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THE IDENTIFICATION OF HABITAT IMPROVEMENT OPPORTUNITIES FOR ADULT AND SUB-ADULT SPORT FISH IN THE UPPER PINE RIVER

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for:

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ABSTRACT

During October 1991, B.C. Environment (Fort St. John) completed a low level aerial video of a 60 km (approx.) section of the upper Pine River, between Fur Thief and Callazon creeks. This video, and accompaning 1:50,000 topographic mapping were subsequently analyzed in order to identify habitat enhancement opportunities for adult and sub-adult sport fish in the system; notably, Arctic grayling, bull trout, and rainbow trout. By employing a set of criteria developed for a similar study of the West Kettle River, a total of 14 mainstem candidate enhancement sites were identified in the analysis. These were subsequently inspected in the field (October 29th - November 1st 1991). All 14 sites, and 3 others, were deemed to offer some enhancement potential and the specific merits of each were evaluated and priorized on the basis of hydraulic, geomorphological, and logistical criteria measured in the field. Based on existing habitat in the system, and various habitat enhancement guidelines, the emphasis in enhancement prescriptions is on large organic debris (LOD) installations; ie. debris catchers and/or bank LOD. Bank boulder additions are also prescribed as the principal or alternate technique at many sites. The implementation of any or all of the identified opportunities/prescriptions is briefly discussed, relative to attendant management considerations.

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1.0 INTRODUCTION

The Pine River is a major tributary of the Peace River in northeastern British Columbia (Fig.1). It originates in the Rocky Mountains near Pine Pass, and flows east, past Chetwynd to East Pine, then north to the Peace River near Taylor, B.C. The term upper Pine River refers to the 140 km (approx.) of streamlength upstream of Chetwynd.

This portion of the river is followed by highway, railway, and pipeline development, but otherwise, the associated watershed has received a minimum of disturbance, and water quality remains pristine (B.C. Environment, 1991_1). However, several decades of highway and railway construction and pipeline crossings have resulted in substantial channelization/stabilization of the mainstem, and the restriction of its ability to migrate within the floodplain.

The upper Pine River supports populations of Arctic grayling, bull trout, rainbow trout, and whitefish; but numbers are low. This has been attributed to habitat degradation resulting from the various linear developments over the years (*ibid*). Accordingly, under an allocation from the Habitat Conservation Fund, B.C. Environment has initiated a program to consider habitat restoration/enhancement for sub-adult and adult sport fish in this portion of the system, so as to improve the associated fishery. For 1991, the first year of the program, the following objectives were established (*ibid*):

1. *to identify the types and locations for potential habitat enhancements*
2. *to priorize these, and to develop a budget for the installation of these structures.*

Emphasis was to be placed on large organic debris (LOD)[1] habitat in mainstem areas, but the possibility of developing further side channel habitat was also to be addressed, as a lower priority.

To meet the above objectives, it was initially proposed to conduct an intensive field program of habitat description/quantification, and fish enumeration/sampling (T. Down[2], *pers.comm.*). However, late confirmation of funding availability (September, 1991) precluded the orchestration/completion of an effective field-oriented program for 1991. As an alternative, R.P. Griffith and Associates proposed an assessment (identification/evaluation) of enhancement opportunities through analysis of a low level video overflight, followed by limited ground-truthing in the field (Griffith, 1991_1). Initially conceived by B.C. Environment (1991_2), this methodology proved highly efficient for a similar investigation of the West Kettle River, earlier in 1991 (Griffith, 1991_2). Although this approach does not address any <u>biological</u> sampling/assessment, it

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1 The term LOD is used instead of LWD (large woody debris), in keeping with B.C. Environment documents relating to the project.

2 Regional Fisheries Biologist, B.C. Environment, Fort St. John.

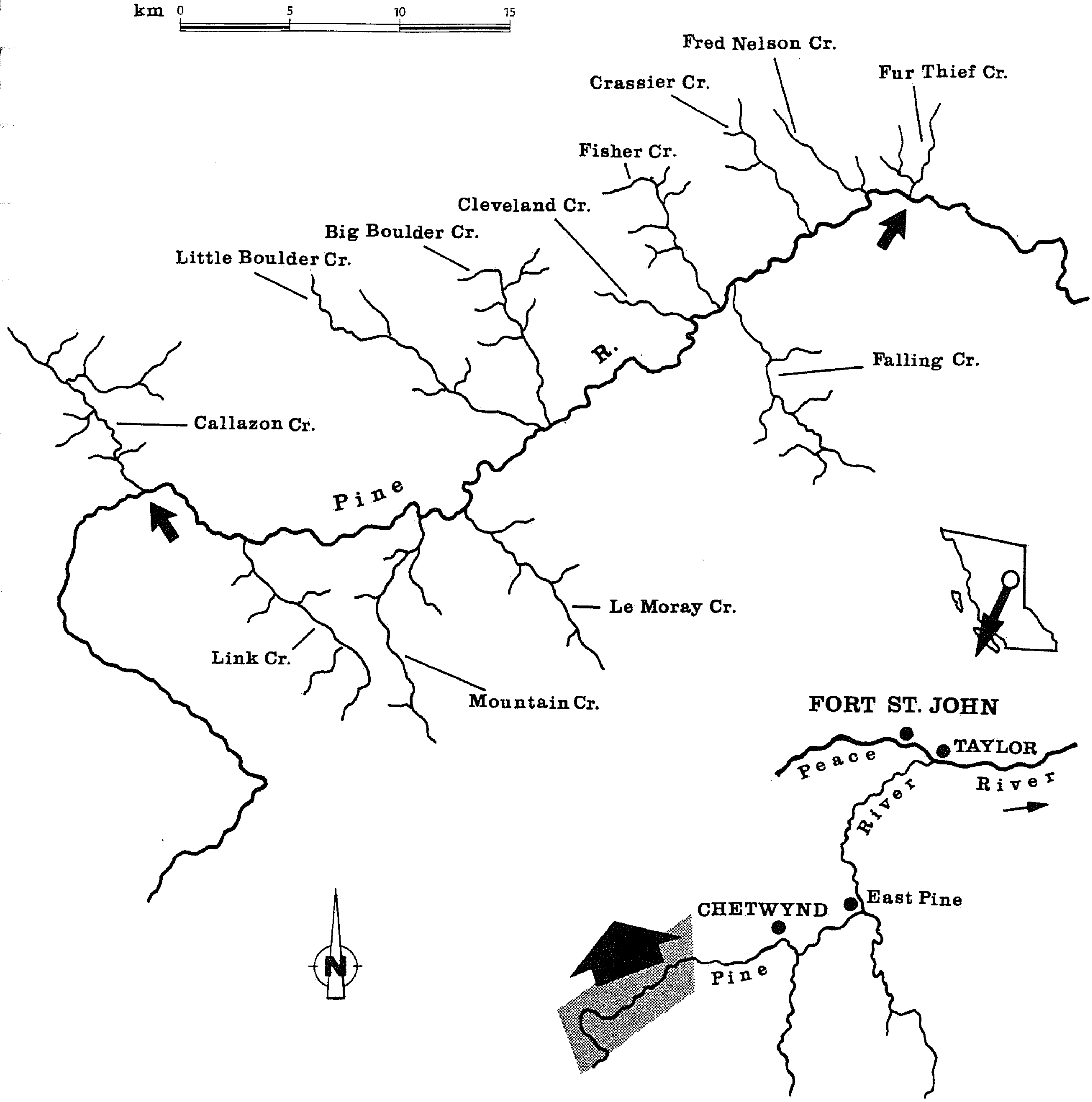


Figure 1.Upper Pine River study section, and selected tributaries.

does provide a highly economical and expedient means of identifying, evaluating, and priorizing the physical characteristics, needs, and enhancement opportunities (including feasibility) of fish habitat in a given system.

In early October 1991, the Pine River proposal from R.P. Griffith and Associates was accepted by B.C. Environment, with principal terms of reference as follows (B.C. Environment, 1991_3):

1. *Analyze an aerial video (to be provided by the Ministry of Environment) of the Pine River from Fur Thief Creek to Callazon Creek to determine potential habitat enhancement sites for indigenous sport species of fish, particularly Arctic grayling, bull trout, and rainbow trout.*

2. *All practical enhancement techniques will be considered; however, the principal emphasis will be on the installation of large organic debris (LOD) collecting systems.*

3. *Priorize site-specific opportunities for habitat enhancement, and estimate costs for completing all aspects of structure installations and assessments in the project area.*

4. *Long extended riffles and shallow glides should be designated as potential improvement sites. These should be ranked according to hydraulic characteristics, accessibility, and cover, with the highest ranking going to accessible sites with higher velocity, stable banks, and where cover is lacking.*

5. *Control sites, against which the effectiveness of LOD habitat enhancement can be compared, will also be identified.*

The aerial video of the 60 km (approx.) of the Pine River between Fur Thief and Callazon creeks (Fig.1) was completed by B.C. Environment, and was forwarded to R.P. Griffith and Associates on October 11th 1991.

2.0 PROCEDURE, CRITERIA, AND RESULTS OF AERIAL VIDEO AND MAPPING ANALYSIS

The same techniques and terms of reference established for the identification of enhancement opportunities in the West Kettle River (Griffith, 1991_2) were employed for the Pine River study. In the former investigation, every effort was made to reduce risks of failure, as much as possible, by selecting and applying the most reliable and predictable criteria, during the video review process, with the ultimate objective of maximizing potential benefits (and scope of enhancement work) from available funding. These criteria, supporting rationale, and specific application to the Pine River study are detailed below.

2.1 Stream Gradient

Most guidelines for the planning/design of fish habitat improvement projects stress the significance of stream gradient on the types of structures (if any) that are appropriate, and the likelihood of their effectiveness (eg. Rosgen and Fittante, 1986; Anderson, 1989; Crispin, 1989; Lisle and Overton, 1989). Needless to say, the exact gradient at any given site must be determined in the field, and may vary considerably with estimates obtained from mapping. However, computation of gradients between contours on topographic maps does provide an initial indication of the average for sections containing given sites, and accordingly, what sites might be of most importance, and what type(s) of installations might be most approporiate.

For the Pine River study section, analysis of 1:50,000 topographic maps revealed mean gradients (based on 100' contours) ranging between 0.13% and 0.29%, averaging approximately 0.19% (Table 1). Lisle and Overton (1989) recommend that gradients should be less than 1 to 2% for the successful installation of fish habitat improvement structures. However, both Anderson (1989) and Crispin (1989) caution that gradients <0.5% may not be suitable, due to inadequate water depths and/or velocities. In view of the generally low gradients in the Pine River (as in the West Kettle River), attention was focussed on other factors/criteria governing hydraulic energy at specific sites (eg. stream curvature, channel confinement), as well as particular interest in the 21 km of the project section with the highest mean gradient (0.29%: Table 1), between Le Moray and Callazon creeks (Fig.1).

Table 1. Stream gradient analysis of Pine River project section, based on 1:50,000 topographic mapping.

CONTOUR INTERVAL (ft)	STREAMLENGTH (km)	MEAN GRADIENT (%)
2000 - 2100	17.5	0.17
2100 - 2200	24.0	0.13
2200 - 2300	10.5	0.29
2300 - 2400	10.5	0.29

2.2 Access

Obviously, the existence of suitable access (or not) is a key factor in how much can be accomplished within a given budget, and/or what can or cannot be done at all. In main river channels, where fish habitat improvement installations typically involve large size and/or volumes of materials (eg. LOD) the feasibility/ease of delivering such materials, and any equipment required to handle/install them, is a critical factor. Certainly, in many cases where access does not exist, it can be provided one way or another (eg. road construction, helicopter, barge, etc.). However, this increases cost per installation, relative to alternate sites with existing access, and should be avoided if at all possible. In his suggested design procedure for main channel habitat improvement undertakings, Crispin (1989) lists access as the first consideration. Accordingly, the next step in the Pine River investigation was to identify all sites appearing to have good road access. This was initially conducted on the 1:50,000 topographic mapping, and was further evaluated on the aerial video. Road development along the Pine River study section is limited to Highway 97, and very few side roads. In total, just over 20 stream sections appeared to have potentially suitable access by road (mostly from Highway 97, directly).

Access at approaches of the B.C. Railway line that follows the river were also considered. However, during the site priorization process, most were discounted unless accompanied by reasonably close road access. Although rail vehicles (or road vehicles adapted for rail) might be used to transport requisite materials and/or machinery over long distances of track, this would add substantially to both organizational and operational tasks (and associated costs) of any habitat enhancement undertakings. Given the logical objective of identifying the simplest and most cost-effective options (following the above rationale), and with the existence of numerous equal or better opportunities with road access, efforts were concentrated on the latter.

2.3 Channel Pattern

Based on the double spiral pattern of flows in streams, Anderson (1989) provides an excellent discussion of hydraulic factors associated with fish habitat improvement structures in curved vs. straight stream sections. In the simplest unobstructed conditions, the energy of flows in straight sections is dissipated across the channel width, in the basic form of two opposing spirals of similar magnitude. However, in curved sections, the concentration of flows on the outside of the curve magnifies the spiral (and associated energy) on that side, simultaneously diminishing that on the inside. In other words, flow energy is concentrated against the outside bank in curved sections, and generally speaking, is further amplified by the degree of flow confinement.

