 78 + 167	565.52	÷ 7	81

Sum of Individual FCI Scores	**569**
Divide by the Number of Functions Scored	**÷ 7**
Composite FCI Score	**81**

Figure A3-1: FACWet summary for the 5.3 acres of existing wetland east of the berm.

Landscape Variables

Var 1: Connectivity

The connectivity variable rates the degree of connection between the assessment wetland area and neighboring riparian and wetland habitats within a 500-meter radius. Disconnection, or isolation, can occur by two mechanisms including (1) the loss of neighboring wetlands or (2) separation from neighboring wetlands due to artificial barriers. Each of these mechanisms is considered under a separate subvariable. The berm is responsible for all of the impairment to this variable. The only wetlands loss within the 500-meter Habitat Connectivity Envelope (HCE) is the approximately 1.8 acres on and adjacent to the berm footprint. This 1.8 acres is less than 5% of the total area of neighboring and adjacent wetlands, justifying a rating of mild impairment (86/100, B) for the wetlands loss subvariable.

The berm is also the only significant stressor acting as a barrier to migration and dispersal. Permeability of this barrier is high for most organisms, but it comes between the AA and about 30% of the neighboring wetland within the HCE. This is mild impairment due to barriers (84/100, B). The overall rating of impairment to connectivity is mild (85/100, B).

Var 2: Contributing Area

The contributing area variable rates the impact of surrounding land use and the effectiveness of a buffer area to mitigate any negative effects to the assessment area. This AA has a mostly natural buffer area with no development within the 250 meters and very little harmful land uses anywhere near. Impairment to the contributing area variable is negligible (95/100, A).

Hydrology Variables

Var 3: Water Source

The AA relies on a direct connection to the Slate River for its water source. In the reference condition, water communicates between the wetland and the river through groundwater connections and via overbank flooding. The transfer of water via both of these routes is hampered by the berm. Channel bed down-cutting also exacerbates the issue. Impairment is rated as significant (72/100, C). Because the wetland relies almost completely on floodplain connection to the river for water source, this variable should be scored similarly to the V_{con} in FACStream which is scored 78/100. It makes sense that this score is higher because V_{con} considers connectivity on both sides of the river, and the right side (the side without a berm) is still well connected.

Var 4 and 5: Water distribution and Outflow

There are few additional stressors to water distribution or outflow on top of the impaired water source. Numerous worn cattle and game trails may have some impact on water distribution, but the effects are negligible compared to the water source impact. Thus, the ratings for both distribution and outflow are set to the maximum value attainable given the water source issues which is significant impairment (82/100, C).

Abiotic and Biotic Habitat Variables

Var 6: Geomorphology

There are few impacts to geomorphology within the AA. Again, the numerous worn cattle and game trails are about the only impact observed. Any ditches and fills on other parts of the floodplain are outside the AA. Impairment to geomorphology is negligible (92/100, A).

Var 7: Chemical Environment

The chemical environment score (78/100, C) reflects contamination of Slate River water by mine effluent and high priority 303d listing. It is unknown how much of this contamination is expressed within the actual AA, since surface water connections with the river are rare and most water is communicated through the alluvial aquifer. The other major concern with chemical environment is the degree of unnatural drying of the soil due to a diminished water source. Periods of unnatural drying and desaturation within upper soil horizons allows for aerobic respiration and the oxidation of soil components, radically changing the chemical environment of the soil and leading to mineralization of accumulated organic material.

Var 8: Vegetation Structure and Complexity

Vegetation structure is surprisingly intact within the AA, despite the amount of drying that has occurred. The rating of mild impairment (83/100, B) reflects a combined influence of several minor stressors including unnatural drying, grazing, vegetation clearing associated with the Nordic ski trail that passes through the property, and the presence of several invasive species. Note that the vegetation score for this AA is quite a bit higher than the V_{veg} score made for the riparian area in the FACStream assessment. This is due to the fact that the highly impaired berm area is included within the area assessed in the FACStream V_{veg} variable, but outside the AA for this FACWet assessment. The berm area is part of a separate 1.8 acre wetland area which has been completely converted to upland.

Appendix 4: Construction Details

Channel Morphology Design Criteria

Natural Channel Design (NCD) criteria for the pattern, dimension, and profile of the proposed new channel were obtained from a nearby stable reference reach that is in excellent functional condition (table A4-1).

Table A4-1: NCD stream morphology design criteria.

Peanut Lake Reach Planform Parameters

Parameter	Reach	Mean	Max	Min
Side channel network	Reference reaches	Extensive		
	Peanut Reach (existing)	None		
	Peanut Reach (proposed)	Reconnected		
K	Reference reaches	1.14	---	---
	Peanut Reach (existing)	1.02	---	---
	Peanut Reach (proposed)	1.06	---	---
$L_{meander}$	Reference reaches	587	837	396
	Peanut Reach (existing)	673	787	600
	Peanut Reach (proposed)	563	660	450
MLR	Reference reaches	9.1	14.6	7.1
	Peanut Reach (existing)	9.3	10.9	8.3
	Peanut Reach (proposed)	9.0	10.6	7.2
$W_{meander}$	Reference reaches	169	290	110
	Peanut Reach (existing)	187	240	140
	Peanut Reach (proposed)	151	170	120
MWR	Reference reaches	2.9	5.2	1.9
	Peanut Reach (existing)	2.6	3.3	1.9
	Peanut Reach (proposed)	2.4	2.7	1.9
R_C	Reference reaches	323	666	103
	Peanut Reach (existing)	309	600	90
	Peanut Reach (proposed)	385	600	260
R_C/W	Reference reaches	7.1	11.6	3.6
	Peanut Reach (existing)	4.3	8.3	1.2
	Peanut Reach (proposed)	6.2	9.7	4.2

Peanut Lake Reach Dimension Parameters

Parameter	Reach	Mean	Max	Min
W	Reference reaches	57	72	36
	Peanut Reach (existing)	73	107	56
	Peanut Reach (proposed)	62	75	50
W/D	Reference reaches	57	72	36
	Peanut Reach (existing)	73	107	56
	Peanut Reach (proposed)	62	75	50
ER	Reference reaches	25	63	9
	Peanut Reach (existing)	41	[illegible]	[illegible]
	Peanut Reach (proposed)	48	---	---
A	Reference reaches	120	---	---
	Peanut Reach (existing)	136	---	---
	Peanut Reach (proposed)	125	---	---

Peanut Lake Reach Profile Parameters

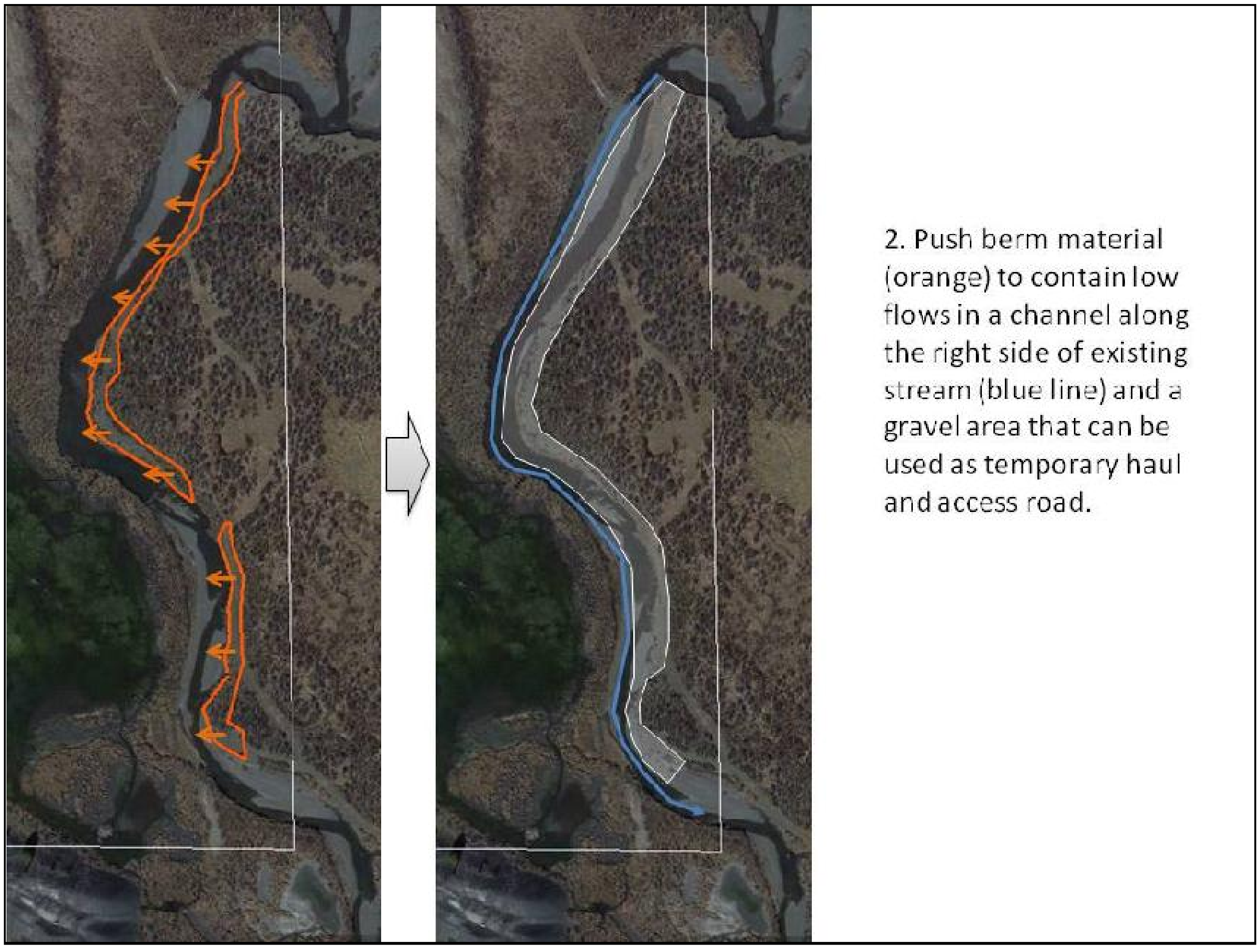
Parameter	Reach	Mean	Max	Min
S	Reference reaches	0.28%		
	Peanut Reach (existing)	0.28%		
	Peanut Reach (proposed)	0.26%		
BHR	Reference reaches	0.9	1.1	0.8
	Peanut Reach (existing)	1.4	1.6	1.1
	Peanut Reach (proposed)	1.0	1.1	0.8

