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Water Consulting, Inc.

GEOMORPHIC ASSESSMENT REPORT AND PROPOSAL FOR THE RESTORATION OF THE SYCAN RIVER NEAR BEATTY, OREGON

KRONENBERGER PROPERTY
BEATTY, OREGON

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HAMILTON & WHITEFISH
MONTANA

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1.0 INTRODUCTION

The Klamath Falls office of the U.S. Fish & Wildlife Service (USFWS) has retained Water Consulting, Inc. (WCI) to provide conceptual design recommendations for several stream and fish habitat restoration projects located in the Sycan and Sprague River drainages of the Klamath River Basin in Southwest Oregon. The project areas specific to the Kronenberger Ranch included two stream reaches located on the Sycan River, referred to herein as Upper Brown Springs Reach and Lower Gowdawa Springs Reach, and one spring creek located on the north half of the property commonly referred to as Brown Springs Creek. The project areas are located near the town of Beatty, OR approximately 40 miles northeast of the city of Klamath Falls, Oregon (see Figure 1 Project Vicinity Map).

WCI, in cooperation with the USFWS, conducted a reconnaissance field tour of the project areas on November 6, 2001, to document existing channel conditions, evaluate potential geomorphic trends of the river systems, and collect preliminary survey information on channel morphology. Channel metric data were subsequently provided to WCI by the USFWS. Data included channel cross-sections and longitudinal profiles of the above referenced project areas, and aerial photos including the 1941 and 1998 series. Additionally, WCI researched and compiled historic streamflow gauging data for several USGS gauging stations situated on the Sycan River (USGS Stations 11499000, 11499100). Preliminary flood frequency analyses have been completed to assist with development of conceptual design recommendations and channel-floodplain dimensions.

The following report provides a brief overview of the project areas, describes the existing geomorphic trends, probable historic conditions, and outlines several alternative feasible restoration treatments for the project areas.

2.0 KRONENBERGER PROJECT AREA DESCRIPTION

The following section describes the existing and potential geomorphic conditions of the Kronenberger Ranch. The project area includes three sections or "reaches", referred to in Section 2.1 as 1) *Upper Brown Springs Reach,* 2) *Lower Gowdawa Springs Reach,* and 3) *Brown Springs Creek.*

2.1 EXISTING AND POTENTIAL CONDITIONS

2.1.1 UPPER BROWN SPRINGS REACH

Streams in this morphological setting are typically very narrow and deep and are highly sinuous within a very broad floodplain. This streamtype is described as an E type channel by the Rosgen classification system (Rosgen, 1996). The floodplains are typically heavily vegetated with sedge and shrub type vegetation communities, which are the dominant bank and bed stabilization feature. It is the root structure that binds the channel bank materials and without the dense root structure, the banks could not remain stable for long. Typically, streams of this type are extremely sensitive to vegetation removal (due to grazing or direct removal) and will respond quickly once the vegetation has been removed. Based on the aerial photos from 1941