In straight sections, particularly at low gradients, structures installed as fish cover may simply serve to cause bedload deposition, and ultimately direct flows away from themselves, overcoming the relatively weak flow energies along both sides of the stream. Such effects are difficult to predict (*ibid.*). However, if installed along the outside of a curve, structures are far less likely to divert flows, and far more likely to result in localized, and on-going scouring, conducive to the development and perpetuation of complex habitat preferred by adult sport fish. Accordingly, although the merits of all stream segments (including straight sections) were evaluated during the analysis of the Pine River mapping and video, the priorization process involved emphasis on sites with at least some degree of curvature. This does not infer that there may not be other opportunities to simultaneously confine/stabilize and complex various straight segments within the Pine River project section. The initial (and final) focus on curved sections was simply to optimize chances of success, and minimize risks, in the identification of sites and opportunities, consistent with established guidelines.

2.4 Channel Stability and Confinement

The reduction of flow energy on the inside of a stream curve generally results in the deposition of bedload in the form of a bar (Anderson, 1989). This is referred to as a point bar in strongly curved sections, and a side bar in more gently curved sections (Chamberlin, 1980). In either case, the degree of deposition, as evidenced by the side and stability of the bar, provides an indication of the degree to which flow energy is concentrated and maintained along the outside bank.

Accordingly, the presence/size of point bars or side bars, and associated confinement, as evidenced in the aerial video, was used as a further indication of the relative stability (and according suitability for enhancement) of the various accessible sites. Lisle and Overton (1989) stress that braided stream sections should not be considered for the installation of habitat improvement structures. Channel shifts may subsequently occur, isolating the structures, and rendering them useless. Consequently, the many areas of the Pine River study section where such instability is evidenced (Fig.2) were excluded from further consideration for such installations.

Figure 2. Example of channel instability in the Pine River mainstem between Fisher and Crassier creeks.

2.5 Hydraulic Habitat Type

As outlined earlier, project terms of reference (B.C. Environment, 1991_3) specified the following:

> *Long extended riffles and shallow glides should be designated as potential improvement sites.*

Accordingly, an evaluation of basic hydraulic habitat types was intrinsic to the consideration of channel characteristics and flow dynamics at candidate sites. To the extent possible, the aerial video was used to tentatively identify, and qualify, the dominant habitat type(s) at each site, with emphasis on riffles and glides. Since highest priority was to be placed on *accessible sites with higher velocity* (*ibid*), special attention was focussed on those sites containing, or adjacent to, higher velocity habitats (particularly if confined). At the same time, other habitat types were also considered, relative to any exceptional enhancement opportunities specifically presented.

2.6 Appropriate Enhancement Structures

Crispin (1989) stresses that the best route to the successful selection of fish habitat improvement structures, for a given stream, is to mimic those sites and elements already providing effective habitat in the system. Consequently, the aerial video was used to determine what types of effective habitat for adult sport fish were currently found in the Pine River study section. This was followed by an evaluation of what techniques might be used to replicate such habitat, with the direction (B.C. Environment, 1991_3) that *all practical enhancement techniques* should be considered, but with *primary emphasis* placed *on the installation of LOD collecting systems*.

Consistent with the latter, the aerial video clearly showed that LOD is, by far, the dominant form of fish cover in the project section. It is found, to varying degrees, in most section segments and components. It is frequently <u>abundant</u> in tight meanders and side channel areas, but is also present, to varying/lesser degrees, in many of the more stable and confined areas throughout the streamlength addressed (Figs. 3 and 4). Generally speaking, it tends to be least abundant in straight confined sections, as well as sites of highway or railway encroachments. In the latter case, riprap materials, displaced from associated bank armouring, appear to represent the most frequent form of cover for adult sport fish. Since streambed substrates tend to be small throughout the project section, there is relatively little in the way of <u>natural</u> boulder cover. One area particularly lacking in cover, in general, is the 7.5 km immediately downstream of Link Creek, near the upstream end of the project section.

Based on the aerial video, the sites appearing to offer higher velocities and the most complex cover tended to be curved, relatively confined sections, consistent with previous discussions. At sites of this type, other than highway/railway encroachments, cover (if present) was usually in the form of stable and/or transient LOD. Consistent with these observations, project terms of reference, and Crispin's (*ibid*) rationale, it appeared that the following structures were most worthy of consideration for the Pine River project section:

Figure 3. Example of LOD in Pine River mainstem downstream of Cleveland Creek.

Figure 4. Example of LOD in Pine River mainstem downstream of Link Creek.

1. Debris catchers: (Fig.5)

- similar to pilot structures already installed in the West Kettle River (Griffith, 1991_3).

- floating, V-shaped log structures, anchored to the stream bottom near the outside bank of curved sections; objective to trap and retain organic debris.

- may also require accompanying armouring of bank.

2. Bank LOD: (Fig.6)

- LOD elements anchored at the streambank, and protruding down into the channel.

- may consist of log groupings, as installed in the upper Cowichan River (Griffith, 1991_4), entire trees (Rosgen and Fittante, 1986), or both (Crispin, 1989).

3. Bank boulders: (Fig.7)

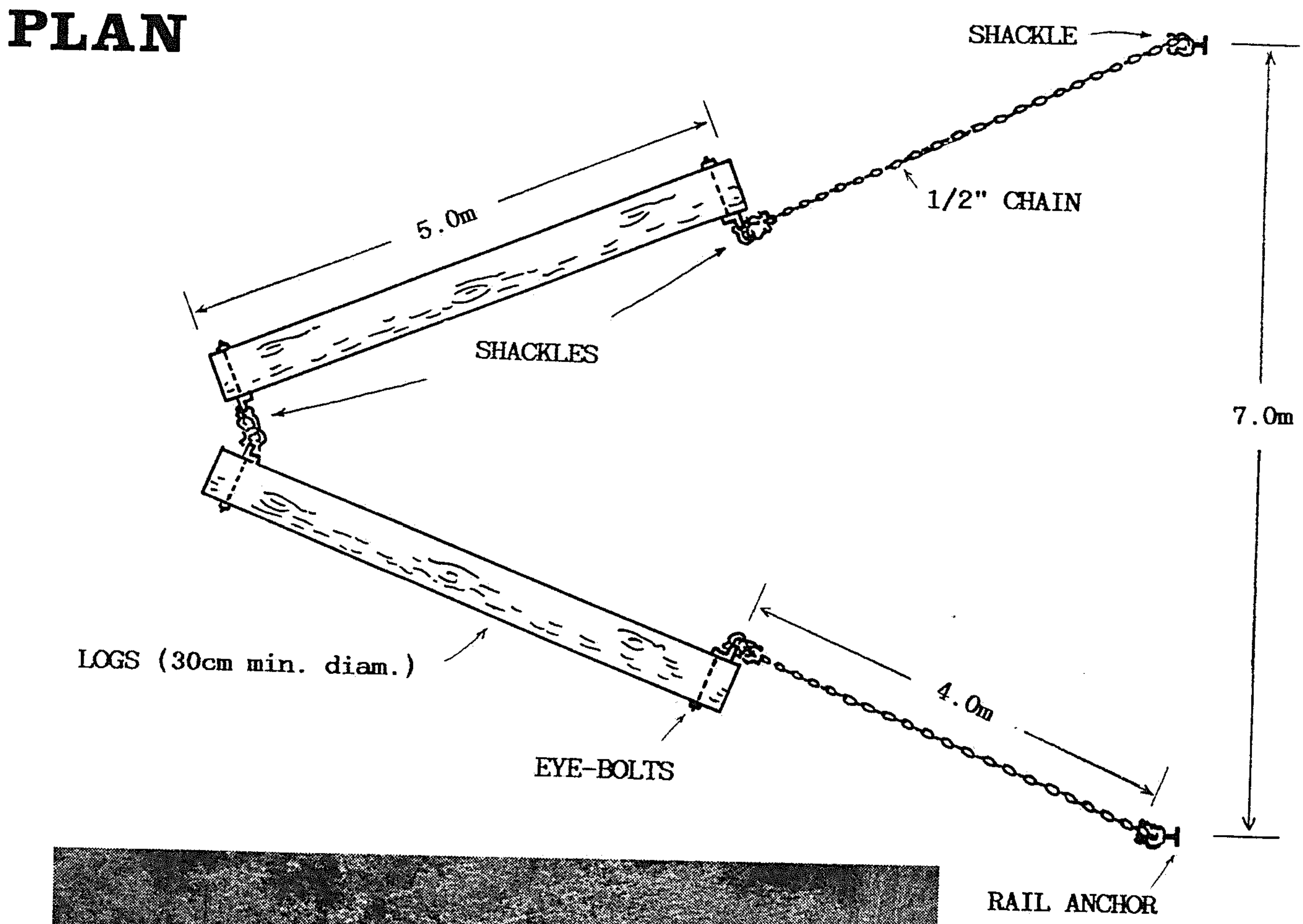
- additions of large boulder materials along the outside bank of curved sections; placed loosely, and extending out as random groupings on the streambed (simulating existing displaced rip-rap).

- includes armouring of bank itself (eg. augmentation of existing rip-rap) to prevent/curtail erosion, if necessary.

This selection of techniques is the same as that recommended for the West Kettle River (Griffith, 1991_2), another meandering system with low gradient. For such systems, both Crispin (1989) and Anderson (1989) recommend that full-spanning structures (eg. weirs) should be avoided, and advocate the use of partially-protruding structures, like those listed above. And again, as evidenced by the aerial video, the predominance of natural LOD habitat in the Pine River project section advocates debris catchers and bank LOD as favoured enhancement techniques for this system.

2.7 Final Selection/Priorization of Mainstem Sites for Field Investigation

In addressing all of the above criteria, the aerial video and topographic mapping were reviewed, in their entirety, on several occasions. In addition, segments relating to specific candidate sites were reviewed on numerous other occasions, as warranted by particular concerns. The end product of the process was a list of 14 mainstem sites with good access, and most favourable characteristics in terms of morphometric, hydraulic, and other physical criteria discussed above. These were designated as priority sites for field investigation/evaluation (Table 2).



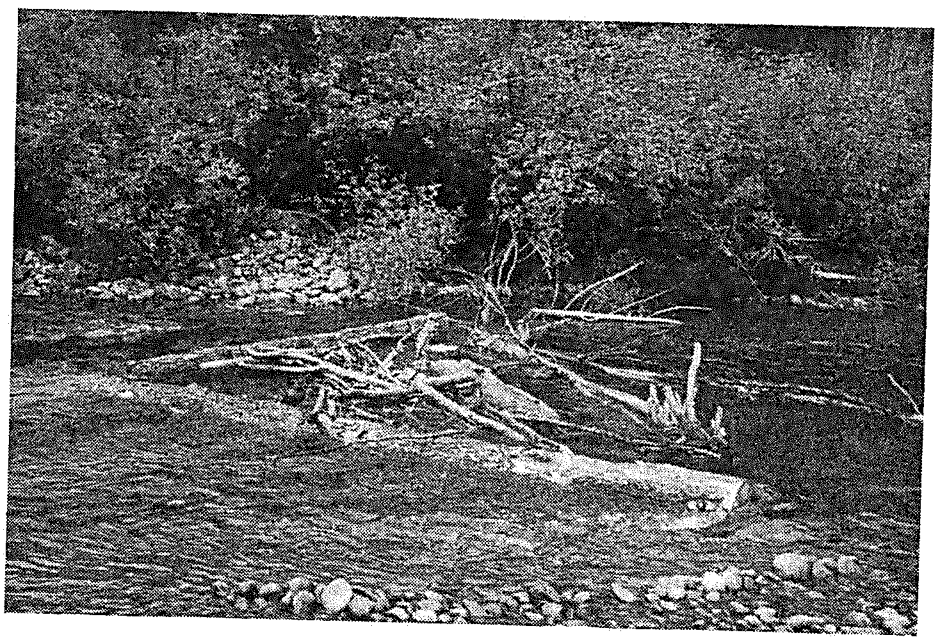


Figure 5. Debris catchers installed in the West Kettle River, 1991.

Figure 6. Example of bank LOD structures installed in the Cowichan River, 1991.

Figure 7 Example of displaced rip-rap in the upper Pine River.

Table 2. Candidate enhancement sites investigated in the field, October 29th - November 1st, 1991.

