1996 MAXAN WATERSHED STREAM HABITAT RESTORATION AND ENHANCEMENT DESIGN REPORT

Submitted To:

Dz'ilh K'Az Kwa Development Corporation
Burns Lake, British Columbia

Submitted By:

AGRA Earth & Environmental Limited
Prince George, British Columbia
Calgary, Alberta

March 1997

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AGRA Earth & Environmental
ENGINEERING GLOBAL SOLUTIONS

AGRA Earth & Environmental Limited
221 - 18th Street S.E.
Calgary, Alberta
Canada T2E 6J5
Tel (403) 248-4331
Fax(403) 248-2188

March 4, 1997
KX02779

Mr. Ben Rencoret
Dz'ilh K'Az Kwa Development Corporation
P.O. Box 1030
Burns Lake, British Columbia
V0J 1E0

Dear Mr. Rencoret:

RE: 1996 MAXAN WATERSHED HABITAT RESTORATION AND ENHANCEMENT

AGRA Earth & Environmental Limited (AEE) is pleased to present our report outlining site-specific 1996 restoration and enhancement design plans for the Maxan Watershed. This design report is based upon preliminary surveys conducted in 1995 and detailed ground surveys carried out in 1996.

We thank you for providing us with the opportunity to complete this work.

Should you have any questions concerning this document, please contact the undersigned.

Yours truly,

AGRA Earth & Environmental Limited

Joseph (Sepp) Muhlberger, B.Sc.
Environmental Scientist

JM:cj

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

Page

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS (continued)

Page

APPENDICES

1.0 INTRODUCTION

1.1 BACKGROUND

In the summer of 1996, AGRA Earth and Environmental Limited (AEE) was retained by the Yin Waghunlee Habitat Enhancement Corporation (now Dz'ilh K'Az Kwa Development Corporation) to design stream habitat restoration and enhancement measures in the Maxan watershed. Enhancement measures, as described in this report, are intended to:

- increase the availability of spawning, rearing and feeding areas for salmonids through accentuation (rather than alteration) of existing stream habitat and flow conditions;
- increase the recruitment of spring and fall salmonid species;
- protect and maintain downstream water quality through activities that control erosion while providing an abundance of fish cover;
- provide volunteer teams and interest groups with "hands-on" experience that will help to promote stewardship of the resource; and
- provide the basis for subsequent stream habitat enhancement projects in the Maxan watershed.

1.2 STUDY AREA

The Maxan watershed covers approximately 83,000 ha and consists of four sub-basins: Maxan, Crow, Day Lake and Bulkley (Figure 1). Streams within the study area are known to support important resident and/or migratory fish populations. For example, the Bulkley River supports anadromous populations of salmon (*Oncorhyncus spp.*), Dolly Varden (*Salvelinus malma*) and steelhead (*Oncorhyncus mykiss*), and maintains a regionally and provincially important sport fishery (Class II Water - BC Environment, 1994).

As a result of past land use activities (i.e., road development, agriculture and clearcutting), the Maxan watershed is subject to poor water retention and flashy flows during spring melt and after large rainstorm events. Within the watershed (i.e., Foxy and Lower Maxan Creeks), increased flows have impacted channel geometry through increased streambed scour and streambank erosion. Lower gradient systems, such as the Bulkley River, have been adversely impacted by increased streambank erosion and sediment deposition. Combined, these conditions have reduced the quality and quantity of salmonid spawning, rearing, feeding and overwintering habitats.

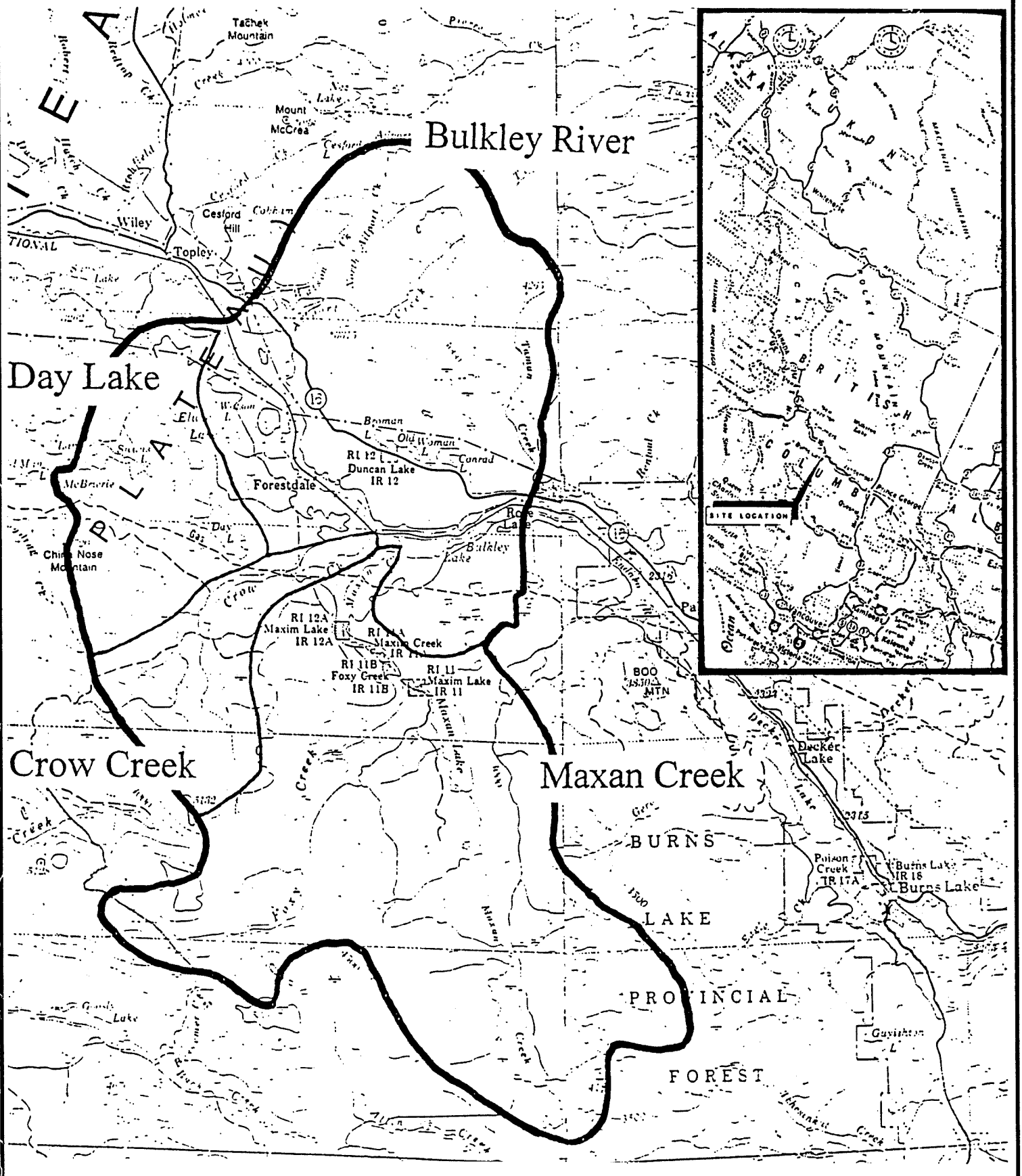

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Figure 1 Study Location: Watershed and Sub-Basin Boundaries for the Maxan Watershed - Lakes Forest District

1.3 OBJECTIVES

As per Schedule "A" of the service contract, the primary objectives of the Maxan watershed stream habitat restoration and enhancement program were to design prescriptions intended to rehabilitate or remedy impacted sites. The objectives, as outlined in this report, include:

- a geographical location of each site(s) complete with sub-unit and reach identified;
- photographs of impact(s);
- a description of works to be completed (i.e., restorative, rehabilitative and/or mitigative);
- a budget estimate for construction works (i.e., labour, equipment and materials); and
- a timeline estimate that would consider:
  - minimizing impacts to the aquatic resources that may be affected by the work;
  - any other WRP work that is occurring in the area where cost sharing can be incorporated; and
  - an outline of all regulatory agency approvals required prior to commencement of any work.

Based on findings in the Phase 1 assessment (AEE 1996) and through conversation with Tom Olson (BCMOE), it was decided that activities would focus on high priority watercourses such as the Bulkley River and Foxy and Maxan (Upper and Lower) creeks.

In October 1996, AEE completed a helicopter and ground survey of highly visible degraded habitats for design purposes. Due to snow cover, a detailed survey could not be conducted.

Existing stream habitat characteristics and enhancement measures are described in the following sections. Summaries of equipment, materials and manpower requirements are provided for each project area. Cost estimates for the various project components are also provided.

2.0 FISH SPECIES COMPOSITION AND DISTRIBUTION

In total, 18 species of fish have been reported from the Maxan watershed (Table 1). Of these, five represent anadromous salmonids, four resident sport fish, four coarse fish (Pacific lamprey are anadromous) and five forage fish species. Lakes provide summer feeding habitat for resident fish and rearing habitat for anadromous stocks. It is not known if bull trout (*Salvelinus confluentus*), the only blue-listed fish species in the Lakes Forest District, inhabit the watershed. Information about fish populations within the study area is patchy and there are almost no data about fish population characteristics and key habitats.

Table 1
Known Fish Species Composition and Distribution in the Maxan Watershed

Species	Scientific Name	Distribution
Pacific lamprey	*Entosphenus tridentatus*	Reach 1/2 - Foxy Creek
Coho salmon	*Oncorhychus kisutch*	Bulkley Lake Reach 1 - Ailport Creek Reach 1 - Upper Maxan Creek
Sockeye salmon	*O. nerka*	Bulkley Lake
Chinook salmon	*O. tshawytscha*	Reach 1/2 - Foxy Creek Reach 1 - Watson Creek Reach 1 - Lower Maxan Creek
Steelhead trout	*O. mykiss*	Bulkley River and Reach 1 - Watson Creek
Rainbow trout	*O. mykiss*	Reach 1/2 - Foxy Creek Reach 1 - Ailport Creek Reach 1 - Crow Creek Reach 1 - Watson Creek Reach 1 - Lower Maxan Creek McBrierie, Swans, Day, Elwin, Ailport, Old Woman, Conrad, Broman and Bulkley Lakes
Dolly Varden	*Salvelinus malma*	Reach 1/2 - Foxy Creek Reach 1 - Lower Maxan Creek
Lake whitefish	*Coregonus clupeaformis*	Day Lake
Mountain whitefish	*Coregonus clupeaformis*	Day Lake
Mountain whitefish	*Prosopium williamsoni*	Reach 1/2 - Foxy Creek, Elwin Lake
Burbot	*Lota lota*	Bulkley Lake
Northern squawfish	*Ptychoheilus oregonensis*	Elwin and Day Lakes
Lake chub	*Couseius plumbeus*	Elwin Lake
Peamouth chub	*Mylocheilus caurinus*	Day Lake
Longnose dace	*Rhinicthyes cataractae*	Reach 1/2 - Foxy Creek
Redside shiner	*Richardsonius balteatus*	Day Lake
Longnose sucker	*Catostomus catostomus*	Reach 1/2 - Foxy Creek, Day Lake
Largescale sucker	*C. macrocheilus*	Day and Elwin Lakes
Prickly sculpin	*Cottus asper*	Reach 1/2 - Foxy Creek

Note: Based on a review of government files and consultant reports.

3.0 STREAM HABITAT CHARACTERISTICS

The following sections discuss the characteristics of the Bulkley River, Lower Maxan Creek, Upper Maxan Creek and Foxy Creek as observed in the fall of 1995 and 1996. Photographs detailing typical habitats are provided in Appendix A.

3.1 BULKLEY RIVER SUB-BASIN

The Bulkley River sub-basin consists of a sequence of lakes (Broman, Old Woman and Conrad) connected by ephemeral tributaries to each other and to Bulkley Lake, which collectively form the headwaters for the Bulkley River. The sub-basin also contains a third-order stream, Ailport Creek, which flows into the Bulkley River about 16 km north of Bulkley Lake.

3.1.1 Bulkley River

The Bulkley River supports anadromous populations of salmon, Dolly Varden and steelhead, and maintains a regionally and provincially important sport fishery. The river originates in this sub-basin and flows north from Bulkley Lake to the watershed boundary at Topley and west to the Skeena River. The Bulkley River receives inflow from two third-order (Crow and Ailport), one second-order and several first-order tributaries.

The portion of the river contained within the watershed boundary consists of a single major reach. The river is highly sinuous with numerous oxbow lakes and meander scrolls, which indicate the dynamic nature of this system (Photo 1). The riparian zone has been significantly altered by various land use practices.

The Bulkley River meanders through agricultural land (crop and pasture) and is occasionally confined by the Canadian National Railroad mainline. Road and rail crossings are common. Timber has been removed from most of the banks and the remaining canopy is almost completely open. Shrub communities (i.e., willow spp.) provide patchy overhead fish cover. Banks are typically vertical (eroding) and comprised primarily of fines. Land use practices have impacted flow conditions, bank and channel stability, habitat diversity, substrate composition, benthic community structure, nutrient dynamics, and productivity in the river. This reach is colonized by numerous beaver.

AEE assessed and designed enhancement plans for 13 sites along the Bulkley River. Degraded habitats were located along agricultural land, the CNR mainline, the Rose Lake Cutoff Road and at a hydroline crossing.

3.2 MAXAN CREEK SUB-BASIN

3.2.1 Lower Maxan Creek

Lower Maxan Creek meanders north from Maxan Lake for about 16 km to Bulkley Lake. The stream is joined by Foxy Creek and four second-order tributaries, making lower Maxan Creek a fifth order stream.

Reach 1

Reach 1 of Lower Maxan Creek meanders through flat bottomland for 8 km (Photo 2). It is a highly sinuous, irregular meander which is occasionally confined. The banks are low and generally well vegetated with herbaceous vegetation, dense shrub thickets and mixed timber stands. Banks are comprised primarily of fines. The substrate is dominated by clean gravels/cobbles and is ideal for spawning. Abundant Large Woody Debris (LWD) provides overhead and instream cover. Frequent, deep scour pools have been created off the tips of this debris. Minor beaver activity was noted in the reach. According to Department of Fisheries and Oceans (DFO) files, chinook salmon and rainbow trout spawn within the reach. Dolly Varden may also spawn in Reach 1.

It is estimated that approximately half of the land surrounding Reach 1 is used for agriculture. Woody vegetation along the creek has been removed in much of the agricultural land. About 30% of the forest situated east of the reach has been harvested. A number of deactivated bridge crossings and fords are located towards the downstream end of the reach. A network of rudimentary trails provide access to the surrounding land on both sides of the stream.

Due to snow cover, no enhancement sites were selected along Reach 1.

Reach 2

Reach 2 is 8.5 km long and is the principal outlet of Maxan Lake (Photo 3). This reach is a sinuous, irregular meander which is occasionally confined. Banks are comprised primarily of fines. Agricultural and forestry activity have removed about 50% of the riparian vegetation. Windthrow material has accumulated in large debris jams. Beaver activity has created some off-channel habitat within Reach 2. The main Maxan Creek road parallels the creek for most of its length. There is one bridge crossing. Reach 2 supports chinook salmon and rainbow trout.

As a result of snow cover, only one enhancement site was selected in Reach 2 (near the Thompson Road bridge crossing).

3.2.2 Upper Maxan Creek

Upper Maxan Creek is a fourth-order, low-gradient stream which meanders north about 15 km from bog headwaters into Maxan Lake. Three small lakes are present in the headwaters (Intel Lakes I, II and III) of the mainstem. Five third-order streams, four second-order streams and numerous first-order and/or ephemeral streams flow into the creek. The creek consists of two distinct reaches.

Reach 1

In this reach, the stream is an unconfined, irregular meander which wanders through flat, marshy bottomland (Photo 4). The channel is confined between low, stable, heavily vegetated banks. The substrate is generally compacted. Occasional sand/gravel long bars and side channels are present. Pool and run complexes are dominant in this reach. A few harvested openings have been cleared near the mainstem. Coho salmon were observed in 1970 by DFO staff.

Narrow, deep, well-vegetated streambanks indicate that Reach 1 has not been significantly impacted by hydrologic increases. No enhancement or restoration works were designed for this reach due to overall good habitat conditions and poor access.

