MELP

FINAL REPORT

Interior Watershed Assessment Procedure and Rehabilitation Options

Falls Creek

Prepared for:

Small Business Forest Enterprise Programme
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SUMMARY

This report presents the findings of an Interior Watershed Assessment of the Falls Creek watershed, a Community Watershed west of Nelson, B.C. The report also provides rehabilitation options for the watershed. Two hydrologic maps have been prepared as part of this study: *Hydrologic Features and Sediment Sources Map* and *Hydrologic Recovery and Proposed Development Map.*

The following table summarises the development indicators for the existing and proposed development:

Indicator	Units	Existing				Proposed
		North Subwatershed	Northwest Subwatershed	Lower Face Units[1]	Total Watershed	Total Watershed
Area	ha	649.7	998.4	1331.7	2979.8	2979.8
Private Land	%	0	0	2.8	1.2	1.2
ECA – unweighted	%	15.4	20.4	13.6	16.3[2]	18.7
ECA –weighted	%	20.3	29.5	17.5	22.2[3]	24.8
1958 ECA –weighted	%	72	112	76	87	-
Total road density	km/km²	2.3	1.22	0.81	1.27	1.44
High hazard roads	km	0.75	0.25	0.78	1.79	n/a
Moderate hazard roads	km	0.76	1.91	1.07	3.73	n/a
Roads on Terrain Stability Class IV/V	km/km²	0.78	0.33	0.28	0.40	0.41
Roads on Sediment Yield H/VH	km/km²	0.18	0.07	0.18	0.43	0.44
Density of TRIM Stream Crossings	no/km²	1.69	1.20	0.75	1.11	1.21
Number of Landslides	no	7	0	8	15	-
Disturbed Mainstem Channel	km	most	most	all	~all	-

[1] The Lower Face Units compose the Residual area in the southern section of the watershed.
[2] Given the uncertainty resulting from the poor forest-cover typing, these values contain uncertainty of 1-2 % (+/-)

Existing hazards are given in the following table in addition to the level of risk in each hazard class (and expected hazard) associated with the proposed development:

Indicator	Existing Hazard	Proposed Development	
		Associated Risk[2]	Resulting Hazard
Sediment Sources	M-H	unknown[1]	unknown
Peak Flow	M	+	**M-H**
Channel Stability	H	(+)	H
Riparian Function	M-H	o	M-H

[1] Requires field determination.
[2] Associated risk: o – none; (+) – insignificant increase; + – significant increase; ++ – major increase; (-) – insignificant decrease; "-" – significant decrease; "- -" – major decrease

Risk reduction strategies are provided in terms of specific road deactivation options including a detailed deactivation prescription for the lower section of the Main Road (to 2+172). Other risk reduction strategies and their suggested sequencing are discussed with respect to landslide rehabilitation, channel restoration, and riparian rehabilitation. A rehabilitation strategy is recommended in addition to potential development opportunities and recommendations on the proposed development. The strategy to be pursued may depend on other considerations of the Watershed Assessment Committee and the budget available.

1.0 INTRODUCTION

This report presents the findings of an Interior Watershed Assessment of the Falls Creek watershed, a Community Watershed west of Nelson, B.C. Falls Creek provides domestic water supply to the Beasley and Bonnington areas. This work has been completed in conjunction with the preparation of options for watershed rehabilitation.

The report is prepared for Rick Mazzocchi of the Small Business Forest Enterprise Program (Kootenay Lake Forest District) with the technical cooperation of Alan Davidson, District Earth Scientist of the Kootenay Lake Forest District.

The terms of reference for this work were to conduct data collection and hydrologic assessments consistent with the requirements of the Interior Watershed Assessment Procedure (IWAP) Version 2 (Anonymous 1999). This work included a sediment-source assessment, riparian assessment, a peak flow assessment including a detailed ECA determination, and calculation of other indicators of forest development. The reconnaissance channel assessment was completed earlier (October 1998) in conjunction with Level B/C terrain mapping for the same area (Utzig and Carver 1999).

Deliverables include two maps and one report. The *Hydrologic Features and Sediment Sources* map is referred to as Map 1 in this report. The *Hydrologic Recovery and Proposed Development* map is referred to as Map 2.

Field work was conducted during October 5, 11, 12, and 15 and November 9 (1999).

1.1 Limitations and Reliability

This report and accompanying maps are based on airphoto interpretation, literature review, and limited field checking. The hazard assessments and mapping completed in this project are of a reconnaissance nature and are not intended for road layout nor cutblock design. The maps are intended to fulfil part of the requirements of the Interior Watershed Assessment Procedure.

Given that this study's terms of reference specifically excluded mapping of tributary streams, the streams shown on Maps 1 and 2 cannot be considered reliable. As a result, the reader is cautioned to examine the waterborne sedimentation hazard identified in Utzig and Carver (1999). In addition, the terms of reference did not allow the authors to view these road segments during the spring freshet, somewhat reducing the reliability of observations regarding road-related water diversions.

1.2 Previous Work

A reconnaissance channel assessment (ReCAP) was described by Utzig and Carver (1999). Utzig and Carver (1999) also provided the results of Level B terrain mapping. Jungen (1980) mapped the soils and terrain of the area at a scale of 1:100,000. Little (1960,1973) provided mapping of the area's geology. Utzig (1996a, 1996b) provided terrain mapping in small portions of Falls Creek watershed adjacent to the Garrity/Smallwood and Smoky Creek/Mt. Stewart areas.

2.0 STUDY AREA

The Falls Creek study area is shown in Figure 2.1. The watershed is 29.8 km^2 in area and is located 16 km west of Nelson, B.C.

2.1 Bedrock and Terrain

The following description of the bedrock and terrain is summarised from Utzig and Carver (1999).

The western portion is defined by biotite quartz monzonite (the Valhalla Gneiss Complex) whereas in the eastern portion there is found resistant granodiorite with minor diorite (Nelson Intrusives). The diorite often weathers sporadically to saprolite with sandy or silty textures or to clays with abundant seepage.

The entire study area was over-ridden by the regional ice of the last major Pleistocene glaciation. The upper ridge crests are dominated by morainal veneers, saprolite veneers, and bedrock outcrops with isolated occurrences of glaciofluvial deposits and local occurrences of steep bedrock cliffs and associated talus slopes. Glaciofluvial and deeper morainal materials are usually associated with the upper-elevation lakes and wetlands. The headwater tributaries are dominated by steep rock outcrops and associated colluviums and morainal materials. The western slopes are dominated by veneers of a wide range of material types (bedrock, morainal, galciofluvial, colluvial, saprolitic), especially at higher elevations. The saddle between the Smoky and Falls Creek watersheds is dominated by sandy, silty, and gravelly sandy glaciofluvial terraces, dissected terraces and blankets. The gentle ridge crest between Smallwood/Garrity Creeks and Falls Creek is domainted by bedrock and associated shallow soils, including veneers of saprolite and morainal and eolian materials. Lastly, the lower slopes of Falls Creek are a complex of steep dissected glaciofluvial terraces, morainal slopes, and colluviums with signficant local occurrences of interbedded silty glaciolacustrines. The morainal materials vary from sandy loam to silt loam and can sometimes include significant amounts of clay. In addition, there are sporadic occurrences of sandy gravelly galciofluvial terraces and fluvial fans along the valley bottom.