SITE	VIDEO REF.[1]	LOCATION
1.[2]	0015	adjacent to (and downstream of) picnic site at "old oxbow" (ca. 2 km downstream of Fur Thief Creek confluence)
2.[2]	0025	bend area adjacent to Hwy.97 just upstream of "old oxbow" (ca. 1.5 km downstream of Fur Thief Creek confluence)
3.	0070	adjacent to Hwy.97 immediately upstream of Fur Thief Creek
4.	0370	adjacent to Hwy.97 2.5 km east of Fisher Creek bridge crossing (ca. 3 km downstream of Fisher Creek confluence)
5.	0410	adjacent to Hwy.97 at "old diversion"; curved section downstream (ca. 2 km downstream of Fisher Creek confluence)
6.	0435	adjacent to Hwy.97 at "old diversion"; upstream of picnic site (ca. 1 km downstream of Fisher Creek confluence)
7.	0740	meander joining Hwy.97, 2 km east of Big Boulder Creek crossing (ca. 3.5 km downstream of Big Boulder Creek confluence)
8.	0910	immediately adjacent to Lemoray airfield (curve at downstream end of straight section adjacent to Hwy.97)
9.	0940	bend joining Hwy.97, 1.5 km upstream of Lemoray airfield (curve at upstream end of straight section adjacent to Hwy.97)
10.	1115	adjacent to B.C. Railway, 1 km downstream of Hwy.97 West Pine bridge crossing
11.	1140	immediately upstream of recent highway diversion #5 (ca. 700 m upstream of Hwy.97 West Pine bridge crossing)
12.	1150	adjacent to B.C. Railway ca. 200m downstream of new Solitude One bridge crossing
13.	1160	between new Solitude One bridge crossing (downstream) and short straight section along Hwy.97 (upstream)
14.	1168	between new Solitude Two bridge crossing (upstream) and short straight section along Hwy.97 (downstream)
15.[2]	1172	adjacent to rock quarry, immediately upstream of new Solitude Two bridge crossing
16.	1176	adjacent to B.C. Railway immediately upstream of temporary bridge (ca. 300 m upstream of new Solitude Two bridge crossing)
17.	1225	between recent highway diversions #1 and #2 (commences immediately upstream of diversion #2)

1 VCR counter at normal speed (SP).

2 not originally identified for field investigation; sites 1 and 2 are actually downstream of specified end point of project section; included due to proximity to Fur Thief Creek, and excellent access

These sites were scattered throughout the 60 km project section. However, there was a concentration in the higher gradient areas towards the top end of the project section (Appendix 1). This is not surprising, given the specific emphasis on higher velocity habitat (B.C. Environment, 1991_3).

2.8 Mainstem Control Sites and Side Channel Areas

Consistent with the project terms of reference, during the video/mapping review various sites with reasonable access (suitable for swim surveys) were identified as controls, with respect to abundance of cover for adult fish. In terms of low abundance of LOD, specifically, any of the candidate enhancement sites listed in Table 2 could serve as lower limit controls. However, most of these sites contain some amount of cover in the form of displaced rip-rap (Appendix 2). Given the apparent effectiveness of rip-rap habitat (though limited in abundance) at many sites, and the associated potential of bank boulders as an alternate enhancement technique, specific controls with maximum rip-rap/boulder cover, versus absence of such, were also identified.

In terms of upper limit (high abundance) controls for LOD, special efforts were made to select sections with dominant hydraulic characteristics as similar to the candidate enhancement sites, as possible. Accordingly, most of the areas with particularly high densities of LOD were excluded (eg. slow meanders). These tend to involve excessive distances between access points, in any event. Several sections with lesser to moderate abundances of LOD were identified, and are likely most appropriate as realistic targets for potential LOD enhancement undertakings in the system.

In total, 16 candidate control sections were identified, addressing all categories (including very little cover of any form). These vary in length from 300m to 2 km. The location of each, and relevant details, are provided in Appendix 3.

As a final consideration, the 1:50,000 mapping and aerial video were also used to identify accessible side channel areas for field investigation. Given the wide distribution, abundance, and undoubted significance of side channels within the Pine River project section, it was concluded that some evaluation of these areas should be conducted, consistent with the original objectives of the study. Accordingly, 5 such areas, with reasonable to good access, were identified for field investigation. Again, their location is shown in Appendix 1, and details (ultimately determined in the field) are provided in Appendix 4.

3.0 PROCEDURE AND CRITERIA EMPLOYED FOR FIELD INVESTIGATIONS

The purpose of the field investigations was to provide the final evaluation of potential opportunities tentatively identified in the review of the aerial video and mapping. The approach for the Pine River was the same as that employed for the West Kettle River (Griffith, 1991_2). In establishing the process for the latter study, the principal challenge was to derive an expedient yet adequate set of criteria to enable inspection/measurement at all candidate sites, given little field time. The following list of parameters was ultimately selected, in line with guidelines discussed above:

1. **Access for enhancement operations**

any and all possible constraints to access, relevant to potential enhancement operations, were to be considered; this would include special consideration of machinery that might be required (eg. excavator for debris catchers, some form of winch for LOD and large boulders, etc.), perhaps within the channel itself.

2. **Hydraulic habitat type**

the basic habitat type (eg. riffle, pool, glide) was to be confirmed, and mean water velocity conditions were to be measured, by flow meter (Mead HP-302 mechanically driven electronic flow meter) and rod.

3. **Section length (enhanceable length)**

at each site, the total streamlength worthy of consideration for enhancment was to be measured by rangefinder (Ranging 600 Optical Tapemeasure; 96.7% accuracy at 600').

4. **Gradient**

the mean gradient of the water surface was to be measured by surveyor's level (Nikor AX-1) and rod, over the specific section length identified above.

5. **Mean wetted width and depth**

the mean wetted width of the section was to be estimated, using tape or rangefinder, as warranted; at the point of wetted width measurement, a calibrated wading staff was to be used to provide a general estimate of mean depth within the section as a whole.

6. **Dominant streambed substrates**

over the entire section area (to the extent possible), the substrate types dominating and typifying streambed composition were to be visually identified.

7. **Bank composition and stability**

for both stream banks, the dominant substrates were to be similarly identified, and general stability assessed; any particular indications of instability (eg. erosion) were to be noted.

8. **Bank height**

an estimate of the mean height of each bank was to be made visually (aided by surveyor's rod as practicable); at sites with poor bank definition (eg. point bars), the commencement of substantial riparian growth was to indicate bank position and associated elevation (Chamberlin, 1980).

9. **Entrenchment/confinement**

at each site, a simple estimate was to be made of the degree to which the stream banks (and/or bars) provide containment and concentration of flows; classical definitions of entrenchment and confinement were not intended; the objective would be to provide a general, pragmatic indication of general risks associated with the interruption/diversion of flows, channel/thelweg shifts, flooding, etc. associated with potential installations; to the extent possible, implications relative to high water levels were to be given full consideration.

10. **Existing habitat complexity**
a description was to be made of any and all elements providing/constituting habitat for adult sport fish at each site; special attention was to be focused on elements and conditions appearing to provide the most effective habitat.

4.0 RESULTS OF FIELD INVESTIGATIONS

Field inspections were conducted during October 29th-November 1st 1991, and were hampered by low atmospheric temperatures (down to -23° C, excluding wind factor) and snow cover. Unfortunately, the snowfall occurred on the first day of the field work (October 29th), and accumulated to depths of up to 15cm overnight, complicating determination of bar composition (substrates), bank characteristics, etc. at many locations. Due to slush and otherwise poor transparency, it was often difficult to determine the composition of streambed substrates. As a result of slush and freezing, the mechanically driven flow meter (Mead HP-302) performed erratically, or not at all. Consequently, water velocity determinations were by the floating chip method, estimating surface velocities only. Gradient determinations (by surveying level and rod) were hampered by shelf ice at many locations. With the additional problems of flowing slush (disruptive to instrument stability) and/or excessive water depth, it was necessary to determine gradients from ice surfaces at some sites. Even photography was hampered by dark skies and poor light. Due to the substantial water depths involved, and the extreme hazard of wading under such conditions, maximum depths were not determined. Mean depths and velocities were measured for the first 5m from the appropriate stream bank.

Despite these complications, all 14 designated mainstem sites, and 3 others, were inspected (Table 2). At each site, the following data were collected, as accurately as possible:

1. hydraulic habitat type (riffle, glide, etc.)
2. streamlength suitable for enhancement
3. gradient
4. characteristics of banks (composition, height, stability)
5. composition of streambed substrates (excluding rip-rap)
6. mean water depth within 5m of outside bank
7. mean water velocity (surface) within 5m of outside bank
8. mean wetted width (by rangefinder)
9. mean channel width
10. type/abundance of existing cover for adult fish.

The locations of these sites are shown in Appendix 1. Full date and photo documentation for each site are provided in Appendix 2. The 5 accessible side channel areas, identified in the video/mapping analysis, were also inspected. Photographs and comments are provided in Appendix 4.

4.1 Final Prescription of Structure Types and Numbers

The final prescription (and options) of enhancement structures at candidate sites is provided in Table 3. Details and rationale with respect to each site are provided in Table 4. Consistent with the project terms of reference, first consideration has been given to the installation of LOD structures (particularly debris catchers) at all candidate sites. The field investigations further confirmed that LOD is the most abundant form of cover for adult sport fish in the Pine River study section, as a whole. However, some presence of LOD (and/or smaller organic debris) was only encountered at 7 of the final 17 candidate enhancement sites, and in all cases, the abundance was low (Table 4). Accordingly, if site characteristics (channel morphometry, hydraulics) were ammendable, and logistical considerations acceptable, debris catchers were prescribed in Table 3. Bank LOD could only be considered for a few sites, since suitable anchoring elements (eg. large standing trees near bank) were lacking at most. Experiences in the Cowichan River have demonstrated the critical importance of adequate anchoring for such structures (Griffith, 1992). This is even more the case for a larger river, like the Pine. Any installations of this kind should likely be considered experimental, until durability in this large river has been assessed.

The most common cover element at the candidate sites (13 of 17) was rip-rap, displaced from adjacent bank armouring (Table 4). This, of course, is an artifact, associated with the impacts of the road (or rail) encroachments providing the access to these sites. Consistent with the video analysis, very little natural boulder cover was observed anywhere in the Pine River project section. However, where displaced rip-rap occurred at candidate enhancement sites, it frequently appeared to offer the potential of effective (though limited) cover for adult fish (Appendix 2). Where this occurred, and the installation of LOD structures was somehow precluded, bank boulders have been prescribed in Table 3. In cases where bank boulders might be considered as an alternative to LOD structures at a given site, the latter are given preference in Table 3, with the former indicated in brackets below. Lastly, where debris catchers have been prescribed at sites with questionable bank stability, armouring with rip-rap is also prescribed.

As it was for the West Kettle River (Griffith, 1991_2), the prescription of LOD structures and bank boulders for the upper Pine River is supported by guidelines provided by Rosgen and Fittante (1986). These involve a classification system based on the criteria shown in Table 5 (site-specific results for the Pine River are provided in Table 4 and Appendix 2). The similarity in results between candidate enhancement sites in the West Kettle River and the upper Pine River is remarkable. Unfortunately, results for neither system fully correspond with any single classification given by Rosgen and Fittante (*ibid.*). However, for the classification with the greatest similarity (C_2, Table 5), floating log cover (similar to debris catchers, but less complex), submerged shelters (same as bank LOD), and bank boulders all rate as excellent in terms of suitability and likelihood of success.

Table 3. Prescription and priorization of habitat enhancement opportunities.

SITE	LENGTH (m)	SUGGESTED STRUCTURE(S)	# OF STRUCTURES	TOTAL COST	FEASIBILITY/ PRIORITY
1.	200	debris catchers (bank boulders)[1]	4 (200m)	$ 7,400.00 ($ 5,200.00)	LOW
2.	200	debris catchers (bank boulders)	4 (200m)	$ 7,400.00 ($ 5,200.00)	LOW
3.	150	debris catchers + bank armouring	3	$ 6,600.00	MOD./LOW
4.	100	debris catchers + bank armouring	2	$ 4,400.00	LOW
5.	200	bank boulders	200m	$ 5,200.00	HIGH
6.	250	debris catchers (bank boulders)	5 (250m)	$ 9,250.00 ($ 6,500.00)	HIGH
7.	200	debris catchers + bank LOD	2 3	$ 3,700.00 +$ 2,100.00	MOD.[2]
8.	200	debris catchers (bank boulders)	4 (200m)	$ 7,400.00 ($ 5,200.00)	HIGH
9.	150	debris catchers + bank armouring	3	$ 6,600.00	LOW
10.	300	bank boulders	300m	$ 7,800.00	MOD.
11.	200	debris catchers + bank armouring	4	$ 8,800.00	MOD./LOW
12.	150	debris catchers (bank boulders)	3 (150m)	$ 5,550.00 ($ 3,900.00)	HIGH
13.	150	debris catchers	3	$ 5,500.00	LOW
14.	150	debris catchers + bank LOD	2 1	$ 3,700.00 +$ 700.00	MOD.
15.	100	bank boulders	100	$ 2,600.00	HIGH
16.	200	debris catchers	4	$ 7,400.00	LOW
17.	300	debris catchers + bank armouring	6	$13,200.00	HIGH

[1] brackets indicate possibility as alternative.

[2] site potential excellent; however, LOD/debris fairly abundant in immediately adjacent sections, both upstream and downstream.