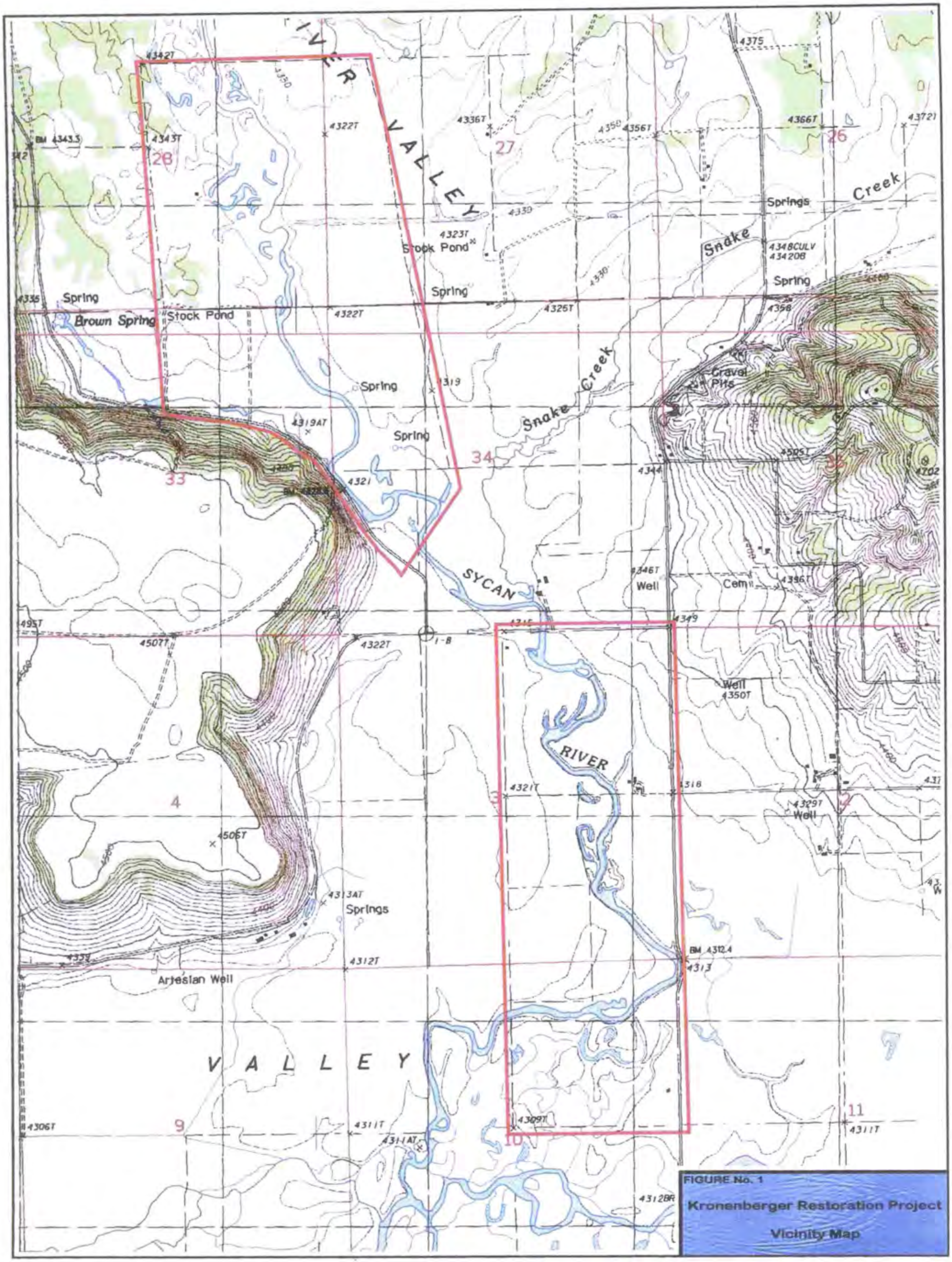


FIGURE No. 1
Kronenberger Restoration Project
Vicinity Map
VALLEY
SYCAN
RIVER
V A L L E Y
Snake Creek
Springs Creek
Snake
Spring
Brown Spring
Stock Pond
Spring
Spring
Spring
Springs
Gravel Pits
Cem
Well
Well
Well
Artesian Well
28
27
26
33
34
4
9
10
11
4342T
4343T
4322T
4336T
4356T
4366T
4372T
4375
4323T
4322T
4325T
4319
4319AT
4321
4346T
4344
4349
4322T
4321T
4318
4313AT
4312T
BM 4312.4
4313
4306T
4311T
4311AT
4309T
4312BR
4505T
4507T
4506T
4350T
4329T
4348CULV
4342OB
4358

and 1998, this river has experienced drastic changes in form and streamtype over the years (see Appendix A Photographic Journal).

When vegetation is removed and the stream banks lose their competency to resist the erosive forces during high runoff periods, the stream rapidly widens through bank erosion. The streams then begin to migrate laterally at an accelerated rate, and then cut through one or more of the torturous meanders. When this process occurs, called an avulsion, the resultant channel is much steeper than the original channel, which increases the shear stress, or energy, on the bed of the stream. The bed then becomes unstable and the stream begins to downcut into its floodplain. Once the stream has downcut more than about one foot, the bank:height ratio increases dramatically, and any remaining woody vegetation loses its ability to stabilize the streambanks and the whole process of erosion and downcutting (channel incision) is accelerated. Incised stream channels typically confine all flood flows within the channel banks rather than spreading and dissipating onto the floodplain since the historic floodplain is now abandoned and considered a "terrace" feature. Consequently, during each significant flood event, this increased energy accelerates both the lateral erosion and downcutting processes. When downcutting occurs over a long reach of stream, the process is called degradation, which is defined as lowering of the base elevation of the streambed.

When the streambed reaches a new equilibrium elevation, the stream begins to widen its floodplain through bank erosion. Over a long period of time, the floodplain is widened enough to allow a new stream to form within the gully. In the absence of grazing, dense riparian vegetation can form on the new floodplain, which will begin to narrow the channel over time. This is a typical evolutionary process as described by Rosgen (1996). The stream evolves from an E type to an F type through downcutting and bank erosion, then to a C type stream as the gully widens, and finally to an E type as the riparian vegetation matures and the stream begins to narrow its width. One major drawback to this whole process is that the stream is now at a lower elevation than its historic floodplain, which lowers the water table and changes the vegetation types on the abandoned floodplain (now a higher terrace) to drier, xeric vegetation community types.

The Sycan River has degraded in a process similar to the previous scenario for quite some distance upstream from the upper Kronenberger Ranch. We have little data at present to determine the true cause or extent of the degradation, however, the cause is most likely historic grazing that was intensive enough to remove most of the shrub and sedge vegetation communities. Through the upper Ranch, the stream has downcut approximately 4 to 6 feet and is still in a relatively early stage of evolution. It is predominantly an F type channel that is highly entrenched into its floodplain, however, a few short C type reaches are starting to form where the entrenchment is not as great and where some narrow floodplain benches are starting to form. At present, it is unknown how far upstream this condition exists.

Vegetation within the floodplain is almost non-existent with the exception of grasses starting to colonize the narrow floodplain benches. The upper banks are almost continually eroding along both sides of the stream and the upper banks and terraces are vegetated with grasses, noxious weeds and sage. The most likely trend for this stream in its current condition and management is to continue to widen and possibly continue to degrade. When the streambed reaches some equilibrium condition, the stream will continue to widen its floodplain until it can increase its length by meandering within the present confining banks as described previously.

Data from the existing longitudinal profiles and cross sections indicate that the width:depth ratio ranges from 26 to 33, the entrenchment ratio averages about 1.3. The stream has an extremely flat gradient of 0.0003 ft/ft and a sinuosity of 1.27. The channel substrate is predominantly sands and silts with some small gravel.

Preliminary assessment of existing stream gage data indicates that the bankfull discharge for this channel system is about 750 cubic feet per second (cfs). This value correlates well with the cross section data and field indicators. Based on preliminary hydraulics modeling, the bankfull cross sectional area should be about 280 square feet with a velocity of about 2.8 fps.

2.1.2 Lower Gowdawa Springs Reach

The lower project area is different from the upper reach in many respects. The impacts appear to be similar to the upper reach and primarily due to the removal of shrub and other riparian vegetation by grazing or other direct removal. Based on the aerial photos from 1941 and 1998, the pattern is similar, but somewhat less sinuous than the historic channel (see Appendix A Photographic Journal). The pattern, form, function and channel capacity is much different than its historic condition. This reach of stream should be similar to the upper reach in terms of potential condition. The stream was most likely a highly sinuous, narrow and deep E type channel. The floodplains are typically heavily vegetated with sedge and shrub type vegetation communities, which are the dominant bank and bed stabilization feature. It is the root structure that binds the channel bank materials together and without the dense root structure, the banks could not remain stable for long. Typically, streams of this type are extremely sensitive to vegetation removal (due to grazing or direct removal) and will respond quickly once the vegetation has been removed.

