Brohm River Salmonid Habitat Restoration Prescriptions

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Funding Provided By:

Habitat Conservation Trust Foundation

and

Living Rivers Georgia Basin/Vancouver Island Program

BC Conservation Foundation Report # BRO-2008b
August, 2008

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TABLE OF CONTENTS

Executive Summary

During late winter to early spring of 2008, habitat restoration prescriptions were completed at the Brohm River over a distance of 3 of 4 km. Application of fish habitat assessment procedure (FHAP) indicated that although the stream was on a positive recovery trend, there were several eroding unstable banks sites at risk of further erosion, highway encroachments for >30 % of stream length, and sparse LWD in lower-gradient Reach 2 for 1 km. As well, off-channel refuges were sparse. Based on a review by PSlaney Aquatic Science Ltd (2008) native coho salmon were largely extirpated, although stock status of the steelhead population was relatively strong as a result of a high incidence of boulder/pocket pool habitats throughout 0.7 km of Reach 1 and 2.5 km of Reach 3-7.

Prescribed habitat restoration involves boulder cluster placements and securing LWD mainly in Reach 2, less so in Reach 6, and to a small degree in Reach 1. Total numbers of structures are 54 boulder clusters, 15 two-rootwad triangles and parallel roodwads/logs, with most of the latter for eroding bank stabilization. Four to five Newbury riffles are also prescribed for improving rearing, spawning gravel deposition and culvert access. In addition, a productive 400 m side-channel within a relic channel on the east floodplain of Reach 2 is prescribed to offset extensive historical highway encroachment in Reach 2. Restoration implementation requires two years to complete during summer of 2008 and 2009. Of note, LWD anchoring in Reach 2 avoids highway fill-slopes on the right bank and LWD should not occupy more than a small percentage (10-15 %) of the channel width where a prescribed geomorphic setting is confined by the highway. Year-2 construction of the side-channel will reduce excessive confinement.

Estimated costs of habitat rehabilitation, adjusted for cost increases since the 1990s, are estimated at $126,300 in 2008 and $120,400 in 2009, (excluding administrative overhead for technical support). This includes the cost of design and construction of a 400 m side-channel which incorporates a Shovelnose-type flow-throttled intake that transports fine, but not coarse sediments.

Streambank-attached LWD and boulder clusters structures have had high physical and biological success rates, as documented in Wilson et al. (2002). Boulder ballasting acts as a secure replacement for the very large root masses that anchor large wood in unlogged natural old-growth channels. Habitat restoration (mainstem) and compensation (side-channel) measures at Brohm River would be beneficial to stream ecosystem biodiversity, significantly increasing the abundance of wild steelhead trout and coho salmon. Habitat structures are expected to be functional over a 40 year time horizon until mature trees of the riparian zone provide natural recruitment of LWD. Large wood complexes also cause re-sorting of transported sediments, accumulate salmon carcasses, and trap woody debris as driftwood and leaf litter, which is documented to substantially improve productivity of salmonid food chains.

1. Introduction

1.1. Background

Twenty thousand years ago in southern British Columbia, glaciers had filled the hollows of the coastal mountains. Higher up on the mountain peaks of the Coast and Tantalus ranges, existing glaciers had spread downwards into the vegetated hillsides. Over the next 15,000 years, a major glacier deepened and widened the valleys around the Cheakamus and Squamish Rivers, and pushed into Howe Sound, along with transported sand and gravel sediments which formed the river fans and deltas. Thereby, a massive ice sheet, about 2000 m in average thickness, evolved to cover the Squamish area except for a few projecting coastal mountain peaks (Armitage 1997). Gradually, with the next climate change, the encircling ice sheet retreated, and volcanic activity at Mount Garibaldi heralded a new era, which out-spread volcanic rock and ash in all directions. As the ice melted from the lava and ash flows, about 26 km^2 of the Cheakamus valley floor rest on a layer of rocks and rubble that once formed Mount Garibaldi's western slopes. About 10,000 years ago, after the glacial ice suppression, the land finally regained some of its original height, modified by the glacial and volcanic activity. The latter charged the soils with rich nutrients in the Brohm River watershed and stimulated lush re-vegetation of mosses, ferns and bushes and trees, culminating in productive forests of Douglas fir, western red Cedar and other conifers.

It was after this era about 9,000 years ago that among BC pioneers from the ice-free south, the Squamish people colonized the Squamish area, and were extremely reliant on abundant salmon, game, roots and berries, as well as cedar for winter homes, and in summer, often utilizing foraging/camping sites along Howe Sound and Burrard inlet. Salmon in summer-fall and steelhead in the winter-spring were fished near their villages on the Squamish-Cheakamus Rivers. These vital fishes returned annually, providing much relied-upon and revered sustenance for the Squamish people, which they also preserved by dry-smoking for later winter consumption (Armitage 1997). The Cheakamus River and key tributaries such as Brohm River (Figure 1) were key fish sources, and in Salish language, "Cheakamus" means "basket catch fish" or "salmon weir place" (Armitage 1997). Fish species caught at Brohm River were trout and salmon (Reimer 2003).

Overall, the Garibaldi area glacial-volcanic history had surcharged the Cheakamus system and its key local tributaries with an overlaid volcanic geology, which is evident by the rich layer of diatom-dominated periphytic algae on Brohm River substrates during stable base flows. Salmon runs returning from the Pacific Ocean were only lightly fished prior to European settlement, and augmented the natural volcanogenic nutrients and minerals dissolved in streams.

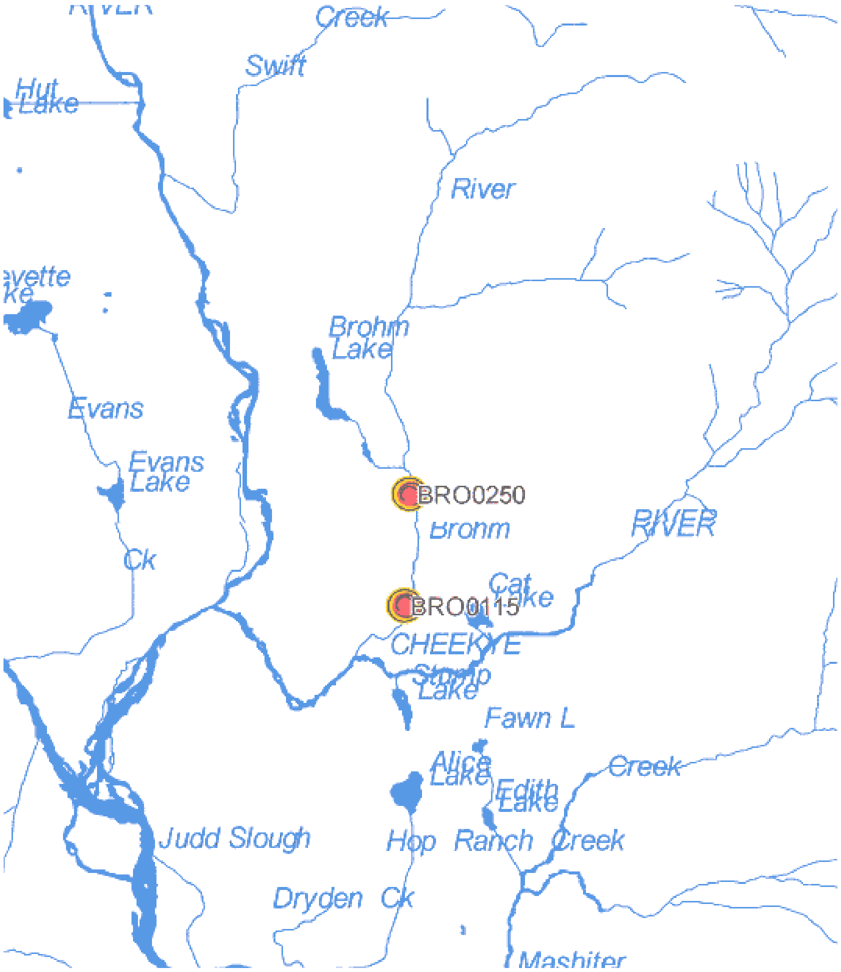

Figure 1. Cheakamus watershed area showing Brohm Lake and the mainstem river downstream to its confluence with the larger glacial Cheekye River (BC Conservation Foundation 2002-04 fish sampling sites are shown in the lower and upper river (from Hanson and Hryhorczuk 2005).

Brohm River waters contributed historically to a large fishery in the Cheakamus, which later became well used by Squamish and Greater Vancouver European settlers, in addition to the Squamish Nation people. A sizeable steelhead fishery developed which was heavily based at a famous steelhead fishery camp ("Fergies") situated on the Cheakamus River, 0.5 km downstream of the Cheakamus-Cheekye confluence. Steelheaders from the Lower Mainland began to congregate there for several decades after extensive European settlement of the BC Lower Mainland. At its peak as a significant regional recreational consumptive fishery, estimated steelhead angler days on the Cheakamus were 6500 whereby an estimated peak of 1130 steelhead were caught and retained, with a retained catch success of 0.2 per day. Over the next decade such high harvests in this range changed the nature of fishery and its management, with harvests curtailed to reflect over-harvest, habitat impacts and later in the mid-1990s, sharply reduced survivals of salmon and steelhead in the ocean as a result of climate change at BC south to mid-coastal latitudes.

1.2. Restoration Objectives

As in many other areas in the Pacific Northwest, historical practices of riparian logging or clearing and road encroachment along the Brohm River has resulted in significant losses of large wood/log jams and other cover features, as well as off-channel habitats. Such losses can greatly affect river geomorphology and result in significant losses of fish habitat, including flood shelters and cover features (Slaney and Zaldokas 1997).

The mainstem of the Brohm River supports significant populations of steelhead trout and to a lesser degree, coho salmon, and tributaries support coho salmon and coastal cutthroat trout, although tributary use is poorly documented. A Late winter- to spring-run of steelhead frequent the river, and this stock is considered at moderate risk owing to a sharp reduction in smolt-to-adult survival in the ocean caused by the climatic regime shift over the past decade (Lill 2002). A major caustic soda spill in Cheakamus canyon in the summer of 2005 increased the risk to Cheakamus steelhead including fry and parr originating from Brohm River. Freshwater conditions are also less favourable as a result of an increased frequency of droughts and flood events associated with climate change, as well as past habitat impacts. The strategy of the Greater Georgia Basin Steelhead Recovery initiative is to compensate for poor smolt survivals in the ocean by increasing wild stock productivity in freshwater (Lill 2002). In the case of Brohm River, historical highway encroachment, past riparian logging as well as storm debris-flows have degraded coho salmon and steelhead habitats, and reduced their access, to the degree that significant stock recovery gains can be achieved via habitat restoration and compensation measures. A more recent proposal to develop a major ski and recreational resort at Brohm Ridge presents renewed risks to salmonid habitats and thus habitat restoration measures should be implemented well before this large-scale development is implemented in the Brohm watershed.

The purpose of this report is to provide prioritized habitat restoration prescriptions for the Brohm River (Figure 1) in advance of extensive renewal of land development activities within Brohm watershed. Fish habitat assessments (FHAP) and suggested habitat protection measures are described in more detail in PSlaney Aquatic Science Ltd. (2008).

2. Methods

2.1. Fish Habitat Assessments

During late February, the Fish Habitat Assessment Procedure (FHAP) of the Watershed Restoration Program (WRP) (Johnston and Slaney 1996) was conducted throughout the fish-accessible length of Brohm River. The FHAP originated in the Pacific Northwest for quantitatively assessing the effects of past logging activities on forested streams. The procedure was adapted for use in

British Columbia (Johnston and Slaney 1996), and ideally it should be applied using diagnostic data collected from old-growth forested watersheds similar to the targeted watershed. Where diagnostic data is unavailable, which is typical, generic diagnostics are utilized (Table 5 in Johnston and Slaney 1996). During the Watershed Restoration Program (WRP) of 1994-2002, an unpublished evaluation of the technique by the Ministry of Water, Land and Air Protection provided support for its use, particularly for the large wood diagnostics. The procedure was developed mainly for small to medium sized streams in the order of 15 m channel widths, or similar to Brohm River. Some limitations are associated with percent pool and pool frequency ratings, but this is resolved by including glides with primary and pocket pools in the pool tally. The procedure is also designed to identify opportunities for restoration or for compensating for impaired and lost habitats.

