Peace Project Water Use Plan

Williston Reservoir Trial Tributaries

Site Selection Report

Reference: GMSWORKS-19

Site Selection and Design Recommendations for Williston Reservoir Tributary Fish Access Mitigation Trial, Northern British Columbia

Study Period: 2009

Synergy Applied Ecology

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SITE SELECTION AND DESIGN RECOMMENDATIONS FOR WILLISTON RESERVOIR TRIBUTARY FISH ACCESS MITIGATION TRIAL, NORTHERN BRITISH COLUMBIA

ABSTRACT

Normal reservoir operations have the potential to effectively disconnect tributaries from the reservoir and limit fish migration during the low water drawdown period, when streamflow into the reservoir may become shallow and braided across the exposed reservoir floodplain or large woody debris accumulates. This report builds on previous recommendations and proposes an experimental mitigation trial using proven techniques to improve fish access to affected tributary systems. Following aerial reconnaissance, 9 tributary watercourses were assessed for degree of impact on fish access and potential for successful mitigation. Based on biophysical, archaeological and environmental assessments, we selected Six Mile Creek and Chichouyenily Creek as the 2 top-ranked sites for tributary access mitigation trials. We provide mitigation trial design recommendations and considerations for regulatory requirements and performance monitoring. The design recommendations are widely applied stream mitigation techniques that can be implemented at a relatively small scale to test their feasibility and effectiveness in trial projects while moving towards mitigation of more complex sites using an adaptive management approach.

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INTRODUCTION

Acting on the recommendations of public consultation, the Planning Committee for the Peace Project Water Use Plan (WUP) recommended a number of operational and non-operational initiatives focused on increasing access and use of water resources throughout the Williston Reservoir watershed while still allowing for the normal operation of existing hydroelectric facilities on the Peace River, northern British Columbia (B.C.; BC Hydro 2008b). One of these initiatives is focused on facilitating improved fish access into direct tributaries of the Williston Reservoir affected by seasonal water level fluctuations.

Large woody debris (LWD) introduced from reservoir development and active shoreline erosion is mobilized at high water levels and deposited on shore during drawdown. In natural systems, LWD is an important functional component of fish habitat. Although the potential for LWD to result in a physical barrier that is completely impermeable to fish is likely low, LWD in reservoirs can have a scouring effect on shoreline substrates that increases sedimentation, limits vegetation growth, and erodes stream channels in reservoir drawdown zones. Normal reservoir operations also have the potential to effectively disconnect the tributary from the reservoir during the low water drawdown period, when stream flow into the reservoir may become shallow and braided across the exposed reservoir floodplain. Additional hindrances to fish passage are the lack of cover and habitat complexity in drawdown areas, rendering migrating fish susceptible to predation from piscivorous fishes and avian predators. These factors are exacerbated when reservoir water levels are lowest.

Large rivers with high discharge rates and typically wide, deep channels are much less affected by reservoir water level fluctuations due to the scouring power of high volumes of flowing water eroding through the floodplain and maintaining the predictable channel characteristics of natural, upstream reaches. The power of these systems also renders them less susceptible to LWD accumulation by forcibly transporting woody debris or scouring underneath or around the obstruction. However, reservoir drawdown and LWD aggregation may have significant impacts on small to mid-size streams that lack the discharge-dependent power to mobilize in-stream objects and maintain channel structure across the drawdown zone.

Fish evolve behaviour and life history characteristics that maximize fitness by ensuring they will be in the best habitat to fulfill requisite life cycle objectives. If the physical environment changes, it may cease to provide favourable conditions or required resources. Effective management strategies recognize that species depend not only on a matrix of suitable habitat, but on the availability of certain habitats in the right place at the right time (Naiman and Latterell 2005). Reservoir drawdown may impact mature, adfluvial early-spring (April-March) spawning fish as they migrate to natal streams, such as Arctic grayling (*Thymallus arcticus pop.1*) and burbot (*Lota lota*), that encounter barriers due to low discharge and water depth before the onset of spring freshet. Further, young of the year fall spawning fish, such as bull trout and kokanee, may suffer the same physical barrier during emigration to reservoir rearing habitats in late-winter, low-flow periods.

Many of the rivers and streams draining into Williston Lake are under-populated with fish species. Fish distribution and demographic trends since initial impoundment in the early 1970’s have shown an increase in the proportion of fishes adapted to lacustrine habitat while riverine adapted fish have declined (Langston and Blackman 1993). Regionally significant fish species such as Arctic grayling, bull trout (*Salvelinus confluentus*) and kokanee (*Oncorhynchus nerka*) have responded differently to habitat alteration. Bull trout, blue-listed in B.C. (MoE 2009), are reported to have shifted habitat preference and are successfully utilizing the Williston Reservoir for forage where they feed primarily on lake whitefish (*Coregonus clupeaformis*) and kokanee (Blackman *et al.* 1990; Stewart *et al.* 2007). Grayling and mountain whitefish (*Prosopium williamsoni*) have suffered drastic population declines since the early 1980’s when stocks were reported healthy in the reservoir and its tributaries (Northcote 2000; Blackman

2001). Grayling now appear to be restricted to a small number of watersheds above the W.A.C. Bennett and Peace Canyon Dams and are estimated to be less than 1% of their historical population size (Stamford and Taylor 2005). As a result, the grayling (population 1) is red-listed in B.C. (http://a100.gov.bc.ca/pub/eswp/) and requires considerable attention to support recovery of the population. Arctic grayling depend on the lower reaches of larger mainstem rivers, or the reservoir embayments that these watercourses empty into, for adult rearing habitat (Clarke *et al.* 2007; McPhail 2007).

The Peace/Williston Fish and Wildlife Compensation Program (PWFWCP) has collected a large body of data relevant to reservoir impacts on tributary access for native fishes to develop potential compensation solutions, but as of yet little progress has been made implementing previously proposed mitigation recommendations (Langston 1992; Fielden *et al.* 1993; Langston and Blackman 1993; Morgan 1995; Aquatic Resources Limited 2002). This report builds on previous recommendations and proposes an experimental mitigation trial using proven techniques to improve fish access to affected tributary systems. Although we are not aware of any previous examples of similar projects implemented in reservoirs elsewhere, the designs we recommend have been successfully implemented in many stream mitigation and restoration projects and follow recognized hydraulic design principles (Newbury and Gaboury 1993).

Specifically, our objectives are to improve or restore fish access to fluvial habitats isolated by LWD accrual and/or drawdown effects resultant from normal reservoir operation, with a focus on increasing access to available habitat of listed and regionally significant fish. This report discusses:

- Inventory and ranking of candidate tributary sites
- Biophysical description of 2 sites recommended for trial mitigation
- Conceptual design recommendations for mitigation works to restore access and improve fish habitat at tributary mouths by rehabilitating channel characteristics between the reservoir's low and high water levels
- Management and maintenance plans for proposed physical works
- Cost estimate for proposed physical works

STUDY AREA

The Williston Reservoir is the largest man-made, freshwater, hydroelectric reservoir in B.C. with an area of 1779 km^2 and a shoreline perimeter of 1700 km (Figure 1). The W.A.C Bennett dam at Hudson's Hope is one of the largest earthen dams constructed at a height of 183 m and a crest length of approximately 2 km. Construction began in the early 1960s and impounded water reached full storage level behind the dam in 1972 (Bruce and Starr 1985). The maximum licensed water level is 672 masl and a minimum level of 640 masl, with the lowest water levels typically reached in April annually (Figure 2). The Williston watershed occupies an area of 72000 km^2 supplying an average monthly inflow of 1165 m^3s^{-1}. At full volume, reservoir capacity is 7.43 x 10^{10} m^3 with a mean depth of 43.3 m. The residence time of inflowing water is 2.2 years and is largely responsible for the limited primary productivity and tends the system towards oligotrophy (http://www.ilec.or.jp/database/database.html; Harris *et al.* 2005). The mixing regime is dimictic and as a result nutrients are limited to cycle throughout the water column during spring and late fall when the theromocline is weakly developed and the density of the water column is relatively homogenous. The reservoir is often referenced by three discreet reaches named after the major rivers that preceded them: the Finlay, Parsnip and Peace. The watershed includes the communities of Mackenzie, Germansen Landing, Manson Creek and First Nations villages of Tsay Keh Dene and Fort Ware (Figure 1).

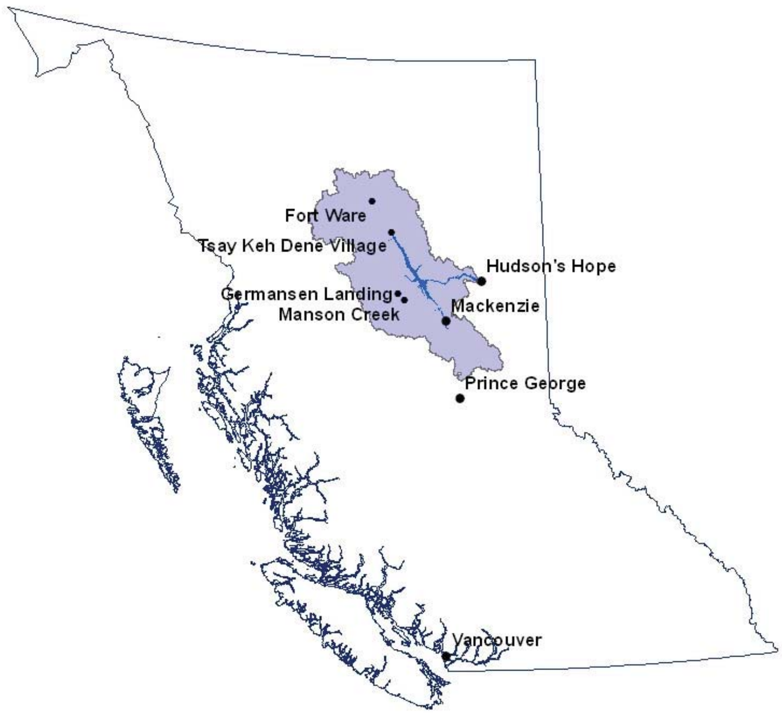

Figure 1. The Williston Reservoir and surrounding watershed boundary in northern British Columbia. The W.A.C Bennett and Peace Canyon generation stations are on the Peace River adjacent to the community of Hudson's Hope.

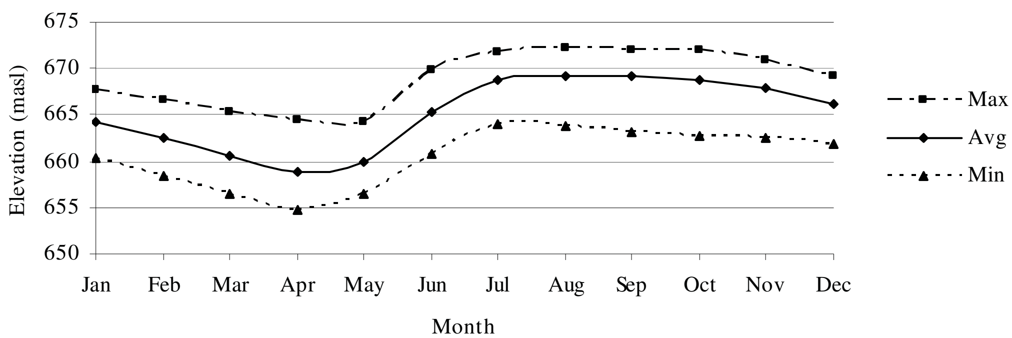

Figure 2. Average monthly water levels from 1984-2009 for the Williston Reservoir, reported as metres above sea level.

INVENTORY AND RANKING OF CANDIDATE SITES

Selection criteria

Our focus was strictly on identifying potential tributary isolation and/or barriers due to LWD accrual or annual water level fluctuations associated with normal reservoir operation. We defined candidate sites with potential for reservoir impacts on fish migration as those direct tributaries to the reservoir having extensive drawdown zones with negligible fish habitat value at low reservoir water levels, or LWD accumulations that may present barriers to fish passage.

Ranking of candidate sites incorporated methods described by Aquatic Resources Limited (2002). Watercourses verified to support populations of fish species listed as threatened or endangered, provincially or federally, were ranked higher for mitigation potential. Key assessment criteria to prioritize 2 candidate sites for trial remedial work included:

- Fish and wildlife species diversity, abundance and sensitivity/risk
- Suitability for enhancement measures
- Biological impacts and mitigation options
- Cost-effectiveness
- Proximity to infrastructure, equipment, and labour
- Potential collaboration with concurrent or future enhancement and/or mitigation projects within the Williston watershed

Emphasis was given to tributaries potentially impacted by drawdown or LWD accumulation that emptied into the many embayments along the Williston Reservoir shoreline. Embayment streams were given preference as they appear to be less prone to wind and wave action and resultant mobilization of sediments and woody debris during weather events and are therefore likely to provide more favourable conditions for trial mitigation performance monitoring. Further, a number of embayments offer additional hindrances to fish passage as the lack of cover and habitat complexity (Payne and Lapointe 1997) renders migrating fish susceptible to predation from piscivorous fishes and avian predators. These factors are exacerbated when reservoir water levels are lowest.

Given that this is a trial mitigation project, cost-efficiencies, site access, and potential for public involvement and education/outreach were considered important. We also favoured sites where a before-after-control-impact (BACI) experimental design could be incorporated into the mitigation trial. A BACI design with fish presence confirmed in upstream reaches a priori ensures that the trial’s success in enhancing fish habitats and population productivity is not limited by constraints outside the scope of the trial.

Reconnaissance surveys

Preliminary assessments included review of existing literature and available information on tributary habitats in the Williston watershed. PWFWCP biologists, familiar with the issues motivating this initiative and impact potential within the watershed, provided insight and sampling recommendations during the planning phase.

Aerial and ground reconnaissance surveys were conducted to corroborate existing data and identify candidate sites with the highest mitigation potential. We conducted 2 aerial reconnaissance flights targeting direct tributaries throughout the Parsnip, Peace and lower Finlay reaches of the Williston Reservoir to identify low and high water impacts, and mitigation potential. The first helicopter flight was conducted during low water conditions in the Manson Arm, Parsnip, and Peace reaches in May 2009 to identify watercourses that appeared to limit migration potential of mature, adfluvial fish that immigrate into lotic habitats to spawn, or juveniles that emigrate to lentic rearing habitat in the spring, due to factors associated with low reservoir water level. A second flight was conducted in September 2009 within the lower two thirds of the Finlay reach to assess the degree of LWD accumulation at the confluence of tributaries to the reservoir during high water, as recommended by PWFWCP fisheries biologists.

Assessment of potential fish migration barriers

To test if LWD accumulation at the confluence of direct tributaries to the reservoir created an obstruction to fish passage at high water, we timed our sampling during the period where fall spawning fish were likely to have entered selected streams, but had not yet commenced active spawning (Fielden 1991; Langston and Zemlak 1998; O'Brien 2001; McPhail 2007). We made the assumption that adfluvial fish were larger than stream residents (Hendry and Quinn 1997), and as such, the sample streams were not able to provide habitat and metabolic requirements (Weatherley 1990) to sustain larger, sexually mature fish through the winter. As a result, iteroparous species would emigrate to the reservoir and semelparous fish would expire after each spawning season and remaining fish present would be of the stream resident form. If LWD accumulation presented a barrier to fish migration then we expected to see size differences in fish between direct tributaries with accumulations of LWD that are dominated with resident fish, and those that have no accumulation and thus, no hindrance with respect to fish movement in and out of a given tributary. We chose to use fish length as the factor for our test statistic because fish growth in terms of length for a multitude of species follows a normal distribution whereas fish weight does not (Ricker 1979).

We compared streams of similar morphology and proximity to each other that had either LWD accumulations or were clear of debris and sampled 200 m sections of the most downstream reaches consecutively, expending the same fishing effort. Due to the sensitive timing of sampling, every effort was made to avoid redds and minimize disturbance to spawning gravels and behavior. We performed an Analysis of Variance (ANOVA) to determine if there were differences in mean length of fish caught in each stream. If differences in mean length between affected and control streams existed we concluded the LWD accumulation prevented immigration of adfluvial fish.

We did not perform statistical analyses comparing size structure between spring and fall capture sessions to determine whether selected watercourses were impacted by drawdown effects. Project timing did not allow us to conduct spring fish capture during the expected migration window for early spring spawning fish such as grayling. As such, the probability of detection of larger, sexually mature, adfluvial fish within the system was deemed too low to test our hypothesis. We felt that making size structure comparisons between sample populations comprised of resident fish only at the onset and end stage of the growing season would be biased and unreliable. Instead, we used widely accepted stream channel and fish habitat assessment procedures reported in the literature as the basis for evaluation of impacts (Newbury and Gaboury 1993; Harrelson *et al.* 1994; MoF 1998; Fevold *et al.* 2000; MoF 2001; Rosgen 2001; MoF 2002). Key parameters in this instance were presence of sexually mature fish, differences in fish species observed, channel stability, substrate composition and functional variability (Payne and Lapointe 1997) of reach segments subjected to variable water levels, and upstream reaches not subject to inundation during high water conditions.

Biophysical fish habitat assessments at candidate sites

In preparation of field sampling at candidate sites, we reviewed historical biophysical data relevant to targeted watercourses from PWFWCP, Field Data Information System (FDIS) and Fisheries Information Summary System (FISS) datasets. We also acquired spatial fish distribution and obstruction data from the Land and Resource Data Warehouse (LDRW) Geographic Information System (GIS) data repository. Watercourses were also assessed for morphology and hydrology and included both office based investigations and site visits. GIS aided analysis of basin topography for each selected tributary to construct longitudinal profiles of the mainstem based on 100 m contour intervals, and determination of total channel length, average slope and drainage area. Profiles also aided the identification of sampling locations to validate the expected length of accessible upstream habitat. The benefit of this approach allowed us to identify stream features such as potential slope/velocity barriers at the reach scale. Upstream habitats and barriers affecting fish migration were investigated to determine mitigation value with respect to the amount of available upstream habitat potential made accessible by proposed works.

Fish capture was accomplished utilizing a backpack electrofisher, minnow (Gee) traps and angling. Electrofishing was the primary method used and employed low intensity, open, single pass sampling techniques. All fish captured were identified, measured for length, and weighed. Much of the existing fish distribution data for the project area were collected several years ago and given the reported habitat shifts of native fishes following impoundment, the primary objective of fish sampling was to verify the persistence, or absence, of these fish species over time and the upstream limits of fish distribution within the selected watercourses, where practical. Selected tributaries impacted by drawdown and/or LWD were field sampled during low water conditions and after the reservoir reached maximum elevation for the year. Streams with LWD accumulations at high water were sampled once as close to the expected migration window of fall spawning fish as the collection permit conditions allowed.

One of the goals of mitigation is to restore and maintain the predictable channel characteristics of natural, upstream reaches in the reservoir drawdown zone. To estimate required channel characteristics of proposed mitigation works, hydraulic data were recorded for selected streams from a minimum of three representative transects within adjacent, natural, fish-bearing reaches. Cross section data estimated average bankfull width, depth and actual discharge at time of sampling. Froude's number was derived to describe local flow conditions of fish bearing habitat (Newbury and Gaboury 1993).

Because field sampling to collect hydraulic data took place during low flow conditions, we took random samples of substrate material and estimated Manning's roughness using a case II scenario where the average depth of flow is less than 3 times the median bed material (Newbury and Gaboury 1993). Using Manning's calculated value, bankfull (or trim line) velocity and discharge were estimated.

Archaeological assessment

We liaised with archaeologists to determine the most cost-effective method and timing for completion of Archaeological Overview Assessments (AOAs). The best approach was to perform site-specific data reviews (e.g., local site records and Remote Access to Archaeological Data database) and office-based probability modeling once tributary site selection was finalized and preliminary mitigation design plans were established. Office-based AOAs are likely to provide sufficient indication of the sites' potential to contain archaeological resources and the need for more in-depth field assessments. Site assessments (particularly field reconnaissance) prior to development of mitigation plans would not effectively assess risk to any archaeological resources, if present, at the candidate sites as a result of the proposed enhancements.