Reach 2

Reach 2 is an unconfined, irregular meander which runs through marsh and meadow land (Photo 5). Characteristic low banks are well vegetated with herbaceous vegetation and shrub thickets. Occasional timber stands occur where suitable conditions exist. There is some beaver activity within the reach. Meander pools and long glides typify the habitat. Two harvested openings have been cleared in the lower portion of the reach. A logging road east of the reach crosses six tributaries as well as the mainstem near the headwaters and "Bernadette" Creek near the mouth. Fish species composition, distribution and use are unknown, but it is likely that coho salmon inhabit the reach given their presence in Reach 1 and the lack of obvious barriers to upstream fish movement.

No enhancement activities are recommended for Reach 2 due to good habitat conditions and poor site access.

3.2.3 Foxy Creek

Foxy Creek is a shallow second-order, low-gradient stream. The creek originates in a bog and meanders north-northeast for about 15 km to join Maxan Creek near Maxan Lake. Numerous streams flow into the mainstem: one third-order, six second-order and five first-order and/or ephemeral tributaries. There are four distinct reaches in the mainstem.

Reach 1

Reach 1 of Foxy Creek is dynamic and aggrading (Photo 6). It flows for about 3 km through several unconfined, braided channels separated by mid-channel islands. Shrubs and herbaceous vegetation afford some bank protection and undercut banks are relatively common. Several sections of bank are denuded and aggrading. Abundant side and off-channel habitat exists within the reach, and provides rearing and overwintering habitat for fish. Plentiful LWD supplies overhead cover and has encouraged scour pool development. Shallow pools are common. Spawning gravels are abundant in the cobble-gravel substrate.

This reach is productive, as evidenced by good macrophytic growth (filamentous algae) and eight species of fish which it supports (Bustard & Associates, 1989). The reach contains suitable rearing habitat for anadromous fish (chinook salmon, Dolly Varden, pacific lamprey, and steelhead), regional sportfish (mountain whitefish, rainbow trout) and several coarse fish species (longnose dace, longnose sucker and prickly sculpin). The reach supports high densities of juvenile rainbow trout (Bustard & Associates, 1989). The presence of juveniles in Reach 1 implies that resident and migratory fish spawned further upstream.

About one third of the low- to midslope forest surrounding this reach has been harvested. A buffer strip was retained on the only opening (#6) that is adjacent to the creek. A logging road crosses the stream mid-reach and a deactivated spur crosses the stream near the mouth. There is one ford in the reach.

Two enhancement sites were chosen along Reach 1. Sites are located at one active and one deactivated bridge crossing.

Reach 2

Foxy Creek is entrenched and confined within a deep canyon in Reach 2 (Photo 7). Mature pine and spruce stands provide limited canopy cover over the stream. Banks are protected by bedrock ledges as well as cobble and boulder materials. Small bank slumps are common throughout the reach. Two extensive bank slides and accumulated debris across the creek are major point sources for sediment input into the stream. A large slope failure has also occurred downslope of a clearcut (Opening #45). Two large log jams partially dam the creek and may be barriers to fish movement during low flow events. Abundant LWD obstructions form the pool-glide sequences which typify the habitat. Spawning gravels are limited in the cobble-bedrock dominated substrate. Reach 2 supports the same eight fish species as Reach 1. However, use of this reach by individual life history stages is not known. Bustard & Associates (1989) confirmed that rainbow trout spawn and rear within the reach.

Land surrounding Reach 2 has been developed for forestry purposes. Approximately 30% of the timber has been removed from the benchlands adjacent to the canyon. Windthrow is common along harvesting opening edges. Harvesting has accelerated the natural instability

of the steep banks and resulted in numerous slope failures. This is especially apparent downslope of Openings #25 and #45. A network of logging roads provides access to the clearcuts. There are no stream crossings within the reach.

Snow cover impaired visual observations along this reach. As a result, no design plans were developed.

Reach 3

Reach 3 of Foxy Creek is occasionally confined between steep banks as it meanders irregularly downslope (Photo 8). Some side channel development and braiding exists. Banks are naturally unstable and prone to mass wasting and toe erosion. Mixed spruce and pine stands provide a dense overhead canopy. Fish habitat consists mainly of pool-riffle sequences. Abundant LWD supplies good overhead and instream fish cover. A few harvested openings have been cleared in lands surrounding the reach.

Reach 3 was sampled in 1984, however no fish were captured (Bustard and Associates, 1989). Despite this, "point-in-time" sampling does not account for seasonality nor population fluctuations. The reach appears to have the potential to support fish and likely does, at least seasonally. Still, it is possible that barriers in Reach 2 prevent fish from accessing this reach.

Due to snow conditions, AEE personnel were unable to adequately assess Reach 3 in the fall of 1996. No enhancement measures would be recommended for this reach until fish presence-absence is determined.

Reach 4

Reach 4 of Foxy Creek originates in bog headwaters and flows into a confined channel (Photo 9). The banks are well vegetated with herbaceous vegetation at the headwaters and mixed timber where the channel becomes more defined. Long riffles and short glides typify the habitat. The substrate is coarse and frequent plunge pools form behind boulders.

This reach is probably devoid of fish (Bustard & Associates, 1989). Several falls within the reach restrict upstream fish passage. Land surrounding the reach has been heavily developed. Equity Mines operated an open-pit silver extraction mine near the headwaters from the 1970s through the 1980s. The mine has been inoperable for several years but the tailings pond has not been decommissioned. Drainage adjacent to the mining operation was modified. Logging activity is present in land surrounding the reach.

No enhancement activities are recommended for this reach.

4.0 STREAM HABITAT ENHANCEMENT MEASURES

4.1 BANK STABILIZATION/COVER ACTIVITIES

4.1.1 Tree/Shrub Revetments

Revetments are an effective erosion control measure which provide bank protection, and abundant overhead and instream fish cover along eroding streambanks. Revetments have a natural appearance, and promote natural revegetation and stabilization of the protected streambank. These devices may be constructed from trees and/or dense shrub bundles.

Tree revetments will be constructed from 5 to 10 m long, well-branched spruce trees or spruce tree sections. Each tree will be selectively harvested from local stands. Trees will not be felled close to the streambanks so as to maintain channel stability, instream shading and overhead cover. Depending on access and design specifications, a trackhoe, quad or truck will be used to transport the trees to installation sites.

Shrub revetments (i.e., willow or alder) will also be constructed in the project area. Individual shrub clumps (bushes) will be cut near the base and bound with heavy biodegradable twine and #9 galvanized wire. Shrub bundles will be transported to site by hand or with a quad.

Revetments will be installed manually or with the aid of a trackhoe. Where trackhoe access is unnecessary or impossible, each butt (tree or shrub) will be secured to the top of the bank with an 8' T-post deadman and #9 galvanized wire. Where hoe access is good, AEE recommends that "green" posts hewn from locally available trees be used to replace the metal T-posts. The hoe will be used to pound these posts (one end sharpened) in the bank. Both methods will require the burying of tie wires into streambanks. Each tree tip will be secured to the streambed with either a wire/T-post or wire/concrete swamp weight combination.

4.1.2 Log Terraces

Terraces are designed to increase slope stability by decreasing slope gradient. Terracing reduces erosion by decreasing overland flow velocities and trapping fine materials.

Log terraces will be constructed from dead or dying trees in close proximity to the sites. The trees will be cut into manageable lengths (5 to 10 m) and transported to the sites by quad, truck or hoe.

Logs will be positioned above the high water mark on unstable banks. Four T-posts will be pounded (two at each end) into the banks on each side of the logs. If site conditions are favourable, it may be possible to pound sharpened stakes or posts into the banks instead of

using T-posts. Galvanized wire will secure the logs to the posts. The spaces behind the terraces will be backfilled with soil, compacted, staked with shrub cuttings and seeded.

4.1.3 Riprap

Riprap, is used to control streambank erosion and encourage revegetation and natural stabilization. Armoured banks enhance fish resources by reducing sediment loadings, increasing habitat diversity and restoring streamside cover characteristics. A reduced rate of siltation is expected to increase the availability of benthic microhabitats, resulting in increased invertebrate productivity (i.e., increased diversity and abundance) and fish food resources.

Angular, Class 2-3 riprap (0.30 to 1.2 m diameter; Table 2) will be obtained from nearby rock quarries and/or rockslides. Prior to installation, eroding banks will be graded to 2H:1V. Geotextile fabric, or filtercloth, will then be laid on the bank to allow water passage while containing the movement fine materials away from the bank. The fabric will be pinned in place using 6" loose filtercloth staples. Using a trackhoe, riprap will be placed on the filtercloth from the toe of the slope to the high water mark. Rock armour will only be applied along severely eroded streambanks which are subject to high flow attack.

4.1.4 Shrub Log Walls

Shrub "logs" reduce erosion, encourage natural revegetation and blend into the surrounding environment. Shrub logs are designed to last long enough for the establishment of well-rooted vegetative growth.

Shrub log walls will be constructed from nearby shrub species (i.e., willow and/or alder). Each log will be 2.0 to 2.5 m long, 0.3 m wide and held together with heavy biodegradable twine. Overlapping bundles will be placed in horizontal rows across the base of affected streambanks. Alternating pegs and twine will be used to secure the logs to the bank. Logs will be stacked on top of each other to account for water level fluctuations and steep slopes. Areas behind these structures will be infilled with soil, compacted, staked with shrub cuttings and seeded. For additional stability where direct flow attack occurs, spruce tree sections will be incorporated into these structures.

4.1.5 Shrub Staking

Shrub staking is intended to control erosion, improve bank stability and restore stream shading and overhead fish cover.

Table 2
Rock and Riprap Class Sizes

	Class 1		Class 2		Class 3	
	Size[1] (mm)	Mass (kg)	Size[1] (mm)	Mass (kg)	Size[1] (mm)	Mass (kg)
Nominal Size	300		500		750	
Riprap Gradation Percent Passing[2]						
100	450	130	800	700	1200	2300
30 - 80	350	70	600	300	900	1100
30 - 60	300	40	500	200	800	700
5 - 20	200	10	300	40	500	200

Notes:

1 Sizes quoted are equivalent spherical diameter, where relative density is in the range of 2.4 to 2.9.

2 Percentages quoted are by mass.

Hand cut stakes, approximately 45 cm long, will be collected from nearby willow and alder bushes. The tips will be removed and the stakes will be cut near the bottom of the branch. Planted at 1 m spacings (1 m centres), the stakes will be pushed into soft bank material above the high water mark. If the banks are too hard, it may be necessary to punch holes into the ground using rebar and a sledge hammer. Each shoot must be almost completely covered by soil to limit desiccation.

4.1.6 Brush Layering

Brush layering, like staking, is intended to reduce erosion, improve bank integrity and provide overhead fish cover.

Brush layering will involve hand or hoe excavation of shallow, horizontal benches (20 - 30 cm deep) along reposed banks. Each bench will be spaced approximately 1 m apart. Shrub cuttings (30 to 40 cm long) will be densely layered in each bench. Excavated spoil will be backfilled over the brush layers and thoroughly compacted. Approximately 5 to 10 cm of each stake will be exposed.

4.1.7 Wattle Bundling

Wattle bundles reduce erosion, improve bank stability and re-establish streamside cover.

Wattle bundles will be constructed from quick suckering species (i.e., willow and alder). Each bundle will be 2.0 to 2.5 m long, 0.3 m wide and held together with heavy biodegradable twine. Hand-hewn stakes will be pounded immediately downslope of the wattle trench (trench depth = 1/3 to 2/3 of wattle diameter). Wattles will be overlapped in the trench, staked and backfilled with trench spoil. With approximately 10 to 20% of the wattle exposed, each bundle will be compacted thoroughly.

4.1.8 Seeding

A seed broadcaster will be used to spread Canada #1 forestry seed mix on exposed areas above the high water mark. This mixture contains 5% alfalfa, 10% red clover, 10% alsike clover, 20% timothy, 25% fescue and 30% crested wheatgrass. This seed mix has proven effective at numerous other AEE stream habitat enhancement sites.

4.2 INSTREAM ACTIVITIES

4.2.1 Rock Ledges, Pools and Riffles

Pool and riffle habitat in the study area will be restored and enhanced through accentuation, rather than alteration, of existing stream conditions. Existing riffle crests, for example, will be replaced with more permanent rock ledges, or "V" weirs, that will stabilize bed movement and encourage localized gravel and cobble deposition. As constructed, these structures will maintain excellent pool and run habitats suitable for feeding, resting and refuge. Gravel deposits on the upstream side of ledges and in pool tailouts may also enhance spawning capabilities.

Rock ledges will be constructed from Class 2 and/or 3 riprap. Individual rocks will be fit tightly together in a shallow trench excavated across the creek channel and into the banks. The rocks will slope down the banks to the lowest rock situated at the upstream point (apex) of the weir. This design ensures that flows are centred in the channel and not directed into streambanks. It is a stable design which promotes self-scouring of downstream pools.

Shallow pool areas located immediately downstream from ledge sites will be excavated to depths varying from 0.5 to 1.0 m. Pools will be deepest at the upstream end and gradually taper downstream. The turbulence created from water spilling over the ledge is expected to maintain pool depth through continued streambed scour. Pools control stream gradient, create turbulence and holding sites, and help facilitate upstream fish passage during high flows.

Riffle areas will be created directly upstream of weirs to prevent undermining and improve water and fish passage over the structure. Clean, hand-placed cobbles will be spread across the channel bed and banks to a point 3 m upstream of the ledge. It is expected that spawning gravels will naturally deposit at the upstream end of the riffle.

Fine spoil material that remains after trench and pool excavation will be spread away from the banks or buried to reduce silt loadings during spring runoff or rainstorm events. Large cobble and boulder material contained in the spoil will be used to armour banks adjacent to rock ledge tie-in points.

4.2.2 Rock Clusters

Rock clusters, or boulder groups, will be positioned by hand and/or machine. These devices provide cover, as well as feeding and resting habitat for fish in relatively shallow riffles and runs. They are especially important when used by fish during upstream migration. They also encourage streambed scour and create pocket water and back-eddies, which provide fish holding areas.

Riffle/run habitat will be improved with single, double and triple boulder cluster configurations constructed from Class 1 and 2 rock material (0.20 to 0.80 m diameter) obtained locally or from nearby rock deposits. Clusters will be positioned in relatively high velocity riffle/run areas and at the tailouts of deeper pools. They will be distributed across the channel to provide variable habitat conducive for adult, juvenile and young-of-the-year salmonids. Rocks will be placed on the channelbed to maintain downstream water quality. In riffle habitat, pocket water areas will be hand-excavated immediately downstream of the boulders to promote self-scouring.

4.2.3 Wing Deflectors

Wing deflectors are used to narrow stream channels in order to concentrate low to moderate streamflows, and encourage streambed scour and pool development. Higher flows pass smoothly over their surfaces. Self-scouring pool and run areas created by flow deflection provide excellent rearing environments.

Deflectors will consist of a triangular riprap frame constructed from Class 2 and 3 riprap which will be infilled with local cobble material. The riprap frame will be set tightly into a shallow trench excavated with a hoe. Boulders will taper down the bank to the lowest rock located at the apex of the structure. Angled 45° downstream, the design gently turns primary flows into the centre of the channel. Secondary flows are pulled downstream, behind the groyne, which encourages deposition of fines in shoreline areas downstream from the structure. High flows will pass smoothly over the deflector surface.

4.2.4 Boulder / Log Groynes

Single boulder/log groynes are designed to reduce bank erosion by deflecting currents away from the bank. The bank is also reinforced by sediment deposition resulting from flows pulled downstream, behind the groyne. Back-eddies immediately downstream of the structures create localized resting areas which facilitate upstream fish migration.

Using the trackhoe, Class 1 to 3 rocks will be spaced randomly along the bank. The trackhoe bucket will be used to position the boulders and push them into the toe of the bank.

Log groynes will be constructed from large-diameter tree trunks (10 to 12' diameter) selectively harvested from nearby stands. Trees will be bucked and cut into 5 to 8 m lengths. Each log will be transported to the sites using a quad, truck or hoe. One end will set into a shallow trench excavated into the bank. A T-post and #9 galvanized wire will secure the log into the bank. Log tips will be anchored to the channelbed using #9 galvanized wire and 110-pound swamp weights.

4.2.5 Bendway Weirs

Bendway weirs can be used alone or in combination with other methods to reduce the amount of armouring materials needed to stabilize a bank. Stable scour pools at the stream end of the weirs and occasional deep pools within the weir field are among the habitat improving benefits.

Bendway weirs will be constructed from Class 1 to 3 riprap. Each device will be positioned in a row (up to 3 m long and 1.5 m wide) placed perpendicular to the streamflow. Bendway weirs redirect the force of the stream or river away from the outer bank and toward the inner part of the bend. At the same time, the deepest part of the channel will be moved toward the middle of the stream and velocities will be reduced near the eroding outer bank.