Hydraulic units were separated into riffles, glides and pools at low winter flows (1-1.5 $m^3 \cdot sec^{-1}$). Glides were subdivided further into glide flats and glide flat-runs and pools into pools and runs, to improve designation of prime turbulent trout habitats versus more marginal non-turbulent habitats. Several physical characteristics were measured with a meter rod and a laser range finder, the latter accurate to + or - 1.0 m. Measurements included lengths of hydraulic units (riffle, glide pool), bankfull width, wetted width, bankfull depth, mean wetted depth, maximum pool depth, and residual pool depth. Channel type was also classified according to Table 1 in Johnston and Slaney (1996), which is mixed riffle-bar-pool and cobble-boulder step-pools in Brohm River.

Estimates of several other features were made, including dominant substrate size, sub-dominant substrate size, gradient, surface velocity, percent total cover, percent boulder cover, percent large woody debris (LWD) in pools, and cover types per habitat unit.

Total large wood, defined as all wood >2 m in length and >10 cm in diameter, was counted within the bankfull channel. Functional large wood was that which influenced the nature of the hydraulic units in terms of scour and salmonid cover, and LWD was counted by size category according to basal diameters of 10-20, 20-30, 30-40, 40-50 and >50 cm.

In the riparian zone on each bank, dominant trees were classified as pole sapling (including shrub), young forest, and mature forest. The zone was also classified as deciduous, conifer or mixed structure, and the percent canopy closure over the channel was visually estimated.

Further, within each hydraulic unit, percent useable steelhead fry and parr habitat was assessed by visually estimating useable depths and velocities criteria from experience with quantitative assessments. Based on velocity and depth measurements at a sample of riffle transects in the Capilano River in 2002, visual estimates approximated measured useable parr habitat, although were less accurate for fry habitat. Thus, the estimates of parr habitat provided an added overall rating of rearing habitat quality in Brohm River.

Values of the various parameters were converted to those required for FHAP diagnostics as percent pool, pool frequency (channel widths per pool), total large wood per channel width, functional large wood per channel width, percent woody debris in pools, percent boulder cover in riffles, percent total cover and substrate quality.

2.2. Habitat Prescriptions

A restoration strategy that prioritizes and integrates restoration was followed (e.g., Roni et al. 2002). As an initial overview, hillslope conditions were only inspected from air photos. Thus, road/gully stability should be confirmed once the hill-slope snow cover melts in the spring.

Fish Habitat rehabilitation prescriptions largely followed Slaney and Zaldokas (1997) including chapters by Newbury et al., Slaney et al. and Ward (1997). The primary large wood structure prescribed is the lateral triangle design because of its high stability (Slaney et al. 1997, D'Aoust and Miller 2000). The fixed triangle attached to streambank trees (or very large boulders or buried dead-heads) resists frontal hydraulic drag forces, and sufficient boulder ballast on the apex offsets buoyancy forces. Further research data and hydraulic computations are described in detail in D'Aoust and Millar (1999).

Minor design modifications reflect more recent experience gained with these and related structures at the West Kettle, Keogh, Seymour and Silverhope rivers. For example, in addition to the two logs or rootwad-logs that form the triangle of the structure, 2-3 additional logs are employed to provide a ballasted ramp to collect driftwood, thus acting as a "hybrid" between a "debris groin" and a "lateral triangle structure". At the same time this ensures that the streambank is armoured with large wood and ballast boulders.

3. Results and Discussion

3.1. Brohm River Fish Habitat Assessment

Fish habitat assessments are summarized in detail in an earlier report that also addresses habitat protection measures related to the proposed ski and resort development (PSlaney Aquatic Science Ltd. 2008)

3.2. Brohm River Habitat Ratings

Seven reaches were designated within the mainstem Brohm River as accessible to steelhead/salmon, which were separated largely by gradient characteristics:

- Reach 1: 691 m steep gradient mix of steep riffle and step-pool riffles;
- Reach 2: 930 m low gradient riffle-bar-pool as riffles, glides and pools;
- Reach 3: 311 m canyon outwash fan of riffle-bar-pool geomorphology;
- Reach 4: 524 m canyon comprised of bedrock-boulder step-pools;
- Reach 5: 319 m steep large boulder riffles of riffle-bar-pool sequences;
- Reach 6: 904 m steep gradient riffles as riffle-bar-pool geomorphology;
- Reach 7: 351 m of boulder step pools with 8 m chute fish barrier at 4 km.

Reach 1 to 3 were classified a "lower river" whereas the canyon upstream, as Reach 4 to 7, was designated as "upper river". Historically, there were potential salmon migration barriers in the canyon, which were recorded as blocked with transported logging debris during 1980s storm debris-flow events (Clark 1980).

Average bankfull widths within Reaches 1, 2 and 3-7 were 13.4, 13.5 and 13.5 m, which was remarkably consistent. Respective average wetted widths were 7.2, 8.2 and 9.3 m, or very similar to Clark (1981). Even in the fairly confined canyon (Reach 4), respective average bankfull and wetted widths were similar to other reaches, or 15 m and 12 m (9.3 m wetted width excluding an atypically wide lower-most log-jam pool) (PSlaney Aquatic Science Ltd 2008).

Average gradients per reach were striking dissimilar in Reach 2 than other reaches: Reach 1: 2.4 %; Reach 2: 0.6 %; and Reach 3-7: 3.3 %. Yet, respective velocities were similar, (0.8, 0.6 and 0.7 $m^3 \bullet sec^{-1}$) as a result of highway-induced channel confinement in Reach 2. Average depth, maximum depth and bankfull depth was similar in the reaches, ranging from 0.3-0.4 m, 0.7-0.8 m and 1-1.6 m, respectively, based on staff-rod measurements (Appendix 2).

Primary pools were sparse in Brohm River, yet boulder pocket pools were abundant in Reach 1 and Reach 3 to 7. With inclusion of glide-runs and pocket pools as pool habitat, there was 10.4 % pool in Reach 1, 17.6 % pool in Reach 2 and 12.4 % pool in Reach 3 to 7. Pool frequencies (including pocket pools) as channel widths per pool were 2.5, 4.6 and 1.9, respectively, in these respective reaches. Ratings were mainly poor to fair except Reach 3-7 where frequency of channel widths per pool (<2) had a good quality rating owing to abundant pocket pools (Table 1).

Most LWD in Brohm River was functional in generating or enhancing fish habitats, particularly in lower gradient Reach 2. Functional LWD accounted for 54 %, 76 % and 56 % of total in-channel LWD in Reach 1, 2 and 3-7, respectively (Appendix 2). Regardless, both total and functional LWD was sparse overall in Brohm River in 2008 (Table 1). Functional wood frequencies in Reach 1, 2 and 3-7 were only 0.4, 1.1 and 0.3 per channel width, respectively, thus rating as poor quality, low-fair quality and poor quality, as habitat quality indicators (Table 1). This was because all riparian areas, except for a short segment of mature forest in the canyon, were currently logged 2nd growth forests that were "functioning at risk", with little large wood recruitment. Most riparian zones require another half century to recover LWD supply functions, even though leaf litter is well supplied, and rooted bank stability had recovered in most of the channel (PSlaney Aquatic Science Ltd 2008).

Overall, average estimated total salmonid cover in Reaches 1, 2 and 3-7 was 35 %, 17 % and 36 %, respectively, which is moderately high except in Reach 2 (Appendix 2). Despite this, average percent wood in pools was very low at 3 %, 7 % and 2 % in these respective reaches (Table 1), which reflected sharply declining LWD recruitment from an immature/young riparian forest and likely greater stability of hillslope gullies in the watershed. Mean percent overhead cover (cutbanks, turbulent pool depths, overhanging vegetation or woody debris) was slightly more prevalent in steeper reaches, or 8 %, 5 % and 10 % in Reach 1, 2 and 3-7, respectively. Average protruding boulder cover was 24 %, 4 % and 25 % in Reaches 1, 2, and 3 to 7, respectively. Of note, boulder cover was a high proportion of total cover in both Reaches 1 and 3-7 (or 65-70 % of all cover) but much less so (25 % of all cover) in lower-gradient Reach 2. Habitat quality ratings for wood in pools, overhead cover, and protruding boulder cover were poor, poor and near-good in Reach 1, respectively; poor overall in Reach 2 aside from near-fair woody pool cover; and poor, fair and near-good, respectively, in Reaches 3 to 7 (Table 1). Of crucial significance, it was boulder cover that has largely maintained a fair-plus to near-good cover rating of three of the four accessible km, or 75 % of Brohm River. The latter explains why past fish inventories and stock status surveys indicate that steelhead densities were relatively high compared to coho densities because boulder cover is most efficiently utilized by steelhead in rivers.

Salmonid spawning sites were restricted to infrequent primary and lateral pools which retained sparse amounts of spawning gravels (PSlaney Aquatic Science Ltd 2008). There were 0 spawning sites in Reach 1, 2-3 sites in Reach 2, and 3 sites in Reach 3-7. One of the latter was a recent coarse gravel-cobble placement at the tail-out of the outlet pool at Brohm Lake outlet culvert (with 25 % of estimated mainstem flow), recently replaced and expanded to improve fish passage. Most step-pools did not retain gravels and had cobble to boulder tail-out areas. Regardless, only a few (5-10) spawning gravel sites would be required over a distance of 4 km in order to saturate rearing habitat with fry (PSlaney Aquatic Science Ltd 2008). Overall, measures to increase spawning gravel deposition at some sites would be beneficial for steelhead and coho.

Estimated percent useable fry and parr rearing habitat was relatively high for a period of moderate winter flows which ranged from 1-1.5 $m \bullet sec^{-1}$ (Table 2). Accordingly, there was sufficient useable fry habitat over the 4 accessible km to saturate parr rearing habitat, given that parr territories are 5-10 times larger than fry territories (Slaney and Northcote 1972). Thus, clearly, Brohm River is parr habitat-limited for steelhead trout production, as early-mid-summer flows are similar or about 1 $m \bullet sec^{-1}$ (McCusker et al. 2002).

Table 1. Fish habitat quality rating of Brohm River using the Fish Habitat Assessment Procedure; diagnostics from Table 5 of Johnston and Slaney (1997) (pool ratings in reaches adjusted for gradient class; from PSlaney Aquatic Science Ltd 2008).