Environmental assessment

We conducted an overview environmental assessment of the two tributary sites selected for mitigation, including the area surrounding the selected sites, to record the relative importance of the riparian zone and adjacent upland area to terrestrial species. Evidence of use of riparian and upland vegetation by forest dwelling birds and animals was documented. Emphasis was placed on identifying potential impacts associated with access to the construction site and construction activities related to the physical works, including any upland areas that may be required for access to the tributary.

INVENTORY RESULTS AND SITE SELECTION

Aerial reconnaissance was completed for 64 watercourses across all three reaches of the Williston reservoir (Figure 3). We concluded that:

- 16 watercourses were assessed to have drawdown impacts
- 17 watercourses had variable levels of LWD accumulation
- 31 watercourses had no or minimal perceived impacts from LWD or drawdown as a result of normal reservoir operation; tributaries with limited upstream habitat were grouped in this category

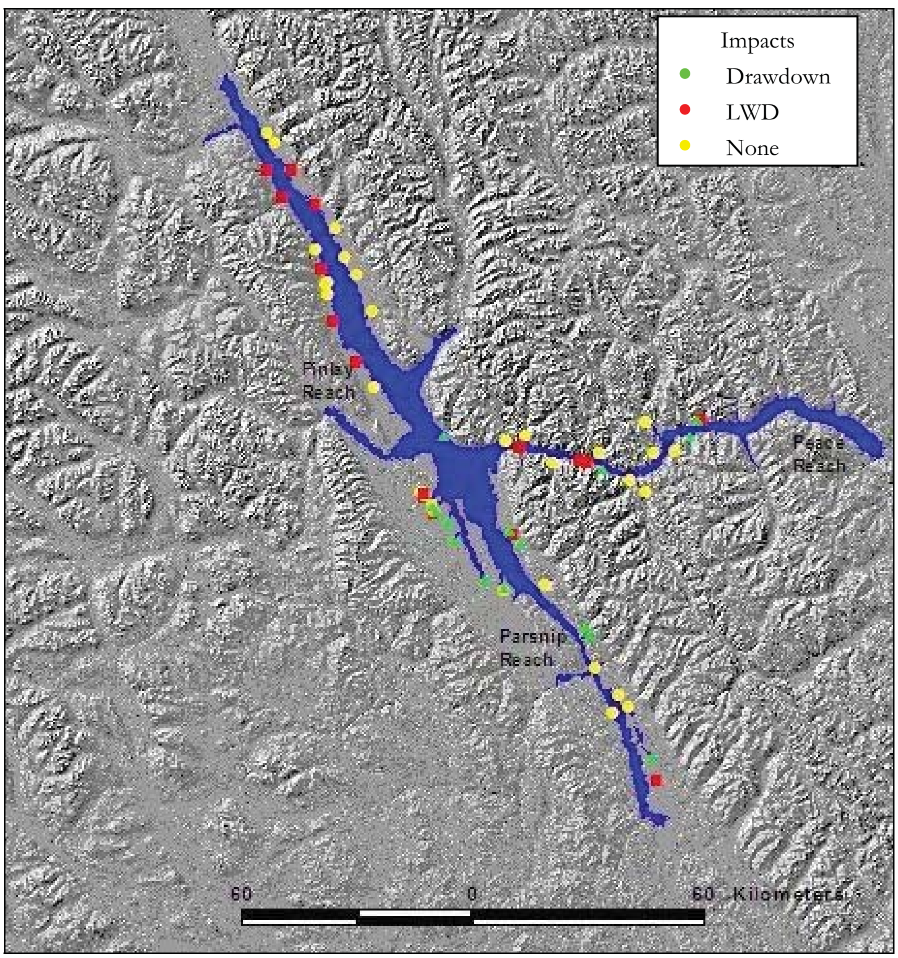

Figure 3. Overview map of 64 tributaries assessed during aerial reconnaissance conducted in May and September 2009. Tributaries were identified for impact by reservoir drawdown, LWD accumulation or not impacted (none).

Following aerial reconnaissance, we conducted site assessments on 9 tributary watercourses affected by drawdown or LWD accumulation (Table 1).

Table 1. Selected tributaries to the Williston Reservoir assessed for potential access impacts related to reservoir drawdown or large woody debris accrual.

Gazetted Name	Watershed Code	Reservoir Reach	Primary Impact
Six Mile Creek	230-902800-00000	Parsnip	Drawdown
(tribs. Patsuk Creek	230-902800-13100	Parsnip	Drawdown
Kimta Creek)	230-902800-64600	Parsnip	Drawdown
Lamonti Creek	230-902900-00000	Parsnip	Drawdown
Chichouyenily Creek	230-905600-00000	Parsnip	Drawdown
Weston Creek	230-901500-00000	Parsnip	Drawdown
Gagnon Creek	230-905800-00000	Parsnip	LWD
Ole Creek	230-960400-00000	Finlay	LWD
Bruin Creek	230-962600-00000	Finlay	LWD
Lorimer Creek	230-957300-00000	Finlay	LWD
Factor Ross Creek	230-977300-00000	Finlay	LWD

We sampled four Finlay Reach tributaries on September 11-12 2009 (Figure 4). Two tributaries (Lorimer Cr and Factor Ross Cr) were observed to be free of LWD accumulation and two (Ole Cr and Bruin Cr) had significant accumulations (Photos 1 - 4). Sexually mature bull trout and kokanee were present in all four watercourses. Further, results of ANOVA revealed that LWD did not appear to affect adfluvial fish immigration into sampled spawning tributaries as we observed no difference in fish length between impacted and control reaches (Table 2, Lorimer vs Ole, $F_{1, 28} = 1.18$, $P = 0.29$; Table 3, Factor Ross vs Bruin, $F_{1, 13} = 0.0005$, $P = 0.98$).

Photo 1. Lorimer Creek

Photo 2. Ole Creek

Table 2. Electrofisher equipment settings and fish data for Lorimer Creek and Ole Creek, sampled to test if LWD accumulation at tributary confluence inhibits fish passage.

	Lorimer	**Ole**
LWD accrual	no	yes
Effort (secs)	805	625
Settings (volts, Hz, duty cycle (%))	560, 30, 12	660, 30, 12
Water temp. (^oC)	9	9
# fish caught	17	13
Fish species	bull trout, mountain whitefish, kokanee, sculpin	bull trout, mountain whitefish, kokanee, sculpin
Mean length (mm)	100.9	124.2

Photo 3. Factor Ross Creek

Photo 4. Bruin Creek

Table 3. Electrofisher equipment settings and fish data for Factor Ross Creek and Bruin Creek, sampled to test if LWD accumulation at tributary confluence inhibits fish passage.

	Factor Ross	**Bruin**
LWD accrual	no	yes
Effort (secs)	437	478
Settings (volts, Hz, duty cycle (%))	360, 30, 12	240, 30, 12
Water temp. (^oC)	9	10
# fish caught	9	6
Fish species	bull trout, kokanee, sculpin	bull trout, kokanee, sculpin
Mean length (mm)	155.2	156

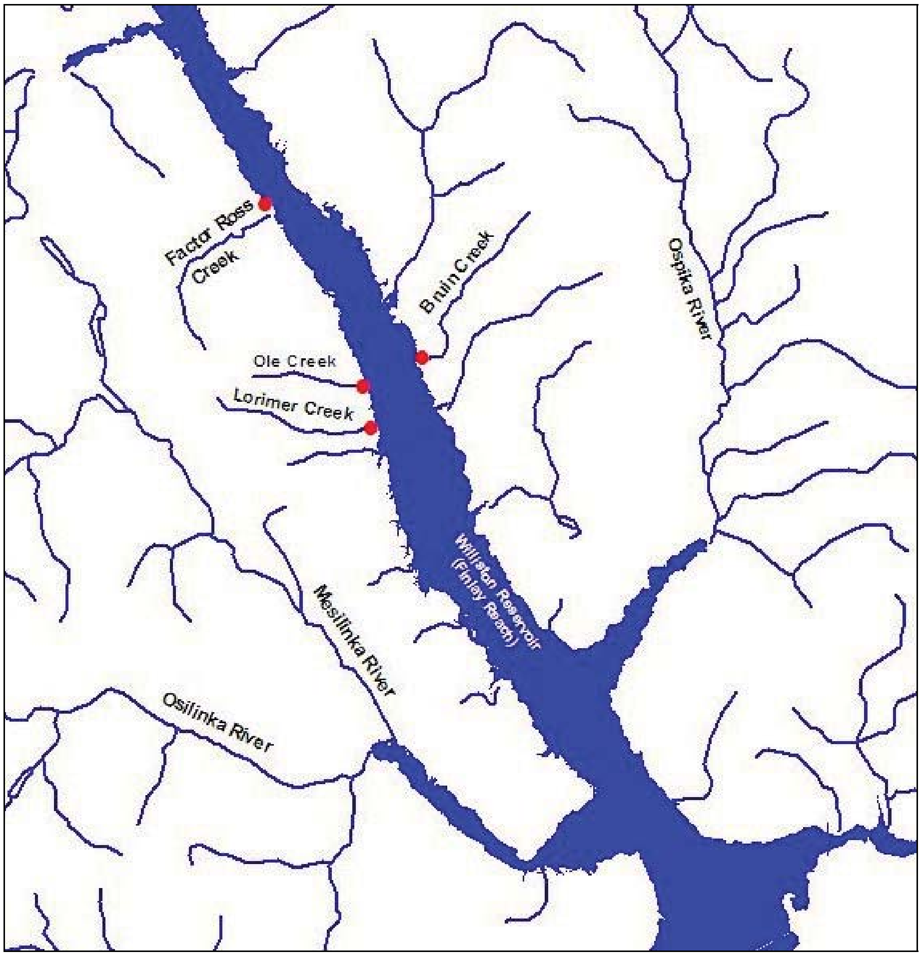

Figure 4. Sample locations within the Finlay Reach of the Williston Reservoir assessed to test if LWD accumulation at tributary mouth inhibits fish passage.

Our results suggest LWD accumulations during reservoir high water levels do not restrict fish passage in or out of tributaries and access may be a function of water depth, discharge and the buoyancy of LWD. In this instance, LWD may benefit fish by providing overhead cover and offer prey fish refugia from predators. As a result reservoir drawdown is likely to impose greater constraints on fish migrations in early-spring in the presence or absence of LWD accrual, due to lower water depth and unconfined discharge over porous reservoir substrate.

Two examples of these drawdown effects on fish access at tributaries that meet our selection criteria and have high mitigation potential include Six Mile Creek and Chichouyenily Creek. These two sites were selected as the 2 top ranked tributaries for access mitigation trials (Figure 5).

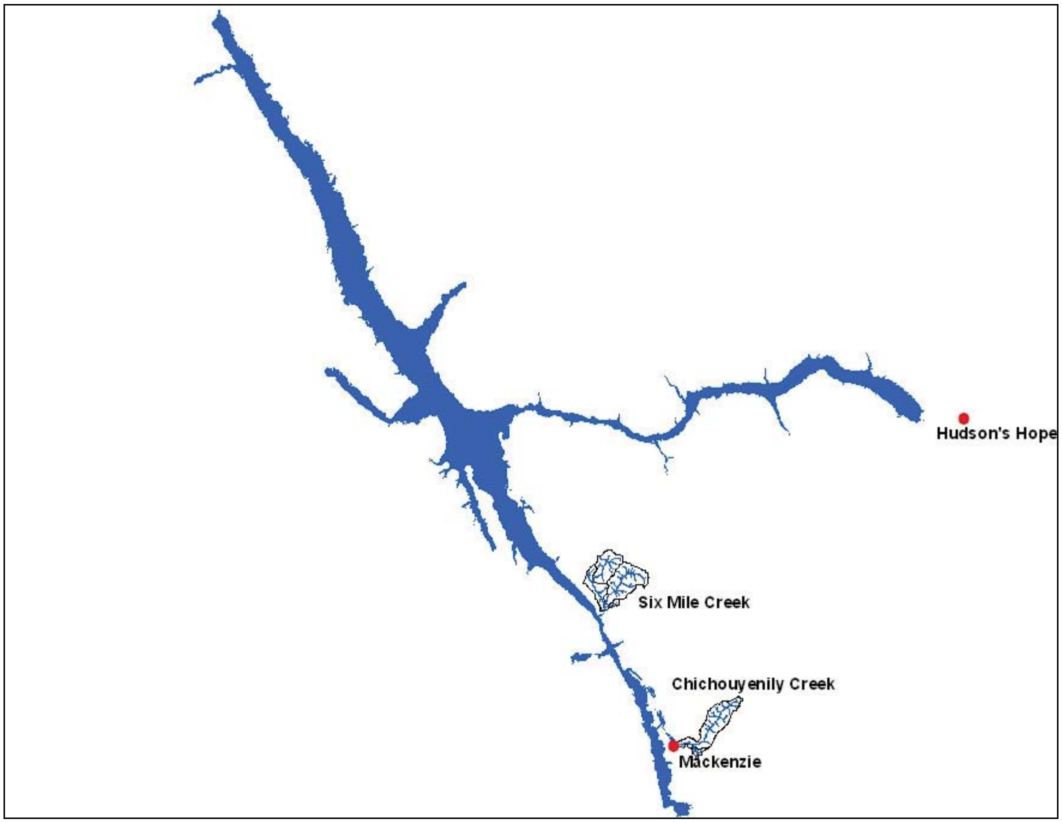

Figure 5. Overview map of tributaries within the Williston watershed selected for access mitigation trials. Also shown are tributaries of the selected systems and their watershed boundaries.

SITE DESCRIPTIONS

Six Mile Creek

Overview

Six Mile Creek is a tributary to the Parsnip Reach of the Williston Reservoir, emptying into Six Mile Bay approximately 40 km north of Mackenzie. Implementing physical works trials on the Six Mile Creek complex has the potential to restore year round fish access to approximately 12 kms of high value habitat for listed and regionally important fish species while still allowing normal operation of the Williston Reservoir. Six Mile Creek, and its upstream tributaries Patsuk and Kimta Creeks (Figure 6), have high value fluvial habitat supporting small numbers of regionally significant and provincially-listed fish species. Reservoir drawdown in spring likely hinders fish passage for mature adults seeking upstream spawning habitat, due to shallow braided streamflow across the drawdown zone (Appendix A). Juveniles emigrating from overwinter habitats in the stream to rearing habitat in the reservoir are subject to high predation risk in the drawdown zone. Rehabilitation of the stream channel in the drawdown zone is expected to improve fish access to high value fluvial habitats and increase fish population productivity locally. Additional enhancements to improve structural diversity of fish habitat in the drawdown zone are also recommended.

Lamonti Creek, a second direct tributary to Six Mile Bay, has similar mitigation potential but is recommended as an unmitigated control system for measuring the effectiveness of trial mitigation on Six Mile Creek.

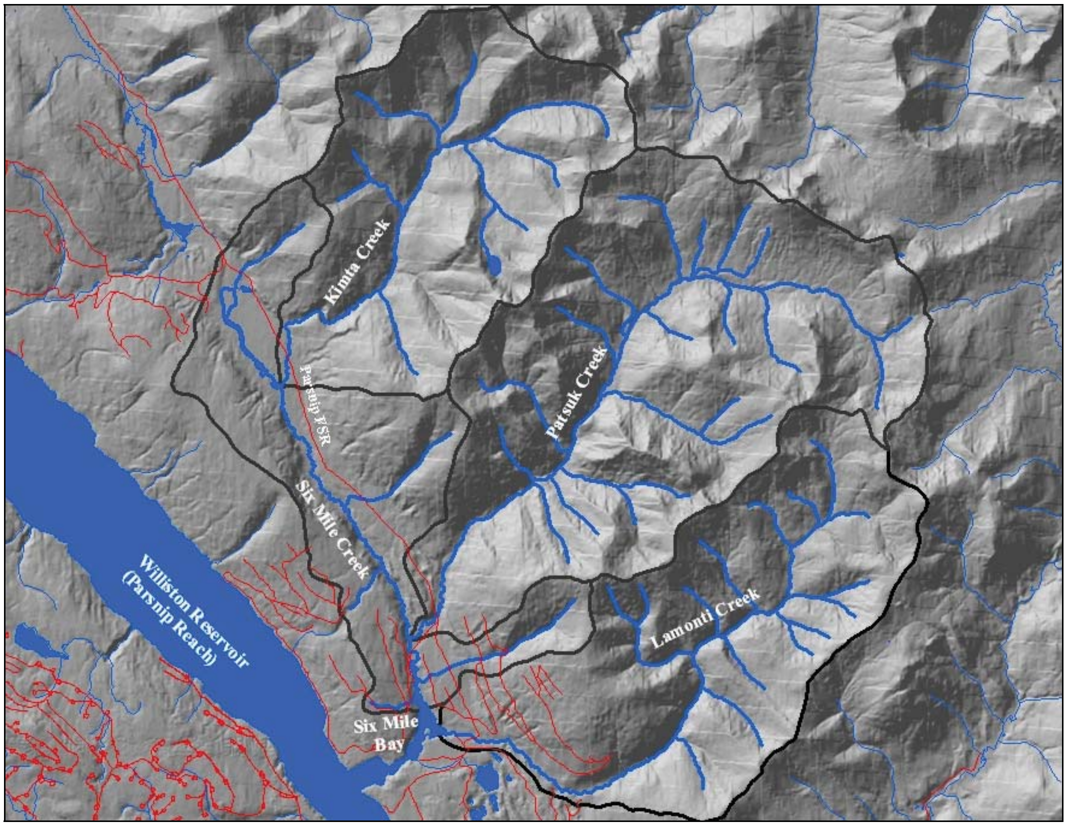

Figure 6. Overview map of Six Mile Creek stream channel network and watershed boundary. Map also shows contributing tributary streams, their respective watershed boundaries and surrounding topology.

Biophysical description

Six Mile Creek is a 4th order, low average gradient stream (Figure 7) with a watershed area of approximately 30 km^2 that empties into the northern portion of Six Mile Bay. The stream drains headwater wetlands that support a healthy population of lake chub (*Couesius plumbeus*) and perennial standing water volume is maintained by a series of beaver dam complexes that support a modest colony of beaver (*Castor Canadensis*). Although the beaver dams appear to limit the migration of fish in both upstream and downstream directions there is sufficient accessible downstream habitat of approximately 7-8 km channel length to support both spring and fall spawning fishes within the creek habitats. An advantage of beaver dams is their potential to regulate seasonal water flow by attenuating instantaneous flood peaks (Green and Westbrook 2009) and as such limits the potential for increased sediment transport caused by increased flow depth, velocity and dynamic lateral movement from decreased riparian function.

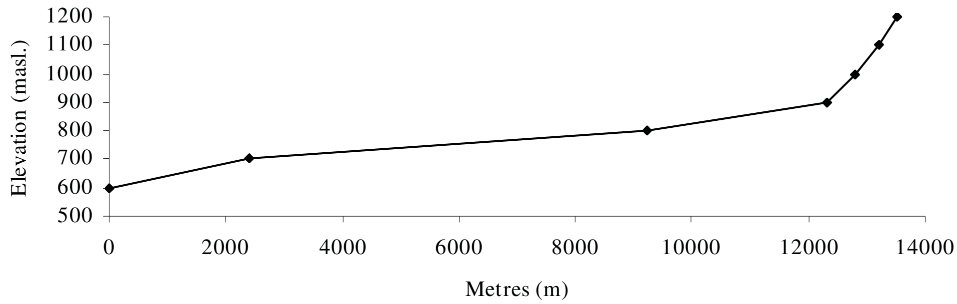

Figure 7. Longitudinal profile of the mainstem of Six Mile Creek. Channel length is expressed in metres for every 100 metre gain in elevation measured as metres above sea level. The average slope for the total mainstem length is 0.04.

Fish sampling confirmed historical records of fish presence by bull trout, rainbow trout (*Oncorhynchus mykiss*), and slimy sculpin (*Cottus cognatus*). A small escapement population of spawning kokanee and prickly sculpin (*Cottus asper*) were observed during sampling but have not been previously documented in historical accounts. As well, historical accounts indicate Arctic grayling inhabited the watershed during the late 1980's to early 1990's (Langston and Blackman 1993) but were not observed during our sampling efforts. Dolly Varden (*Salvelinus malma*) were also reported present (Langston and Blackman 1993), but are most likely bull trout due to similarities of distinguishing characteristics (McPhail 2007).