Construction steps

This section describes the specific stages of construction and construction details.

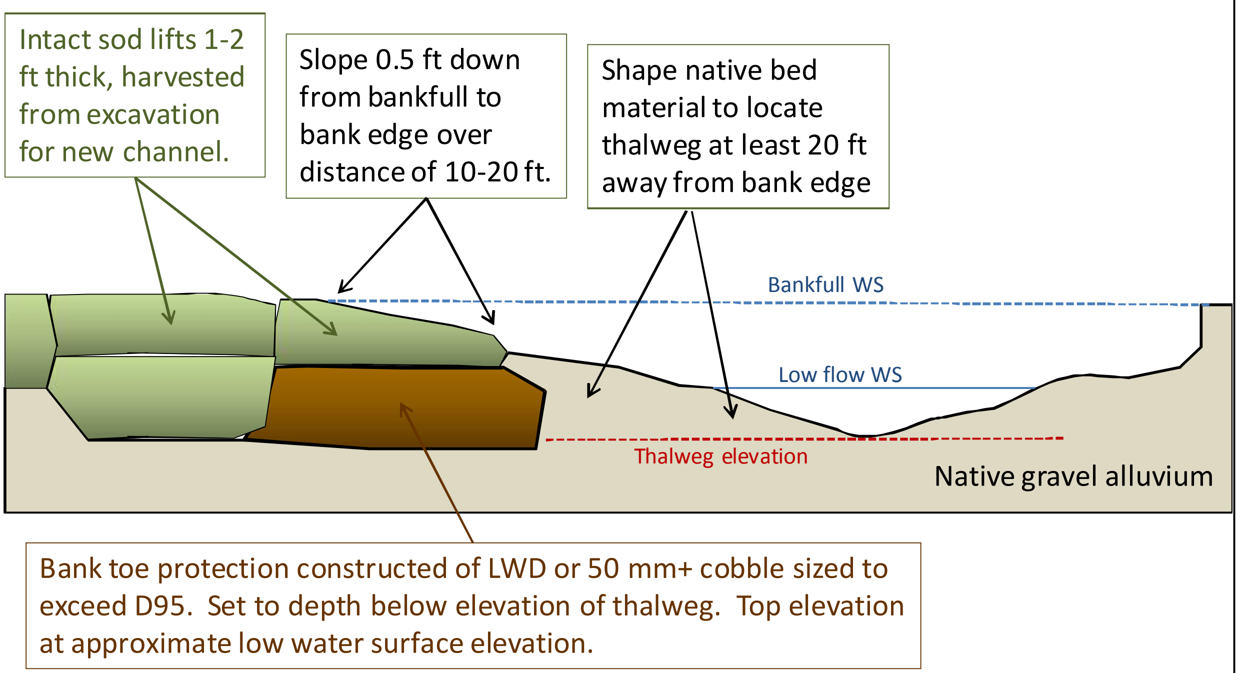
1. Access site with equipment via Rice parcel. Travel on gravel bars in channel to site.

2. Push berm material into the left side of the existing channel. This will create a gravel bed that is suitable for use as a temporary haul road on the left side of the channel. Stream flows will be temporarily routed along the right side of the existing channel to separate it from construction activities. It is important that these steps be carried out during periods of low flow to maintain separation of the stream flow from construction areas.

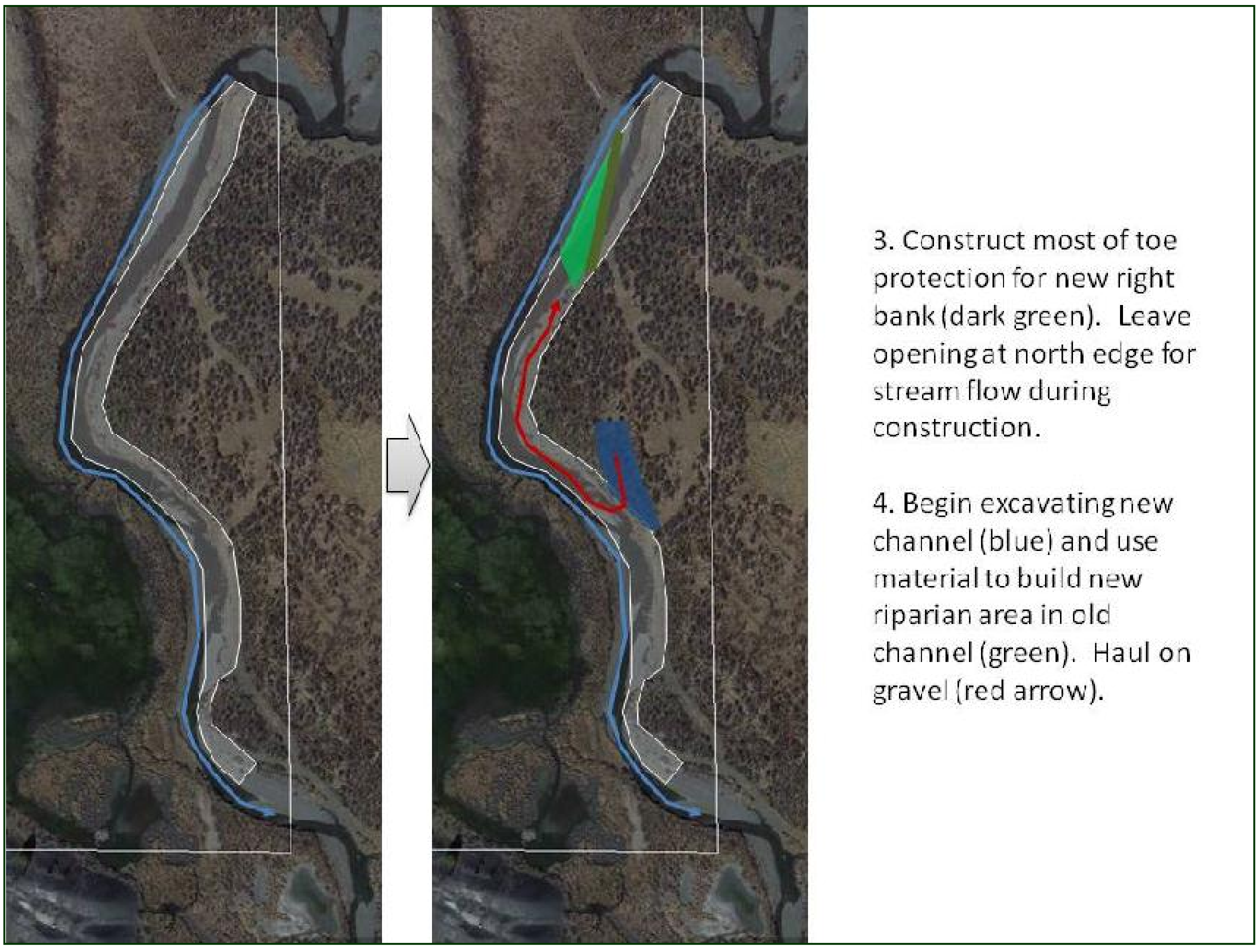


3. Construct toe protection along the right bank of the new channel on the segment where the new right bank crosses the existing channel.
    - Toe protection is set into a "trench" excavated to a depth below the thalweg elevation and width of about 20 feet with top elevation approximately equal to the low water surface.
    - Toe protection material will be a lattice of large woody debris including logs and coarse material filled and compacted, or compacted gravel/cobble mix sized so that D50 of the toe material exceeds D95 of the existing riffle bed composition (about 50 mm).
    - Leading edge of the toe material fill is covered using native bed material so that the thalweg is greater than 20 feet from the bank edge.
    - New bank and floodplain wetland area is constructed of large intact sod blocks 1-2 ft thick, harvested from the excavation of the new channel, set to top height not to exceed bankfull elevation by more than 0.2 ft. The front edge is sloped down at least 0.5 ft over 10-20 feet to create a sloping sod bench bank.

