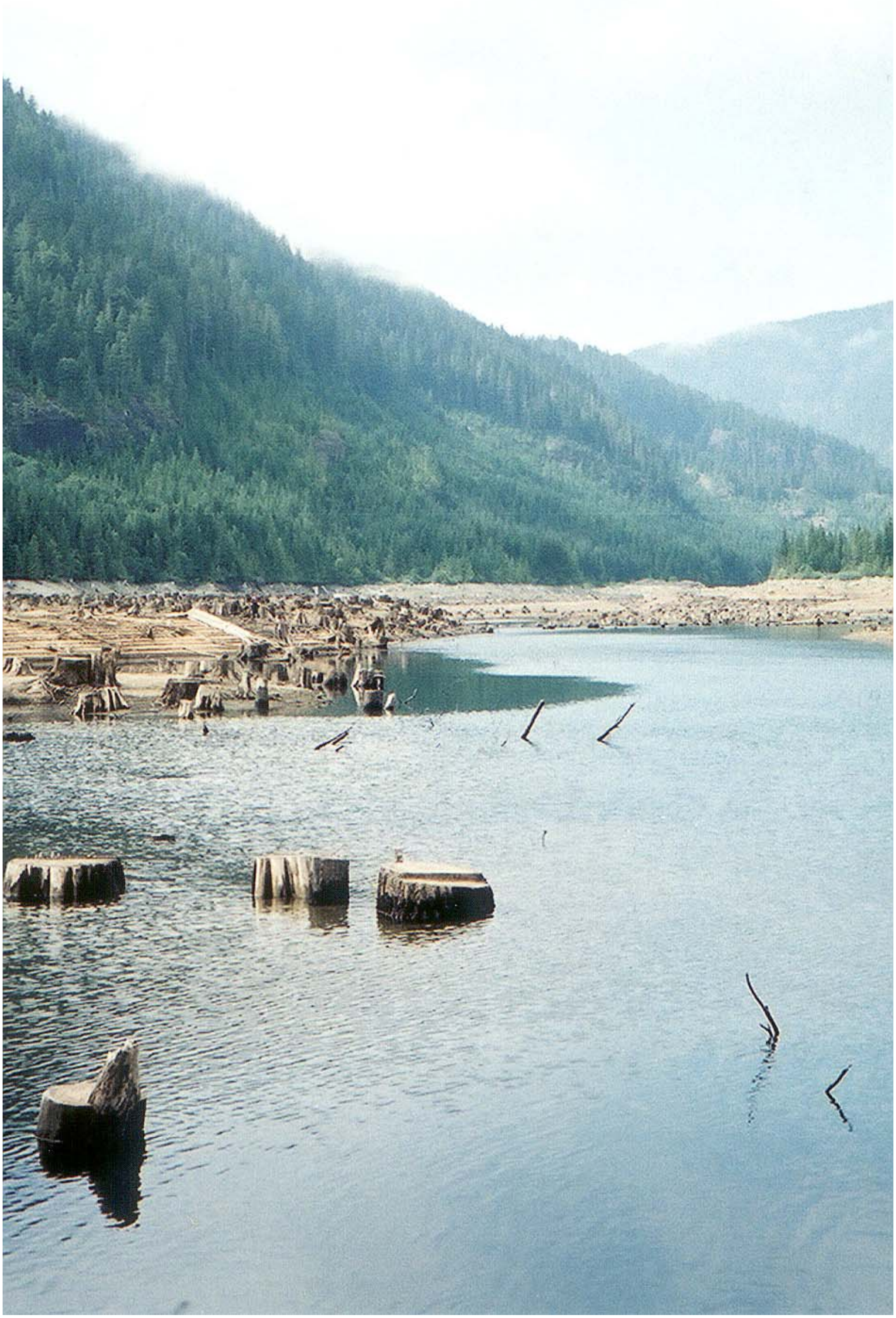

Assessment of Fish and Fish Habitat in the Elsie Lake Basin and Identification of Restoration Options

Prepared for
Hupacasath First Nations, Port Alberni

With the Financial Support of: **BC Hydro, Bridge Coastal Fish and Wildlife Restoration Program**

Prepared by
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and
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May 2003

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Hupacasath First Nations
Port Alberni, B.C., V9Y 7M7

With the Financial Support of :

BC Hydro, Bridge Coastal Fish and Wildlife Restoration Program

May 9, 2003

By

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Cover:
Looking west at the Elsie Lake/Upper Ash River confluence
after Elsie Lake has been drawn down 12 m
(Photo 13-1, August 16, 2001)

EXECUTIVE SUMMARY

In April 2002 the Hupacasath First Nations received funding through BC Hydro's Bridge Coastal Restoration Program (BCRP) to undertake restoration initiatives on Elsie Lake and its associated inlet tributaries. Two projects were awarded by the BCRP: one to examine the fisheries resources in the area, and the other to examine its wildlife resources. This report provides results on the fisheries study.

Since very little was known on the habitats and life stages that may be limiting fish production within the Elsie Lake basin, the goal of this study was to conduct a field program that provided sufficient knowledge to identify meaningful prescriptions for future years. Thus, no specific prescription works were undertaken in 2002, but rather an inventory of fish and fish habitat was completed. The specific objectives of the 2002 Elsie Lake Fisheries BCRP were as follows:

1. Conduct field investigations to describe fish habitat and fish use in Elsie Lake and its inlet tributaries.
2. Use the knowledge gained from the field studies to determine restoration strategies that addressed limiting habitats, and to identify potential sites for restoration options.
3. Undertake detailed surveys of potential restoration sites.
4. Compile a report that summarised habitat and fish data, and provided work plans/costs of identified restoration options.

The results of the fish habitat and fish population surveys are covered in Part A of this report, while details on an initial set of restoration prescriptions are covered in Part B (other restoration options can be addressed in future funding requests).

Tasks completed as part of the fish and fish habitat assessment included 1) biophysical surveys of tributary habitats (with emphasis on migration barriers and quantification of spawning gravel), 2) fish population inventories on all major tributaries using total removal electrofishing techniques (6 sites, 4 tributaries), 3) an assessment of riparian and drawdown habitat around Elsie Lake, 4) fish population sampling in Elsie Lake using scientific gill nets, minnow traps, and angling, and lastly 5) water quality sampling at the deepest location on Elsie Lake.

With respect to limiting factors, key results from the fish and fish habitat surveys were:

1. Spawning gravel accessible to adfluvial fish appears to be in very short supply and may limit the recruitment of juvenile trout to the Elsie Lake population pool. Current spawning habitat above full pool amounts to only 82 m^2 for all creeks combined, assuming limited or no access up Ramsay Creek. This shortage of gravel is a direct result of Elsie Lake reservoir which has inundated approximately 96% of spawning gravels historically available to adfluvial fish (Table

5). The above assumption for Ramsay Creek requires further investigation since it has a large supply of gravel in its upper reach (primarily beginning at 2.1 km from the mouth). Our assessment to date suggests that most trout are unable to ascend the 900 m long step cascade section in the lower reach of Ramsay Creek, with the exception of some larger or hardier individuals.

2. The stream surveys indicated that there is only 1.2 – 2.1 km of stream habitat available for juvenile rearing depending on the level of spring runoff (greater runoff allows greater access to small tributaries). This indicates that there is also a shortage of stream rearing habitat and consequently, only a few spawners are required in any individual tributary to produce sufficient fry to saturate available rearing space. The implication of this is that much of each year's fry population is probably forced migrate to the lake shortly after emergence due to competition for food and special resources.

3. If indeed the bulk of juvenile trout rearing occurs in the lake, then the quality of littoral nursery habitats are crucial to juvenile survival and subsequent adult recruitment. The lake survey found that the annual drawdown has for the most part prevented aquatic plants from colonising littoral habitats. Instead we found terrestrial species such as grasses, buttercup, and field mint in the drawdown. Small tufts of sedge were found in isolated depressions fed by groundwater. Similarly, riparian vegetation (a source of terrestrial insects) was limited to shrub willow at the mouths of a few creeks with gentler slopes in the initial part of the drawdown. The lack of emergent and submergent aquatic plants, as well as riparian vegetation suggests a shortage of both cover and food supply for juvenile nursery habitats.

The above findings suggested that the two most crucial habitats impacted by Elsie Lake reservoir are the lack of spawning habitat, and the poor quality of littoral nursery habitats. For these reasons our initial set of prescriptions in Part B focused on the addition of spawning gravels, and on the creation of wetland habitat. With respect to the option of constructing spawning habitats, we were restricted to larger tributaries to ensure adequate flow. Further, within these tributaries it was very difficult to find locations that satisfied the criteria of a) being close to the lake, b) having suitable gradient, and c) having topography that permitted machine access. In the end we identified locations for 2 spawning platforms on Creek 2 (Prescription 1), and one spawning platform on Katlum Creek (Prescription 2). These 2 prescriptions have the potential of providing an additional 137 m^2 of spawning habitat, resulting in 2.7 fold increase in the amount of gravel currently available from all creeks combined (again excluding Ramsay Creek).

With respect to the creation of wetland habitat in Elsie Lake, we identified several potential sites and Part B provides details and drawings for two of the more likely candidates. However, the feasibility of this type of prescription requires further investigation, in particular, a need to enlist the expertise of an engineer and possibly a geomorphologist. We would like to pursue the feasibility of the wetland creation under future BCRP funding.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOS

ACKNOWLEDGEMENTS

We would like to thank staff of the Hupacasath First Nations office for their support and assistance in carrying out this project. In particular, Trevor Jones for initiating this venture and providing administrative support, and Tom Tatoosh for organising Hupacasath crews to assist in field activities. Crew members included Cameron Tatoosh, Shawny Lauder, and Jason Lauder. Our thanks also to Lorraine Lauder for assisting with data entry.

A number of others helped with various aspects of this project. Steve Toth assisted with plant identification and his knowledge and insights during the course of the field program were greatly appreciated. Kent Handy of Sea-Tech Environmental Services completed the total station surveys. Sherri McPherson prepared digital images of all scale samples, and Bob Griffith (formally RP Griffith and Associates) kindly aged these samples.

Lastly, we are grateful to BC Hydro's Bridge Coastal Fish and Wildlife Restoration Program which provided the financial support that made this project possible.

PREFACE

In April 2002 the Hupacasath First Nations received funding through BC Hydro's Bridge Coastal Restoration Program (BCRP) to undertake restoration initiatives on Elsie Lake and its associated inlet tributaries. Two projects were awarded by the BCRP: one to examine the fisheries resources in the area, and the other to examine its wildlife resources. This report provides results on the fisheries study, while results from the wildlife study can be found in Toth (2003).

Since very little was known on the habitats and life stages that may be limiting fish production within the Elsie Lake basin, the goal of the 2002 program was to undertake a field program that provided sufficient knowledge to identify meaningful prescriptions for future years. Thus, no specific prescription works were undertaken in 2002, but rather an inventory of fish and fish habitat was completed. The area of study included Elsie Lake and its inlet tributaries including the upper Ash River. The specific objectives of the 2002 Elsie Lake Fisheries BCRP were as follows:

5. Conduct field investigations to describe fish habitat and fish use in Elsie Lake and its inlet tributaries.
6. Use the knowledge gained from the field studies to determine restoration strategies that addressed limiting habitats, and to identify potential sites for restoration options.
7. Undertake detailed surveys of potential restoration sites.
8. Compile a report that summarised habitat and fish data, and provided work plans/costs of identified restoration options.

This report is divided into 2 parts: Part A summarises the results of fish habitat and fish population surveys, while Part B provides details on proposed restoration options based on 2002 prescription surveys.

PART A: FISH HABITAT AND FISH POPULATION SURVEYS

1. INTRODUCTION

The objectives of the fish and fish habitat surveys were to gather sufficient information on the state of fish habitat and fish populations as to be able to identify factors that are likely constraining the health of fish stocks within the basin as a result of impacts from Elsie Lake reservoir. Specific tasks undertaken to achieve this goal included the following:

1. Gather and review background information, maps and air photos for the study area.
2. Undertake fish habitat inventories on inlet tributaries to describe biophysical characteristics, potential barriers, and to quantify spawning habitat.
3. Conduct fish population surveys on inlet tributaries using total removal techniques such that density and biomass of fish could be determined.
4. Undertake a habitat survey on Elsie Lake to describe the state of habitat.
5. Conduct a fish population survey on Elsie Lake using angling, minnow trapping, and gill netting techniques.
6. Undertake water quality sampling at the deepest part of the lake to augment existing water chemistry information
7. Use the knowledge gained from the field studies to identify restoration strategies for lake and stream habitats.

2. BACKGROUND

2.1 Description of Study Area

Elsie Lake is located about 30 km northwest of Port Alberni. It can be accessed by taking the Great Central Lake Road cut-off from Highway 4, proceeding north to the Arc Resort, and then taking the Ash River Road (Ash Mainline) to the west side of Elsie Lake. Branch 114 provides access along the north shore of Elsie Lake as far as Ramsay Creek, however there is no longer a bridge crossing Ramsay Creek. To access the east side of Elsie Lake one must backtrack along Ash River Road, take Branch 103 east, and then the Valley Link Highway (Comox Mainline) north and hook up with the Long Lake Road which traverses the east side of Elsie Lake. An alternative approach to the roads around Elsie Lake is via Beaver Creek Road out of Port Alberni. Figure 1 shows the location of Elsie Lake and the various access roads.

At full pool, features of Elsie Lake include: area 672 ha, mean depth 8 m, maximum depth 30 m, length ~7 km, and width ~1 km (BC Hydro 2001). The 1:20,000 TRIM map of the area (92F045) shows 23 tributaries flowing into Elsie Lake (including the upper Ash River). Of these, only the upper Ash River, Ramsay Creek, Katlum Creek, and Creek 2 have significant year-round flows. The remaining 19 creeks are small and often ephemeral (our observation). The natural outflow to Elsie Lake is the middle Ash River, however BC Hydro also diverts an average of 10.7 cms through the tunnel located on the south shore of Elsie Lake (described in the next section).

Fish species occurring within Elsie Lake and its tributaries include rainbow trout (*Oncorhynchus mykiss*) and cutthroat trout (*O. clarki clarki*) (Triton 1995, BC Hydro 2001, FISS online data warehouse). In addition, mixed features observed during our work suggest the occurrence of some hybridization between these two species ("cutbows"). Anadromous species do not occur within Elsie Lake and its tributaries due to the Ash River Dam which forms a complete barrier to upstream migration. However, during 1982 to 1997 juvenile steelhead were released into the study area on 9 separate years as part of the Provincial colonization program. Releases were generally as fry but also included parr in 1992 and smolts in 1997 (see www.bcfisheries.gov.bc.ca/fishinv/db/default.asp, Fishery Inventory Stocking Report for Elsie Lake).

2.2 BCH Facilities and Associated Impacts

BC Hydro's Ash River Project was completed in 1958 and consists of five impoundment dams along the northeast side of Elsie Lake and a diversion tunnel located on the south shore of the lake (Figure 1). The impoundment structures include a main dam (Elsie Dam) at the outlet of Elsie Lake, and four saddle dams in low relief areas to the south of the main dam. These structures have allowed the elevation of Elsie Lake to be raised from 312.5 m to 330.7 m, an increase of 18.2 m (Triton 1995). Saddle dam 1 is outfitted with a spillway at its southern end and a fish flow release culvert at its midpoint, each with a separate channel connecting to the Ash River mainstem. The fish flow release culvert is 2.5 m in diameter and outflows are controlled by a hollow cone valve. In 2002, saddle dam 1 was modified to include an additional flow release structure in the form of an undersluice opening outfitted with a vertical lift gate. This feature was installed under the spillway at an elevation of 324.1 m (Peter Warburton, environmental monitor to BC Hydro, pers. comm.).

The diversion facility on Elsie Lake consists of a tunnel and penstock which carries water 7.8 km to a powerhouse on the shore of Great Central Lake (see Figure 1). The powerhouse has a nameplate capacity of 25.2 MW and a dependable capacity of 27 MW (BC Hydro 2001).

The water licence issued to BC Hydro for the Elsie Lake facilities include the following conditions (from Hirst 1991):

- A maximum storage of 76.5 million m^3 per annum.
- A maximum diversion of 339 million m^3 per annum (10.8 cms).
- Regulated releases into the Ash River are to maintain a minimum mean monthly flow of 3.5 cms at the WSC gauging station near the mouth (08HB023, see Figure 1 for station location).
- Discharges from Elsie Lake may not be less than 0.7 cms during June – August, and not less than 0.3 cms at all other times.

Impacts of hydroelectric facilities on fish production and fish habitat in the Ash River watershed are documented in BC Hydro (1991). Impacts specific to Elsie Lake and its inlet tributaries are outlined in Table 1.

Table 1. Summary of hydroelectric facility impacts on fish and fish habitat in Elsie Lake and its inlet tributaries (adapted from BC Hydro 2001).