Natural channel morphology shows a favourable matrix of habitat types in the form of modest pools, riffles and cutbanks. Figure 8 illustrates a typical cross section. Upstream, there is evidence of slope instability of coupled upland areas likely due to logging operations that have released and deposited sediments into the channel several years ago, redirecting channel flow. However, the volume of the mass wasting is insufficient to significantly alter channel flow or degrade habitat. Substrate composition is dominated by cobbles and boulders with intermittent gravels and fines (Figure 9).

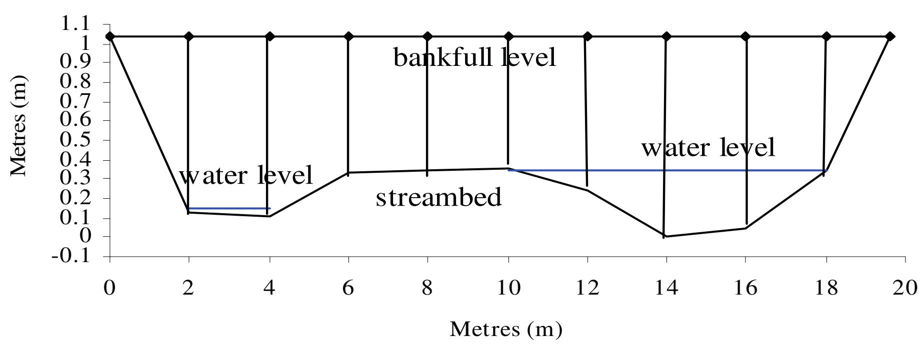

Figure 8. Typical cross section of sampled reach of Six Mile Creek. Cross section shows channel width at bankfull level and water level during time of field sampling in late August. Vertical lines illustrate locations where hydraulic data were recorded.

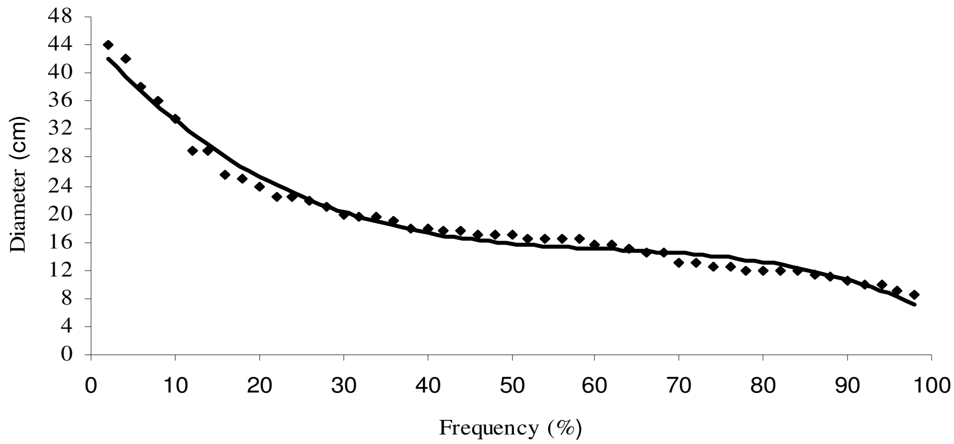

Figure 9. Substrate material composition frequency analysis for Six Mile Creek sample reach. D_{50} size is estimated to be 17 cm.

Below the point at which the reservoir regularly floods Six Mile Bay, an average elevation of 669 masl, the natural channel characteristics (Table 4) and substrate composition changes drastically where the substrate appears to be a combination of glaciofuvial and glaciolacustrine sands and silts overlying alluvial gravels. Riparian vegetation is absent along the stream channel within the embayment where remnant tree stumps and root wads provide evidence of deforestation to accommodate reservoir flooding. Subsequently, annual standing water volume as the reservoir fills throughout the growing season inhibits re-establishment of riparian vegetation along the stream channel.

Table 4. Hydraulic channel characteristics for Six Mile Creek. Drainage area includes tributary watercourses Patsuk Creek and Kimta Creek. The tabulated data are intended to guide the design of the mitigation reach to emulate hydraulic characteristics that favour fish presence and channel stability.

Channel Characteristics	
Drainage area (km^2)	131
Avg. bankfull width (m)	19.2
Avg. bankfull depth (m)	0.64
Hydraulic radius (m)	0.60
Slope	0.02
Avg. velocity ($m\ s^{-1}$)	0.23
Discharge during site visit ($m^3\ s^{-1}$)	0.60
Resistance ($m^{1/6}$)	0.15
Bankfull velocity ($m\ s^{-1}$)	0.69
Froude number	0.21
Bankfull discharge ($m^3\ s^{-1}$)	8.4
Tractive force ($kg\ m^{-2}$)	11.7
Minimum rip rap size (cm)	17.6

Note: Hydraulic data were collected in late August

The channel morphology reaching the drawdown zone is highly homogenous and, as such, lacks complexity and functional variability associated with high value fish habitat. Given the available fine sediments, multiple channel braiding occurs, the predictable pool-riffle pattern is compromised and accumulations of sediments occur in areas where streamflows converge.

Tributary streams

Patsuk Creek

Patsuk Creek is a 3rd order tributary of Six Mile Creek with a total watershed area of 63 km^2. Historical fish data reported the presence of Arctic grayling, bull trout, rainbow trout, mountain whitefish and slimy sculpin. We observed bull trout and slimy sculpin currently utilizing Patsuk habitats. Channel morphology shows a varied matrix of habitat types, LWD structure, riparian vegetation and flow regimes that remain suitable for historical and current resident fish species. Sampling confirmed fish distribution approximately 1 km upstream from the confluence with Six Mile Creek but longitudinal profiling conservatively suggests fish are likely occupying habitats 2-3 kms upstream (Figure 10).

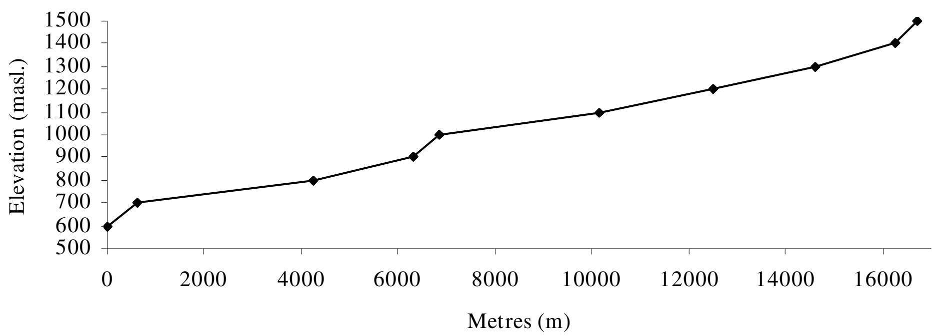

Figure 10. Longitudinal profile of the mainstem of Patsuk Creek, a tributary to Six Mile Creek. Channel length is expressed in metres for every 100 metre gain in elevation measured as metres above sea level. The average slope for the total mainstem length is 0.05.

A 554 ha upland area is designated as an ecological reserve created to protect 60-80 year old stands of white paper birch (*Betula papyrifera*) that are believed to have established after a fire had burned the area (http://www.env.gov.bc.ca/bcparks/eco_reserve/patsuk_er.html). One rare plant, the mountain bladder fern (*Cystopteris montana*), is associated with blue clay soils in the reserve. The primary role of Patsuk Creek Ecological Reserve is to protect excellent examples of paper birch forest and a rich assemblage of associated plants. Two stressors or threats were identified for the ecological reserve: fire suppression was rated as highly significant; forest harvesting activity was rated with medium significance. The ecological reserve has been in place since 1978 rendering the upland areas unaffected by anthropogenic impacts. This is a significant advantage to downstream restoration efforts as the hydrologic regime should remain constant and predictable over time.

Kimta Creek

Kimta Creek is a 3rd order stream with a watershed area of 38 km^2. There is a Forest Service Recreation Site adjacent to the stream channel approximately 800 m upstream from the confluence with Six Mile Creek. The site serves as the trailhead for the Kimta Trail, a popular hiking and ATV trail that extends into the alpine offering impressive views of the Williston Reservoir and surrounding area.

Fish distribution is limited to the first 1.5 km upstream of the confluence with Six Mile due to an impassible waterfall and cascade obstruction. Historical observations reported the lower reach below the obstruction supports Arctic grayling, bull trout, rainbow trout and mountain whitefish. Although channel profiling (Figure 11) suggests a variety of salmonids should be able to utilize the lower reach, fish observed during sampling of this reach was limited to resident slimy sculpins. Reconnaissance of Six Mile Creek below the Kimta confluence identified a large beaver dam that appears to be limiting migration of fish. As well, water velocity was higher than normal due to recent precipitation preceding the site visit and hindered our ability to catch fish. Sampling was suspended earlier than planned as a result of fast flowing water that created a safety hazard.

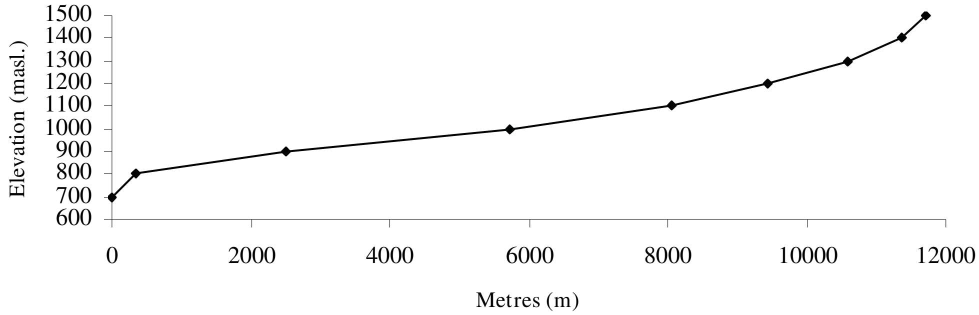

Figure 11. Longitudinal profile of the mainstem of Kimta Creek, a tributary to Six Mile Creek. Channel length is expressed in metres for every 100 metre gain in elevation measured as metres above sea level. The slope profile is misrepresented between the 700 and 800 m contour due to the origin of the channel segment nearer to the 800 m contour making the slope appear steeper than it actually is. The average slope for the total mainstem length is 0.06.

Remediation potential

Effects of reservoir drawdown can be effectively mitigated by restoring the stream channel and structural complexity and functional variability of fish habitat in the drawdown zone to facilitate fish migration in late winter and early spring (Figures 12 and 13).

Mitigation recommendations include:

- Renovation of the stream channel in the drawdown zone. A defined channel with gravel substrates, riffles, and pools of sufficient depth modeled after natural stream characteristics would provide the structural complexity fish require to effectively navigate the drawdown zone.
- Addition of cover structures, both in-stream and on the adjacent drawdown floodplain, to reduce predation on migratory fish, and encourage development of aquatic invertebrate communities.
- Use of retention structures to promote riparian plant growth along the high water shoreline. This reduces soil erosion and LWD introduction to the reservoir, promotes development of aquatic invertebrate communities, and may also benefit a diversity of terrestrial invertebrates, small mammals, and amphibians associated with riparian habitats.

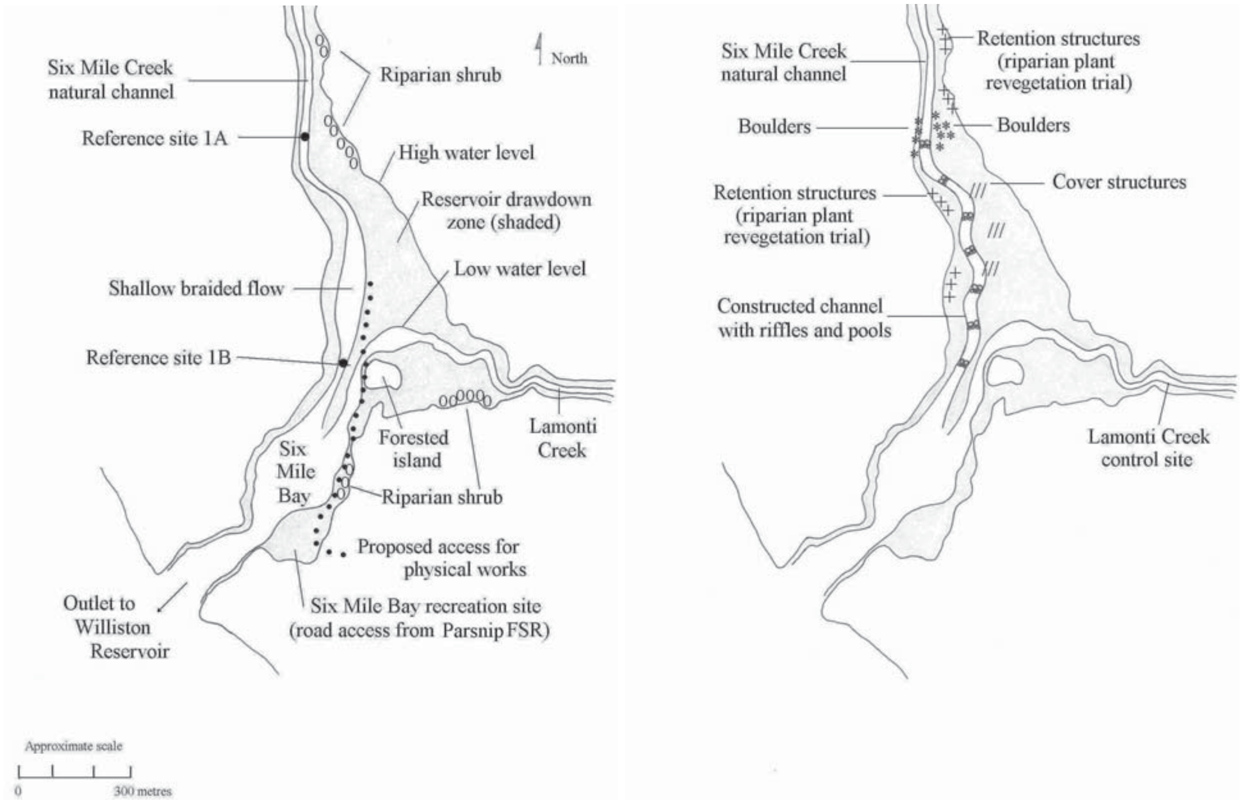

Figure 12. An overview drawing of Six Mile Bay at low reservoir water levels, before (left) and after (right) mitigation. Reference sites refer to plan view of Six Mile Creek rehabilitation reach in Figure 13.

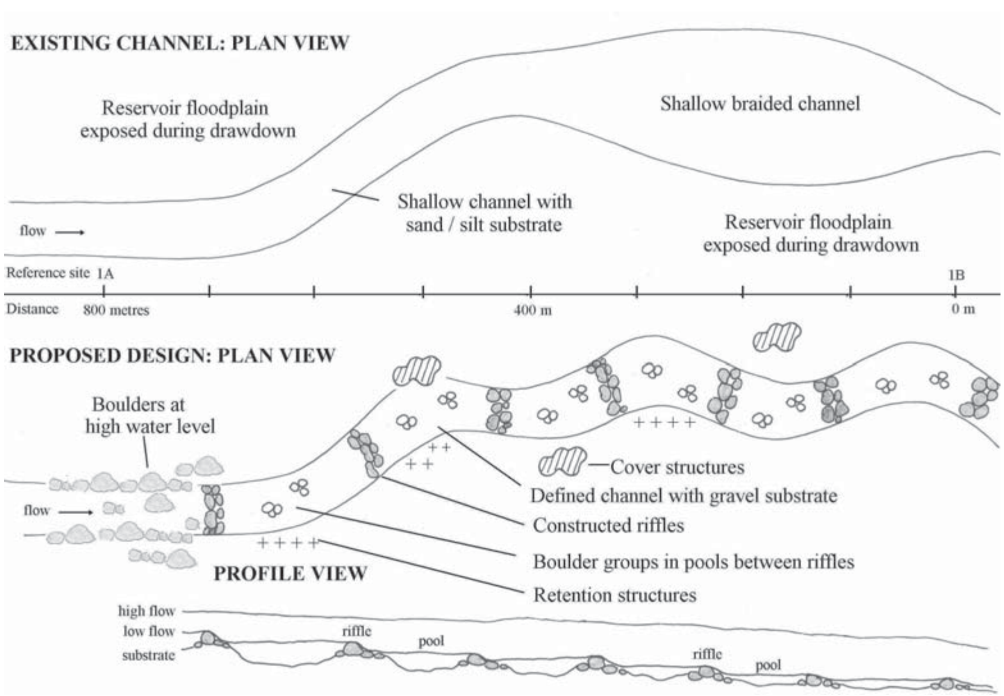

Figure 13. Conceptual design of Six Mile Creek mitigation modeled using channel characteristic data derived from biophysical site assessments.

Control site (Lamonti Creek)

Lamonti Creek, a second direct tributary to Six Mile Bay, has excellent mitigation potential, but is recommended here as a control site for measuring the effectiveness of trial mitigation on Six Mile Creek because of it's proximity to Six Mile Creek and associated tributaries.

Draining an area of 43 km^2, Lamonti Creek is a 3rd order stream approximately 14 km in length (Figure 14). Fish sampling identified bull trout, rainbow trout, sculpin and burbot inhabiting the stream. We confirmed fish distribution 2 km from the confluence, however longitudinal profiling (Figure 14) suggests that resident fish likely occupy favourable habitat upstream to 5 km. Site assessment identified an area of disturbance approximately 400 m from the creek mouth. An accumulation of large logs jammed the channel, likely during freshet, altering stream flow and causing overland flow to scour terrestrial vegetation and mineral soil leaving exposed alluvium.

There are no historical fish occurrence or distribution data available for this watershed, however, channel morphology (Figures 15 and 16) and associated habitat suggest that Lamonti Creek would likely support spawning Arctic grayling and kokanee. Despite lower flow than streams of similar characteristics (Table 5), capture yielded numerous fish with minimal effort, perhaps due to the cobble-boulder bed material that provides interstitial refugia for fish from young of the year to resident adults. Because of this, Lamonti Creek should be given consideration as a lower cost mitigation alternative if the two top ranked systems are deemed cost or regulatory prohibitive.

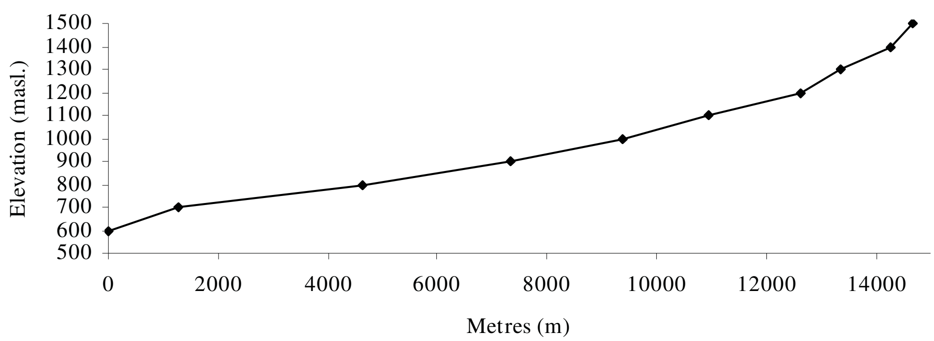

Figure 14. Longitudinal profile of the mainstem of Lamonti Creek. Channel length is expressed in metres for every 100 metre gain in elevation measured as metres above sea level. The average slope for the total mainstem length is 0.06.