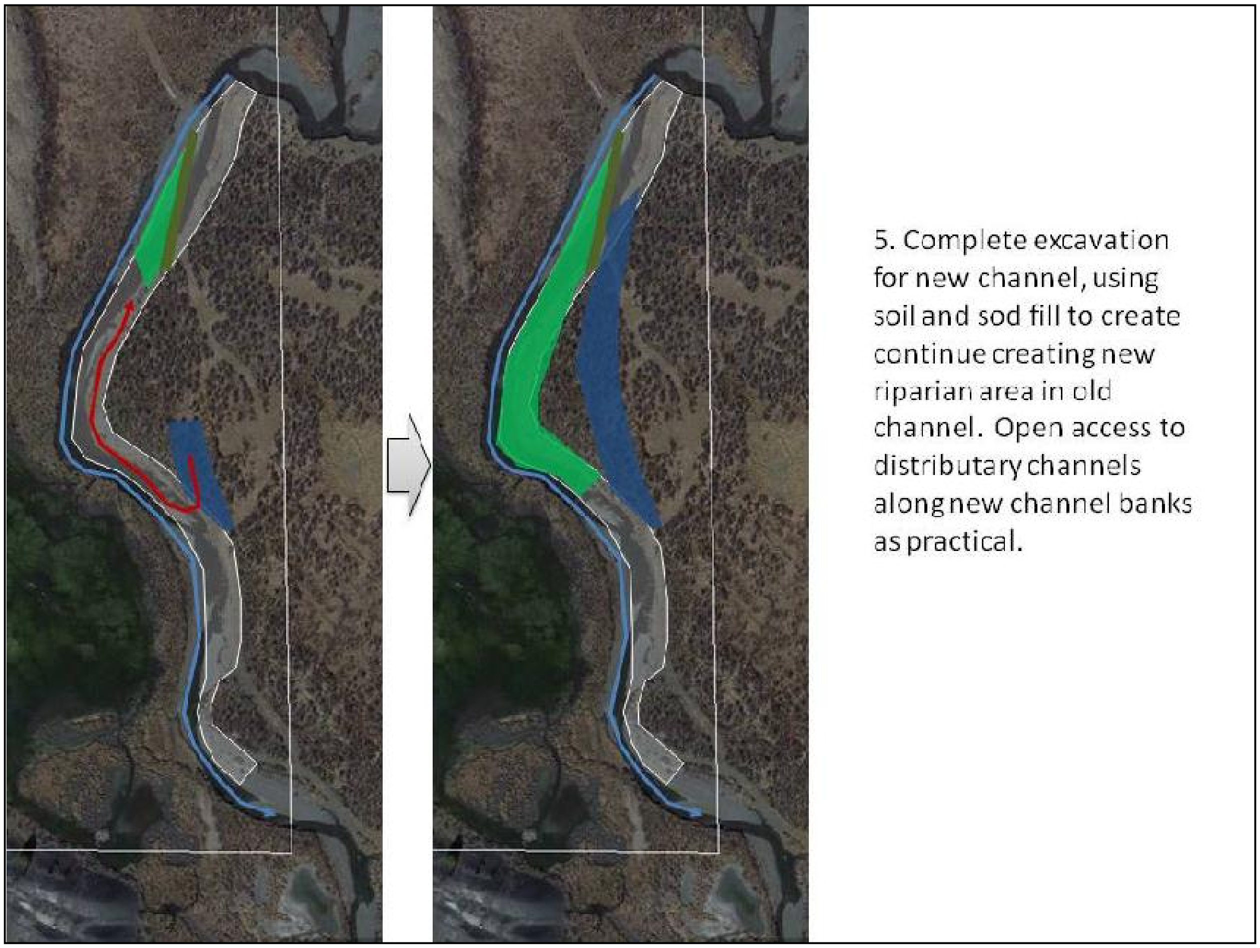
Typical design for toe-protected bank. XS view is from downstream looking up (right bank is on the left side of the drawing).



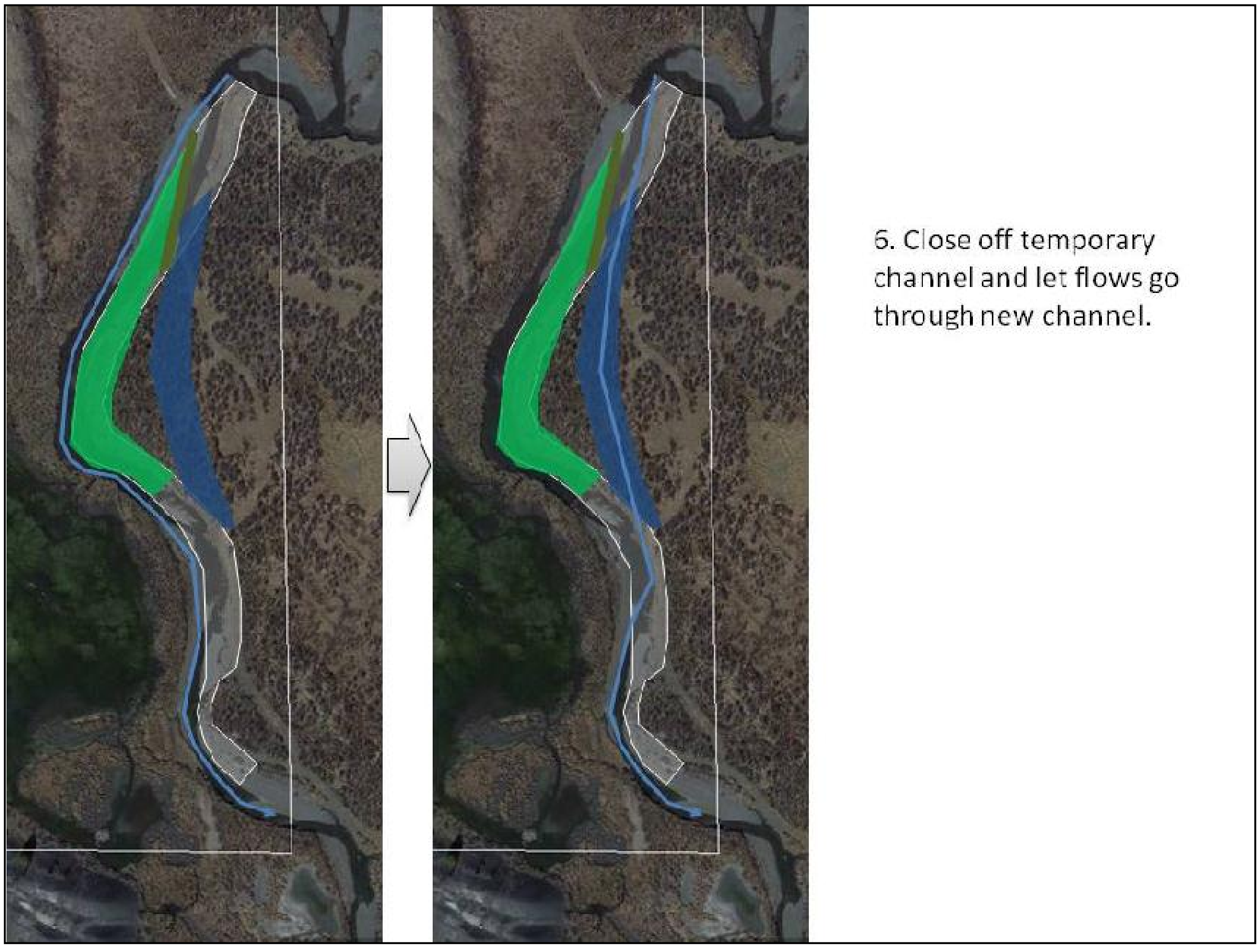
4. Begin excavating new channel from the downstream end. Harvested intact sod material is transported for use in filling the existing channel to create a floodplain wetland area. Filling begins at the upstream end, proceeding downstream. Maintain a temporary channel to convey stream flows along right edge. This channel must be wide enough to accommodate equipment. Special care must be taken in the way material is excavated, transported, and re-planted to maintain the existing soil profile and to keep vegetation root structures as intact as possible. We anticipate using a large loader for this purpose so that we can move very large sod/soil lifts up to 2 feet thick without handling them more than once.