Habitat Parameter	Reach Amount	Rating	Target (Good Quality)
% Pools-Glides including Pocket-pools:			
Reach 1	10.4	Poor	40 % (<30 % poor)
Reach 2	17.6	Poor	55 % (<40 % poor)
Reach 3-7	12.4	Poor	40 % (<30 % poor)
Pool-glide & Pocket-pool Freq. (ch.wd per pool):			**Good<2 ch.wd/pool (2-4 = fair)**
Reach 1 primary	25.8	Poor	
Reach 1 prim+pkt	2.5	Fair	
Reach 2 primary	6.9	Poor	
Reach 2 prim.+pkt	4.6	Poor	
Reach 3-7 primary	11.9	Poor	
Reach 3-7 pr.+pkt	1.9	Good	
Pieces of Functional LWD/ Channel Width:			**Good >2 pieces/ channel width (1-2 pieces = fair)**
Reach 1	0.4 pieces/ch. wd.	Poor	
Reach 2	1.1 pieces/ch.wd.	low-Fair	
Reach 3-7	0.3 pieces/ch.wd.	Poor	
% Woody Cover (pool-run+glides and in total):			
Reach 1	3 %	Poor	**>20 % Good Quality**
Reach 2	7 %	low-Fair	**(6-20 fair)**
Reach 3-7	2 %	Poor	
% Overhead Cover			
Reach 1	8 %	near-Fair	**>20 % Good Quality**
Reach 2	5 %	Poor	**(10-20 fair)**
Reach 3-7	10 %	Fair	
% Boulder Cover protruding in riffles			
Reach 1	24 %	near-Good	**>30 % Good Quality**
Reach 2	4.3 %	Poor	**(10-20 fair)**
Reach 3-7	25 %	near-Good	

Off-channel or side-channel salmonid habitats were sparse: 20 m in Reach 1, 100 m in Reach 2, and 250 m in Reach 3-7 (Appendix 2). In addition, there were tributaries that entered the channel at accessible low gradients at km 1.6 from the west, and 2.3 km from the east; however, fish access is flow-dependent. These are too small (< 3 m width) for access of adult steelhead, yet they may be useable by coho fry and steelhead parr, seeking winter refuge from the mainstem In early August (2008), two steelhead parr were minnow-trapped by Squamish Stream-keepers within a West tributary pond located 300 m upstream from Brohm River. Other than two small ponds, the lower reach of West tributary was dewatered in mid-summer as a result of sandy bed load deposition for 300-400 m upstream of the highway culvert. Historically, adult coho and cutthroat spawners would have utilized these tributaries, the former near-extirpated in Brohm River. Further upstream, a minor groundwater stream enters from the east at 3.1 km. Brohm lake outlet, 0.5 km in length with a flat-gradient, enters from the west at 3.5 km. A large 400 m relic side-channel was identified in Reach 2, located 60-80 m to the east of the mainstem river (Figure 2). This entire low floodplain area should be incorporated within an extended riparian reserve boundary, utilizing the eastern toe of the steep mountain terrain, where several decades ago a channel flowed through existing coarse cedar LWD (PSlaney Aquatic Science Ltd 2008a). Provision of side-channel spawning and rearing habitats would be beneficial to anadromous salmonid production because of historical highway confinement of the mainstem channel, with losses of riparian functions and spawning gravel deposition, particularly in Reach 2 (Figure 2).

Table 2. Estimated percent useable fry and parr rearing habitat in Brohm River at 1-1.5 $m \cdot sec^{-1}$ flow during mid- to late-February 2008 (from PSlaney Aquatic Science Ltd 2008a).

	Useable Fry Habitat	Useable Parr Habitat
Reach 1	***16 %***	***26 %***
Reach 2	***17 %***	***14 %***
Reach 3-7	***13 %***	***31 %***

3.3. Brohm River Habitat Restoration Prescriptions

Habitat restoration prescriptions were focused on boulder cluster and large wood structures in riffles and glides, respectively. Restoration sites were selected that lacked preferred velocities, depths and cover for sustaining abundant rearing salmonids in summer, and particularly during winter flood conditions.

The layout of Brohm habitat rehabilitation prescriptions are summarized in Figure 2. Detailed prescriptions of structures are provided in Table 3, with GPS UTMs at each site. Distances (m) are from the Brohm-Cheekye confluence as the starting point. All LWD and boulder cluster sites are flagged on-site and color photos of prescribed sites are also provided in Appendix 2. Conceptual designs of ballasted LWD designs are provided in Figures 3, 4, 5 and 6.

3.4. Habitat Structure Conceptual Designs

To restore and augment large wood in the Brohm River channel, well-ballasted lateral triangular structures were mainly prescribed because hydraulic engineering research has confirmed their stability (D'Aoust and Millar 2000).

Triangular structures offset frontal drag forces by means of fixed point on-shore anchors (tree bases and/or large boulders) (Figures 3, 4, 5 and 6). Thus, only buoyancy forces need to be offset with boulder ballasting. Scour at the triangle apex tends to offset any reduction in channel flow capacity.

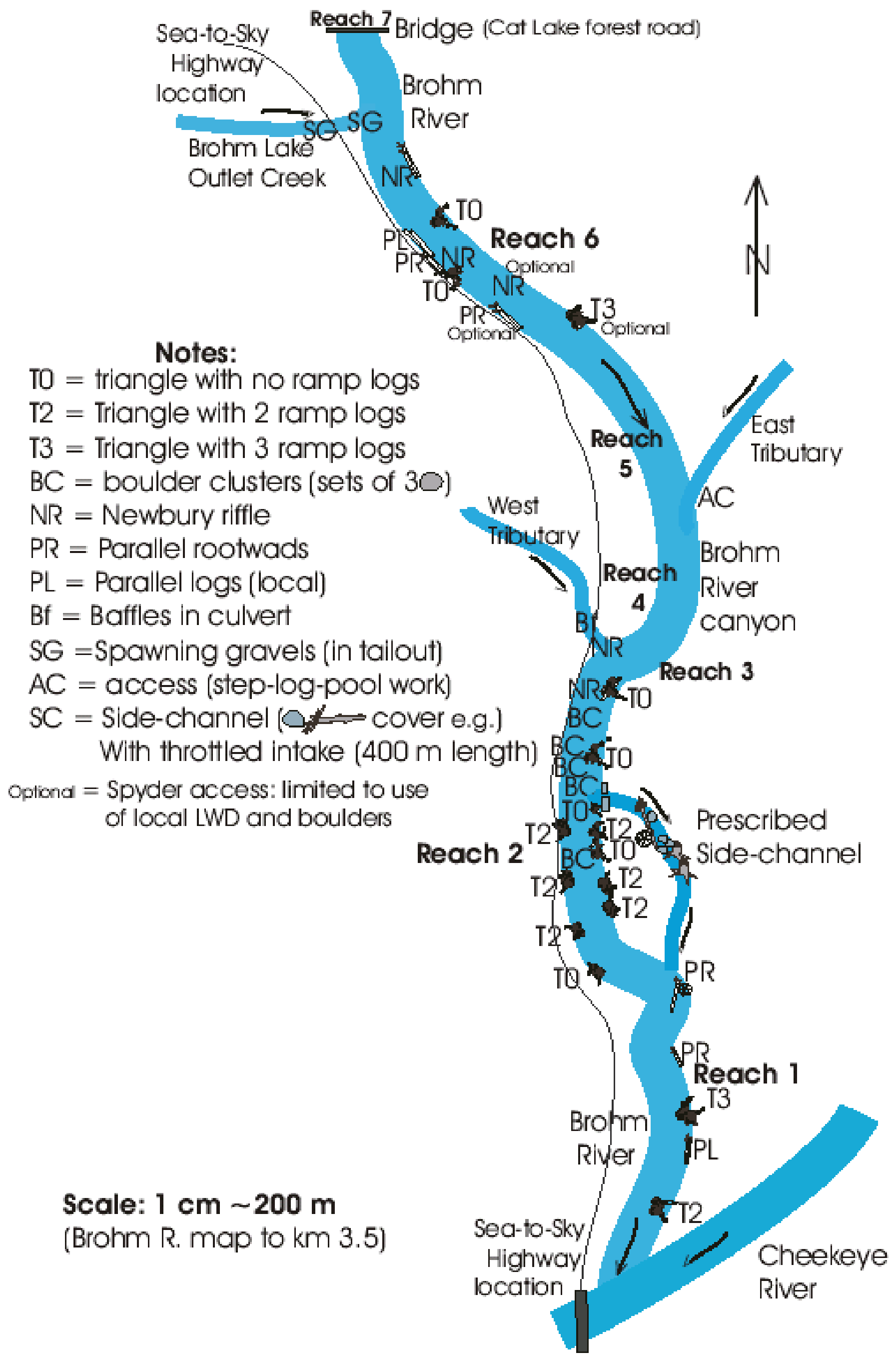

Figure 2. Map of the Brohm River (km 0-3.5) showing locations of prescribed habitat restoration structures, access/spawning sites, and Reach 1 side-channel (Note: culvert baffles require hydraulic engineering input and MoT approval).

Table 3. Site locations and habitat restoration prescriptions in Brohm River. Distance is to the upstream end of habitat unit, and the starting point is at the confluence of Brohm River and Cheekeye River (Figure 1).

Station Number, Habitat Unit	Distance m and Reach	Habitat Restoration Prescription (each site flagged on-site) (distance in meters from the confluence of Brohm River and Cheekye)
	Reach 1	
2. Riffle	234	1 two-rootwad left bank triangle with two ramp logs + 2 3-boulder clusters in top end of d/s riffle to add residual pool depth: 490524 5515810
4.StRiffle	329	1 two-rootwad triangle with three ramp logs at top of riffle to re-deflect flow plus one set of 3 stacked parallel logs secured to bank 10-20 m d/s 490609 5515920 (local ballast at site and from slope of first site at 234 m)
9.StRiffle	656	2 parallel stacked rootwads on denuded powerline eroding left bank
	Reach 2	
11.Glide	712	Shift natural rootwad d/s by 10 m and ballast stem; 490855 5516038
12. Pool-Rif Seq.	763	1 two-rootwad triangle off right bank to generate pool tail-out spawning gravels and deepen adult holding/parr rearing pool; UTM approx. as above
13. Riffle	820	1 two-rootwad triangle off right bank with 2-3 ramp logs to generate pool tail-out gravels: 490855 5516113
14. Glide	850	2 two-rootwad triangles left bank with 2 ramp logs; rearing-spawning sites 490900 5516137
16 Glide Highway		1 two-rootwad triangle right bank with 2 ramp logs; rearing-spawning sites; pre-load LWD as bank erosion control measure; 490965 5516137
17 Riffle Highway	1006	14 three-boulder clusters in thalweg;0.6 m diameter: 490996 5516197
20. Glide Highway	1081	1-two rootwad triangle off left bank: 490178 5516133
21.Riffle Highway	1124	2-two rootwad opposing triangles with 2 ramp logs on left and right banks 491118 5516184
22.SRiffle Highway	1218	1 two-rootwad flat triangle with 2-ramp logs on left bank plus 12 three-boulder clusters; 491139 5516206
23. Riffle-pool-jam Highway	1268	[1]Side-channel intake[2] from jam pool with lock-blocks intake at bank: 400 m long side-channel at cliff lwd toe: 490982 5516028 d/s to 491204 5516289
24. Riffle Highway	1317	1-two rootwad triangle off left bank, plus 6 3-boulder clusters in thalweg using 0.6 m diameter boulders; 491211 5516338
25. Glide Highway	1332	Potential 2ndary side-channel intake site for Station 23 (prime habitat)
26. Riffle Highway	1387	7 three-boulder clusters in thalweg using 0.6 m boulders 491247 5516391
28. Riffle	1534	15 three-boulder clusters in thalweg with 0.6m boulders; 491267 5516391

Highway 29.Pool-t Highway	1551	1 two-rootwad triangle off left bank with 5 m Newbury riffle in tail-out to elevate residual depth by 0.5 m; 491267 5516391 (u/s near above gps)
30. Riffle Highway	1621	West tributary river km 1.6; add 0.3 m boulders from mainstem for access, plus Newbury riffle to backwater trib. culvert, plus a set of baffles in culvert
	Reach 6	
49.StRiffle	2918	1-two rootwad triangle with three ramp logs -eroding left bank; 491325 5517572: *Optional site, as spyder access is limited to use of local materials*
51.Glide	3004	2-parallel rootwads on left bank in run; 491297 5517572: *Optional site, as spyder access is limited to use of local materials*
53.Glide[3]	3049	Newbury 5m riffle at tail-out of run (spawn site) to elevate residual depth 0.5 m. *Optional site, as spyder access is limited to use of local materials*
55.Gl-riffle	3194	2 parallel stacked rootwads on right bank + 2 parallel stacked cedar (local) logs, plus one 3 m Newbury riffle with 1 2-rootwad triangle; eroding glide-riffle crossing site (good access from tote road and BCH power-line road) 491284 5517745
57.Gl-riffle	3285	1 two-rootwad triangle off left bank, tree bases and local rock as local ballast 491299 5517824
60.Glide	3454	2 parallel ballasted rootwads (or logs) plus 5m Newbury riffle at pool tail-out 491167 5517960
61.pool tail-outs	Brohm Lake Outlet Creek	Spawning gravel additions at both inlet (7 m^3) and outlet (5 m^3) of culvert at pool tail-out into riffle (mixed 0.5 cm fine to dominant 5-7 cm coarse gravel)

[1]The Reach 2 floodplain side-channel site is largely dewatered except for minor groundwater flow in the downstream 100 m. A created tote road (from the old forest camp site on the right river bank) should be used for excavator access to the side-channel from its right bank. Thus, the side-channel design including riffle-pool sequences should be laid out and flagged well in advance of material access. Side-channel intake materials (lock-blocks) and boulders required for side-channel cover and bend armouring can also be transported via this tote road. Old-growth LWD, cobbles and gravels can be sourced locally along the length of the side channel.