4.2.6 Large Woody Debris

Large Woody (organic) Debris, or LWD, provides instream and overhead fish cover. In shallow riffle and run areas, LWD creates back-eddies and low velocity zones favourable for fry rearing.

Woody material will be collected above the high water mark so as to not limit available refugia provided during high flows. Large material (i.e., stumps) will be transported with the hoe and set into excavated trenches along the bank, where it will be pinned into place with #9 galvanized wire and T-posts.

5.0 STREAM HABITAT ENHANCEMENT DESIGNS AND SITE-SPECIFIC COST ESTIMATES

The following site designs have been developed using the "best" materials to achieve the desired results. It should be noted, however, that different materials can be used, or interchanged, to achieve similar results at a site. For example, boulder groynes can be replaced with LWD (i.e., root wads) dug into a bank. By using different materials, and hence installation methods, costs could be reduced at some of the sites.

The use of volunteer groups (instead of paid labourers) could also reduce costs. Then too, by using two experienced AEE supervisors and two 2-person labour crews, construction costs could be reduced by completing the activities over a shorter time period (i.e., two to three weeks instead of four). AEE is not aware of any other WRP work occurring in the area where cost sharing could be incorporated.

The cost estimates provided in this report are based on other enhancement works conducted for the British Columbia Ministry of Environment (BCMOE) by AEE.

Schematic overviews of recommended design plans and tables outlining equipment, manpower and cost requirements are provided throughout this section. Photographs depicting site characteristics have been included in Appendix B.

5.1 STANDARD TRANSPORTATION AND EQUIPMENT REQUIREMENTS

Transportation and equipment requirements outlined in Table 3 will be necessary (standard) for most, if not all, the construction sites. For simplification purposes and to prevent overlap, the cost of this equipment has been tallied and will not be included in site-specific cost estimates. It will, however, be included in the total cost summary provided in Section 6.

5.2 BULKLEY RIVER

5.2.1 Site 1

Site 1 (BR-S1) is located about 500 m downstream of the Bulkley Lake outlet (based on thalweg distance). It is 280 m long and is situated between a Canadian National Railway (CNR) crossing and an active bridge. Channel constriction at the crossing has resulted in increased flow velocities and erosion of a 30 m section along the right bank (looking downstream). Resultant mass wasting processes threaten to undermine the Rose Lake Cutoff Road (Photo 10). Excluding a 70 m section of riprap along the CNR tracks, banks at this site are partially reposed to vertical (eroding), comprised of fines and have little shrub and tree cover (Photo 11).

Table 3
Standard Transportation and Equipment Costs

Cost Component	Hours, Rates and Costs	Cost ($)
Trackhoe Transport (Burns Lake - Bulkley River - Burns Lake)	3 hours @ $125/hour	$ 375
Trackhoe Transport (Bulkley River - Foxy/Lower Maxan Creeks - Burns Lake)	5 hours @ $125/hour	625
2 sledge hammers	$30 each	60
2 shovels	$30 each	60
1 hammer	$15 each	15
2 wire cutters	$10 each	20
2 tree clippers	$10 each	20
1-1/2" rebar (10' length cut in half)	$3 each	3
2 machettes	$15 each	30
1 seed broadcaster	$70 each	70
20 rolls heavy biodegradable twine	$10 each	200
1 bag Canada #1 forestry seed mix	$300 each	300
2 pairs chest waders	$100 each	200
1 choker (9' x 9/16")	$56 each	56
1 T-post pounder	$50 each	50
ESTIMATED PROJECT TOTAL		**$ 2,084**

Initial bank stabilization activities of the slump will involve flattening of the slope to 2H:1V. Excess material (2 loads) will be transported and stockpiled at Site 2. Filter cloth (Petromat 4553) will then be laid across the bottom of the bank (up to the high water mark) to allow water passage and containment of fines. Filtercloth loose staples (6") will pin the fabric in place. Haul trucks (with rock boxes) will dump riprap at the top of the bank to facilitate hoe installation of the material. Wattle bundles, brush layers and shrub stakes will be installed on the recontoured surface above the riprap. Canada #1 forestry seed mix will be broadcast on all disturbed areas.

Bank stabilization and cover characteristics at BR-S1 will also be improved by intensive shrub staking along the left and right banks. Cuttings will be obtained locally and will be planted up to 5 m back from the left and right banks.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

A schematic overview of recommended enhancement works at BR-S1 is provided in Figure 2. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 4.

5.2.2 Site 2

Site 2 (BR-S2) is located 100 m downstream of Site 1 (Photo 12). Banks consist primarily of fine material. Right bank erosion (24 m long and 1.5 m high) is gradually undermining the Rose Lake Cutoff roadbank. High flow back-eddies have accelerated erosion around a small hanging culvert at the upstream end of the site. A blowout has also occurred at the downstream end. Herbaceous vegetation and some shrubs overhang the river.

AEE recommends that blowouts around the culvert and at the downstream end of the site be infilled with 2 loads (1 load each) of spoil material acquired from Site 1. A tree revetment constructed from five 10 m long, well-branched spruce trees will then be installed along the bank. Trees will be transported to the site and positioned using a hoe and 9' x 9/16" choker. Rebuilt bank sections will be staked and seeded. It is expected that bank building will occur as a result of sediment and debris deposition within and behind the structure.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

A schematic overview of recommended enhancement works at BR-S2 is provided in Figure 3. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 5.

GPS Coordinates
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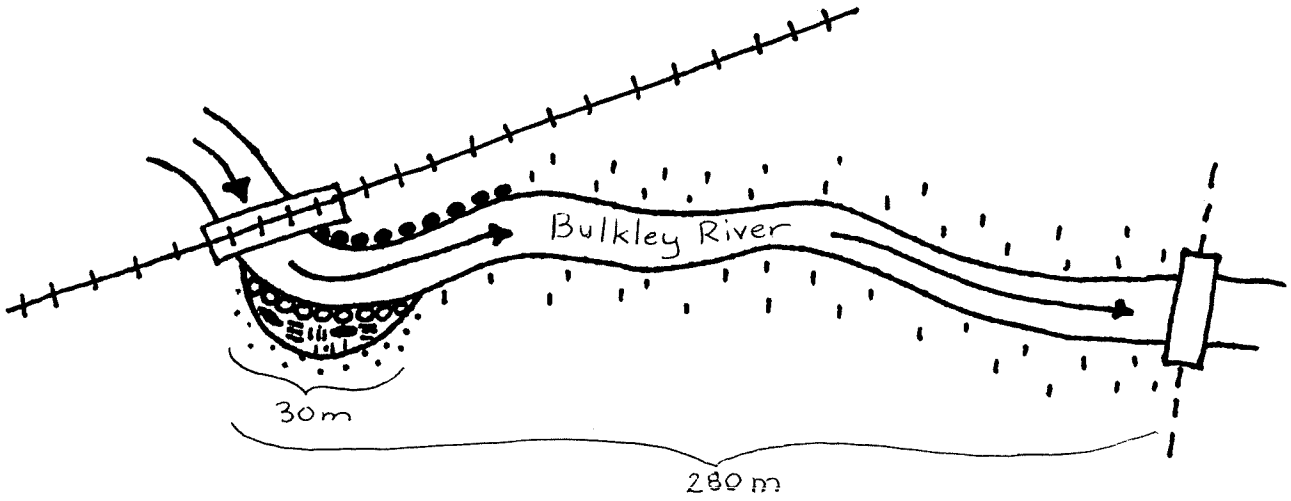
60306.32 N



LEGEND

- Flow direction
- CNR mainline
- Bridge crossing
- Existing riprap
- Riprap
- Wattle bundles
- Brush layers
- Seeding

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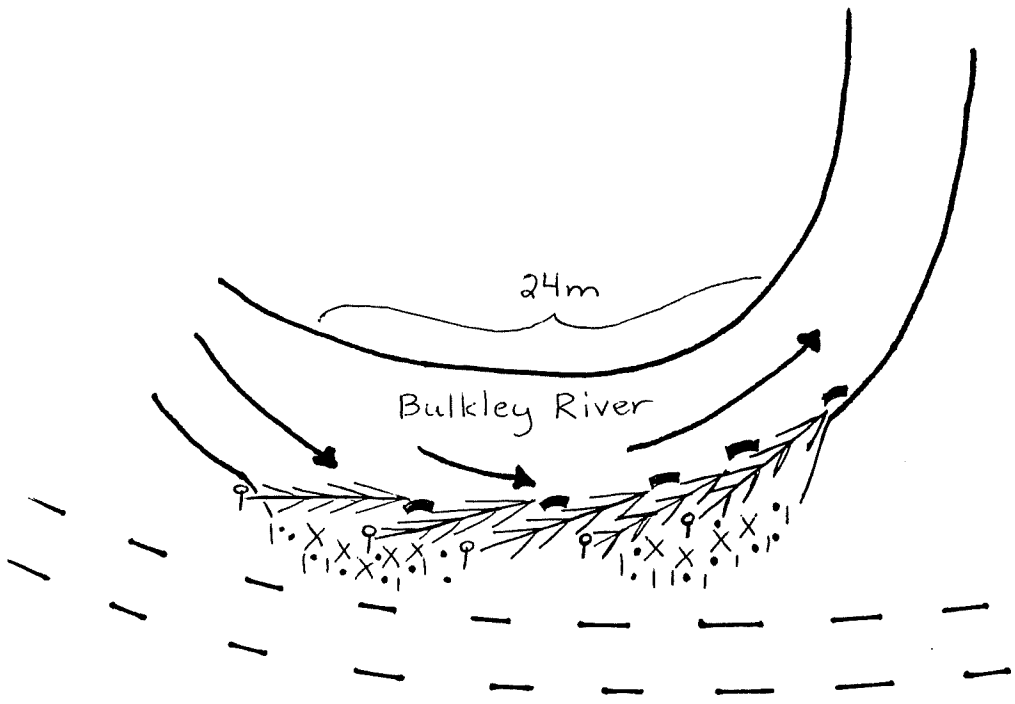
Figure 2 Schematic overview of BR-S1 stream habitat restoration and enhancement site.

Table 4
Cost Estimate To Complete BR-S1

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	20 hrs @ $56.00/hr	1,120
CONTRACTOR FEES & EXPENSES • Hoe Operation • 2 labourers • 12 loads of Class 2 and/or 3 riprap • 1 roll geotextile fabric (4.6 m x 72 m) • 6" loose staples	 15 hrs @ $120/hr 2 x 20 hrs @ $30/hr $300/load $450/roll (incl. transport) $50/1000	 1,800 1,200 3,600 450 50
ESTIMATED SITE TOTAL		8,220

GPS Coordinates
6856.60 E
60304.60 N



LEGEND
- Flow direction
- Rose Lake Cutoff Road
- Tree revetment
- Swamp weights
- T-posts
- Fill material
- Shrub stakes
- Seeding

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Figure 3 Schematic overview of BR-S2 stream habitat restoration and enhancement site.

Table 5
Cost Estimate To Complete BR-S2

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES		
• Project Supervision Sepp Muhlberger	10 hrs @ $56/hr	560
CONTRACTOR FEES & EXPENSES		
• Hoe Operation	8 hrs @ $120/hr	960
• 2 labourers	2 x 10 hrs @ $30/hr	600
• 12 loads of fill cobbles from Site 1	1 hr of haul time @ $70/hr	70
• 5, 8' T-posts	$5 each	25
• 30 m of #9 galvanized wire	$0.60/meter	18
• 5, 110 pound swamp weights	$100/each	500
• chainsaw	1 day @ $30/day	30
ESTIMATED SITE TOTAL		2,763

5.2.3 Site 3

Site 3 (BR-S3) lies adjacent to a log sort situated 300 m downstream of Site 2. The site consists of a shallow riffle complex and a partially unstable right bank (40 m long and 3 - 3.5 m high) comprised largely of fines (Photo13). Stockpiled pipes are slumping down the bank (Photo 14). No trees or shrubs have established on the bank and instream cover is marginal (Photo 15).

A modular timber bridge (10' span) will be placed at the base of the bank to prevent channel bed disturbance and assist with rock cluster installation. The bridge section will be placed on unbranched logs laid on the channel bed, parallel to the streamflow. It will be hoisted into position using a sling and track hoe. Planks will be laid on the bridge to protect the driving surface from the hoe tracks. Support logs will be removed from the channel following rock cluster installation and will be hauled from the site and/or utilized as terraces along the bank.

Using the track hoe, rock clusters will be randomly scattered throughtout the riffle complex (it may be necessary to set-up the bridge in two separate locations to cover the entire riffle area). Class 2 and 3 rocks will not need to be installed in excavated depressions. Pools will be hand-excavated immediately downstream of rock clusters to provide pocket water and holding areas.

Following bridge removal, the right bank will be recontoured. Groynes consisting of single boulders will be placed along the base of the bank. These structures will deflect primary flows away from the toe of the bank and encourage the deposition of fines behind each boulder. Proper spacing will be determined during construction. A tree revetment consisting of eight 10 m long trees will be installed over the groynes to increase bank integrity and improve streamside fish habitat. Dense brush layers will be planted in shallow trenches excavated across the upper bank. Shrub stakes will be planted up to 5 m back from the bank.

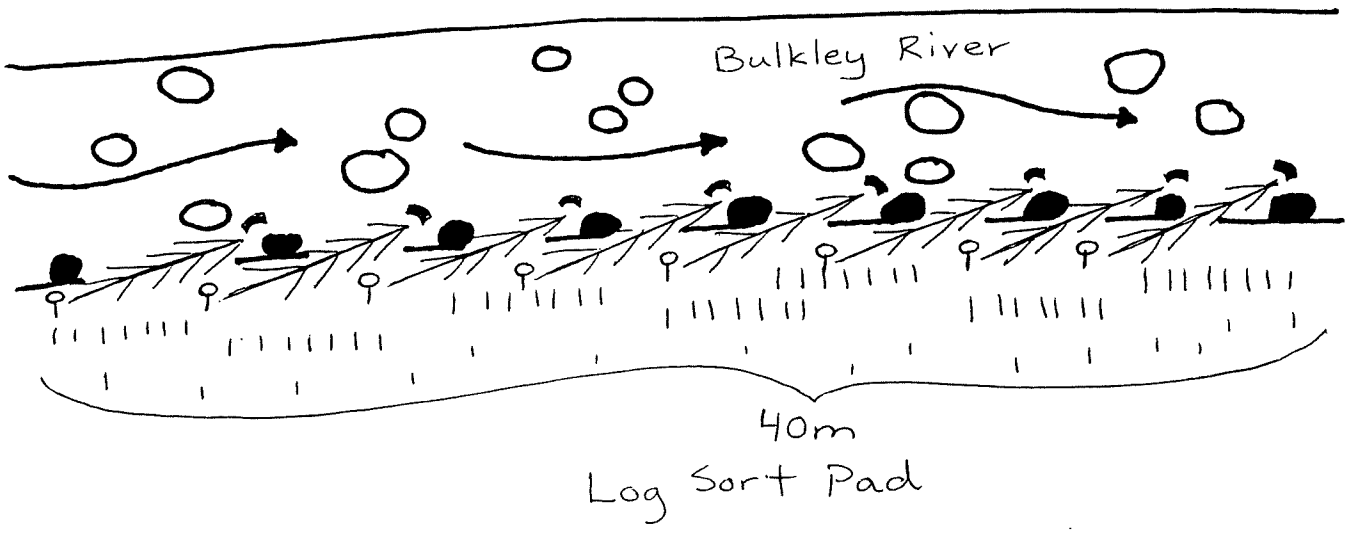
Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

A schematic overview of recommended enhancement works at BR-S3 is provided in Figure 4. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 6.

5.2.4 Site 4

Site 4 (BR-S4) is located 300 m downstream of Site 3 and lies parallel to the Rose Lake Cutoff Road (Photo 16). It is 60 m long and is characterized by a long run. Although generally stable, minor slumping is occurring at this site. Herbaceous vegetation dominates and a few willow bushes have colonized the bank.

GPS Coordinates
6855.11 E
60304.62 N



LEGEND
- Flow direction
- Rock clusters
- Boulder groynes
- Tree revetment
- Swamp weights
- T-posts
- Brush layers
- Shrub stakes

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Figure 4 Schematic overview of BR-S3 stream habitat restoration and enhancement site.