Facility	Description of Hydroelectric Impacts	Neg.	Pos.	Source
Elsie Lake Reservoir	Reservoir footprint flooded 5 km of mainstem channel and associated riparian zone (primarily in the upper Ash River).	X		GIS; Griffith 1993
	Reservoir footprint flooded 4.6 km of tributary channel and associated riparian zone (loss of habitat in lower reaches of inlet tributaries).	X		GIS; Triton 1995
	Reservoir flooded 271 ha of lake habitat (including shoals, wetlands, and riparian). May have been partially offset by gain of 401 ha in reservoir habitat and uncalculated volume.	X	X	GIS
	Fluctuating water levels of 15 m reduced productivity by exposing littoral habitats.	X		Triton 1995
	Fluctuating water levels of 15 m may limit fish access to tributaries.	X		BC Hydro 1994
Elsie Dam	Dam footprint caused loss of instream, riparian and upland habitats.	X		
	Dam has reduced recruitment of LWD to river habitats downstream.	X		Workshop
	Elsie Dam blocks the movement of resident trout to and from downstream reaches of the Ash River.			Griffith 1993

2.3 Previous Studies

Previous fisheries assessments in the study area (Elsie Lake and inlet tributaries) include works by Horncastle (1978), Triton (1995), and Lewis (2001). The study by Horncastle (1978) involved inventory of various reaches of the Somass Watershed and included a snorkel survey of the upper Ash R. from Oshinaw Lake to Elsie Lake. This portion of the Ash River was subdivided into 3 reaches and general notes were taken for each reach (channel characteristics, substrate, vegetation, benthos, fish observations, barriers, and suitability for spawning, rearing, and holding). They noted that the upper Ash River had excellent fish habitat although a 3 m fall 0.5 km from the lake may limit fish access.

The Triton (1995) study was conducted in 1993 and 1994 to assess the potential impacts of using flashboards on the Elsie Lake spillway to raise the storage capacity of the reservoir by an additional 0.9 m. Activities undertaken included a bathymetric survey, limnological sampling, and fish population sampling on Elsie Lake, as well as a habitat survey of the lower 100 m of the inlet tributaries.

The study by Lewis (2001) was conducted in August 2001 as part of the Ash River Water Use Plan (note: field surveys were conducted by Dave Burt, Cedric Robert, and Cameron Tatoosh). This study was completed during a time of large drawdown (lake elevation ~ 318.7 m) and focussed on assessment of tributary habitats within the drawdown zone. Data were collected in geo-referenced increments from lake level to full pool and included various channel features, gradient, obstructions, and quantity of spawning gravel (m^2).

3. METHODS

3.1 Stream Surveys

The assessment of Elsie Lake tributaries consisted of two components: a fish habitat survey, and a fish population survey. The goals of the habitat survey were to describe biophysical characteristics of Elsie Lake tributaries, determine the availability of flow for spawning and rearing, quantify potential spawning habitat, identify access constraints to spawning habitats, and assess options for providing access to upstream spawning habitats. The goal of the fish population survey was to determine the population structure of fish using the inlet tributaries (e.g., species, density, age groups present, length and weight at age). The following describes methods employed for each survey component.

Habitat Survey

The stream habitat survey was conducted by a 2-person crew (one biologist and one Hupacasath technician) during June 3 – 21, 2002. A total of 20 streams were examined, the locations of which are shown in Figure 2. Each stream was walked in an upstream direction beginning at the point of full pool elevation[1]. For smaller streams, the distance surveyed was to a point where the stream emerged from a groundwater source, or where the gradient exceeded 20%, or where a major barrier was encountered. For larger tributaries the lowermost reach was walked in its entirety, while subsequent reaches were walked in sections close to access points (e.g., the upper Ash River and Ramsay Creek).

For each stream or reach section walked, habitat data were collected for a minimum of 5 locations, with site selection based on representative habitat. Information on barriers and potential spawning gravel was collected whenever these features occurred. A hipchain, zeroed at the full pool elevation, was used to reference habitat features. In addition, GPS coordinates were taken at the full pool location. Photos were taken of the mouth of each creek and of key features encountered during the stream walks (e.g., barriers, spawning habitats). Table 2 provides a listing of habitat parameters collected and associated methods. For further details on sampling methods see Anon. (1995).

Table 2. Biophysical data collected during stream surveys (see Anon. 1995 for details).

Parameter	Units	Measured (M) or Estimated (E)	Method
Discharge	m^3/s or L/s	M or E	M – Swoffer flow meter; E – estimated using time to fill a cup
Water Temperature	ºC	M	Handheld thermometer
Chain Distance	m	M	Hipchain
Habitat Type	—	—	Pool, glide, riffle, cascade, or falls
Stream Gradient	%	M	Abney level
Channel Width	m	M	Tape measure
Wetted Width	m	M	Tape measure
Substrate Size Distribution	%	E	Fines, gravel, cobble, boulder, and bedrock
Substrate D95	cm	E	Tape measure
Cover	%	E	Overstream and instream vegetation, cutbank, small and large woody debris, boulder
Spawning Gravel (10–75 mm)	m^2	M	Tape measure
Spawning Gravel Category	—	—	Pocket(s) or continuous
Fines in Spawning Gravel	%	E	A measure of gravel quality
Barriers – Depth of Pool	m	M	Tape measure or wading rod
Barriers – Height	m	M	Tape measure or wading rod
Barriers – Water Depth at Lip of Falls	m	M	Tape measure
Photos	—	—	Roll#, photo#, orientation, description

[1] These same streams were assessed from a lake elevation of 318.7 m to the full pool elevation (~ 331 m) in 2001 as part of the WUP program. Our surveys carried on from where the WUP surveys left off.

Fish Population Survey

The fish population survey on Elsie Lake tributaries was conducted from September 15–19, 2002 during which 6 sites were sampled. Sample locations are shown in Figure 2 and included 2 sites on Katlum Creek, 2 on Ramsay Creek, 1 on the upper Ash River, and 1 on Creek 2. The remaining creeks were dry or possessed only a trickle of water at the time of sampling. Activities undertaken at each site included 1) fish sampling by electrofisher, 2) collection of depth and velocity data along a transect within the site, and 3) collection of site biophysical characteristics. The following describes the methods used to collect each of these data sets.

Fish population sampling was performed with an electrofisher using the "removal method" with a 2-catch removal pattern (2 separate catches for each site). Statistical aspects of the removal method are described in Seber and Le Cren (1967), and sampling protocols in De Leeuw (1981). The procedure involved enclosing a stream section with stop nets, using rocks to mould the lead line to the bottom topography, and aluminium poles to hold the float line above water. The nets used were 8.5 mm nylon hexagonal mesh, 1 m in height, and 10 and 20 m in length. Enclosures ranged in size from 45 to 113 m^2. In smaller streams, enclosures spanned the full stream width, while in larger streams a longitudinal section adjacent to the bank was enclosed. The setups of netted enclosures are shown in Photos 5 through 10 (Appendix A).

Electrofishing was performed by a 3-person crew using Smith-Root model 12A backpack electrofisher. For each catch, 3 or more circuits were made within the netted enclosure (e.g., up, down, up). This high level of effort per catch generally resulted in removal of most fish within the enclosure such that the contained population was either slightly greater than, or equal to the sum of catch 1 and catch 2. After each catch, fish were identified and measured for fork length (to nearest 1.0 mm). Weights were also taken from a subsample of the captured fish (nearest 0.1 g, OHAUS portable electronic balance, model C-505). Alka-seltzer tablets (CO2) were used as an anaesthetic. Scales were taken from a small subsample of captured trout and mounted on slides on site for later age determination. The above procedures are described in Anon. (1995, Chapter 8).

After completion of the fish sampling, a transect was run across the enclosure at a representative hydraulic location using a 30 m tape. Depth, velocity, and substrate data were recorded at 20–50 cm intervals along the transect. This data was later used to determine the amount of suitable rearing habitat within the netted enclosure, and provided a means of prorating fish population densities by the amount of suitable habitat (described below in “Analysis of Fish Population Data”). Depths were measured using a 1.5 m top-setting rod. Velocities were taken at 40% of the depth (from the bottom) using a Swoffer flow meter mounted to the top-setting rod. Substrate material was categorized into dominant and subdominant types based on the modified Wentworth Scale (Anon. 1995).

General habitat information was collected at each fish population site following the methods outlined in Anon. (1995), "Lake and Stream Inventory Standards and Procedures." Table 3 summarises habitat data collected at fish population sites and associated collection methods.

Table 3. Habitat data collected at fish population sites and associated methods

Parameter	Units	Measure (M) or Estimated (E)	Method
Coordinates	UTM	M	Garmin GPS 76
Habitat Type	—	—	Pool, glide, riffle or cascade
Mainstem or Sidechannel	—	—	Channel type designation
Field Gradient	%	M	Suunto clinometer
Sample Width	m	M	Tape measure (mean width of site)
Mean Depth	m	M	Top-setting rod
Maximum Depth	m	M	Top-setting rod
Mean Velocity	m/s	M	Velocity meter
Maximum Velocity	m/s	M	Velocity meter
Turbidity	–	E	Designated as clear, glacial, tannic, etc.
Temperature	ºC	M	Hand held thermometer
Time	—	—	Time temperature taken
Conductivity	µs	M	Horiba Twin Conductivity B-173 Compact Meter
Total Alkalinity	mg/L	M	Hach alkalinity test kit
Cover	%	E	Overstream & instream vegetation, cutbank, large woody debris, and boulder
Substrate Size Distribution	%	E	Fines, small and large gravel, cobble, boulder, and bedrock
Substrate Compaction	—	E	Identified as low, medium, or high
Sand in Substrate	—	E	Identified as low, medium, or high
Substrate D90	cm	M	Tape measure
Substrate Dmax	cm	M	Tape measure
Photos	—	—	Roll#, photo#, orientation, description

Analysis of Fish Population Data

Analysis of the fish population data involved 1) calculation of the amount of usable trout habitat (m^2) within netted enclosures, and 2) calculation of trout densities (fish/100 m^2) within the enclosures. In this analysis, age 0^+ rainbow and cutthroat trout were pooled due to difficulties in distinguishing the 2 species (possibly made more difficult by hybridization). For older age groups, the 2 species were more easily distinguished and the analyses were performed separately on each species.

Calculation of usable habitat within electrofishing enclosures involved the pairing of depth and velocity data from the site transects with habitat suitability index (HSI) values currently in use in B.C. Water Use Planning (WUP) projects (curves dated February 2001). The rational for this approach is that within any given fish sample site there is usually a portion of the site that is unsuitable for rearing due to inappropriate (insufficient or excessive) depths and/or velocities. The portion of the site that has suitable depths/velocities can be termed usable habitat. Quantification of the amount of usable habitat within the electrofishing enclosures involved 1) determining the proportion of the sample site width that was usable (percent usable width or PUW) for each species and age group, and 2) multiplying PUW values by the total area of the site to obtain weighted usable area (WUA). This analysis was applied to age 0+ fry and 1+ parr of rainbow and cutthroat trout.

Determination of percent usable width (PUW) involved coupling depth and velocity measurements from each position along a given transect with an associated HSI weighting factor for each species/age group (see Milhouse, Wegner, and Waddle 1984 for a detailed explanation). The calculation can be expressed as follows:

$$C_i = f(D)_i \times f(V)_i$$

Where C_i = *the composite weighting factor for a given species and age in cell i*
$f(D)_i$ = *the suitability weighting factor for depth in cell i*
$f(V)_i$ = *the suitability weighting factor for velocity in cell i*

The composite weighting factors (C_i) were used to weight the width of each transect cell (i.e., $C_i \times W_i$, where C_i = above and W_i = width of cell i). The sum of all cell weighted widths (C_iW_i) provided weighted usable width for each transect by species. These calculations were facilitated through a database program developed by J. Lettic (Digital Information Services, Nanoose Bay, B.C.), using algorithms from a spreadsheet by MWLAP (Ptolemy, Bech, and Night 1993).

Percent usable width (PUW) for each transect was obtained by dividing the weighted usable width by the transect width. Weighted usable area (WUA) was derived by multiplying PUW by the total area of the site enclosure.

Calculation of fish density at a given electrofishing site first involved estimation of the total fish population (by species and age group) within the netted enclosure. This was then divided by the area of the enclosure to determine observed density, or by the weighted usable area (WUA) of the enclosure to determine weighted usable area adjusted density. In this study, densities are expressed as the number fish per unit area (FPU) where a unit area equals 100 m^2. Thus, observed densities are designated as FPU_{Obs}, and weighted usable area adjusted densities as FPU_{WUA}. The following describe the formulae used to estimate fish population, FPU_{Obs}, and FPU_{WUA} for fish population sites.

Estimation of fish populations (ñ) within netted enclosures, and associated probability of capture values ($\tilde{p}$), relied on formulae from Seber and Le Cren (1967). There are 2 formulae for calculating ñ, the choice of which depends on whether $\tilde{p}$ is less than or greater than 0.5. Thus it is important to determine $\tilde{p}$ prior to calculation of ñ. The formulae are as follows:

$$\tilde{p} = \frac{(C_1 - C_2)}{C_1}$$

For probability $\tilde{p} > 0.5$:

$$\tilde{n} = \frac{C_1^2}{(C_1 - C_2)}$$

For probability $\tilde{p} \leq 0.5$:

$$\tilde{n} = \frac{(C_1 + C_2)}{\tilde{p}_{est}}$$

Where $\hat{p}$ = *probability of any 1 fish being caught*
$\tilde{n}$ = *population of fish within the enclosure*
$\hat{p}_{est}$ = *estimate of the proportion of fish captured in C_1 and C_2 combined*
C_1 = *number of individuals in the first capture*
C_2 = *number of individuals in the second capture*

Calculation of fish densities was achieved by dividing the population estimates ($\tilde{n}$) from above by the total area of the enclosure to achieve observed density, or by the weighted usable area within the enclosure to achieve the weighted usable area adjusted density. The equations for these calculations area as follows:

Observed density:
$$FPU_{Obs} = \frac{\tilde{n}}{TA} \times 100$$

WUA adjusted density:
$$FPU_{WUA} = \frac{\tilde{n}}{WUA} \times 100$$

Where FPU = *fish per unit area (fish per 100 m^2)*
$\hat{n}$ = *population estimate within the enclosure*
TA = *total area of the electrofishing enclosure*
WUA = *weighted usable area within the electrofishing enclosure*

3.2 Lake Surveys

The assessment of Elsie Lake consisted of three components: a fish population survey, an assessment of water chemistry, and a survey of habitat in the riparian and drawdown zones. For the most part, activities were conducted from a 3.6 m aluminium pleasure craft powered by a 9.0 hp outboard motor. The following describes each of these components.

Fish Population Survey

The fish population survey on Elsie Lake was conducted from August 6–10, 2002 and involved the setting of gill netting (2 sites), minnow trapping (15 sites), and general fish observations. In addition, angling was employed on several occasions during the various field trips to the area. The locations of gill net and minnow trap sites are shown in Figure 2. Fish capture methods followed the guidelines described in Fish Collection Methods and Standards – Version 4 (RIC 1997). Sample locations were geo-referenced using a hand held GPS with an integrated DGPS receiver (model Garmin 76).

The first gillnet (standard 6-panel floating type) was set in the littoral zone perpendicular to shore, on the southeast side of the mouth of Creek 2 (Site GN1, Figure 2). The second net (standard 6-panel sinking type) was set perpendicular to shore on the southeast side of the large island in Elsie Lake (Site GN2). The sinking net sampled depths between 3.5 and 5.9 m from the water surface. Both nets were left fishing overnight and captured fish were retrieved and sampled the following day. All captured fish were identified and measured for fork length (nearest 1.0 mm), while weights were taken from a subsample of the catch (nearest 0.1 g, OHAUS C-505 portable electronic balance). Finally, scales were taken from a small subsample and were mounted on slides on site for later age determination.

A total of 15 minnow traps were set along the perimeter of the lake to determine juvenile fish distribution. Of these, 9 were set near the mouths of tributaries. All traps were baited using commercial grade fish pellets and were set in locations with some form of cover nearby (e.g., root wads, logs, boulders). Captured fish were sampled as described above.

Water Chemistry

The water quality sampling was conducted on August 7, 2002 at a single limnological station in the deepest portion of the lake (station L2). This station was in the same general area as previous studies (e.g., L2 in Lewis 2001 and Triton 1995). The location of the station was geo-referenced using the hand held GPS unit, and is shown in Figure 2 (p. 10). For the most part, sampling procedures followed RIC water quality collection standards (RIC 2001).

Paired water samples were taken from the surface and bottom of the water column. Surface water samples were collected using a siphon (1.5 cm diameter, 12 m long), and were transferred into a 4 L sterilized pail to ensure homogeneity of the sample. Two subsamples were then taken from the pail and transferred into 500 ml sterilized plastic sample bottles supplied by the lab. The bottom water samples were collected using a 1 litre Van Dorn sampler and were transferred into 500 ml sterilized plastic sample bottles also supplied by the lab. Chlorophyll-a samples were transferred into two 500 ml sterilized dark glass bottles (one from the surface sample and one from the bottom sample). All samples were kept on ice and couriered to the lab within 30 hours of collection.