The processes are different in this reach of channel, probably due to the influence of the Sprague river floodplain. This reach has not downcut or degraded to the extent of the upper reach, but it is still somewhat entrenched. The entrenchment is more due to the excessive width:depth ratios rather than downcutting. All except the highest flood flows are mostly confined within the channel, providing more energy and shear stress than the streambanks can withstand. The result of these processes is for the channel to widen and straighten over time through erosion, lateral migration and finally, channel avulsion.

Data from the longitudinal profiles and cross sections indicate that the width:depth ratio ranges from 24 to over 60, the entrenchment ratio averages about 1.6 and the sinuosity is approximately 1.3. Channel substrate is predominantly sands and fine gravel. Stream type changes from a more entrenched F5 channel in the upper part of this reach transitioning into a C5 channel in the lower reaches. With appropriate width:depth ratios typical of an E type channel, the entire reach would have adequate access to the floodplain.

2.1.3 BROWN SPRINGS CREEK

This stream originates in a series of springs upstream and through the Upper Kronenberger Ranch, where it flows through several constructed ponds. At the lowermost pond, the stream exits through a gated outlet structure under the access road. This structure is a fish migration barrier limiting fish from accessing the upper stream and ponds. The ponds probably elevate temperatures due to the longer exposure time to solar energy. The stream flows for approximately 1/2 mile before its confluence with the Sycan River.

Brown Spring Creek was flowing at about 5 to 7 cubic feet per second (cfs) at the time of survey downstream from the lowermost pond. The stream below the pond is a C5/E5 channel type (Rosgen, 1996) with an adequate floodplain. The floodplain and riparian area along the stream has been heavily grazed, which has had a negative effect on the channel conditions and potential habitat development. Grasses rather than sedges and shrubs dominate the riparian area and floodplain. Minimal cover and habitat are available for fish or riparian dependent species.

The stream evidently went through a period of downcutting in the distant past in response to the Sycan River degradation (see Section 2.1.1). However, the stream has re-established a floodplain within the former gully through the typical evolution process described by Rosgen (1996). The stream was most likely an E type channel originally, but downcut during and after the Sycan river degradation into an F type channel, which is a relatively wide, flat channel with a high width: depth ratio and no floodplain (completely entrenched). Then, over an extended time period, the stream widened the gully through excessive bank erosion until it formed a meandering channel within the gully system, as described in the previous section. The sinuosity is lower than would be expected for a spring dominated E channel. The channel pattern is somewhat irregular, with longer straight sections and fewer tortuous meanders than would be expected. Over time, in the absence of intense grazing, the stream would revert back to an E channel with a very narrow width:depth ratio. The evolutionary endpoint of this type stream is a narrow E channel with dense floodplain vegetation consisting of shrubs and sedges.

3.0 RESTORATION ALTERNATIVES

The following section describes feasible restoration treatments for the Kronenberger Ranch project areas. Alternative descriptions are summarized for each individual project area since the range of feasible treatments will vary based on channel conditions, valley morphology, and restoration potential. Cost estimates for project design (engineering) and construction are provided and are initial estimates based on available survey data and stream gage information. Realistically, actual costs may vary by +/- 25% of quoted estimates in this proposal. This range is due to uncertainty in costs for materials including native vegetation (rootstock, plugs, and container stock), root wads, whole trees, and other common materials incorporated in natural stream channel design projects. Following selection of the preferred alternative, more accurate cost estimates (+/- 10%) can be developed for individual project areas.

3.1 UPPER BROWN SPRINGS REACH CONCEPTUAL RESTORATION DESIGN

A range of restoration design concepts are available including: 1) reconstructing a new "E" type channel at the historic floodplain elevation (Preferred Alternative), 2) stabilizing the existing channel in place with grade control structures, 3) widening the belt width and constructing a new channel at the existing elevation, and 4) no action, or allowing the stream to evolve and eventually stabilize through processes of erosion and deposition over time. Table 1 lists the four potential restoration alternatives and their associated advantages and disadvantages.

Any of the alternatives would need a strict grazing management plan including fencing of the stream and floodplain. There would need to be a period of complete rest for the floodplain area to allow the revegetation effort to mature. Careful grazing could occur in the future, but it would need to be very limited in season and duration to minimize the risk of damage to health and vigor of the riparian vegetation. Managing for riparian succession, within the context of the historical regime, is of paramount importance with any selected alternative.

3.1.1 FEASIBILITY OF ALTERNATIVES

Of these four Alternatives, reconstructing the stream to its original elevation (Alternative 1) is the most advantageous restoration alternative for several reasons, namely: project cost, project risk, long-term maintenance requirements, and benefit to native TE fish species and riparian resources. Usually, when compared with more traditional forms of stabilization (e.g. stabilize in place), this options tends to present the lowest implementation and post-monitoring costs, poses the least risk in terms of failure, and provides the greatest beneficial effects to water quality, fish habitat, land productivity, and riparian and wetland resources. However, in this case, Alternative 1 may not be feasible because the extent of the degradation (downcutting) extends upstream from the Kronenberger Ranch. In order to make this Alternative feasible, the origin of the headcut must be located. The knickpoint, or origin of the headcut, would serve as the start point for new channel construction. In this case, the origin of the headcut has not been located to date and is upstream an undetermined distance. The headcut most likely is located between the "falls" shown on the USFS maps and the Kronenberger Ranch. Since the lowest falls occur about 2 miles upstream, the headcut is probably between one and two miles upstream.

The existing channel could be "plugged" leaving open water areas between the plugs or filled completely to the floodplain elevation. In either case, the existing channel would become wetlands with Alternative 1. Water surface profile modeling using the US Army Corps of Engineers HEC-RAS model would be required to ensure water surface elevations and velocities are within a permissible range for overbank floodprone areas.

Alternative 2 is a variation of Alternative 1 (construct a C channel at the historic floodplain elevation instead of an E channel) and would have the same limitations. It would have much higher costs, and therefore, was not considered in greater detail.