Further details can be found in Utzig and Carver (1999).

2.2 Climate and Hydrologic Regime

Utzig and Carver (1999) described the general climate and hydrologic regime of the study area. The study area is located in the southern portion of the "Interior Wet Belt". The general patterns of temperature and precipitation are typical for mountainous terrain with increases in mean annual precipitation and decreases in mean annual temperature coincident with increasing elevation. Precipitation increases with elevation to about 1500 m above which it often decreases slightly. (The inflection point moves higher in the summer.) The annual precipitation distribution is seasonal with a maximum during mid-winter (December-January) and a minimum in mid-summer (July-August). These temperature and precipitation patterns result in rapidly increasing snowpack with elevation. At the lower elevations, the winter maximum may be reached in January while at the higher elevations, it continues to collect until April. Nearby climate stations indicate total valley-bottom precipitation in the range of 500-800 mm/year and show an increasing trend over the past 75 years (based on long-term averages at Nelson, Deer Park, and New Denver stations).

The annual hydrograph is snowmelt-dominated with typically over 90% of the annual runoff occurring in April, May, and June. The Water Survey of Canada has collected water quantity data at two locations on Falls Creek:

- 08NJ163 Falls Creek above B.I.D. Diversion (1981-1988)
- 08NJ018 Falls Creek near South Slocan (1921, 1923, 1932, 1933, 1947, 1948, 1967-1970)

These flow data have been collected during April through September only, presumably due to difficult access/conditions during the winter months. The following information is extracted from these data:

- average mean daily flow in April (11 years) = 1.8 m^3/s
- average mean daily flow in May (11 years) = 3.2 m^3/s
- average mean daily flow in June (11 years) = 1.5 m^3/s
- annual maximum mean daily flow (11 years) = 8.5 m^3/s (range 5.1-8.5 m^3/s)
- date of annual maximum mean daily flow (11 years) = mid-May (range: April 24 to June 3)
- date of annual low flow (3 years) = mid-August to mid-September

There are no data available on water quality.

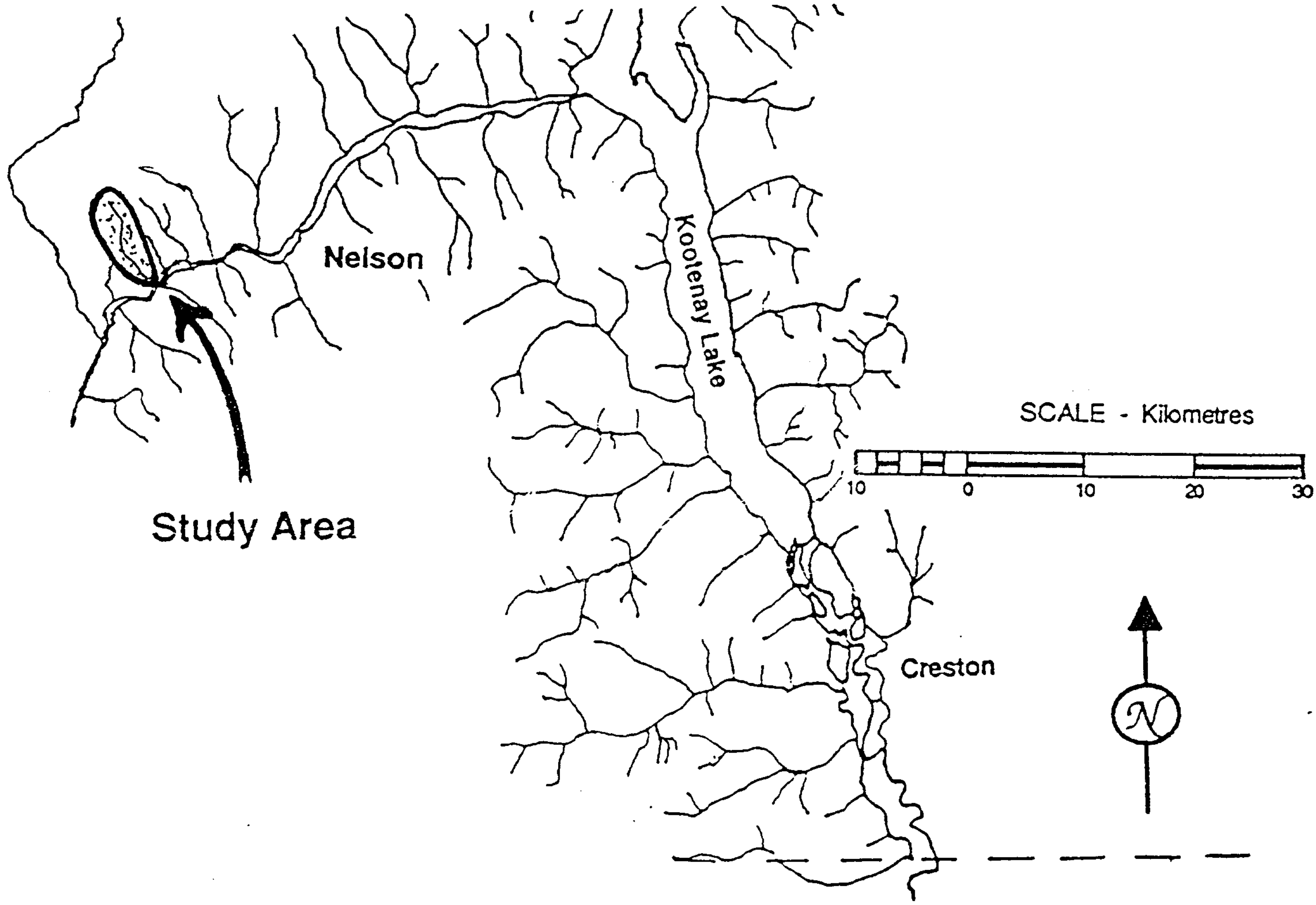

Figure 2.1. Study area location.

2.3 Water Licensing & Point of Interest

Appendix A1 summarizes water-licensing information for the study area as provided by the Water Management (MELP) website on February 15, 2000.