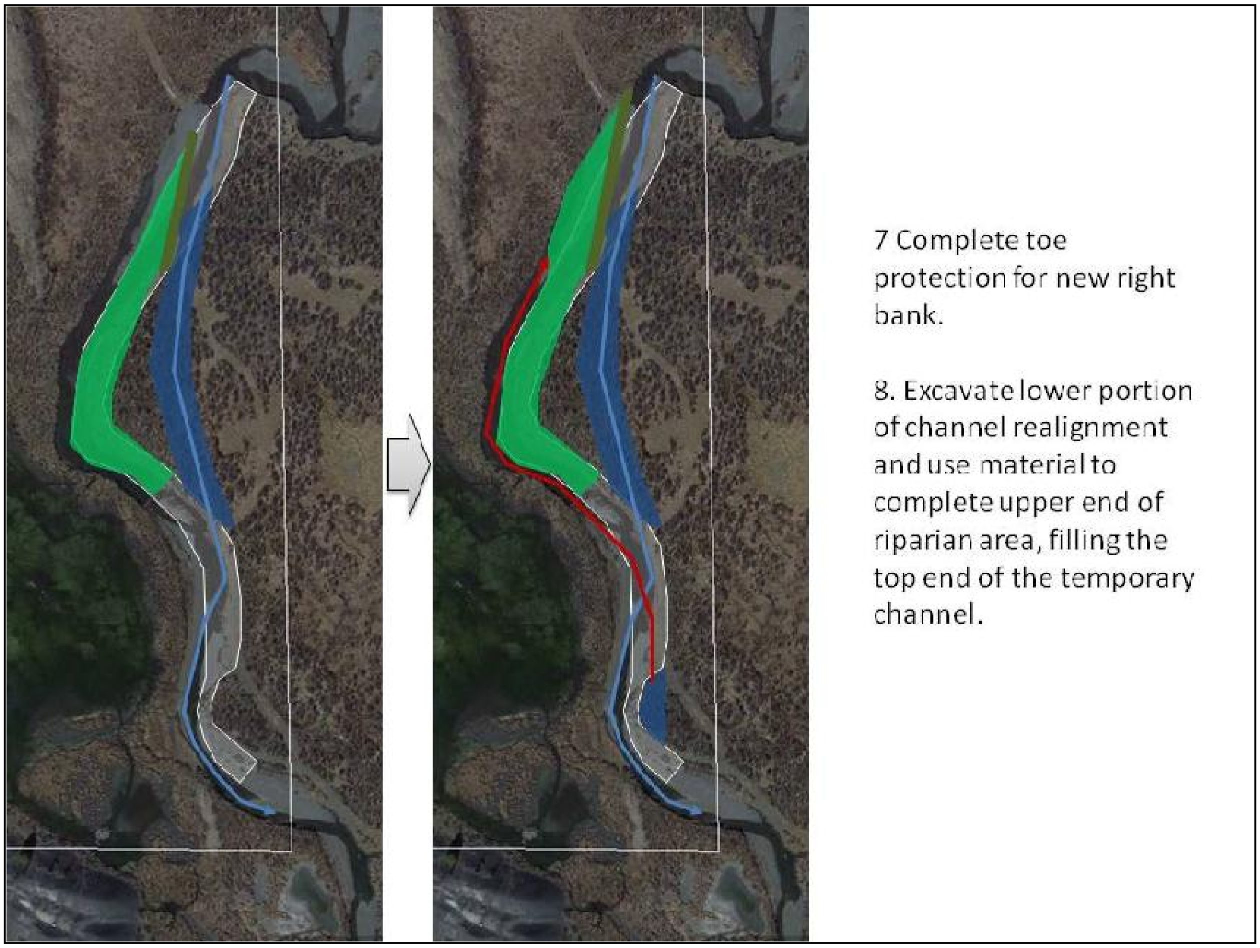
5. Continue building new channel and using material to construct the floodplain wetland until the new channel is complete to the bottom of the realignment section. Open access to side channels and overflow swales on left bank as practical.



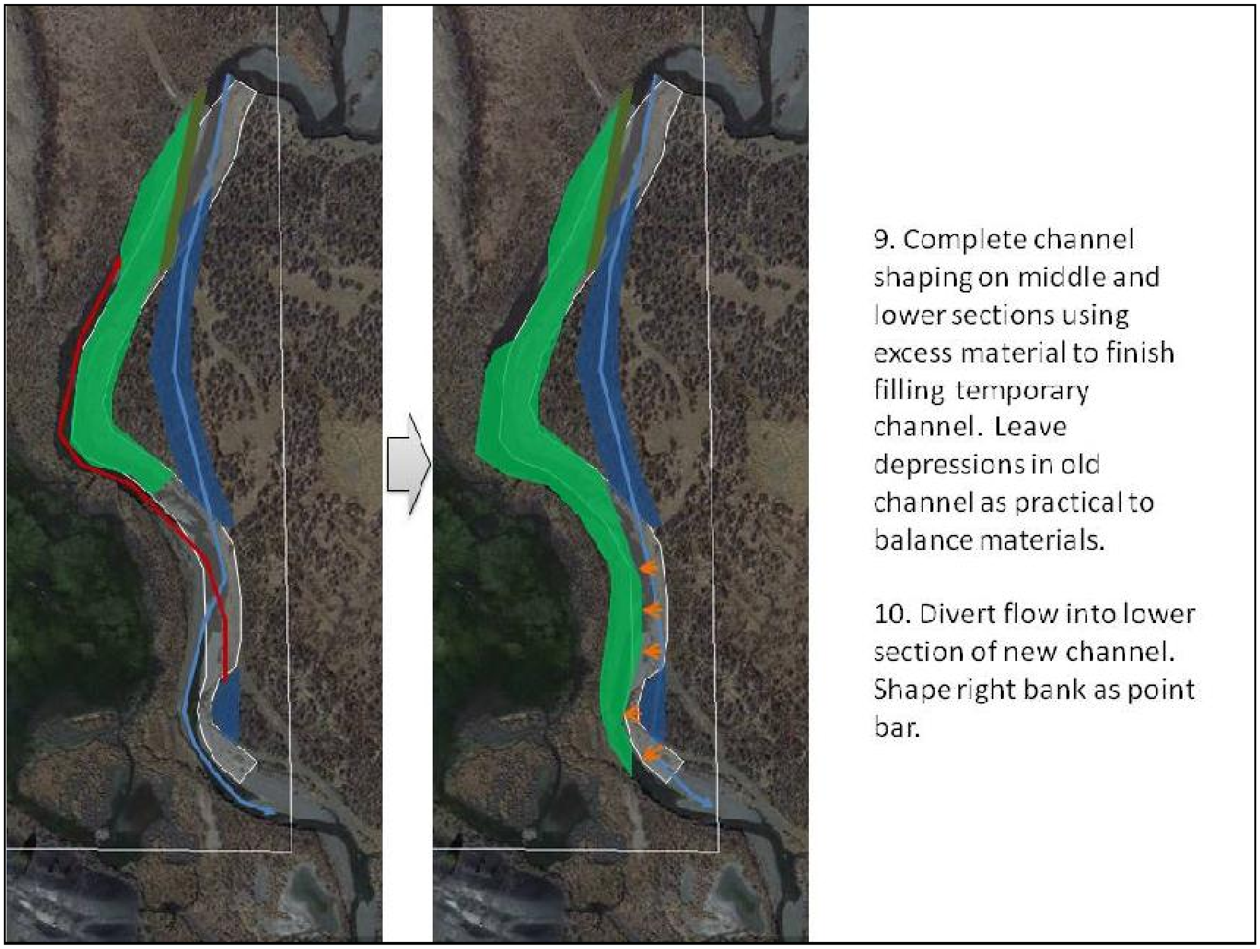
6. Complete finish grade on the new river channel according to design specifications. Close off the temporary channel and allow flows to run through the new channel.