[2] The side-channel intake could either be located at the jam pool, or within a stable pool-run located about 50 m upstream. For the latter, additional parallel LWD would be secured to the left bank to deepen the pool at the low-bank intake site. The intake design concept is a “Shovelnose-type intake”, thereby transporting fine sediments through the proposed side-channel.

[3] Note that this optional site (Appendix Figure 20) is currently utilized for steelhead spawning; it could be deleted, and replaced by a ramped triangular structure designed to deposit spawning gravels behind it, and located on the right bank 10-15 m downstream of Cat Lake road bridge. (The upper reach above Brohm Lake outlet creek lacks a steelhead spawning site and has a low recorded fry density).

Lateral rootwads are a secondary structure which minimizes drag forces because only a small cross section of wood is exposed to frontal drag forces (Figure 6). Streambank anchoring of both types of large wood structures ensures stability and trapping of driftwood. Bank-toe ballast boulders ensure adequate ballasting, minimizes excessive boulder mass at the apex, provides over-winter fish cover, and ensures bank stability at erosion-risk settings. Tree bases in the riparian zone are used for on-shore anchoring, and where trees are unavailable, large ballast boulders are secured on the bank by excavation to prevent slippage. Instream ballast boulders combined with woody debris provide prime salmonid habitats, especially in substrates where turbulent pools or runs are scoured during floods.

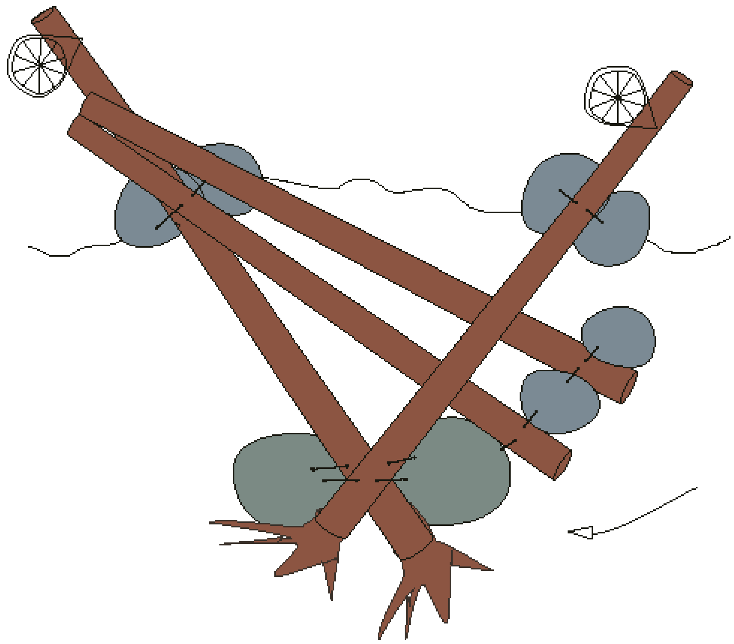

Figure 3. Conceptual ballasted triangular rootwad structure with two ramp logs, designed to trap driftwood, enhance scour and protect the streambank.

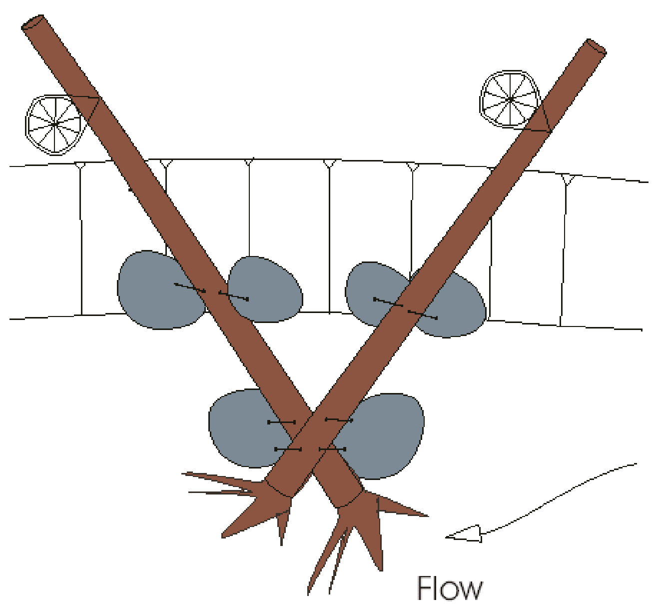

Figure 4. Conceptual ballasted triangular rootwad structure without ramp logs.

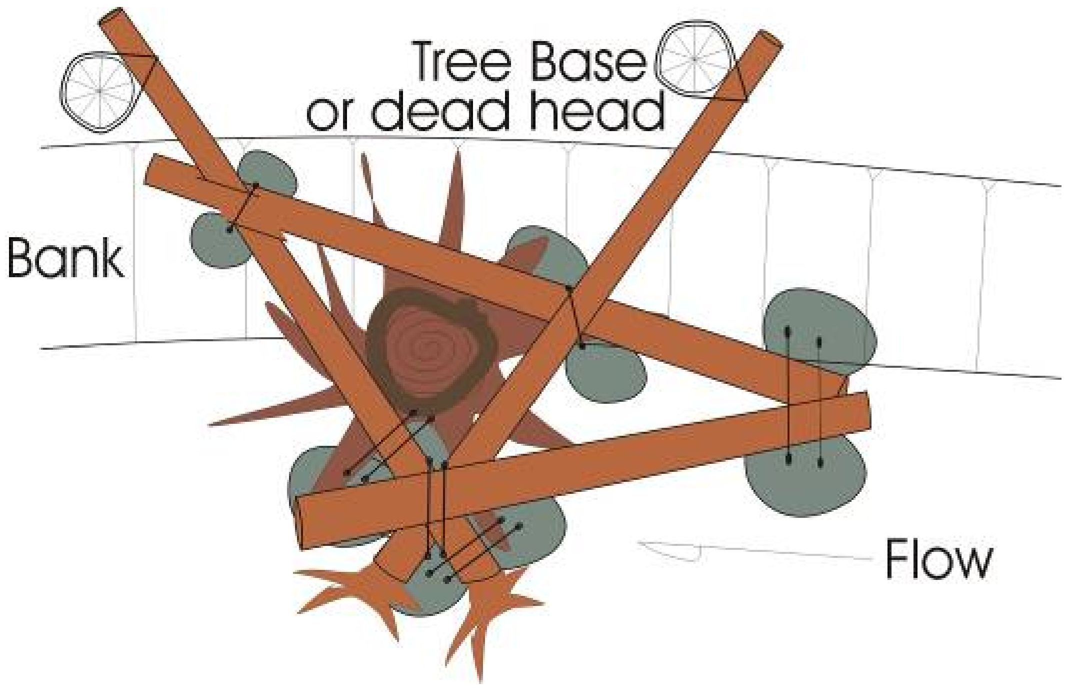

Figure 5. Alternative lateral triangular rootwad-structure design with two ramp logs and attached stump-rootwad to add habitat complexity.

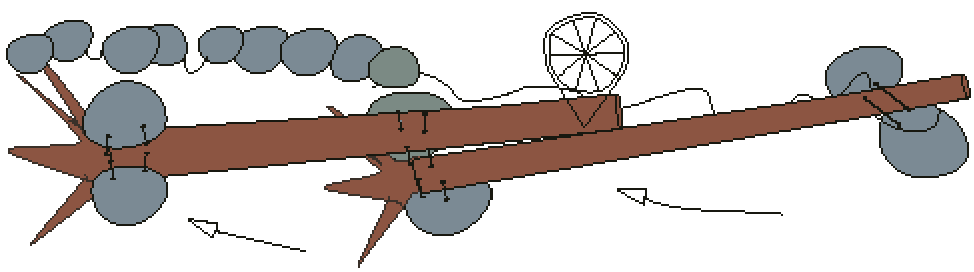

Figure 6. Conceptual parallel rootwads secured both to the streambank and to instream ballast boulders to provide instream LWD and boulder cover.

3.5. Machine and Material Access to Restoration Sites

There are three suitable machine access points to prescribed restoration sites in Reach 1, 2 (lower river) and 6 (upper river). A Spyderhoe low-impact excavator is required for all in-river and bank structure placements. Materials (rootwads, logs and boulders) could efficiently be provided by unloading trucked large wood and ballast boulders (0.7 m and 0.5 m diameter) and cluster boulders (0.6 m diameter) at several flagged points along the highway by placements on the highway fill-slope that is rip-rap armoured at the right (west) river margin. This option would require MoT approval and contracting of a highway traffic flagging crew.

Alternatively, the materials can be sequestered at three machine access sites and machine (front-end loader) transported, which would be most efficient in Reach 6 and for the side-channel project in Reach 2. The alternative material access/sequester sites are:

- Reach 1: A tote road pullout on the Sea-to-Sky Highway, 200 m upstream from Cheekye River bridge (LWD materials for lower three sites);
- Reach 2: An old forest camp site road to river at river km 1 (requires temporary removal of 2-3 concrete curb barriers) for (a) access of a single upper Reach 1 site (power-line bank stabilization) (b) materials access to Reach 2 restoration sites via track-excavator or front-end loader;
- Reach 6: A BCH-gated power-line road at the east side of the forestry bridge on the Cat Lake forest access road. At a point 300 m south on the road, a 100 m long tote road leads to an abandoned crossing of the river at river km 3.2.

Access to the side-channel site from the Sea-to-Sky Highway would be via the old forest camp in Reach 2 (Table 2: side-channel prescriptions footnote).

3.6. Restoration Materials: LWD, Ballast and Cluster Boulders

A 2-year schedule would be efficient logistically: Reach 1 and 2 in Year 1, and Reach 6 and the Reach 2 side-channel in year 2. Total external materials and total numbers of structures are summarized in Table 4. Some additional ballast boulders (externally supplied) are included in the Reach 2 tally to account for riparian ballasting where large tree bases are unavailable.

Of the tally, Reach 1 and 2 in 2008 account for 4 of 6 of the 2-rootwads triangles without ramp logs, 9 of 10 of the 2-rootwad triangles with 2 to 3 ramp logs, 2 of 4 of the two-parallel rootwads/logs, 54 clusters of 3-boulder clusters, and 2 of 4 of the 20 boulder Newbury riffles (each comprised of ten 0.3 m and ten 0.6 m boulders). Reach 6 (2009) accounts for 2 of 6 of the 2-rootwad triangles without ramp logs, 1 of 10 of the 2-rootwad triangles with ramp logs, 4 of 6 of the 2-parallel rootwads or logs, 0 of 54 of the 3-boulder clusters, and 2 of 20-boulder

Newbury riffles. Thus, detailed quantities of materials per reach, as required from local and external sources, were as follows:

Table 4. Total external rootwad, log and boulder materials, and total numbers of each structure type prescribed in Reach 1, 2 and 6.

Total (2-year) External Materials		Total (2-year) Structures Tally	
Rootwads	36	*RW Triangles no ramp*	6
Logs	22	*RW Triangles 2-3 log ramp*	10
Rootwad ballasts	82	*Parallel 2-Rootwads/Logs*	6
Ramp log ballasts	34	*Boulder clusters (sets of 3)*	54
Newbury riffle boulders	80	*Newbury riffles*	4
(40 at 0.3 m + 40 at 0.6 m diam.)			