Table 6
Cost Estimate To Complete BR-S3

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES		
• Project Supervision Sepp Muhlberger	15 hrs @ $56/hr	840.00
CONTRACTOR FEES & EXPENSES		
• Hoe Operation	15 hrs @ $120/hr	1,800.00
• 2 labourers	2 x 15 hrs @ $30/hr	900.00
• 3 loads of Class 2 and/or 3 riprap	$300/load	1,900.00
• 8 T-posts	$5 each	40.00
• 48 m of #9 galvanized wire	$0.60/m	800.00
• 8, 110 pound swamp weights	$100 each	100.00
• modular bridge	1 day @ $100/day	60.00
• chainsaw	2 days @ $30/day	420.00
• flatbed (bridge transport)	6 hours @ $70/hour	
ESTIMATED SITE TOTAL		5,888.80

No track hoe work is planned at this site in order to maintain bank integrity and good vegetative ground cover. "Soft" bank stabilization measures will include staking and brush layering.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

A schematic overview of recommended enhancement works at BR-S4 is provided in Figure 5. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 7.

5.2.5 Site 5

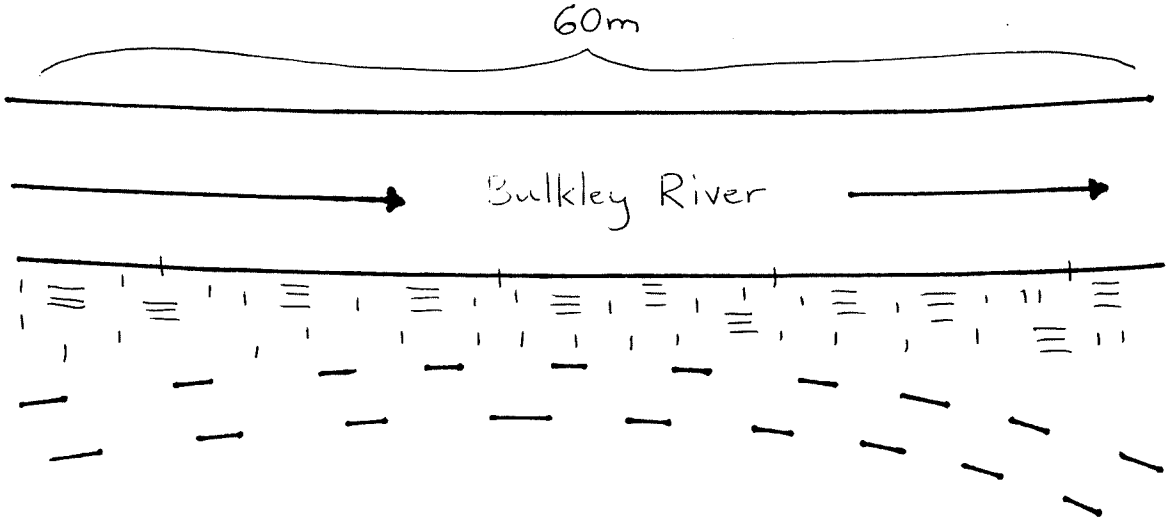
Site 5 (BR-S5) is located 2.8 km downstream of Site 4 and flows beside the Rose Creek Cutoff Road (Photo 17). Positioned on a meanderbend, the site is characterized by a deep pool complex. Direct flow attack along the upstream 40 m has resulted in oversteepened, unstable banks (Photo 18). This section is partially protected by overhanging clumps of herbaceous vegetation. The downstream 60 m of this site has reposed, stable banks with good ground cover. Shrub and tree cover is limited (Photo 19).

Bank stabilization/cover and instream fish habitat will be improved through the installation of 3 bendway weirs along the upstream end of the site. Each weir will be spaced roughly 15 m apart, with the first structure installed at the upstream end of the site. It is estimated that one weir will require 3 loads of Class 1 to 3 riprap (9 loads total). Rock material will be dumped beside the road and placed with the track hoe. A spruce tree revetment consisting of eight 10 m long, well-branched spruce trees will be installed over the weirs. This will inhibit back-eddy erosion downstream of each weir while also improving instream and overhanging habitats. The entire bank (105 m total) will be staked with shrubs following construction.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

A schematic overview of recommended enhancement works at BR-S5 is provided in Figure 6. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 8.

GPS Coordinates
6852.56 E
60305.27 N



LEGEND
- Flow direction
- Brush layers
- Shrub stakes
- Rose Lake Cutoff Road

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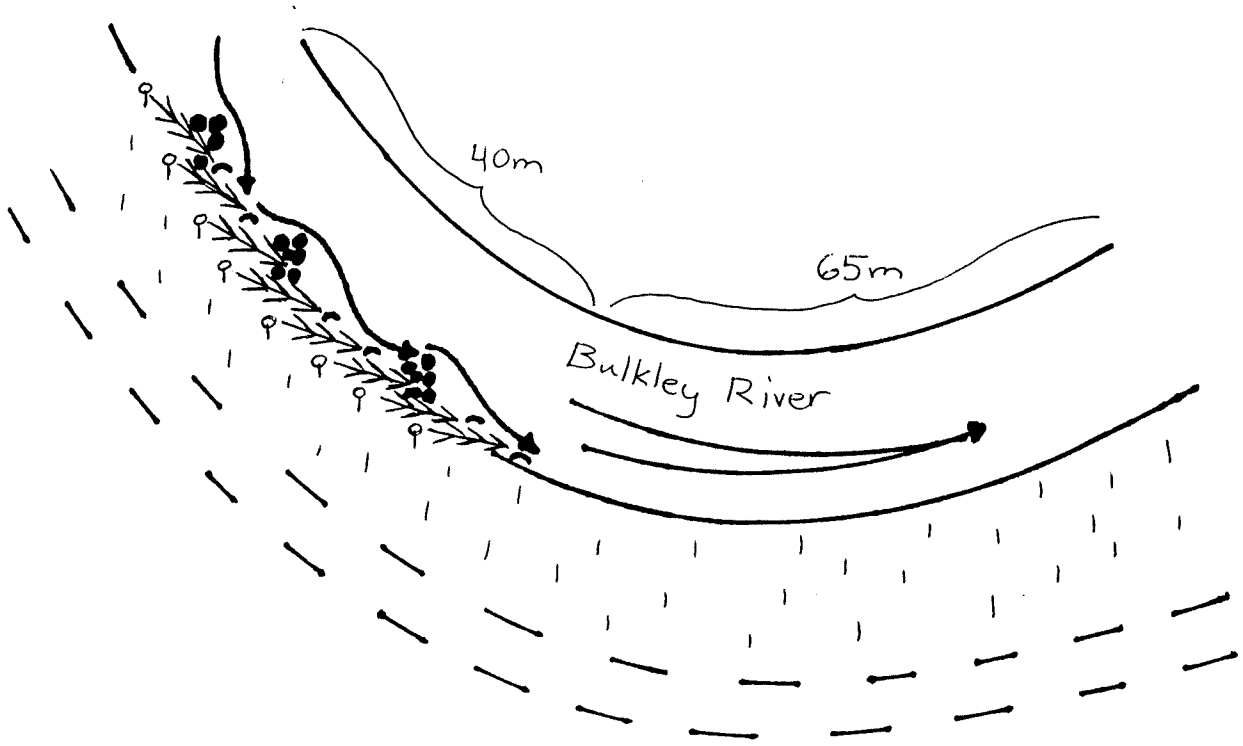
Figure 5 Schematic overview of BR-S4 stream habitat restoration and enhancement site.

Table 7
Cost Estimate To Complete BR-S4

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	10 hrs @ $56/hr	560
CONTRACTOR FEES & EXPENSES • 2 labourers	2 x 10 hrs @ $30/hr	600
ESTIMATED SITE TOTAL		1,160

GPS Coordinates
6839.61 E
60320.07 N



LEGEND
- Flow direction
- Rose Lake Cutoff Road
- Bendway weirs
- Tree revetment
- T-posts
- Swamp weights
- Shrub stakes

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Figure 6 Schematic overview of BR-S5 stream habitat restoration and enhancement site.

Table 8
Cost Estimate To Complete BR-S5

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	20 hrs @ $56/hr	1,120.00
CONTRACTOR FEES & EXPENSES • Hoe Operation • 2 labourers • 3 loads of Class 2 and/or 3 riprap • 8, 8' T-posts • 48 m of #9 galvanized wire • 8, 110 pound swamp weights	 20 hrs @ $120/hr 2 x 20 hrs @ $30/hr $300/load $5/each $0.60/meter $100/each	 2,400.00 1,200.00 2,700.00 40.00 28.80 800.00
ESTIMATED SITE TOTAL		8,288.80

5.2.6 Site 6

Site 6 (BR-S6) is situated 250 m downstream of Site 5 and flows parallel to the Rose Creek Cutoff Road (Photo 20). The site is characterized by a 50 m long and 7 m high unvegetated right bank. A long, deep pool provides good fish cover and overwintering habitat. Overall, bank stability appears to be good at this site - logs, boulders and herbaceous vegetation protect the bank from erosion. Overhanging banks and LWD provide abundant cover opportunities. No shrubs or trees grow along the bank (Photo 21).

AEE recommends that shrub stakes be planted over the entire bank to maintain bank stability at this site. Shrubs will also increase streamside cover characteristics. No heavy equipment will be required.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

A schematic overview of recommended enhancement works at BR-S6 is provided in Figure 7. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 9.

5.2.7 Site 7

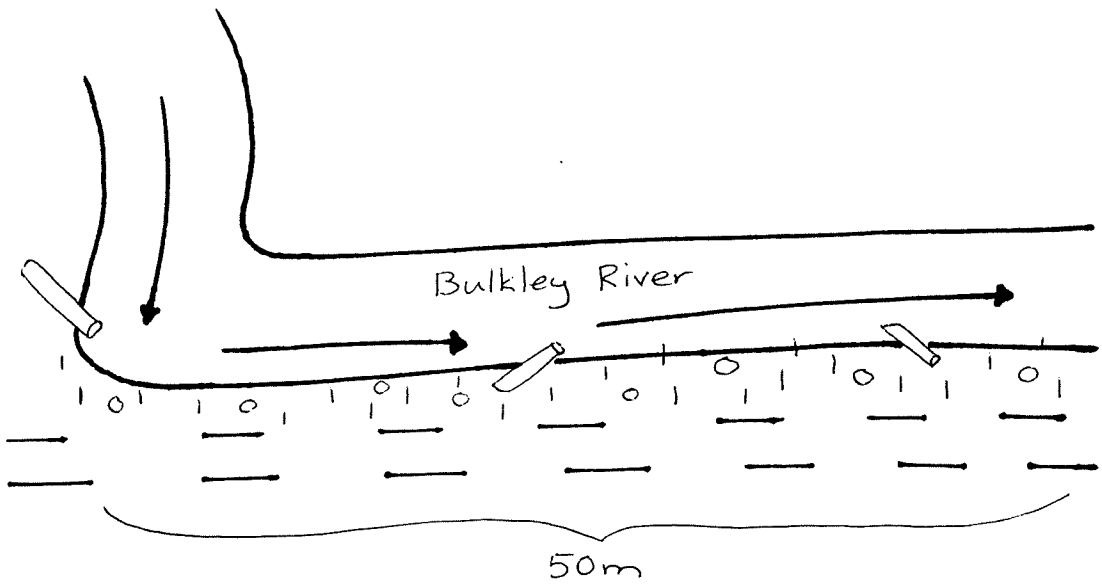
Site 7 (BR-S7) is 70 m long and lies immediately downstream of a permanent timber bridge located 200 m from Site 6 (Photo 22). Back-eddies have removed vegetation and undercut the right bank downstream of the bridge crib. A pool-riffle-run sequence is found in this reach. A gravel/cobble longitudinal bar has been deposited in a slack water area on the left side of the channel. Buried wood protruding from the right bank and channel bed near the downstream end of the site has focussed low-moderate flows into the middle of the channel. Resultant channel scour has created a deepened thalweg and backwater area. Heavily grassed banks overhang a majority of the reach while shrub cover is patchy (Photo 23).

Sediment loadings into the Bulkley River will be reduced by installing a 10 m long shrub log wall on the right bank immediately downstream from the bridge. Overhead cover will be improved by planting shrub stakes along both banks.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

A schematic overview of recommended enhancement works at BR-S7 is provided in Figure 8. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 10.

GPS Coordinates
6837.57 E
60319.70 N



LEGEND
- Flow direction
- Rose Lake Cutoff Road
- Existing LWD
- Existing riprap
- Shrub stakes

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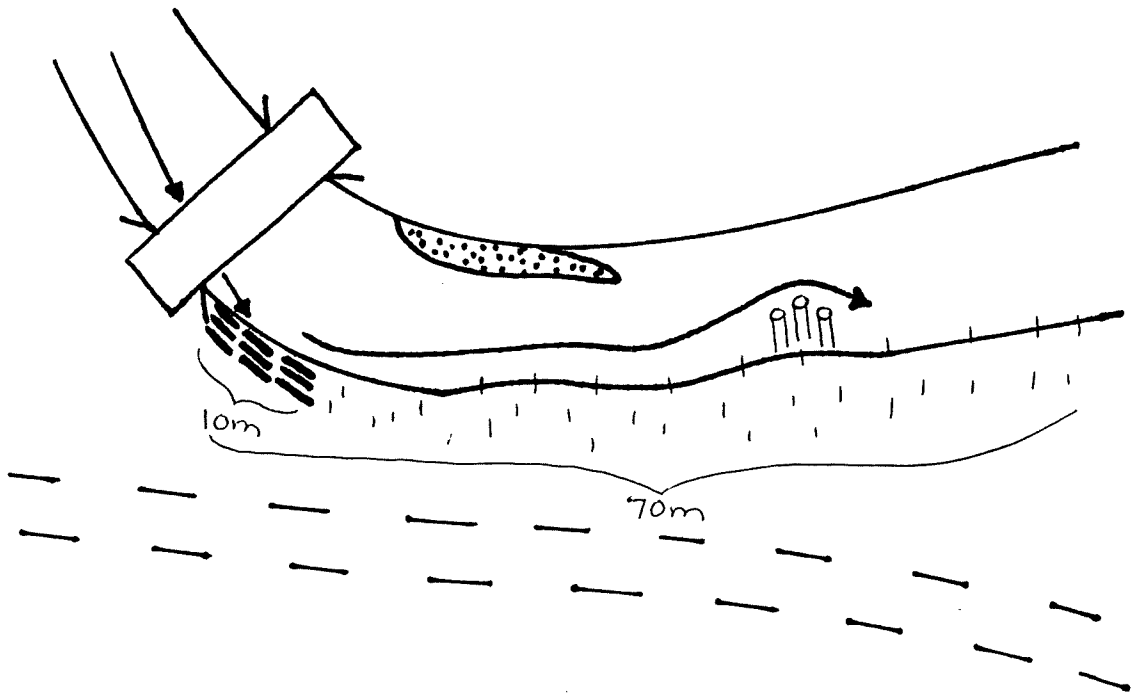
Figure 7 Schematic overview of BR-S6 stream habitat restoration and enhancement site.

Table 9
Cost Estimate To Complete BR-S6

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	8 hrs @ $56/hr	448
CONTRACTOR FEES & EXPENSES • 2 labourers	2 x 8 hrs @ $30/hr	480
ESTIMATED SITE TOTAL		928

GPS Coordinates
6836.79 E
60320.79 N



LEGEND
- Flow direction
- Rose Lake Cutoff Road
- Bridge
- Gravel bar
- Embedded logs
- Shrub log walls
- Shrub stakes

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Figure 8 Schematic overview of BR-S7 stream habitat restoration and enhancement site.

Table 10
Cost Estimate To Complete BR-S7

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	10 hrs @ $56/hr	560
CONTRACTOR FEES & EXPENSES • 2 labourers	2 x 10 hrs @ $30/hr	600
ESTIMATED SITE TOTAL		1,160

5.2.8 Site 8

Site 8 (BR-S8) parallels the Rose Creek Cutoff Road and is located 160 m from the downstream end of Site 7 (Photo 24). The right bank is 140 m long, 7-10 m high, comprised of fines and generally stable. Grasses and overhanging banks provide limited fringe habitat. No woody vegetation has established along the roadbank. A long, deep pool runs along the entire length of the meanderbend.

AEE recommends that the lower and middle bank be staked with quick suckering shrub species. Increased shrub growth will improve bank cohesion and provide additional fish cover.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

A schematic overview of recommended enhancement works at BR-S8 is provided in Figure 9. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 11.