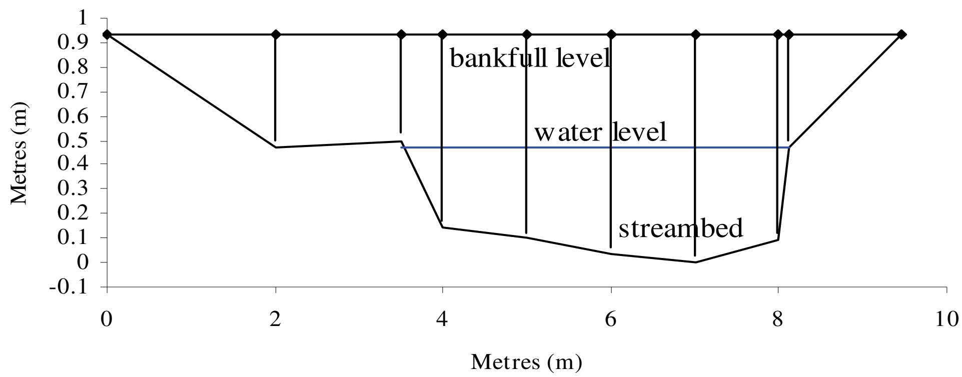

Figure 15. Typical cross section of sampled reach of Lamonti Creek. Cross section shows channel width at bankfull level and water level during time of field sampling in late August. Vertical lines illustrate locations where hydraulic data were recorded.

Table 5. Hydraulic channel characteristics for Lamonti Creek. The tabulated data are intended to guide the design of the mitigation reach to emulate hydraulic characteristics that favour fish presence and channel stability.

Channel Characteristics	
Drainage area (km^2)	42
Avg. bankfull width (m)	8.7
Avg. bankfull depth (m)	0.60
Hydraulic radius (m)	0.53
Slope	0.015
Avg. velocity ($m\ s^{-1}$)	0.15
Discharge during site visit ($m^3\ s^{-1}$)	0.11
Resistance ($m^{1/6}$)	0.60
Bankfull velocity ($m\ s^{-1}$)	0.45
Froude number	0.16
Bankfull discharge ($m^3\ s^{-1}$)	2.37
Tractive force ($kg\ m^{-2}$)	9.0
Minimum rip rap size (cm)	13.5

Note: Hydraulic data were collected in late August

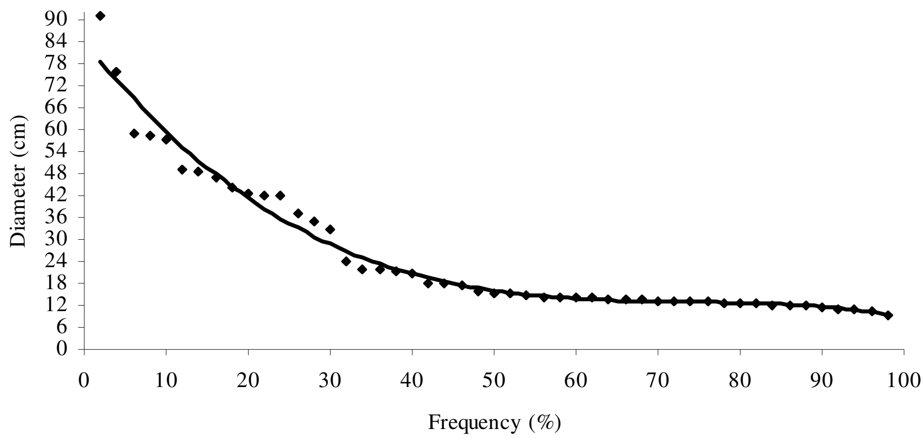

Figure 16. Substrate material composition frequency analysis for Lamonti Creek sample reach. D_{50} size is estimated to be 15.5 cm.

Archaeological and environmental considerations

Office-based AOA did not identify any known archaeological resources in Six Mile Bay and the immediate surrounding area (Appendix B).

Ecological assessments confirmed presence of several avian and mammal species in the embayment area. A breeding pair of osprey (*Pandion haliaetus*) were observed occupying an active nest at the crest of a dead snag on the northwest shore of Six Mile Bay and actively fishing in the embayment area throughout the summer. As well, tracks of red fox (*Vulpes fulva*), moose (*Alces alces*), black bear (*Ursus americanus*) and numerous waterfowl sign were sighted along the shoreline and adjacent riparian shrub (*Salix spp*.) habitats between May and October 2009.

Six Mile Creek is easily accessible from 41 km on the Parsnip Forest Service Road, a wide, gravel mainline that provides all-season access to active forestry blocks and local residents. There is a narrow dirt spur road approximately 1 km in length that terminates at the Six Mile Forest Recreation Site, located at the southern portion of Six Mile Bay, and is not maintained during winter. The recreation site has an existing narrow dirt boat launch that is suitable for large equipment to access the proposed work site by traversing the bay during low water when the expected physical works will be conducted. A worst case scenario is that a temporary road will need to be constructed if the substrate within the bay is too soft to support heavy equipment. If this is cost prohibited, alternative access is an old deactivated spur road north of the bay. Site access from the south west (i.e., Six Mile Bay Recreation Site boat launch) will require that the lowest reaches of Lamonti Creek (within the reservoir drawdown zone) be crossed by machinery during construction.

A private residence exists in the upland area south of Lamonti Creek and east of the Six Mile Bay Recreation Site. No conflicts are anticipated with either site access or mitigation plans at Six Mile Creek.

Overall, the potential for environmental impact associated with implementation of an access mitigation trial is negligible given current site conditions and existing access points. Recommended construction time for proposed mitigation works should be in late winter and early spring when water levels are lowest and minimizing disturbance to terrestrial species at sensitive times of the year (e.g., nesting periods). Standing snags, favoured nesting sites for osprey, should be maintained in the bay and drawdown zone. To attenuate impacts to sensitive aquatic species during construction, regulatory permit conditions will likely require isolation of the work area and temporary fish removal within the construction zone until works are completed.

Chichouyenily Creek

Overview

Chichouyenily Creek is a direct tributary to the Parsnip Reach of the Williston Reservoir, emptying into Chichouyenily Bay approximately 5 km southwest of Mackenzie (Figure 17). Chichouyenily Creek supports small numbers of regionally significant and provincially-listed fish species. An extensive drawdown zone with no structural complexity or functional habitat variability in the embayment may hinder fish passage to upstream spawning habitat (Appendix A). Young fish emigrating from overwinter habitats in the stream to rearing habitat in the reservoir are likely subject to high predation risk in the drawdown zone. Further, degraded stream channel habitat coupled with lack of vegetation limit invertebrate production and as a result, forage opportunities for fish. Rehabilitation of the stream channel in the drawdown zone, or implementation of a control structure to reduce drawdown in the Chichouyenily Creek embayment, is expected to improve fish access to high value fluvial habitats and increase fish population productivity locally. Additional enhancements to improve structural diversity of fish habitat in the drawdown zone are also recommended. The embayment has two natural narrows which provide opportunities for construction of simple water control structures. Utilizing a water control structure to offset the degree of drawdown by maintaining a minimum volume of water that more closely resembles natural lake drawdown dynamics would improve fish access to upstream habitats, reduce potential predation risk to fish during low water periods and create new rearing habitat for young fish.

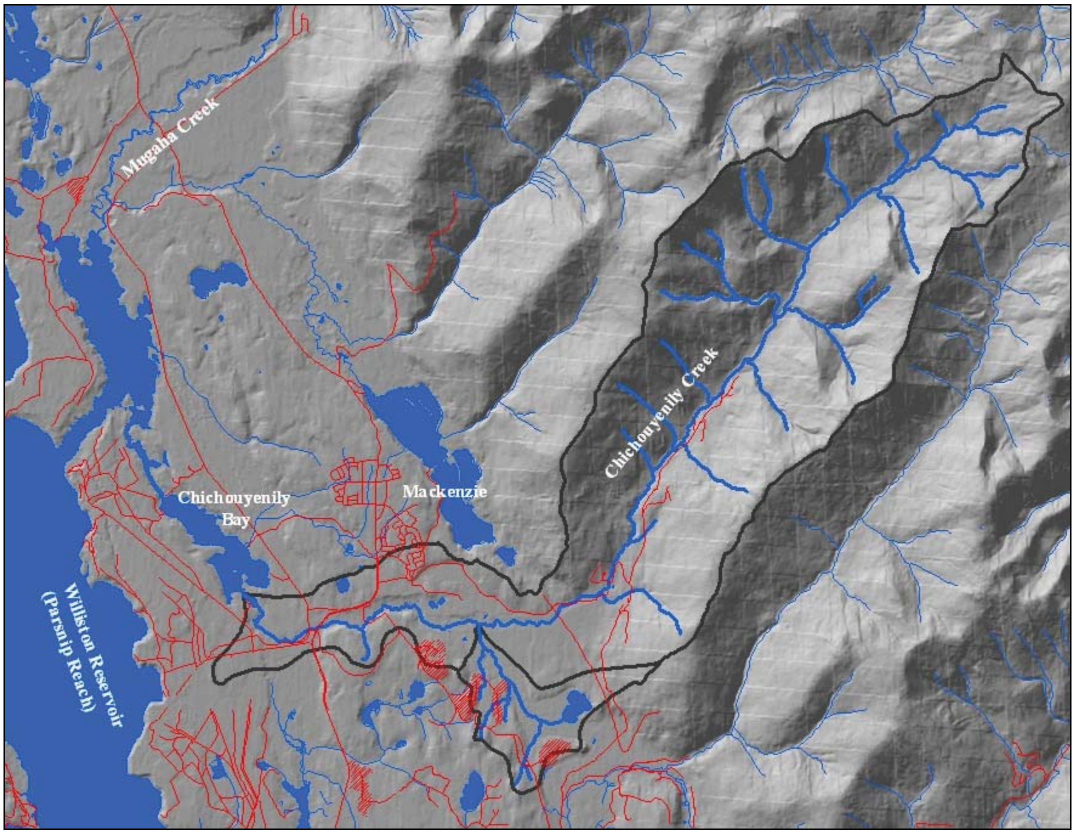

Figure 17. Overview map of Chichouyenily Bay showing Chichouyenily Creek, watershed boundary and surrounding topology.

Biophysical description

Chichouyenily Creek is a 4th order watercourse with a length of approximately 24 km (Figure 18). It is selected for mitigation trial due to it's proximity to infrastructure, equipment and labour as it is situated adjacent to the town of Mackenzie. Sampling confirmed fish distribution at least 8 km upstream from the confluence with the reservoir embayment. The stream supports resident bull trout, rainbow trout, slimy sculpin, prickly sculpin and a small escapement population (< 25) of kokanee. Historical records list Dolly Varden presence but these accounts are likely bull trout. We observed no evidence of Arctic grayling in Chichouyenily Creek.

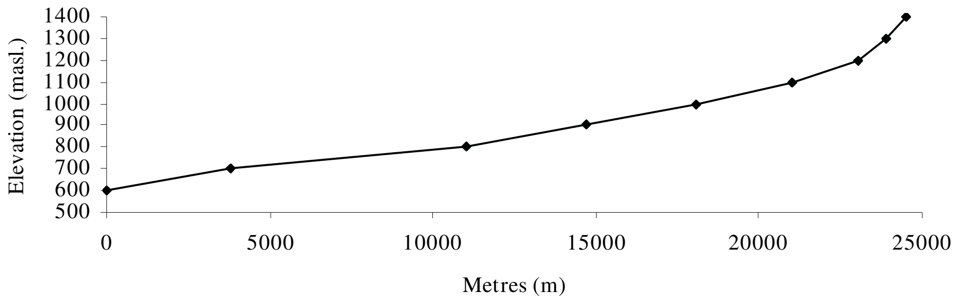

Figure 18. Longitudinal profile of Chichouyenily Creek. Channel length is expressed in metres for every 100 metre gain in elevation measured as metres above sea level. The average slope for the total mainstem length is 0.03.

The headwater areas of the watershed have been subject to logging over the years while the lower reach approximately 300 m from the confluence is traversed by an overhead electrical transmission line and an underground gas pipeline. Approximately 1.5 km upstream, channelized water flows under highway 39 through 2 large culverts. Observed impacts from reservoir water level fluctuations on Chichouyenily are similar to Six Mile Creek (i.e., homogenous channel lacking complexity and muddy/silty substrate). Figure 19 illustrates a typical cross section of natural channel. Bed material is dominated by cobble, mixed with a small proportion of gravels and fines (Figure 20). Stream characteristics are provided in Table 6.

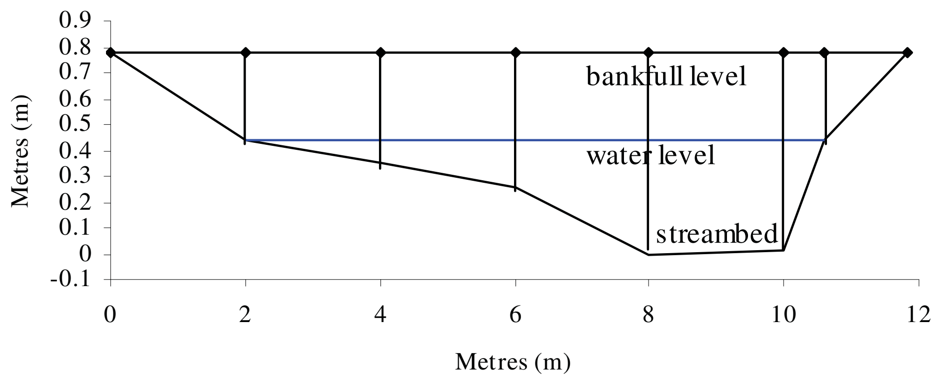

Figure 19. Typical cross section of sampled reach of Chichouyenily Creek. Cross section shows channel width at bankfull level and water level during time of field sampling in late August. Vertical lines illustrate locations where hydraulic data were recorded.

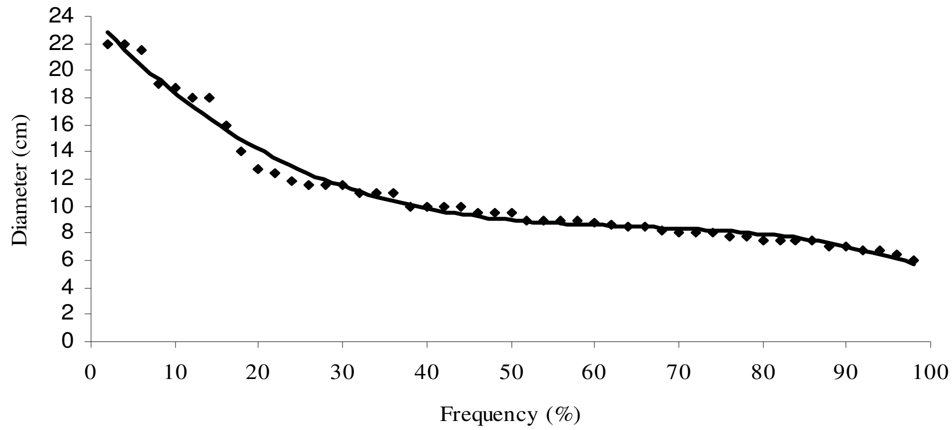

Figure 20. Substrate material composition frequency analysis for Chichouyenily Creek sample reach. D_{50} size is estimated to be 9.5 cm.

Table 6. Hydraulic channel characteristics for Chichouyenily Creek. The tabulated data are intended to guide the design of the mitigation reach to emulate hydraulic characteristics that favour fish presence and channel stability.

Channel Characteristics	
Drainage area (km^2)	74
Avg. bankfull width (m)	13.3
Avg. bankfull depth (m)	0.36
Hydraulic radius (m)	0..34
Slope	0.03
Avg. velocity ($m\ s^{-1}$)	0.20
Discharge during site visit ($m^3\ s^{-1}$)	0.26
Resistance ($m^{1/6}$)	0.21
Bankfull velocity ($m\ s^{-1}$)	0.42
Froude number	0.18
Bankfull discharge ($m^3\ s^{-1}$)	2.0
Tractive force ($kg\ m^{-2}$)	10.8
Minimum rip rap size (cm)	16.2

Note: Hydraulic data were collected in late August

Remediation potential

Chichouyenily Bay is a representative example of many embayments in the Williston watershed, dominated by homogeneous sandy substrate offering very little functional habitat complexity. The lack of wood cover associated with the substrate likely limits development of aquatic invertebrate communities, and also contributes to increased fish predation (Naiman and Latterell 2005). Adverse effects of reservoir drawdown and LWD can be effectively mitigated by restoring the stream channel and structural complexity of fish habitat in the drawdown zone to facilitate fish migration in late winter and early spring (Figures 21 and 22).

Mitigation recommendations include:

- Restoration of the stream channel in the drawdown zone. A defined channel with gravel substrates, riffles, and pools of sufficient depth (modeled after natural stream characteristics) would provide the structural complexity fish require to effectively navigate the drawdown zone.
- Addition of cover structures, both in-stream and on the adjacent drawdown floodplain, to reduce predation on migratory fish, and encourage development of aquatic invertebrate communities
- Use of retention structures to promote riparian plant growth along the high water shoreline. This reduces soil erosion and sedimentation by wave action in the reservoir, promotes development of aquatic invertebrate communities, and may also benefit a diversity of invertebrates, small mammals, and amphibians associated with riparian habitats.
- Mugaha Creek is suggested as a control system as there are existing fish and stream data available from previous PWFWCP initiatives.

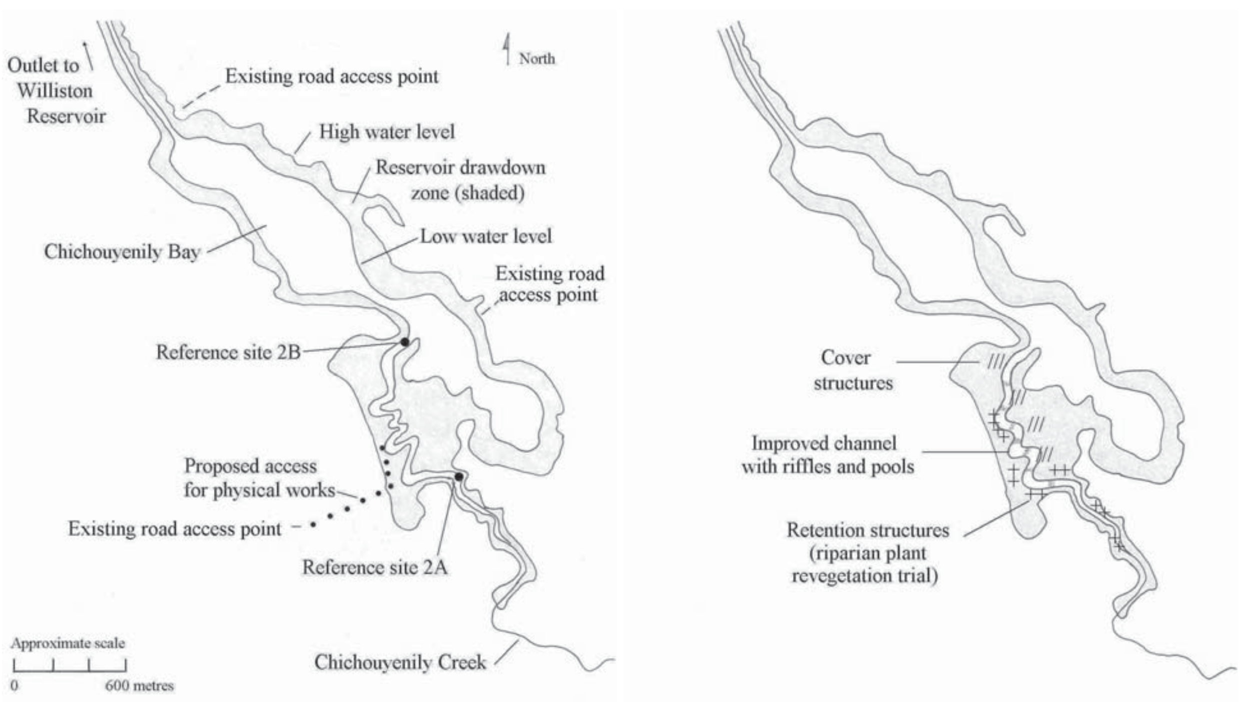

Figure 21. An overview drawing of Chichouyenily Bay at low reservoir water levels, before (left) and after (right) mitigation. Reference sites refer to plan view of Chichouyenily Creek rehabilitation reach in Figure 22.