The Beasley Water Users Community (BWUC) and the Bonnington Improvement District (BID) take water from Falls Creek at Point of Diversion (POD) N7/X7 (see Map 1). In addition, there exist other independent licenses for diversion at N7/X7 and, further upstream, at S6. Although WW is indicated by the MELP website as being a POD used by the BID, Jo-Ann Nassey of the Water Management Branch has indicated (Nassey 1999) that the BID actually takes all of its water from the N7/X7 POD. She also noted that West Kootenay Power no longer uses its waterworks license at WW for dwellings below the highway. As a result, that license may be amended in the future. Based on this information, Alan Davidson and Jo-Ann Nassey have instructed the authors to use the N7/X7 POD as the Point of Interest in the present assessment.

2.4 Disturbance History

The disturbance history over the last century in the Falls Creek watershed has been a complex mix of fires, forest harvesting, road construction and landslides. Based on a review of 1939 airphotos, Falls Creek was mainly forested during the early decades of the 20^{th} century, with a significant fire occurring sometime in the 1930s. Only one landslide was visible on these early airphotos (#3 in Table A2.1). It is not known whether the fire was natural or human-caused. This fire denuded a significant portion of the rocky slopes on the west side between Smoky Creek and the major confluence, and the lower-to-mid slopes on the east side. The riparian zone was left mainly intact, with some minor areas burned. The 1939 stream channel shows no signs of disturbance or natural instability and there were no landslides evident.

By 1952, the date of the next set of airphotos examined, another fire (likely mid-to-late 1940s) had re-burned the northern fringes of the 1930s burn area, and extensive areas of both of the headwaters sub-basins. Again, it is not known whether the fire was natural or human-caused. Between 1939 and 1952 a road was built to the major confluence, and most of the riparian area and lower slope remnant forest patches from the 1930s fires had been harvested. The 1930s burn areas showed some regeneration to both brush and young trees while the 1940s burn areas were mainly shrubs and very young regeneration. The haul roads and skid roads created some riparian disturbance, but no large landslides were evident. The stream channel showed little change from the 1930s.

Airphotos from 1958 depict major changes from 1952. Extensive road systems were built into both headwater sub-basins, accompanied by extensive forest harvesting. The haul road and skid road systems created significant riparian disturbance, and were associated with a number of landslides. In some cases skid roads were located in, or became, stream channels. The riparian areas just above the upper confluence were extensively impacted. Harvesting was concentrated in the lower-to-mid portions of the upper two sub-basins, on the ridge between them, and on the eastern slopes and ridge extending into Smallwood Creek. It appears that the harvesting was about 80% complete in 1958. The stream channel below the confluence appears to have been widened with the establishment of new flood channels. Three bridges appear to have been still in place and the roads were still active. Most of the landslides appear to have been initiated between 1952 and 1958. Forest regeneration and hydrologic recovery has continued on both the 1930s and 1940s burned areas.

The Ministry of Forests was able to provide only very limited information concerning early forest development activities in the drainage. Della Peterson has suggested that a trail existed in the 1930s and that work was undertaken by the Ministry of Forest in both the 1930s and the 1950s to improve the trail for better access for fire prevention. The indications provided by the airphotos are expected to be more reliable than these uncertain accounts. Silvicultural records describe further logging activities as having occurred in 1965-1968 and then again later in 1980-1982.

3.0 METHODS

The methods used in the reconnaissance channel assessment have been presented earlier in Utzig and Carver (1999) where the results of that assessment were first presented.

3.1 Determination of Equivalent Clearcut Area

Hydrologic recovery and equivalent clearcut area (ECA) were determined primarily by utilizing existing data on forest cover and regeneration, with confirmation during field work. The method follows that developed in Carver and Utzig (1999) and varied depending on data availability. The primary sources of information included:

- BC MoF Forest Cover Inventory (mapsheets 82F043 and 82F053 – all FIP files updated to January 1, 1998)
- BC MoF Silviculture Information System Records (ISIS & MLSIS databases – all regeneration records updated to January 1, 1998))
- Airphotos (1939, 1952, 1958, 1997)
- Field transect notes

For the purposes of calculating ECA, six hydrologic recovery classes were defined as follows:

Table 3.1. Definition of classes of hydrologic recovery.

Recovery Class	Hydrologic Recovery (%)
5	100
4	90
3	75
2	50
1	25
0	0

Hydrologic recovery ratings were assigned to all existing forest cover polygons. In some areas, particularly those with a disturbance history in the last century, the detail and reliability could be significantly improved by redrafting the forest cover polygons (beyond the scope of this study). All stand inventory information was updated to 1998. For recently-logged openings – i.e., those polygons with stocking (total stems/ha) and height data available from the BC MoF Silviculture Information System (MLSIS or ISIS) – stand characteristics were updated according to the following growth rates (applied by leading species):

Table 3.2. Growth rates used in updating ISIS/MLSIS data to 1998.

Site Class	Fd, Pl, Lw	S, B, Cw, Hw
Good	50 cm/yr	40 cm/yr
Medium	30 cm/yr	20 cm/yr
Poor	15 cm/yr	10 cm/yr

For recently logged openings, recovery class was determined using Table 3.3a or 3.3b (depending on the height of the canopy layer). The tree height and stocking data in Table 3.3a are adapted from the initial FPC IWAP Guidebook (Anonymous 1995, Table 8-1 p. 64), an estimate of crown closure from average crown diameters, field observations, and expert opinion. Table 3.3b, using tree heights over 10.5m and stocking density to predict recovery, is based on using predicted average crown diameters to estimate crown closure, combined with field observations and expert opinion.

Table 3.3a. Hydrologic recovery for recently-logged openings with maximum tree height of 10.4 m.

Tree Height (m)	**<3**	**3-4.9**	**5-6.9**	**7-8.9**	**9-10.4**
Stocking (st/ha)			**Recovery Class**		
>1250	**0**	**1**	**2**	**3**	**4**
1000 – 1250	**0**	**0**	**1**	**2**	**3**
750 – 999	**0**	**0**	**0**	**1**	**2**
500 – 749	**0**	**0**	**0**	**0**	**1**
< 500	**0**	**0**	**0**	**0**	**0**

Table 3.3b. Hydrologic recovery for recently-logged openings with tree height at least 10.5 m.

Tree Height (m)	**10.5 – 15.0 m**	**15.1 – 19.4 m**	**>19.4 m**
Recovery Class		**Stocking (st/ha)**	
5	> 1200	> 800	> 600
4	1000 – 1199	700 – 799	500 – 599
3	750 – 999	475 – 699	275 – 499
2	500 – 749	250 – 474	200 – 274
1	250 – 499	175 –249	125 –199
0	< 250	< 175	< 125

Multi-layered stands were assigned the recovery class of the most-recovered layer, or a higher class if other layers were felt to make an additional contribution to overall recovery. Stand densities (total stems/ha) were discounted for deciduous components. Crown closure data from the SIS files were found to be of poor reliability and hence were avoided. Non-productive portions of the openings were assumed to be recovery class 0 but were generally insignificant portions of the openings.