Samples were analyzed for pH, conductivity, total dissolved solids (TDS), total alkalinity, total ammonia N, nitrate N, nitrite N, total dissolved phosphate, total phosphorus, chlorophyll-a, and turbidity. Water chemistry parameters were analysed by North Island Laboratories in Courtenay.

In addition to the above, dissolved oxygen (DO) and temperature (°C) profiles were taken, as well as a Secchi depth reading (m). DO and temperature profiles were measured simultaneously using a YSI meter (model 58). Readings were taken at 1 m intervals both on the descent and ascent of the probe. Measurements were subsequently averaged for each depth interval. Water transparency was measured using a standard 20 cm Secchi disk. Readings were taken on the shaded side of the boat at 1:00 pm under a clear sky. Secchi readings were taken during both the descent and ascent of the disk, and averaged to determine the extinction depth (m).

Shoreline Habitat Assessment

The core of the shoreline habitat assessment was conducted during August 7–10, 2002. Data collected during previous and later outings were also integrated into the assessment. Thus, we were able to observe shoreline habitat conditions from a high lake level (330.8 m) to a very low lake level (318.1 m). The assessment consisted of collecting qualitative information on shoreline characteristic including: substrate types, aquatic flora (emergent and submergent vegetation), cover types and abundance, and riparian plant community. The assessment was carried out by walking portions of the lake perimeter and the drawdown down zone. Plant samples were collected and were later identified using popular BC field identification keys.

4. RESULTS – STREAM ASSESSMENT

4.1 Stream Habitat Surveys

The stream habitat surveys were conducted from June 3–21, 2002 during which reservoir levels ranged from 330.8 m to 330.5 m (close to full pool). Surveys were completed on all Elsie Lake tributaries with road access (only three small creeks on the southeast side of the lake were omitted). In all, 20 creeks were examined resulting in a combined survey length of 9.1 km of stream. Locations of the study streams were shown previously in Figure 2 (p. 10).

Table 4 summarises results of the habitat surveys on Elsie Lake tributaries. The discharge, channel width, and wetted width data (columns B, G, and H, respectively), show that in early June, most Elsie Lake tributaries are quite small with flows measured in L/s, channel widths < 5 m, and wetted widths < 2 m (note, some of the channels have been unnaturally widened by torrent events associated with upstream roads and culverts). The most significant tributaries in terms of flow, included the Upper Ash River (11.3 m^3/s), Ramsay Creek (1.8 m^3/s), Katlum Creek (0.4 m^3/s), and Creek 2 (0.3 m^3/s). These four tributaries contributed 99.87% of total Elsie Lake inflows at the time of the habitat surveys.

An important goal of the stream habitat surveys was to determine which streams were accessible to trout for spawning. Because of this goal, it was desirable to undertake the surveys during the trout spawning period in order to capture habitat and access conditions under appropriate stream flows (WUP studies in 2001 showed that many of the smaller streams became dry as summer progresses).

Angling at the mouths of some of the creeks demonstrated that rainbow trout were in their spawning phase during the first half of June[2], while cutthroat had probably spawned a month or more earlier. Thus the habitat surveys captured stream conditions representative of rainbow trout migration and spawning, but not necessarily of cutthroat trout.

The stream surveys revealed 3 conditions that prevent fish in Elsie Lake from gaining access to a particular tributary: 1) insufficient flow, 2) barriers or subsurface flow at the mouth, and 3) excessively high gradient at the mouth. As a result of these conditions, there were only four or five creeks that demonstrated a combination of sufficient flow (≥ 10 L/s), favourable gradient, and access at the mouth. These included the Upper Ash, Katlum Creek, Creek 2, Creek 10, and possibly Ramsay Creek. There was some uncertainty regarding access to Ramsay Creek due to the numerous cascades in its lower reach (discussed later in this section). Minor creeks with a small amount of length available for trout included Creeks 1, 7, 9, and 15. Total stream length available for adfluvial trout at the survey flow was only about 1.18 km without Ramsay Creek, but jumps to 13.73 km if Ramsay Creek is accessible (Column E in Table 4).

In years with higher spring runoff than experienced in 2002, it is likely that more of the minor tributaries would have sufficient flow to permit fish access. Column D in Table 4 shows potential stream length available to adfluvial fish under increased flows (values indicate stream length from the mouth to the first major physical barrier). Thus, under higher spring flows, the number of streams potentially available to adfluvial fish increases from 9 to 14, and available stream length increases to about 2.09 km without Ramsay Creek and to 14.64 km if Ramsay Creek is accessible.

[2] In 2002 the main rainbow spawning was probably mid May to mid June with spawning mostly complete by the end of the second week in June. Cutthroat trout were well past the kelt stage.

Table 4. Summary of habitat data collected on Elsie Lake inlet tributaries (June 3 – 21, 2002).

(A) Stream	(B) Discharge At Time Of Survey	(C) Survey Distance	(D) Distance To Adfluvial Barrier	(E) Available Length At Survey Flow	(F) Mean Field Gradient	(G) Mean Channel Width	(H) Mean Wetted Width	Mean Substrate Characteristics						Mean Cover Characteristics						
								Fi	Gr	Co	Bo	Br	D95	Bo	LWD	SWD	IV	OV	CB	DP
	(m^3/s or L/s)	(m)	(m)	(m)	(%)	(m)	(m)	(%)	(%)	(%)	(%)	(%)	(cm)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Upper Ash, R1	11.3 m^3/s	1,338	35	35	1.6	19.5	19.5	1	5	31	41	17	140	24	0	0	0	2	0	13
Upper Ash, R2	11.3 m^3/s	1,050	—	—	0.4	28.5	27.0	15	68	18	0	0	9	0	0	0	0	7	3	0
Ramsay Creek, R1	1.8 m^3/s	930	—	—	3.5	17.1	13.2	3	8	38	43	9	313	35	0	0	0	1	0	3
Ramsay Creek, R2	1.8 m^3/s	1,877	12,550	(12,550)	0.6	19.8	18.8	19	19	47	15	0	80	12	0	0	0	9	3	0
Katlum Creek, R1	0.4 m^3/s	982	157	157	2.6	9.7	7.2	14	24	39	20	3	89	11	1	0	0	6	2	1
Katlum Creek, R2	0.4 m^3/s	50	—	—	2.0	7.7	5.0	20	30	50	0	0	20	ns						
Creek 1	0.5 L/s	80	20	3	5.4	3.0	1.0	23	48	15	6	9	15	0	6	8	0	5	4	0
Creek 2	0.3 m^3/s	1,148	813	813	5.2	15.3	10.1	4	9	25	27	31	122	14	0	0	0	5	0	2
Creek 3	0.01 L/s	74	0	0	40.8	2.5	0.3	8	30	40	23	0	33	6	6	3	0	3	3	0
Creek 3a	Dry L/s	20	0	0	36.0		Dry	ns						ns						
Creek 3b	Dry L/s	20	0	0	36.0	2.5	Dry	10	15	45	30	0	40	ns						
Creek 4b	0.2 L/s	101	0	0	17.1	2.2	0.7	38	23	23	18	0	25	5	0	28	0	5	0	0
Creek 5	0.1 L/s	20	0	0	38.0	1.8	0.2	20	15	20	45	0	30	70	0	0	0	15	0	0
Creek 6	2.5 L/s	98	49	0	19.4	2.7	0.8	40	35	20	5	0	17	1	5	30	0	5	10	0
Creek 6b	2.5 L/s	245	350	0	4.0	2.2	1.3	33	41	20	6	0	16	4	3	8	13	20	8	0
Creek 7	0.8 L/s	219	40	3	5.6	2.5	1.9	49	40	10	1	0	9	0	13	27	0	26	0	0
Creek 7b	1.0 L/s	50	0	0	20.0	ns	ns	ns						ns						
Creek 8	Dry L/s	30	30	0	1.0	ns	Dry	ns						ns						
Creek 9	0.3 L/s	186	112	14	5.0	2.8	1.4	8	18	58	15	3	31	12	2	1	0	2	1	0
Creek 10	10.0 L/s	275	275	129	8.0	4.1	2.3	10	23	39	27	0	57	23	0	0	0	0	0	0
Creek 13	0.3 L/s	156	77	0	8.0	3.7	1.2	8	35	35	18	0	35	8	0	0	0	4	0	0
Creek 14	0.1 L/s	58	47	0	16.0	2.7	0.7	13	39	16	30	3	43	15	1	3	0	2	2	0
Creek 15	0.1 L/s	112	81	27	4.5	4.2	1.7	8	28	10	24	32	27	0	9	0	0	0	1	0
Totals (w/o Ramsay)			2,085	1,182																
Totals (with Ramsay)	13.7 m^3/s	9,118	14,635	13,732																

Because of the potential importance of the Upper Ash River, Ramsay Creek, Katlum Creek, Creek 2, and Creek 10, the following is a brief description of the survey reaches for these streams. Descriptions draw upon data in Table 4 as well as general notes collected during the field surveys. References to stream mouths refer to the stream-lake connection when Elsie Lake is at full pool (i.e., an elevation of 331 m).

Upper Ash River

We surveyed the lower 2.4 km of the Upper Ash River encompassing two distinct reaches. The lowermost reach (Reach 1) is 1.3 km in length with a channel flowing through a steep walled canyon. Stream substrates are coarse and dominated by boulders, cobbles, and bedrock. The average field gradient was 1.6% but there are numerous bedrock cascades much steeper than this. In the lower portion of this reach there are a number of deep canyon runs and pools and adult trout (20 – 30 cm in length) were observed to be holding and feeding from within these habitats.

In Reach 2 the valley walls open up, stream gradient diminishes (average 0.4%), and the channel becomes wider and more meandering comprised mainly of riffle/glide sequences. Substrate materials in this reach were found to be dominated by cobbles and gravels, and excellent spawning habitats were found, particularly toward the upper extent of our survey.

A significant feature of the Upper Ash River is a 3.6 m rock falls located in Reach 1, 35 m above the mouth (Photo 1 in Appendix A). This falls was felt to be a barrier to adfluvial trout during spawning migrations, however, we could not rule out the possibility that larger trout may be able to ascend the falls in late summer when flows in the Upper Ash are substantially reduced (in July trout were observed attempting to jump the first step in the falls, although none were successful). Our conclusion is that this falls likely prevents Elsie Lake trout from accessing the abundance of high quality spawning habitat located in Reach 2 of the Upper Ash River.

Ramsay Creek

Habitat surveys on Ramsay Creek covered 2.8 km of stream encompassing the first 2 reaches above the mouth. Within the first reach (0.9 km) the river is confined within steep valley walls with a channel characterised by step cascades (mean gradient 3.5%). Substrates tend to be coarse (mainly boulders and cobbles, with spawning gravels restricted to a few isolated pockets along the stream margin. Photo 4 in Appendix A shows typical habitat in this reach. The reach offers excellent rearing habitat for trout parr (age 1^+ and older). No complete fish passage barriers were found in this reach, however, a 1.1 m falls 120 m above the mouth and the numerous cascades may make ascent difficult. Observation of one adult trout in spawning colour half way up the reach attests that passage is possible for at least some fish.

In Reach 2 the valley walls open up, the channel widens, and the gradient diminishes to an average of 0.4%. Dominant substrates include cobbles, gravels, and fines. Spawning gravels were initially in pockets but became virtually unlimited beginning at 2.1 km from the mouth. Fresh redds were found in some of the pocket gravel locations and became more plentiful at the 2.1 km point. Hand digging within a few redds indicated that development was at the eyed egg stage (June 20). Given the distance from the lake, and the diversity of habitat in upper Ramsay Creek, it was difficult to say whether the redds observed at the 2.1 km point were from adfluvial fish or from stream resident spawners.

Katlum Creek

In the reach above Elsie Lake (Reach 1), Katlum Creek tends to have a relatively straight channel with the sections entrenched between bedrock walls or within a stable gully. The average channel width 9.7 m and the field gradient from field survey was 2%. At 157 m above the mouth there is a large log jam that has created an impassable barrier in the form of a 3 m fall onto a bedrock shelf (see Photo 2 in Appendix A). The arrangement of the log jam however, has allowed some spawning gravels to accumulate below the log jam. A few small pockets of gravel were also found in pool tailouts between the log jam and stream mouth. The occurrence of redds and eggs found in these pockets suggested that every available spawning space had been utilized in spring 2002. This may be because of the proximity of these spawning sites to Elsie Lake, and because the lower 157 m has easy access.

Creek 2

The habitat survey on Creek 2 encompassed the first 1.1 km of stream above the mouth. The channel in this reach has an average width of about 15 m and is confined within stable banks. Longitudinally, this reach has a step-cascade profile with an average gradient of about 5%. Substrates are dominated by cobbles and boulders with the exception of several sections where the stream flows over bedrock shelves. Upstream migration of adfluvial fish is possible for the first 813 m at which point a 5 m rock falls blocks further ascent. Spawning habitat is very limited below this barrier and occurs only in isolated pockets, primarily within the first 140 m above the mouth. Although not extensive, one of the key spawning areas for this creek is on the fan at the creek mouth (~30 m below the logging road bridge crossing). Unfortunately, this area is inundated at full pool and thus its availability for spawning is dependent on reservoir level.

Creek 10

Creek 10 is substantially smaller than the creeks previously described, however, it is included here because it appeared to have sufficient flow to permit adults to ascent for at least part of its length. The survey on this creek extended upstream for 275 m, at which point a complete barrier was encountered (2 m vertical rock falls). However, at the survey flow (10 L/s) adult trout may only be able to ascend to a cascade at 129 m (11% gradient on the cascade). This stream runs across the forest floor with little vertical erosion (down-cutting) but with some lateral erosion of banks. The average gradient within the survey reach was 8% and the average channel width about 4 m. Spawning gravels occur in pockets with the best gravel in the 30 m section between Elsie Lake and the logging road.

Spawning Habitat

During the stream habitat surveys, potential spawning gravels were quantified whenever they were encountered. Table 5 shows total amounts of spawning gravel within the accessible reach for each stream surveyed (3^{rd} column), as well as amounts above adfluvial barriers (5^{th} column). The 4^{th} column shows the amount of spawning gravel in the study streams below full pool and provides an estimate of available spawning gravel before impoundment of Elsie Lake. The latter data were collected in 2001 as part of the WUP program, and encompassed stream surveys from 318.7 m to 331 m elevations.

Column 3 of Table 5 shows that without Ramsay Creek, Elsie Lake tributaries only provide a total of 82 m^2 of spawning gravel. When Ramsay Creek is included, available gravel increases to 1,592 m^2. Thus, the majority (95%) of potential spawning gravel for Elsie Lake trout is supplied by Ramsay Creek. This assumes that trout are able to ascend the cascades in Reach 1 of Ramsay Creek to gain access to spawning habitats in Reach 2. There is some circumstantial evidence that some trout have difficulty migrating up Ramsay Creek. For example, rainbow trout were observed milling back and forth off the mouth of Ramsay Creek on June 4 2002, and when some of these fish were subsequently angled, they were found to be in an advance stage of ripeness (eggs and milt extruded with light pressure on the abdomen).

Column 4 in Table 5 shows that prior to the impoundment of Elsie Lake and the lower reaches of its tributaries, there was about 37,000 m^2 of spawning habitat available to adfluvial fish. This represents a 96% loss of spawning habitat that was historically available to Elsie Lake fish. The greatest contributor of historic spawning gravel was the lower section of the Upper Ash River (~34,000 m^2) (see Photo 3 in Appendix A). The reason that such large amounts of spawning gravel were inundated is that Elsie Lake is situated in a bowl with lowest gradients closer to the original lake elevation. Tributaries flowing through these lower gradient areas naturally accumulate spawning sized substrates due to reduced tractive forces.

The last column of Table 5 shows that a major accumulation of spawning gravel lies in Reach 2 of the Upper Ash River. This habitat is currently not available to Elsie Lake trout due to a 3.6 m rock falls located 35 m above the mouth. This falls consists of three steps of 1.1, 1.5, and 1.0 m (see Photo 1 in Appendix A). Restoration options that provided access over this falls would more than double the amount of spawning habitat currently available to Elsie Lake trout.

General observation of redd locations during the course of the habitat surveys, and of freshly emergent fry during later surveys (July), suggested that spawning habitats close to stream mouths were being fully utilised whenever gradients and flow permitted access. In some cases this was only a few small pockets within the first several meters from the lake. In other cases greater length was available (e.g., Katlum Creek). Pockets of gravel no larger than 0.1 m^2 were being utilised, and some sites were very poor quality (e.g., 5 cm of gravel over a bedrock shelf).

Table 5. Quantities of spawning gravel currently available in Elsie Lake tributaries. Spawning gravels below full pool are also shown to illustrate gravel available to Elsie Lake trout prior to impoundment.