Alternative 3 would convert the existing F channel to an E channel for the entire length of the reach at the existing base elevation. This alternative would require extensive excavation of the high streambanks and sloping the banks back to a 2:1 or flatter slope. Within the channel system itself, floodplain benches would be constructed to narrow the channel to appropriate dimensions, increase sinuosity, increase floodplain width and stabilize streambanks. At least two grade control structures would need to be constructed at the upstream end and downstream ends to ensure that the reach does not degrade in the future. As described in Table 1, there are a number of advantages and disadvantages with this Alternative. Costs will be considerable given the large excavation quantities involved. Without first widening the floodplain, this Alternative would be infeasible because shear stresses would be extreme during flood events and would have a high risk of damaging the bankfull floodplains or initiating local downcutting. The extent of the excavation could not be determined at this time without hydraulic modeling of the proposed channel conditions. However, a rough estimate is provided in the next section.

Bank stabilization with Alternative 1 or 3 would be a combination of composite root wad revetments at the highest shear stress areas, log and shrub revetments, sod and shrub revetments, bankfull floodplain construction, and in some cases geotextile fabric with vegetation planting in the lower stress areas. The emphasis should be on vegetative stabilization through whole shrub transplanting and rooted stock planting while minimizing wood and rock structures. Grade control structures would need to be very carefully designed in this environment to minimize backwater effect and maintain channel function. Low head rock cross vanes (Rosgen, 2001) would probably be the best choice for grade control structures at either end of the project area.

Alternative 4, or the No Action Alternative, is always feasible, however, the immediate and long-term impacts of the continued instability are not acceptable to either the landowner or the public. It will most likely require many decades, if not centuries, for this system to stabilize through natural processes. This conclusion would be true even with a complete change in land management and aggressive revegetation of the channel and narrow floodplain. For this channel system to stabilize through natural processes, the base elevation would need to remain constant and the high streambanks (terraces) eroded sufficiently to provide an accessible, adequate floodplain. This process would need to occur throughout the entire reach that is incised into the floodplain. The hundreds of thousands of tons of sediment that would result from this erosional process would probably not be acceptable. For these reasons, Alternative 4 will not be considered in greater detail.

Under any of the Alternatives, a river crossing should be designed into the project. Either an 80 to 100 foot span bridge that would span the channel and a portion of the floodplain could be included into the design or a hardened stream crossing suitable for crossing during low flow time periods could be incorporated. Bridges that span only the active channel should be discouraged in this type of setting because of the significant upstream and downstream effects during flood events. The backwater effects of a bridge with inadequate capacity have the potential to undo all of the positive benefits of a stream restoration project.

Table 1
Summary of methods, advantages, and disadvantages of restoration alternatives for the Sycan River[1].

Alternatives	Restoration Methods	Advantages	Disadvantages
▪ Alternative 1: Preferred Convert existing 'F' reach to 'E' channel at the historic floodplain elevation	• Reconstruct bankfull E channel at the historic floodplain elevation. Utilize historic channel patterns to design dimensions and plan view geometry. Revegetate riparian, provide grade control and instream structures to enhance aquatic habitat. Convert 'F/G' channel to depressional wetlands / oxbow features.	• Reduce instream erosion and subsequent property loss • Raise water table and improve land productivity • Decrease downstream sedimentation and improve site water quality and habitat • Create wetland and riparian habitat • Aesthetics	• Increased floodprone width limits development and agricultural practices • Lack of existing vegetation would require extensive riparian planting and channel stabilization
▪ Alternative 2 Convert the existing "F" channel to a 'C' type channel at the historic floodplain elevation	• Construct a two-stage, low gradient 'C' bankfull channel and floodplain at the historic floodplain elevation. Revegetate riparian, and convert existing 'F' channel to depressional wetlands/oxbow features.	• Reduce instream erosion and property loss • Decrease downstream sedimentation • Improve water quality and aquatic habitat (spawning) • Create wetland habitat • Enhance sediment transport	• Excessive excavation due to two-stage channel design • High costs associated with construction • Not representative of historic channel type prior to channelization
▪ Alternative 3 Convert 'F' reach to E channel within incised reach (at the existing elevation)	• Excavate vertical banks to stable 2:1 slope. Re-establish natural meander width ratio, which may require extensive excavation in channelized reaches. Construct new floodplain and revegetate for stability.	• Reduces bank height, erosion, sedimentation • Reduces near-bank stress • Improves aquatic habitat • Prevents wide-scale flooding of historic floodplain surface • Lowers risk of future heaductting	• Increases shear stress due to narrower floodplain • Water table remains lower than historically • Excessive excavation required due to bank heights and degree of incision
▪ Alternative 4 No Action	• Allow time and erosional processes to "heal" the channel in its current location.	• No financial costs.	• Extensive land loss • Continued water quality impairment caused by turbidity • Habitat degradation • Lowering of water table • Loss of historic wetlands and riparian resources • Maintains low productivity land.

[1] *from Rosgen, 1997. A Geomorphological Approach to Restoration of Incised Rivers.*

3.1.2 ESTIMATED COSTS AND BENEFITS OF ALTERNATIVES

The feasibility of implementing Alternative 1 is contingent on physically locating the headcut and securing both landowner permission and funding to construct a new channel at the historic elevation (beginning at the headcut). Some coarse estimates of channel construction are provided for only those stream segments located on the Upper Brown Springs Reach. When the physical location of the headcut is determined, the unit costs provided here can be extrapolated upstream to include the additional channel lengths. Assuming the total channel length of about 13,600 feet (valley length of 6,800 feet with a sinuosity of 2.0), the total costs of Alternative 1 and 2 would be approximately $1.1 million. That equates to a cost of about $81 per linear foot of channel, including design, construction, revegetation and construction oversight. As stated previously, there should be a potential error factor of about 25% with an estimate at this scale of analysis.

Potential advantages and disadvantages are shown in Table 1. In addition to providing the most productive and ecologically correct channel type in this area, there would be about 95 acres of wetland associated with the channel and floodplain. Habitat improvements would include lowered water temperatures, increased pool depth and quality, cleaner substrate and more exposed gravel and stable undercut banks. Also, the new channel would be constructed "in the dry" while the water continued to flow in the existing channel. This results in less turbidity and suspended sediment loading during construction. One additional drawback to this Alternative would be that the existing ponds on the ranch would likely be converted into floodplain wetlands or abandoned oxbows, rather than disconnected ponds. A gain in wetlands would occur, but additional mapping and analysis would need to be conducted to determine the total increase in wetland acreage.