For stands with tree heights greater than 10.4 m, and where no detailed stocking data were available (i.e., stands that had not been logged recently), preliminary recovery classes were determined using Table 3.4. The prevalence of shallow soils and subalpine climatic conditions in the upper elevations were accounted for by requiring less crown closure for full hydrologic recovery at elevations in excess of 1700 m.

All forested forest-cover polygons with a tree height of less than 10.4 m and without stocking data, or with a preliminary recovery class less than 5, were individually assessed on the 1997 airphotos to determine final recovery class. The general criteria used were soil characteristics and disturbance history. Airphoto interpretation of soil characteristics, site series, fire history, stand age, tree height and species composition was used to assign recovery classes for specific forest cover polygons. Open stands with ages greater than 100 years were generally considered fully recovered if located on excessively coarse-textured, shallow or poorly-drained soils. Younger stands on similar sites were assigned recovery classes similar to those on adjacent sites. Stands with previous harvesting and/or skidroad networks were also assigned recovery classes based on airphoto interpretation of crown closure. Rock outcrops, wetlands and other naturally occuring non-forested areas were always rated to be recovery class 5 (100%).

Table 3.4. Preliminary hydrologic recovery class for stands lacking detailed stocking data (not recently logged).

	Crown Closure Class	
Recovery Class	**Elev. $\leq$1700m**	**Elev. >1700m**
5	$\geq$ 5	$\geq$4
3	4	3
2	3	2
1	2	1
0	0 & 1	0

Forest cover polygons designated non-forested or non-productive were rated individually based on airphoto interpretation and information recorded during field transects. These included forest cover types such as: non-commercial brush, not satisfactorily restocked, non-commercial forest, alpine, alpine forest, non-productive, rock and burned. In areas with extensive fire history, especially at upper elevations, these forest cover designations were found to be generally unreliable. Based on field checks and terrain mapping, it was found that the areas were mistakenly classified as non-productive or non-forested designations because of slow regeneration, rather than an inherent inability to support closed canopy forest. For example the presence of deep soils and large stumps and/or coarse woody debris remaining from a stand pre-dating the last fire, clearly indicate an area which is capable of supporting a forest, not a non-productive site. These areas were rated according to the height and stocking of the present stand, in relation to the potential stand, rather than automatically rating them recovery class 5. Actual rock outcrops and other non-forested areas were still rated recovery class 5. Where the non-forested or non-productive areas were associated with fully-stocked stands with ages >100 years old, they were generally designated recovery class 4 or 5 (the assumption being that they had restocked to their capacity). When associated with fire-origin stands of <100 years in age, they were generally assigned a recovery class similar to the adjacent stands, based on airphoto interpretation as described above.

Fully stocked deciduous and mixed-deciduous stands were generally designated recovery class 5, as it was assumed they are a naturally-occurring portion of the landscape.

Cleared, cultivated or urban polygons were designated recovery class 0. Swamps and fens were designated recovery class 5. Clearing on private land was updated based on clearing visible on 1997 airphotos and field transect notes, with some forest polygons being pro-rated based on partial clearing. Full account may not have been made for some recent private-land harvesting and clearing.

The results were compared with observations of stocking and tree height from field transects. The correlation was found to be good overall.

The ECA ratings for the "proposed development" scenarios do not include consideration of growth and recovery over the next five-year period. Given the lack of details available for the silvicultural systems to be used, the ECA effect was calculated in direct relation to the "percent basal area removal."

3.2 Sediment Source Survey

Two classes of sediment sources are considered in this study - point sources and roads.

3.2.1 Point Sources

Definitions

Three types of point sediment sources are recognised and defined as follows:

Inactive Source (Past) : sources which have been active in the past but are now largely inactive

Active Source (Present): sources with exposed material, generating sediment on an ongoing basis – these sources have a component which was active in the past and will be active in the future

Potential Source (Future): locations with the potential to generate sediment but which have resulted in no production to date

Sources without connection to the stream network are not included in the sediment-source inventory.

The definition of source size varies with source type as described in Table 3.5. Table 3.6 provides the definitions of the size classes.

Table 3.5. Definition of source size in relation to source type.

Source Type	Size Definition
Inactive	total amount of sediment estimated to have been produced at the slide site
Active	total amount of additional sediment expected to be produced at the site if remediation action is not pursued.
Potential	total amount of sediment expected to be produced at the site if remediation action is not pursued (this can be the size of the potential landslide, the amount of vulnerable material at a bridge crossing with the potential to fail, the amount of material which may be mobilised as a result of an avulsion, etc.)

Table 3.6. Definition of sediment-source size classes.

Source Size Class	Size of Sediment Source (Volume, m^3)
Low	< 10
Moderate	10 – 100
High	100 – 500
Very High	> 500

Sediment source delivery refers to the extent to which mobilised material is delivered to a stream able to carry the material to the mainstem. Delivery classes are defined in Table 3.7.

Two types of potential sediment sources are distinguished as shown in Table 3.8.

Table 3.7 Definition of classes of sediment delivery.

Source Delivery Class	Percentage of Sediment Source Delivered to Stream Network
Low	< 10
Moderate	10 – 50
High	50 – 80
Very High	> 80

Table 3.8 Classes of potential sediment sources according to likelihood of occurrence.

Likelihood of Occurrence	Definition	Field Indicators
Probable (High)	Without remediation, expected to occur as a result of annual variability	Recent evidence of instability (recent tension cracks, nearby slide in same situation, newly-diverted drainage, high risk of further drainage diversion, etc.)
Possible (Moderate)	Situation that could be a problem but only with a significant (100-yr) event	Past evidence of instability (old tension cracks, long-diverted drainage, etc.)

Description Variables

For each source described, the following are provided:

- type
- cause
- size class
- delivery class

For debris slide source types only, the following are also provided:

- area disturbed (m^2)
- present degree of revegetation (surface %)

Minimum Requirements for Description

Threshold requirements for description were followed as presented in Table 3.9.

Table 3.9. Threshold requirements for sediment-source inventory.

Source Type	First Filter	Second Filter	
Inactive	If Size=Low, no description	If Delivery=Low	Locate
		If Delivery>Low	Describe
Active	If Delivery=Low, no description	If Size=Low	Locate
		If Size>Low	Describe
Potential		If Size=Low	No description
		If Size>Low	Describe

3.2.2 Roads

Many of the haul and spur roads (but not all) were field reviewed during this study. A few other roads were examined using airphoto interpretation. Based on these observations, roads were classified according to their potential for delivering sediment to the stream network. For the three classes of road hazard recognised in this study, Table 3.10 provides typical characteristics. All moderate- and high-hazard designations resulted from ground observations. Most roads were well-vegetated. except for those cases where there are continuing avulsions down road surfaces.