Reach 1 (excluding the single power-line site near Reach 2):

- Rootwads: 4 (0.5+ m basal diameter and15 m length);
- Logs: 8 (0.4 m basal diameter and 10-15 m length);
- Local boulder LWD ballast (local ballast available at 234 m site, plus tri-site at 329 m has 2 local ballast boulders for rootwads):
    - for rootwads: 6 local boulders of 0.7 diam. (range 0.6-0.8)
    - for ramp logs: 10 local boulders 0.5 m diam. (range 0.5-0.6 m)
    - for lateral logs: 10 local boulders 0.6 m diam. size (range 0.5-0.7 m)
- Local cluster boulders: 6-9 (local boulders 0.6m diameter placed at 234 m site in tail-out of triangular structure (add pool depth plus slow velocity).

Reach 2 (including single Reach 1 power-line bank erosion site):

- Rootwads**:** 24 12-15 m in length and 0.5 m basal diameter);
- Ramp logs: 14 (10-15 m in length and 0.5 m basal diameter);
- Boulder LWD ballast:
    - rootwads: 66 boulders of 0.7 diam. (range 0.6-0.8)(incl.bank stems)
    - ramp logs: 28 boulders 0.5 m diam. (range 0.5-0.6 m)
- Cluster boulders: 162 (target 0.6 m diam; acceptable range 0.5-0.6m);
- Newbury riffle (2) boulders**:** 40 (target 20 at 0.3 m diam. and 20 at 0.6 m).

Reach 6 (plus spawning gravel for Brohm Lake outlet creek):

- Rootwads: 8 (15 m in length and 0.5+ m basal diameter) (4 local);
- Ramp logs: 3 (local) (10-15 m in length and 0.5- m basal diameter);
- Local logs: 2;
- Boulder LWD ballast:
    - rootwads: 16 boulders of 0.7 diam. (range 0.6-0.8)(incl. para.rw)
    - ramp logs: 6 local boulders 0.5 m diam. (range 0.5-0.6 m)
- Newbury riffle boulders: 40 (20 at 0.3 m diam. + 10 at 0.6 m diam.;
- Local Newbury riffle (2) boulders: 40 *(*site 55&60: 20 at 0.3 m+20 at 0.6 m).

In Reach 6, some local boulders are also available to supplement externally supplied ballast and re-constructed riffle boulders.

3.7. Boulder Ballasting and Sizing Guidelines

Ballasting of LWD structures is set by guidelines provided in Slaney et al 1997, using a *minimum safety factor of 1.25* (This can be increased to 1.5-2, based on D'Aoust and Millar (1999, 2000); however, excessive instream ballast boulders reduce habitat space and can deposit excessive fine sediments). Note that the rootwad logs need to be securely attached to these large boulders to ensure stability, and fixed attachment to proximal (>30 cm) tree bases is required as well. Where adequate tree bases are unavailable, then boulders (or buried deadheads) must be used. Typically, 1 cubic meter (as two 0.7 m diameter boulders) of epoxy-cabled boulders is needed per log end at the instream apex. A secure tree base can form the fixed anchor at the riparian end, plus cabled ramp logs do not require boulder ballast at the upper cabled ends. For the ramp logs, two 0.5 m diameter boulders per submerged end is adequate from past experience owing to downward hydraulic forces on the sloped ramp logs. Triangulated log structures with a fixed apex attachment and two fixed bank attachments offset frontal drag forces, and thus only buoyancy forces are ballasted to the target safety factor (D'Aoust and Millar 2000).

Further, to provide a safety factor on cable attachments, 2 attachments per boulder are advised for redundancy on the instream apex joint. To ensure logs do not shift, cable holes are drilled in the outer portions (skins) of the log surface, which minimizes cable flexing and cable visibility (Figure 7).

Figure 7. Example of cabling of triangular rootwads using Hilti expoxi to secure LWD to boulder ballasts (with left mid-cable not yet inserted).

Cable epoxy attachments to ballast rocks ***must adhere*** to the following specifications to be highly effective:

- use only solid ½" galvanized steel cable (and not cable with a plastic or rope core or used cable as the former enables the cable to compress bracket;
- 9/16" rock holes must de drilled to a minimum 10" depth;
- to ensure 100 % cable-epoxy bonding, holes must be thoroughly cleaned to eliminated all rock dust, by repeated wire brush and rinse water use;
- redundant cabling is to be used per apex boulder, with holes >8" apart;
- underwater applications of epoxy have about 50 % less pull strength before failure.

3.8. Estimated Restoration Costs: Brohm River

Competitive bidding is recommended to ensure material and machine contracting costs are not over-inflated. A cost estimate from past experience with triangulated large wood structures was $2000 to $3,500 per large wood structure in 1998. The lower cost was where access was readily available from adjacent roads and stream bars, large wood was donated, and boulders were available at little or no cost. The higher cost was where purchased materials were transported long distances to the stream reach by truck and then by constructed tote-roads or by helicopter. Using these estimates, $3,000 per large wood structure is a conservative estimate that accounts for contingency costs. To adjust for inflation since 1997/98, this average cost per LWD structure should be increased by 50 % to $4,500 per structure in 2008 dollars. If large amounts of boulder armouring are required and LWD and/or boulder materials must be hauled from a distance, the latter cost may increase by 50-100 % to $7,000-$9,000 per structure in 2008 dollars. No significant boulder armoring is anticipated at Brohm River, other than what is accounted for in materials, both local and external.

Thus, 15 LWD structures in Reach 1 and 2 at a cost of $4,500 are estimated to cost $67,500 in 2008 dollars. Seven (7) LWD structures in Reach 6 (as a 2nd year phase) are estimated to cost $31,500 in 2009. Included in this cost are transported boulders from a local Squamish-Mamquam pit for ballasting LWD structures. This includes an estimated to cost of $15-20 per ballast boulder, LWD at $300 per piece, material transport and Spyder-hoe cost of $2450 per day. Supervisory cost is included ($670 + $150 travel =$820) at 3 structures per day or 4 days in 2008 (+ $3,280) and 2 days in 2009 (+$1,640). Technical support for cabling and re-vegetation ($14,500) is additive (Table 4).

Boulder clusters transported by truck from a Mamquam pit are estimated to cost $12 per boulder x162 (including taxes), or $2,000, plus the cost of moving boulders along the river by loader (2 days at $1,200 day plus $1,200 loader transport by low-bed truck) and into position by spider hoe, estimated at 1+ 3 days at $2,150/day (including gst). In addition, movement and placement of local boulders will require an additional day of spider-hoe time. Local travel and accommodation are $150/day or $750. Supervision costs for cluster placements are estimated at $2,400 (4 days x $630 including gst) plus travel and accommodation expenses ($670), or $3,200. Thus, at Brohm River Reach 1 (local boulders) and 2 (external boulders) the cost of boulders, transport and placement including supervision is estimated to cost ($2,000+ $3,600 $11,500+$3,200) or $23,500 in 2008.

Two Newbury riffles in each of Reach 2 and Reach 6 are comprised of ten 0.3 m small boulders and ten 0.6 m boulders, which equates to 40 small boulders at $6 plus 40 large boulders at $12 transported to the Brohm sites for a total cost in $720, plus transport to two river reaches (1 day at $630) plus loader transport ($1,260) or $2,610 in total in 2008. Placement cost amounts to 1 Spyder day at Reach 2 plus 1 day of supervision and $150/day (x2) travel/accom. $2,400 + $670 +$300 or $3,370 in 2008. Thus, for the two Newbury riffles in Reach 2, cost including boulder cost and transport (Reach 2 and 6) and placement (Reach 2) totals $6,000. Placement cost for 2009 (material on-site from 2008) is $3,400.

The side-channel is proposed as a year-2 project (2009) and requires a profile (elevation) survey with channel, cover feature and intake design. A preliminary cost estimate for the 400 m side-channel and intake is estimated at $7,000 in 2008 for planning and design costs including a conceptual drawing, and $60,000 in 2009 for construction and re-vegetation.

Spyder-hoe travel cost to and from the site is $1000 in 2008 (Reach 1 and Reach 2) and $1000 in 2009 (Reach 6) assuming shared with another restoration project in the Lower Mainland.

In addition, a restoration technician is required for the duration of the project to plan logistics of the project, secure materials, contract equipment, and cable-secure the LWD structures. A total of 1 month is required involving 22 working days including travel and accommodation costs ($7,000), plus truck rental and incidental material costs of $4,000 (e.g., revegetation materials, cable and epoxy and drill bits, and chain saw rental, etc). A 2nd technician is required for a period of 10 days ($3,500 including travel costs) in both 2008 and 2009 for assisting with cabling-securing LWD structures as well as hay-mulching and re-vegetation of disturbed soils. Total cost per year is estimated at $14,500 in 2008 and $14,500 in 2009. As well, there are also costs associated with regulatory approvals (government agencies) and consultations (funding sources, angler groups, land tenure holders) and for report preparation, which are estimated to each cost $5000, or in total $10,000 per year.

Costs associated with two spawning gravel placements (10 m^3) at Brohm Lake outlet creek and culvert baffle design and installation at the west tributary (river km 1.6) are not included. It is assumed these costs can be accommodated elsewhere, or alternatively deferred to 2009 or 2010, as colonization with stranded coho fry from Swift Creek (M. Foy per com, DFO, 2008) would likely ocurr in 2008 to 2009 (assuming agency approvals). However adult coho would not return to spawn until 2011 to 2012 (A pre-assessment of the adequacy of minimum summer flows in the west tributary is advised).

Thus, the total restoration costs are estimated at $126,300 in 2008 and $120,400 in 2009 (Table 5), which does not include overhead costs for project technicians.

Table 5. Estimated costs of Brohm River salmonid habitat restoration over two years, 2008 and 2009 (excluding overhead costs on technician support).

Component	Estimated Costs – 2008	Estimated Costs - 2009
LWD Structures	$67,500	$31,500
Boulder Clusters	20,300	0
Newbury Riffles	6,000	3,400
Side-channel (Reach 2)	7,000	60,000
Project Technican including Materials & Tech. Assist. Consultations and Reporting	14,500 10,000	14,500 10,000
Spyder Mobilization/demo.	1,000	1,000
Total	**$ 126,300**	**$ 120,400**

3.9. Estimated Benefits of Habitat Restoration: Brohm River

Prescribed LWD structures would add 2-3 times the functional pieces of large wood to the channel beyond the existing LWD. With collection of driftwood during flood events, a substantial increase in functional LWD and the frequency of small complex lateral log jams would occur. Thus, LWD in the Brohm River Reach 2 would increase from fair to excellent quality. Similarly, key cover features would be increase to high quality. Rearing habitat quality would also increase in Reach 1 and Reach 6, although less so than Reach 2. Boulder cover in Reach 2 would increase to a good quality rating with the addition of 54 three-boulder clusters in riffles, and thus combined with LWD as overhead and pool-run cover, total salmonid cover would be substantially greater than pre-treatment. Furthermore, aquatic insect abundance can be expected to increase significantly with woody debris restoration, based on woody debris removal experiments in the south eastern USA. Woody debris jams, in particular with their depositions of woody materials, leaf litter and salmon carcasses store nutrients and carbon, elevating stream productivity. Because dissolved phosphorus concentrations are unusually high in Brohm River (PSlaney Aquatic Science Ltd 2008a), salmonid benefits of habitat restoration will be greater than other coastal streams.

The LWD structure sites in Reach 2 are anticipated to largely generate prime higher velocity run habitats preferred by steelhead parr and pre-smolts. This contrasts with an existing dominance of low-cover riffles and glides. Based on monitoring of parr to adult rainbow trout at the West Kettle River, 3-fold increases in trout parr abundance, with larger increases in coho smolts, can be expected in sections rehabilitated.

Similarly, boulder cluster additions in riffles with low percent boulders has been shown to increase steelhead parr and coho fingerling densities in the more infertile Keogh River by 1 steelhead parr and 3 coho fingerlings per boulder, assuming some depth scour develops within the 0.6 m boulder clusters (Ward 1997). As Brohm is much more nutrient-rich than Keogh, there would be at least a 2-fold increase in parr and smolts in Reach 1, plus over-winter survival would be about 2-fold greater. Thus 162 riffle boulders in 54 clusters can be expected to result in about 200 steelhead smolts and 500 coho smolts per year, or 8-24 adult steelhead (at 4-12 % survival) and 10-50 coho (at 2-10 % survival), equating to 80-240 steelhead adults and 200-1000 coho adults (Slaney et al. 2003).