Table 4. Summary of field data at candidate enhancement sites, and assignment of priorities.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Access for enhancement	excellent	excellent	poor	poor	excellent	excellent
Hydraulic habitat type	glide	run	glide/riffle	glide	fast glide/run	riffle
Enhanceable length (m)	200	200	150	100	200	250
Gradient (%)	0.08	0.04	0.38	0.03	0.04	0.12
Mean depth (m)	0.5	1.4	0.8	0.4	1.2	1.0
Mean surface velocity (m/s)	0.5	0.4	0.9	0.5	0.8	0.9
Stability of bank	stable	stable	significant erosion	stable	stable	stable
Height of bank (m)	1.5	1.5	4	10	3.5	3
Entrenchment, confinement	moderate	moderate	moderate/good	moderate	moderate	moderate
Existing cover	rip-rap	rip-rap	very little (LOD downstream)	rip-rap	rip-rap	rip-rap
% Area (approx.)	1-2	1-2	< 1	1-2	2-5	5
PRIORITY	LOW	LOW	MODERATE-LOW	LOW	HIGH	HIGH
Comments	poor combination of depth (<) & velocity (<)	low velocity	difficult access present erosion	poor combination of depth (<) & velocity (<) difficult access	good for boulders depth may be excessive for LOD catchers	excellent for boulders also suitable for LOD catchers

Table 4. (cont'd)

	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12
Access for enhancement	good	excellent	limited	limited	poor	fair
Hydraulic habitat type	fast glide	glide/riffle	fast riffle	riffle/glide	glide	glide/riffle
Enhanceable length (m)	200	200	150	300	100	150
Gradient (%)	0.15	0.17	0.66	0.14	0.49	0.13
Mean depth (m)	0.8	0.8	0.5	0.6	0.3	0.6
Mean surface velocity (m/s)	0.9	0.8	1.1	0.8	0.7	0.9
Stability of bank	some erosion (lower 1/2)	stable	some erosion	stable	substantial erosion	stable
Height of bank (m)	1.5-2	2.5	2.5	10+	1.5	10
Entrenchment, confinement	moderate/good	moderate	good	good	moderate/good	moderate/good
Existing cover	rip-rap, LOD	rip-rap	LOD	rip-rap (LOD downstream)	small debris	rip-rap
% Area (approx.)	< 1	1-2	< 1	< 5	< 1	< 5
PRIORITY	MODERATE-HIGH	HIGH	LOW	MODERATE	MODERATE-LOW	HIGH
Comments	good depth & velocity for LOD catchers anchoring for bank LOD but substantial LOD already, in adjoining areas	good site for LOD catchers or boulders	thalweg not close to bank present erosion access limitations	access limitations	access limitations shallow depth access provision likely a problem	excellent depth/velocity short access road required offset by high potential

Table 4. (cont'd)

	Site 13	Site 14	Site 15	Site 16	Site 17
Access for enhancement	good	fair	excellent	good	good
Hydraulic habitat type	riffle	glide/riffle	riffle/glide	glide/riffle	fast glide/riffle
Enhanceable length (m)	150	150	100	200	300
Gradient (%)	0.21	0.08	0.30	0.16	0.28
Mean depth (m)	0.4	0.7	0.6	0.6	0.7
Mean surface velocity (m/s)	0.8	0.8	0.7	0.5	0.8
Stability of bank	stable	some erosion (top 1/2)	stable	stable	slowly eroding
Height of bank (m)	2.5+	1.5-5+	1-10+	8	1.5-2
Entrenchment, confinement	fair/moderate	fair/moderate	moderate/good	moderate	moderate/good
Existing cover % Area (approx.)	rip-rap < 1	rip-rap < 1	rip-rap 5	rip-rap (LOD upstream) 2	small debris (some LOD) < 5
PRIORITY	LOW	MODERATE	HIGH	LOW	HIGH
Comments	channel not well confined no side bar to work from depth rather shallow	short access road likely required offset by opportunity for both bank LOD & LOD catchers	existing rip-rap effective site adjacent to quarry	low velocity no side bar to work from	armouring required, due to erosion, but ideal site for LOD catchers

In terms of the number of structures recommended, the following guidelines were applied to the total enhanceable length at each site:

1. Bank boulders: continuous treatment of outside bank (and adjacent streambed) over the full section length.

2. Bank LOD: approximately 1 channel width between installations (R. Ptolemy[3], *pers.comm.*); 30m spacing adopted for the West Kettle River study section.

3. Debris catchers: minimum spacing of 50m between structures (P.Slaney[4]; *pers. comm.*).

Table 5. Comparison of selected geomorphological results for candidate enhancement sites in the upper Pine and West Kettle rivers to classification criteria from Rosgen and Fittante (1986).

PARAMETER	PINE RIVER SITES	WEST KETTLE RIVER SITES	CLASSIFICATION CRITERIA (C2)
Gradient (%)	0.03-0.66 (0.20)[1]	0.04-0.63 (0.21)	0.3-1.0
Sinuosity[2]	1.1-1.8 (1.3)	1.2-1.6 (1.3)	1.3-1.5
Entrenchment/ Confinement	primarily moderate to good	primarily moderate to good	moderately entrenched, well confined
Dominant stream-bed substrates	gravel/cobble or cobble/gravel	cobble/gravel to cobble/small boulders	large cobble with gravel or small boulders

[1] brackets indicate mean values.

[2] ratio of actual streamlength to direct distance down the valley (based on 5 km valley distance, centrered on each site).

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4.2 Final Priorization of Candidate Sites and Associated Options

All sites and prescriptions listed in Table 3 are worthy of some consideration for enhancement. However, in order to indicate relative merits, between sites, a priority rating was assigned. This process took all relevant criteria into consideration, as summarized in Table 4. Sites assigned a LOW or LOW/MODERATE priority involve either some potential risk of failure, or particular logistical complications and/or constraints. MODERATE to HIGH priorities indicate good to excellent potential (and feasibility) for the enhancement structures prescribed. The majority of the Pine River candidate sites/options were rated as MODERATE, or better (9/17); and of these, two thirds (6/9) were rated as HIGH (Table 3). At all of the latter sites, riffle and/or glide habitats dominate, with mean depths and velocities (within 5m of streambank) ranging between 0.6m and 1.2m, and 0.7 m/s to 0.9 m/s, respectively (Table 4). The depth values are consistent with conditions apparently preferred by adult grayling in the Pine River, but some velocities may be a little high (Slaney, 1991). However, with disruption of flows and cover provided by appropriate enhancement structures, such habitat would undoubtedly be suitable not only to grayling, but bull trout and rainbow trout as well (Griffith, 1979; Stuart and Chislett, 1979; Raleigh *et al*, 1984). It is interesting to note that the 6 sites ultimately identified as HIGH priority candidates had stream gradient measurements ranging from 0.04% to 0.30% (ave. 0.17%; Table 4). Once again, these results are virtually identical to those of the West Kettle River, where the 8 HIGH priority sites/options for trout habitat enhancement had gradients ranging from 0.07% to 0.30%, and also averaged 0.17% (Griffith, 1991_2). This may be purely coincidence. However, contrary to what might be expected, in neither study did the sites with the highest gradients (up to 0.66% at site 9 in the Pine River; 0.63% for the West Kettle River) rank among the best opportunities, when all factors were considered.

4.3 Side Channel Areas

At 3 of the 5 side channel areas inspected, ice cover was complete, and was overlaid by snow, restricting evaluation to emergent habitat elements only (Appendix 4). At one of these sites (side channel C), it could be confirmed that there is moderate to high complexity in the form of LOD, smaller debris, cutbanks, etc. At the other two sites (side channels A, B) it appeared that LOD (at least) was not abundant, and one might offer enhancement opportunities, if a lack of submerged cover elements is also confirmed (side channel A, associated with the entry of Fred Nelson Creek; Appendix 1). The lowermost 100m of side channel D, just downstream of Le Moray Creek, might also be enhanced. However, this would seem unwarranted in view of the extremely abundant LOD habitat commencing almost immediately upstream. Furthermore, in general, and based on what could be observed at all of the above sites, it was concluded that side channel enhancement is not as warranted, nor as promising (particularly for adult fish) as mainstem opportunities listed in Table 3.

5.0 COST ESTIMATES

In Table 3, cost estimates are provided for the installations prescribed for each site. These were generated on the basis of the following structure-specific estimates, and relate to construction phases only:

1. **Debris catchers:**
   - based on 1991 West Kettle River installations (Griffith, 1991_3), with some rounding and adjustments.

Cost per structure without bank armouring:

Rail anchors	*2 @ 5m (100 lb gauge)*	$ 200.00
Chain and shackles	*1/2" gauge*	310.00
Logs and delivery	**2 @ 5m**	40.00
Eye bolts (custom made)	*4 @ $25 each*	100.00
Excavator/operator	*1 @ day approx. $1000/day*	1,000.00
Biological supervisor/ participant	*1 @ day approx. $200/day*	200.00
Total		**$ 1,850.00**

Cost per structure with bank armouring:

Basic structure cost (above)		$ 1,850.00
Armouring (20m)	*materials/installation**	350.00
	(excavator already on site)*	
Total		**$ 2,200.00**

2. **Bank LOD:**
   - based on 1991 upper Cowichan River installations of 12 multi-log structures; 3 or 4 logs per structure (Griffith, 1991_4).
   - assumes installation of 5 structures, each involving 4 logs (ie. one truck load of 20 logs).

Cost per structure:

Logs/delivery	*1/5 of $500/load*	$ 100.00
Wire rope (5/16")	*100 @ $0.40/ft*	40.00
Wire rope clamps, staples, rope, etc.		10.00
Equipment costs	*winch, chainsaw(s), peevee poles, etc.*	50.00
Biological supervisor/ participant	*1 day @ $200/day*	200.00
Assistants (2)	*1 day @ $150/day ea.*	300.00
Total		**$ 700.00**

3. Bank boulders:

- based on costs of bank armouring associated with debris catcher installations in the West Kettle River in 1991 (Griffith, 1991_3)

- assumes an average of 1 truck load per 10m, and installation by excavator at an average rate of 10 truck loads per working day; includes consideration of access constraints at some sites, Highway related complications at others, etc.

Cost per 100m section:

Blast rock	*10 loads @ approx. $110/load*	$ 1,100.00
Excavator/operator	*1 day @ approx. $1,000/day*	1,000.00
Biological supervisor/ participant	*1 day @ approx. $200/day*	200.00
Assistants (eg.flag persons)	*2 @ approx. $150/day*	300.00
Total		**$ 2,600.00**

All of the above costs are based on rates and dollar value at time of writing (January 1992). They pertain solely to implementation phases, and do not include any consideration of organization/preparation time requirements, administration, or reporting. Furthermore, no vehicle, food, or accommodation allowances are included. Lastly, figures have been rounded upwards, as warranted, so as not to under-estimate costs, but further additions may be required for taxes, inflation, materials supply, etc., as well as the northern location of the Pine River project section. Based on recent installations elsewhere in B.C. (*ibid*), budgeting should allow at least double the costs indicated above, per structure, to cover all the additional preparatory and sundry expenses.

On the other hand, the estimates have been prepared cautiously from a contractor's perspective, and include contingencies for unforeseen difficulties and associated time losses experienced in past undertakings of this type. Slaney (1992) reports that debris catchers, for instance, have cost as little $1,100.00 (or less) in other B.C. streams. With competitive bidding, potential economy of scale (cosistent with the total number and juxtaposition of structures), such estimates might apply to the Pine River as well. Furthermore, costs could be substantially reduced through donations of materials and/or equipment from B.C. Highways (rip-rap/hauling), local forest companies (logs/ hauling), B.C. Rail and/or Westcoast Energy (debris catcher hardware), etc.

Since the object of the installations would be to enhance habitat for adult sportfish, it is assumed that post-installation assessment would be based primarily on swim survey observations/enumeration of adult fish. It is also assumed, that water depth/velocity transects and other habitat description would also be desired (eg. Griffith, 1990; Griffith, 1991_4). With at least 3 separate structures/installations per site, a minimum of 1/2 day would be required in the field to assess each enhancement site, employing a 2-person crew (est. $400/site including all travel, equipment, and other operational expenses). Depending on precise terms of reference (depth of detail in assessment, and/or objectives) data management and reporting could bring the total cost to $1,000/site.

6.0 MANAGEMENT CONSIDERATIONS

The purpose of this study was to identify and priorize sites for potential habitat enhancement undertakings. Needless to say, the effort and cost of fish habitat enhancment projects can only be justified if such work is reasonably successful in producing and maintaining the desired effect. A structure may be useless, or even deleterious, unless installed in a suitable location. Due to the complexity of stream dynamics, it is inherently difficult to predict the exact outcome of any such installation (Anderson, 1989; Lisle and Overton, 1989).

Lisle and Overton (*ibid*) caution that no desk-top inspection of maps and air photos is fully adequate to predict the outcome of fish habitat improvement endeavors. Detailed guidelines are available to promote successful installations, but their application involves the collection of extensive and detailed field data at candidate sites, under a variety of flow conditions (*ibid*). With ever increasing demands on available funding, and prevailing attitudes dismissing extensive studies in favour of most immediate implementation, this would seem to be only rarely practical. There is the reciprocal dilemma, of course, that funds which <u>are</u> obtained may be wasted if implementation proceeds in the absence of adequate planning/evaluation.

In the investigation of the Pine River study section, as in the earlier study of the West Kettle River (Griffith, 1991_2), every effort was made to reduce risks of failure, to the fullest possible extent, by selecting and applying the most reliable criteria in a conservative fashion. With the ultimate goal of maximizing potential benefits (including scope of work) from funds available for implementation, the primary objective was to identify the most suitable sites and techniques that could be implemented in the most cost effective way.