Although not comprehensive, a majority of the significant sediment sources in the study area have been identified. The moderate- and high-hazard road segments shown on Map 1 illustrate where remediation should be focused when developing a watershed rehabilitation strategy.

Table 3.10. Qualitative definitions of road hazard classes in terms of sediment-source observations and general road characteristics.

Hazard Class	Potential Characteristics
Low	• few sediment sources with connection to stream network • no indication of drainage diversions with consequence for sediment yield to stream • dry and rocky, far from streams
Moderate	• small active sediment sources with direct connection to stream or larger sources with partial connectivity • drainage diversions which are likely to result in landslides with partial stream connectivity
High	• larger active sediment sources with high delivery • drainage diversions likely to result in landslides which can reach the creek • steep, gullied terrain; steep road gradient

Note: not all characteristics apply to each road segment in a given hazard class.

3.3 Riparian Assessment

For each reach, riparian hazard is assessed based on channel hazard and floodplain hazard. Observations to determine these hazards were made during field transects and supplemented with airphoto interpretation.

Channel Hazard

Determination of the channel hazard is made based on two component hazards: channel-wood and channel-stability hazards. Each component hazard is determined by examining the channel for three indicators as outlined in Table 3.11.

Table 3.11. Indicators used to determine the channel-hazard components.

Channel Wood	Channel Stability
absence of wood	avulsion channels
abundant small wood	bank erosion
dysfunctional wood	bars

See Anon (1996a) for description of indicators.

For each of these component hazards, if two or more of its indicators are observed to be significant in the channel, the result is High, if only one indicator is observed, the outcome is Moderate (otherwise, the hazard is Low). Observations from the ReCAP (see Appendix A3) are used here. Using the two component hazards, the channel hazard is determined from Figure 3.1.

Figure 3.1. Determination of channel hazard component of the riparian hazard assessment.

		Channel Wood		
		L	**M**	**H**
Channel Stability	**L**	L	L	M
	M	L	M	H
	H	M	H	H

Floodplain Hazard

The floodplain hazard is based on a qualitative judgment of floodplain condition. Determination of this component hazard (Low, Moderate, or High) is based on observation of the following:

- reduced stocking (generally from forest harvest)
- extent of landsliding onto the floodplain
- loss of productivity (generally from road building)

Riparian Hazard (Integration)

The channel and riparian component hazards are combined using the matrix shown in Figure 3.2.

Figure 3.2. Determination of riparian hazard based on floodplain and channel component hazards.

		Floodplain Hazard		
		L	**M**	**H**
Channel Hazard	**L**	L	L	M
	M	L	M	H
	H	M	H	VH

3.4 Reconnaissance Channel Assessment

A hybrid approach to reconnaissance channel assessment was developed by supplementing BC's Channel Assessment Procedure (CAP - Anon. 1995) with additional observations and interpretations. The approach involves three steps: identifying reach breaks, conducting field observations, and carrying out interpretations.

Preliminary reach breaks were established in the office using TRIM maps and airphotos to define homogeneous sections of stream channel. Final stream reaches were recognized in the field by their physical characteristics – including gradient, channel form, riparian vegetation, bed materials, bank materials, confinement, and hillslope-to-channel coupling. In addition, confluences and changes in sediment supply were also utilized as reach breaks.

Field observations included an assessment of channel disturbance according to the indicators and approach provided in the CAP, and additional observations in the form of detailed channel descriptions for selected reaches. All observations were carried out by foot traverse due to poor access to Falls Creek. A significant majority of the channel was traversed – enough that each reach could be characterized as to its level of disturbance. The frequency of disturbance indicators and the detailed descriptions were used to identify the extent of disturbance existing in each reach.

Interpretations followed the CAP, supplemented by other quantitative measurements of channel bed, banks, and riparian areas. Definitions of these other parameters are provided in Appendix 6. These data were interpreted to provide additional objective measures of channel condition. Table 3.12 describes four non-dimensional indices employed to provide further insight into channel stability.

Table 3.12. Indicators and indices for rating stream channel instability.

Indicator	Description	Index
storage capacity	ratio of bankfull width to bankfull depth	w_b/d_b
transport capacity	ratio of surface to subsurface mean bed grain-size	$d_{50,sfc}/d_{50,subsfc}$
bed stability	ratio of bed grain-size to bankfull depth	$d_{90,sfc}/d_b$
confinement	ratio of gully width (at 1 m) to bankfull channel width	w_{1m}/w_b

3.5 Indicator Information, Hazard Interpretations, and Risk Assessment

Selected indicators are calculated for the hydrologic units under study as defined in Table 3.12. Using these indicators and other observations, hazards are determined for each unit. Four hazards are assessed: peak flow, sediment sources, riparian function, and channel stability.

Table 3.12 Definitions of watershed indicators.

Indicator		Definition
ECA – unweighted	%	Equivalent Clearcut Area without a weighting factor
ECA –weighted	%	Equivalent Clearcut Area with areas above the H60 weighted 1.5
Total Road Density	km/km^2	Total density of haul and spur roads
High Hazard Roads	km	Total length of high hazard roads
Moderate Hazard Roads	km	Total length of moderate hazard roads
Roads on Terrain Stability Class IV/V	km/km^2	Density of roads on terrain with Class IV and V stability
Roads on Sediment Yield H/VH	km/km^2	Density of roads on terrain with Class 4 and 5 hazard of waterborne sediment yield
Density of TRIM Stream Crossings	no/km^2	Total density of TRIM stream crossings of haul and spur roads
Number of Landslides	no	Total number of landslides connected to streams
Disturbed Mainstem Channel	km	Total length of moderately- and severely-disturbed mainstem channel.

Hazards are rated in four classes (low, moderate, high, and very high). In addition, the risk is assessed of increasing the current hazards with implementation of the proposed development. The increase or decrease in risk is assessed as none, insignificant, significant, or major.

4.0 ASSESSMENT COMPONENTS

Section 2.4 provides historic disturbance information essential to understanding the assessments in this chapter. Current disturbance is notably in contrast with the lack of natural instabilities as evident on the 1939 airphotos. In this report, three road sections are named. The Main Road extends from the southern boundary with private land to the major confluence in the middle of the watershed. The North Main Road continues directly north from this confluence while the Northwest Road goes up the other major tributary.