Large wood structures would double to triple salmonid smolt yields by converting featureless riffle-glide habitats into run habitats. At Keogh such glides supported 1.7-7.4 parr 100 m^2 (average 4.5), whereas runs support 11 parr per 100 m^2, or 2.5-fold. Coho fry/fingerling densities were more a function of overhead cover and low velocities in these habitats and thus a 3-fold increase could be expected with lower velocities and development of pool depths, or an increase from 10 per 100 m^2 to 30 per 100 m^2. As the fertility of Brohm River is much higher than Keogh River, 2 times this density increase can be expected and at a much higher over-winter survival by 2-fold or 2x parr density and 2x the smolt yield from both species. Thus 22 steelhead parr and 60 coho fry per 100 m^2 and 70 % and 60 % survival to smolt stage equates to 15 and 36 respectively per 100 m^2. As each created habitat spans 8 m of the stream width over a distance of 25 m, or 200 m^2, numbers of steelhead and coho smolts per LWD structure equate to 30 and 72, respectively, and from a total of 11 LWD structures a total of 330 steelhead smolts and 790 coho smolts per year which equates to 13-40 (4-12 % survival) and 16-79 (2-10 % survival) adults. Over 20 years, this amounts to 260-800 adult steelhead and 320-1580 adult coho.

Side-channel development of a relic channel on the east floodplain of Reach 2 would add about 400 m x 5 m or 2000 m^2 of well-flowing complex riffle-pool side-channel. Infertile streams/rivers support 2 steelhead and 10 coho smolts per 100 m^2. More productive stream support 3 times this smolt yield. At 3 times the infertile Keogh-type yield a 2000 m^2 well-flowing side-channel would support 120 and steelhead and 2000 coho smolts per year. Over 20 years this equates 80-240 steelhead adults (4-12 % survival) and 800 to 4000 coho adults (at 2-10 % survival).

Smaller increases would occur from habitat restoration in Reach 1 and 6, as there are cobble to boulder substrates, and most of stream restoration works in these reaches are directed at bank stabilization and spawning gravels deposition. However, if the steelhead smolt yield from these reaches is fry density limited, as it is for coho, benefits could be similar to Reach 2. There is evidence from juvenile sampling in 2007 that the reach located upstream of Brohm Lake outlet creek supports few steelhead fry owing to a lack of suitable spawning gravels.

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5. Acknowledgements

Greg Wilson, regional fish biologist for the BC Ministry of Environment, Lower Mainland Region, requested a fish habitat assessment and thereafter habitat restoration prescriptions for Brohm River. Greg Wilson assisted with assessment of Brohm canyon Reach 4 to 5 along with Sheldon Reddekop, ecosystem biologist of Ministry of Environment, Surrey. Dave Harper, fisheries technician for BCCF assisted with habitat restoration prescriptions in the lower river in Reach 2-3., as did Linda Slaney with Reach 1. Ken Ashley, assisted with off-channel and riparian reserve prescriptions and recommendations in Reach 2 and 4. Matt Foy, habitat and enhancement biologist for the Department of Fisheries and Oceans, Lower Mainland, provided suggestions related to coho salmon recovery in Brohm River and its tributaries. Squamish River Streamkeepers Society also provided input on early (pre 1970s) history of anadromous salmonid migration in the Brohm system, including the inlet (Bratt Creek) to Brohm Lake.

Subsequent to circulation of a draft of this report by Ministry of Environment, there has been financial support from Ministry of Transportation and CN Rail for implementation of the Brohm River restoration plan during the summer of 2008. In addition, the Garibaldi at Squamish project has expressed an interest in supporting habitat restoration of the Brohm River system in 2009.

6. Appendix 1. Photo series of Brohm River restoration sites in Reach 1, 2 & 6.

Appendix Figure 1. Reach-1 234 m glide-riffle: 2-rootwad 2 ramp log triangular structure (external) off left bank with three boulder clusters placed at tail-out to elevate residual depth and slow glide velocities (local boulders and ballast).

Appendix Figure 2. Reach-1 329 m steep riffle: top; 2-rootwad 3 ramp log triangle at left bank (local ballast) plus 3 parallel logs on bank 15m d/s (erosion).

Appendix Figure 3. Reach-1 656 m steep riffle: 2 parallel rootwads off left bank using local ballast boulders, for erosion control on BCH power-line right-a-way.

Appendix Figure 4. Reach-2 712 m glide-run: shift natural left bank rootwad downstream 5 m and ballast root to tree bases and stem to water surface level.

Appendix Figure 5. Reach-2 763 m riffle-shallow pool: 2-rootwad 0-ramp log right bank triangle with local rock clusters at pool tail-out for gravel deposition.

Appendix Figure 6. Reach-2 820 m riffle: 2-rootwad 2-ramp logs right bank triangle for cover/sp. gravel deposition (may need rock riffle added at tail-out).

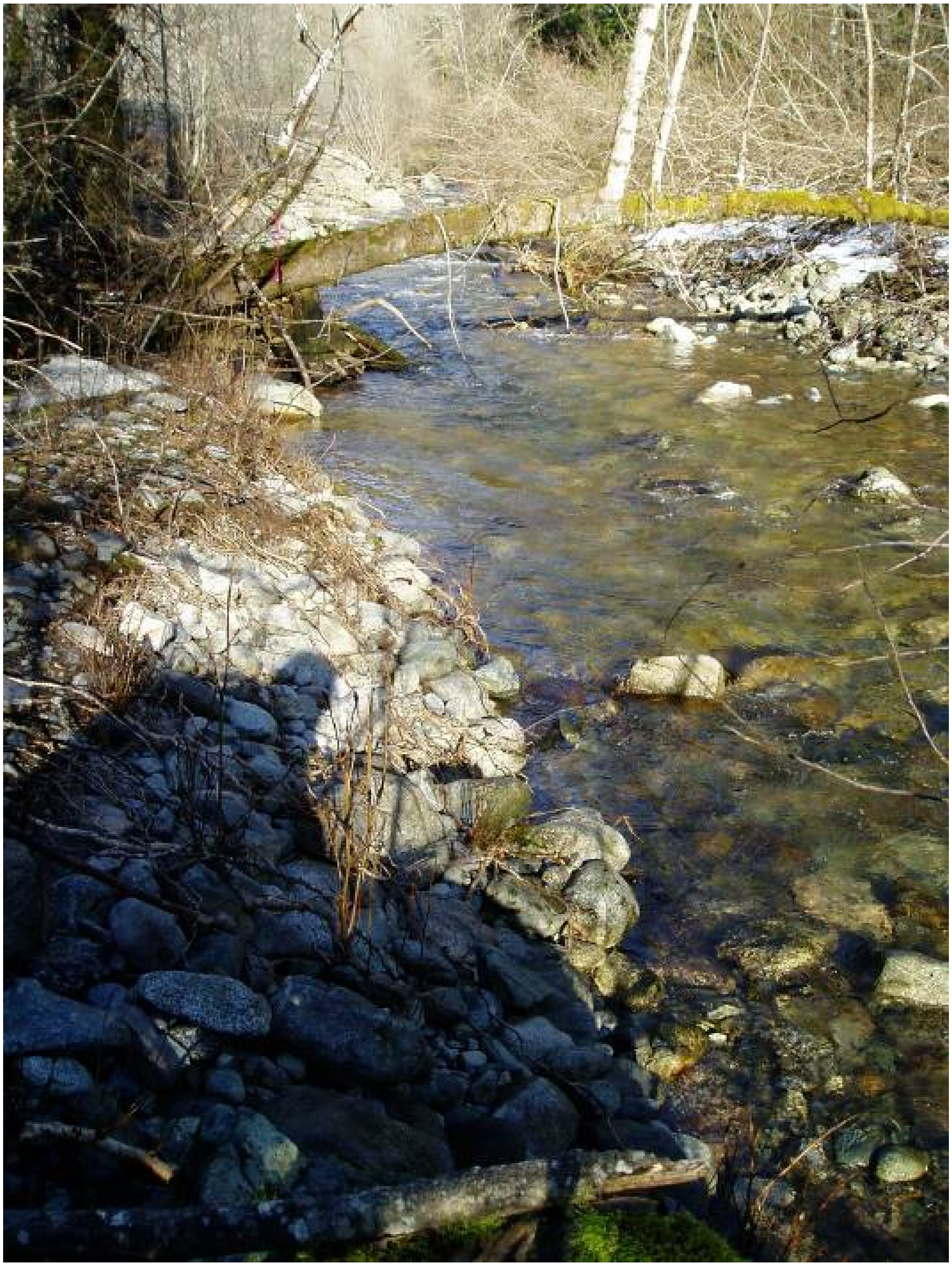
Appendix Figure 7. Reach-2 850 m glide: <u>two</u> 2-rootwad 2-ramp log left bank triangle structure for prime rearing habitats and some tail-out gravel deposition.

Appendix Figure 8. Reach-2 921 m glide-run: 2-rootwad 2-ramp log right bank triangle for prime rearing/wintering habitat and potential sp. gravel deposition.

Appendix Figure 9. Reach-2 1006 m highway-encroached riffle: 14 3-boulder 0.6 m clusters within thalweg with boulders 0.5 m apart, clusters 3 m apart.

Appendix Figure 10. Reach-2 1081 m: 2-rootwad 0-ramp left bank triangle.

Appendix Figure 11. Reach-2 1124 m highway encroached riffle: 2 2-rootwad 2-ramp log opposing right and left bank triangles.



Appendix Figure 12. Reach-2 1218 m riffle: 2-rootwad 0-ramp right bank flat triangle (under overhanging cottonwood), plus 12 3-boulder within tail-out (2-3 clusters) and within highway-encroached steep riffle upstream (9-10 clusters), within thalweg with boulders 0.5 m apart and clusters 3 m apart.

Appendix Figure 13. Reach-2 1317 m highway-encroached riffle: 2-rootwad 2-ramp log left bank triangle, plus 6 3-boulder clusters, staggered at 3 m apart.

Appendix Figure 14. Reach-2 1387 m highway-encroached riffle: 7 3-boulder clusters staggered within thalweg with boulders 0.5 m apart, clusters 3 m apart.

Appendix Figure 15. Reach-2 1534 m highway-encroached riffle: 15 3-boulder clusters staggered within thalweg with boulders 0.5 m apart, clusters 3 m apart. Note: boulder clusters to be mainly placed in the upper segment of long riffle.

Appendix Figure 16. Reach-2 1551 m highway-encroached overly-fast pool-run: 2-rootwad triangle off left bank, plus Newbury riffle of ten 0.3 m boulders and ten 0.6 m boulders plus local infill cobbles to elevate residual depth by 0.3-0.5 m.

Appendix Figure 17. Reach-2 1600 m highway-culverted west tributary: Newbury riffle to elevate residual depth to backwater culvert for access of coho spawners at moderate to higher fall flows, with later baffle installations.(Note: subject to hydraulic engineering input and MoT approval)

Appendix Figure 18. Reach-6 2918 m steep riffle: top; 2-rootwad 3-ramp log left bank triangle/groyne using local rootwads/logs and boulder ballast (optional site).

Appendix Figure 19. Reach-6 3004 m glide-run (upper); 2- parallel rootwads secured to right bank using local rootwads/logs & boulder ballast (optional site).

Appendix Figure 20. Reach-6 3049 m glide-run; Newbury riffle using local 0.3 m to 0.6 m boulders to augment spawning gravel deposition (local boulders reliant).

Appendix Figure 21. Reach-6 3194 m 45 m glide-run; 2 stacked rootwads (external) and 2 stacked (local) cedar logs for right bank stabilization, plus 3 m Newbury riffle using transported 0.3 m to 0.6 m boulders to add residual glide-run depth, plus one 2-rootwad triangle (external) off right bank d/s of Newbury riffle.