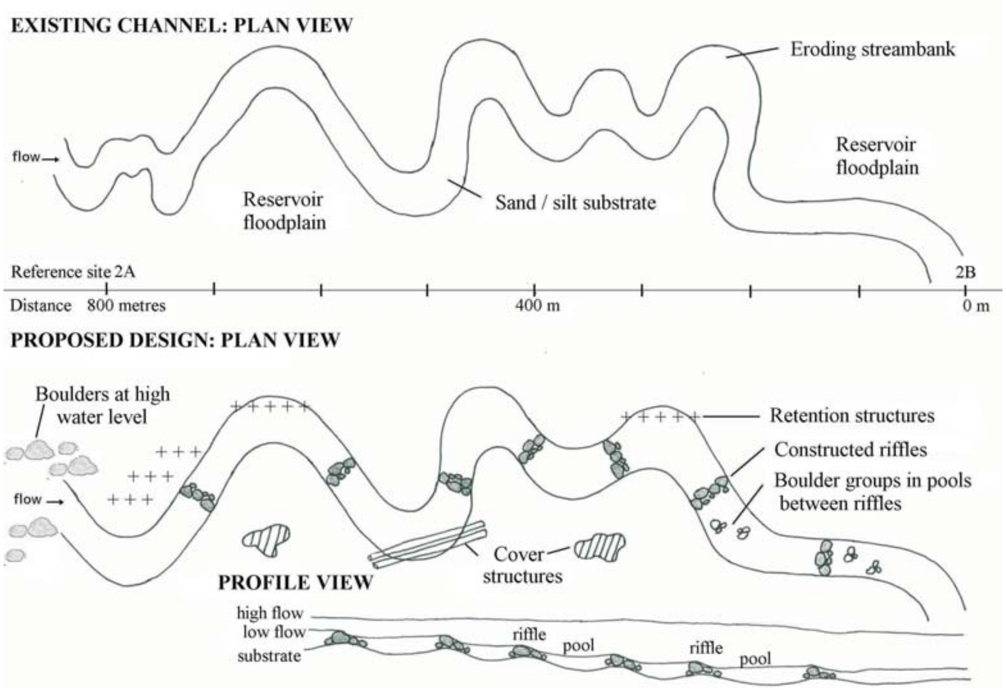

Figure 22. Conceptual design of Chichouyenily Creek mitigation modeled using channel characteristic data derived from biophysical site assessments.

Given the structure of Chichouyenily Bay, managers should also give due consideration to a second, larger-scale mitigation option suitable for trial in the Chichouyenily embayment. The embayment has two natural narrows which provide opportunities for construction of simple water control structures. Utilizing a water control structure to offset the degree of drawdown by maintaining a minimum volume of water that more closely resembles natural lake drawdown dynamics would improve fish access to upstream habitats and reduce potential predation risk to fish during low water periods. Design of the control structure should give consideration to maximizing the residence time of embayment water volume.

Mitigation recommendations include:

- Installation of a water control structure at one of the natural narrows in Chichouyenily Bay (2 possible sites with spans of approximately 85 m and 225 m; Figure 23). If Chichouyenily Bay is cut in half at the Option B narrows then the northern portion of the bay could serve as the unmitigated experimental control site. Design of the control structure would incorporate mechanisms to vary water levels as needed and allow fish passage.
- Addition of cover structures on drawdown floodplain, to reduce predation on migratory fish and encourage development of aquatic invertebrate communities.
- Use of retention structures to promote riparian plant growth along the high water shoreline. This reduces soil erosion and LWD introduction to the reservoir, promotes development of aquatic invertebrate communities, and may also benefit a diversity of invertebrates, small mammals, and amphibians associated with riparian habitats.

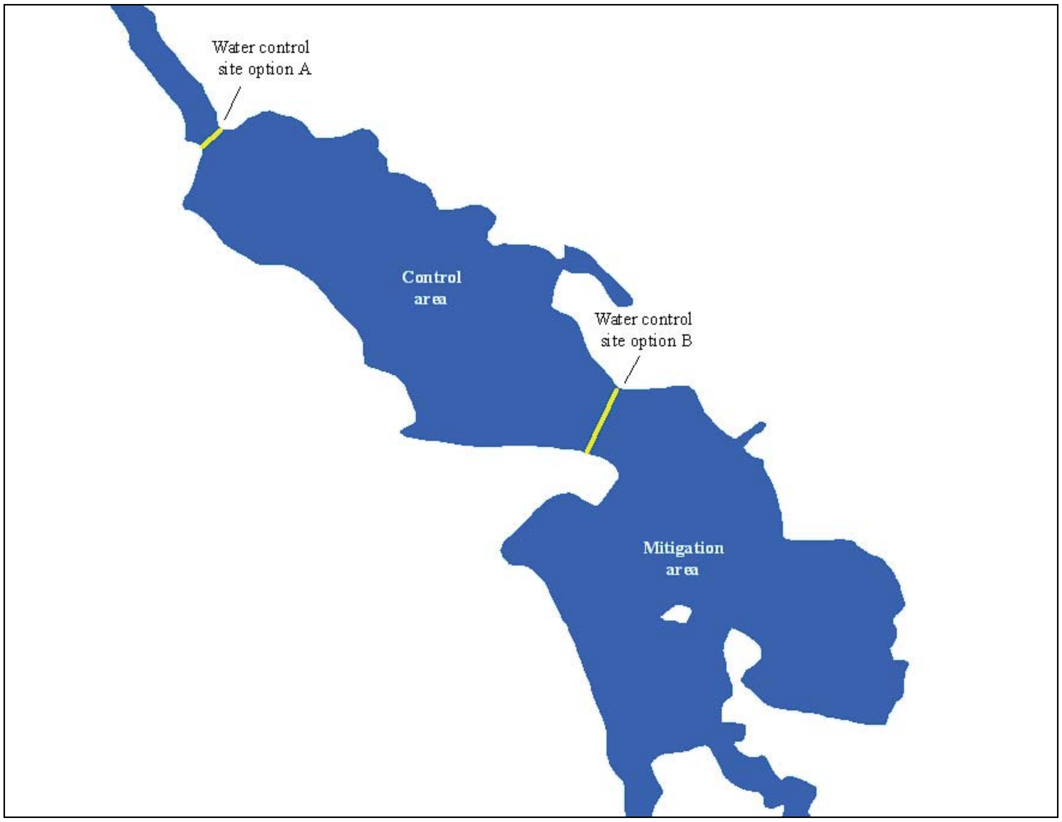

Figure 23. Potential locations for water control structures in Chichouyenily Bay.

Archaeological and environmental considerations

Office-based AOA did not identify any known archaeological resources in Chichouyenily Bay and immediate surrounding area (Appendix C).

Environmental assessment confirmed presence of several avian and mammal species in the embayment area. A breeding pair of bald eagles (*Haliaetus leucocephalus*) were observed occupying an active nest in a cottonwood tree adjacent to the west shoreline of lower Chichouyenily Creek and actively fishing in the embayment area. As well, red fox (*Vulpes fulva*), moose (*Alces alces*), mule deer (*Odocoileus hemionus*), wolf (*Canis lupus*) and coyote (*Canis latrans*) were sighted along the shoreline and adjacent uplands of Chichouyenily Bay between May and October 2009.

Upstream of the embayment, riparian vegetation is comprised of willows (*Salix spp*.), twinberry (*Lonicera involucrata*) and other shrubs. The Mackenzie Nature Observatory (http://www.bsc-eoc.org/national/mno.html), who operates the Mugaha Marsh Bird Banding Station, considers the riparian area along the creek important to a number of avian species (Table 7) and maintains a migratory bird transect established along the lower reach of Chichouyenily Creek (Vi Lambie, pers. comm.). A notable observation in past surveys is the red-listed, yellow-breasted chat (*Icteria virens*) which nests and forages in densely vegetated riparian areas and usually breeds in the southern Okanagan and Similkameen valleys. Singing males have been reported in the Kootenays and Chilcotin (MoF 1997).

Table 7. Avian species identified using the riparian area within the lower reach of Chichouyenily Creek.

Common Name	Scientific Name	Status[1]
yellow breasted chat	*Icteria virens*	red
northern rough-winged swallow	*Stelgidopteryx serripennis*	yellow
yellow warbler	*Dendroica petechia*	yellow
white-throated sparrow	*Zonotrichia albicollis*	yellow
warbling vireo	*Vireo gilvus*	yellow
black-capped chickadee	*Poecile atricapillus*	yellow
red breasted sapsucker	*Sphyrapicus ruber*	yellow
American robin	*Turdus migratorius*	yellow
bald eagle	*Haliaetus leucocephalus*	yellow

[1] B.C. conservation status: Red-listed (endangered or threatened), Yellow-listed (not threatened).

Chichouyenily Bay has several existing road access points, including 3 Parsnip FSR spur roads with direct access to the reservoir drawdown zone. Existing access in the immediate vicinity of the proposed mitigation eliminates any need for timber harvesting, road construction, and subsequent maintenance or de-activation.

Chichouyenily Bay is the outlet for the District of Mackenzie municipal sewage effluent, draining from upland treatment ponds to the east. This has potential benefits for the embayment mitigation trial option and is discussed further in the 'Design Options' section.

Overall, the potential for environmental impacts associated with implementation of an access mitigation trial is negligible given current site conditions and existing access points. The proposed mitigation is likely to have a range of positive outcomes for raptors, passerines, amphibians, small mammals, and invertebrates that may benefit from increased riparian vegetation and productivity. Further, construction times for proposed mitigation structures would likely be in late winter and early spring when water levels are lowest, minimizing disturbance to terrestrial species at sensitive times of the year (e.g., nesting periods). To attenuate impacts to sensitive aquatic species during construction, regulatory permit conditions for in-stream works will likely require isolation of the work area and temporary fish removal within the construction zone until works are completed and salvaged fish can be returned to the site.

CONCEPTUAL DESIGN RECOMMENDATIONS

Constructed stream channels

Selected tributary mitigation designs should attempt to mimic the flow regimes and hydraulic characteristics of natural, unaltered aquatic environments whenever possible. The data collected during site visits to selected tributaries, and subsequent analysis, followed the proven methods described in Newbury and Gaboury (1993). The construction of a stable, riffle-pool reach through the drawdown zone is expected to confine perennial streamflow within a defined channel to maintain seasonal discharge and water depth similar to the upstream fish bearing reach immediately above the reservoir high water elevation. Confined flows will offer increased power to do work as discharge increases, and is expected to sort bed material and orient LWD parallel to flow and reduce or eliminate fish passage hindrances. Large boulders placed just below the high water level will provide in-stream complexity, and also armour the reach bank structure and adjacent reservoir shoreline. The boulders are also intended to capture larger wood debris whose mass and area resist streamflow force and suspend them (partially) in the air as reservoir levels recede, to provide relatively unimpeded water flow and fish access upstream and downstream year-round. The following is a synopsis of considerations to integrate into the design of physical works.

Dimensions

Preferred designs that are stable and able to withstand flood discharges, mimic dimensions observed in naturally mobile streams:

- Channel width (W) and discharge (Q) relationship is characterized by $W=4.5Q^{0.5}$ (Kellerhals and Church 1989)
- Meander length must be 10-14 times the channel trim width (Rice *et al.* 2009)
- The optimal average radius of curvature is predictable at approximately 2.4 times the channel bankfull width (Rice *et al.* 2009). As well, the flow of water follows a predictable pattern as it travels around the channel curvature creating optimal fish forage opportunities based on natural hydraulic characteristics.

Substrate

Empirical relationships between tractive force and the size of bed material that can be mobilized varies widely. Use a varied size of bed material that is equivalent to the frequency of sampled stream substrate to minimize erosion potential. The bed material should be comprised of non acid-generating material, preferably with chemical composition similar to that found in substrates of upstream reaches.

In fine-grained materials such as those typically observed in the Williston reservoir, cohesion binds these materials up to a predictable threshold before motion occurs. Assuming uniform flow conditions, estimates of shear force acting on bed material can be derived assuming that it is equal to the downslope component force of gravity acting on the flow. Shear tractor force (τ) = 1000DS where τ is expressed as kg m^{-2} translates into zero motion. As modeling forces are mathematically simplified due to the complex nature of this observation, this is reduced to the tractive force equal to the bed material diameter (Φ) at incipient motion (Lane 1955).

We emphasize that the intent of constructed channels in the drawdown zone is not to create specific habitat, but rather to facilitate fish access to existing upstream habitats such as spawning areas. For example, a potential concern with fish spawning in the drawdown zone is that reservoir inundation will occur during the egg/alevin development stage, possibly inhibiting fry emergence and increasing incubation mortality. Additionally, when the reservoir is at or near full pool, fry that may emerge will be in a lacustrine environment and susceptible to increased predation at an earlier development stage than if they were able to rear in low velocity areas of their natal stream.

Riffles and pools

- Riffle crests should be built across the stream with >0.8 m diameter boulders, with the next largest stones placed on the downstream side of the riffle crest (Figure 24).
- Riffle crests should have a V-shape, dropping 0.5 m down from bankfull height towards the centre of channel (Figure 24).
- Use rock groupings placed 20-30 cm apart on the downstream face of the riffle to form low-flow fish passage channels.

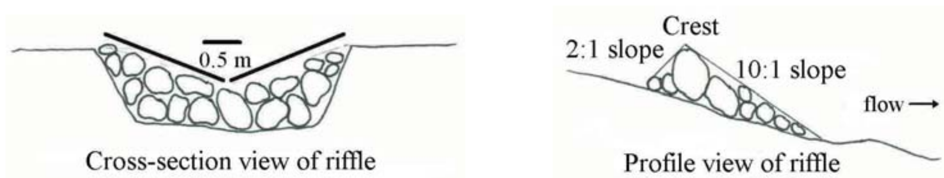

Figure 24. Conceptual design for riffles. Dimensions are from Newbury and Gaboury (1993).

Cover structures

LWD is an integral component of aquatic systems, as it promotes organic material retention, habitat formation, and productivity (Stauffer *et al.* 2000). Fish and aquatic invertebrates often decline after LWD removal and tend to increase with LWD additions (Naiman and Latterell 2005). Although variable due to factors such as landscape composition, topography and discharge regime, it is abundant in natural lakes and streams of all sizes. LWD may reside in channels for decades; studies have shown that LWD exposed to wetting and drying normally remains in the channel for 70-100 years (Murphy and Koski 1989; Hyatt and Naiman 2001). The residence time of wood is influenced by similar factors affecting LWD abundance and distribution, but also wood decay rate, extent of wood exposure, as well as bed stability, channel morphology and flood intensity in fluvial systems (Hilderbrand *et al.* 1998; Naiman *et al.* 2002).

Excess wood debris could be used to construct structures to provide refugia for fish of all age and size classes in stream channels and reservoir drawdown zones. These structures would also support increased invertebrate production and periphyton growth and benefit the food web (Hilderbrand *et al.* 1997; Lemly and Hilderbrand 2000). Wood structures can also be constructed to attenuate bank erosion, limit introduction of land based debris and promote the establishment of revegetation trials. Logs collected locally or from reservoir debris projects can be utilized to construct these structures and offset costs associated with piling and burning.

Due to their low specific weight and large surface area, lift forces on LWD can place a heavy strain on anchoring systems. This condition is exacerbated by the tendency of LWD structures to capture floating debris, increasing the drag force on the anchors placed in flowing water. The force on the anchors should be calculated by estimating the surface area of the debris structure exposed to current perpendicular to the flow using the method described in Fischenich and Morrow Jr. (2000). The total drag can be divided by the number of anchors to determine the per-anchor force. A safety factor is recommended in the calculations to allow for the capture of additional debris, weakening of anchoring materials, and associated uncertainty.

Aggregates of LWD may be more effective in creating and maintaining pools than single pieces. If in-stream structures are to be constructed, many stationary pieces can be anchored and protected by specifying a large anchoring log on the downstream end of an aggregate group to maintain stability. The longest log in the aggregates that remained stable was significantly longer than the longest log in the unstable aggregates (Lienkaemper and Swanson 1987). Use smaller pieces within the channel to promote channel complexity (Carlson *et al.* 1990). Research has shown that logs longer than the mean channel width were significantly less likely to move than logs shorter than the mean channel width (Hilderbrand *et al.* 1998).

Retention structures

Readily available LWD can also be used to build retention structures in the form of lattices designed to improve slope stabilization and promote vegetation growth (Figure 25). Logs would be cabled together, with steel collars on cable between LWD logs to maintain a space of 12 – 18"; the open space provides a protected area for riparian plant establishment and growth (Abiola *et al.* 2008). Cables would be anchored to tether the structure to streambanks. This design could also be loosely tethered in shallow areas to provide a floating cover structure which supports emergent vegetation, aquatic invertebrates, and nesting/resting habitat for waterfowl.

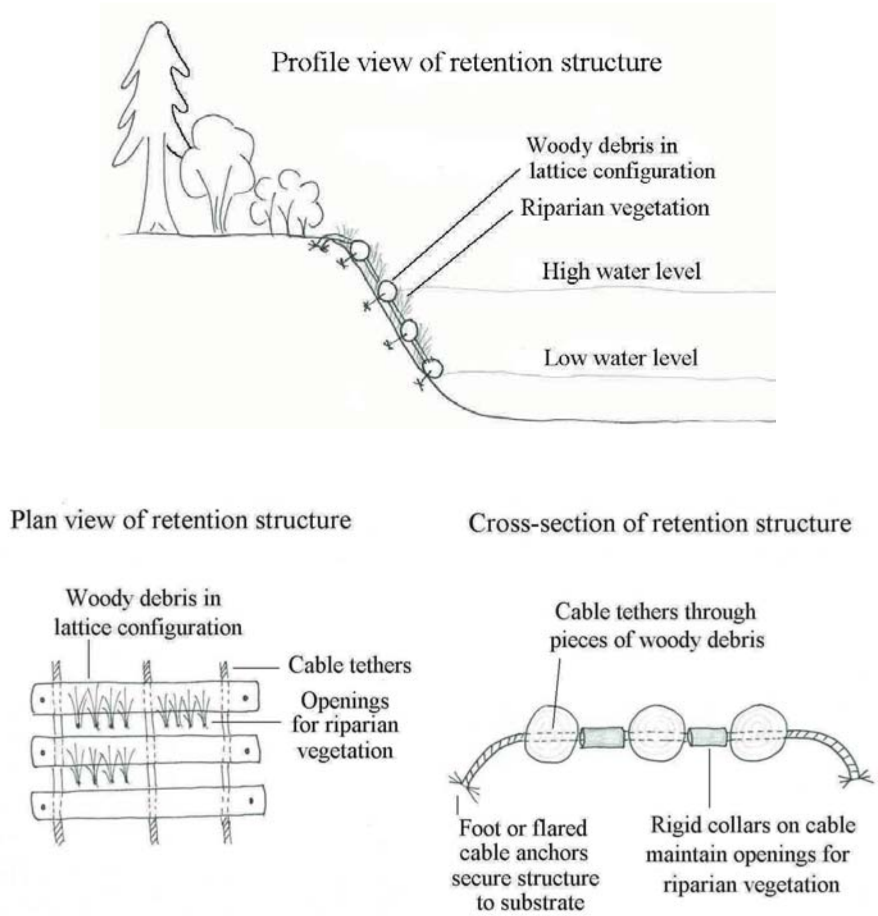

Figure 25. Conceptual design for retention structures.

Riparian plants

Based on a literature review of studies that reported success and limitations of revegetation initiatives, we compiled a list of suitable riparian plants that are likely to be tolerant of both local climate conditions and atypical fluctuations in reservoir levels (Table 8). We contacted local suppliers of riparian plants (CRV Greenhouses, Mackenzie BC) to ascertain their interest, ability, experience and constraints with respect to the propagation and survival probabilities of these proposed plant species. They also provided information on timelines required to propagate plants to a stage that would increase their chance of survival during drawdown and throughout the winter months. Generally, willows are hearty and able to survive areas with low soil nutrient concentrations, long, cold winters typical for this area, windy conditions and submergence up to 1.6 metres (Abiola 2008). Planting trials in Upper Arrow Lake found water sedge (*Carex aquatilus*) survival rate was 79% at 5 m depth, and 28% survival at 8 m (Carr and Moody 1992). In habitats with variable water levels, survival rates among plant species and persistence at submerged depths can vary widely (Fielden 1993, Carr and Moody 1992). Careful selection of plants that are tolerant of local conditions is a key factor in the success of revegetation trials. Plant species identified as likely candidates for propagation and revegetation trials in the Williston watershed are presented in Table 8.