It is not suggested that this study has identified <u>all</u> habitat enhancement opportunities for adult sport fish in the Pine River study section; nor is it suggested that total success is assured at the sites that have been identified. This is implicit in the priorization process itself. However, it is believed that the present study has successfully identified habitat enhancement opportunities of optimum potential and minimum risk, within the specified terms of reference. As mentioned earlier, implementation of any options listed in Table 3 would undoubtedly result in some increase of habitat for adult sport fish in the project section.

However, if the objectives of habitat enhancement in the Pine River study section are simply to provide more habitat for adult sport fish, would the degree of increase (relative to what exists already) warrant the effort, not the mention the expense? Complex LOD habitat is already very abundant in many portions of the Pine River project section, and is present to varying degrees throughout most of it. Although much of this may be of marginal value during lower flows, at least (eg. low velocity meanders, bars, side channels, etc.), it would seem from both the aerial video and the October 1991 field inspection that a substantial proportion of it <u>is</u> of some value to adult sport fish as winter and/or summer habitat. The total cost of the undertakings prescribed in Table 3 (excluding alternatives in brackets) is just over $115,000.00, and this is for construction materials and labour only. With preparation and sundry expenses, the actual cost could be double this figure. In comparison, the total streamlength involved

(3.2 km) represents only 5% (approx.) of the project section's overall length, excluding consideration of side channels.

At the same time, implications may be quite different on a more localized basis. As previously noted, the 7.5 km of the Pine River study section between the West Pine highway crossing (downstream) and Link Creek (upstream) is relatively lacking in cover elements for adult fish, compared to other portions of the project section. Implementation of options in this segment (sites 10 to 17; Tables 2 and 3) might well be justified in terms of relative abundance of habitat. Furthermore, since the segment includes the area of recent/on-going highway construction, cost-sharing possibilities might exist, further favouring implementation, at least in this area.

In addition, structure installations need not relate solely to total (or relative) abundance of habitat. If biological data indicate that available habitat for adult fish in the upper Pine River (or specific sections of it) is currently at (or near) saturation, then the provision of additional habitat can be directly justified on the basis of its own merits. Such enhancement might also be aimed at altering the distribution of fish and associated angling opportunity. It was clear from this investigation that cover for adult fish tends to be lacking at most locations approached/encroached by the highway. This, of course, has obvious relevance to the distribution of adult fish, and associated catch success at these access points. Theoretically, enhancement of habitat at any or all of the accessible sites listed in Table 3 should result in greater accessibility to (and catch of) adult fish. Depending on the current strength of fish populations, and angler effort and catch in the system, this may be desirable, and sufficient to implement habitat enhancement. On the other hand, if numbers of fish are presently low, enhancement at accessible sites could conceivably result in accelerated catch and decline of numbers, and would be highly inadvisable. It should be noted, however, that habitat enhancement activities may not be effective in substantially altering the distribution of adult fish, in any event (P. Slaney, *pers.comm.*).

The resolution of these and other management issues is beyond the domain and terms of reference of this study. They are mentioned simply because of their potential influence on the ultimate value of any (or all) of the enhancement opportunities identified here. Nonetheless, an effort has been made to suggest an overall ranking of the best 10 of these opportunities, in Table 6. This is based on priorities assigned in Tables 3 and 4, with emphasis on undertakings in the particularly habitat-poor 7.5 km section downstream of Link Creek.

Table 6. Suggested ranking of enhancement opportunities identified in the Pine River study section.

RANK	SITE NO.	LENGTH (m)	SUGGESTED STRUCTURE(s)	NO. OF STRUCTURES	COST OF INSTALLATION[1]
1.	17	300	debris catchers + bank armouring	6	$ 13,200.00
2.	15	100	bank boulders	100m	$ 2,600.00
3.	12	150	debris catchers (bank boulders)[2]	3 (150m)	$ 5,550.00 ($ 3,900.00)
4.	8	200	debris catchers (bank boulders)	4 (200m)	$ 7,400.00 ($ 5,200.00)
5.	6	250	debris catchers (bank boulders)	5 (250m)	$ 9,250.00 ($ 6,500.00)
6.	5	200	bank boulders	200m	$ 5,200.00
7.	14	150	debris catchers + bank LOD	2 1	$ 4,400.00
8.	10	300	bank boulders	300m	$ 7,800.00
9.	7	200	debris catchers + bank LOD	2 3	$ 5,800.00
10.	11	200	debris catchers + bank armouring	4	$ 8,800.00
TOTAL		2,050			$ 70,000.00 ($ 63,400.00)

1 cost of actual construction work and materials only.

2 brackets indicate alternative.

ACKNOWLEDGEMENTS

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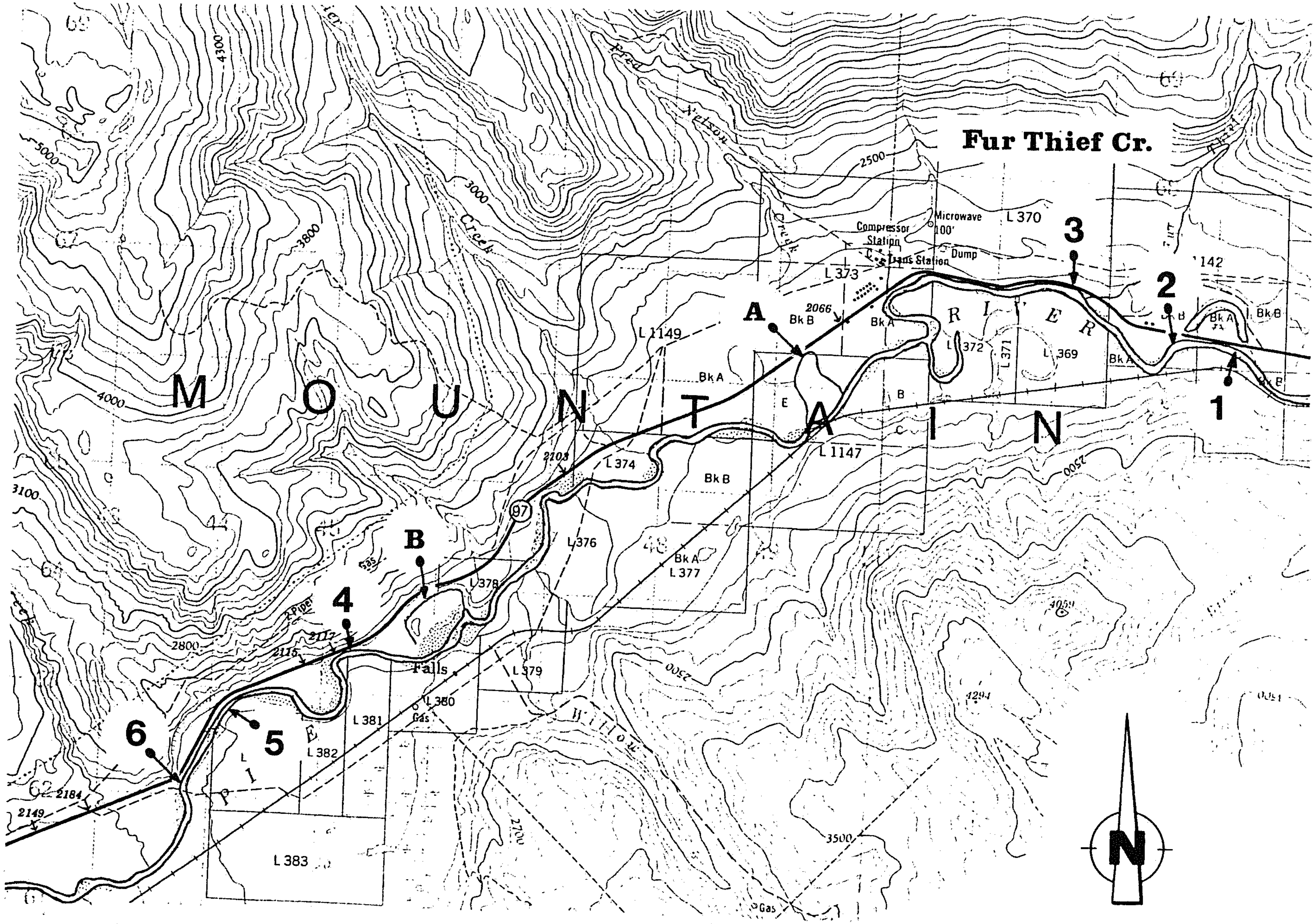
Appendix 1. Location of field investigation sites, October 29th - November 1st, 1991.

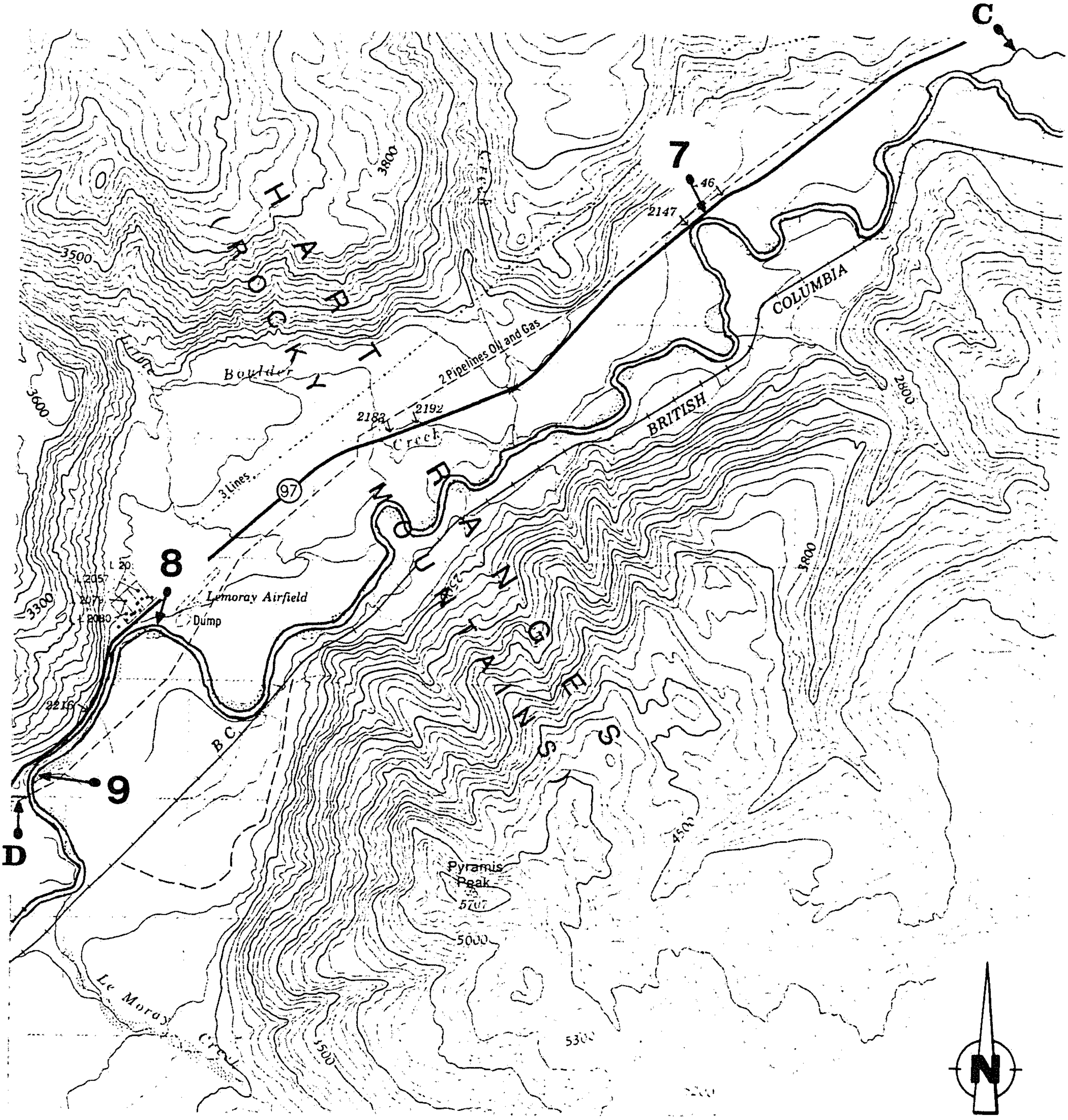
<u>Note</u>:

1) Mainstem candidate enhancement sites 1 - 17.