Stream	Distance Full Pool To Adfluvial Barrier	Quantity Of Spawning Gravel		
		Full Pool To Adfluvial Barrier	Below Full Pool [a]	Above Adfluvial Barrier
	(m)	(m^2)	(m^2)	(m^2)
Upper Ash, R1	35	0	33,549	46
Upper Ash, R2	—	—		1,700+
Ramsay Creek, R1	—	11	49	
Ramsay Creek, R2	12,550	(1,500+)[b]		
Katlum Creek, R1	157	13	579	121
Katlum Creek, R2	—	—		
Creek 1	20	2	12	
Creek 2	813	23	192	
Creek 3	0	0	116	
Creek 3a	0	0		
Creek 3b	0	0		
Creek 4b	0	0	11	
Creek 5	0	0	0	
Creek 6	49	0.2	2	
Creek 6b	350	18		
Creek 7	40	5	5	
Creek 7b	0	0		
Creek 8	30	0		
Creek 9	112	5	544	
Creek 10	275	6	1,483	
Creek 13	77	1	36	
Creek 14	47	1	10	
Creek 15	81	8	14	
Totals (excluding Ramsay)	2,085	82		
Totals (including Ramsay)	14,635	1,593+	36,602	1,867
Total all creeks as % of pre-impoundment gravel		4%	96%	

Note:

[a] Amounts of spawning gravel below full pool are from WUP surveys conducted by DBA and CBR & Associates in 2001 and encompassed habitat surveys of Elsie Lake tributaries from the 318.7 m elevation to full pool (331 m).

[b] Spawning gravel in Ramsay Creek is shown in brackets because it is not know whether fish can access the main spawning beds in Reach 2.

4.2 Stream Population Surveys

Location and Habitat Characteristics of Fish Population Sites

During September 15–19, 2002, 6 total removal electrofishing sites were completed on Elsie Lake tributaries. Sites were located on Katlum Creek (2 sites), Ramsay Creek (2 sites), the Upper Ash River (1 site) and Creek 2 (1 site). Site locations are shown in Figure 2. For sites where few or no parr were captured, additional spot shocking was undertaken to determine the presence of these older age groups. The upper site on Katlum Creek (site 2) and the site on the Upper Ash River were situated above barriers, and therefore sampled fish were likely from stream-type adults as opposed to lake-type fish captured at the other sites. The general habitat characteristics of the 6 electrofishing sites are shown in Table 6. Photos of the 6 sites are provided in Appendix A (Photos 5–10).

Table 6. General habitat characteristics of the 6 fish population sites on Elsie Lake tributaries.

Site	Stream	Distance From Mouth	Conduc-tivity	Mean Depth	Mean Velocity	Cover		Substrate	
		(m)	(µs)	(m)	(m/s)	%	Dom/ Subd	Dom/ Subd	D95 (cm)
EL01	Katlum Creek	90	70	0.15	0.03	16	B/OV	Co/Gr	70
EL02	Katlum Creek	225	84	0.10	0.03	34	OV/Log	Gr/Fi	17
EL03	Ramsay Creek	200	43	0.29	0.17	50	B	Bo/Co	90
EL04	Ramsay Creek	1,270	46	0.16	0.06	10	OV/B	Gr/Co	80
EL05	Ash River	5,770	30	0.08	0.07	10	OV	Gr/Fi	12
EL06	Creek 2	2	50	0.29	0.05	51	B/OV	Bo/Co	60

Notes

Cover codes: Log=logs, B=boulders, IV=instream vegetation, OV=overstream vegetation, CB=cutbanks.

Substrate codes: Fi=fines, Gr=gravel, Co=cobble, Bo=boulder.

Fish Population Characteristics

Fish species captured in stream sample sites included rainbow and cutthroat trout, and possibly some hybrids of the two species. Species identification of fish in their first year (age 0^+) was sometimes difficult due to lack of development of distinguishing characteristics, and because of an overlapping of rainbow and cutthroat characteristics (possible hybridization). Older age groups were more easily distinguished, however, here too some fish showed overlapping characteristics. Because of the identification difficulties with age 0^+ fish, we have lumped all age 0^+ fish as trout (abbreviated as TR) in much of the analysis.

The length frequency distribution of juvenile trout from all stream sample sites is shown in Figure 3. This histogram includes both rainbow and cutthroat trout and is based on a sample size of 309 fish. Arrows at the base of the chart show the general size range of each age group. Age designation was based on review of fish size distributions on a site by site basis in conjunction with results from scale analysis (25 scale samples). It should be noted that these size-at-age boundaries are not absolute, but rather some overlap was observed between the different age groups. Another point worth noting is that during sampling there appeared to be two size groups within the age 0+ fish. We could not determine whether this was due to two groups of rainbow spawning and emerging at different times, or whether one group was cutthroat fry and the other rainbow fry (circumstantial evidence suggests cutthroat adult spawn 1–4 months earlier than rainbow).

The distribution of lengths in Figure 3 shows that age 0+ fish dominated the trout population within Elsie Lake tributaries, followed by 1+ fish, and then 2+ fish. Mixture analysis (MIX 3.1 software) indicated that the stream populations were comprised of 88% 0+, 9% 1+, and 3% 2+ fish.

Length, weight, and condition factor statistics for all juvenile trout captured by electrofishing in Elsie Lake tributaries are summarised in Table 7. Among the parr age groups (1^+ and 2^+), rainbow were on average smaller than cutthroat, but had a higher condition factor than cutthroat. The differences in condition factor indicate that at a given length, rainbow tended to have a “fatter” body shape than cutthroat.

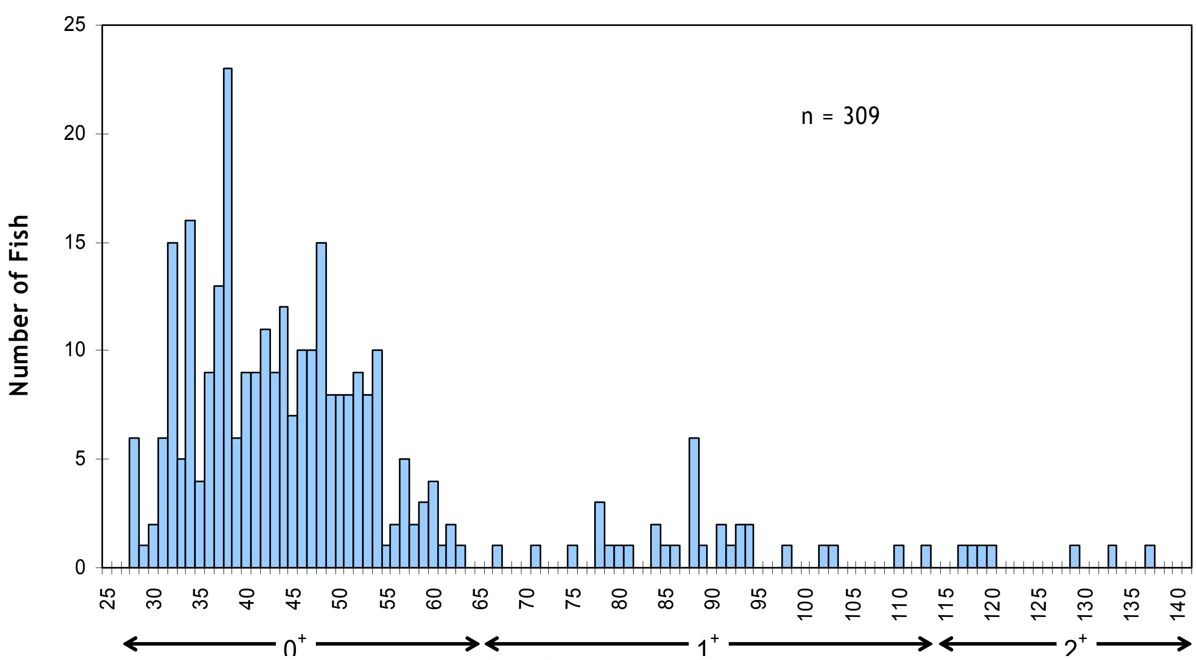

Figure 1. Length frequency distribution of juvenile trout from tributary fish population sites (rainbow and cutthroat combined).

Table 7. Mean Length, weight, and condition

factor for trout captured in Elsie Lake tributaries (September 15–19, 2002).

Age		n	Mean Length (mm)	Length Range (mm)	Mean Weight (g)	Mean K
0^+	Trout	270	43	28-63	0.9	1.01
1^+	Rainbow	12	83	67-102	6.5	1.11
	Cutthroat	21	94	78-120	9.5	1.08
2^+	Rainbow	4	112	85-129	16.8	1.15
	Cutthroat	2	135	133-137	25.1	1.02
All Ages	Trout	309		28-137		1.02

Notes:

Statistics are based on fish captured from total removal electrofishing sites and from spot electrofishing.

K = Fulton's condition factor (Weight$_{(g)}$ ÷ Length^3 x 100,000).

Density and Biomass of Tributary Fish Populations

The objectives of stream population surveys were to 1) determine the relative abundance of fish in the various Elsie Lake tributaries using fish density as an index of abundance, and 2) determine the level of habitat saturation by relating fish biomass to the theoretical maximum biomass based on stream alkalinity (from Ptolemy 1993). Both density and biomass were adjusted by the weighted usable Area (WUA) within the electrofishing enclosures as derived from depth/velocity transects completed within the site enclosures. These adjustments tend to remove variances associated with differences in depth and velocity between sites and allows for more meaningful comparison among sites. For simplicity, and because of difficulties distinguishing rainbow and cutthroat fry (age 0^+), both species were lumped in this part of the analysis. In this report density and biomass are expressed as fish per unit area (FPU) and biomass per unit area (BPU), where the unit area is 100 m^2.

Table 8 summarises the results of the density and biomass calculations for each fish population site. It is important to note that sites EL02 on Katlum Creek and EL05 on the Upper Ash River are above major barriers, and thus density and biomass values likely reflect spawning from stream resident fish as opposed to spawning from Elsie Lake populations.

Table 8. Summary of trout density and biomass statistics from electrofishing sites on Elsie Lake tributaries.

Site	Stream	Above or Below Barrier	Site PUA %	Adjusted Density (fish/100 m^2)	Adjusted Biomass (g/100 m^2)	Alkalinity (mg/L)	Theoretical Maximum Biomass (g/100 m^2)	Biomass as Percent of Maximum (%)
0^+ Age Group								
EL01	Katlum Cr.	Below	68	113.3	90.8	41	232	39
EL03	Ramsay Cr.	Below	53	86.7	98.6	24	178	55
EL04	Ramsay Cr.	Below	74	59.4	33.6	24	178	19
EL06	Creek 2	Below	50	237.6	258.6	27	189	137
EL02	Katlum Cr.	Above	60	239.0	217.5	41	232	94

EL05	Ash R.	Above	77	6.4	6.1	20	162	4
1^+ Age Group								
EL01	Katlum Cr.	Below	50	37.4	295.9	41	232	128
EL03	Ramsay Cr.	Below	48	0.0	0.0	24	178	0
EL04	Ramsay Cr.	Below	21	0.0	0.0	24	178	0
EL06	Creek 2	Below	70	33.7	329.2	27	189	174
EL02	Katlum Cr.	Above	10	0.0	0.0	41	232	0
EL05	Ash R.	Above	11	0.0	0.0	20	162	0

Notes:

Site PUA = Percent Usable Area = weighted usable area as a percent of total site area. Weighting was based on rainbow habitat suitability index curves (see Methods).

Adjusted density = Observed density ÷ PUA × 100

Adjusted Biomass = Observed biomass ÷ PUA × 100

Theoretical Maximum Biomass = $(\text{Alkalinity})^{.5}$ × 36.2 (see Ptolemy 1993)

Percent of Maximum biomass = Adjusted Biomass ÷ Theoretical Maximum Biomass × 100

In Figure 4, adjusted densities of 0^+ and 1^+ trout from Table 8 have been plotted to provide a visual comparison among streams. Bars for EL02 and EL05 (above barriers) were given a hatched fill to distinguish them from the other sites. For sites below barriers, fry densities ranged from 59 – 237 FPU and parr densities from 0 – 37 FPU. Katlum Creek and Creek 2 had the highest densities for both fry and parr age groups. These creeks have easy access at their mouths (in spring) and pockets of spawning gravel close to the mouth. On the other hand, Ramsay Creek has a 900 m long step cascade section (beginning with a 77 m long cascade of 5% gradient) before any significant amount of spawning gravel occurs.

For sites above barriers, EL02 (Katlum Creek) had a very high density of fry while EL05 (Upper Ash River) had the lowest fry density of all fish the population sites. No 1^+ parr were captured at either of these sites, however, moderate numbers were caught spot shocking near EL02 and one parr near EL05. The high abundance of fry at EL02 on Katlum Creek may be explained by the observation of 4 adult trout in a pool immediately above the electrofishing site in conjunction with a sizeable pocket of high quality spawning gravel in the pool tailout. The low abundance of fry at the Upper Ash site indicates low spawning activity, at least in the vicinity of the sample site (stream resident fish).

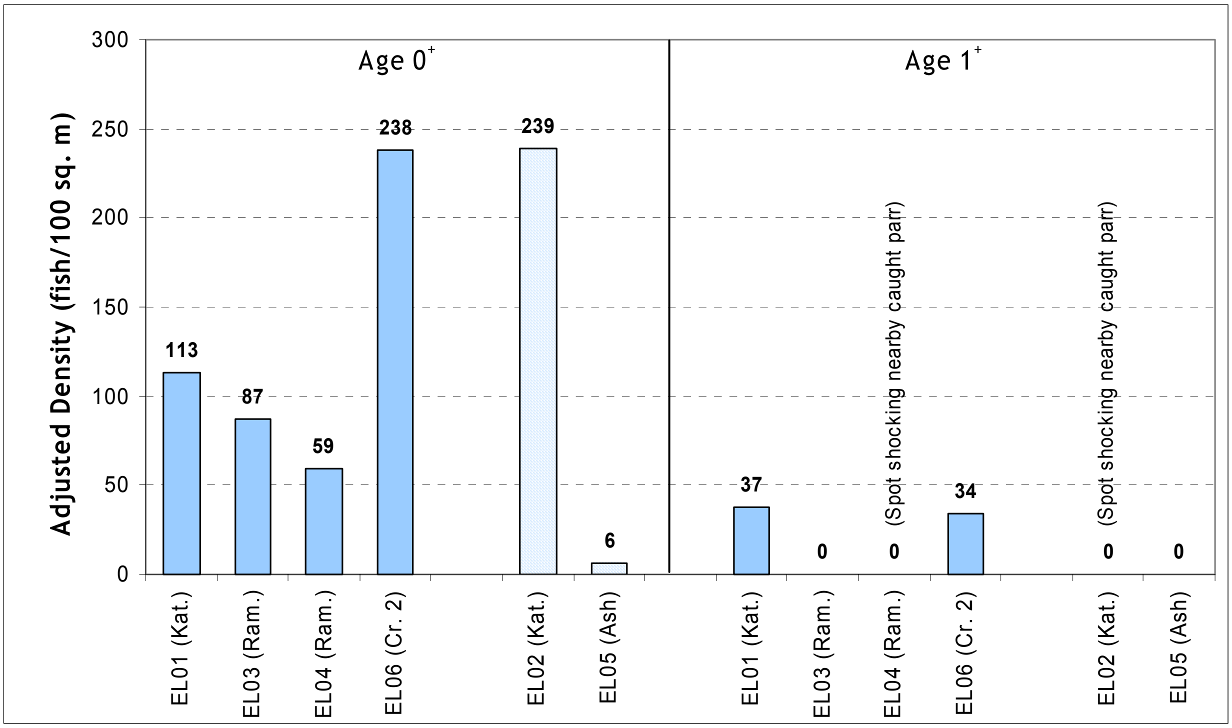

Figure 2. Adjusted density of 0+ and 1+ trout for fish population sites on Elsie Lake tributaries. Hatched bars indicate sites above barriers.

While the abundance of fry in Elsie tributaries reflects spawner activity that spring, biomass is a better measure of the level of habitat saturation. This is because mean weight of fry tends to decrease as fry numbers approach or exceed stream rearing capacity. In Figure 5, adjusted biomass has been expressed as a percentage of theoretical maximum biomass (values are from the last column in Table 8). This approach provides a tool to gauge the level of habitat saturation in Elsie Lake tributaries. The data show several sites with values that approximate or exceed the theoretical capacity biomass. These include the Creek 2 site (for both fry and parr age groups), the upper Katlum Creek site (fry), and the lower Katlum Creek site (parr). In contrast, it would appear that habitat at the Ramsay Creek sites and at the Ash River site is underutilised relative to its capacity.