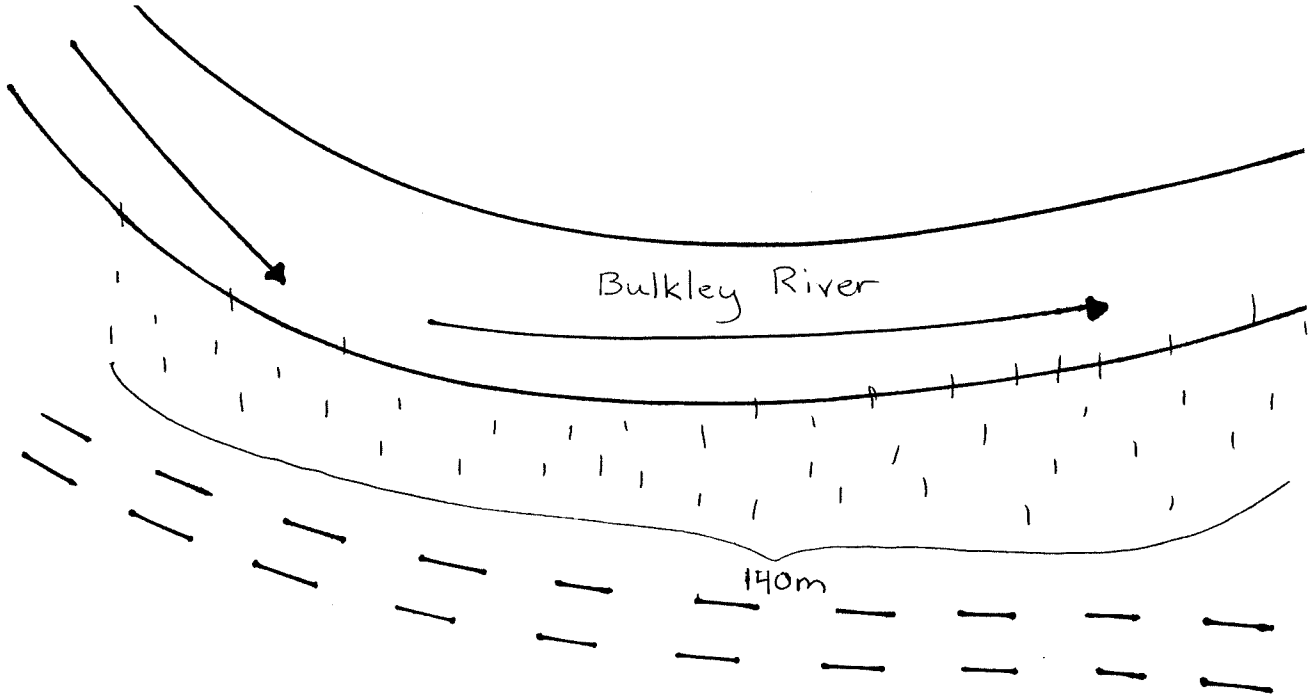
5.2.9 Site 9

Site 9 (BR-S9) is located upstream of a railway crossing and is approximately 750 m downstream of Site 8 (Photo 25). Variable habitat at the site is provided by a 50 m long pool-riffle-run complex. Clean gravels and cobbles have deposited on the inside of the meanderbend. The right streambank is eroding (near vertical to vertical) and is composed of fines (Photo 26). Deep-rooted vegetation along the right bank is limited and overhanging vegetation provides abundant fish cover opportunities. Riprap protecting the base of the right crib has pulled away from the bank and is scattered on the channelbed.

A shrub/tree revetment will be positioned along the right bank to control erosion and provide overhead fish cover. Shrub revetments will be constructed from individual shrub clumps (bushes) which will be cut near the base and bound with heavy biodegradable twine and #9 galvanized wire. Trees and shrub bundles will be transported to the site by quad. If possible, revetment tips will be anchored near the base of the bank using T-posts. Tips will not be anchored if the posts cannot be pounded flush into the base of the bank. A floating revetment has the ability to move laterally, as well as up and down as streamflow rates increase and decrease. It is expected that continued build-up of material behind the structure will create a relatively stable overhanging bank while also enhancing fish habitat.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

GPS Coordinates
6834.69 E
60322.38 N



LEGEND
- Flow direction
- Rose Lake Cutoff Road
- Shrub stakes

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Figure 9 Schematic overview of BR-S8 stream habitat restoration and enhancement site.

Table 11
Cost Estimate To Complete BR-S8

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	8 hrs @ $56/hr	448
CONTRACTOR FEES & EXPENSES • 2 labourers	2 x 8 hrs @ $30/hr	480
ESTIMATED SITE TOTAL		928

A schematic overview of recommended enhancement works at BR-S9 is provided in Figure 10. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 12.

5.2.10 Site 10

Site 10 (BR-S10) is situated 2 km downstream of Site 9. Variable stream habitat is provided by a series of pool-riffle-run complexes. Banks are steep to reposed and are comprised of fines. Long sections of bank along the Rose Lake Cutoff Road have no established woody cover. Overhanging banks and large sections of sloughed bank provide ample streamside cover. A deep beaver pond at the upstream end of the site provides good overwintering habitat. Clean spawning gravels have been deposited in riffles at near the lower end of the site. The site is 200 m long and consists of two separate enhancement areas (120 m total).

At the upstream end of BR-S10, the Rose Lake Cutoff Road is gradually being undermined by a 30 m section of actively eroding streambank (Photo 27). Bank removal has left a hanging livestock fence over the edge of the beaver pond. Banks along an 80 m stretch in the middle of the site are well-vegetated and stable. Of the remaining 90 m, the upstream 70 m of the left bank are reposed, covered with dense herbaceous vegetation and stable. No shrubs have established (Photo 28). The lower 20 m of BR-S10 is steep and unstable (Photo 29).

Bank stabilization/cover measures along the upstream 30 m will involve recontouring of the slope to 2H:1V. Geotextile fabric (left over from BR-S1) will then be placed on the bank and covered with 8 loads of Class 2 and/or 3 riprap. Bank stability, as well as instream and overhanging fish cover, will be further improved through installation of a 30 m long tree revetment over the riprap. The revetment will be constructed from six 10 m long, well-branched spruce. Swamp weights will help anchor the tree tips to the base of the bank. Following construction, unvegetated banks near the site will be staked and disturbed areas will be seeded.

Slope stabilization/cover techniques recommended along the downstream 90 m section will involve dense shrub staking on the upper 70 m. Steep banks along the downstream 20 m will be stabilized with a tree revetment. Each 5 m tree (8 in total) will be transported to the site using a quad and/or truck. They will be installed manually and anchored with T-posts at the base of the bank. This device will provide good cover during all flow conditions.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

A schematic overview of recommended enhancement works at BR-S10 is provided in Figure 11. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 13.

GPS Coordinates
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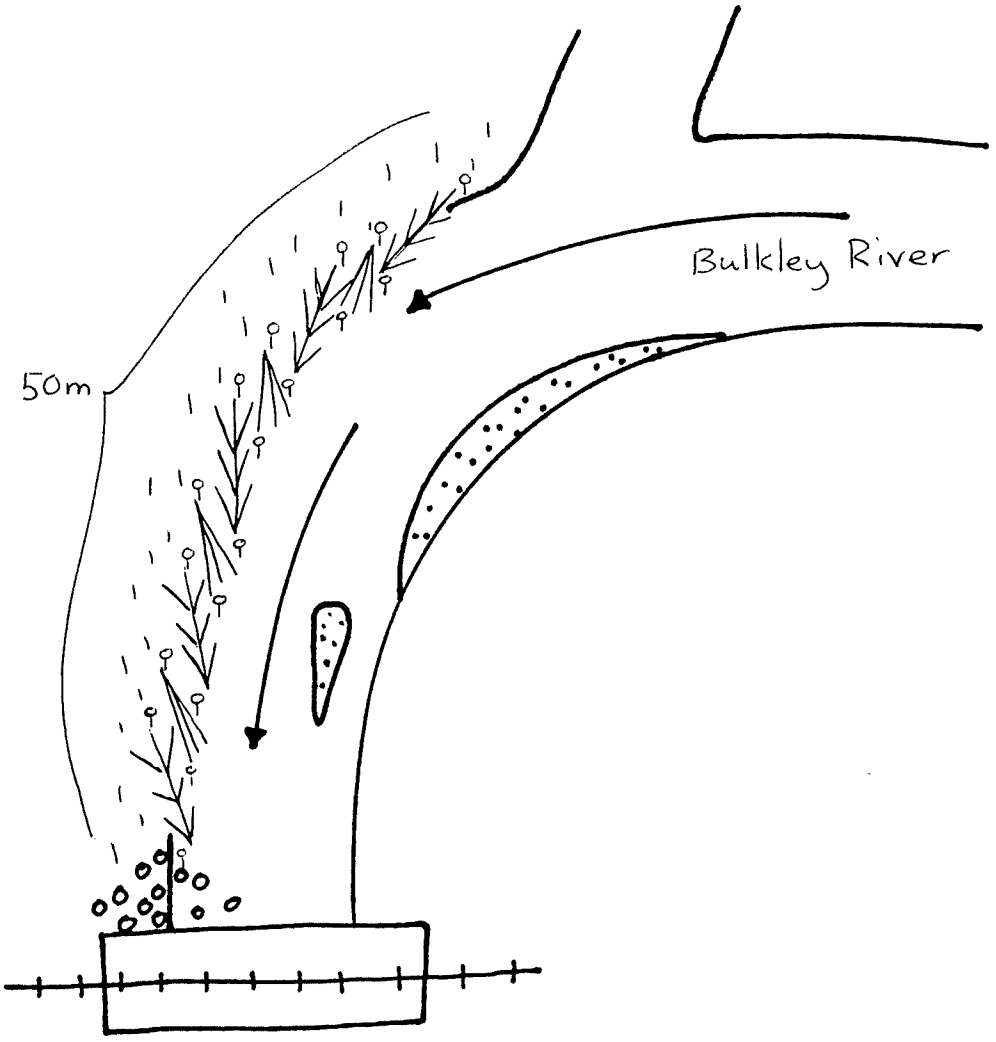
60321.49 N



LEGEND
- Flow direction
- CNR crossing
- Existing riprap
- Gravel deposits
- Tree/shrub revetment
- T-posts
- Shrub stakes

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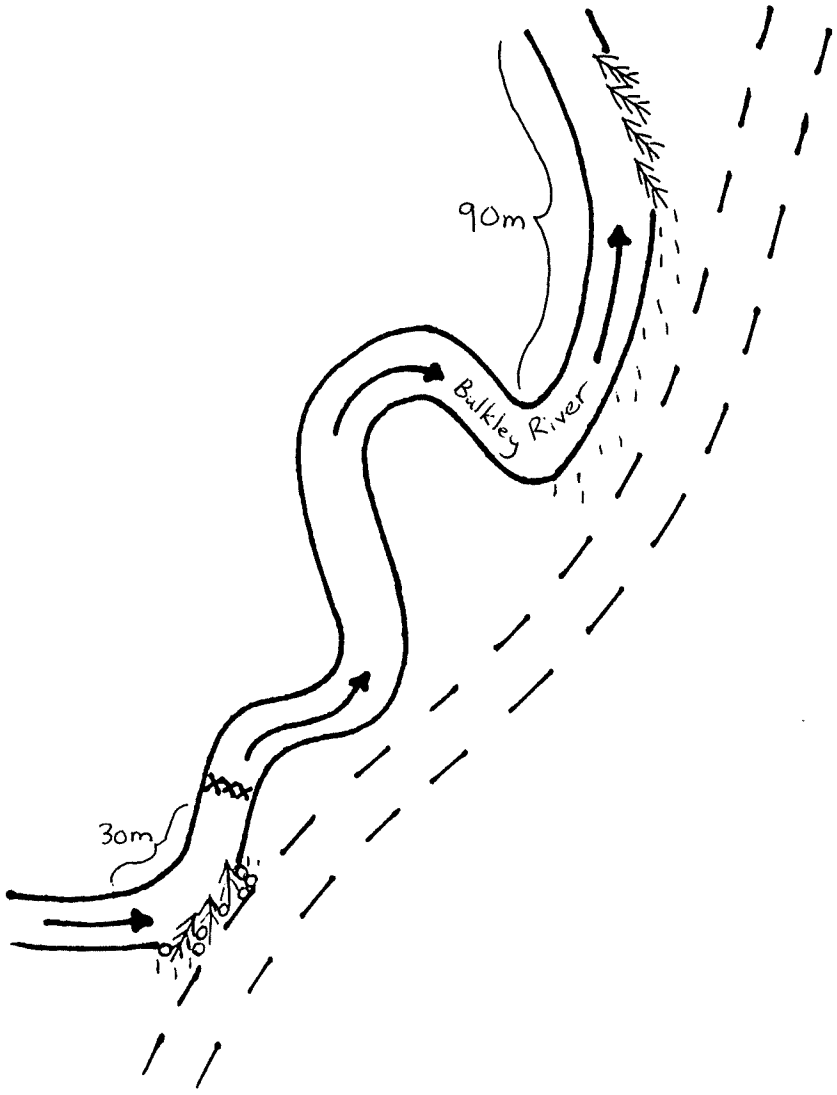
Figure 10 Schematic overview of BR-S9 stream restoration and enhancement site.

Table 12
Cost Estimate To Complete BR-S9

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	20 hrs @ $56/hr	1,120
CONTRACTOR FEES & EXPENSES • 2 labourers • 1 quad (w/winch) • 40 T-posts • 80 m of #9 galvanized wire	2 x 20 hrs @ $30/hr 2 days x $125/day $5/each $0.60/meter	1,200 250 200 48
ESTIMATED SITE TOTAL		2,818

GPS Coordinates
6820.47 E
60327.62 N



LEGEND
- Flow direction
- Rose Lake Cutoff Road
- Beaver dam
- Tree revetment
- Riprap
- Shrub stakes

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Figure 11 Schematic overview of BR-S10 stream habitat restoration and enhancement site.

Table 13
Cost Estimate To Complete BR-S10

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	20 hrs @ $56/hr	1,120
CONTRACTOR FEES & EXPENSES • Hoe Operation • 2 labourers • 6 loads of Class 2 and/or 3 riprap • 24, 8' T-posts • 70 m of #9 galvanized wire • 6, 110 pound swamp weights • 1 quad	 4 hrs @ $120/hr 2 x 20 hrs @ $30/hr $300/load $5/each $0.60/meter $100/each 2 days x $125/day	 480 1,200 1,800 120 42 600 250
ESTIMATED SITE TOTAL		5,612

5.2.11 Site 11

Site 11 (BR-S11) is located 100 m downstream of Site 10. It is positioned at a meanderbend near an active bridge crossing. The banks upstream of the bridge are sloped approaches from a former (deactivated) bridge. The banks consist of a combination of fines to cobbles. No vegetation has rooted on either approach (Photo 30). The downstream left bank is receiving direct flow attack and is backcutting into the new bridge approach and nearby bank. A deep upwelling pool at this location is hastening undercutting of the bank (Photo 31). No shrubs or trees are present along the left bank (30 m total) downstream of the bridge crossing (Photo 32).

AEE recommends that the upstream banks be stabilized and vegetated with wattle bundles and grass seed. These measures will reduce sedimentation inputs and improve cover characteristics.

Immediately downstream of the bridge crossing, the left bank should be pulled back and recontoured to 2H:1V. Geotextile fabric (left over from BR-S1) will be laid along the upper 10 m section of bank. Haul trucks will stockpile Class 2 and/or 3 riprap near the site to facilitate trackhoe installation of the material. Spoil material will be loaded onto haul trucks, removed from the site and dumped at an undetermined location. Dense brush layers will be planted upslope of the riprap. Three 10 m long, well-branched spruce will then be placed, using the track hoe, downstream of the riprap. Remaining bank will be stabilized with brush log layers and shrub stakes.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

A schematic overview of recommended enhancement works at BR-S11 is provided in Figure 12. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 14.