The goal of Alternative 3 would be to construct a modified E channel with an approximate 40 foot wide channel and a 120 foot wide base floodplain (low stage floodplain). The sinuosity would be approximately 1.4, which would increase channel length and sinuosity somewhat over existing conditions. Total proposed channel length would be about 9,500 feet. There would need to be some excavation of one or both banks to widen the floodplain sufficiently to accommodate major floods without damage to the channel or streambanks. Some of the excavated material could be used to create the bankfull benches used to narrow the channel and some of the material would need to be hauled away and used to fill a non-wetland site. The total cost of Alternative 3 would be about $485,000. That equates to a cost of about $51 per linear foot of channel, including design, construction, revegetation and construction oversight. There should be a potential error factor of about 25% with an estimate at this scale of analysis. The potential advantages and disadvantages are shown in Table 1. Other benefits of this Alternative include:

- Improvement in riparian and fisheries habitat, including increased pool depth and quality, cleaner substrate and more exposed gravel and stable undercut banks,
- Increase in wetland acreage by about 15 to 20 acres,
- Potential reduction in flood stage for moderate sized floods due to enlarged floodplain,
- Ability to construct wetland ponds in the historic abandoned oxbows, and
- Lowered water temperatures.

Additional risks of this alternative are documented in Table 1. Alternative 3 would probably result in more turbid water during construction because the construction could not be done "in the dry" for many reaches. This would result in higher short-term sediment loads during construction.

With Alternative 1 or 3, a bridge or hardened ford crossing could be incorporated into the design. A hardened ford for low water time periods would cost approximately $5,000 to $10,000 using small rock, geotextile fabric and imported fill material. A bridge that would span the channel and provide floodplain relief would need to be 80 to 100 feet in length. Several bridge design options exist and costs could range between $25,000 and $100,000 depending on the load bearing requirements and design criteria. For Alternatives 1 and 2, it is likely that water would flow around the bridge during larger floods, leaving the bridge isolated. More refined costs could be provided when design criteria are established. For Alternative 3, the bridge crossing site could be located such that the bridge could span the entire channel and floodplain. However, during the largest floods, water would probably flow outside of the constructed floodplain and could isolate the bridge.

3.1.3 Information Needs

Before an effective design could be completed for the Upper Brown Springs Reach, there are a number of information needs that should be addressed, including:

- Refining project goals and objectives,
- Completing a more detailed assessment of river conditions and geomorphic potential of the river system,
- Validation of the channel design dimensions and flood series analysis,
- Locating the upstream extent of the degradation and location of the headcut,
- A survey of the entire reach or aerial photogrammetry to develop a detailed topographic map of the project area, and
- Modeling the floodplain and determining the existing floodplain boundaries.

The potential costs for completing analyses have not been estimated at this time. The USFWS or other partners providing assistance could potentially complete some of the information needs. WCI could complete any or all of the assessment needs, if desired. Further discussions on the potential scope of work are necessary to determine total potential costs.

3.1.4 Conclusions and Recommendations

Of the four Alternatives presented, Alternative 1 would be the best long-term treatment of the river and floodplain corridor. Costs and benefits would be the highest with this alternative and cooperation of upstream landowners would be required.

Alternative 3 may meet most of the objectives of the USFWS in restoring the Sycan River corridor though the Kronenberger Ranch. This option would provide a long-term solution to the existing unstable and deteriorating system and may fall within the available funding sources. It would not restore the entire river and floodplain corridor to its ultimate potential, but may be adequate to meet the needs of the landowner and USFWS.

Alternative 4 would not meet any of the objectives of the landowner or USFWS and existing impacts and damages would continue to occur. This Alternative is not recommended.

3.2 Lower Gowdawa Springs Reach

The lower Sycan River is not as deeply entrenched as the upper section, however, the alternatives for restoration are very similar. The main difference would be with Alternative 2, where the existing channel would be stabilized in place with a 'C' type channel. Please refer to Table 1 for a description of the restoration philosophy as well as advantages and disadvantages for the range of alternatives.

Like the Brown Springs Reach, any of the alternatives would need a strict grazing management plan including fencing of the stream and floodplain. There would need to be a period of complete rest for the floodplain area to allow the revegetation effort to mature. Careful grazing could occur in the future, but it would need to be very limited in season and duration to minimize the risk of damage to health and vigor of the riparian vegetation.

3.2.1 Feasibility of Alternatives

Alternatives 2 and 3 would be the most feasible, with the least disturbance to the landowner and existing land uses and facilities. Alternative 1 could result in a wider grazing exclosure and may require some movement of existing facilities. Landowner agreement would be paramount with Alternative 1 early in the design phase. As with the Upper Brown Springs Reach, Alternative 4 would not meet the goals of the USFWS or the landowner for many decades in the future. Even with a fenced exclosure, it would take several decades for the stream to recover some semblance of its historic conditions. The more deeply entrenched reaches may not stabilize within this century, even with restricted grazing. The effects of continuing the existing conditions would be similar to those described for the Upper Brown Springs Reach and in Table 1.

3.2.2 Estimated Costs and Benefits of Alternatives

Alternative 1 may not be feasible unless landowner permission and funding were available to construct a new channel at the historic elevation beginning at the county road bridge at the upstream end of the project. Assuming a total channel length of approximately 18,000 feet (valley length of 9,000 feet with a sinuosity of 2.0), the total costs of Alternative 1 would be approximately $1.5 million. That equates to a cost of about $84 per linear foot of channel, including design, construction, revegetation and construction oversight. As stated previously, there should be a potential error factor of about 25% with an estimate at this scale of analysis.