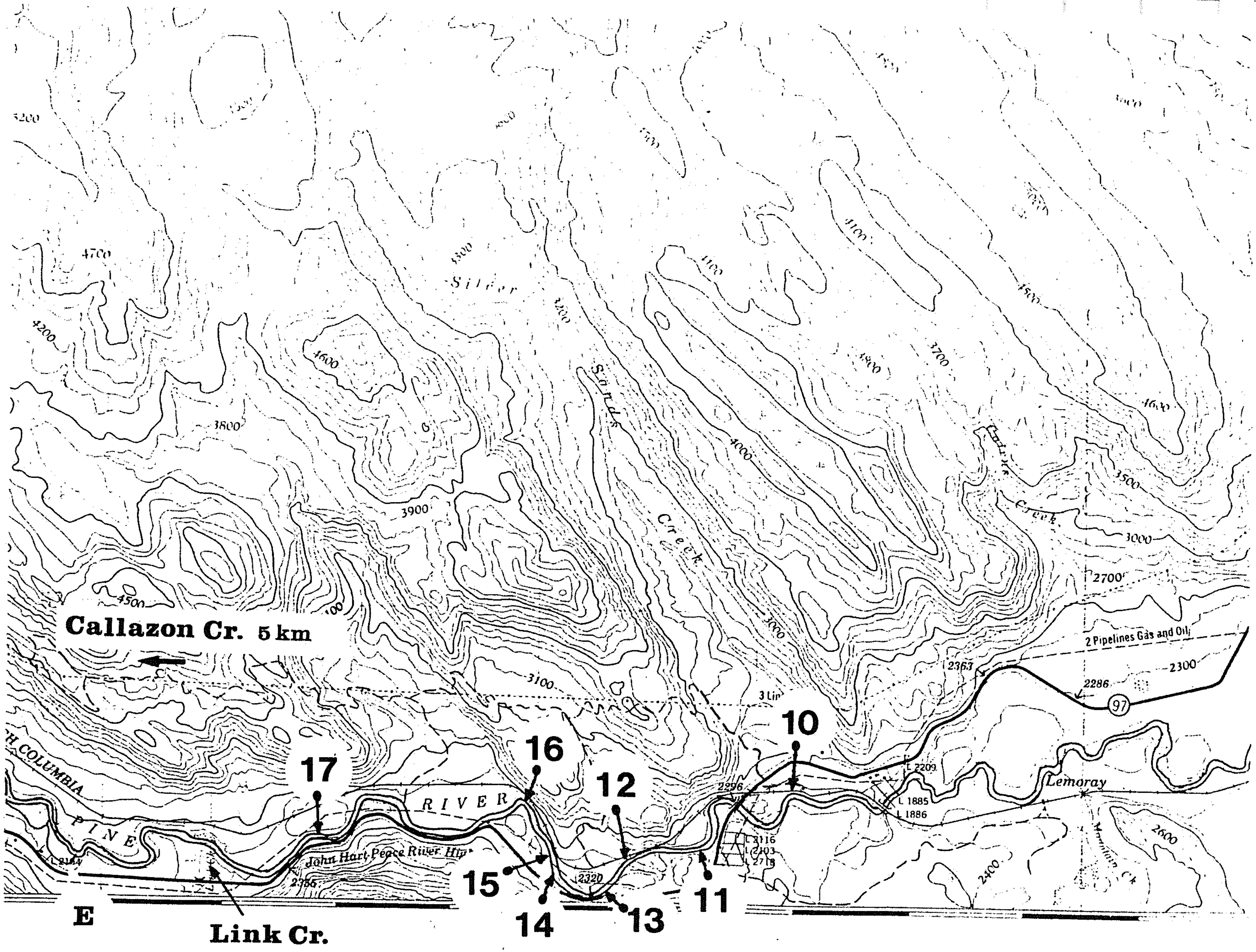
2) Side channel investigation sites A - E.



Field investigation sites downstream of Fisher Creek, on 1:50,000 topographic map 93-O/9.



Field investigation sites upstream of Fisher Creek, on 1:50,000 topographic map 93-O/9.



Field investigation sites on 1:50,000 topographic map 93-O/10.

Appendix 2. Data and photographs obtained for candidate enhancement sites in the Pine River mainstem, October 29th - November 1st, 1991.

System: Pine River Section: 1 Date: Oct 29/91
Section location: adjacent to (and downstream of) picnic site off Hwy.97 at old oxbow; ca. 2 km downstream of Fur Thief Creek

Section length (m):	200	Gradient (%):	0.08
Sinuosity (from map):	1.1	Habitat type:	glide
Wetted width (m):	60	Channel width (m):	70
Width/depth ratio:	40 est.	Outside bank:	left

Mean water depth within 5m of bank (m): 0.5
Mean water velocity within 5m of bank (m/s): 0.5 (surface)
Streambed substrates (% composition):

fines <2mm	10	small cobble 64-128mm	10
small gravel 2-16mm	40	large cobble 128-256mm	<10
large gravel 16-64mm	30	boulders >256mm	<1
other	0	D_{90} (mm)	10

Bank characteristics:

	LEFT OUTSIDE	RIGHT INSIDE
dominant materials	rip-rap	gravel/cobble
average height (m)	ca. 1.5	ca. 1
stability	stable	side bar

Entrenchment/confinement: moderate
Existing cover: rip-rap in association with left bank (ca. 1-2 % of total section area)

Access (including enhancement considerations):
excellent, full access to left bank from picnic area off Hwy.97; however, rip-rap complicates access to channel for machinery

Enhancement options/recommendations:
channel characteristics and logistical considerations appear suitable for debris catchers, or additional bank boulders along left bank; however, average water velocity and depth may be inadequate (low); suggest LOW priority for any installations

System: Pine River Section: 2 Date: Oct 29/91
Section location: upstream end is located ca. 1.5 km downstream of Fur Thief Creek; adjacent to Hwy.97 upstream of oxbow picnic site.

Section length (m):	200	Gradient (%):	0.04
Sinuosity (from map):	1.1	Habitat type:	run
Wetted width (m):	40	Channel width (m):	70
Width/depth ratio:	40 est.		

Mean water depth within 5m of bank (m): 1.4
Mean water velocity within 5m of bank (m/s): 0.4 (surface)
Streambed substrates (% composition):

fines <2mm	10	small cobble 64-128mm	10
small gravel 2-16mm	40	large cobble 128-256mm	<10
large gravel 16-64mm	30	boulders >256mm	<1
other	0	D_{50} (mm)	6

Bank characteristics:

	LEFT OUTSIDE	RIGHT INSIDE
dominant materials	rip-rap	gravel/cobble
average height (m)	1.5	1
stability	stable (rip-rap)	stable (side bars)

Entrenchment/confinement: moderate
Existing cover: limited almost entirely to rip-rap on left bank (ca. 1-2 % of total section area)

Access (including enhancement considerations):
excellent, full access to left bank from picnic area off Hwy.97; however, rip-rap might complicate machine (eg. excavator) access to channel

Enhancement options/recommendations:
morphometric features and associated implications similar to section 1; suggest bank boulders due to water depth > 1m; LOW priority due to low water velocity

System: Pine River   Section: 3   Date: Oct 30/91

Section location: adjacent to Hwy.97 immediately upstream of Fur Thief Creek confluence

Section length (m):	150	Gradient (%):	0.38
Sinuosity (from map):	1.2	Habitat type:	glide/riffle
Wetted width (m):	35	Channel width (m):	70
Width/depth ratio:	30 est.		

Mean water depth within 5m of bank (m): 0.8

Mean water velocity within 5m of bank (m/s): 0.9 (surface)

Streambed substrates (% composition):

fines <2mm	20	small cobble 64-128mm	15
small gravel 2-16mm	40	large cobble 128-256mm	5
large gravel 16-64mm	20	boulders >256mm	0
other	0	D_{90} (mm)	8

Bank characteristics:

	LEFT OUTSIDE	RIGHT INSIDE
dominant materials	sand/gravel/cobble	gravel/cobble bars
average height (m)	4 (top half sand/clay)	4 (veg. above bars)
stability	eroding	stable (side bars)

Entrenchment/confinement: well entrenched and moderately confined

Existing cover: essentially none, except small debris jam at downstream end of section (not included)

Access (including enhancement considerations):

immediately adjacent to Hwy.97, but stream bank height and additional bank (ca.5m) up to highway would complicate unloading of materials and/or access for machinery

Enhancement options/recommendations:

debris jam at downstream end suggests suitability of debris catchers; however, the latter appears to be accelerating erosion, and rip-rapping would undoubtedly be advised for any installations of this kind; anchoring elements lacking for bank LOD; site potential good, but logistics poor; suggest MODERATE-LOW priority

System: Pine River Section: 4 Date: Oct 30/91

Section location: ca. 3 km downstream of Fisher Creek confluence; immediately adjacent to Hwy.97, 2.5 km east of Fisher Creek crossing

Section length (m): 100 Gradient (%): 0.03

Sinuosity (from map): 1.3 Habitat type: glide

Wetted width (m): 60 Channel width (m): 70

Width/depth ratio: 60+ est.

Mean water depth within 5m of bank (m): 0.4

Mean water velocity within 5m of bank (m/s): 0.5 (surface)

Streambed substrates (% composition):

fines <2mm	10	small cobble 64-128mm	30
small gravel 2-16mm	25	large cobble 128-256mm	10
large gravel 16-64mm	25	boulders >256mm	<1
other	0	D_{50} (mm)	13

Bank characteristics:

	LEFT OUTSIDE	RIGHT INSIDE
dominant materials	rip-rap/vegetation	gravel/small materials
average height (m)	ca. 10	2-3
stability	stable	moderately stable

Entrenchment/confinement: moderate, but braiding in evidence immediately downstream (mid-channel bar exposed)

Existing cover: essentially limited to rip-rap along left bank (ca. 1-2 % of total section area)

Access (including enhancement considerations):

access problematic for machinery; bench areas both upstream and downstream, but also bordered by high steep bank up to highway

Enhancement options/recommendations:

potential for debris catchers (substantial debris observed downstream); however, suggest LOW priority due to access constraints, and low water depth/velocity

System: Pine River Section: 5 Date: Oct 30/91

Section location: ca. 2 km downstream of Fisher Creek confluence; immediately adjacent to Hwy.97, 2 km east of Fisher Creek crossing

Section length (m):	200+	Gradient (%):	0.04
Sinuosity (from map):	1.4	Habitat type:	fast glide/run
Wetted width (m):	40	Channel width (m):	60
Width/depth ratio:	25 est.		

Mean water depth within 5m of bank (m): 1.2

Mean water velocity within 5m of bank (m/s): 0.8 (surface)

Streambed substrates (% composition):

fines <2mm	>5	small cobble 64-128mm	40
small gravel 2-16mm	5	large cobble 128-256mm	30
large gravel 16-64mm	15	boulders >256mm	<5
other	0	D_{90} (mm)	15

Bank characteristics:

	LEFT	RIGHT
	OUTSIDE	INSIDE
dominant materials	rip-rap	gravel bar/vegetation
average height (m)	3.5	1.5
stability	stable	stable (side bars)

Entrenchment/confinement: moderate

Existing cover: limited primarily to rip-rap on left bank (ca. 2-5 % of total section area)

Access (including enhancement considerations):

excellent access directly from highway; only difficulty for machinery would be the stream bank itself

Enhancement options/recommendations:

site appears particularly well suited to further bank boulder installations (additional rip-rap), both hydraulically and logistically; water depth appears excessive for debris catchers; suggest HIGH priority for boulders

System: Pine River Section: 6 Date: Oct 30/91

Section location: ca. 1 km downstream of Fisher Creek confluence; immediately adjacent to Hwy.97 at "old diversion" (upstream of picnic site)

Section length (m): 250 | Gradient (%): 0.12
Sinuosity (from map): 1.3 | Habitat type: riffle
Wetted width (m): 55 | Channel width (m): 60
Width/depth ratio: 50 est.
Mean water depth within 5m of bank (m): 1.0
Mean water velocity within 5m of bank (m/s): 0.9 (surface)
Streambed substrates (% composition):

fines <2mm	>5	small cobble 64-128mm	40
small gravel 2-16mm	5	large cobble 128-256mm	30
large gravel 16-64mm	15	boulders >256mm	<5
other	0	D_{90} (mm)	18

Bank characteristics:

	LEFT	RIGHT
	OUTSIDE	INSIDE
dominant materials	rip-rap	gravels/fines
average height (m)	3	1-3
stability	stable	slowly eroding

Entrenchment/confinement: moderate
Existing cover: considerable amount of rip-rap in channel providing effective cover; ca. 5 % of total section area

Access (including enhancement considerations):
excellent access directly from highway; only difficulty for machinery would be the stream bank itself

Enhancement options/recommendations:
the highly beneficial effect of existing rip-rap in the channel suggests best possibilities from augmenting such habitat; all logistical conditions are well suited to further bank boulder additions or debris catchers; recommend HIGH priority for either

System: Pine River   Section: 7   Date: Oct 30/91

Section location: ca. 3.5 km downstream of Big Boulder Creek confluence; meander joining Hwy.97, 2 km east of Big Boulder Creek crossing

Section length (m): 200   Gradient (%): 0.15
Sinuosity (from map): 1.8   Habitat type: fast glide
Wetted width (m): 40   Channel width (m): 60
Width/depth ratio: 25 est.
Mean water depth within 5m of bank (m): 0.8
Mean water velocity within 5m of bank (m/s): 0.9 (surface)

Streambed substrates (% composition):

fines <2mm	10	small cobble 64-128mm	35
small gravel 2-16mm	20	large cobble 128-256mm	<5
large gravel 16-64mm	30	boulders >256mm	<1
other	0	D_{90} (mm)	10

Bank characteristics:

	LEFT OUTSIDE	RIGHT INSIDE
dominant materials	gravel/fines	gravel/fines
average height (m)	1.5-2	ca. 1 (mostly)
stability	eroding (lower 100m)	wide side bars

Entrenchment/confinement: moderate-good

Existing cover: abundant LOD is present in sections immediately upstream and downstream; some rip-rap is also present immediately upstream; some LOD in section 7 itself (< 1 % of total section area)

Access (including enhancement considerations):

short road (ramp) off highway provides access to bench area along left bank; some clearing of trees/underbrush would be required

Enhancement options/recommendations:

site characteristics and logistics appear well suited to installation of debris catchers (upper 100m) and bank LOD (lower 100m); suggest MODERATE-HIGH priority for either, or both (would be HIGH, except for abundance of existing cover adjacent to section)

System: Pine River Section: 8 Date: Oct 30/91

Section location: immediately adjacent to Lemoray airfield

Section length (m):	200	Gradient (%):	0.17
Sinuosity (from map):	1.6	Habitat type:	glide/riffle
Wetted width (m):	35	Channel width (m):	60
Width/depth ratio:	60 est.		