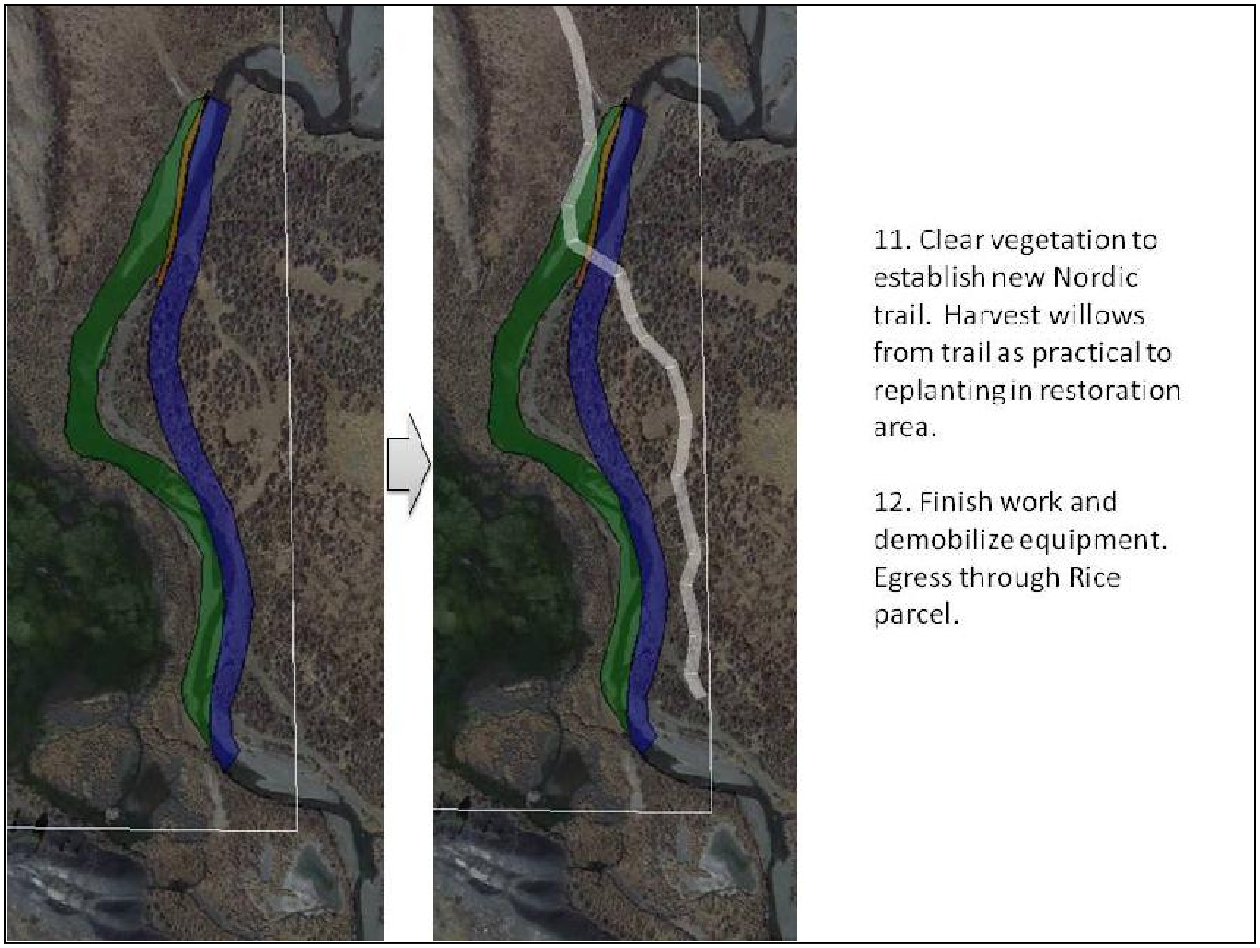
7. Complete construction of the right bank toe protection at the upstream end across the area where the temporary channel was flowing.
8. Begin excavating the lower portion of the channel alignment. Haul intact sod material to fill the temporary channel starting at its upstream end.



9. Complete channel shaping on middle and lower sections of the new channel using excess material to finish filling the temporary channel area. Depressions in this area may be left to create floodplain topography and wetland depressions as practical to balance cut/fill materials.
10. Complete finish grade of the lower portion of the new channel, then divert flow into it. Shape the right bank of the lower section as a gravel point bar.



11. Clear tall vegetation to establish new alignment for Nordic ski trail (if desired) Harvest willows from this area as practical for replanting in newly restored wetland areas.
12. Finish work and site clean-up prior to demobilization of equipment. Egress through the Rice Parcel.



13. Complete riparian planting.

Construction BMPs

Best management practices (BMPs) will be implemented during construction, including the following:

- No equipment or construction materials (including fill) will be staged or stored within 50 feet of wetlands or other water features
- No chemicals, such as soil stabilizers, dust inhibitors and fertilizers will be used within 50 feet of wetlands or other water features
- Equipment will be refueled in designated contained areas, at least 50 feet away from wetlands or other water features
- Any wetlands temporarily disturbed will be restored to original contours and conditions, and seeded with native species
- All equipment will be thoroughly cleaned before entering the project area to avoid noxious weed introductions
- There will be no vehicle access in wetland areas outside the limits of permanent impacts.
- No temporary access areas through wetlands will be used by equipment for more than two trips (a "trip" is defined as driving into the area and back out).

Appendix 5: River Surveys

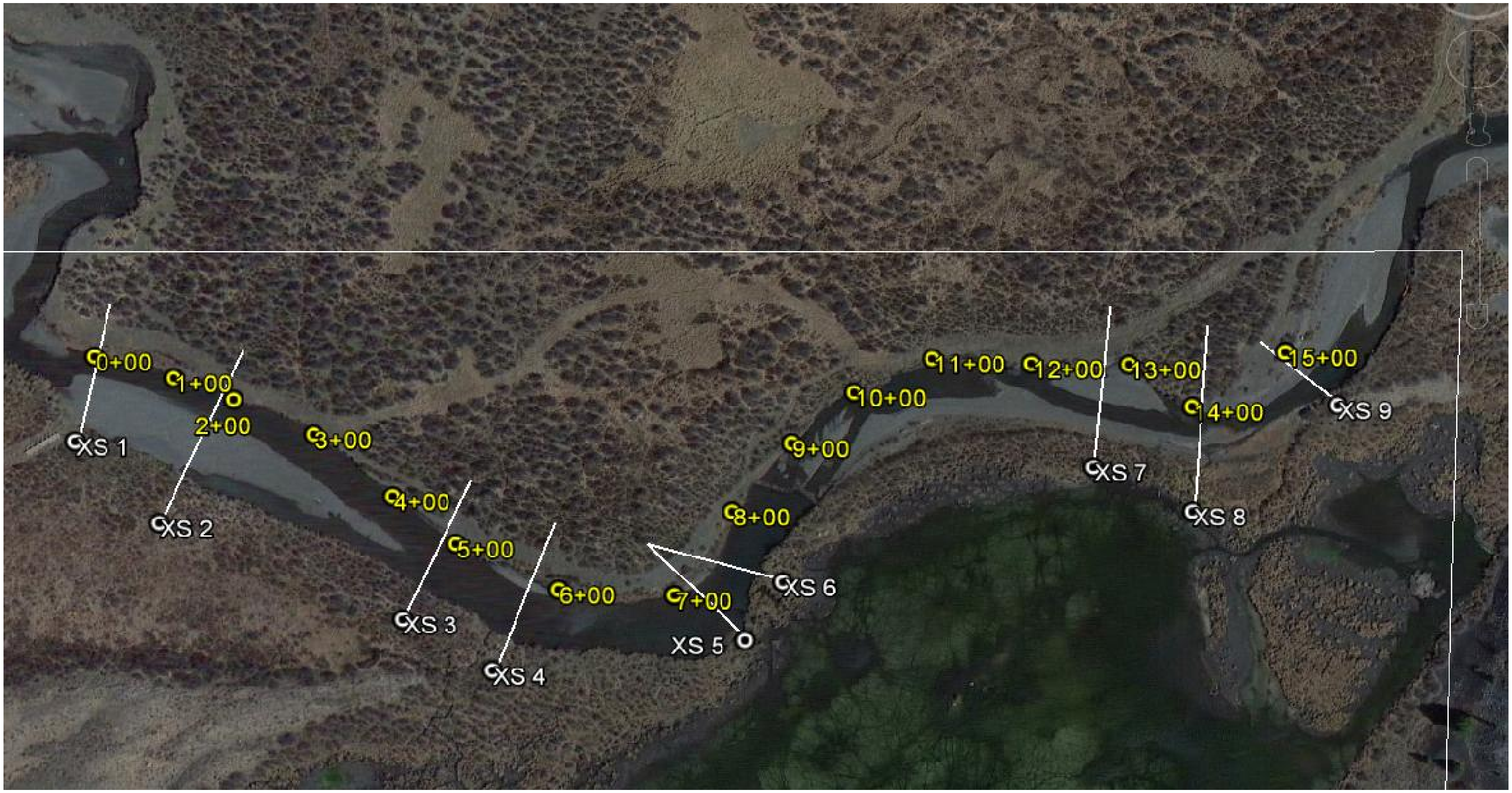


Figure A5-1: Site map showing stationing for the longitudinal profile survey (yellow) in feet, and location of the 9 XS transects.