4.1 Sediment Source Survey

Note: the terms of the present study did not allow the authors to view these road segments during the spring freshet, somewhat reducing the reliability of observations regarding road-related water diversions. Many landslide sites were observed during field work but are not mentioned in this report - these showed sediment production with no connection to the stream system and with consequence only for site productivity. In addition, there was not sufficient time to field traverse all areas and as a result there may be other sediment sources not inventoried here (particularly in the Northwest sub-basin).

As discussed in section 2.4, many of the sediment sources which are important to current watershed condition occurred during the 1950s as a result of forest development activities. A total of 43 sites where material has been delivered to the mainstem has been described in the sediment-source inventory (see Appendix A2). These sources occurred between 5 and 60 years ago with the majority being created about 40-50 years ago. In addition to these sites, there may be other unidentified past sediment sources, especially in the larger streams of the Northwest sub-basin where field work was less extensive. Debris slides were the most common source type with channel avulsions and erosion gullies also being numerous. Most debris slides were caused by oversteepened fillslopes, drainage diversion/concentration, or both. Most channel avulsions came about as a result of collapsed bridge crossings. Although not as numerous as the debris slides, channel avulsions have provided an important portion of the total input due to their significant contribution per site. As shown on Map 1, the sources are concentrated in the vicinity of the major confluence with a scattered presence along the entire length of the Main Road.

The sediment-source inventory located 34 sites where it is expected that material will be delivered to the Falls Creek mainstem in the near future (i.e. in the next 5-20 years). In most cases and as with those in the past, these sources continue to be a direct result of early forest-development activities. Additional sites may be present, particularly in the roaded area of the Northwest sub-basin. These 34 sites can be summarised according to the five road sections as shown in Table 4.1.

Table 4.1 Summary description of present/future sediment sources according to five road sections.

Road Section	Dominant Causes of Present/Future Sediment Yield
Main Road below 2+172	debris slides from oversteepened fill; further erosion of existing slide paths and headwalls; some drainage concentration
Main Road 2+172 to 3+866	debris slides from oversteepened fill; destabilised tributaries from instream machine travel; additional erosion of existing slides and existing erosion gullies
Main Road 3+866 to 4+600	stream channel avulsions continuing to erode their unstable channels; new channel avulsions
North Main Road 0+200 to 0+800 and 1+485 to 1+620	debris slides from oversteepened fill and drainage diversions; additional erosion on existing slide paths and headwalls
Northwest Main	debris slides and slumps due to drainage diversions and oversteepened fillslopes; erosion from road surfaces and existing slide paths

Given that most of the roads in this watershed are well vegetated (except for the ones which continue to have avulsions down their surfaces), sedimentation concerns relate almost exclusively to point sources.

There is a legacy of past sources in the channel in the form of large sediment wedges. In addition, the unstable channel continues to produce more sediment as it moves laterally. The magnitude of the problem is reflected at Highway 3A. There is an ongoing maintenance problem where Falls Creek enters the highway culvert. The abundant sediment currently in transit in Falls Creek requires a trash rack with regular maintenance throughout the freshet period. Recently, steps were taken to install a new grizzly because the old one was restricting flow and had become hard to clean (Brent Bailey personal communication).

Statistics on the inventoried sediment sources have been summed by road section as presented in Table 4.2. The road sections selected correspond with those presented in Chapter 6 where rehabilitation options are discussed. These compilations provide *crude* estimates of the magnitude of the past sediment delivery to the creek and in comparison with the potential in the near future. These compilations also highlight the expected distribution of future sediment inputs for consideration during rehabilitation planning.

Note: Table 4.2 provides estimates of future sediment input should no rehabilitation action be pursued; no similar estimates can be provided in relation to the rehabilitation options presented in Chapter 6 because required information related to access and machinery remains unavailable. It is, however, reasonable to say that the difference in effectiveness between the machine options would be less than the difference between them and the handwork option. In addition, the large machine option may be able to address better a few situations in comparison with the small machine however, it may also cause greater disturbance to provide access to all locations – as a result, the difference in effectiveness between the two machine options may not be great.

From Table 4.2, it is calculated that a total of 7600 m^3 of sediment was delivered to Falls Creek from the inventoried sources. The same inventory suggests that a further 6600 m^3 (or a further 86%) is yet to be delivered to the creek in the near future from these sources (i.e in the next 5-20 years). Of this total, roughly 19% is expected due to the Main Road below 3+866, one third is expected from the Main Road between 3+866 and 4+600 and the remainder – almost 50% - is expected from the sections of the North Main Road between 0+200 and 0+800 and 1+485 to 1+620.

Table 4.2 also identifies the expected sediment source types by road section. Whereas debris slides will be by far the dominant type in the North Main section, further production due to the many channel avulsions are expected to be the main type in the upper section of the Main Road. Sediment production from the lower sections of the Main Road will involve a variety of types including debris slides, erosion gullies, and further erosion associated with existing slide paths.

4.2 Reconnaissance Channel Assessment

A reconnaissance channel assessment was carried out by Martin Carver in conjunction with terrain mapping done in 1998. The result has been presented earlier in Utzig and Carver (1999). Ten reaches were identified between the Kootenay River and the basin headwaters. Figure 4.1 provides the findings on a longitudinal profile of Falls Creek. The following is a brief summary - further details are provided in Appendix A3.

Logging and road building during the 1940s and 1950s have caused extensive damage to the mainstem and riparian areas of Falls Creek. The results show that 89% of surveyed reaches are moderately or severely aggraded. Collapsed road crossings have caused avulsions creating major new channels on old road beds. In addition, many road-related landslides have deposited directly into the creek. Reaches 8 through 10 are in better condition than the lower reaches – these reaches were not as affected by such disturbance and have recovered somewhat from the riparian logging. In reach 7, evidence of landsliding is common. Below this, reaches 5 and 4 have been destabilized by collapsed road crossings both on the mainstem and on the major headwater tributary (reach 11 in Table A3.1). Channel condition worsens steadily downstream with long sections rated as severely aggraded. Prominent in the channel are frequent debris jams retaining massive sediment wedges of up to 500 m^3. A large majority of the bed is active annually and elevated bars occur throughout reaches 1 through 7. (Typically 80% of the bed was observed to be annually mobile – see Appendix A5 of Utzig and Carver (1999) for the detailed data.) Avulsions are common in reaches 3 and 4. Long-term wood recruitment has been impaired by the widespread removal of riparian vegetation. As a result, wood is rarely present in the channel and almost never functioning.

There are some limited signs of recovery. Pools exist especially in the upper reaches however they are limited in extent presumably due to annual infilling during the freshet. The large boulders are typically stable and provide important anchoring to the bed.

Table 4.2 Crude estimates of past/upcoming sediment delivery to Falls Creek from hillslopes sediment sources.