Mean water depth within 5m of bank (m): 0.8

Mean water velocity within 5m of bank (m/s): 0.8 (surface)

Streambed substrates (% composition):

fines <2mm	>5	small cobble 64-128mm	25
small gravel 2-16mm	20	large cobble 128-256mm	25
large gravel 16-64mm	20	boulders >256mm	<5
other	0	D_{90} (mm)	15

Bank characteristics:

	LEFT OUTSIDE	RIGHT INSIDE
dominant materials	rip-rap	gravel/cobble/fines
average height (m)	2.5	1.5
stability	stable	wide side bars

Entrenchment/confinement: moderate

Existing cover: limited to rip-rap along left bank; some looks excellent (large material out from bank), but limited in abundance (ca. 1-2 % of total section area)

Access (including enhancement considerations):

excellent; unobstructed and drivable access along top of rip-rap; easy machine access to channel at downstream end of rip-rap

Enhancement options/recommendations:

site well suited to installation of either debris catchers or additional bank boulders; suggest HIGH priority for either

System: Pine River   Section: 9   Date: Oct 30/91
Section location: bend joining Hwy.97 at Lemoray, 1.5 km upstream of Lemoray airfield

Section length (m):	200	Gradient (%):	0.66
Sinuosity (from map):	1.3	Habitat type:	fast riffle
Wetted width (m):	25	Channel width (m):	65
Width/depth ratio:	30 est.		

Mean water depth within 5m of bank (m): 0.5
Mean water velocity within 5m of bank (m/s): 1.1 (surface)
Streambed substrates (% composition):

fines <2mm	5	small cobble 64-128mm	30
small gravel 2-16mm	15	large cobble 128-256mm	20
large gravel 16-64mm	25	boulders >256mm	5
other	0	D_{90} (mm)	20

Bank characteristics:

	LEFT OUTSIDE	RIGHT INSIDE
dominant materials	cobble/boulder	gravel/cobble/fines
average height (m)	2.5 (+15 up to hwy.)	3+
stability	some erosion	wide point bar

Entrenchment/confinement: good
Existing cover: some blow-down and other LWD, but limited (< 1 % of total section area)

Access (including enhancement considerations):
road access (off Hwy.97) and ramp into channel at downstream end of riprapped section immediately upstream of section; no access along bank (steep and densely vegetated with trees); all work would have to be via and within the stream channel, likely utilizing the wide point bar on the right bank for materials storage, preparation, etc.

Enhancement options/recommendations:
gradient/velocities may be excessive; furthermore, thalweg is not close to outside bank (left), except for lowermost 30-50 m (where some erosion appears to be occurring); debris catchers most suitable, but suggest LOW priority, due to above factors and access limitations

System: Pine River   Section: 10   Date: Oct 31/91
Section location: ca. 1 km downstream of West Pine bridge crossing (Hwy.97)

Section length (m): 300   Gradient (%): 0.14
Sinuosity (from map): 1.4   Habitat type: riffle/glide
Wetted width (m): 35   Channel width (m): 40
Width/depth ratio: 50 est.
Mean water depth within 5m of bank (m): 0.6
Mean water velocity within 5m of bank (m/s): 0.8 (surface)
Streambed substrates (% composition):

fines <2mm	10	small cobble 64-128mm	25
small gravel 2-16mm	15	large cobble 128-256mm	15
large gravel 16-64mm	25	boulders >256mm	10
other	0	D_{90} (mm)	25

Bank characteristics:

	LEFT OUTSIDE	RIGHT INSIDE
dominant materials	rip-rap	gravel/fines
average height (m)	10+ (top 8 gravel/fines)	ca. 1-1.5
stability	steep but stable	some erosion

Entrenchment/confinement: good; thalweg close to outside (right) bank
Existing cover: some large rip-rap materials out from bank providing some excellent cover, but not abundant (< 5% of total section area); also, some LOD both immediately upstream and immediately downstream

Access (including enhancement considerations):
access road off Hwy.97, 0.5 km east of West Pine bridge crossing; B.C. Railway follows bank, and is bordered by a road; however, all work would involve crossing railway tracks to reach bank; access of machinery to channel precluded by steep high bank

Enhancement options/recommendations:
based on effectiveness of rip-rap already in channel, additional bank boulder installations could be highly beneficial; debris catchers do not seem feasible, due to access constraints for machinery; anchoring elements for bank LWD are lacking; suggest MODERATE priority site for bank boulders (materials could be dumped down bank from railway track, but must evaluate potential de-stabilization of banks from dumping of rock materials)

System: Pine River Section: 11 Date: Oct 31/91

Section location: ca. 700 m upstream of West Pine highway crossing (Hwy.97); immediately upstream of lowermost recent diversion (#5)

Section length (m):	200	Gradient (%):	0.49
Sinuosity (from map):	1.2	Habitat type:	riffle/glide
Wetted width (m):	25	Channel width (m):	45
Width/depth ratio:	40 est.	Outside bank:	right

Mean water depth within 5m of bank (m): 0.3

Mean water velocity within 5m of bank (m/s): 0.7 (surface)

Streambed substrates (% composition):

fines <2mm	10	small cobble 64-128mm	30
small gravel 2-16mm	15	large cobble 128-256mm	15
large gravel 16-64mm	30	boulders >256mm	>1
other	0	D_{90} (mm)	15

Bank characteristics:

	LEFT INSIDE	RIGHT OUTSIDE
dominant materials	fines/gravel/cobble	gravel/fines/vegetated
average height (m)	ca. 1.5	1-1.5
stability	eroding	wide side bar

Entrenchment/confinement: well confined but not deeply entrenched

Existing cover: some sparse transient debris cover (< 1% of total section area),

Access (including enhancement considerations):

access problematic; dense tree/underbrush growth along bank; highway diversion (rip-rapped) immediately downstream; any work would require construction of access ramp to channel, and machine work within channel (using side bar on left bank as work area)

Enhancement options/recommendations:

hydraulically, the site is good for debris catchers, except for shallow depths; due to existing erosion, bank armouring would be required; in view of this, and access constraints, suggest MODERATE-LOW priority

System: Pine River Section: 12 Date: Oct 31/91

Section location: section along B.C. Railway tracks immediately (ca. 200m) downstream of Solitude One bridge crossing (new)

Section length (m):	150	Gradient (%):	0.13
Sinuosity (from map):	1.4	Habitat type:	glide/riffle
Wetted width (m):	30	Channel width (m):	40
Width/depth ratio:	30 est.	Outside bank:	left

Mean water depth within 5m of bank (m): 0.6

Mean water velocity within 5m of bank (m/s): 0.9 (surface)

Streambed substrates (% composition):

fines <2mm	10	small cobble 64-128mm	30
small gravel 2-16mm	15	large cobble 128-256mm	15
large gravel 16-64mm	35	boulders >256mm	5
other	0	D_{90} (mm)	20

Bank characteristics:

	LEFT OUTSIDE	RIGHT INSIDE
dominant materials	rip-rap	gravel/fines
average height (m)	ca. 10	ca. 1.5
stability	steep but stable	some erosion (shallow side bar)

Entrenchment/confinement: well confined but not deeply entrenched

Existing cover: some good cover provided by existing rip-rap, but limited in abundance (< 5% of total section area)

Access (including enhancement considerations):

access would have to be from highway side (right bank), using side bar as work area for installations along left bank; an access road would have to be constructed from the highway to the right bank

Enhancement options/recommendations:

due to good effect of existing rip-rap in channel, further bank boulder additions would likely be beneficial; the site is also well suited to debris catchers; suggest HIGH priority in view of relatively little cover in adjacent sections (despite access complications)

System: Pine River   Section: 13   Date: Oct 31/91

Section location: between Solitude One bridge crossing (downstream) and short straight section along Hwy.97 (upstream)

Section length (m):	150	Gradient (%):	0.21
Sinuosity (from map):	1.4	Habitat type:	riffle
Wetted width (m):	35	Channel width (m):	45
Width/depth ratio:	60 est.	Outside bank:	right

Mean water depth within 5m of bank (m): 0.4

Mean water velocity within 5m of bank (m/s): 0.8 (surface)

Streambed substrates (% composition):

fines <2mm	10	small cobble 64-128mm	30
small gravel 2-16mm	20	large cobble 128-256mm	10+
large gravel 16-64mm	25	boulders >256mm	<5
other	0	D_{90} (mm)	18

Bank characteristics:

	LEFT INSIDE	RIGHT OUTSIDE
dominant materials	gravel/cobble	rip-rap (mostly)
average height (m)	ca. 2	2.5+
stability	some erosion (no bar)	stable

Entrenchment/confinement: moderate entrenchment but little confinement (wide and shallow)

Existing cover: a limited amount of existing rip-rap in channel (< 1% of total section area)

Access (including enhancement considerations):

access can be gained from left bank immediately upstream of Solitude One bridge, but at the flows observed, there was no side bar to use as work area or for access up the section

Enhancement options/recommendations:

some potential for debris catchers, but due to lack of confinement, access constraints, and shallow depth, suggest LOW priority

System: Pine River **Section:** 14 **Date:** Oct 31/91

Section location: between new Solitude Two bridge crossing (upstream) and straight section along Hwy.97 (downstream)

Section length (m):	150	Gradient (%):	0.08
Sinuosity (from map):	1.4	Habitat type:	glide/riffle
Wetted width (m):	30	Channel width (m):	35
Width/depth ratio:	40 est.	Outside bank:	right

Mean water depth within 5m of bank (m): 0.7

Mean water velocity within 5m of bank (m/s): 0.8 (surface)

Streambed substrates (% composition):

fines <2mm	10	small cobble 64-128mm	30
small gravel 2-16mm	15	large cobble 128-256mm	10+
large gravel 16-64mm	30	boulders >256mm	<5
other	0	D_{90} (mm)	18

Bank characteristics:

	LEFT INSIDE	RIGHT OUTSIDE
dominant materials	gravel/cobble	gravel/cobble/rip-rap
average height (m)	ca. 1	1.5(top end)-5+(bottom)
stability	some erosion	some erosion at top end

Entrenchment/confinement: moderately confined, but not well entrenched

Existing cover: basically limited to existing rip-rap along highway at downstream end (< 1% of total section area)

Access (including enhancement considerations):

machine access to channel currently possible at Solitude Two bridge crossing, but no bars to work from; bench area on right bank could be used, but would require some clearing of underbrush and/or trees, and access road provision (from Solitude Two construction area)

Enhancement options/recommendations:

due to presence of fairly large trees for anchoring, bank LOD installations could be considered at this site; however, number of locations offering anchorage is limited; also suitable for debris catchers; suggest MODERATE priority in view of access limitations

System: Pine River Section: 15 Date: Oct 31/91

Section location: adjacent to rock quarry, immediately upstream of Solitude Two bridge crossing

Section length (m):	100	Gradient (%):	0.30
Sinuosity (from map):	1.4	Habitat type:	riffle/glide
Wetted width (m):	30	Channel width (m):	35
Width/depth ratio:	40 est.	Outside bank:	left

Mean water depth within 5m of bank (m): 0.6

Mean water velocity within 5m of bank (m/s): 0.7 (surface)

Streambed substrates (% composition):

fines <2mm	10	small cobble 64-128mm	20
small gravel 2-16mm	20	large cobble 128-256mm	15
large gravel 16-64mm	30	boulders >256mm	<5
other	0	D_{90} (mm)	15

Bank characteristics:

	LEFT	RIGHT
	OUTSIDE	INSIDE
dominant materials	rip-rap	gravel/cobble/fines
average height (m)	1-10+	ca. 1-1.5
stability	stable	disturbed (construction)