Table 8. Riparian and aquatic plants that have been reported successful in revegetation efforts within the Pacific Northwest. Emphasis was placed on species that have the highest probability of survival in climates similar to the Williston watershed, northern B.C.

Common Name	Scientific Name
horsetails	
dwarf scouring rush	*Equisetum scirpoides*
scouring rush	*Equisetum hyemale*
common horsetail	*Equisetum arvense*
willows	
felt-leaved willow	*Salix alaxensis*
Little-tree willow	*Salix arbusculoides*
Pacific willow	*Salix lucida ssp. lasiandra*
Scouler’s willow	*Salix scouleriana*
Grey-leaved willow	*Salix glauca*
Mackenzie’s willow	*Salix prolixa*
aquatic grasses	
Blue-joint reedgrass	*Calamagrostis canadensis*
tall mannagrass	*Glyceria elata*
sedges and rushes	
cattail	*Typha latifolia*
water sedge	*Carex aquatilis*
graceful mountain sedge	*Carex podocarpa*
Arctic rush	*Juncus arcticus*
small-flowered bulrush	*Scirpus microcarpus*

Control structures

Water control structures at embayment narrows should include the following design components:

- Height of control structure should be designed to maintain embayment water levels 1-3 m above typical reservoir drawdown level
- Variable water level controls (e.g., removable stop-logs capped with an adjustable v-shaped gate) to facilitate fine-scale adjustments to water discharge rates
- A French drain at the base of the control structure that can be opened to accommodate embayment drawdown when necessary (e.g., for maintenance of the control structure)
- A constructed stream channel on the downstream (reservoir) side of the control structure, complete with riffles and pools at an overall 20:1 slope, to enable fish passage across the control structure at low reservoir water levels

This design is intended to allow for the normal operation of the reservoir, with no considerable changes to the water flow regime and only a small retention water volume behind the control. Backflooding behind the control structure increases overwinter habitat, reduces shoreline erosion by promoting riparian vegetation and increases the residence time of embayment water volume to allow for the uptake of limiting nutrients into the food web. LWD accumulation, particularly at the control, will require mechanical removal on an as needed basis if control function is affected.

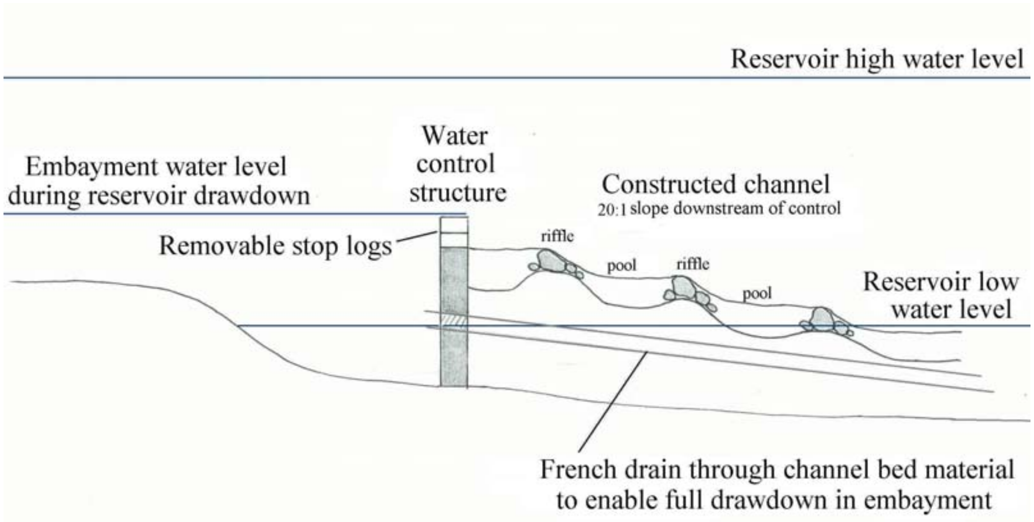

Figure 26. Conceptual design for water control structures: profile view.

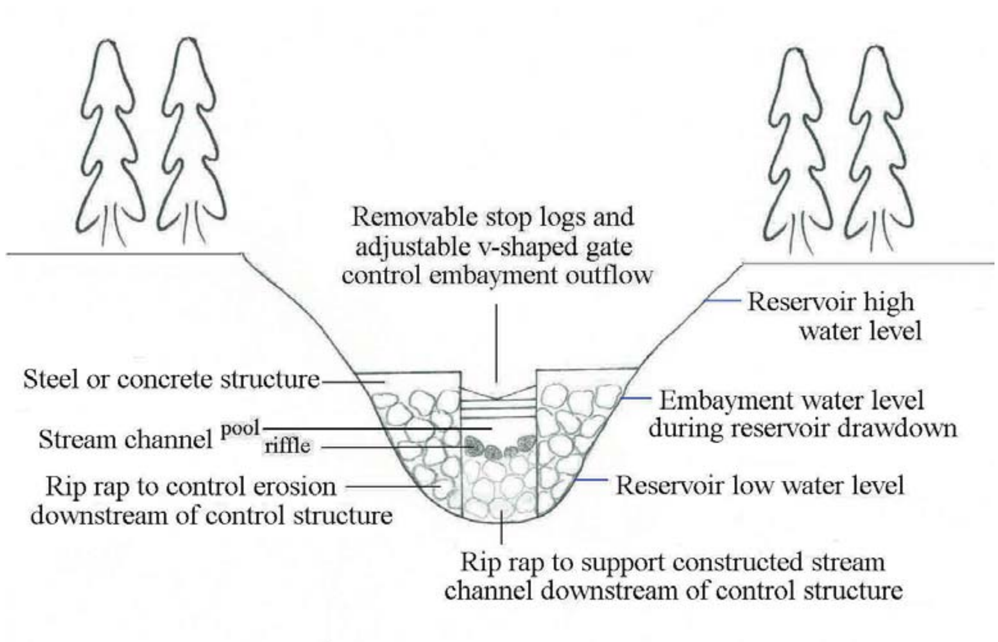

Figure 27. Conceptual design for water control structures: cross-section view.

IMPLEMENTATION RECOMMENDATIONS

Design options

The proposed conceptual design is intended to address both LWD and drawdown impacts concurrently by implementing physical works in a relatively controlled embayment environment, with minimal LWD accumulation, to assess the design performance and make adjustments to optimize the design and its ability to mitigate access impacts. The design is intended to maintain fish passage in areas of high LWD accumulation as well, although mechanical removal may be required in exceptional circumstances. The design recommendations are widely applied stream mitigation techniques that can be implemented at a relatively small scale to test their feasibility and effectiveness in trial projects while moving towards mitigation of more complex sites using an adaptive management approach. These trials could be readily accomplished at both Six Mile and Chichouyenily Creeks with the ultimate goal of mitigating more complex sites by building on the lessons learned from the trials.

Because the severity of LWD accumulations on a given tributary appear to be variable from year to year, a trial project focused on mitigating the effects of LWD accumulation on tributaries identified during a single reconnaissance survey may hinder monitoring programs due to annual variability of such occurrences. A multi-year study currently being undertaken to determine LWD trends within the Williston Reservoir should provide increased confidence in site selection for future works. As such, the primary recommendations for mitigating fish access to Six Mile Creek and Chichouyenily Creek focus on habitat mitigation within the drawdown zone using a controlled experimental approach, channel reconstruction, addition of cover structures, and retention structures to support revegetation.

Chichouyenily Bay's configuration also provides an excellent opportunity to increase the scope of the mitigation trial to test an innovative mitigation design idea that could have broader benefits for reservoir productivity. Primary productivity is limited by a combination of contact time and nutrient concentration. Nutrient flows in reservoirs with short residence times are controlled by nutrient quality of inflowing streams. Because inflowing waters typically have such a short residence time within the boundary of a hydroelectric reservoir before being discharged through the generation complex (Rueda et al. 2006), the low productivity of the system limits biomass (Downing *et al.* 1990; Pauly and Christensen 1995; Death and Zimmermann 2005). Research has shown that baroclinic variation is the dominant force in terms of embayment water exchange with the main water body in natural systems (Rueda, 2005). As a result, the traditional calculation method underestimates residence time in embayments with morphology similar to that of Chichouyenily and Six Mile Bays. Barotropic forcing is likely what drives residence time in hydroelectric reservoir embayment complexes, and drawdown of the Williston Reservoir exacerbates this process. To increase residence time in the embayment, a control structure could be installed at a narrow portion of the embayment to retain a standing water volume that more closely mimics natural water level fluctuations. Conversion of phytoplankton into fish production is 100 times more efficient in oligotrophic lakes than in highly eutrophic systems (Downing *et al.* 1990). Fertilization projects to increase nutrient concentration have been conducted in the Williston watershed (Larkin *et al.* 1999). Within Chichouyenily Bay, primary productivity can be enhanced as a result of effluent from District of Mackenzie municipal sewage currently discharged into the Bay. If effluent is sequestered in the non-mixing hypolimnion (or transported out by barotropic forcing) mixing may be induced by aeration in the embayment to increase nutrient concentration (Knud-Hansen et al. 1991).

The primary goal of the embayment mitigation trial would be to increase total productivity of the Williston reservoir system by managing and maximizing productivity in small high-density areas of the reservoir. In other words, while the main body of the reservoir continues to have very short residence time associated with a primary focus on the production of hydroelectrical power, productivity and biomass of tributary embayments are maximized to support ecological values. Overall, the productivity and biomass of the Williston system would be derived from smaller areas (e.g., tributary embayments) managed for high-density and high productivity. The embayments are mitigated to behave more like natural lake systems, and can increase suitable habitat for listed species. This idea has been partially addressed in previous compensation projects. For example, in the 1990's PWFWCP biologists proposed stocking strategies in select fluvial systems throughout the reservoir to increase resident fish populations and develop nursery streams for sport fish such as rainbow trout and kokanee to increase recruitment in the main reservoir body and embayments (Blackman *et al.* 1990).

A notable advantage to both the stream and embayment mitigation recommendations is that they were conceived to be scalable, in that the same techniques can be applied to systems of larger size and discharge. Scalability was a desirable feature in developing mitigation designs as these works are intended as small-scale trial projects complete with a monitoring program to measure successes and shortfalls of the trials and build towards initiatives for future mitigation of larger, remote systems distributed throughout the reservoir watershed. The conceptual designs for the proposed projects are intended as scalable in degree of mitigation value, complexity and cost in order to provide the most flexibility to BC Hydro. As we were not aware of the cost expenditure budgeted for this initiative a measure of conjecture was needed to conceive ideas that satisfied the often conflicting requirements of biological needs and budgetary constraints. As such, the level of the mitigation expenditure intended by BC Hydro can ultimately guide site selection and the scope of the proposed works. This should offset the probability of the project trials not undertaken due to financial constraints or implementation uncertainties.

Maintenance requirements

Long-term maintenance requirements for constructed stream channels will depend on sedimentation levels and LWD accumulation. Once construction is completed and the system has fluxed through a full year's cycle of variable water flows, site visits will be required at low reservoir water levels to assess changes in riffle and pool depths and structural stability of the channel. Some maintenance may be required in post-construction years 1 and 2 to make adjustments to mitigation works (e.g., adjust placement of boulders to maintain structural integrity of the channel and adjust the energy budgets of riffles and reduce sedimentation, if needed). If the constructed works are hydraulically sound, channel instability and sedimentation should not compromise the mitigation works and we expect only minor annual maintenance primarily limited to site inspections at low and high water levels. These site inspections could be readily integrated with the mitigation monitoring program (BC Hydro 2008a). If sedimentation is found to cause dewatering of the constructed channel, establishing small pools along the channel will help to maintain sufficient water flows during reservoir drawdown and aid in the transport of sediments downstream.

Project budget

Six Mile Creek Mitigation Cost Estimate			
	Unit	Unit cost	
Surveys	6 pd	950.00	5,700.00
Design	15 pd	2,000.00	30,000.00
Construction monitor	18 pd	550.00	9,900.00
Fisheries consultant (permit, isolation, fish salvage)	6 pd	550.00	3,300.00
Bed material	6000 m^3	12.00	72,000.00
Misc. equipment/supplies			3,000.00
Riparian plants (propagation, planting)			15,000.00
Labourer	15 pd	350.00	5,250.00
Excavator	100 hrs	130.00	13,000.00
Hauling	600 hrs	110.00	66,000.00
Sub-total			223,150.00
Contingencies (10%)			22,315.00
Total			**245,465.00**

Chichouyenily Creek Mitigation Cost Estimate			
	Unit	Unit cost	
Surveys	6 pd	950.00	5,700.00
Design	18 pd	2,000.00	36,000.00
Construction monitor	25 pd	550.00	13,750.00
Fisheries consultant (permit, isolation, fish salvage)	8 pd	550.00	4,400.00
Bed material	8000 m^3	12.00	96,000.00
Misc. equipment/supplies			3,000.00
Riparian plants (propagation, planting)			20,000.00
Labourer	20 pd	350.00	7,000.00
Excavator	130 hrs	130.00	16,900.00
Hauling	600 hrs	110.00	66,000.00
Sub-total			268,750.00
Contingencies (10%)			26,875.00
Total			**295,625.00**

Chichouyenily Bay Mitigation Cost Estimate			
	unit	unit cost	
Surveys	10 pd	950.00	9,500.00
Design	60 pd	2,000.00	120,000.00
Construction monitor	40 pd	550.00	22,000.00
Fisheries consultant (permit, isolation, fish salvage)	8 pd	550.00	4,400.00
Bed material	4000 m^3	12.00	48,000.00
Labourer(s)	200 pd	350.00	70,000.00
Excavator	130 hrs	130.00	16,900.00
Excavator2	200 hrs	80.00	16,000.00
Hauling	900 hrs	110.00	99,000.00
Control structure			300,000.00
Signage and buoys			3,000.00
Misc. equipment/supplies			7,000.00
Riparian plants (propagation, planting)			30,000.00
Sub-total			745,800.00
Contingencies (15%)			111,870.00
Total			**857,670.00**

Units: pd = person days.

Links to other projects and initiatives

BC Hydro may receive approval to raise the maximum allowable elevation of the Williston Reservoir in the near future. If the maximum elevation is increased then appropriate changes to the elevation of the mitigation works will be necessary.

BC Hydro is currently (2009/10-2010/11) assessing LWD mobilization and accumulation in the Williston Reservoir. Project results may coincidentally identify tributaries with LWD barriers that could be considered for future mitigation trials. The project may also identify excess LWD that could be utilized to construct cover and retention structures.

BC Hydro is also currently (2009/10) conducting a feasibility study for the development of wetlands. Efforts to stabilize and revegetate portions of the reservoir drawdown zone and the suggested embayment mitigation trial are small and large-scale examples of activities that could help address a number of the objectives associated with the wetlands trial.

Further, BC Hydro is currently assessing (2009/10) the feasibility of boat launch improvements at the Six Mile Bay recreation site. If construction phases for both projects are timed concurrently, there may be opportunities for cost-efficiencies. Perhaps more importantly, however, proximity to Mackenzie and ease of access offer excellent potential to develop public outreach and education opportunities that showcase the Six Mile Creek fish access mitigation trial. The same is true for mitigation trials at Chichouyenily Bay.

The mitigation trials present excellent opportunities to collaborate with local agencies and organizations, and engage local labour and expertise in the implementation of the projects. Involving local members of the community in the construction and monitoring process has a number of intangible benefits. Instilling local residents with a sense of ownership of proposed works should reduce potential for vandalism and malicious acts.

The current global economic downturn has extended into rural northern British Columbia and as a result the unemployment rate of forestry workers, among others, has increased dramatically with little optimism of a reversal to this trend in the immediate future. In response to the high unemployment rate, municipal and provincial governments have implemented job opportunity programs in rural communities to offset the financial hardship that follows the loss of employment income. Local job opportunity programs to recruit, train, organize and equip skilled workers for community development projects offer a unique opportunity for BC Hydro to collaborate with local initiatives and benefit from a readily-available motivated, safety conscious work force and infrastructure to complete the proposed physical works in a cost-effective and timely manner. This opportunity should be considered time limited as government funding and interest will likely wane and the workforce will disperse in the near future.

Mackenzie Nature Observatory (MNO) expressed interest in participating in bird monitoring at the mitigation trial sites, if applicable, and may have additional funding or ideas to support this work. The MNO also operates a bird banding station at the extreme northern portion of the Chichouyenily/Mugaha embayment, adjacent to Mugaha Marsh. They maintain a database of all avian species occurrences locally, and have offered to provide this information upon request.

Relevant suppliers were contacted to gauge interest and experience pertaining to the proposed physical works. Local (Mackenzie B.C.) services and suppliers that could be considered for implementation of the mitigation trials include individuals and organizations with expertise in propagation of wetland plants, gravel suppliers, excavators and other heavy machinery operators, and Job Opportunities Program labourers.

Applicable permits, regulations, and jurisdictions

The Six Mile Creek mitigation site is on crown land, while the Chichouyenily Creek mitigation site is within the District of Mackenzie (DMK) municipal boundary. The DMK, Ministry of Forests (MoF) and Ministry of Environment (MoE) must be notified in writing prior to the start of construction for approval, permitting or unforeseen hindrances related to the physical works. As the proposed sites are likely in First Nations traditional territory, consultation with local native bands will be required. Consultation can be a lengthy process so sufficient lead time to undertake this initiative should be considered.

Ownership of water and watercourses lies with the Crown and “changes in or about a stream” are regulated by the Water Act. The Water Act Regulation ensures that water quality, the rights of water licensees, fish and wildlife habitat are not compromised. Notification must be submitted to the MoE in writing at least 45 days prior to the start of construction for approval of complex works and the storage or diversion of water. Construction of a dam requires a license.

In-stream works would be scheduled for late winter and early spring, when water levels are lowest. Because this is outside of the allowable timing windows within the Omineca Management Region for in-stream works (Fisheries Act), special permitting considerations would apply. Some effort may be required to convince regulators that the proposed works will subject habitats to temporary impacts but that the impacted reach offers little to no habitat value and as such the cost of altering the habitat will be offset by the long-term gain of increased access to high value habitat. Works may be undertaken outside of the recommended timing windows if an adequate technical methodology is submitted by a qualified professional and demonstrates negligible risk to fish and wildlife and requisite habitats. Technical methodology will include construction procedures that attain the objectives outlined in standards and best practices for in-stream works (MWLAP 2004).

The Department of Fisheries and Oceans (DFO) may interpret the works as harmful alteration, disruption or destruction (HADD) of fish habitat. DFO may wish to review project information, the importance or sensitivity of habitat and the management options provided to determine HADD. The DFO may require several months to review the proposal and the proponent must provide 45 days notice prior to commencement of work.

A qualified environmental monitor will be required on site during the initial phase of the works and during any sensitive in-stream activity. The monitor will be provided with written authority to alter or cease construction if necessary. Under the Wildlife Act of British Columbia, a fish collection permit is required for fish salvage before commencing the construction of physical works.

Depending on weather and site conditions and equipment limitations, alternate access routes into the bay may have to be developed for Six Mile Creek mitigation. This may require Ministry of Forests permits for timber removal, if needed, to develop a temporary access corridor through upland areas. Due to existing road infrastructure at several access points to Chichouyenily Bay, no permits will likely be required for site access.

The federal Species at Risk Act does not apply as there are no known species at risk occurrences identified within the site specific project area.

Table 9. Applicable legislation relevant to the proposed mitigation works.

Legislation	Section	Subsection
Fisheries Act	35	2
	37	2
BC Water Act	9	
BC Water Act Regulation	37	4 (a)(b)
	38	1 (b)
		2
	41	(a)(b)(c)(d)(e)(f)(g)
	42	1 (a)(b)(c)(d)(e)(f)(g)(h)
Navigable Waters Act	5	1 (a)

Best management practices for field personnel

Construction personnel should follow guidelines presented in the Standards and Practices for In-stream Works (MWLAP 2004).