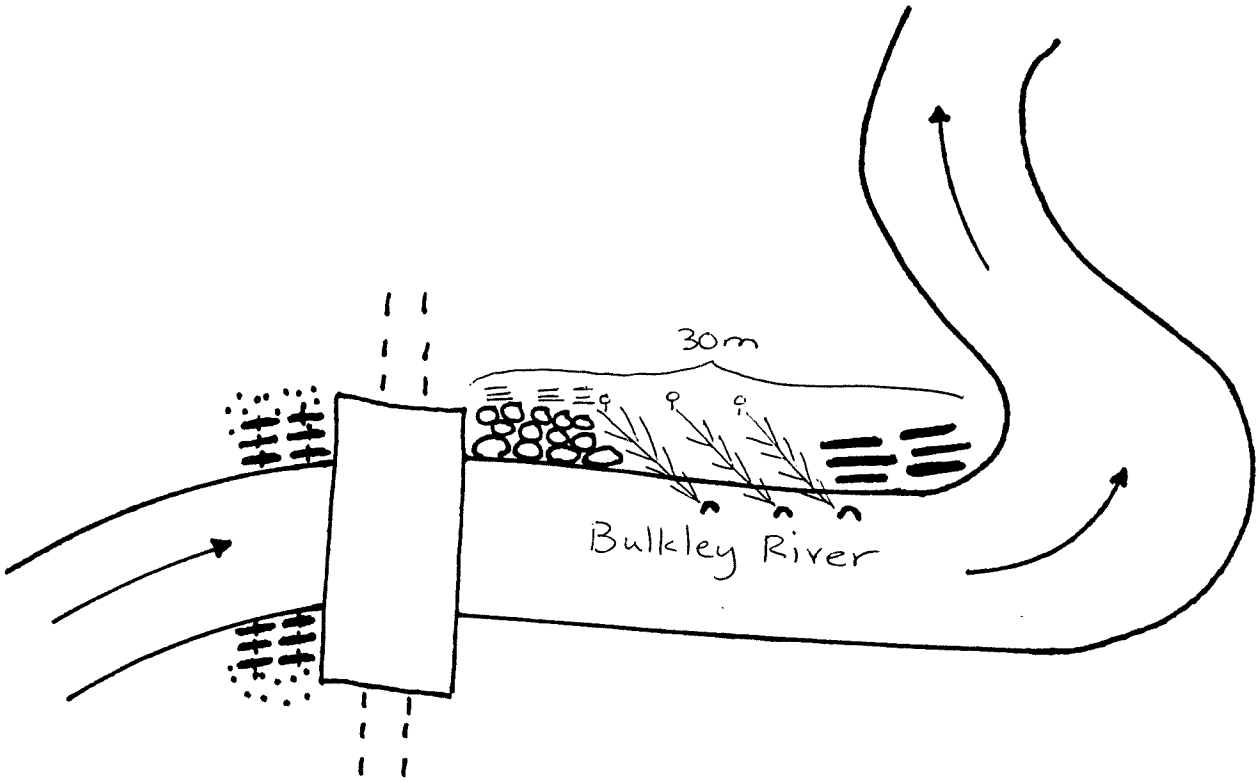
5.2.12 Site 12

Site 12 (BR-S12) is located parallel to the CNR tracks 1550 m downstream of Site 11. It is 90 m long, partially armoured with riprap and stable. Herbaceous vegetation overhangs the banks but no shrubs are present (Photo 33).

In order to improve overhanging vegetation along the bank, the site will be intensively staked with quick-suckering shrubs.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

GPS Coordinates
6818.04 E
60327.21 N



LEGEND

- Flow direction
- Rose Lake Cutoff Road bridge
- Riprap
- Tree revetment
- T-posts
- Swamp weights
- Wattle bundles
- Shrub log walls
- Brush layers
- Seeding

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Figure 12 Schematic overview of BR-S11 stream habitat restoration and enhancement site.

Table 14
Cost Estimate To Complete BR-S11

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	30 hrs @ $56/hr	1,680
CONTRACTOR FEES & EXPENSES • 2 labourers • 8 loads of Class 2 and/or 3 riprap • 2 haul trucks • 3 T-posts • 3, 110 pound swamp weights • 18 m of #9 galvanized wire	 25 hrs @ $120/hr 2 x 30 hrs @ $30/hr $300/load 2 x 10 hrs @ $70/hr $5/each $100/each	 3,000 1,800 2,400 1,400 15 300
ESTIMATED SITE TOTAL		10,595

A schematic overview of recommended enhancement works at BR-S12 is provided in Figure 13. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 15.

5.2.13 Site 13

Site 13 (BR-S13) is located near a hydroline which crosses the Bulkley River 5.7 km downstream of Site 12 (Photo 34). Over 350 m of bank (left and right) is undergoing extensive erosion. Banks are 2 - 6 m high and are comprised of fine materials (Photo 35). The right bank has been clearcut upstream and downstream of the hydroline. Deep binding roots are absent and cover is marginal. Channel bed cobbles and gravels are veneered with silt. Bank stability and vegetation have been impacted by unrestricted livestock access - wide, flat channel morphology with low banks are indicative of prolonged livestock use (Photo 36).

Banks at this site should be restored and enhanced to: increase edge habitat with high diversity; provide overhead and instream cover characteristics; decrease water velocities; and decrease summer water temperatures. Healthy bank vegetation binds sediment that otherwise would settle on food producing areas, on fish spawning and rearing sites or in pools, where sediment build-up reduces winter survival space.

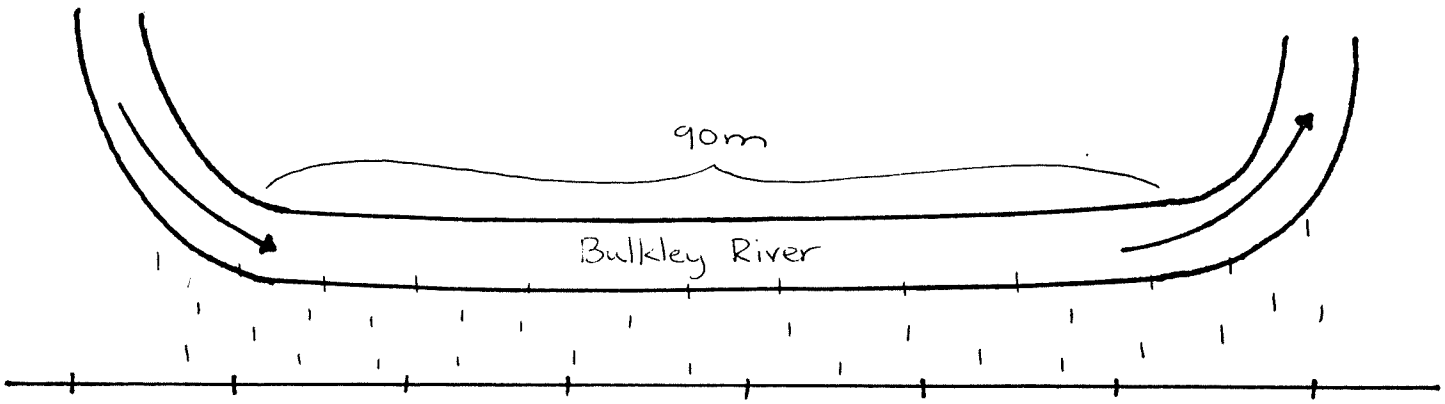
Bank stabilization and cover characteristics at this site will be improved by implementing the following techniques: tree/shrub revetments; log terraces; shrub log walls; shrub stakes; log walls; brush layers; wattle bundles and seeding. Combined, these methods are expected to gradually re-establish bank structure and cover at BR-S13.

Instream enhancement activities will include rock cluster and log groyne installations. Rock material will be hauled to the site using nearby trails (3 loads of Class 1 and 2 riprap). Log groynes will be constructed from unbranched logs selectively harvested from dead and/or dying trees in the area. Cut in 5 - 8 m lengths, each groyne will be constructed from 1 - 3 logs. One end will be secured to the top of the bank with a T-post and #9 galvanized wire. The other end will be angled 45° downstream. A 110 pound swamp weight will pin the tip of the log to the channelbed. Self-scouring pool and run areas created by flow deflection will provide excellent rearing environments.

Livestock access to this site (and along all watercourses and waterbodies in the watershed) should be restricted to protect downstream water quality and aquatic resources. This will involve large scale participation of landowners in the area. Ranchers, for example, should be educated about livestock impacts and learn the different methods available to mitigate these impacts.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

GPS Coordinates
N/A



LEGEND
Flow direction
CNR mainline
Shrub stakes

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Figure 13 Schematic overview of BR-S12 stream habitat restoration and enhancement site.

Table 15
Cost Estimate To Complete BR-S12

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	8 hrs @ $56/hr	448
CONTRACTOR FEES & EXPENSES • 2 labourers	2 x 8 hrs @ $30/hr	480
ESTIMATED SITE TOTAL		928

A schematic overview of recommended enhancement works at BR-S13 is provided in Figure 14. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 16.

5.3 FOXY CREEK

5.3.1 Site 1

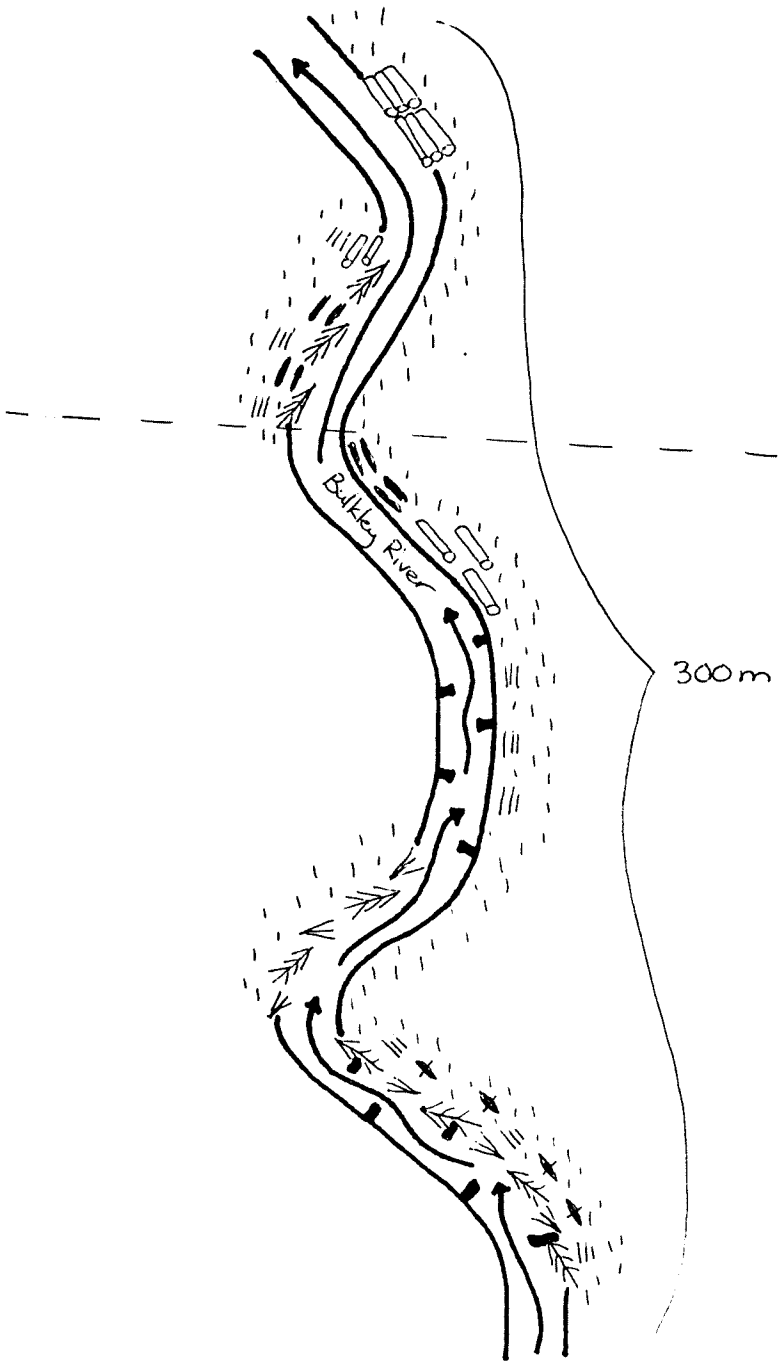
Site 1 (FC-S1) is 70 m long and located at a deactivated bridge crossing about 250 m upstream of the Foxy/Lower Maxan confluence (Photo 37). It is situated on a gentle meanderbend and is made up of a relatively shallow riffle-run-pool complex. The left bridge approach appears to be generally stable with minor toe erosion at the downstream end (Photo 38). The right approach, in contrast, has undergone considerable erosion (Photo 39). Banks and approaches are comprised of unconsolidated fines to cobbles. Banks (excluding bridge approaches) are well vegetated with grasses and forbes. A log jam spanning the creek at the downstream end of the site provides good cover opportunities.

Pocket water and resting areas will be improved through installation of rock clusters (singles, doubles and triples) along the riffle and run areas. Shallow pools (i.e. to 0.3 m deep) will be excavated in association with each cluster. The intent is to create holding areas that will become self-scouring, not deep pools subject to infilling. The right bridge approach will be recontoured using the hoe. Both approaches will be stabilized, above the high water mark, with brush layers and wattle bundles. Willow stakes will be planted on each bank to provide overhead fish cover and increase root mass within the banks. All disturbed areas will be seeded.

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

A schematic overview of recommended enhancement works at FC-S1 is provided in Figure 15. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 17.

GPS Coordinates
5426.21 N
12612.20 W



LEGEND
- Flow direction
- Hydroline
- Log groynes
- Tree/shrub revetments
- Brush layers
- Wattle bundles
- Log terraces
- Shrub log walls
- Log walls
- Shrub stakes

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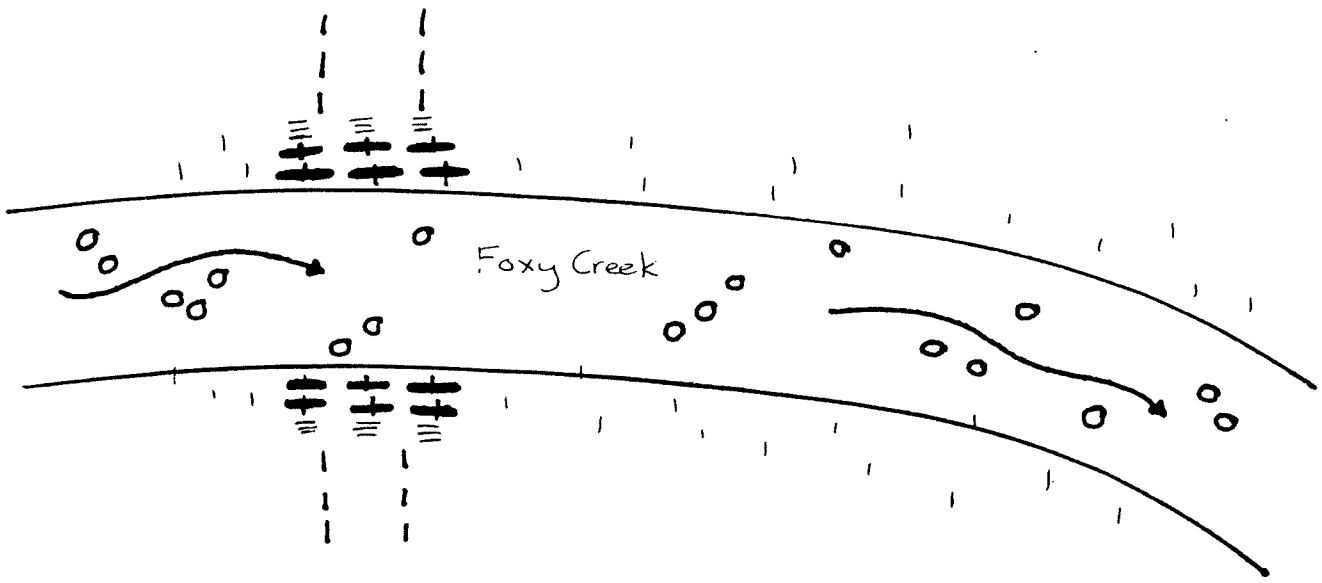
Figure 14 Schematic overview of BR-S13 stream habitat restoration and enhancement site.

Table 16
Cost Estimate To Complete BR-S13

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	50 hrs @ $56/hr	2,800
CONTRACTOR FEES & EXPENSES • 2 labourers • quad (with winds) • 50 T-posts • 120 m of #9 galvanized wire • 3 loads Class 1 and 2 riprap • 10, 110 pound swamp weights	 2 x 50 hrs @ $30/hr $5 days @ $125/day $5/each $0.60/m $300/load $100 each	 3,000 625 250 72 900 1,000
ESTIMATED SITE TOTAL		8,647

GPS Coordinates
N/A



LEGEND
- Flow direction
- Access road
- Rock clusters
- Wattle bundles
- Brush layers
- Shrub stakes

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Figure 15 Schematic overview of FC-S1 stream habitat restoration and enhancement site.