Entrenchment/confinement: well confined, but not well entrenched

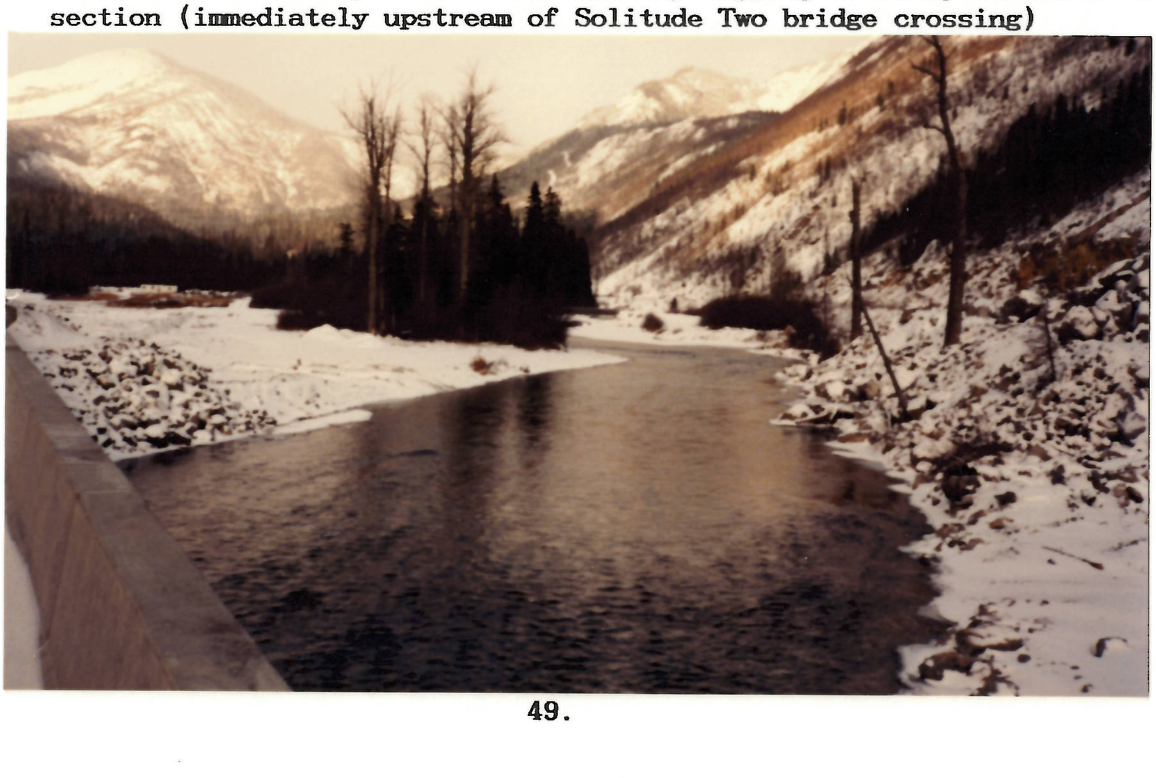
Existing cover: some very effective cover provided by rip-rap in channel at present (ca. 5% of total section area)

Access (including enhancement considerations):

full access along banks on both sides of channel as a result of highway construction; machine access via right bank (shallow and cleared)

Enhancement options/recommendations:

based on the effectiveness of existing rip-rap in the channel, additional bank boulders are recommended; suggest HIGH priority, given the proximity of large rock materials (the quarry), the on-going construction at the site, and the likely need of further rip-rapping to fully stabilize this section (immediately upstream of Solitude Two bridge crossing)



System: Pine River   Section: 16   Date: Oct 31/91

Section location: section adjacent to B.C. Railway immediately upstream of temporary bridge (ca. 300m upstream of Solitude Two bridge)

Section length (m):	200	Gradient (%):	0.16
Sinuosity (from map):	1.4	Habitat type:	glide/riffle
Wetted width (m):	35	Channel width (m):	40
Width/depth ratio:	45 est.	Outside bank:	left

Mean water depth within 5m of bank (m): 0.6

Mean water velocity within 5m of bank (m/s): 0.5 (surface)

Streambed substrates (% composition):

fines <2mm	10	small cobble 64-128mm	25
small gravel 2-16mm	15	large cobble 128-256mm	15
large gravel 16-64mm	35	boulders >256mm	<1
other	0	D_{90} (mm)	15

Bank characteristics:

	LEFT OUTSIDE	RIGHT INSIDE
dominant materials	gravel/cobble/fines	gravel/fines
average height (m)	ca. 8	1-1.5
stability	stable	some erosion (narrow bar)

Entrenchment/confinement: moderate

Existing cover: some rip-rap cover adjacent to railway (ca. 2% of total section area); small LOD jam/accumulation immediately upstream of section

Access (including enhancement considerations):

access to channel provided by ramp on upstream side of temporary bridge; however, little to no bar area to work from

Enhancement options/recommendations:

hydraulic and channel characteristics perhaps best suited to debris catchers, but suggest LOW priority due to access/working constraints and relatively low velocity

System: Pine River   Section: 17   Date: Oct 31/91

Section location: section between recent diversions #1 and #2; commences immediately upstream of diversion #2

Section length (m):	300	Gradient (%):	0.28
Sinuosity (from map):	1.2	Habitat type:	fast glide/riffle
Wetted width (m):	25	Channel width (m):	45
Width/depth ratio:	35 est.	Outside bank:	left

Mean water depth within 5m of bank (m): 0.7

Mean water velocity within 5m of bank (m/s): 0.8 (surface)

Streambed substrates (% composition):

fines <2mm	10	small cobble 64-128mm	30
small gravel 2-16mm	10	large cobble 128-256mm	20
large gravel 16-64mm	25	boulders >256mm	<5
other	0	D_{90} (mm)	18

Bank characteristics:

	LEFT OUTSIDE	RIGHT INSIDE
dominant materials	gravel/cobble/fines	gravel/cobble/fines
average height (m)	1.5-2	ca. 1
stability	slowly eroding	wide point/side bar

Entrenchment/confinement: well confined, moderately entrenched

Existing cover: some blow-down and other debris (< 5% of total section area)

Access (including enhancement considerations):

access for machinery via construction area at upstream end of diversion #2; wide bar on right bank to serve as work area

Enhancement options/recommendations:

site appears excellently suited to debris catchers; due to erosion on left bank, installations should include armouring; access is not ideal, but adequate, with a wide bar to work from; suggest HIGH priority due to excellent site characteristics

Appendix 3. Suggested mainstem control sections.

Note: some of the potential control sites listed here are essentially continuous with one another; in such cases, they are identified separately to enable optimum options in terms of length, replication, etc., or due to differences in habitat type/abundance.

Control No:	C 1	VCR Count (speed SP):	0037-0045
Control Type:	natural boulders + rip-rap	Length:	300m

Location: top end ca. 500m downstream of Fur Thief Creek confluence; bottom end at B.C. Rail encroachment.

Access: private (?) dirt road off Hwy. 97 at "old oxbow"

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Control No:	C 2	VCR Count (speed SP):	0085-0220
Control Type:	moderate LOD	Length:	1.5 km

Location: top end at B.C. Rail encroachment at Fred Nelson Creek; bottom end where river joins Hwy. 97 downstream.

Access: top end - B.C. Rail; bottom end - Hwy. 97

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Control No:	C 3	VCR Count (speed SP):	0255-0285
Control Type:	low - moderate LOD	Length:	1 km

Location: top end at forestry road bridge upstream of Crassier Creek, bottom end at mouth of unnamed tributary ca. 400m downstream of Crassier Creek.

Access: top end - forestry road bridge; bottom end - hike out to Hwy. 97

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Control No:	C 4	VCR Count (speed SP):	0355-0370
Control Type:	very little cover (some LOD)	Length:	1 km

Location: top end at Hwy. 97 encroachment immediately upstream of Falls railway siding; downstream end at small unnamed tributary at Falls siding (B.C. Rail).

Access: top end - Hwy. 97; bottom end - B.C. Rail

Control No:	C 5	**VCR Count (speed SP):**	0380-0415
Control Type:	very little cover (some LOD)	**Length:**	1.5 km

Location: top end at downstream end of "old diversion"; bottom end at return to Hwy. 97 (ca. 200m upstream of control no. 4).

Access: Hwy. 97 at both ends

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Control No:	C 6	**VCR Count (speed SP):**	0435-0450
Control Type:	natural boulders + rip-rap	**Length:**	1 km

Location: top end at mouth of Fisher Creek; bottom end where river joins Hwy. 97 at candidate enhancement site 6.

Access: top end - B.C. Rail (closest); bottom end - Hwy. 97

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Control No:	C 7	**VCR Count (speed SP):**	0545-0595
Control Type:	moderate LOD	**Length:**	2 km

Location: bottom end at B.C. Rail encroachment ca. 800m upstream of Cleveland Creek confluence; top end near mid-point of next B.C. Rail encroachment upstream.

Access: B.C. Rail at both ends

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Control No:	C 8	**VCR Count (speed SP):**	0870-0885
Control Type:	little cover (some LOD)	**Length:**	1 km

Location: top end at bottom of first B.C. Rail encroachment downstream of Lemoray air field; bottom end at top of next B.C. Rail encroachment downstream.

Access: B.C. Rail at both ends

Control No:	C 9	VCR Count (speed SP):	0895-0905
Control Type:	very little cover (minimal LOD)	Length:	1 km
Location:	top end immediately downstream of Lemoray airfield; bottom end at top of first B.C. Rail encroachment downstream.		
Access:	top end - Hwy. 97; bottom end - B.C. Rail		

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Control No:	C 10	VCR Count (speed SP):	0945-0965
Control Type:	very little cover (some boulder)	Length:	800m
Location:	top end at Le Moray Creek confluence; bottom end at pipeline crossing just upstream of joining Hwy. 97.		
Access:	top end - B.C. Rail; bottom end - Hwy. 97		

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Control No:	C 11	VCR Count (speed SP):	1055-1090
Control Type:	abundant LOD (some areas hazardous)	Length:	2 km
Location:	top end at railway bridge crossing river; bottom end at next B.C. Rail encroachment downstream (just upstream of Mountain Creek confluence.		
Access:	B.C. Rail at both ends		

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Control No:	C 12	VCR Count (speed SP):	1125-1135
Control Type:	very little cover	Length:	1 km
Location:	top end near top of recent diversion #5 (Hwy. 97); bottom end at first bend downstream of West Pine highway bridge.		
Access:	Hwy. 97 at both ends (short hike from downstream end)		

Control No:	C 13	VCR Count (speed SP):	1140-1155
Control Type:	very little cover (some rip-rap and boulder)	Length:	1 km

Location: top end at Solitude One new bridge crossing; bottom end at top of recent diversion #5.

Access: Hwy. 97 at both ends

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Control No:	C 14	VCR Count (speed SP):	1200-1220
Control Type:	very little cover (some rip-rap and boulder)	Length:	1 km

Location: top end near bottom of recent diversion #2; bottom end at top of recent diversion #3.

Access: Hwy. 97 at both ends

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Control No:	C 15	VCR Count (speed SP):	1240-1260
Control Type:	little cover (some LOD, boulders)	Length:	1 km

Location: top end at B.C. Rail encroachment ca. 500m upstream of Link Creek; bottom end at top of recent diversion #1.

Access: top-end - B.C. Railway; bottom end - Hwy. 97

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Control No:	C 16	VCR Count (speed SP):	1365-1370
Control Type:	rip-rap	Length:	200m

Location: uppermost 200m of B.C. Rail encroachment 3 km downstream of Callazon Creek road bridge.

Access: B.C. Rail

Appendix 4. Side channel areas investigated, October 29th - November 1st, 1991.

Note: Specific sites are not necessarily shown on the aerial video; VCR count refers to glimpses of side channel, or general locale.

Side Channel: A | VCR Count (speed SP): 0180

Location: side channel into which Fred Nelson Creek empties

Comments:
- total coverage with ice and snow
- channel width ca. 12m; well entrenched/confined
- banks ca. 0.75m high; vegetated to water
- habitat/cover unknown; however, little LOD
- at least 300m accessible for enhancement, if warranted; via bench, off Hwy. 97
- smaller secondary channels associated

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Side Channel: B   **VCR Count (speed SP):** 0350

Location: 2.5 km (highway distance) southwest of Crassier Creek

Comments:
- total coverage with ice and snow
- channel width ca. 20m; entrenchment unknown
- banks 1m+ (up to 10m+ on highway side); vegetated to water
- habitat/cover unknown, but does not appear abundant; little LOD
- access would be extremely difficult due to steep high bank to highway

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Side Channel: C | VCR Count (speed SP): 0668

Location: hike through bush, off Hwy. 97, 2.5 km southwest of Cleveland Creek

Comments:

- total coverage with ice and snow
- channel width ca. 8m; well entrenched/confined
- banks 1.5-2m, and complex, with roots, cutbanks, debris, etc.
- fair amounts of apparently stable LOD as well
- no reasonable access, and enhancement would not seem warranted, in any event

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Side Channel: D VCR Count (speed SP): 0947

Location: channel enters mainstem on upstream side of pipeline crossing ca. 2 km upstream of Lemoray airfield

Comments:
- channel open at various locations
- channel width ca. 15m, but variable

Lower 500m:
- riffle/pool sequences
- highly abundant LOD, especially in corner pools

Lowermost 100m:
- riffle/rapid; gradient = 0.49%
- mean depth approx. 0.4m; mean surface velocity approx. 1.3 m/s
- rip-rap dyke along left bank (highway side), ca. 3m high
- streambed substrates dominated by small cobbles (30%), large cobbles (30%), and a few small boulders (5%)
- approximately 100m could conveivably be enhanced with debris catchers but not warranted in view of abundant, complex organic habitat immediately upstream

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Side Channel: E VCR Count (speed SP): 1290

Location: hike through bush, off Hwy. 97, 1.5 km west of Link Creek

Comments:

- near total coverage with ice and snow
- channel width ca. 18m; well entrenched, but some braiding
- banks 1-2m (primarily), and vegetated to water
- some roots, debris, cutbanks, etc. (debris fairly abundant, but tends to be small in size)
- difficult access, due to bush

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