MONITORING RECOMMENDATIONS

Implemented mitigation measures will be monitored over several years to assess their efficacy in facilitating fish movement between lentic and lotic habitats throughout the year (BC Hydro 2008a). Well designed monitoring programs to measure the benefits or deficiencies of the physical works implemented are necessary to objectively quantify or characterize outcomes. Establishing a priori hypotheses are imperative for effective monitoring programs. The sites proposed for mitigation offer a number of monitoring opportunities relating to each component of the proposed works.

Mitigation design is best undertaken using specialized hydraulic modeling software. There are numerous programs available free of charge or at nominal cost for more sophisticated models. Hydraulic function that encourages substrate sorting but limits erosion will promote the stability of constructed works. Monitoring the hydraulics of the renovated channel reach is of primary importance to ensure that the physical works emulate model output parameters with respect to channel characteristics conducive to stability and desired function.

Channel substrate complexity provides in-stream roughness that effectively reduces the available energy for erosion and sediment transport. Quantifying sediment transport can be difficult given the variability of contributing factors such as sediment supply in a drainage basin. Long term sampling under different discharge regimes is currently the best method for predicting sediment transport as a function of discharge (Kondolf 2000). In light of this difficulty, a surrogate measure to consider is the specific energy (H) of reach segments which can be calculated from the backwater curve depth using the Bernouilli equation $H = D + V^2 / 2g$ where D = depth, V = velocity and g = gravitational acceleration.

Depending on the mitigation option chosen there are several options for population estimation, including the Lincoln-Petersen capture-recapture model or a multi-pass removal method such as the Jolly-Seber model. Both methods utilize a similar approach deriving a count divided by an estimate of detection probability. When designing monitoring programs that intend on estimating population size of fish, birds, wildlife or invertebrates detection probabilities should be calculated.

Smaller-scale habitat associations of fish are commonly defined in terms of preference for discrete habitat types (e.g., pools versus riffles). Monitoring programs could incorporate stratified sampling protocols to measure the response to mitigation by constructing structures at specific locations and comparing fish abundance and species diversity with areas that do not contain enhancement structures, wood or macrophytes.

Finally, if the embayment design option is chosen, changes in primary productivity of the water column can be monitored in relation to increased residence time and changes in effluent volume, by using phosphorous concentration as the primary indicator species with nitrogen, dissolved organic carbon and chlorophyll *a* as other parameters to consider. Changes to seasonal water clarity, temperature, oxygen, and pH profiles can be assessed as well as bacteria loads to derive a reliable linmological response to mitigation.

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APPENDIX A. Aerial photos of drawdown and full pool at Six Mile Bay and Chichouyenily Bay


Synergy Applied Ecology
Chichouyenily 090522-347


Synergy Applied Ecology
Chichouyenily 090912-2154

APPENDIX B. Archaeological overview of Six Mile Bay

AN ARCHAEOLOGICAL OVERVIEW OF PROPOSED ENHANCEMENT PROJECT SIX MILE BAY

Norcan Consulting Ltd

1486 Second Ave.

Prince George, B.C.

V2L 3B6

Principle investigator:

Normand Canuel

Signed______________________ September 28, 2009

1 INTRODUCTION

This report has been developed to assist B.C. Hydro and Power Authority (B.C. Hydro) in an effort to determine the risk of altering a heritage site as defined by The Heritage Conservation Act. This assessment is not an Archaeological Impact Assessment, as defined by the Heritage Conservation Act, however, the results of this assessment will supply sufficient information for B.C. Hydro to assess their risk with concerns to cultural heritage resources within the project area.

Under the Heritage Conservation Act, "A Person" may not destroy, alter or remove heritage objects from a heritage site. A heritage site is defined as cultural materials created, deposited or constructed prior to 1846. For the purpose of this report all pre-1846 sites are considered archaeological resources. All post-1846 remains or features are considered cultural heritage sites.

An archaeological overview entails the review of historical documents, maps, archaeological databases and pertinent information relating to the development area. In addition air photos (if available), terrain maps and geophysical maps are reviewed. This data is a tool the archaeologist will use in determining the potential for archaeological sites to occur within the boundaries of the proposed development.

The proposed enhancement project for Six Mile Bay is located within the Williston reservoir approximately 45 minutes north of Mackenzie B.C, via the Parsnip FSR. The study area is a proposed trial remedial work to restore access to the reservoir and to manage coarse woody debris. The boundaries of the project were defined by Synergy Applied Ecology.

2 OBJECTIVES

Conduct an archaeological overview assessment to ensure that the site access and proposed physical works to remediate tributary access are not expected to result in impacts to known cultural values at the candidate enhancement sites.

3 SCOPE OF WORK

1) Review maps, reports on prior archaeological work in the area, site records and other pertinent historical or ethnographic studies for the enhancement site(s). Review the "Remote Access to Archaeological Data (RAAD) database to determine if there are any registered archaeological resources at the proposed locations.
2) Document any surface evidence of archaeological sites near the selected tributary site in accordance with BC Hydro's Reservoir Archaeology General Technical Standards and provide recommendations regarding project design changes or further archaeological work needed to address unavoidable impacts, if any.
3) Identify potential conflicts between project objectives and any known archaeological sites, in accordance with BC Hydro's "Best Management Practices" (BMP) for heritage resources. Conduct interviews with local First Nations as needed to obtain additional information.

4 ARCHAEOLOGICAL OVERVIEW

This study includes a review of the archaeological site inventory, available overview assessments, historic maps, local histories, ethnographies, paleoecological studies and reported archaeological investigations in the study area. Topographic maps, (no air photos were made available from the proponent) and orthographs of the study area were carefully examined and a determination archaeological potential was made. The criteria used to predict the potential for archaeological resources included proximity to lakes, streams, and wetlands, proximity to archaeologically significant geological features such as post-glacial lake shores or early Holocene drainage systems, soil types, proximity to known archaeological sites, and known aboriginal or historic trail systems. The analysis results in a prediction for archaeological potential. Archaeological prediction involves the compilation of data that might be relevant to the position of a site on the landscape within a specific region. Sufficient site inventory and the collection of site related data are required so that existing correlations in the distributional archaeology and other variables can be documented and analyzed. It is important to note that this sufficient site inventory data does not exist for the Mackenzie region and more specifically for the Williston Reservoir. As a result only broad generalization can be ascertained from the known site loci of the geographical area.

The interpretation of ortho-photographs, satellite imagery and topographic maps resulted in the elimination all areas with slopes greater than 20%, gullied or broken terrain and wet areas. These areas are assigned low archaeological potential values. Prominent geographical features such as knolls, ridges, elevated benches, terraces and the like were assigned high archaeological potential values. Analysis of this combined information resulted in a detailed pre-field assessment of the survey areas and their potential for prehistoric use.

It is important to note here that criteria used for assessing archaeological potential are not applicable to Culturally Modified Trees (CMT). CMT clusters, not associated with other archaeological resources, do not fall within the predictability of this assessment. The location and number of CMTs are affected by the availability of the appropriate tree species at the time of their creation. In the Central Interior, the majority of CMTs are cambium stripped in origin and therefore their locations are specific to areas with the conditions necessary for the development of Lodgepole Pine stands. CMTs may be found in any stand of trees that have a Pine component, regardless of distance from water, slope, or any other criteria commonly used to determine archaeological potential. CMT sites, therefore, are generally found and recorded incidentally in the process of investigating other archaeological resources.

4.1 Biophysical Features

The study area is within the Arctic Watershed and is located in the geographic feature known as the Rocky Mountain Trench in North Central British Columbia. Within the Arctic watershed, glacial till and lacustrine deposits are thick along the valley bottoms and lower hills, with rocky outcrops on steep, unstable upper slopes. Holland (1976) describes the Rocky Mountain Trench as an erosion feature between the Rocky Mountains and the height of land between the Parsnip River and McLeod Lake.

4.2 RAAD Results

There are no recorded archaeological sites within the project area. (Remote Access to Archaeological Data (RAAD) database as of September 28, 2009)

4.3 Data Review

A review of maps, known reports on prior archaeological work in the area, site records and other pertinent historical or ethnographic studies for the enhancement site was completed.

4.4 Previous Archaeology

The Mackenzie Forest District has seen some overview assessments and regional inventory surveys, but few development based studies and no excavation or academic based work has been conducted. The Western Heritage Services Inc. overview and inventory assessments provide the best summary of the previous work in the area and add some sites through directed surveys (Gibson et al. 1997, Low et al. 1998). The majority of sites identified are small lithic scatters and CMT sites, as well as historic cabins. The archaeological impact assessments conducted in the region provide similar results (Rousseau et al. 1993, Yellowhorn and Rousseau 1997, Kinzie, J. 2001), however only an extremely small percentage of the area has been subject to any kind of survey. To the best of this authors knowledge there has been no previous archaeological studies filed with the Archaeology Branch relating directly to the project area.

4.5 Ethnography

The territory of the Sekani people cover the area of the Parsnip, Finlay and Upper Peace River and extending west to include the Carp Lake area where the group referred to by Jenness (1937) as ‘Tsek’ehne’ resided. At the time of contact with Europeans and before, the people wintered east of the Rocky Mountains hunting buffalo and other large game. Summer was spent on the west side of the mountains fishing and hunting caribou, moose, and smaller game including sheep, beaver, porcupine and rabbit. The Sekani people were efficient hunters and carried out this activity all year round. Gathering was also important, and many of the plants local to the area were utilized for food and medicinal purposes. The Sekani lived a nomadic lifestyle with a well defined seasonal round using the same areas for the same resources each year. The group was organized at the band level and split up into smaller family groups when food was scarce. Because of their frequent movement from one area to another, the Sekani had no permanent village sites. It must be assumed also that if the people customarily wintered east of the mountains there would be no winter villages west of the Rockies as can be found for groups further south and west. Dwelling and shelters were often built in the shape of a tipi and covered with moose hide or bark. Tool technology included the use of bows and arrows; bone for clubs, hooks, scrapers and fleshers; stone for scrapers and other tools; willow and nettle fibers for fishing nets; and bark and spruce roots for baskets. Small family units staying in temporary way-camps or hunting camps would be the primary land use for this area. Typically, not much is preserved for the archaeological record at these types of sites. Small depressions such as roasting pits or cache pits, surface

or subsurface scatters of cultural materials, trails or trail indicators such as tree blazes and trees stripped of their bark for cambium collection, are among the known types of features to be found in this locality.
No contact was made to First Nation groups with traditional claims over the study area.

4.6 Trails and Trailways

These features served important functions in hunter and gatherer culture. However, just as structural trail locations may change so do their functions change through time. Sekani trails in particular were essential arteries contributing to the mobility of various groups and individuals, directly relating to their survival capabilities. They often served conjointly as physical and social threads within and between the various Sekani communities and with outsiders. They served a dual purpose with both physical and social functions combined.
The most obvious physical function of these routes was for travel and resource exploitation. “Trips on foot of up to 200 to 300 km were not unusual (Hooper 1978:3).” Whole families spent weeks traveling trails to trade and exploit resources along the way (Carlson 1995:26). However, most trips were short and the trails more localized in development and use. Trails were necessary to connect various households in seasons when bands were dispersed for resource exploitation (Blacklaws 1980:3). They contribute to the overall distribution of archaeological sites. One cannot underestimate the importance of trails in determining Carrier settlement patterns. Carlson and Mitchell (1997:38) have conclusively demonstrated that in the Vanderhoof Forest District 65% of all known recorded archaeological sites are within one kilometer of historically documented trails. Connections between archaeological and modern settlement patterns by trails give credence to assertions of long-term occupation in the area (Albright 1987). Complex trail systems were necessary to gain access to the resources of particular watersheds and between different watersheds. First Nation groups controlled direct access to resources (hunting, fishing, trapping, and quarrying) within sections of watersheds and river boundaries were not often crossed over (Harmon 1911:255, Hudson 1983:236, Klippenstein 1992:50). These areas were used seasonally, provided the mainstay of their hunting and gathering lifeways, and allowed for the necessary redistribution of resources between local groups. Household groups were not self-sufficient and often relied on the resources of other watersheds, which were accessed through clan systems. In addition, a system of cross-cousin marriages provided the framework for movements on trails between resource areas. In this way resources were transferred from areas of surplus to areas of scarcity.
A review of historical maps and microfiche found no known trails within the proposed project area.

5 DETERMINATIONS

At the time of this study there was such a paucity of pre-contact archaeological information from the Mackenzie region that it is very difficult to extrapolate the local archaeological recoveries in a manner which would allow for accurate predictions for archaeological site occurrences within the study area.

1) There are no known archaeological or cultural heritage sites within 1 km of the study area.

2) To the best of this authors knowledge there has been no previous archaeological studies filed with the Archaeology Branch relating directly to the study area.
3) There are no known historic or prehistoric trails within 1 km of the study area.
4) There are distinguishing features within the study that could or would be considered high archaeological potential areas and therefore require an archaeological field assessment prior to development activities.

6 RECOMMENDATIONS:

Due to the minimal information directly or regionally applying to the study area it is recommended that an archaeological preliminary field reconnaissance be conducted on the areas to be directly affected by the proposed development. At this point in the archaeological review it is unknown exactly what will be affected by the development therefore it is impossible to state if the development activities would fall within high archaeological potential zones. For the purpose of this study high potential zone is defined as any area with less than 20% slope and within 100 meters of the original water channels.

The developer should be aware that even the most thorough investigation might fail to locate all archaeological remains. In the event that archaeological remains are encountered during operations, all ground disturbance activities in the vicinity of the archaeological remains must be suspended immediately. It is the individual's responsibility to inform the project manager and the Archaeological Planning and Assessment, Registries Department, as soon as possible.

The present study was designed solely as an archaeological review and was not intended to evaluate traditional aboriginal use of the areas in which development is proposed. The results of this study should not be considered valid for that purpose. We recommend that the appropriate First Nation Group(s) be contacted in an effort to locate any cultural resource they may know of.

7 LIST OF POTENTIALLY AFFECTED FIRST NATION GROUPS

McLeod Lake Indian Band
General Delivery
McLeod Lake B. C.
V0J 2G0
Phone 250-750-6835
Fax 250-750-4420

Takla Lake First Nation
General Delivery
Fort St. James, B. C.
VOJ 2T0
Phone 250-564-7303

Fax 250-564-7303

Tsay Keh Dene Band

#11 1839 1st Ave.

Tsay Keh Dene Band

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Phone 250-562-8882

Fax 250-562-0099

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Heffner Ty and Normand Canuel.

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Watson Keli and Normand Canuel

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Yellowhorn, Eldon and Mike K. Rousseau

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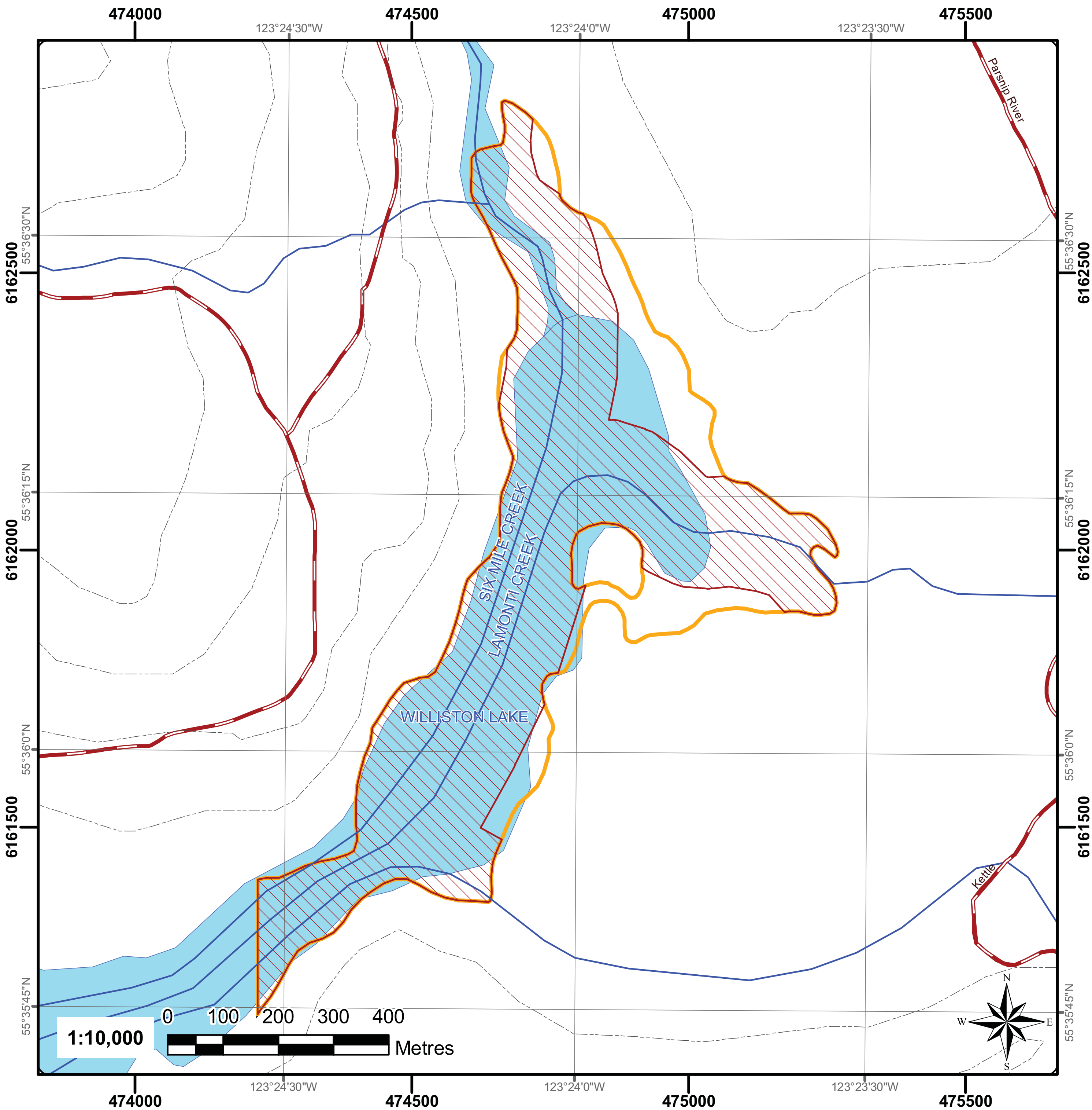
Assessment Area: 6 Mile Creek



Field Survey Map

Company: BC Hydro
Forest District: Mackenzie
Location: on 6 Mile Creek
BCGS Mapsheet: 093O.064 093O.063 093O.054 093O.053
NTS Mapsheet: 093O/11
Date: 09/25/2009
Area: 46.2 ha
Block Center:
UTM 10 474747E 6161985N
Latitude: 55° 36' 11.33" N

Legend

- Assessment Area
- Other Block Boundaries
- Built Road
- Proposed Road
- River/Stream
- Lake Boundary
- Wetland Boundary
- Contour
- Trail
- Slope Edge
- Edge of Forest
- Beaver Dam
- Wetland
- Lake/River
- Low Potential
- High Potential
- Archaeological Site
- CMT Cluster
- Individual CMT
- Cultural Depression
- Surface Find
- Logged Block
- Wetland
- Cabin
- Recreation
- Previously Recorded Site
- Blazed Tree

NorCan Consulting Ltd

APPENDIX C. Archaeological overview of Chichouyenily Bay

AN ARCHAEOLOGICAL OVERVIEW OF PROPOSED ENHANCEMENT PROJECT CHICHOUYENILY BAY

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1486 Second Ave.

Prince George, B.C.

V2L 3B6

Principle investigator:

Normand Canuel

Signed______________________ September 28, 2009

1 INTRODUCTION

This report has been developed to assist B.C. Hydro and Power Authority (B.C. Hydro) in an effort to determine the risk of altering a heritage site as defined by The Heritage Conservation Act. This assessment is not an Archaeological Impact Assessment, as defined by the Heritage Conservation Act, however, the results of this assessment will supply sufficient information for B.C. Hydro to assess their risk with concerns to cultural heritage resources within the project area.