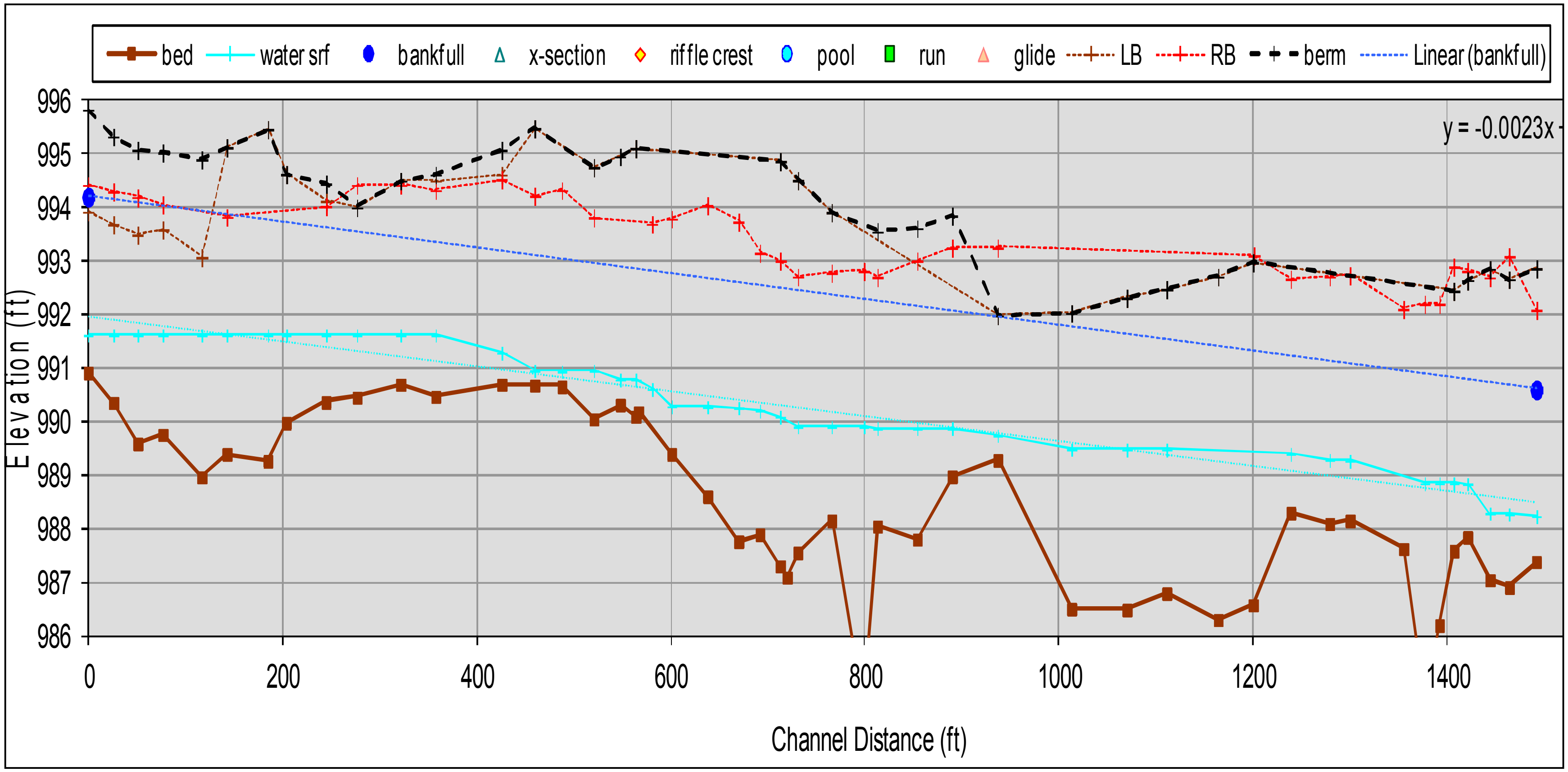
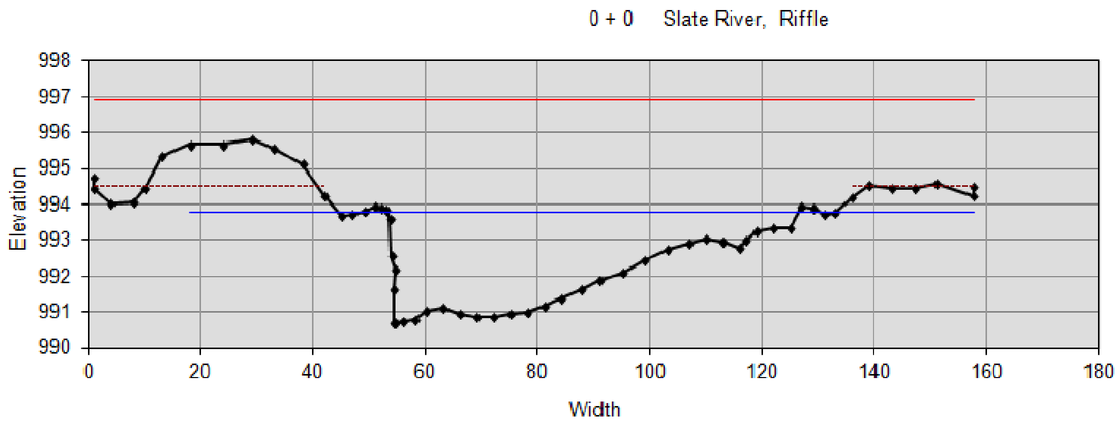


Figure A5-2: Longitudinal profile.



Bankfull Dimensions	
135.8	x-section area (ft.sq.)
80.2	width (ft)
1.7	mean depth (ft)
3.1	max depth (ft)
83.3	wetted parimeter (ft)
1.6	hyd radi (ft)
47.4	width-depth ratio

Flood Dimensions	
---	W flood prone area (ft)
---	entrenchment ratio
3.8	low bank height (ft)
1.2	low bank height ratio

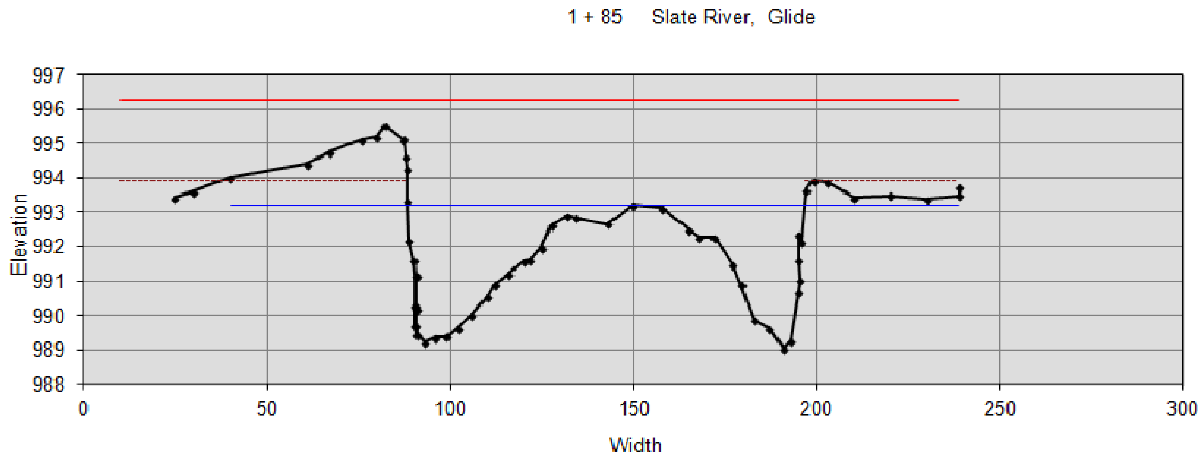
Materials	
14	D50 Riffle (mm)
29	D84 Riffle (mm)
12	threshold grain size (mm):

Bankfull Flow	
3.6	velocity (ft/s)
494.6	discharge rate (cfs)
0.50	Froude number

Flow Resistance	
0.027	Manning's roughness
0.07	D'Arcy-Weisbach fric.
10.5	resistance factor u/u*
17.8	relative roughness

Forces & Power	
0.23	channel slope (%)
0.23	shear stress (lb/sq.ft.)
0.35	shear velocity (ft/s)
0.88	unit strm power (lb/ft/s)

Figure A5-3: XS 1. The 2-ft tall berm is obvious on the left bank.



Bankfull Dimensions	
185.9	x-section area (ft.sq.)
106.3	width (ft)
1.7	mean depth (ft)
4.2	max depth (ft)
113.4	wetted parimeter (ft)
1.6	hyd radi (ft)
60.7	width-depth ratio

Flood Dimensions	
	W flood prone area (ft)
	entrenchment ratio
	low bank height (ft)
	low bank height ratio

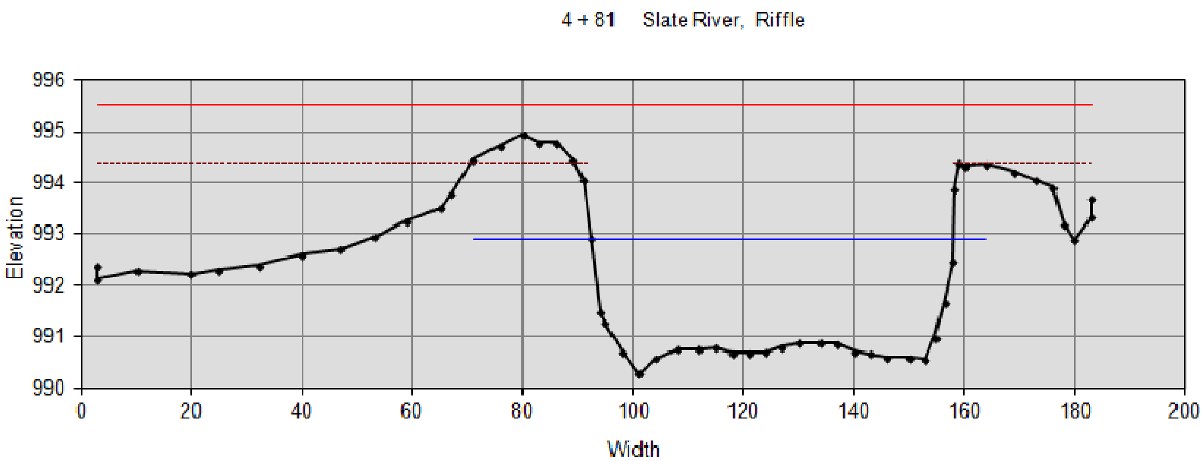
Materials	
	D50 Riffle (mm)
	D84 Riffle (mm)
	threshold grain size (mm):

Bankfull Flow	
	velocity (ft/s)
	discharge rate (cfs)
	Froude number

Flow Resistance	
	Manning's roughness
	D'Arcy-Weisbach fric.
	resistance factor u/u*
	relative roughness

Forces & Power	
	channel slope (%)
	shear stress (lb/sq.ft.)
	shear velocity (ft/s)
	unit strm power (lb/ft/s)

Figure A5-4: XS 2. At this location, the river has eroded through half of the berm.