Table 17
Cost Estimate To Complete FC-S1

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	10 hrs @ $56/hr	560
CONTRACTOR FEES & EXPENSES • Hoe Operation • 2 labourers • 2 loads of Class 2 riprap	4 hrs @ $120/hr 2 x 10 hrs @ $30/hr $300/load	480 600 600
ESTIMATED SITE TOTAL		2,240

5.3.2 Site 2

Site 2 (FC-S2) is located at an active bridge crossing approximately 1.45 km upstream of Site 1 (Photo 40). This site consists of a series of pool-riffle-run sequences. Banks comprised of fines to cobbles vary from reposed and stable to steep and unstable. The stream is generally featureless at this site, providing marginal fish habitat (Photo 41). Banks along the middle section of the reach are well vegetated with shrubs and spruce. Banks adjacent to the bridge are poorly vegetated. The channel bed is clean and comprised mainly of cobbles. Riprap protects the right bank upstream of the crossing. Minor bank erosion has occurred immediately upstream of the riprap (Photo 42). A 40 m long and 2 m high bank is actively eroding at the downstream end of the site (Photo 43). Deep scour pools upstream and downstream of this bank provide good salmonid refugia. Bank stability is likely affected by a swale area behind the bank which collects water and saturates the bank.

Site Set-Up

Depending on discharge at the time, the site will be isolated in two locations using the dam and pump method (upstream and downstream of the bridge crossing). Accurate flow data must be obtained prior commencing activities at this site.

Prior to construction, AEE recommends that 7 loads of Class 1 to 3 riprap be transported and stockpiled near the site. A rock sled should also be transported to the site.

Sediment mats will be pieced together immediately downstream of the site. Sediment mats are designed to: provide first flush protection by trapping and removing sediment; prevent silt damage to stream beds during construction; and protect oxygenated gravels. Mats are constructed from a biodegradable sediment blanket overlain with coir mesh. They will be placed perpendicular to the flow with the upstream edges held down with rocks to prevent sediment from passing underneath. The leading edge of the downstream edge will be tucked under the trailing edge of the upstream mat.

With the sediment mats in position, the trackhoe will carefully place two to three 10" submersible electric pumps into existing pool areas located immediately upstream of the intended construction areas. Pool depth will be maintained by installing a 50' aquadam immediately downstream of each pool. Sand bags will be used to slow seepage rates underneath the dam. Pumps are powered by two 150 KW diesel generators transported to site on a high boy. Generators will be left on the high boy during construction. Up to 300' of 10" discharge hose will be attached to each pump. Individual hose sections (50' each) will be joined together with metal clamps and rubber gaskets. To minimize streambed scour, discharge water will be blown onto a metal diffuser plate laid on the streambed. The ends of the discharge hoses will be pinned on the streambed using large boulders. Spill clean-up kits will be provided.

A 3" pump attached to as much 300' of discharge hose (depending on proximity to the nearest natural depression used as a natural sedimentation pond) will be positioned in shallow pool areas created by sandbag dams installed at the downstream ends of the sites. Turbid water collected in these pools will be pumped into temporary sedimentation ponds.

At each crossing site, fish will be salvaged from drying channel beds immediately following channel isolation.

Upstream Enhancement Activities

LWD (i.e., root wads) will be trenched into the left bank at the upstream end of the site to provide refuge in nearshore areas. Woody material will be collected above the high water mark so as not to limit available refugia provided during high flows. Root boles will be transported with the track hoe. T-posts, wire and backfill material will help to secure the devices in place. Spacing will be determined on-site.

An off-centre, continuous rock 'V' ledge will be installed at the top end of the meanderbend upstream of the bridge crossing. The ledge will be constructed from one load of angular Class 3 riprap. An additional load of Class 1-2 rock material will be used for rock arms tied into the streambanks. This design concentrates primary flows over the ledge apex which, in turn, promotes continuous scour of downstream pools, facilitates fish passage and prevents lateral erosion during periods of high flow.

A pool approximately 1 m deep will be excavated downstream of the rock ledge. It will be deepest at the upstream end and gradually approach original bed grade with distance downstream. Ledge and pool complexes control stream gradient through energy dispersal; provide fish cover and refugia; and help to facilitate upstream fish passage during different flow conditions. Gradient control reduces the rate of streambed scour and encourages the sorting of bed material in pool and riffle areas. As a result, these features enhance invertebrate production and fish rearing capabilities. Gravel deposits in pool tail-outs are often suitable for salmonid spawning.

A riffle area will be installed immediately upstream of the rock ledge to allow flows to pass smoothly over ledge surfaces and to prevent undermining of the riprap blocks. The riffle will be constructed from spoil material obtained from the pool excavation. Cobble and gravel material will be spread across the channel and extended up to 3 m upstream of the ledge structure.

Class 1-2 riprap (1 load) will be placed at the upstream end of existing riprap on the right bank. This measure will protect the bank from further erosion and provide good edge habitat along the excavated pool.

Downstream Enhancement Activities

To access the right bank at this site, a narrow access trail will need to be cleared through the forest. Thinning will be done by hand and all material will be incorporated bank stabilization structures at the site.

In the straight run section downstream of the bridge crossing, AEE recommends the installation of three wing deflectors. Wing deflectors are used to narrow stream channels in order to concentrate low to moderate streamflows and encourage streambed scour and pool development. Self-scouring pool and run areas created by flow deflection provide excellent rearing environments.

Each deflector will consist of a triangular riprap frame constructed from Class 2 and 3 riprap which will be infilled with local cobble material (may require a shallow excavation pit). Rocks will be transported via the trail in the rock sled. The riprap frame will be set tightly into a shallow trench excavated with a hoe. Boulders will taper down the bank to the lowest rock located at the apex of the structure. Angled 45° downstream, the design gently turns primary flows into the centre of the channel. Secondary flows are pulled downstream, behind the groyne, which encourages deposition of fines in streambank areas downstream from the structure. High flows will pass smoothly over the deflector surface.

Single double and triple rock clusters will be installed in the riffle/run situated downstream of the deflector site. Small hand-excavated, self-maintaining pools created by these devices will help facilitate upstream fish passage.

The unstable bank at the downstream end of the site will be recontoured prior to installation of an eight tree revetment. Cleared trees and brush from the access trail will be incorporated into this structure. T-posts, #9 galvanized wire and swamp weights will secure the revetment along the bank. This structure will provide abundant pool and riffle cover adjacent to the structure.

Unvegetated streambanks will be stabilized with shrub stakes and disturbed areas will be seeded.

Site Clean-Up

During the installation of instream devices, a 1½" gas pressure pump with 50' of hose and a fire nozzle will be used to wash fines from the channel bed. Dirty water will be flushed downstream into temporary sedimentation ponds. Flushing will continue until clear water flows down the channel.

Upon completion of instream activities, the upstream pump(s) will be turned off at intervals to allow pulses of water to flush sediment down the channel. Turbid water, collected in

sandbagged containment pools at the downstream ends of the sites will subsequently be pumped with one 10" pump into natural sedimentation ponds. Flushing will continue until clear water flows down the channels. The sediment mats will be carefully removed from the channel and will be used for slope stabilization purposes.

A schematic overview of recommended enhancement works at FC-S2 is provided in Figure 16. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 18.

5.4 LOWER MAXAN CREEK

5.4.1 Site 1

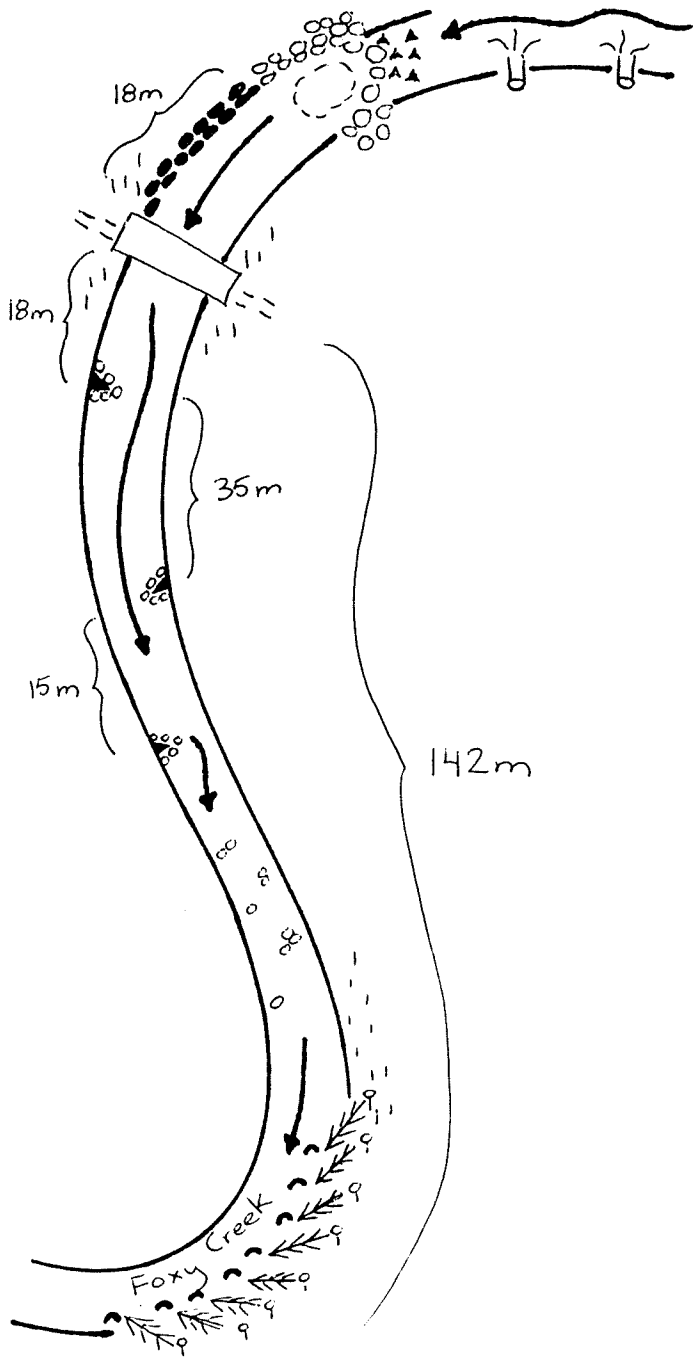
Site 1 (LMC-S1) is located at the Thompson Road bridge about 1.8 km downstream of the Maxan Lake outlet (Photo 44). Banks are reposed to steep and consist of fines to cobbles. Instream habitat is characterized by a shallow riffle-run at the upstream end and a long, deep pool downstream. Direct flow attack from the run complex has scoured a pronounced "nick point" in the right bank 16 m upstream of the crossing. Resultant downstream back-eddies are gradually eroding the downstream bank and will eventually cut behind the right bridge crib (Photo 45). Channel constriction, hardened artificial banks (wooden bridge cribs) and turbulent back-eddies have accelerated erosion along a 28 m long and 1.5 m high bank immediately downstream of the crossing (Photo 46). The left bridge approach is eroding through an underground piping system which has developed behind the crib (Photo 47). The absence of deep, well-rooted vegetation along the banks has decreased bank integrity, increased sedimentation rates and limited streamside fish cover. Instream habitat, excepting that provided by the deep pool, is limited.

AEE recommends that the two unstable banks be restored and enhanced with tree revetments (three 10 m trees upstream and five downstream), shrub log walls and shrub stakes. These methods will protect bank integrity while also providing abundant overhanging and instream fish habitat. Small scour pools will be hand-excavated behind rock clusters installed throughout the riffle complex at the upstream end of the site. A track hoe will carefully place Class 2 rocks on the channel bed to prevent unnecessary siltation of downstream habitats. Shrub stakes will be planted on all banks at the site. The unstable, eroding bridge approach should be reconstructed (no costs have been associated with this component since it is expected that this work will be conducted by the wood lot licensee in the area).

Given that no instream machine excavation is necessary, diversion and isolation of the channel will not be required.

A schematic overview of recommended enhancement works at LMC-S1 is provided in Figure 17. Equipment, manpower and cost requirements necessary to complete activities at this site are provided in Table 19.

GPS Coordinates
6867.70 E
60222.77 N



LEGEND

- Flow direction
- Bridge
- Maxan road
- LWD
- Riffles
- Off-centre rock ledge
- Excavated pool
- Riprap
- Existing riprap
- Wing deflectors
- Rock clusters
- Tree revetment
- T-posts
- Swamp weights
- Shrub stakes

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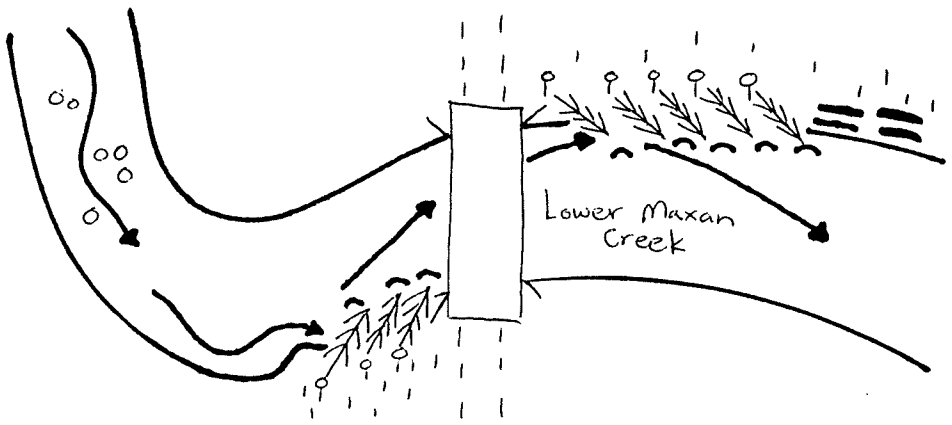
Figure 16 Schematic overview of FC-S2 stream habitat restoration and enhancement site.

Table 18
Cost Estimate To Complete FC-S2

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES		
• Project Supervision Sepp Muhlberger	40 hrs @ $56/hr	2,240
CONTRACTOR FEES & EXPENSES		
• Hoe Operation	40 hrs @ $120/hr	4,800
• 2 labourers	2 x 20 hrs @ $30/hr	1,200
• 7 loads Class 1-3 riprap	$300/load	2,100
• rock sled	3 days @ $100/day	300
• 70 m of #9 galvanized wire	$0.60/m	42
• 8, 110 pound swamp weights		
• 50' x 2' aquadam	1 x $800	800
• Sediment mats	$200 (incl. transport)	200
• 150 kW Genset	2 x $250/day or $1,000/wk	2,000
• 10" x 50' discharge hose	18 x $60/day or $180/wk ea.	1,080
• 10" submersible electric pump	3 x $400/day or $1,600/wk	4,800
• 100 amp 140' cord	2 x $50/day or $150/wk	300
• Emergency spill kit	No charge	
• Diffuser plate	$100/week	100
• Tractor trailer	8 hrs @ $125/hr	1,000
• High boy	$100/day or $600/wk	600
• Forklift (loading of equipment)	2 hrs @ $100/hr	200
• 3" trash pump	1 x $35/day or $140/wk	140
• 3" x 20' suction complete with screen	1 x $10/day or $30/wk	30
• 3" x 50' discharge	6 x $10/day or $30/wk	180
• 1½" pump	1 x $22/day or $88/wk	88
• 1½" 20' suction complete with screen	1 x $7/day or $21/wk	21
• 1½" x 50' discharge	1 x $7/day or $21/wk	21
• Fire nozzle	1 x $5/day or $10/wk	10
ESTIMATED SITE TOTAL		25,012

GPS Coordinates
6865.92 E
60238.08 N



LEGEND
- Flow direction
- Bridge
- Thompson Road
- Rock clusters
- Tree revetments
- Shrub log walls
- T-posts
- Swamp weights
- Shrub stakes

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Figure 17 Schematic overview of LMC-S1 stream habitat restoration and enhancement site.

Table 19
Cost Estimate To Complete LM-S1

Cost Component	Hours, Rates and Costs	Cost ($)
AEE FEES • Project Supervision Sepp Muhlberger	20 hrs @ $56/hr	1,120.00
CONTRACTOR FEES & EXPENSES • Hoe Operation • 2 labourers • 2 loads of Class 2 riprap • 8 T-posts • 48 m of #9 galvanized wire • 8, 120 pound swamp weights	15 hrs @ $120/hr 2 x 20 hrs @ $30/hr $300/load $5/each $0.60/meter $100/each	1,800.00 1,200.00 600.00 40.00 28.80 800.00
ESTIMATED SITE TOTAL		5,588.80

6.0 MAXAN WATERSHED COST ESTIMATE

AEE's cost estimate to complete all activities outlined in Part 5.0 above is $98,861.40. This estimate assumes that spruce trees, tree stumps, etc., will be available at no charge. AEE fees and expenses and the cost of contract requirements are summarized below for each project component.