Appendix Figure 22. Reach-6 3285 m glide-riffle: highway-encroached fast glide-run: 2-rootwad triangle off left bank via local ballast and tree base anchors.

Appendix Figure 23. Reach-6 3454 m glide-run: 2 ballasted parallel rootwads on left bank, plus Newbury riffle using external 0.3 m to 0.6 m boulders & local cobble; designed for spawning gravel deposition and to stabilize tail-out left bank.

Appendix Figure 24. Brohm Lake outlet creek 10 m downstream of replaced highway culvert: pool tail-out for addition of less-coarse spawning gravels.

Appendix Figure 25. Brohm Lake outlet creek 15 m upstream of replaced highway culvert: ideal pool tail-out site for placement of spawning gravels.

Appendix 2.				Habitat/Channel Assessment/Prescriptions							Recorders: PS, DH				Project: Brohm River Assess.& Prescriptions						
Date: F		eb18,19,20,25/		/08 St	tream: Brohm		River	Loc:	Accessible Length 4.0 km						Condition:		Sunny Feb 18,19, 20, 25/2008				
		GpsUTM							BF	Wt					Dom.	S-dm	Est.%	Est.	#Pk	M2	
St	Rh	Dist m	HabTp	HabC	Len.m	MxDm	MBDm	MnDm	Wm	Wm	PoT	PMxD	PMnD	PRsD	Sb.m	Sb.m	Grad.	Vel.	Po	Pk	Struc.Site GPS
1	1	165	St Rif	rbp	165	0.9	2.2	0.45	10	8	pkt				0.3	0.6	2	0.8	5	50	
2	1	234	Riffle	rbp	69	0.6	0.75	0.23	18	9					0.25	0.15	1.3	0.5	0	0	0490524 5515810
3	1	269	Gl-run	rbp	35	0.75	0.9	0.5	12	7	sc	0.9	0.5	0.2	0.35	0.2	0.15	0.4	0	0	
4	1	329	St Rif	rbp	60	0.5	0.7	0.3	18	5.5					0.4	0.2	2.5	1	1	5	0490609 5515920
5	1	353	St Rif	rbp	24	0.5	0.8	0.35	15	7					0.4	0.25	2	1	1	5	
6	1	370	Pool	b.step	17	1	1	0.7	14	7	sc	1	0.7	0.25	0.4	0.15	0.1	0.4	0	0	
				pool							bdrk										
7	1	425	St Rif	cb.stp	55	0.65	0.8	0.35	15	8					0.6	0.3	5	0.8	3	20	
				riffle																	
8	1	593	St Rif	cbstp	168	0.4	0.6	0.25	14	7					0.35	0.25	2	1	1	5	
				riffle																	
9	1	656	St Rif	cbstp	63	1	0.6	0.35	11	8					0.45	0.25	5	0.8	5	70	no gps: site d/s of
				riffle																	of 35 m br canyon
10	1	691	Cas.rif	bedrk	35	0.85	1.5	0.45	7	5					0.45	0.3	4	1	3	30	
				riffle																	
Means/tot.					**691**	**0.72**	**0.99**	**0.39**	**13.40**	**7.15**					**0.40**	**0.27**	**2.41**	**0.76**	**19**		**185**
11	2	712	Gl-run	rbp	21	0.95	0.5	0.55	15	5	sc	0.95	0.55	0.35	0.2	0.1	0.15	0.7	0	0	0490855 5516038
12	2	763	Rif-pool	rbp	51	0.95	0.5	0.35	14	7					0.2	0.1	0.15	0.5	0	0	same above gps
			sequen																		2 min.pools+ 2rifs
13	2	820	Riffle	rbp	57	0.45	0.5	0.2	12	10					0.2	0.1	0.5	0.5	0	0	0490855 5516113
14	2	850	Glide	rbp	30	0.8	0.7	0.35	10	6					0.15	0.07	0.1	0.4	0	0	0490900 5516137
15	2	901	Riffle	rbp	51	0.35	0.7	0.2	20	11					0.2	0.1	0.06	0.5	0	0	
16	2	921	Gl-run	rbp	20	0.85	1.1	0.35	15	8.5	sc	0.85	0.35	0.2	0.2	0.1	0.1	0	0	0	0490965 5516137
17	2	1006	Riffle	rbp	85	0.5	1	0.25	8	6					0.25	0.1	1	1	1	5	0490996 5516197
			Hwy																		
18	2	1041	Gl-run	rbp	35	0.6	0.9	0.35	10	5					0.2	0.1	0.25	0.8	0	0	
			old jam																		
19	2	1061	Riffle	rbp	20	0.35	0.6	0.2	13	10					0.2	0.1	1.5	1	1	5	
			Hwy																		
20	2	1081	Glide	rbp	20	0.65	0.7	0.35	11	9	sc	0.65	0.35	0.2	0.2	0.1	0.15	0.5	0	0	0491078 5516133
			Hwy																		
21	2	1124	Riffle	rbp	43	0.4	0.9	0.25	10	8					0.25	0.15	0.7	0.7	0	0	0491118 5516184
			Hwy																		
22	2	1218	St Rif	rbp	94	0.6	1	0.25	11	7					0.35	0.15	1.3	0.8	0	0	0491139 5516206
			Hwy																		
23	2	1268	Riffle-w	rbp	50	0.7	1	0.15	17	14					0.2	0.1	1	0.8	0	0	
			Hwy																		
24	2	1317	Riffle	rbp	49	0.3	0.5	0.15	16	9					0.2	0.1	0.5	0.6	0	0	0491211 5516338
			Hyw																		
25	2	1332	Glide	rbp	15	0.8	0.6	0.5	14	6	sc	0.8	0.6	0.2	0.2	0.1	0.15	0.4	0	0	
			Hwy																		
26	2	1387	Riffle	rbp	55	0.7	1	0.3	13	11					0.25	0.15	1	0.6	0	0	0491247 5516391
27	2	1404	Gl-run	rbp	17	1.1	1.5	0.6	11	9	sc	1.1	0.6	0.35	0.25	0.15	0.2	0.7	0	0	
											silog										
28	2	1534	Riffle	rbp	130	0.6	1	0.3	14	10					0.3	0.2	1.8	0.9	3	30	0491267 5516391
																					1 20m2 pkt pool
29	2	1551	Pool-	rbp	17	0.9	1.5	0.4	10	7	sc	0.9	0.4	0.3	0.2	0.05	0.1	0.7	0	0	0491267 5516391
			turbulnt								strif										close-by (no sats)
30	2	1606	Riffle	rbp	55	0.4	1.4	0.25	20	7					0.25	0.2	1.2	1	0	0	0491292 5516594
																					key rt bk trib.Gps
31	2	1621	Pool	rbp	15	0.85	1.5	0.45	20	6	sc	0.85	0.45	0.25	0.2	0.03	0.1	0.4	0	0	
Means/tot.					**930**	**0.66**	**0.91**	**0.32**	**13.52**	**8.17**					**0.22**	**0.11**	**0.57**	**0.64**	**5**	**40**	

32	3	1714	St Rif	rbp	93	0.6	1.4	0.35	10	7					0.35	0.2	2.8	1	2	10	
out	fan																				
33	3	1816	St Rif	rbp	102	0.45	1	0.25	11	8					0.4	0.25	2	0.8	0	0	
out	fan																				
34	3	1932	St Rif	rbp	116	0.55	0.5	0.2	20	17					0.3	0.2	2	0.8	0	0	
out	fan																				
35	4	1952	Pool-	rbp	20	1.1	1.5	0.7	37	35	sc	1.1	0.7	0.8	0.35	0.25	0.15	0.4	0	0	
	can		logjam								jam										
36	4	2062	St Rif	rbp	110	0.7	1	0.35	11	7					0.4	0.25	4	0.8	1	50	
	can																				
37	4	2082	Cascde	bstep	20	1.7	2	0.8	20	15	plng	1.7	0.8	0.35	0.5	0.6	10	1	0	0	
	can		pools	pools							pool										
38	4	2182	Cascde	bstep	100	1.4	3	0.6	10	7					1.2	0.7	10	0.7	8	99	
	can		pools	pools																	
40	4	2227	pools	canyn	45	1.5	3	0.8	16.2	13.6	bdrk	1.5	0.8		1	0.4	2	0.5			unsurveyed Broh.
			est. dist	stp po							pools										River R-4 segment
			inaccessable																		0491355 5517204
																					(may be 50-75 m)
41	4	2325	St Rif	bsp	98	0.9	1.5	0.32	16	14					0.75	0.4	7	0.7	2	5	mid tailout of Gl-rn
																					water level 2.86m
42	4	2354	Gl-run	bsp	29	1.2	1.5	0.44	8.5	6.4	sc	1.2	0.44	0.3	0.3	0.45	0.1	0.4			east trib inpt lft bk
																					0491358 5517200
																					trib 22 % river flow
43	4	2406	Rif-Stp	rif-bsp	52	0.92	1.45	0.35	11	5.5					0.4	1	6	0.7	2	30	0491355 5517248
			pools																		
44	4	2456	St Rif	cbsp	50	1.1	0.7	0.35	8.6	5.5	pkt				0.5	0.25	4	1	5	17	pocket mean 0.55
			Stp pkt								bdrk										meters depth
45	5	2612	St Rif	bsp	156	0.65	0.7	0.25	14.5	11.5					0.5	0.3	3	0.7	4	12	*spawn pkt po.top*
																					0491297 5517394
46	5	2701	St Rif	rbp	89	0.5	1	0.25	11.5	9.5					0.7	0.3	4.5	0.8	2	7	
47	5	2775	vStRif	bsp	74	0.9	2.3	0.4	13	10.6					0.7	0.5	4.2	0.7	5	20	0491317 5517504
48	6	2876	St Rif	rbp	101	0.55	2.8	0.2	18.7	11					0.35	0.2	3	0.6			0491330 5517530
																					40 m lft bk erosion
49	6	2918	St Rif	rbp	42	0.6	2.2	0.22	18	14					0.3	0.2	4	0.7	2	5	0491325 5517572
											old relic flood chan lft bk										up lft erosion site
50	6	2978	St Rif	rbp	60	0.5	0.8	0.3	17.5	12					0.35	0.2	3.3	0.8	3	10	
51	6	3004	Gl-run	rbp	26	0.8	1.6	0.5	10	6.5	sc	0.8	0.5	0.25	0.4	0.2	0.5	0.8			0491297 5517572
																					2 para rws rt bk
52	6	3034	St Rif	rbp	30	0.5	1.6	0.3	14	7					0.4	0.25	3	0.7			
53	6	3049	Gl-run	rbp	15	1.1	1.1	0.75	10	5.5	sc	1.1	0.75	0.3	0.25	0.05	0.1	0.6			*pocket spawn.hab*
54	6	3149	St Rif	rbp	100	0.5	2.3	0.3	12	8.5					0.4	0.2	3.5	0.8	2	7	
55	6	3194	Gl-Rif	rbp	45	0.65	1.45	0.45	12	7.3					0.4	0.2	0.5	0.5			491284 5517745
56	6	3268	St Rif	rbp	74	0.55	0.8	0.3	11	8	old concret rd brge abut				0.5	0.3	4	0.8	2	8	nil - ok
57	6	3285	Gl-Rif	rbp	17	0.6	1.35	0.35	9	7					0.2	0.4	0.2	0.8	1	6	0491299 5517824
58	6	3365	St Rif	rbp	80	0.8	2.1	0.3	16	8					0.4	0.2	3.5	0.8	2	15	nil - ok
											70 m lft bk erosion 10 yr										
59	6	3436	St Rif	rbp	71	0.7	2	0.4	11	8					0.4	0.25	2.5	0.7	4	16	nil - ok
60	6	3454	Gl-run	rbp	18	1.3	2.2	0.7	9	5	sc	1.3	0.7	0.3	0.4	0.2	0.1	0.3			0491167 5517960
																					generate spn grav
61	6	3506	St Rif	rbp	52	0.75	1.5	0.5	7	5					0.4	0.25	3.8	0.7	2	17	nil: good habitat
											lake outlet entry (25:75%)										
62	6	3628	St Rif	rbp	122	1	2	0.3	14	6					0.4	0.25	3.6	0.8	3	15	nil -too unstable
63	6	3679	St Rif	rbp	51	0.9	2.5	0.35	10	7					0.5	0.25	3.5	0.7	3	20	nil: bridge road
																					to Cat Lake
64	7	3723	Rifstep	bstp	44					8	upstr.anad.step pool rch								4	15	
			Pool																		
65	7	3829	Rifstep	bstp	106					7									6	20	
			Pool																		
66	7	3946	Rifstep	bstp	117					7									6	20	
8m chte		4030	Pool	barrier	84					6									4	15	
means/tot.					**2409**	**0.84**	**1.64**	**0.41**	**13.47**	**9.33**					**0.46**	**0.31**	**3.25**	**0.70**	**75**		**439**