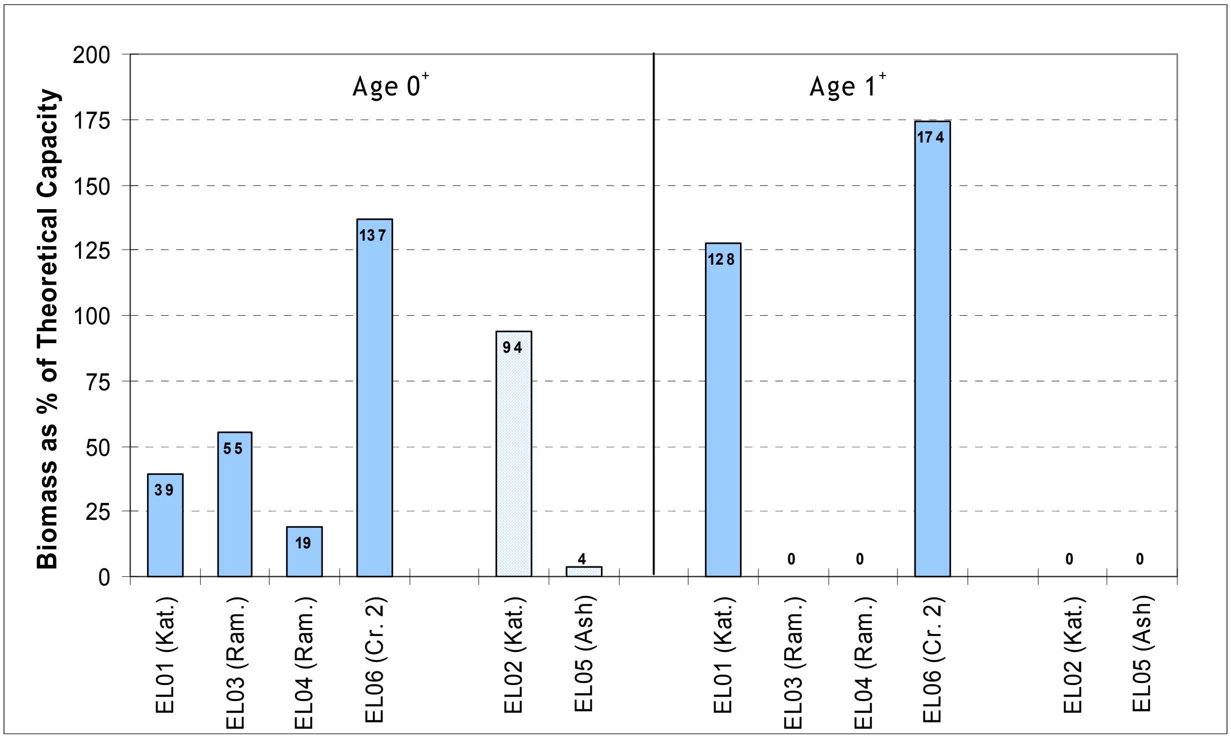

Figure 3. Adjusted biomass of 0+ and 1+ trout as a percentage of theoretical maximum biomass for fish population sites on Elsie Lake tributaries. Hatched bars indicate sites above barriers.

5. RESULTS – LAKE ASSESSMENT

5.1 Lake Habitat Survey

The survey of Elsie Lake habitat occurred from August 7–10, 2002 and was conducted by boat and by walking the shoreline. The boat was launched from ramps located at Creek 2 and at the east side of the main dam. Lake elevation at the time of the survey was 325.1 m, which meant the width of the drawdown zone was 5.9 m (based on a full pool elevation of 331 m).

The slopes surrounding Elsie Lake were comprised of second growth conifers. Dominant species included western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), and Douglas fir (*Pseudostuga menziesii*). A 1951 air photo of the Elsie Lake basin shows that much of the valley was clearcut about this time. Thus much of the timber adjacent to Elsie Lake is about 50 years old. At the full pool elevation line, the plant community changed abruptly to species occurring on the drawdown with virtually no occurrence of riparian vegetation such as alder and shrubs. A few exceptions were found where the initial gradient below full pool was relatively flat. Examples included small areas off the mouths of Creeks 2 and 8 where clusters of shrub willow (*Salix* spp.) extended 30–50 m into the drawdown zone. Plants growing on the drawdown zone consisted primarily of terrestrial species such as western fescue grass (*Festuca occidentalis*), buttercup (*Ranunculus* spp.), and field mint (*Mentha arvensis*). The only aquatic plants found were small clumps of sedge (Kellogg's sedge, *Carex kelloggi*) which tended to occur in depressions fed by groundwater. No submergent plants were observed anywhere around the lake.

Substrates in the drawdown zone varied from silts on lower gradient areas to gravels on steeper slopes. Areas off creek mouths had substrates that ranged from cobbles to sands depending on gradient. Bedrock outcrops were frequent along the northeast shoreline. Fine organic substrates were found in some of the embayments west of BC Hydro's saddle dams.

The sides of Elsie Lake within the drawdown zone are relatively steep and thus from full pool to partial drawdown littoral habitat (< 6 m depth) is restricted to a narrow along the lake margin. The most significant littoral areas were located on shoals off the mouths of Creeks 2 and 8. Given the lack of aquatic plants in littoral areas, however, the function and value of these habitats was uncertain.

Cover for fish was found to be scarce in Elsie Lake, primarily due to the lack of aquatic vegetation. The main source of cover appeared to be remnant root wads on the bottom of the lake (the valley bottom was logged prior to inundation). There were also accumulations of woody debris in the embayments at the northeast end of the lake which likely provide some cover. Given the absence of submergent and emergent vegetation in shoals and lake margin areas, there appears to be little cover for juvenile trout in traditional nursery habitats. Again some nursery cover was provided by the shrub willows off the mouths of Creeks 2 and 8 when lake levels covered these areas (juvenile trout were observed at both locations).

5.2 Limnological Survey

The water quality sampling was conducted on August 7, 2002 at a lake elevation of 325.1 m. The location is shown in Figure 2 (p. 10), and is close to station L2 established by the 2001 WUP survey. This location is the deepest point in the lake.

Dissolved oxygen and temperature profiles taken at this site are shown in Figure 6. Temperatures ranged from 19.7 °C at the surface to 7.2 °C near the bottom and a thermocline was evident between 6 and 11 m. Dissolved oxygen ranged from 9.0 – 11.2 mg/L which indicates favourable levels for fish throughout the water column. A small increase in oxygen was noted between 6 and 11 m, possibly due to photosynthesis by phytoplankton.

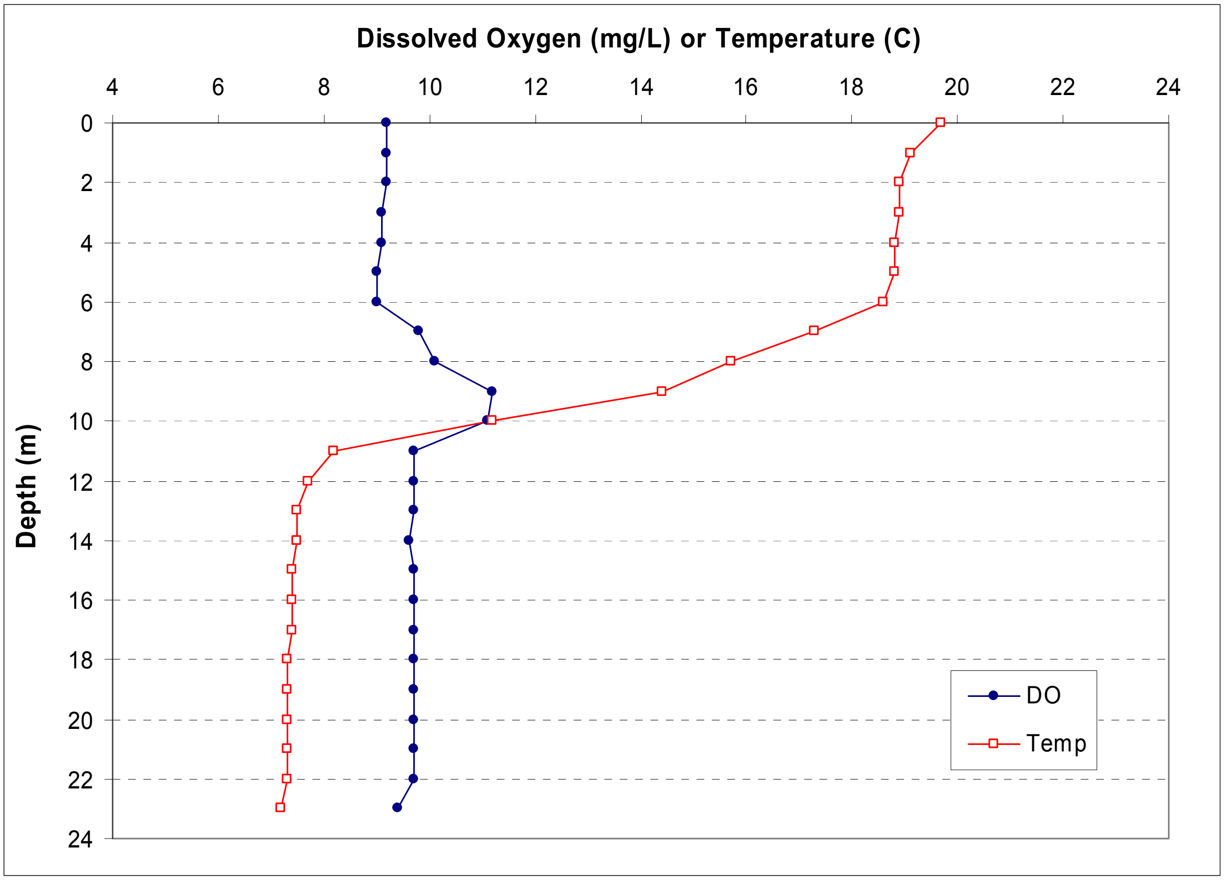

Figure 4. Dissolved oxygen/temperature profile of Elsie Lake, August 7, 2002.

Secchi depth was taken at 1:00 pm under a clear sky and showed an extinction depth of 11.5 m. This is similar to the extinction depth recorded by Triton in May 1994, but deeper than 2 readings by WUP studies in July 2001 (Table 9).

Table 9. Summary of secchi depth readings for Elsie Lake.

Year	Date	Source	Lake Elevation (m)	Secchi Depth (m)
1994	May 25	Triton (1995)	330.9	11.0
2001	July 31	Lewis (2001)	319.0	L2 – 7.6 L3 – 6.5
2002	August 7	This study	325.1	11.5

Water chemistry results from the August 7 samples are shown in Table 10 along with similar data from previous years (1994 and 2001). It would appear that the minimum detectable concentration (MDC) for some nutrient parameters varied among laboratories. Nitrogen, phosphorous, and chlorophyll-a values are all relatively low indicating that Elsie Lake falls in the category of an oligotrophic lake.

Table 10. Summary of water chemistry data from this and previous studies.

Parameter	Units	Strata	This Study Station L2 (7/08/2002)	Lewis 2001 Station L2 (31/07/2001)	Triton 1995 Station L3 (25/05/1994)
pH	pH Units	Epilimnion	7.28	7.41	7.2
		Hypolimnion	6.75	nt	7.1
Conductivity	µS	Epilimnion	41.6	nt	31
		Hypolimnion	49.6	nt	29
Total Dissolved Solids	mg/L	Epilimnion	7	20.4	nt
		Hypolimnion	13	20.5	nt
Total Alkalinity	mg/L	Epilimnion	15	nt	19.9
		Hypolimnion	13	nt	11.7
Total Ammonia N	µg/L	Epilimnion	< 50	2.7	9
		Hypolimnion	< 50	70.2	8
Nitrate N	µg/L	Epilimnion	29	3.24	< 20
		Hypolimnion	< 4	26.4	30
Nitrite N	µg/L	Epilimnion	< 2	1.24	< 5
		Hypolimnion	< 2	nt	< 5
Total Dissolved Phosphate	µg/L	Epilimnion	<1	nt	nt
		Hypolimnion	<1	nt	nt
Total Phosphorous	µg/L	Epilimnion	nt	1.49	< 3
		Hypolimnion	nt	2.46	< 3
Chlorophyll-a	µg/L	Epilimnion	0.6	0.576	nt
		Hypolimnion	nt	nt	nt

nt = Not Taken

5.3 Lake Population Survey

Fish sampling on Elsie Lake involved minnow trapping, angling, and gillnetting. Minnow trap sites were located around the lake margin and often close to creek mouths. In most cases they were placed close to some form of cover (e.g., root wads, logs or boulders). Angling was done off the mouth of Creek 2. Two gillnet sets were completed with a floating gillnet set off the mouth of Creek 2, and a sinking gillnet set off the east side of the island. Locations of all sample sites are shown in Figure 2.

A summary of sampling effort and fish captures are provided in Table 11. Only rainbow and cutthroat trout were captured, with the exception of one fish that appeared to be a hybrid (designated CTB). Catch success in minnow traps was very low: only two rainbow parr despite 15 minnow trap sets. We did however, observe pockets of trout fry along the lake margin and in proximity to some creek mouths. These fry tended to be very small and the low catch rate of 0^+ fish in the minnow traps may have been in part due to fry being able to escape through the mesh of the minnow traps (¼ inch). Of the two gillnet sets, the floating gillnet caught many more rainbow trout than the sinking net, while cutthroat captures were similar for both nets.

Although not captured by us, nor identified in the FISS records, there is some question as to whether kokanee exist in Elsie Lake. This question is raised by the capture of one kokanee during fish salvage activities immediately below the spillway in 2002 (Rick Axford, WLAP Nanaimo, pers. comm.). It is conceivable that a small population of kokanee could exist in the lake and not be detected by gillnet activities (they may reside in the middle portions of the lake and/or occupy depths greater than the gillnet sets).

Table 11. Summary of effort and catch for fish sampling on Elsie Lake during 2002.

Site	Method	Set Time, Date	Pull Time, Date	Effort	Species	CPUE
MT01	Gee Trap	1510, Aug. 6	1706 Aug. 7	25.9 hrs	nil	
MT02	Gee Trap	1650, Aug. 6	1640 Aug. 7	23.8 hrs	1 RB	
MT03	Gee Trap	1705, Aug. 6	1625 Aug. 7	23.3 hrs	nil	
MT04	Gee Trap	1530, Aug. 8	1140 Aug. 9	20.2 hrs	1 RB	
MT05	Gee Trap	1600, Aug. 8	1115 Aug. 9	19.3 hrs	nil	
MT06	Gee Trap	1620, Aug. 8	1105 Aug. 9	18.8 hrs	nil	
MT07	Gee Trap	1735, Aug. 8	1205 Aug. 9	18.5 hrs	nil	
MT08	Gee Trap	1745, Aug. 9	Stolen	—	—	
MT09	Gee Trap	1750, Aug. 9	1640 Aug. 10	22.8 hrs	nil	
MT10	Gee Trap	1805, Aug. 9	1635 Aug. 10	22.5 hrs	nil	
MT11	Gee Trap	1800, Aug. 9	1635 Aug. 10	22.6 hrs	nil	
MT12	Gee Trap	1830, Aug. 9	1720 Aug. 10	22.8 hrs	nil	
MT13	Gee Trap	1840, Aug. 9	1720 Aug. 10	22.7 hrs	nil	
MT14	Gee Trap	1850, Aug. 9	1730 Aug. 10	22.7 hrs	nil	
MT15	Gee Trap	1900, Aug. 9	1720 Aug. 10	22.3 hrs	nil	
AG01	Angling	June 22	—	1 hr	1 RB 4 CT	
GN01	Floating GN	1400, Aug. 8	1330, Aug. 9	23.5 hrs	147 RB 4 CT 1 CTB	6.3 RB/hr 0.2 CT/hr
GN02	Sinking GN	1515, Aug. 8	1515, Aug. 9	24.0 hrs	12 RB 3 CT	0.5 RB/hr 0.1 CT/hr

Population Characteristics

Rainbow trout were the dominant species captured in Elsie Lake (162 fish). The length frequency distribution of rainbow trout from all lake sampling is shown in Figure 7. Arrows at the base of the chart show the general size range of each age group (based on age analysis of 57 scale samples), however, it is important to emphasize that boundaries are not absolute and that overlap was observed between the different age groups.