Bank stabilization with any of the Alternatives would be a combination of composite root wad revetments at the highest shear stress areas, log and shrub revetments, sod and shrub revetments and possibly some geotextile fabric with vegetation planting in the lower stress areas. The emphasis should be on vegetative stabilization through whole shrub transplanting and rooted stock planting while minimizing wood and rock structures.

Potential advantages and disadvantages are shown in Table 1. In addition to providing the most productive and ecologically correct channel type in this area, there would be an increase in wetland acreage provided with the channel and floodplain. Additional mapping and analysis would be needed to determine the total increase in wetland acreage. Habitat improvements would include lowered water temperatures, increased pool depth and quality, cleaner substrate and more exposed gravel and stable undercut banks. Also, the new channel would be constructed "in the dry" while the water continued to flow in the existing channel. This results in less turbidity and suspended sediment loading during construction.

Alternative 2 would be the least expensive alternative and could satisfy many of the objectives for the project area. Bank erosion and sedimentation would be greatly reduced and aquatic habitat would be improved. With aggressive revegetation efforts, the stream would begin to narrow itself over time. Sediment would deposit on the inside of meanders, where vegetation would begin to encroach on the channel. Some of the existing meanders would need to be reshaped to bring the meander geometry more in line with normal ranges for this streamtype and size. Disadvantages would be a longer recover time frame, increased risk to the stabilized streambanks by not correcting channel pattern and configuration over the whole project reach and less than ideal habitat until the stream can recovery over time. Assuming a total channel length of 12,000 feet (as indicated by the longitudinal profile), approximately 6500 feet of channel would need to be stabilized. The sinuosity would remain the same at about 1.3. The estimated cost of implementing Alternative 2 would be approximately $350,000, which equates to a cost of about $29 per linear foot of channel, including design, construction, revegetation and construction oversight. There should be a potential error factor of about 25% with an estimate at this scale of analysis.

Alternative 3 would construct a 40 to 50 foot wide 'E' channel with a 100 to 120 foot wide base floodplain (low stage floodplain). The sinuosity would be approximately 1.6, which would increase channel length and sinuosity appreciably over existing conditions. Total proposed channel length would be about 14,400 feet. There would need to be some reshaping of the existing channel and a few short segments of new channel to achieve the desired result. Some of the excavated material could be used to create the bankfull benches and "finger bars" to narrow the channel. The total amount of fill can be minimized by excavating the proper channel depth and using this material to create a "finger bar" or partial point bar on the inside of the meander. This bar divides the main channel from a slack water area on the inside of the bend that is not connected to the stream directly (see Appendix B for an example of finger bar construction).

The total cost of Alternative 3 would be about $580,000. That equates to a cost of about $40 per linear foot of channel, including design, construction, revegetation and construction oversight. There should be a potential error factor of about 25% with an estimate at this scale of analysis. The potential advantages and disadvantages are shown in Table 1. Other benefits of this Alternative include:

- Improvement in riparian and fisheries habitat, including increased pool depth and quality, cleaner substrate and more exposed gravel and stable undercut banks.
- Increase in wetland acreage by about 13 acres,
- Potential reduction in flood stage for moderate sized floods due to enlarged floodplain and more stable channel,
- Ability to construct wetland ponds in the historic abandoned oxbows, and
- Lowered water temperatures.

Additional risks of this alternative are documented in Table 1. Alternatives 2 and 3 would probably result in more turbid water during construction because the construction could not be done "in the dry" for many reaches. This would result in higher short-term sediment loads during construction.

3.2.3 INFORMATION NEEDS

Before an effective design could be completed, there are a number of information needs that should be addressed. Information needs include:

- Refining project goals and objectives,
- Completing a more detailed assessment of river conditions and geomorphic potential of the river system,
- Validating the channel design dimensions and flood series analysis,
- Surveying the entire reach or aerial photogrammetry to develop a detailed topographic map of the project area, and
- Modeling the floodplain and determination of the existing floodplain boundaries;

The potential costs for completing analyses have not been estimated at this time. Some of the information needs could potentially be completed by the USFWS or other partners providing assistance. WCI could complete any or all of the assessment needs, if desired. Further discussions on the potential scope of work are necessary to determine total potential costs.

3.2.4 CONCLUSIONS AND RECOMMENDATIONS

Of the four Alternatives presented, Alternative 1 would be the best long-term treatment of the river and floodplain corridor. Costs and benefits would be the highest with this alternative and cooperation of upstream landowners would be required. Given the large costs involved and ability of other Alternatives to meet most or all of the objectives of the restoration effort, Alternative 1 would probably fall to a lower priority than Alternative 2 or 3.

Alternative 2 may meet most of the objectives of the USFWS in restoring the Sycan River corridor though the Gowdawa Reach. This option would eventually provide a long-term solution to the existing unstable and deteriorating system, although increased risks and lower benefits in the short term would be the disadvantages of this alternative. It would not restore the entire river and floodplain corridor to its ultimate potential, but may be adequate to meet the needs of the landowner and USFWS.

Alternative 3 may provide the best compromise between meeting most or all of the objectives of the restoration project. Costs are a fraction of those estimated for Alternative 1 and the river would be restored to near historic conditions. Alternative 3 would be our recommended action.

Alternative 4 would not meet any of the objectives of the landowner or USFWS and existing impacts and damages would continue or occur. Even with a fenced exclosure and an aggressive revegetation effort, this stream would take decades to stabilize into a productive river.

3.3 BROWN SPRINGS CREEK

This small stream has a high potential for restoration and could be a very important spawning and rearing tributary for the Sycan River native species. Providing fish migration upstream from the lower pond outlet could increase the total length of channel available for spawning. Limiting the solar exposure of the spring water and providing more shade could reduce temperatures. There is an existing pump in the pond that provides water for irrigation. The capacity of the pump is not known at this time. These goals could be accomplished through a number of alternatives, including:

1) Replacing the gated outlet of the lower pond with a fish ladder or "step pool" channel upstream from the road crossing (see Figure 3a),
2) Reducing the size of the pond and constructing a new 'E' channel to the north of the pond to route most of the water around the pond (see Figure 3b), and
3) Eliminating the pond while providing a sump for the pump inlet and constructing a new 'E' channel in its place (see Figure 3c).