St	TW	L1020	L2030	L3040	L4050	L>50	CovTy	TCv%	PoW%	OhC%	B%	OffCm	RipTy	RipSt	CpyC	Ob?	%Ufry	%UP	Rehab.Prescrip. L/R Bk
1	5	0	1	3	1	0	b/d/t	48	3	15	30	0	dec	yf	25	0	10	30	prime parr habitat
2	4	3	0	0	1	0	b/lwd	8	0	5	3	0	mix	yf	20	0	20	5	***1 2-rootwad Triang.lft bk***
																			+ 2 ramp logs (loc.bal.)
3	1	0	0	1	0	0	lwd/d/t	40	20	10	10	0	mix	yf	20	0	10	25	rootwad-generated run unit
							/b												of prime sum./winter hab.
4	3	0	1	0	0	0	b	20	0	0	20	0	mix	yf+	20	0	20	5	***1 2-rootwad Triang.lft bk***
																			+3 ramp logs (loc.bal)as
																			bk. stabilizer deflector +
																			2 para.stacked rootwads
5	7	0	0	1	0	0	b/lwd	15	0	3	12	0	mix	yf/mf	20	0	10	15	above prescript.at tail-end
6	2	0	0	1	0	0	b/d/t	50	2	20	25	0	mix	yf/mf	20	0	0	50	prime turbulent pool hab.
7	2	0	0	0	0	0	b	30	0	5	25	0	mix	yf	30	0	15	30	prime large boulders+pkts
8	3	0	0	1	0	0	b	45	0	5	40	0	mix	yf	25	0	20	30	good parr habitat
9	10	3	0	2	1	0	b/lwd	50	5	5	40	20	dec	ps	5	0	10	40	***2 paral.stacked rootwads***
jam																			***at eroding lft bk (loc bal).***
																			good parr pocket habitat
10	2	0	1	0	0	0	b	40	0	10	30	0	con	mf	50	0	0	30	prime pocket habitat as is
tm	**39**	**6**	**3**	**9**	**3**	**0**		**34.6**	**3.0**	**7.8**	**24**	**20.0**			**23.5**	**0.0**	**11.5**	**26.0**	**LWD/cw=0.75,Funct=0.4**
11	7	2	1	0	0		lwd/d/t	30	10	20	0	0	con	mf	60	0	5	30	***Shift rootwad d/s 10 m;***
																			secure with local ballast
12	8	0	4	2	0	0	lwd/d/t	20	10	10	0	0	dec	yf/mf	25	0	15	20	***1 2-rootwad Triang.rt bk***
																			at d/s pool: for sp.gravel
13	4	0	0	2	0	0	lwd	2	0	2	0	0	dec	yf	25	0	25	2	***1 2-rootwad Triang.rt bk***
																			+2 rmp logs: sp grav site
14	2	0	1	1	0	0	oh/lwd	2	0	2	0	0	dec	yf	25	0	25	2	***2 2-rootwad Triang.lft bk***
																			+2 rmp logs: pot.sp grav
15	2	0	1	0	0	0	lwd	0	0	0	0	0	dec	yf/ps	5	0	30	0	nil: unstable riffle
16	4	2	0	2	0	0	lwd	15	15	0	0	50	dec	yf	25	0	20	15	***1 2-rootwad Triang.rt bk***
																			+2 rmp logs: sp grav site
17	3	0	0	1	0	0	b	5	0	0	5	50	dec	yf	20	0	20	5	***14 3-bould.clusters 0.6m***
														Hwy					
18	10	3	3	3	0	0	lwd	25	25	0	0	0	dec	yf	20	0	15	25	prime log-jam habitat for
														Hwy					sthd holding and rearing
19	2	0	1	1	0	0	lwd	5	5	0	0	0	dec	yf	20	0	10	5	nil: too unstable for bcs
														Hwy					
20	1	1	0	0	0	0	d/oh	10	0	10	0	0	mix	yf	40	0	20	7	***1 2-rootwad Triang.lft bk***
														Hwy					
21	3	3	0	0	0	0	b/lwd	15	3	5	7	0	dec	yf	20	0	20	7	***2 2-rootwad Triangle***
														Hwy					***+2 rmp logs: left & rt bk***
22	3	0	1	2	0	0	b/lwd	25	5	0	20	0	dec	yf	10	0	10	20	***1 2-rootwad flat Triangle***
														Hwy					***+12 3-boulder Clusters***
23	10	2	3	4	0	0	lwd	25	10	5	0	0	dec	yf	20	0	20	20	natural jam with rearing
jam														Hwy					***pot.lft bk jam intake site***
24	5	0	0	0	0	0	b	5	0	0	5	0	dec	yf	10	0	20	3	***1 2-rootwad Triang.lft bk***
														Hwy					***+6 3-boulder Clusters***
25	2	0	1	1	0	0	lwd	35	20	10	5	0	dec	yf	10	0	25	35	***prime habitat as is and***
														Hwy					***poten. 2ndary intake site***
26	1	0	0	0	0	0	b	5	0	0	5	0	dec	ps	2	0	30	4	***7 3-boulder Clusters thal***
														Hwy					
27	5	3	1	1	0	0	d/t/b/	40	10	15	10	0	dec	ps	20	0	5	35	prime turbulent pool
							lwd							Hwy					gnerated by sill log
28	11	1	2	5	3	0	b/lwd	20	5	1	14	0	Mix	yf/ps	10	0	20	12	***15 3-boulder clusters***
														Hwy					
29	1	0	0	0	0	0	d/t/b	30	0	20	10	0	Mix	yf/ps	15	0	7	20	***2 rootwad triangle plus***
														Hwy					***Newbury rif. 17-22m d/s***
30	4	4	0	0	0	0	lwd/b	10	4	0	6	0	dec	yf	5	0	15	7	***unstable fan:at rt bk add***
																			0.3 m b. for trib. access
31	10	0	0	3	1	2	lwd/d	40	25	12	3	0	dec	yf	5	0	2	30	prime habitat as is
tm	**98**	**21**	**19**	**28**	**4**	**2**		**17.3**	**7.0**	**5.3**	**4.3**	**100**			**18.7**	**0**	**17.1**	**14**	**LWD/cw=1.4, Funct=1.1**

32	4	0	0	2	2	0	b	25	5	0	20	0	mix	yf	30	0	20	20	nil: ok as is
33	3	0	1	1	0	0	b	20	0	0	20	0	mix	yf	30	0	20	15	nil: too isolated site for bc
34	10	0	0	0	1	0	b	15	1	0	15	40	dec	yf	20	0	30	13	flood avulsion zone: dry via elevat. fan bar jam
35	10	0	3	3	3	1	lwd/d/b	65	35	20	10	0	mix	yf	20	0	5	55	prime+ log-jam pool for sthd holding and rearing
36	1	0	0	0	0	0	b/d	25	0	5	20	0	mix	mf	40	0	10	20	good boulder & pkt hab.
37	3	0	0	0	1	0	b/d/t	50	0	20	30	0	mix	mf	30	0	0	50	prime falls-pool:1.6m jump sthd juv.barrier&not adults
38	10	0	0	2	4	0	b/d/t	50	0	20	30	0	mix	mf	30	0	0	50	prime pkt-falls-pool habitat
39							canyon												*as above (unsurveyed)*
40	5	1	1	2	1	0	d/t/b	50	7	23	20	0	mix	yf	70	0	0	50	Prime adult holding hab.
41	0	0	0	0	0	0	b	55	0	5	50	0	mix	yf	70	0	5	35	Good parr habitat
42	4	2	0	0	0	0	d/t/b	35	5	20	15	0	mix	yf	80	0	0	30	Good parr habitat
43	2	0	0	0	0	0	b/d/t	30	0	10	20	0	mix	yf	75	0	6	25	Good parr habitat
44	2	0	0	0	0	0	b/d/t	25	0	10	15	0	mix	yf	70	0	7	15	overy fast parr velocities
45	5	2	0	3	0	0	b/pkt	40	0	5	35	0	mix	yf	80	0	25	40	prime sthd parr habitat
46	3	0	0	0	0	1	b/pkt	50	0	10	40	0	dec	yf	50	0	20	35	prime sthd parr habitat minor ditch side-chan.
47	9	1	0	3	0	0	rw/pkt/ d/t	60	0.5	20	40	0	mix	yf	50	0	20	50	prime holding + parr hab.
48	4	1	1	0	0	0	b	20	0	5	15	0	dec	yf	50	0	50	15	funct. alder floodplain prime fry habitat unit
49	2	0	0	0	0	0	b/d/t	20	0	5	15	0	dec	yf	40	0	10	15	***1 tri 3-ramp lft bnk eros.***
50	4	1	1	0	0	0	b/d/t	20	0	5	15	0	dec	yf	40	0	25	20	*Good parr habitat as is*
51	1	1	0	0	0	0	d/t/b	25	0	10	15	0	dec	yf	50	0	7	25	***2 para rw off left bank***
52	2	1	0	0	1	0	b/d/t	50	0	2	48	old fld chan	dec	yf	40	0	15	40	prime boulder parr hab.
53	0	0	0	0	0	0	d/t	35	0	25	10	old fld chan	mix	yf	50	0	2	20	***Newbury bould riffle 5m at tail to add 0.5m depth***
54	4	0	2	0	1	0	b	30	2	3	25	minor flow	mix	yf	50	0	15	25	ok as is: coarse boulders
55	1	0	1	0	0	0	b/lwd	15	0	3	12	minor flow as trib	mix	yf	40	0	0	0	***2 stacked rws plus 1 log 2 paral cedar logs (local) 1 3m Newbury riffle + 1 tri of two rootwads***
56	2	0	0	0	0	0	b	50	0	5	45	trib	mix	yf	40	0	10	40	*good parr habitat as is*
57	2	0	0	0	0	0	b-rd	25	0	5	20	0	mix	yf/mf	40	0	5	20	***1 two rw triangle lft bk off tree base local ballas.***
58	5	0	1	2	0	1	b/lwd	35	3	5	25	0	dec	yf	40	0	25	25	good habitat as is
59	2	0	1	1	0	0	b/d/t	36	1	10	25	0	mix	yf/mf	50	0	10	30	nil: prime habitat
60	1	0	0	0	0	0	d/t/oh	35	5	20	10	0	mix	yf/mf	50	0	5	35	***2 paral. Rootwads ft bk+ Newbury riffle at tailout***
61	1	0	0	0	0	0	b/d/t	45	0	15	30	80 2ndary	mix	yf	38	0	20	45	nil: prime parr habitat
62	4	0	1	0	0	0	b	40	2	7	31	90	dec	yf	40	0	10	40	nil: good parr habitat
63	0	0	0	0	0	0	b/d/t	50	0	10	40	30	dec	yf	40	0	10	50	nil: good parr habitat
64																			***no prescripts. Hereafter:***
stp																			***steep b-step-pool reach***
tm	**106**	**10**	**13**	**19**	**14**	**3**		**36.3**	**2.1**	**9.8**	**25**	**240**			**46.5**	**0**	**12.5**	**31**	LWD/cw=0.58, funct=0.31