Stream habitat restoration and enhancement activities:

• AEE fees	$ 21,896.00
• AEE expenses	7,800.00
• Contract requirements	98,861.40
Total Cost Estimate for Maxam Watershed Activities	**$ 128,557.40**

Detailed cost analyses for all activities are provided in Table 20.

Table 20
AEE Cost Estimate for Maxan Watershed Stream Habitat Restoration and Enhancement Activities

Cost Component	Hours, Rates and Costs	Cost ($)
AEE Fees		
• Travel: Calgary - Burns Lake - Calgary Sepp Muhlberger	12 hrs @ $56/hr	672.00
• Enhancement project supervision and assistance Sepp Muhlberger	299 hrs @ $56/hr	16,744.00
• "As-built" reporting Sepp Muhlberger	80 hrs @ $56/hr	4,480.00
	Subtotal	21,896.00
AEE Expenses		
• Airfare (Prince George to Calgary)	Return ticket @ $800	800.00
• Accommodation	30 days @ $65/night	1,950.00
• Meals	30 days @ $30/day	900.00
• Truck rental	30 days @ $125/day	3,750.00
• Computer charges		200.00
• Communications (courier, fax, phone, mail)		200.00
	Subtotal	7,800.00
Contract Requirements		
• Standard transportation and equipment requirements (refer to Section 5.1 for detailed analysis)		2,084.00
• Hoe operator and labourer truck rental	2 x 30 days @ $100/day	6,000.00
• Site-specific manpower and equipment requirements (refer to Sections 5.2 to 5.4 for detailed analysis)		90,777.40
	Subtotal	98,861.40
TOTAL COST ESTIMATE FOR MAXAN WATERSHED STREAM RESTORATION AND ENHANCEMENT		128,557.40

7.0 CONSTRUCTION TIMING

AEE recommends that construction activities be carried out during low flow periods of August or September. This timing is intended to minimize the potential impacts of construction upon water quality, fish habitat and fish populations (i.e., outside of spring and fall fish spawning windows).

8.0 PUBLIC INVOLVEMENT

It is recommended that volunteers play a role in both on-site and off-site activities. This will help provide volunteer teams and interest groups with "hands-on" experience that will help to promote stewardship of the resource. It is also suggested that ranchers within the watershed be educated about range management techniques such as fencing, salt placement, providing additional water sources, improving trails and herding to improve livestock distribution.

9.0 REGULATORY AGENCY APPROVALS

At some of the sites (i.e., privately owned land along the Bulkley River) it will be necessary to get landowner approval prior to construction. A cutting permit from the Ministry of Forests or landowner permission will be required before locally available trees can be harvested. The department of highways and transportation should be contacted prior to commencement of activities at BR-S11. This department may require detailed site and engineering plans for areas immediately upstream and downstream of the bridge.

10.0 MONITORING RECOMMENDATIONS

10.1 HABITAT MONITORING

Stream habitat characteristics and fish species distribution and abundance should be determined before and after project construction to assess the effectiveness of enhancement measures.

Habitat surveys should quantify channel and flow conditions, streambank and bed characteristics and the proportion of fish cover provided by pool depth, overhanging and floating cover and other features.

In conjunction with habitat assessment, fish species composition, distribution and relative abundance should be documented for different types including pools, runs and riffles. Upstream and downstream blocking nets could be placed across representative stream sections and electrofishing and a multiple pass-removal-depletion technique used to derive fish population estimates for different habitat types. The extent and use of each project reach or enhancement site could then be determined through comparison of the relative numbers of each species and life history stage collected from different locations.

As an indication of changes in environmental quality (and to assess fish food supply), it may be desirable to conduct a quantitative benthic invertebrate monitoring program with surveys before and after construction. Changes in community structure (that can be measured statistically) will provide an indication of the effectiveness of erosion protection measures at controlling streambed siltation. Bed material movement during high flows, and associated substrate cleaning, bed scouring, and bedform movement can have important impacts on the habitat quality.

Volunteers should be encouraged to participate in monitoring activities. Documentation of fish size, numbers and angling effort would contribute to an assessment of the effectiveness of stream habitat enhancement measures.

10.2 HYDROLOGIC MONITORING

Because Maxan Creek project is a prototype for similar projects in the area, it is important that the experience gained here be adapted to other sites. The performance of many components of the proposed works are related to the hydrology and hydraulics of the stream. The monitoring program should include the following elements.

- Measure the stream discharge at regular intervals, with special attention to flood events. A simple method of doing this would be to mount a staff gauge on each

watercourse and have them read by a local resident or other convenient person. More accurate data could be acquired by installing float recorders.

- During or after each flood event, survey the study reaches for the elevations of high water marks. The flood discharge could then be estimated based on channel cross sections using the slope area method.

- Relate experienced flows to regional long term normals.

10.3 EROSION PROTECTION MONITORING

The performance of bank stabilization measures should be monitored after one or two flood seasons. This monitoring would involve a visual inspection of rock riprap, tree revetments etc. Damage to the protection works should be noted and repaired in a timely manner. Bank stability upstream and downstream of the protected lengths should be monitored to determine the need for and extent of additional armouring. Detailed records should be kept so that the design criteria can be refined for other projects.

10.4 INSTREAM STRUCTURE MONITORING

Specific instream enhancement measures included 'V' weirs, pool excavations, rock wing deflectors and rock clusters. AEE recommends that structural integrity be monitored on a regular basis.

11.0 ADDITIONAL ENHANCEMENT ACTIVITIES

Due to snowcover, only the most obvious impacts in the watershed were assessed. It is recommended that additional ground and air surveys be conducted to thoroughly assess the the watershed.

12.0 CONCLUSIONS

Stream habitats in the Maxan watershed will be restored and enhanced using a variety of channel improvement and bank stabilization techniques. The design recommendations contained in this report attempt to recreate natural conditions representative of fish habitat found both in unimpacted reaches within the Maxan watershed and in other comparable streams. A design criteria has been established which is believed to be appropriate for the purpose of the proposed works. The performance of the proposed structures can be enhanced using experienced personnel during construction and by undertaking timely and appropriate maintenance.

13.0 LITERATURE CITED

Bustard & Associates. 1989. *Fish Population Monitoring in Foxy and Buck Creeks.* September 1989. Prep. for Equity Silver Mines Ltd, Houston, B.C.

AGRA Earth & Environmental Limited. 1996. *Level 1 Fish Population and Riverine Habitat Assessment - Maxan Watershed.* Prep. for Yin Waghunlee Habitat Enhancement Corporation, Burns Lake, B.C.

APPENDIX A

PHOTOGRAPHS OF TYPICAL HABITATS OF THE BULKLEY RIVER, LOWER MAXAN CREEK, UPPER MAXAN CREEK AND FOXY CREEK

Photo 1
Typical Habitat along the Bulkley River

Photo 2
Typical Habitat Along Reach 1 of Lower Maxan Creek

Photo 3
Typical Habitat Along Reach 2 of Lower Maxan Creek

Photo 4
Typical Habitat Along Reach 1 of Upper Maxan Creek

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Photo 5
Typical Habitat Along Reach 2 of Upper Maxan Creek

Photo 6
Typical Habitat Along Reach 1 of Foxy Creek

Photo 7
Typical Habitat Along Reach 2 of Foxy Creek

Photo 8
Typical Habitat Along Reach 3 of Foxy Creek

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Photo 9
Typical Habitat Along Reach 4 of Foxy Creek

APPENDIX B

SITE-SPECIFIC PHOTOGRAPHS OF RECOMMENDED ENHANCEMENT SITES

Photo 10
Mass Wasting Along the Right Cutbank of BR-51

Photo 11
Unstable Banks with Limited Overhead Cover at BR-S1

Photo 12
Bank Erosion and Limited Streamside Cover at BR-S2

Photo 13
Shallow Riffle Complex and Partially Unstable Bank at BR-S3

Photo 14
Stockpiled Pipe Slumping Down the Streambank at BR-S3

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Photo 15
Limited Streamside Cover Along the Right Bank at BR-S3

Photo 16
Stream Channel and Bank Characteristics at BR-S4

Photo 17
Stream Habitat at BR-S5

Photo 18
Oversteepened, Unstable Bank
At the Upstream and of BR-S5

Photo 19
Limited Woody Vegetation at the Downstream End of BR-S5

Photo 20

Site Characteristics at the Upstream end of BR-S6

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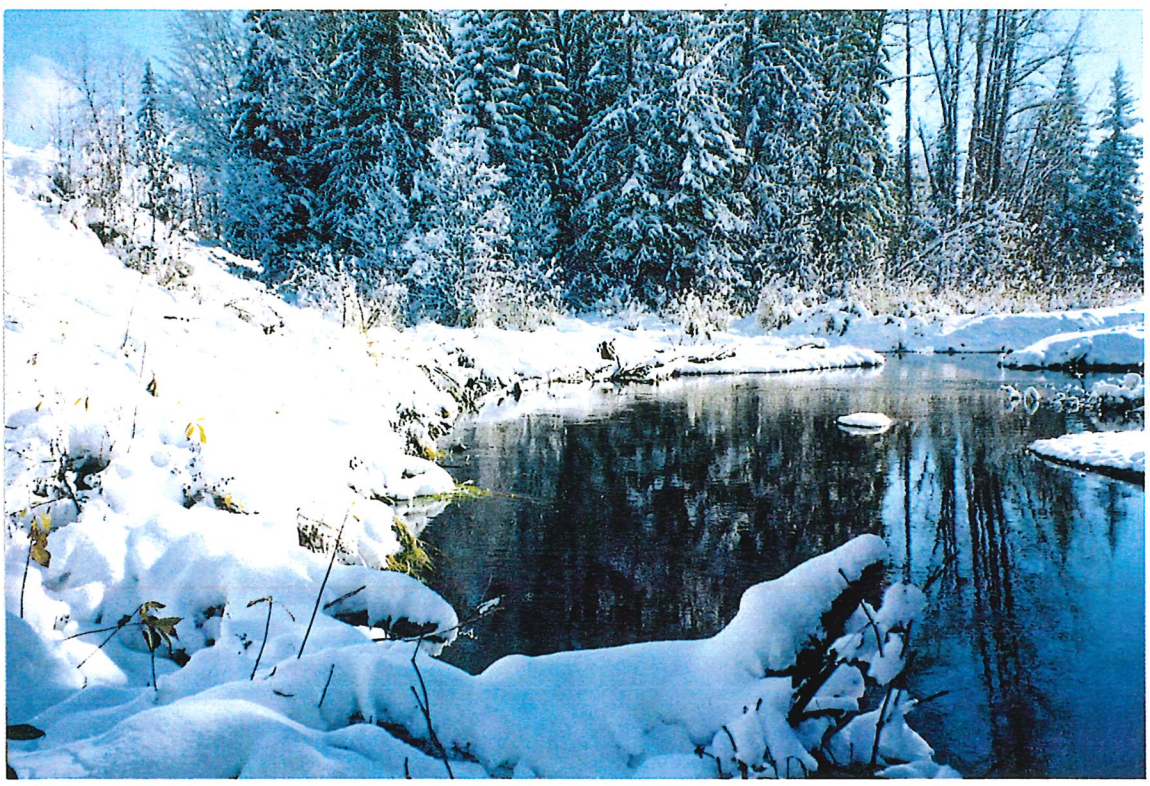

Photo 21
Trees and Shrubs Provide No Overhead Cover at BR-S6

Photo 22
Site Overview of BR-S7

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Photo 23
Patchy Shrub Growth Along the Banks at BR-S7

Photo 24
Stream Habitat Characteristics at BR-S8

Photo 25
Site Overview of BR-S9

Photo 26
Vertical Eroding Banks
at BR-S9

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Photo 27
Bank Erosion is Gradually Undermining the Rose Lake Cutoff Roadbank at BR-S10

Photo 28
Marginal Overhead Fish Cover Near the Downstream End of BR-S10

Photo 29
Steep, Eroding Banks at the Downstream Extent of BR-S10

Photo 30
Unvegetated Former Bridge Approaches Immediately Upstream of the New Bridge at BR-S11

Photo 31
Direct Flow Attack and a Deep Upwelling Pool are Increasing Left Bank Erosion Immediately Downstream of the Bridge Crossing at BR-S11

Photo 32
Slumping, Sparsely Vegetated Banks at BR-S11

Photo 33
Streambank Characteristics at BR-S12

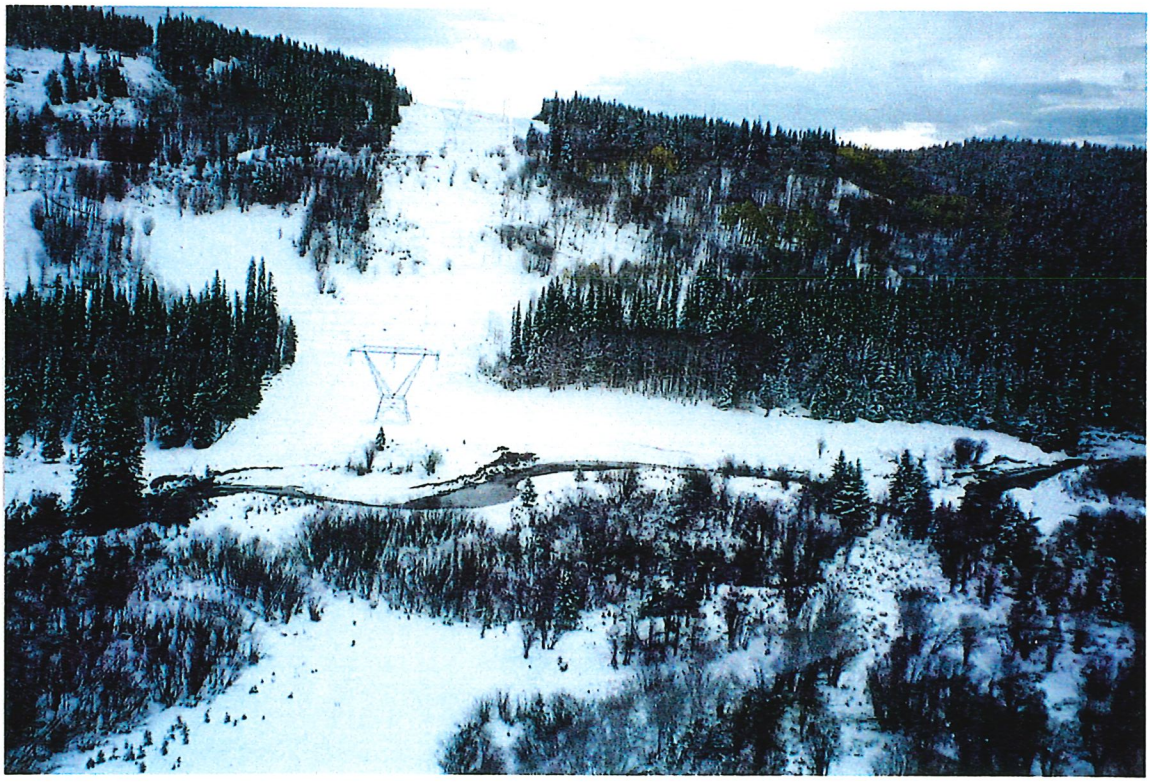

Photo 34
Aerial Overview of BR-S13

Photo 35
Example of an Unvegetated, Eroding Streambank at BR-S13

Photo 36
Livestock Damage to Banks at BR-S13

Photo 37
Aerial Overview of FC-S1

Photo 38
Unvegetated Left Bridge Approach with Minor Bank at Erosion FC-S1

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Photo 39
Extensive Erosion of the Right Bridge Approach at FC-S1

Photo 40
Aerial Overview of FC-S2

Photo 41
Straight, Featureless Stream Habitat at FC-S2

Photo 42
Right Bank Erosion Immediately Upstream of Existing Riprap at FC-S2

Photo 43
Bank Erosion at the Downstream End of FC-S2

Photo 44
Aerial Overview of LMC-S1

Photo 45
Right Bank Erosion Upstream of the Bridge Crossing at LMC-S1

Photo 46
Left Bank Erosion Downstream from the Bridge Crossing at LMC-S1

Photo 47
Erosional Piping Behind the Left Bridge Crib
(looking downstream) at LMC-S1

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