Alternatives 2 and 3 could also be considered for all of the existing ponds along Brown Springs Creek. All alternatives would include restoring the ½ mile of stream downstream from the lower pond and the ¼ mile of stream upstream from the pond.

Like the Sycan River, any of the alternatives would need a strict grazing management plan including fencing of the stream and floodplain. There would need to be a period of complete rest for the floodplain area to allow the revegetation effort to mature. Careful grazing could occur in the future, but it would need to be very limited in season and duration to minimize the risk of damage to health and vigor of the riparian vegetation.

3.3.1 FEASIBILITY OF ALTERNATIVES

All three alternatives are feasible, with varying degrees of effects on the landowner's objectives for the pond complexes. Alternative 1 would keep the existing ponds in place, but would provide fish migration through the system. Alternative 2 would construct a new channel, reduce the size of the ponds and divert some water through the pond to maintain the existing stocked fisheries. Alternative 3 would eliminate the pond fisheries that currently exist, but would replace them with a productive stream fishery and additional valuable wetlands.

3.3.2 ESTIMATED COSTS AND BENEFITS OF ALTERNATIVES

Alternative 1 would replace the existing outlet structure with a step pool structure as shown in Appendix B. The structure is made of native rock and designed to allow fish to leap from one pool to the next to provide passage. These structures have been effective for salmonids, but may not allow fish passage for other species. The road would need to be shifted downstream about 50 feet and a large squash culvert installed with the invert countersunk into the new streambed. The existing pond would be left in place and would continue to increase water temperature. However, the restored stream and riparian area would probably reduce existing temperatures slightly. Approximately 2 acres of wetlands would also be enhanced with this alternative. Total restored stream length would be about 4600 feet.

Alternative 2 could be accomplished with or without the step pool structure. A new stream could be constructed around the pond, then run through a step pool structure, through the culvert and into the existing stream alignment. Another option would construct the stream and floodplain at a slightly higher gradient to match the stream elevations from upstream of the pond to downstream. This option would eliminate the need for a step pool structure, which could be beneficial to fish that do not have strong swimming or leaping capabilities. The new culvert would be needed with this option also. A small diversion could be placed such that a portion of the water would feed the pond and supply the pump with adequate water. Approximately 3 acres of wetlands would be enhanced or created with this Alternative and total restored stream length would be about 5400 feet.

Alternative 3 would eliminate the pond, but maintain a sump to supply water to the irrigation pump. A new 'E' channel and floodplain at a gradient that would connect the upstream and downstream reaches would replace the existing pond. This option would add an estimated 4 acres of wetland to the site and would not require the step pool channel to provide fish passage. Total restored stream length would be about 5400 feet. A large culvert would be required through the existing roadbed.

Costs for all of these Alternatives would be similar. All Alternatives and options would cost between $58,000 and $72,000 depending on the costs of materials. The cost of the step pool structure is comparable to the cost of excavating and creating a floodplain. The cost estimate includes design, materials, revegetation, construction and oversight. As with the Sycan project estimates, a range of +/- 25% should be used with this level of detail.

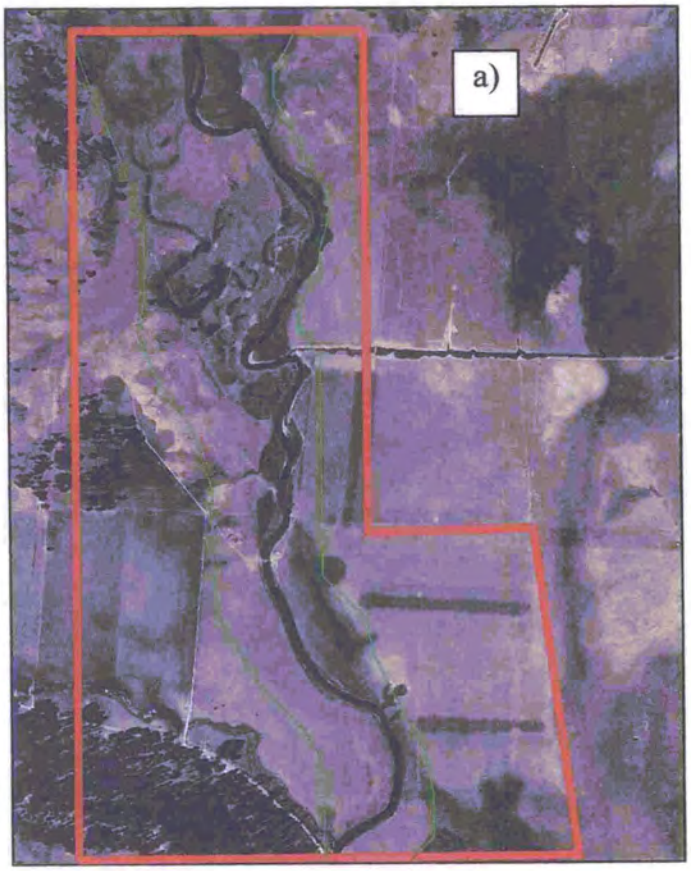
3.3.3 Information Needs

Information needs to complete a design would include:

- Refining the project goals and objectives,
- Validating the channel design dimensions, and
- Surveying the entire reach or aerial photogrammetry to develop a detailed topographic map of the project area.

3.3.4 Conclusions and Recommendations

Any of the Alternatives are feasible and costs would be similar. The preferred Alternative should be selected by the landowner and the USFWS to best meet all partner needs.