Rainbow trout ranged in length from 66 mm to 329 mm, and in age from 1^+ to 5^+. The distribution of lengths in Figure 7 suggests that the rainbow population in Elsie Lake is distributed primarily among the 2, 3, and 4 year old age groups. Mixture analysis on the length frequency distribution (MIX 3.1 software) suggested the following composition for the rainbow trout population:

Age 1+	3 %
Age 2+	34%
Age 3+	28%
Age 4+	33%
Age 5+	2%

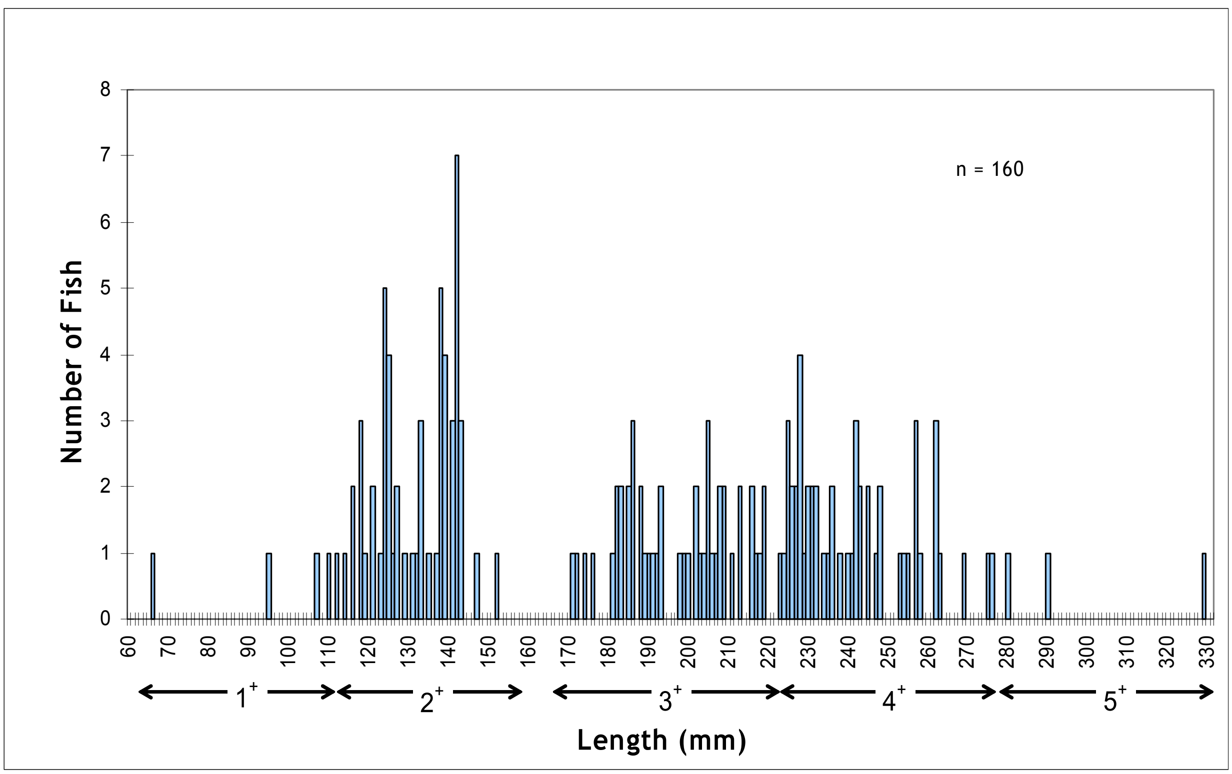

Figure 5. Length frequency distribution of rainbow trout captured in Elsie Lake by gillnet, angling, and by minnow trap.

Cutthroat trout were much less abundant in the lake sampling than rainbow trout (11 fish plus one hybrid). The length frequency distribution of cutthroat trout from Elsie Lake is shown in Figure 8. Ages are indicated above each bar (based on age analysis of 8 scale samples).

Cutthroat trout ranged in length from 133 mm to 400 mm, and in age from 1 to 6 years. The length distribution shown in Figure 8 indicates that the dominant age group was 4^+ fish. The data suggest that the cutthroat population is comprised mainly of the older age groups but this would require greater sampling effort to confirm.

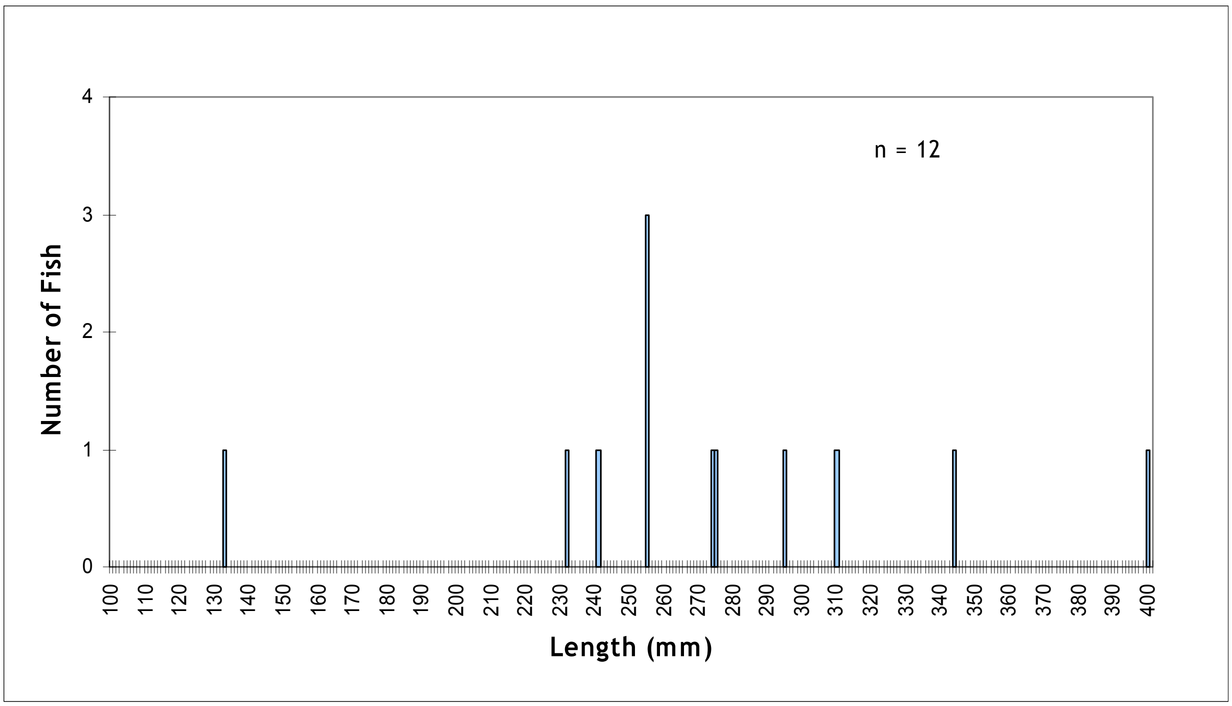

Figure 6. Length frequency distribution of cutthroat trout captured in Elsie Lake by gillnet and by angling (no cutthroat were captured by minnow trapping).

Mean length, weight, and condition factor by age group for all trout captured in Elsie Lake tributaries are summarised in Table 12. Overall, cutthroat tended to be larger than rainbow at a given age, but tended to have a lower condition factor (more slender). For both species there appears to be a slight decrease in condition in older age groups. Rainbow trout were on average smaller than cutthroat, but had a higher condition factor than cutthroat. The differences in condition factor indicate that at a given length, rainbow tended to have a "fatter" body shape than cutthroat.

Table 12. Mean length, weight, and condition factor by age for trout captured in Elsie Lake (August 7-9, 2002).

Age		n	Mean Length (mm)	Length Range (mm)	Mean Weight (g)	Mean K
0	Rainbow	1	66	66	2.9	1.00
	Cutthroat	0	—	—	—	—
1	Rainbow	12	114	95-121	18.6	1.24
	Cutthroat	0	—	—	—	—
2	Rainbow	46	135	118-152	29.0	1.18
	Cutthroat	1	133	133	24.6	1.05
3	Rainbow	51	200	171-231	87.2	1.09
	Cutthroat	0	—	—	—	—
4	Rainbow	45	242	217-275	142.4	1.00
	Cutthroat	8	260	232-295	182.3	1.01
5	Rainbow	5	284	243-329	215.6	0.93
	Cutthroat	2	327	310-344	327.8	0.93
6	Rainbow	0	—	—	—	—
	Cutthroat	1	400	400	640.0	1.00
All Ages	Rainbow	160	188	66-329	84.3	1.09
	Cutthroat	12	272	133-400	231.6	1.00

Notes:
All fish were captured by gillnet with exception of the one 0^+ fish which was captured in a minnow trap.
K = Fulton's condition factor ($Weight_{(g)} \div Length^3 \times 100{,}000$).

Sex determination on 100 rainbow trout from the lake samples indicated that 60% were females yielding a 3:2 sex ratio of females to males. There were insufficient numbers of cutthroat to provide an accurate indication of sex ratio (7 fish sexed: 2 females and 5 males). Visual estimates of gonad development indicated that rainbow trout were either maturing or mature in their third year of life suggesting that first spawning occurs in the third or fourth year of life.

Examination of the stomach contents of lake caught fish found the following food items: snails, ants, beetles, bees, caddis larvae, mayfly nymphs, worms, and chironomids. It is also probable that the larger cutthroat were at least partially piscivorous. Although not specifically identified in fish stomachs, other food items observed around the lake included amphipods (scuds), dragonfly nymphs (Gomphus family), and case caddis nymphs. We were particularly surprised at the abundance of case caddis in the shallows and isolated pools as the lake was drawn down. However, as drawdown progressed over the summer, much of these food items would have perished as their habitat dried up (drawdown rates were as much as 10–20 cm per day during August and September).

6. DISCUSSION

The main objectives of the 2002 BCRP on Elsie Lake were to acquire sufficient knowledge on fish and fish habitat within Elsie Lake and its tributaries, such that factors limiting fish production could be reasonably assessed, which in turn could be used to direct restoration options within the basin.

One of the key lessons from the tributary surveys is that stream habitat available for use by adfluvial trout is in very short supply, about 1.18 km in years with runoff like 2002, and perhaps as much as 2.09 km in wet years (numbers exclude Ramsay Creek). If Ramsay Creek is included, these numbers increase to 13.73 km and 14.64 km, respectively, however, our observations suggest that fish may have difficulty ascending the 900 m long cascade section that comprises the lower Reach Ramsay Creek. In their May 1994 survey, Triton (1995) also questioned the ability of fish to ascend Ramsay Creek. Our best judgement with information to date is that this creek is probably accessible, but only by large or hardier trout individuals.

Another key finding is that spawning habitat is extremely scarce in Elsie Lake tributaries. This is due to the overall lack of accessible stream length, and to the shortage of appropriately sized substrates within accessible sections. The latter is due to the fact that the reservoir has flooded the lower gradient reaches of the inlet streams such that stream mouths are now in the moderate gradient portion of their longitudinal profiles. These gradients are generally too steep to permit the accumulation of spawning gravel. Our results indicated that accessible spawning gravel for all creeks combined amounted to only 82 m^2 (assuming a wet spring and excluding Ramsay Creek). If fish are able to ascend the 900 m cascade section in the first reach of Ramsay Creek, then available spawning gravel increases to 1,593 m^2. The most important spawning streams appear to be Creek 2, Katlum Creek, and if accessible, Ramsay Creek. This said, spawning evidently occurs at the mouths of some of the smaller creeks, even when all that is available is a few isolated pockets of inferior gravel immediately above the lake. Observations of recently emerged fry (~25–35 mm) in the first few metres of some small streams, or in the lake adjacent to their mouths, attested to the potential contribution of these small areas to fry recruitment.

Spawning habitat in Elsie Lake tributaries was also surveyed in May 1994 by Triton (1995). Their surveys were conducted only on the lower portion of the tributaries since the goal was to assess the amount of spawning habitat that would be inundated if flashboards were added to the Elsie Dam spillway in order to raise the storage capacity by an additional 0.9 m. Their results suggested that 512 m^2 of spawning habitat would be inundated by a 0.9 m increase in full pool elevation (102 m^2 for small streams with flow, plus 410 m^2 for Creek 2). This amount is 6-fold greater than our estimate for the entire accessible length of inlet tributaries (82 m^2 without Ramsay). This discrepancy appears to be primarily due to the way in which spawning habitat dimensions were measured. In the Triton survey, it appears that spawning area was calculated by taking the stream width and length within the section that would be inundated under the use of flashboards (even if spawning gravels only occurred in pockets). In our study, spawning area for a given creek was based on estimating the area of each pocket of gravel as it was encountered and summing for the entire accessible stream length. Regardless of these differences, both studies concluded that spawning habitat is in short supply and may very well limit the recruitment of trout to Elsie Lake.

The lack of accessible stream habitat also has implications for the rearing life stages. Given the gradients and barriers in Elsie Lake tributaries, juvenile rearing is restricted to stream sections in the vicinity and downstream of spawning sites. With only short sections of stream available for rearing, it does not take many spawners to produce sufficient fry to saturate available rearing habitat. The biomass of fry and parr in Creek 2 and Katlum Creek support this conclusion (biomass of 0^+ and 1^+ fish was near or greater than the theoretical saturation biomass, Figure 5). The implication is that much of each year's fry population may be forced to migrate to the lake due to competition for food and space resources in the streams.

If a high proportion of the annual fry and parr population rear in Elsie Lake, there is a serious question as to their rate of survival due to the poor quality of nursery habitat within the lake. For example, littoral habitats are for the most part devoid of vegetation (important for food production and cover). At the time that fry enter their rearing phase (~August for rainbow), lake levels are generally partially drawn down such that cover from overhanging vegetation along the lake margin is no longer functional. Cover within the lake itself is primarily restricted to root wads. This general lack of cover in nursery habitats may lead to high rates of predation on trout fry and parr. The main predators are likely to be mergansers and larger rainbow and cutthroat trout (we observed mergansers successfully predate trout parr along the lake margin).

There is some support from our lake survey results for the hypothesis of a high mortality rate among trout during their nursery stages in the lake. For example, in August we observed pockets of small fry along the lake margin, usually in proximity to a creek mouth, however we saw very few parr anywhere along the lake. Also, despite the setting of 15 minnow traps in margin habitats, only two 1^+ parr were captured. Lastly, in our lake sampling, 1^+ parr were underrepresented in the sample population (Figure 7). Additional sampling would be necessary to verify whether the absence of 1^+ fish in our observations and sampling was due to high mortality rates in young fish, or a bias associated with gear selectivity. The worst case scenario is that fry recruitment is limited by a lack of spawning habitat, and that resultant progeny face a high mortality upon entering the lake.

7. RECOMMENDATIONS

The fish and fish habitat survey results suggest that factors mostly likely to be limiting overall fish production within the Elsie Lake basin are a shortage of spawning gravel in the tributaries, and a lack of quality nursery habitat in the lake. Because spawning and nursery habitats appear to be the most crucial, the focus of our prescription surveys in 2002 was on addressing these issues. Proposed prescriptions include the addition of gravel platforms in Katlum Creek and in Creek 2, and the creation of wetland and littoral refuges through dyking. Detailed descriptions of these prescriptions are covered in Part B. Our prescription surveys gathered sufficient information to move ahead with the spawning gravel placements, however, the creation of wetland habitats needs further investigation and will require a feasibility assessment with the aid of an engineer and perhaps a geomorphologist. In Part B we present information gathered to date for the wetland creation concept.

Initially we had also considered a prescription to blast portions of the 3.6 m falls on the Upper Ash River in order to provide fish access past this barrier (see Photo 1 in Appendix A and Figure 2 for location). This is the only serious obstacle on the Upper Ash River and once above the canyon reach there is an abundance of gravel. However, this prescription was subsequently dropped due to the Province's concern of genetic mixing between river resident and lake resident fish.

During the habitat surveys it was apparent that a number of other prescriptions (in addition to those mentioned above) could be instigated to improve the overall health of fish and fish habitat in the Elsie basin. These are described below. Some of these prescriptions may be appropriate for future BCRP funding requests.

Operational considerations

It was apparent from our habitat surveys that a small reduction in lake level below full pool (e.g. 1 m) before or during trout spawning would open up additional habitat for spawning. However, the reduction should not be extensive since the flows in many streams run subsurface in the mid portions of the drawdown (including Creek 2). If such a strategy is employed to increase spawning habitat, it is crucial that the lake not be raised again during incubation period. If lake levels were subsequently raised during incubation, then egg mortality may be high within the inundated redds due to decreased oxygen and removal of waste products. The negative impact of raising lake levels during or after spawning could be substantial given the apparent preference of trout to utilize habitats close to the lake. Lastly, such an operational consideration would need to be coordinated with the WUP process in order to be compatible with downstream fish and wildlife needs.

Maintenance of Stream-Lake Connectivity in Creek 2

As lake levels were drawn down in 2002, all the smaller creeks and one larger creek (Creek 2) had their flows go subsurface in the drawdown zone. While flows above full pool in most of the smaller creeks either dry up or become too low for fish use, Creek 2 sustains year-round flow above full pool and is one of the more important inlet tributaries. In addition, stranding of fry and parr was observed in the drawdown zone of Creek 2. Further, trout captured off the mouth of Creek 2 appeared to key in on insect drift from the creek and loss of the stream-lake connection removes this food source. Thus, future prescriptions may wish to develop options for maintaining the stream-lake connectivity in the drawdown zone of Creek 2. If feasible, this would probably involve creation of a single defined channel within the drawdown zone. The feasibility of this prescription could probably be investigated during the wetland feasibility assessment when the experience of an engineer and/or geomorphologist is onsite.

Riparian planting

Planting of shrubs in the riparian zone would benefit fish populations by providing cover at higher lake levels, and by providing habitat for terrestrial insects (fish food). Riparian plantings are not prescribed by us at this point because this activity will be undertaken by the wildlife BCRP project on Elsie Lake in summer 2003 (see Toth 2003).

Stream Cleaning in Selected Smaller Tributaries

Some of the smaller creeks may be able to provide fish habitat in the spring and early summer if stream cleaning is undertaken in sections immediately above full pool. This would involve the removal of excess woody debris, notching or removal of small log berms, and removal of culvert blockages. Potential streams for this activity include Creeks 1, 6b, 7, and 10. Much of this activity could probably be performed using manual labour. Benefits may be the opening up of short sections of stream immediately above the mouth, with fish use being primarily spawning.