Bankfull Dimensions	
137.1	x-section area (ft.sq.)
65.7	width (ft)
2.1	mean depth (ft)
2.6	max depth (ft)
67.1	wetted parimeter (ft)
2.0	hyd radi (ft)
31.5	width-depth ratio

Flood Dimensions	
---	W flood prone area (ft)
---	entrenchment ratio
4.1	low bank height (ft)
1.6	low bank height ratio

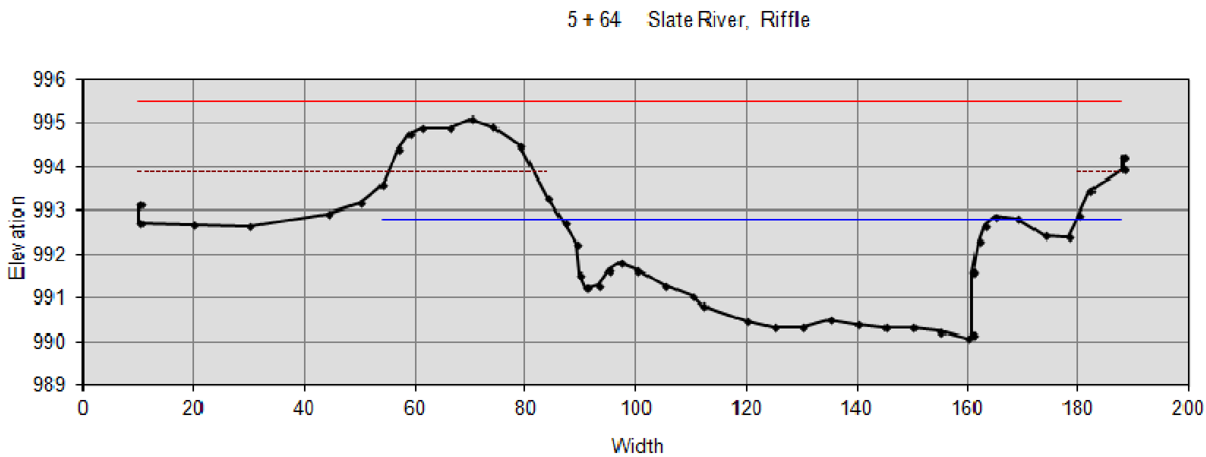
Materials	
14	D50 Riffle (mm)
29	D84 Riffle (mm)
14	threshold grain size (mm):

Bankfull Flow	
4.2	velocity (ft/s)
572.1	discharge rate (cfs)
0.51	Froude number

Flow Resistance	
0.028	Manning's roughness
0.07	D'Arcy-Weisbach fric.
10.7	resistance factor u/u*
21.9	relative roughness

Forces & Power	
0.23	channel slope (%)
0.29	shear stress (lb/sq.ft.)
0.39	shear velocity (ft/s)
1.25	unit strm power (lb/ft/s)

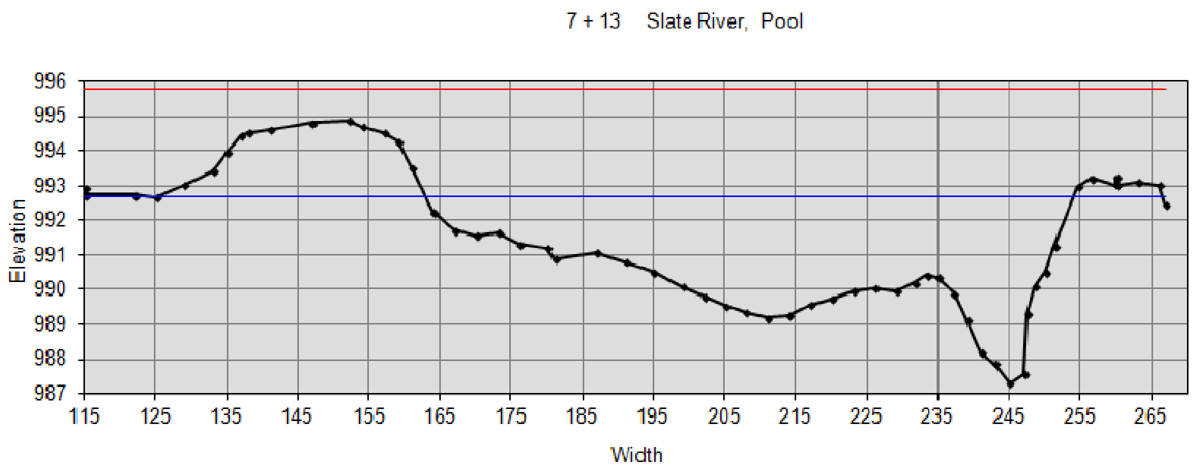
Figure A5-5: XS-3. The berm on the left is obvious.



Bankfull Dimensions		Flood Dimensions		Materials	
154.3	x-section area (ft.sq.)	---	W flood prone area (ft)	14	D50 Riffle (mm)
88.0	width (ft)	---	entrenchment ratio	29	D84 Riffle (mm)
1.8	mean depth (ft)	3.8	low bank height (ft)	12	threshold grain size (mm):
2.7	max depth (ft)	1.4	low bank height ratio		
90.2	wetted parimeter (ft)				
1.7	hyd radi (ft)				
50.1	width-depth ratio				

Bankfull Flow		Flow Resistance		Forces & Power	
3.7	velocity (ft/s)	0.027	Manning's roughness	0.23	channel slope (%)
574.5	discharge rate (cfs)	0.07	D'Arcy-Weisbach fric.	0.25	shear stress (lb/sq.ft.)
0.50	Froude number	10.5	resistance factor u/u*	0.36	shear velocity (ft/s)
		18.4	relative roughness	0.94	unit strm power (lb/ft/s)

Figure A5-6: XS4. The berm on the left is obvious.



Bankfull Dimensions

225.0	x-section area (ft.sq.)
93.9	width (ft)
2.4	mean depth (ft)
5.4	max depth (ft)
97.0	wetted parimeter (ft)
2.3	hyd radi (ft)
39.2	width-depth ratio

Flood Dimensions

	W flood prone area (ft)
	entrenchment ratio
	low bank height (ft)
	low bank height ratio

Materials

	D50 Riffle (mm)
	D84 Riffle (mm)
	threshold grain size (mm):

Bankfull Flow

	velocity (ft/s)
	discharge rate (cfs)
	Froude number

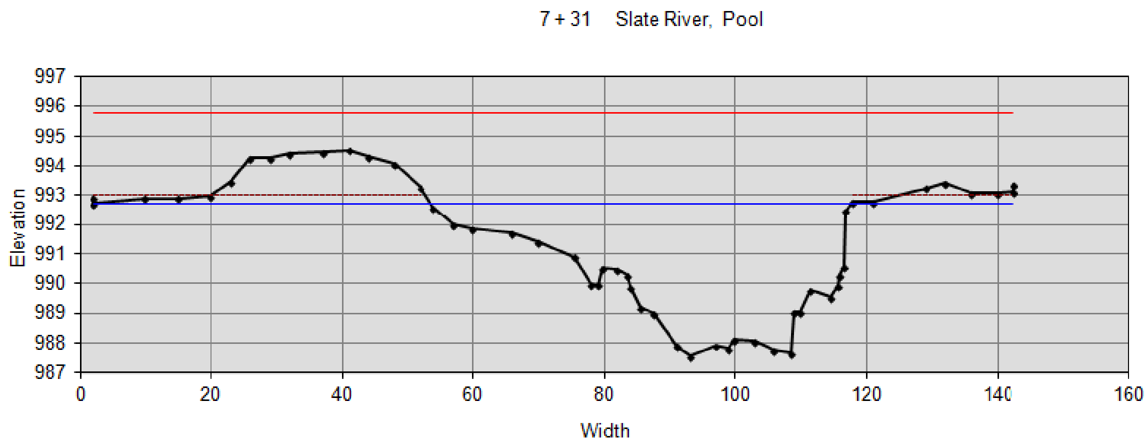
Flow Resistance

	Manning's roughness
	D'Arcy-Weisbach fric.
	resistance factor u/u*
	relative roughness

Forces & Power

	channel slope (%)
	shear stress (lb/sq.ft.)
	shear velocity (ft/s)
	unit strm power (lb/ft/s)

Figure A5-7: XS-5.