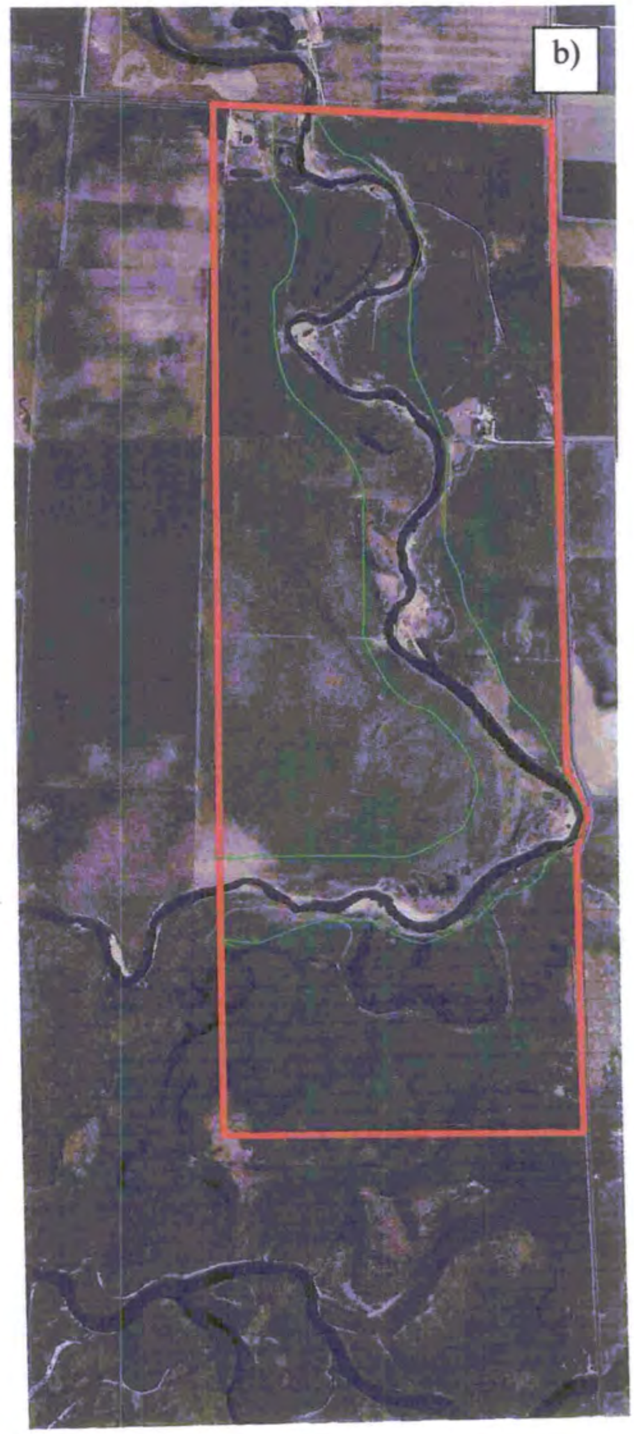


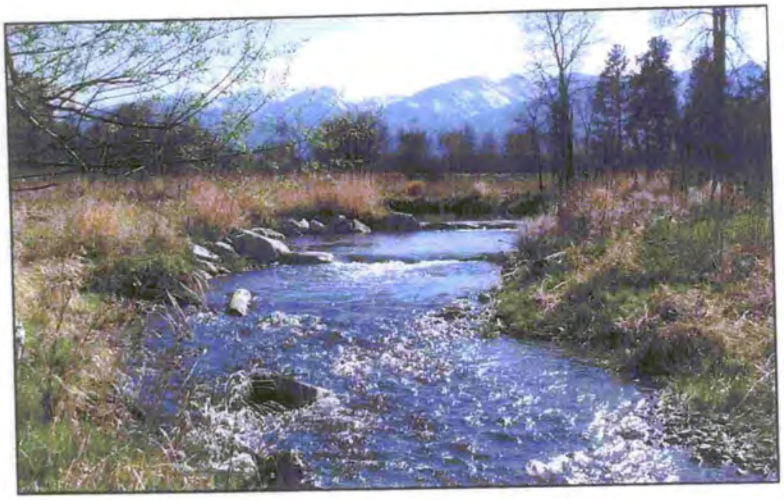
Figure 2: The approximate Sycan River north project area (a) and southern project area (b) are outlined in red. Channel construction will be occur within the existing belt width outlined in green.

Photo 3. Lower Gowdawa Springs Reach. Note lack of bank and floodplain vegetation, accelerated bank erosion, poor riparian and instream habitat, and extremely high channel width : depth ratio. However, channel is not vertically entrenched and has access to a wide floodplain.

Photo 4. Lower Gowdawa Springs Reach. Typical view of lower reach demonstrating lack of riparian vegetation, poor habitat complexity, and extremely high width – depth channel ratios.

Photo 1. Upper Brown Springs Reach. Note high width - depth channel ratio, lack of floodplain and poorly established riparian community due to channel incision and overgrazing.

Photo 2. Upper Brown Springs Reach. Note differences in bank erodibility (left and right banks) and early establishment of natural bankfull floodplain on right bank (view upstream). This channel reach is entrenched and lacks adequate floodplain width to dissipate flood flows, resulting in high near bank stress and accelerated lateral erosion.



A low gradient step pool built to improve fish habitat and to provide grade control in the project area. The three pool structure provides for fish passage and sediment transport.

A log weir focuses the flow towards the middle of the channel. The weir protects the banks both upstream and downstream of the structure. A tear drop-shaped scour pool that forms downstream of the structure provides valuable fish habitat. Gravel sorting upstream of the structure provides spawning opportunities for salmonids.

A three step, step pool structure was built to replace a shallow riffle that had been stabilized with riprap. The step pools provide habitat for both adult and juvenile salmonids. Complex currents through the pools offer both resting and feeding stations. The structure provides for fish passage and sediment transport.

Appendix B

To reduce sediment inputs from an eroding terrace, WCI constructed a bankfull bench. The bench serves as a vegetated buffer separating the eroding terrace and the stream. The channel was also modified to increase complex pool and riffle habitats along the outside of the meander. The bankfull bench is useful for narrowing overwidened channels. When built with bank stabilization and fish habitat structures, fish habitat in the stabilized reach is greatly improved.

Finger bars are built to narrow the stream width and increase channel diversity. Finger bars are usually built on the inside of the meander where shear stresses are lower during high water periods. The created slackwater habitats benefit waterfowl and provides optimal conditions for juvenile fish rearing.