Under the Heritage Conservation Act, "A Person" may not destroy, alter or remove heritage objects from a heritage site. A heritage site is defined as cultural materials created, deposited or constructed prior to 1846. For the purpose of this report all pre-1846 sites are considered archaeological resources. All post-1846 remains or features are considered cultural heritage sites.

An archaeological overview entails the review of historical documents, maps, archaeological databases and pertinent information relating to the development area. In addition air photos (if available), terrain maps and geophysical maps are reviewed. This data is a tool the archaeologist will use in determining the potential for archaeological sites to occur within the boundaries of the proposed development.

The planned enhancement project for Chichouyenily Bay is located within the Williston Reservoir approximately 5 Kms northwest of Mackenzie B.C.. The study area is a proposed trial remedial work to restore access to the reservoir and to manage coarse woody debris. The boundaries of the project were defined by Synergy Applied Ecology.

2 OBJECTIVES

Conduct an archaeological overview assessment to ensure that the site access and proposed physical works to remediate tributary access are not expected to result in impacts to known cultural values at the candidate enhancement sites.

3 SCOPE OF WORK

1) Review maps, reports on prior archaeological work in the area, site records and other pertinent historical or ethnographic studies for the enhancement site(s). Review the "Remote Access to Archaeological Data (RAAD) database to determine if there are any registered archaeological resources at the proposed locations.
2) Document any surface evidence of archaeological sites near the selected tributary site in accordance with BC Hydro's Reservoir Archaeology General Technical Standards and provide recommendations regarding project design changes or further archaeological work needed to address unavoidable impacts, if any.
3) Identify potential conflicts between project objectives and any known archaeological sites, in accordance with BC Hydro's "Best Management Practices" (BMP) for heritage resources. Conduct interviews with local First Nations as needed to obtain additional information.

4 ARCHAEOLOGICAL OVERVIEW

This study includes a review of the archaeological site inventory, available overview assessments, historic maps, local histories, ethnographies, paleoecological studies and reported archaeological investigations in the study area. Topographic maps, (no air photos were made available from the proponent) and orthographs of the study area were carefully examined and a determination archaeological potential was made. The criteria used to predict the potential for archaeological resources included proximity to lakes, streams, and wetlands, proximity to archaeologically significant geological features such as post-glacial lake shores or early Holocene drainage systems, soil types, proximity to known archaeological sites, and known aboriginal or historic trail systems. The analysis results in a prediction for archaeological potential. Archaeological prediction involves the compilation of data that might be relevant to the position of a site on the landscape within a specific region. Sufficient site inventory and the collection of site related data are required so that existing correlations in the distributional archaeology and other variables can be documented and analyzed. It is important to note that this sufficient site inventory data does not exist for the Mackenzie region and more specifically for the Williston Reservoir. As a result only broad generalization can be ascertained from the known site loci of the geographical area.

The interpretation of ortho-photographs, satellite imagery and topographic maps resulted in the elimination all areas with slopes greater than 20%, gullied or broken terrain and wet areas. These areas are assigned low archaeological potential values. Prominent geographical features such as knolls, ridges, elevated benches, terraces and the like were assigned high archaeological potential values. Analysis of this combined information resulted in a detailed pre-field assessment of the survey areas and their potential for prehistoric use.

It is important to note here that criteria used for assessing archaeological potential are not applicable to Culturally Modified Trees (CMT). CMT clusters, not associated with other archaeological resources, do not fall within the predictability of this assessment. The location and number of CMTs are affected by the availability of the appropriate tree species at the time of their creation. In the Central Interior, the majority of CMTs are cambium stripped in origin and therefore their locations are specific to areas with the conditions necessary for the development of Lodgepole Pine stands. CMTs may be found in any stand of trees that have a Pine component, regardless of distance from water, slope, or any other criteria commonly used to determine archaeological potential. CMT sites, therefore, are generally found and recorded incidentally in the process of investigating other archaeological resources.

4.1 Biophysical Features

The study area is within the Arctic Watershed and is located in the geographic feature known as the Rocky Mountain Trench in North Central British Columbia. Within the Arctic watershed, glacial till and lacustrine deposits are thick along the valley bottoms and lower hills, with rocky outcrops on steep, unstable upper slopes. Holland (1976) describes the Rocky Mountain Trench as an erosion feature between the Rocky Mountains and the height of land between the Parsnip River and McLeod Lake.

4.2 RAAD Results

There are no recorded archaeological sites within the project area. (Remote Access to Archaeological Data (RAAD) database as of September 28, 2009)

4.3 Data Review

A review of maps, known reports on prior archaeological work in the area, site records and other pertinent historical or ethnographic studies for the enhancement site was completed.

4.4 Previous Archaeology

The Mackenzie Forest District has seen some overview assessments and regional inventory surveys, but few development based studies and no excavation or academic based work has been conducted. The Western Heritage Services Inc. overview and inventory assessments provide the best summary of the previous work in the area and add some sites through directed surveys (Gibson et al. 1997, Low et al. 1998). The majority of sites identified are small lithic scatters and CMT sites, as well as historic cabins. The archaeological impact assessments conducted in the region provide similar results (Rousseau et al. 1993, Yellowhorn and Rousseau 1997, Kinzie, J. 2001), however only an extremely small percentage of the area has been subject to any kind of survey. To the best of this authors knowledge there has been no previous archaeological studies filed with the Archaeology Branch relating directly to the project area.

4.5 Ethnography

The territory of the Sekani people cover the area of the Parsnip, Finlay and Upper Peace River and extending west to include the Carp Lake area where the group referred to by Jenness (1937) as 'Tsek'ehne' resided. At the time of contact with Europeans and before, the people wintered east of the Rocky Mountains hunting buffalo and other large game. Summer was spent on the west side of the mountains fishing and hunting caribou, moose, and smaller game including sheep, beaver, porcupine and rabbit. The Sekani people were efficient hunters and carried out this activity all year round. Gathering was also important, and many of the plants local to the area were utilized for food and medicinal purposes. The Sekani lived a nomadic lifestyle with a well defined seasonal round using the same areas for the same resources each year. The group was organized at the band level and split up into smaller family groups when food was scarce. Because of their frequent movement from one area to another, the Sekani had no permanent village sites. It must be assumed also that if the people customarily wintered east of the mountains there would be no winter villages west of the Rockies as can be found for groups further south and west. Dwelling and shelters were often built in the shape of a tipi and covered with moose hide or bark. Tool technology included the use of bows and arrows; bone for clubs, hooks, scrapers and fleshers; stone for scrapers and other tools; willow and nettle fibers for fishing nets; and bark and spruce roots for baskets. Small family units staying in temporary way-camps or hunting camps would be the primary land use for this area. Typically, not much is preserved for the archaeological record at these types of sites. Small depressions such as roasting pits or cache pits, surface

or subsurface scatters of cultural materials, trails or trail indicators such as tree blazes and trees stripped of their bark for cambium collection, are among the known types of features to be found in this locality.
No contact was made to First Nation groups with traditional claims over the study area.

4.6 Trails and Trailways

These features served important functions in hunter and gatherer culture. However, just as structural trail locations may change so do their functions change through time. Sekani trails in particular were essential arteries contributing to the mobility of various groups and individuals, directly relating to their survival capabilities. They often served conjointly as physical and social threads within and between the various Sekani communities and with outsiders. They served a dual purpose with both physical and social functions combined.

The most obvious physical function of these routes was for travel and resource exploitation. "Trips on foot of up to 200 to 300 km were not unusual (Hooper 1978:3)." Whole families spent weeks traveling trails to trade and exploit resources along the way (Carlson 1995:26). However, most trips were short and the trails more localized in development and use. Trails were necessary to connect various households in seasons when bands were dispersed for resource exploitation (Blacklaws 1980:3). They contribute to the overall distribution of archaeological sites. One cannot underestimate the importance of trails in determining Carrier settlement patterns. Carlson and Mitchell (1997:38) have conclusively demonstrated that in the Vanderhoof Forest District 65% of all known recorded archaeological sites are within one kilometer of historically documented trails. Connections between archaeological and modern settlement patterns by trails give credence to assertions of long-term occupation in the area (Albright 1987). Complex trail systems were necessary to gain access to the resources of particular watersheds and between different watersheds. First Nation groups controlled direct access to resources (hunting, fishing, trapping, and quarrying) within sections of watersheds and river boundaries were not often crossed over (Harmon 1911:255, Hudson 1983:236, Klippenstein 1992:50). These areas were used seasonally, provided the mainstay of their hunting and gathering lifeways, and allowed for the necessary redistribution of resources between local groups. Household groups were not self-sufficient and often relied on the resources of other watersheds, which were accessed through clan systems. In addition, a system of cross-cousin marriages provided the framework for movements on trails between resource areas. In this way resources were transferred from areas of surplus to areas of scarcity.
A review of historical maps and microfiche found no known trails within the proposed project area.

5 DETERMINATIONS

At the time of this study there was such a paucity of pre-contact archaeological information from the Mackenzie region that it is very difficult to extrapolate the local archaeological recoveries in a manner which would allow for accurate predictions for archaeological site occurrences within the study area.

1) There are no known archaeological or cultural heritage sites within 1 km of the study area.

2) To the best of this authors knowledge there has been no previous archaeological studies filed with the Archaeology Branch relating directly to the study area.
3) There are no known historic or prehistoric trails within 1 km of the study area.
4) There are distinguishing features within the study that could or would be considered high archaeological potential areas and therefore require an archaeological field assessment prior to development activities.

6 RECOMMENDATIONS:

Due to the minimal information directly or regionally applying to the study area it is recommended that an archaeological preliminary field reconnaissance be conducted on the areas to be directly affected by the proposed development. At this point in the archaeological review it is unknown exactly what will be affected by the development therefore it is impossible to state if the development activities would fall within high archaeological potential zones. For the purpose of this study high potential zone is defined as any area with less than 20% slope and within 100 meters of the original water channels.

The developer should be aware that even the most thorough investigation might fail to locate all archaeological remains. In the event that archaeological remains are encountered during operations, all ground disturbance activities in the vicinity of the archaeological remains must be suspended immediately. It is the individual's responsibility to inform the project manager and the Archaeological Planning and Assessment, Registries Department, as soon as possible.

The present study was designed solely as an archaeological review and was not intended to evaluate traditional aboriginal use of the areas in which development is proposed. The results of this study should not be considered valid for that purpose. We recommend that the appropriate First Nation Group(s) be contacted in an effort to locate any cultural resource they may know of.

7 LIST OF POTENTIALLY AFFECTED FIRST NATION GROUPS

McLeod Lake Indian Band
General Delivery
McLeod Lake B. C.
V0J 2G0
Phone 250-750-6835
Fax 250-750-4420

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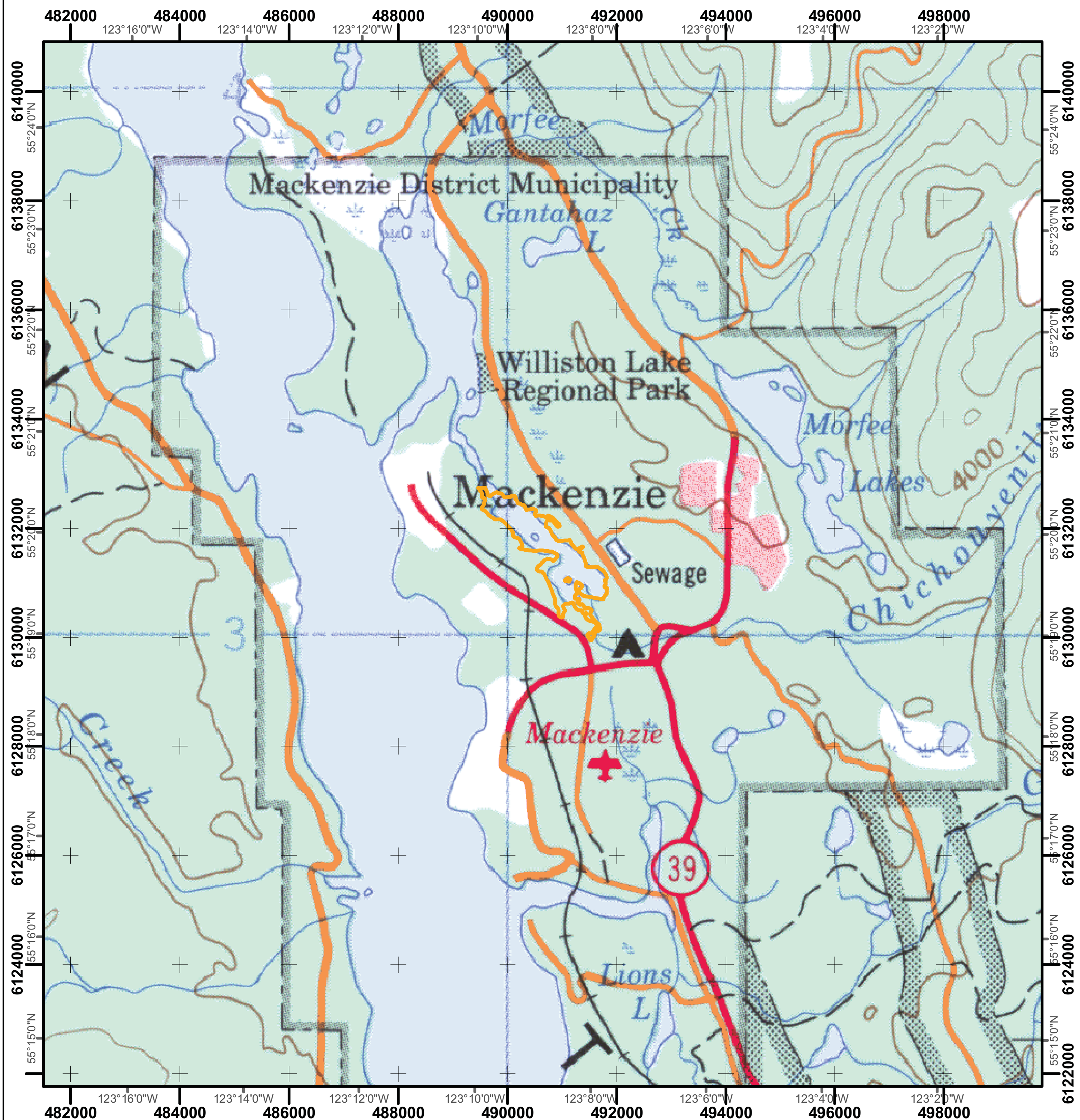


Company: BC Hydro
Forest District: MacKenzie
Location: on Chichouenily Creek
BCGS Mapsheet: 093O.035
NTS Mapsheet: 093O/06
Date: 09/25/2009
Area: 173.3ha
Block Center:
UTM 10 490799E 6131532N
Latitude: 55° 19' 48.25" N
Longitude: 123° 8' 43.23" W
Job #:

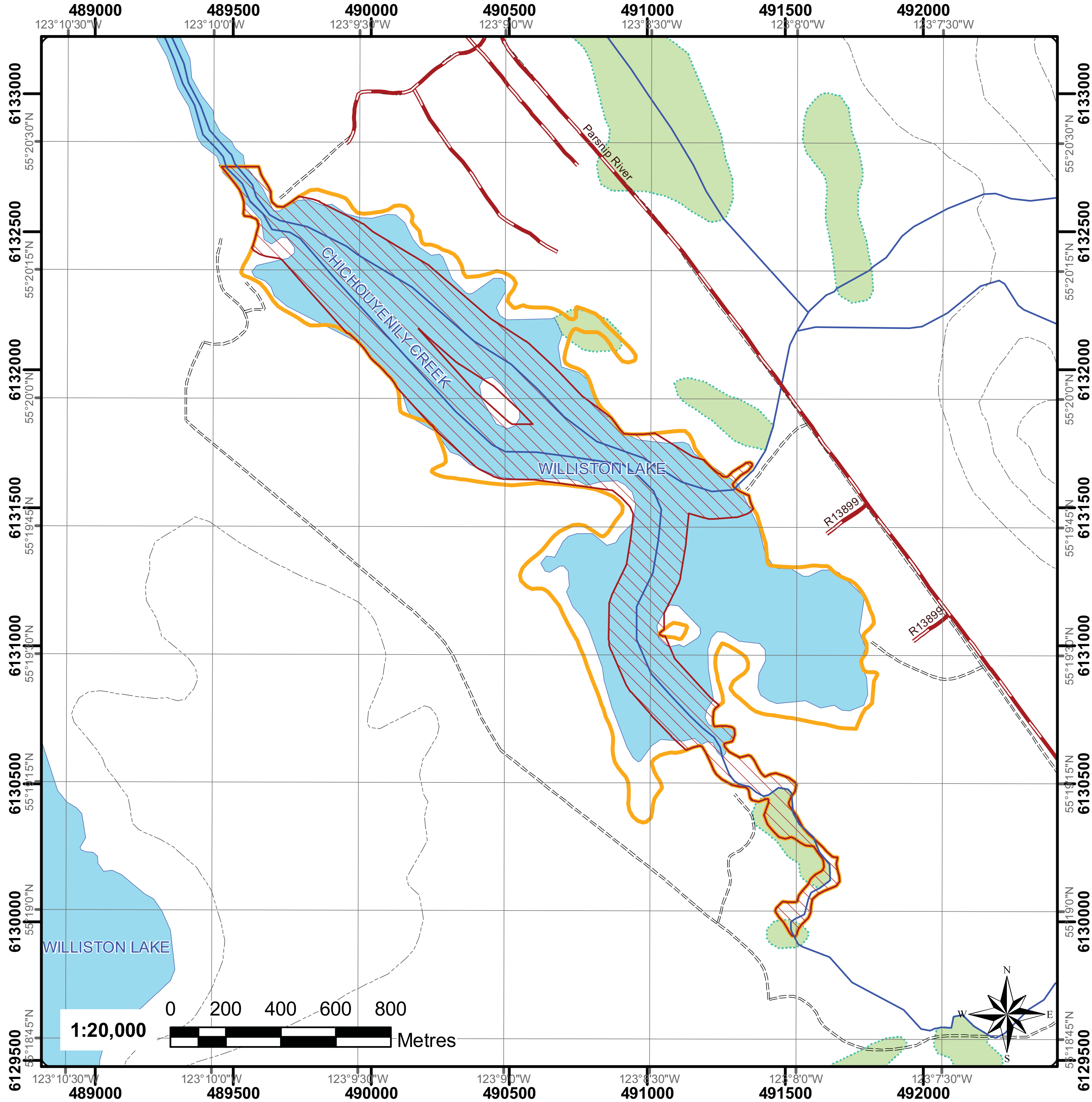
NTS Block Location Map

Metres
0 1,000 2,000 3,000

Map Projection: UTM10
Map Scale 1: 100,000

NORCAN CONSULTING LTD

Assessment Area: Chichouyenily Creek



Field Survey Map

Company: BC Hydro
Forest District: Mackenzie
Location: on Chichouenily Creek
BCGS Mapsheet: 093O.035
NTS Mapsheet: 093O/06
Date: 09/25/2009
Area: 173.3 ha
Block Center:
UTM 10 490779E 6131532N
Latitude: 55° 19' 48.25" N
Longitude: 123° 8' 48.25" W
Job #:

Legend

- Assessed Block Boundary
- Other Block Boundaries
- Built Road
- Proposed Road
- River/Stream
- Lake Boundary
- Wetland Boundary
- Contour
- Survey Line
- Trail
- Slope Edge
- Edge of Forest
- Beaver Dam
- Negative Shovel Test
- Positive Shovel Test
- Individual CMT
- Cultural Depression
- Surface Find
- Logged Block
- Wetland
- Shovel Test Location
- Number of Tests
- Beetle Plot
- Cabin
- Norcan Datum
- Recreation
- Plot Card
- Archaeological Site
- Block Reserve
- CMT Cluster
- Cluster of Surface Finds
- High Potential
- Moderate Potential
- Low Potential
- Lake/River
- Wetland
- Survey Area
- Previously Recorded Archaeological Site
- Previously Recorded Sites
- Blazed Tree
- Fire Scar Tree
- Blazed Trail
- Lean-to