Address Remaining Data Gaps

Perhaps the main data gap still remaining after completion of our study was whether any significant numbers of adfluvial trout are able to ascend the cascades in Reach 1 of Ramsay Creek. Ramsay Creek is the largest inlet tributary (next to the Ash River) and is the only tributary that offers extensive spawning beds (beginning at the 2.1 km point). Possible methods to address this data gap include visual observations at the mouth and at the 1.1 m falls 119 m above the mouth, for the purpose of visually observing whether trout are successfully ascending these obstacles. Another approach may be through radio tagging of adults caught off the mouth in late May – early June and tracking their movements.

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PART B: PRESCRIPTION SURVEYS

1. INTRODUCTION

Results from the fish and fish habitat assessment (Part A), identified two key factors that may constrain the production of trout stocks in Elsie Lake reservoir. These included a shortage of spawning habitat in the inlet tributaries, and a lack of quality nursery habitat along the margin of the lake (i.e., littoral areas). Both habitat deficiencies are a direct result of construction and operation of the Elsie Lake hydroelectric facilities. Thus, the focus of 2002 prescription surveys was on identification of tributaries sites for spawning gravel additions, and location of lake margin areas suitable for wetland creation activities. With respect to spawning gravel additions, one site was identified on Creek 2 (Prescription 1) and one on Katlum Creek (Prescription 2). Detailed level and rod surveys were conducted on these sites in order to develop site specific prescriptions. For the wetland creation prescriptions, 2 sites were also identified: one on the southeast side of Creek 2 and one off the mouth of Creek 16. The wetland prescription sites were surveyed with a total station, however, the feasibility of this option requires further investigation and so we do not present site-specific prescriptions for these sites at this time. However, we do present information gathered to date for this prescription option (Section 6). Locations of the two spawning prescriptions sites and the two wetland sites (potential future prescriptions) are shown in Figure 9.

In the following sections, details are provided on the potential biological benefits, work plan, costing, and monitoring component associated with implementation of each prescription. Also included are analysis techniques and rationale used to develop restoration options. The expected gain from the spawning gravel prescriptions is an additional 137 m^2 of spawning habitat. This would increase readily accessible spawning habitat for all tributaries combined from 82 m^2 to 219 m^2, a 2.7-fold increase in spawning habitat currently available to Elsie Lake trout. These benefits are also explained in greater detail in the ensuing sections.

2. RATIONALE AND PRESCRIPTION SITE SELECTION

The majority of the inlet tributaries of Elsie Lake were found to have insufficient flows to warrant spawning gravel additions. In fact, 80 % of these (16 streams) were completely dry by the end of August or early September 2002. As mentioned in Part A, streams with significant year-round flow were limited to the Upper Ash River, Ramsay Creek, Creek 2, and Katlum Creek. However, our survey of the Upper Ash River suggested that the large quantities of spawning gravel in the second reach of this river (see Table 5) were inaccessible due to a 3.6 m falls near the bottom of Reach 1. The possibility of creating access to the Upper Ash River through blasting of a series of steps was investigated and a level and rod survey completed. This option was subsequently rejected by

MWLAP (due to concerns of genetic mixing), eliminating this prescription as a means of increasing spawning habitat for Elsie Lake fish.

Our habitat surveys also indicated that Ramsay Creek had considerable amounts of spawning gravel, beginning in pockets at 900 m above the mouth, but becoming expansive at 2.1 km. However, we were uncertain as to whether any significant numbers of Elsie Lake trout were able to make use of this spawning gravel. This was due to steep (3.5%), boulder-cascade section comprising the first 900 m from the mouth. We did observe redds beyond the 900 m point, however it was unknown whether these were from river resident or lake resident fish. In addition, our fish sampling captured relatively few juvenile trout in Reach 2. Considering known habitat use, the steep confinement of the channel in Reach 1, and logistics relating to machinery access, the cost-effectiveness of adding spawning habitat in this stream was deemed too poor to warrant development of restoration prescriptions. The various constraints described above limited our restoration options to Creek 2 and Katlum Creek.

In attempt to identify the most appropriate sites for restoration, Creek 2 and Katlum Creek were surveyed and prescription sites selected based on the collection of qualitative and quantitative information. For the most part, the collection of qualitative information consisted of searching for natural spawning gravel deposits by means of visual observation. The process by which these gravels were trapped in 'pockets' was also noted. Our search focused on areas above full pool to avoid issues of inundation at high reservoir levels. Also, observations during stream walks suggested that heaviest spawning use was in areas close to stream mouths.

Following the location of potential gravel placement sites, the area was evaluated in terms of streambed and bank stability, sediment load, stream gradient, discharge, and the natural sequence of pools and riffles. Results from the habitat and fish population surveys were related to these areas to determine whether the existing spawning gravel was being utilised, and whether spawning habitat was available in significant quantities further upstream. In the case of Creek 2, lowest gradient and the majority of existing gravel occurred in the first 100 m above full pool, In the case of Katlum Creek a migration barrier was located 157 m above the mouth. Hence, due to construction cost considerations, gradient constraints, and the observed preference by Elsie Lake fish to spawn close to the lake, our sites were selected near the confluence with Elsie Lake. These sites were deemed as having the highest potential for fish use (see Figure 9).

3. PRESCRIPTION 1: IMPROVE SPAWNING HABITAT IN CREEK 2

3.1 Project Overview

Creek 2 is located on the southwest side of Elsie Lake (Figure 9). It is accessible to lake rearing fish for 800 m above full pool at which point there is a 5 m rock falls. Spawning gravel in the accessible reach is scarce, amounting to a total of 23 m^2 (Table 5). Additional gravel occurs below full pool but its availability is dependent on reservoir level (use of spawning habitats below full pool may result in egg mortalities if lake levels subsequently rise and inundate trout redds).

The proposed prescription in Creek 2 involves the construction of two spawning platforms: one located 11 m downstream from the logging road bridge, and the other located 46 m upstream from the bridge. These locations take into account the natural stepped profile of the stream. Figure 10 provides a plan view, cross-sections, and longitudinal profile of this prescription site. Photos 11 and 12 (Appendix A) provide a visual overview of the upper and lower locations, respectively. The lowest platform site is located immediately above the full pool elevation.

Both sites are characterized by having small isolated gravel pockets on the upstream side of the proposed structures (step tailouts). These gravel deposits are retained in place by larger boulders. The substrate composition in Reach 1 consisted of 27% boulders, 25% cobbles, 31% bedrock, and 13% fines and gravels. The average gradient of Reach 1 was 2% and increased to 5% in Reach 2. Available gravel below the bridge was in short supply and appeared to be fully utilized. There was only one pool within the prescription section (located immediately under the bridge). Stream banks appeared to be stable at all sites. Calculations of tractive force, substrate sizes, flood frequency and magnitude, and construction specifications are presented in *Sections 3.5* and *3.8*.

3.2 Predicted Biological Benefits

The proposed spawning platforms partially address the spawning habitat loss by placing high quality spawning gravels close to the mouth of the stream. The construction of both platforms is expected to increase the available spawning habitat in Creek 2 by a factor of 4-fold (101 m^2 of additional gravel). Assuming 90% fish utilization of this habitat (-10% to exclude stream margins), and considering a mean redd area of 0.2 m^2 per rainbow trout pair (Slaney and Zaldokas 1997), a factor of 4 × redd area for territorial behaviour (Bjornn and Reiser 1991), a mean fecundity of 1500 eggs per female (DFO biostandard), and an accepted 13% egg-to-fry survival rate, the potential biological yield of these structures is a gain of up to 22,300 fry. The proposed platforms could accommodate up to 113 spawning pairs (226 fish). These benefits refer to rainbow trout, however, the platforms are expected to be used by cutthroat trout as well.

3.3 Schedule

Works are to be completed within the BC fisheries operating window and as per conditions outlined under Section 9 of the *Water Act*. As the species composition of Creek 2 is solely comprised of resident fish, the timing of the project does not fall under the jurisdiction of Fisheries and Oceans Canada (FOC). However, any recommendations made by FOC will be considered, and the implementation timing adjusted to meet the recommendations. The operating window for resident salmonids (considering both rainbow and cutthroat trout) in Region 1 is August 1 to September 30.

3.4 Access

Creek 2 is located about 30 km northwest of Port Alberni. It can be accessed by taking the Great Central Lake Road cut-off from Highway 4, proceeding north to the Arc Resort, and then taking the Ash River Road (Ash Mainline) to the west side of Elsie Lake (see Figure 1, Part A, p. 6).

3.5 Work Plan

The construction of each platform involves both streambed excavation and the placement of larger rocks (1 m diameter) across the channel to form a low rock weir (~ 0.7 m high). Excavation would be undertaken to maintain the longitudinal gradient of the stream. The approximation for boulder size and stability was based on methodologies described in Newbury and Gaboury (1993) (refer to *Section 3.8* for details).

The upstream side of the weir would be tapered at a 4:1 ratio, and the downstream side at a minimum of 15:1 ratio (to minimize the risk of failure under flood events). In addition, a gap of approximately 1 m would be left in the thalweg portion of each weir to ensure fish passage during summer low flows. The largest substrate particles (both angular and rocks excavated from the river bed) will be used to build the riffle crest and to armour the downstream slope of the riffle. Remaining large boulders will be used to armour the banks adjacent to the riffle and to roughen the downstream face of the riffle (Allan and Lowe 1997). Trout-sized spawning gravel (0.5–1.5 inches in diameter) would be placed on the upstream side of each weir and layered upstream for a distance of about 5 m. If possible, native gravel would be obtained from nearby sources, otherwise gravels would have to be trucked to the site (e.g., from the gravel pit at the Port Alberni Airport). The proposed structures are spaced 3.7 bankfull widths apart. Further details of this design approach are described in Slaney and Zaldokas (1997, pp. 12-11 to 12-18).

An excavator would perform construction and placement of prescription materials. For the platform above the logging bridge, the machine would operate from the south bank where a relic landing site already exists (probably from bridge construction). For the prescription site below the bridge, the machine would operate from the north bank, accessing the site via the small campsite located on the north shore (Figure 10).

3.6 Construction Monitoring

The construction phase of the proposed prescriptions would be closely supervised by an environmental monitoring crew, following a detailed monitoring program. The program would include specifications and plans on machinery access points, fish removal and exclusion fences, mitigation strategies and sediment control measures, hazardous fluid management, photo-point monitoring (before, during and after completion), safety considerations, and re-vegetation of exposed soils. Details on some of these points are provided below.

Best Management Practices

All instream activities would be conducted in accordance with best management practices and guidelines presented in Environmental Objectives, Best Management Practices and Requirements for Land Development, Region 1 (MOELP 2001), Land Development Guidelines for the Protection of Fish Habitat (Chilibeck 1992), and other relevant documents (e.g., Watercourse Development Permit Area Guidelines 1999, Slaney and Zaldokas 1997, Newbury and Gaboury 1993, etc.).

Fish Removal and Site Mitigation

Trout fry and parr within the work zone would be transferred from the area prior to initiation of work (via electrofishing and netting). Sediment fences and silt traps would be employed, although existing stream substrates have very little fine material (5% fines or less). These may include the combination of any of the following: hay bales, filter fabric, settling ponds, and/or geo-textile mats. The need for building coffer dams and drainage channels would be investigated and built if deemed necessary. In addition, areas disturbed by the excavator would be re-vegetated with grasses and native shrubs. Non-target benefits from the spawning platform installations may be derived from predator species (common loon, common and hooded merganser, American dipper, belted kingfisher, and pine marten have been observed within the watershed).

Hazardous Fluid Management

All operations involving gas-powered tools (e.g., pumps) would be carried out approximately 10 m from TOB. The replenishment of hazardous fluids (e.g., gasoline and oil) would take place approximately 20 m from TOB, in a designated fuelling area (designated in the field prior to commencing the instream works). All heavy machinery operators working in and about the stream would be encouraged to use vegetable-based hydraulic fluids in their units.

3.7 Cost

The costs provided here are for the construction and construction monitoring components of the project (Table 13). Costs associated with post-construction monitoring activities (e.g., those related to monitoring the effectiveness of the spawning platforms) will be presented in the next BCRP funding request.

Table 13. Summary of cost for the construction of spawning platforms in Creek 2.

Task	Cost Per Unit	Units	Fees	Expenses	Contractor
Lowbed transport ($150/hr)	$150.00	9			$1,350.00
Trucking of gravel ($65/hr)	$65.00	20			$1,300.00
Loading/trucking of large rock ($238/hr)	$238.00	8			$1,904.00
Placement of large rock (excavator, $150/hr)	$150.00	10			$1,500.00
Placement of gravel (excavator, $150/hr)	$150.00	10			$1,500.00
Gravel (native gravel, 0.5-1.5 in. dia., $14/m^3)	$14.00	54		$756.00	
Silt traps (hay bales, filter fabric, etc)				$500.00	
Biologist (D. Burt)	$450.00	3	$1,350.00		
Engineer (TBD)	$800.00	1	$800.00		
Hupacasath worker (1 person)	$150.00	3	$450.00		
Meals - biologist	$40.00	3		$120.00	
Mileage - 1 vehicle	$0.40	600		$240.00	
Accommodation - biologist	$95.00	3		$285.00	
Radios – 2	$20.00	3		$60.00	
Electrofisher and stop nets	$100.00	1		$100.00	
Field supplies				$100.00	
Total By Category			**$2,600.00**	**$2,161.00**	**$7,554.00**
Total For Prescription					**$12,315.00**

3.8 Evaluation of Risk

In this report, risk is defined as the possibility of failure of a structure and resulting in damage to the stream. The evaluation of risk is presented in the form of a brief analysis of metered and predicted flood frequency, channel stability and shear stress, and minimum particle size requirements.

Metered Flows and Predicted Flood Frequency

The discharge in Creek 2 was derived from metered depth and velocity data collected in July 2002, and was computed at 0.3 m^3/s. A roughness coefficient (*n*) was calculated from the metered data using Manning's equation (Newbury and Gaboury 1993). The "*n*" value was then used to estimate bankfull flows using the bankfull depth data collected during the prescription survey. Bankfull flows were computed at ~10.9 m^3/s.

The estimates of flood frequency for 1 in 5, 1 in 10, 1 in 20, and 1 in 50 year events were calculated by comparing ratios of watershed area and water yield per unit area using data from WSC station 08HB023 as the reference (Ash River below Moran, 41 years of record). Results are presented in Table 14.

Table 14. Estimates of flood frequency, magnitude, and depth of flow for Creek 2.

Frequency	Flow m^3/s
1 in 5 year	16
1 in 10 year	20
1 in 20 year	23
1 in 50 year	24

Channel Stability, Shear Stress and Particle Diameter

The shear stress and incipient particle diameter ($\varnothing_{particle}$ in cm) was estimated using the calculation for tractive force (τ) described by Allan and Lowe in Slaney and Zaldokas (1997) and by Newbury and Gaboury (1993) as follows:

$$\tau\ (kg/m^2) = 1000 \cdot \text{Depth of flow } (D_{bf}) \cdot \text{Slope of water surface} \cdot 1.5 \text{ (safety factor)}$$

and,

$$\varnothing_{particle}\ (cm) = \tau\ (kg/m^2)$$

The estimate was computed using bankfull flow only, yielding a minimum particle size of 0.87 m. To err on the side of caution and to increase the stability of the proposed structure, a buffer of 20% (0.17 m) was added to the computed particle size. Hence, the key boulders used to build the weir would be approximately 1.0 m in diameter.

Bank and Channel Condition

Photos 11 and 12 (Appendix A) illustrate bank and channel characteristics in the prescription zones. At the lower platform site (Photo 12) both banks were made of a combination of compacted soil, large boulders, and cobbles, and were colonized by a young community of deciduous and coniferous trees. The left bank of the stream was considerably higher than the right bank, with both banks showing a minimal amount of scouring. In fact, signs of bank scouring began appearing only below the full pool level. Although the movement of smaller substrate particles was obvious (based on the amount of gravel found below full pool level and the low abundance of pools in the stream), the channel appeared to be relatively stable, showing no signs of recent lateral movement within the prescription section. The relatively high bank elevation appears to confine the flows and restrict lateral meandering under the 'normal' seasonal conditions observed in the last two years.

At the higher platform site (Photo 11), banks were similar in composition to that described above, with minor differences in overall bank height. Both banks were also colonized by young community of mixed trees. As in the lower platform, bank scouring was minimal and no signs of recent lateral movement were observed.

Summary

Based on calculations of flood frequencies, bankfull flows, and incipient particle diameter, the spawning platforms are expected to remain functional for at least 5 years. When comparing our estimate of bankfull flow with the flood frequency relationship, bankfull flows appear to occur once every 2.7 years. To compensate for the high bankfull flood return rate, a 20 % buffer was added to the particle size to increase the longevity of the structure. The added buffer increases the particle size to 85% of the D95 found in Creek 2, which should enable the structure to withstand 1 in 5 year flood events. The structural integrity of the platform could be at risk during flow events greater than a 1 in 5 flood. Thus, weir maintenance and gravel replenishment may be required periodically (possibly every 5 years).

The risk of negative impacts resulting from the installation of these platforms is anticipated to be minimal. To ensure structural soundness, the construction would follow closely procedures and specifications outlined in this document and those outlined in Newbury and Gaboury (1993) and Slaney and Zaldokas (1997). Direct risk associated with the construction of the platforms would be mitigated during the construction monitoring program as described in *Section 3.6*.