Road Section	Sediment Delivery to Falls Creek due to Inventoried Sources					
	Already Occurred		Yet To Occur in Near Future			
	Amount (m^3)	Source Type	Amount (m^3)	Source Type	% of past production	% of total of the four road sections
Main Bndry to 2+172	2100	debris slides (and erosion gullies)	540	debris slides (some activity from present headwalls)	26	**8**
Main 2+172 to 3+866	350	erosion gullies and debris slides	750	debris slides and erosion gullies	214	**11**
Main 3+866 to 4+600	1470	channel avulsions	2180	channel avulsions and bed instability in "new" channels	148	**33**
North Main 0+200 to 0+800 & 1+485 to 1+620	3700	debris slides	3190	debris slides	86	**48**
Totals	**7620**		**6570**		**86**	100

Note: these totals are computed by using the values at the midpoint of each of the delivery and size classes. These can be considered only very crude due to this rough averaging and to the difficulty of estimating the expected yield for the very-high size classes.

4.3 Riparian Assessment

Riparian hazards are provided in Table 4.3 for each reach.

The channel hazard component is high in most reaches as a result of poor lateral stability and a lack of functional wood. Channel hazard generally declines downstream. The floodplain hazard is moderate in most reaches as a result of reduced forest cover (from 1950s logging) in addition to landsliding. The surface of most roads built in the floodplain have recovered whereas the landslide tracks have only partially revegetated. There is some soil compaction on major skidroads in the riparian zone but based on a few spot checks the compacted areas are not extensive.The continuing legacy of extensive harvest in reaches 4, 5, and 6 in addition to the road-related problems, have resulted in severe floodplain hazards.

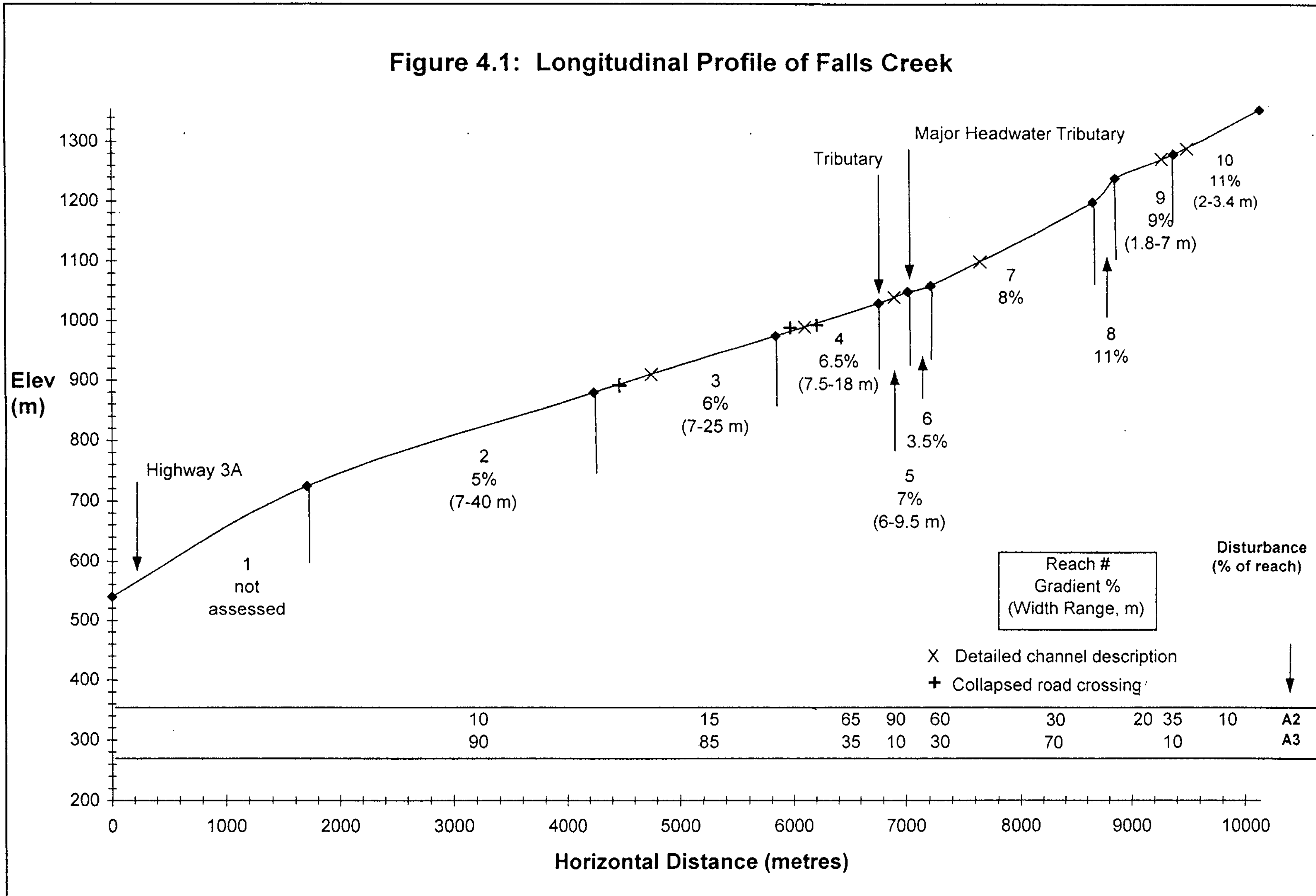
Figure 4.1: Longitudinal Profile of Falls Creek
Elev (m)
Horizontal Distance (metres)
Highway 3A
Tributary
Major Headwater Tributary
1 not assessed
2 5% (7-40 m)
3 6% (7-25 m)
4 6.5% (7.5-18 m)
5 7% (6-9.5 m)
6 3.5%
7 8%
8 11%
9 9% (1.8-7 m)
10 11% (2-3.4 m)
Reach # Gradient % (Width Range, m)
X Detailed channel description
+ Collapsed road crossing
Disturbance (% of reach)
A2
A3
10 90
15 85
65 35
90 10
60 30
30 70
20
35 10
10

Table 4.3. Riparian hazard assessment by reach.

Reach	Channel Hazard			Floodplain Hazard	Overall Riparian Hazard
	Stability	Wood	Overall		
2	H	H	H	L	**M**
3	H	H	H	M	**H**
4	H	H	H	H	**VH**
5	H	H	H	H	**VH**
6	H	H	H	H	**VH**
7	H	H	H	M	**H**
8	M	L-M	M	M	**M**
9	H	H	H	M	**H**
10	M	M	M	M	**M**
11	H	H	H	M	**H**

Reach 1 is outside the study area and was therefore not given a riparian hazard rating.

The overall riparian hazard is very high just above the major confluence and continues high to the base of reach 4, corresponding to the location of most harvest and road-building activity (see section 4.2). The riparian hazard improves somewhat both upstream and downstream of these reaches.