Bankfull Dimensions

180.0	x-section area (ft.sq.)
64.0	width (ft)
2.8	mean depth (ft)
5.1	max depth (ft)
68.4	wetted parimeter (ft)
2.6	hyd radi (ft)
22.8	width-depth ratio

Flood Dimensions

	W flood prone area (ft)
	entrenchment ratio
	low bank height (ft)
	low bank height ratio

Materials

	D50 Riffle (mm)
	D84 Riffle (mm)
	threshold grain size (mm):

Bankfull Flow

	velocity (ft/s)
	discharge rate (cfs)
	Froude number

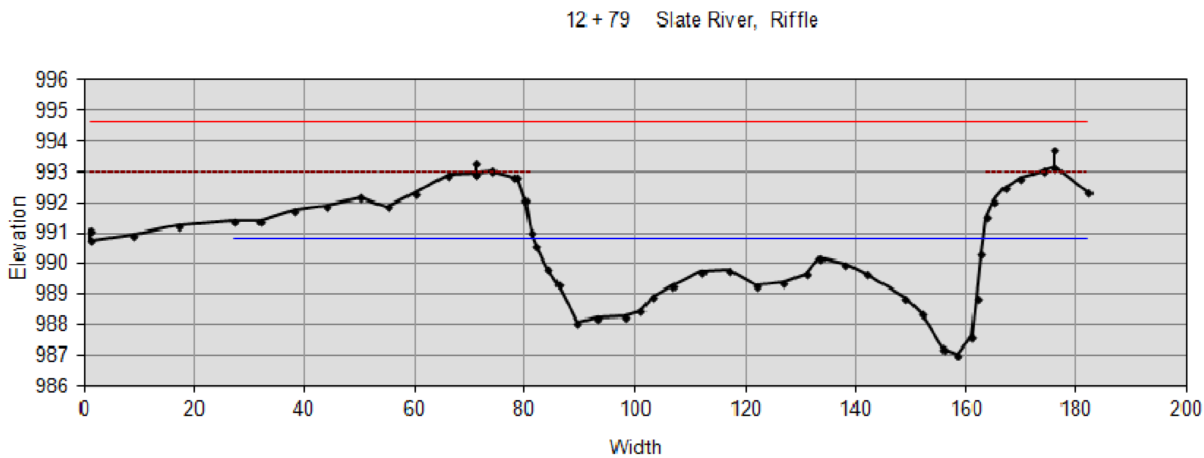
Flow Resistance

	Manning's roughness
	D'Arcy-Weisbach fric.
	resistance factor u/u*
	relative roughness

Forces & Power

	channel slope (%)
	shear stress (lb/sq.ft.)
	shear velocity (ft/s)
	unit strm power (lb/ft/s)

Figure A5-8: XS-6.



Bankfull Dimensions	
145.4	x-section area (ft.sq.)
81.7	width (ft)
1.8	mean depth (ft)
3.8	max depth (ft)
84.5	wetted parimeter (ft)
1.7	hyd radi (ft)
45.9	width-depth ratio

Flood Dimensions	
---	W flood prone area (ft)
---	entrenchment ratio
6.0	low bank height (ft)
1.6	low bank height ratio

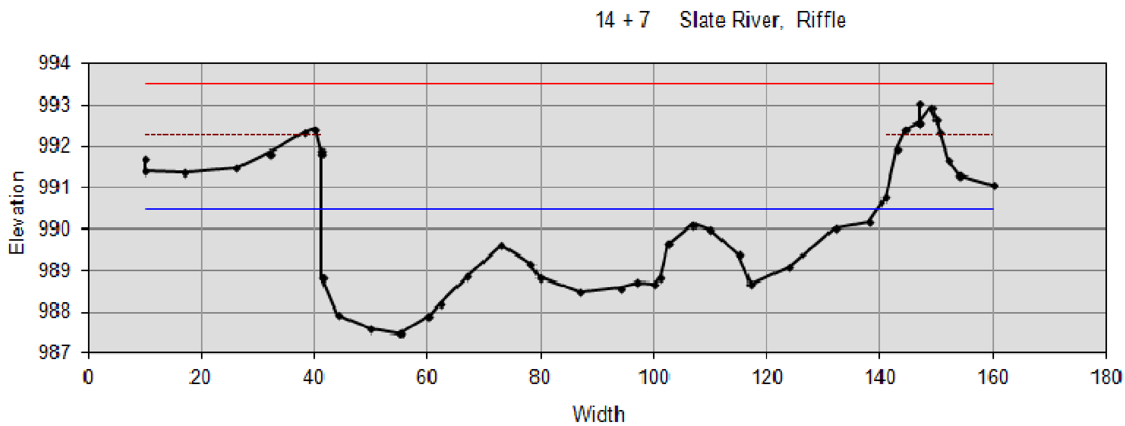
Materials	
14	D50 Riffle (mm)
29	D84 Riffle (mm)
12	threshold grain size (mm):

Bankfull Flow	
3.8	velocity (ft/s)
557.3	discharge rate (cfs)
0.51	Froude number

Flow Resistance	
0.027	Manning's roughness
0.07	D'Arcy-Weisbach fric.
10.7	resistance factor u/u*
18.7	relative roughness

Forces & Power	
0.23	channel slope (%)
0.25	shear stress (lb/sq.ft.)
0.36	shear velocity (ft/s)
0.98	unit strm power (lb/ft/s)

Figure A5-9: XS-7. Here, the berm is against the left bank, and the right bank is adjacent to the beaver dam that surrounds Peanut Lake.



Bankfull Dimensions

155.8	x-section area (ft.sq.)
98.3	width (ft)
1.6	mean depth (ft)
3.0	max depth (ft)
100.8	wetted parimeter (ft)
1.5	hyd radi (ft)
62.0	width-depth ratio

Flood Dimensions

---	W flood prone area (ft)
---	entrenchment ratio
4.8	low bank height (ft)
1.6	low bank height ratio

Materials

14	D50 Riffle (mm)
29	D84 Riffle (mm)
11	threshold grain size (mm):

Bankfull Flow

3.5	velocity (ft/s)
546.6	discharge rate (cfs)
0.50	Froude number

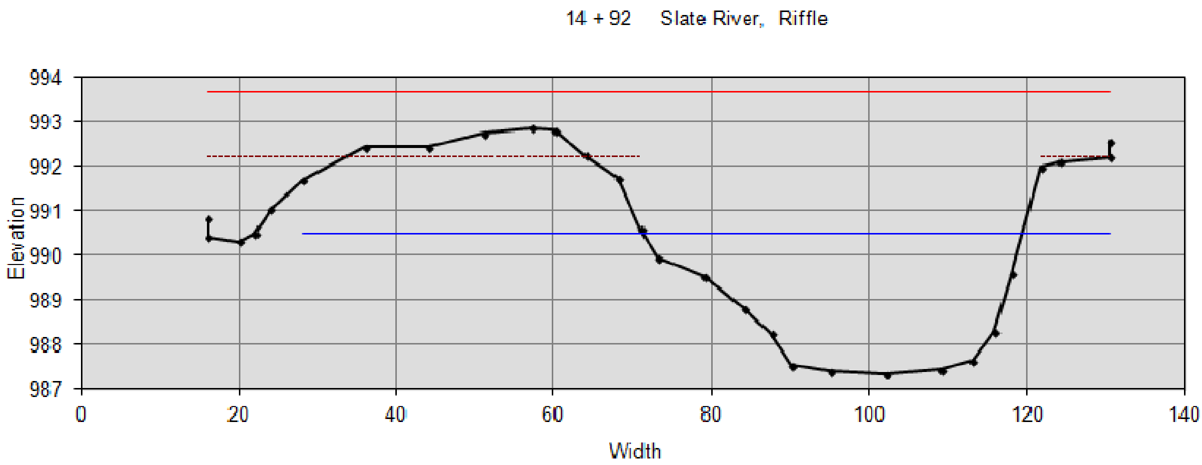
Flow Resistance

0.027	Manning's roughness
0.07	D'Arcy-Weisbach fric.
10.4	resistance factor u/u*
16.7	relative roughness

Forces & Power

0.23	channel slope (%)
0.22	shear stress (lb/sq.ft.)
0.34	shear velocity (ft/s)
0.8	unit strm power (lb/ft/s)

Figure A5-10: XS 8. Here the stream is directly adjacent to Peanut Lake. The water height in the lake is about 2.5 feet above the bankfull elevation of the river, or about 4 feet above the water surface elevation in low flow.



Bankfull Dimensions

107.0	x-section area (ft.sq.)
48.1	width (ft)
2.2	mean depth (ft)
3.2	max depth (ft)
49.1	wetted parimeter (ft)
2.2	hyd radi (ft)
21.6	width-depth ratio

Flood Dimensions

---	W flood prone area (ft)
---	entrenchment ratio
4.9	low bank height (ft)
1.5	low bank height ratio

Materials

14	D50 Riffle (mm)
29	D84 Riffle (mm)
15	threshold grain size (mm):

Bankfull Flow

5.2	velocity (ft/s)
558.6	discharge rate (cfs)
0.62	Froude number

Flow Resistance

0.023	Manning's roughness
0.05	D'Arcy-Weisbach fric.
11.0	resistance factor u/u*
23.4	relative roughness

Forces & Power

0.23	channel slope (%)
0.31	shear stress (lb/sq.ft.)
0.40	shear velocity (ft/s)
1.67	unit strm power (lb/ft/s)

Figure A5-11: XS-9.

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