4. PRESCRIPTION 2: IMPROVE SPAWNING HABITAT IN KATLUM CREEK

4.1 Project Overview

Katlum Creek is located on the northeast side of Elsie Lake (Figure 9). This creek is accessible to lake rearing fish for 160 m above full pool at which point there is a 3 m barrier falls caused by a large log jam. Spawning gravel in the accessible reach is scarce, amounting to a total of only 13 m^2.

The proposed prescription in Katlum Creek involves the construction of a spawning platform approximately 13 m upstream of the logging road bridge crossing (and 13 m upstream of full pool). This location already has the features of a glide tailout, but lacks sufficient rock at the bottom end to retain gravel. The intent is to enhance this location by the addition of large angular boulders to the tailout and loading the upstream side with gravel. Structure design would be similar to Prescription 1. Figure 11 provides a plan view, cross-sections, and longitudinal profile of Prescription Site 2. Refer to Photo 13 (Appendix A) for a visual overview of the setting.

This site is characterized by having small isolated gravel pockets along the tailouts of the glide, on the upstream side of the proposed structure. Gravel deposits are retained in place by scattered larger boulders. The substrate composition in this reach (Reach 1) consisted of 20% boulders, 29% cobbles, 3% bedrock, and 38% fines and gravels. The average gradient of the reach is 2.6%. As observed in Creek 2, the gravel in the accessible reach is in short supply and appears to be fully utilized. The prescription site is characterized by having very stable bedrock banks. Calculations of tractive force, substrate sizes, flood frequency and magnitude, and construction specifications are presented in *Sections 4.5* and *4.8*.

4.2 Predicted Biological Benefits

As with Prescription 1, the proposed spawning platform partially addresses the spawning habitat loss in Elsie Lake tributaries. It addresses this problem by placing quality spawning gravels close to the mouth of the creek, and by increasing the available spawning habitat in Katlum Creek within the accessible reach by a factor of 3-fold (an increase of 36 m^2). Assuming 90% fish utilization of the added spawning habitat (-10% to exclude the stream margin), and considering a mean redd area of 0.2 m^2 per rainbow trout pair (Slaney and Zaldokas 1997), a factor of 4 × redd area for territorial behaviour (Bjornn and Reiser 1991), a mean fecundity of 1500 eggs per female (DFO biostandard), and an accepted 13% egg-to-fry survival rate, the potential biological yield of this structure is a gain of up to 7,800 fry. The proposed platform could accommodate up to 40 spawning pairs (80 fish). This biological yield was calculated for rainbow trout only, however, the platform is expected to be used by cutthroat trout as well.

4.3 Schedule

Works are to be completed within the BC fisheries operating window and as per conditions outlined under Section 9 of the Water Act. As the species composition of Creek 2 is solely comprised of resident fish, the timing of the project does not fall under the jurisdiction of Fisheries and Oceans Canada (FOC). However, any recommendations made by FOC will be considered, and the implementation timing adjusted to meet the recommendations. The operating window for resident salmonids (considering both rainbow and cutthroat trout) in Region 1 is August 1 to September 30.

4.4 Access

Katlum Creek is located about 30 km northwest of Port Alberni. It can be accessed by taking the Great Central Lake Road cut-off from Highway 4, proceeding north to the Arc Resort, and then taking the Ash River Road (Ash Mainline) to the Branch 103 junction just prior to crossing the Ash River. Proceed east on Branch 103 which joins with the Valley Link Highway (Comox Mainline) north. Upon approaching Elsie Lake, turn left on a spur road which hooks up with Long Lake Road. Long Lake Road traverses the east side of Elsie Lake and leads to the bridge crossing Katlum Creek (see Figure 1, Part A, p. 6).

4.5 Work Plan

As described in *Section 3.5*, the construction of this platform would involve placement of larger angular rocks (up to 0.9 m diameter) across the channel to form a low rock weir (~ 0.7 m high). The upstream side of the weir would be tapered at roughly a 4:1 ratio, and the downstream side at a minimum of 15:1 ratio (to minimize the risk of failure under flood events). In addition, a gap of roughly 1 m would be left in the thalweg portion of the weir to ensure fish passage during summer low flows. Trout-sized spawning gravel (0.5–1.5 inches in diameter) would then be placed on the upstream side of the weir and layered upstream for a distance of about 5 m. Native gravels would be used if a source can be found, otherwise gravel would be trucked to the site. Further details of this design approach are described in Slaney and Zaldokas (1997, pp 12-11 to 12-18).

The prescription site has steep banks and access by an excavator is not feasible. For this reason, it is proposed that construction of the Katlum Creek spawning platform be performed by a crane operating from the east side of the logging road bridge crossing. The angle of the bridge is such that it puts the crane close to the prescription site. An excavator would be used to load the crane bucket. While use of a crane adds to the cost of the project, this approach would result in virtually no disturbance to riparian vegetation (note: an alternative may be to use a helicopter with a line and bucket).

4.6 Construction Monitoring

Refer to *Section 3.6* for details.

4.7 Cost

The costs provided here are for the construction and construction monitoring components of the project (Table 15). Costs associated with post-construction monitoring activities (e.g., those related to monitoring the effectiveness of the spawning platform) will be presented in the next BCRP funding request.

Table 15. Summary of cost for the construction of the spawning platform in Katlum Creek.

Task	Cost Per Unit	Units	Fees	Expenses	Contractor
Lowbed transport - excavator ($150/hr)	$150.00	9			$1,350.00
Lowbed transport - crane ($300/hr)	$300.00	8			$2,400.00
Trucking of gravel ($65/hr)	$65.00	10			$650.00
Loading/trucking of large rock ($238/hr)	$238.00	8			$1,904.00
Placement of large rock (crane, $300/hr)	$300.00	5			$1,500.00
Placement of gravel (crane, $300/hr)	$300.00	5			$1,500.00
Excavator support for crane ($150/hr)	$150.00	10			$1,500.00
Gravel (native gravel, 0.5-1.5 in. dia., $14/m^3)	$14.00	17		$238.00	
Silt traps (hay bales, filter fabric, etc)				$500.00	
Biologist (D. Burt)	$450.00	3	$1,350.00		
Engineer (TBD)	$800.00	1.0	$800.00		
Hupacasath worker (1 person)	$150.00	3	$450.00		
Meals – biologist	$40.00	3		$120.00	
Mileage – 1 vehicle	$0.40	600		$240.00	
Accommodations - biologist	$95.00	3		$285.00	
Radios – 2	$20.00	3		$60.00	
Electrofisher and stop nets	$100.00	1		$100.00	
Field supplies				$100.00	
Total by Category			$2,600.00	$1,643.00	$10,804.00

Task	Cost Per Unit	Units	Fees	Expenses	Contractor
Total Prescription 2					$15,047.00

4.8 Evaluation of Risk

The evaluation of risk is presented in the form of a brief analysis of metered and predicted flood frequency, channel stability and shear stress, and minimum particle size requirements.

Metered Flows and Predicted Flood Frequency

The discharge in Katlum Creek was derived from metered depth and velocity data collected in July 2002, and was computed at 0.4 m^3/s. As described in *Section 3.8*, a roughness coefficient (*n*) was calculated from the metered data using Manning's equation (Newbury and Gaboury 1993). The "*n*" value was used to estimate bankfull flows using the bankfull depth data collected during the prescription survey. Bankfull flows were computed at 3.4 m^3/s.

The estimates of flood frequency for 1 in 5, 1 in 10, 1 in 20, and 1 in 50 year events were calculated by comparing ratios of watershed area and water yield per unit area using data from WSC station 08HB023 as the reference (Ash River below Moran, 41 years of record). Results are presented in Table 16.

Table 16. Estimates of flood frequency, magnitude, and depth of flow for Katlum Creek.

Frequency	Flow m^3/s
1 in 5 year	15
1 in 10 year	19
1 in 20 year	21
1 in 50 year	23

Channel Stability, Shear Stress and Particle Diameter

The shear stress and incipient particle diameter ($\varnothing_{particle}$ in cm) was estimated using the calculation for tractive force (τ) described in Slaney and Zaldokas (1997) and in Newbury and Gaboury (1993). The estimate was computed using bankfull flow only, yielding a minimum particle size of 0.29 m. These results appeared surprisingly low considering the similarities in watershed area and magnitude of flood events between Katlum Creek and Creek 2. To err on the side of caution and to increase the stability of the proposed structure, we propose the use of particles that are similar to the D95 found in the stream. Hence, key boulders used to build the weir would be approximately 0.9 m in diameter.

Bank and Channel Condition

Photo 13 illustrates channel characteristics at the prescription site. Both banks were made of a combination of bedrock and large boulders, with small sections being colonized by a young community of mixed trees and shrubs. A small landslide has eroded the left bank, leaving a section of bedrock exposed. Displaced boulders resulting from the slide have accumulated at the toe of the bank, leaving the channel partially coupled (note boulders behind person in Photo 13). The large rocks are covered in moss suggesting no recent movement, and are partially covered in moss. The location of the platform would tie into these boulders to reduce material costs and take advantage of the existing site conditions. The left bank of the stream was considerably higher than the right bank, with both banks showing a minimal amount of scouring. Overall, the channel appeared to be relatively stable, showing no signs of lateral movement above full pool. The bedrock nature of the banks confines the flows and restricts lateral meandering.

Summary

Based on calculations of flood frequencies, bankfull flow, and incipient particle diameter, the spawning platforms are expected to remain functional for at least 5 years. When comparing our estimate of bankfull flow with the flood frequency relationship, bankfull flows appear to occur once every 1.2 years. To compensate for the high bankfull flow return rate, we suggest using boulders similar in size to the D95 found in Katlum Creek. This should enable the structure to withstand a 1 in 5 flood. The structural integrity of the platform could be at risk during flow events greater than a 1 in 5 flood. Thus, weir maintenance and gravel replenishment may be required periodically (possibly every 5 years).

The risk of negative impacts resulting from the installation of the platform is anticipated to be minimal. To ensure structure soundness, the construction of the platforms would follow closely procedures and specifications described in this document and those outlined in Newbury and Gaboury (1993) and Slaney and Zaldokas (1997).

5. POST-CONSTRUCTION MONITORING PROGRAM

Following the construction of the proposed structures, a program to monitor structure integrity and biological effectiveness would be undertaken. The program would involve monitoring both direct and indirect performance measures. Ideally, the monitoring program would be carried out over a series of 3-4 consecutive years, so as to provide robust data on the success (or lack thereof) of enhancing spawning habitat in lower reaches of reservoir tributaries.

A possible direct performance measure would involve visual observations of fish actively using the spawning structures. This could be achieved through one-day field trips near the end of each month, beginning in February with a final field trip occurring sometime in mid June. Based on knowledge from Part A, and from the literature, this timing would coincide with the spawning periods for cutthroat and rainbow trout. Each trip would involve visual observations to search for adults, redds, eggs, and alevins using the platforms (and surrounding area). The information collected would be documented using predetermined photo-point monitoring stations. In addition, angling should be undertaken off the creek mouths to capture rainbow or cutthroat trout for examination of sexual maturity (e.g., to further gauge spawning timing per species). The scheduling of field outings would be flexible to enable the monitoring of structures after larger flood events (to ensure their continuous effectiveness after some settling has occurred). This approach would provide monitoring of both biological benefits, and structural integrity of the platforms.

The second component of the program would consist of monitoring indirect performance measures. This could be achieved by comparing before and after quantitative results of fish population assessments (electrofishing with enclosures). Given that fish densities have been estimated during the 2002 surveys, and that these surveys were carried out in areas adjacent to or at the prescription sites, the monitoring task would require returning to these sites and repeating the procedures of the 2002 sampling program. Results from the comparative analysis would provide general information on the status of the fish population in both creeks, while also providing a reasonably sound indication of success or failure of the platforms. This may also provide non-target benefits such as deriving indices for future similar projects.

6. WETLAND CREATION PRESCRIPTION

6.1 Project Overview

During the 2002 field work, the perimeter of Elsie Lake was investigated for locations where dyking could be undertaken to create shallow littoral and wetland zones. Search criteria included areas with relatively flat topography, close to the full pool level, and with year-round water inflow, either from groundwater or from a local stream. Our hypothesis was that the dyking would retain water during drawdown and external inputs of water may keep the enclosed area wetted throughout the year. The field investigation resulted in the identification of 3 potential sites. Two of these sites were surveyed with a total station to develop site-specific topographic maps. The two sites surveyed included an area on the southeast side of Creek 2, and off the mouth of Creek 16. Locations of these sites are shown in Figure 9. The elevation data from the total station surveys were integrated into drawing software to produce Figures 13 to 18 (beginning at the end of this section). The figures illustrate conditions at each site at low pool, full pool, and with the addition of the proposed wetland and dyke. In addition, a visual overview of each site is provided in Photo 14 (Creek 2 site) and Photo 15 (Creek 16 site) (Appendix A).

There are however several concerns that need to be explored before proceeding with these prescriptions. These include 1) the risk of fish stranding within the enclosures when the reservoir level drops below the dykes, and 2) the potential for excessive heating of the water within the enclosure (with detrimental effects on fish). Thus, at this point the feasibility of this endeavour requires further investigation. This would involve a field visit enlisting the expertise of an engineer or geomorphologist, undertaking a literature search for existing templates of this prescription approach (e.g., Canada, US, international), and compiling a feasibility report outlining potential locations, the planned approach, and potential ways fisheries concerns could be addressed.

Rationale for this feasibility assessment is that such a project has the potential to partially compensate the loss of lakeside, littoral, and wetland habitats due reservoir flooding and frequent fluctuation in reservoir level (BCRP Strategic Plan 2001, Volume 2, Chapter 4, Sections 2.3 and 2.4). Review of historical aerial photo images (1951) clearly indicated that Elsie Lake had large amounts of littoral and wetland habitat prior to being dammed. If successful this type of prescription would partially address the loss of habitat, while also potentially increasing food production for fish and providing nursery habitats for juvenile life stages. It is also likely that these types of restoration activities would compensate reservoir impacts on wildlife. If successful, this kind of prescription may serve as a model for BC Hydro reservoirs elsewhere in the Province. A proposal to conduct the feasibility study will be submitted in future BCRP submissions.

6.2 Predicted Biological Benefits

Virtually all freshwater species of fish are dependent to some degree on wetlands. Wetlands are known to be particularly valuable as nursery areas where young fish can shelter from predation prior to migrating to open waters (Davis, no date; Interagency Workgroup on Wetland Restoration, no date). Many wetlands are highly productive ecosystems in large part because they are rich in organic matter and nutrients. These nutrients support organisms within the marsh, but in many instances the nutrients are also transferred to nearby aquatic systems (lakes, rivers, and estuaries), enhancing the productivity of these systems (Interagency Workgroup on Wetland Restoration, no date).

Although quantification of the biological benefits of wetland creation are impossible without further investigation, it seems fair to assume that an increase in aquatic vegetation would yield an increase in micro biota production, and thus an increase in aquatic insect production. It is also reasonable to assume that an increase in insect production (fish food) would yield an increase in fish production. Figure 12 summarizes, in simple form, the expected ecological interactions and benefits resulting from the creation of wetland habitats.

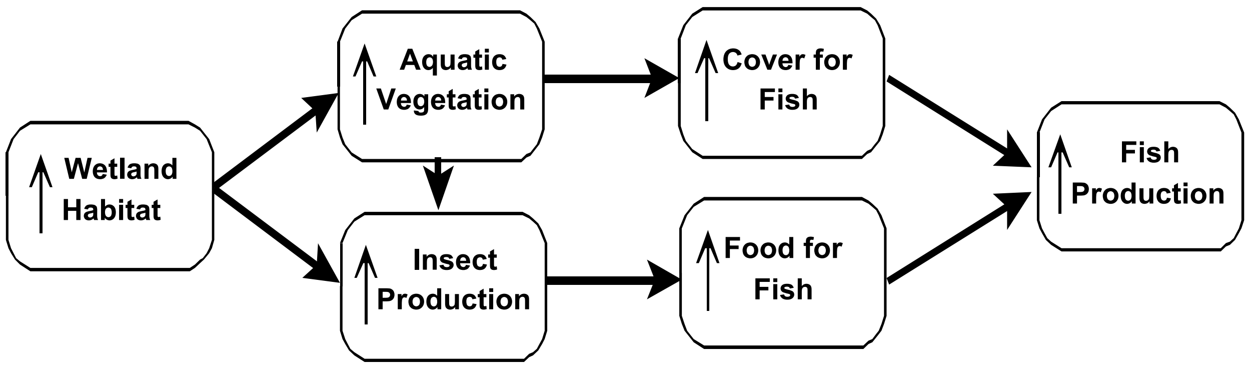

Figure 7. Expected ecological benefits associated with wetland creation.

Given the potential of wetland habitat to increase fish production, and by similar ecosystem processes to potentially increase bird and wildlife production, the benefits of this type of prescription could be significant in the Elsie Lake watershed.

7. REFERENCES

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