4.4 Peak Flow Assessment

At least two forest fires during the first half of the 20th century followed by forest harvesting resulted in a weighted ECA in 1958 for the entire drainage of over 80% (according to the 1958 airphotos). As summarised in section 2.4, the airphoto record suggests that where the fires left riparian areas unburned, subsequent forest harvest activities of the 1950s removed much of this residual riparian forest, yielding a high 1958 watershed ECA. The watershed continues to recover from this loss of forest cover with an ECA today of 22.2% - refer to Table 5.1. (The precise determination of ECA was difficult due to poor resolution in the Forest Cover polygons, hence the range of possible values indicated by the footnote in Table 5.1.) Many of the burned areas are rocky with slow rates of regeneration.

As discussed in section 4.1, mid-century forest-development activities severely disturbed the channel as a result of massive sediment inputs from landslides and channel avulsions. Evidence of this sediment load can be found throughout most of Reaches 2 through 7 (see section 4.3) and continues to create instability today. As a result, the channel is sensitive to increases in the peak-flow regime: increases can be expected to cause an increased incidence of channel avulsions and likely contribute to maintaining mobile the abundant in-channel sediment supply. Until these deposits are revegetated or in some way stabilised by natural channel processes (perhaps through outright removal), it is expected that increases in peak flow will be problematic. Bed re-mobilisation and the re-formation of sediment wedges can work to recruit new material due to bank erosion and in extreme cases, cause channel avulsions onto the floodplain, thereby prolonging the channel instability.

5.0 INDICATOR RESULTS, HAZARD INTERPRETATIONS, & RISK ASSESSMENT

5.1 Indicator Results and Hazard Interpretations – Existing Condition

Table 5.1 summarizes development indicators for Falls Creek basin under existing and proposed development. Weighted ECA is calculated at 22.2% and would rise to 24.8% with the proposed development. This ECA derives from the residual effects of forest fires in the early-to-mid 1900s and from harvesting in the 1950s and 1960s.

Road indicators are generally moderate-to-high. Total road density is projected to increase from 1.27 to 1.44 km/km^2 with the proposed development. There exist 1.79 km of roads with high sediment delivery hazard and 1.91 km of moderate hazard roads. In addition, there is currently 0.40 km/km^2 of roads on Class IV and V terrain and this is projected to increase to 0.41 km/km^2 with the proposed development.

Table 5.1. Report card for Falls Creek Basin.

Indicator	Units	Existing				Proposed
		North Subwatershed	Northwest Subwatershed	Lower Face Units[1]	Total Watershed	Total Watershed
Area	ha	649.7	998.4	1331.7	2979.8	2979.8
Private Land	%	0	0	2.8	1.2	1.2
ECA[2] – unweighted	%	15.4	20.4	13.6	16.3	18.7
ECA[2] –weighted	%	20.3	29.5	17.5	22.2	24.8
1958 ECA –weighted	%	72	112	76	87	-
Total road density	km/km^2	2.3	1.22	0.81	1.27	1.44
High hazard roads	km	0.75	0.25	0.78	1.79	n/a
Moderate hazard roads	km	0.76	1.91	1.07	3.73	n/a
Roads on Terrain Stability Class IV/V	km/km^2	0.78	0.33	0.28	0.40	0.41
Roads on Sediment Yield H/VH	km/km^2	0.18	0.07	0.18	0.43	0.44
Density of Stream Crossings	no/km^2	1.69	1.20	0.75	1.11	1.21
Number of Landslides	no	7	0	8	15	-
Disturbed Mainstem Channel	km	most	most	all	~all	-

[1] The Residual Area comprises a variety of face units in the southern section of the watershed.
[2] Given the uncertainty resulting from the poor forest-cover typing, these values contain uncertainty of 1-2 % (+/-)

Based on these indicators and on the observations of the channel reconnaissance, hydrologic hazards have been identified as summarized in Table 5.2. Peak Flow, Sediment Sources, and Channel Instability, and Riparian hazards all rate between moderate and high (and locally very-high riparian and channel-stability hazard ratings).

Table 5.2. Falls Creek hazard ratings and main causal factors.

Impact Category	Hazard Index	Main Causal Factors
Sediment Sources	Moderate-High^{+}	channel avulsions onto former roads for 100s of metres (due mostly to collapsed bridge crossings and/or construction of roads on the active floodplain); landslide sediment yield due to drainage diversions and fillslope failures
Peak Flow	Moderate	incomplete recovery from forest fires; forest harvest; roads
Channel Instability	High^{+}	major sediment load remaining in channel including road construction debris; historic yarding up and down the creek; numerous channel avulsions due to collapsed road crossings
Riparian Function	Moderate-High^{+}	severe isolated impacts near major confluence; poor lateral stability; extensive harvest; road construction on and landsliding onto the floodplain

$^{+}$ isolated areas exist of very high hazard

The channel degradation visible today was likely initiated by riparian disturbance associated with haul-road and skid-road construction during the 1950s and associated landslide debris deposited in the stream channel at that time. As discussed in section 2.4, the weighted ECA in 1958 is estimated to have been over 80%. The increased peak flows associated with this high ECA at the time likely magnified the effects of any climatic extremes (high spring runoff, major rain-on-snow events, etc.) during the 1960s and 1970s, and further contributed to the channel instability initiated by the road-related sediment influx.

Although the peak-flow hazard is now rated moderate, the channel is not stable and any changes in peak flow can have a potentially greater effect on the channel than they would under pre-disturbance channel-stability conditions. This existing peak-flow hazard is the result of residual effects of forest fires in the 1930s and 1940s, an extensive road network, and the residual effects of forest harvesting in the 1950s and 1960s.

Although the sediment-source hazard has declined from its extreme rating of 40 years ago, it remains moderate-high today. Point sources and channel avulsions continue to occur as a result of old logging roads. Landslides, particularly from the lower section of the North Main Road, continue to occur, depositing material directly into Falls Creek. Channel avulsions remain a problem both in terms of road-related tributary diversions and mainstem avulsions in the floodplain. Many roads are poorly located (on the floodplain). In some cases, avulsions have resulted in significant new channels that now have stable streambeds. The channel itself contributes to the sediment source hazard as it releases material stored in large sediment wedges in much of reaches 2 through 7.

5.2 Risk Assessment - Proposed Development

5.2.1 Description of Proposed Development

Four Information Blocks have been provided for consideration in this assessment. Details about these blocks are summarised in Table 5.3.

Table 5.3. Characteristics of proposed development (information blocks).

Block Labels		Licensee	Unit	Area	Extent of Harvest	ECA	Associated Road	Potential Concerns
WAP	FDP			ha		ha	m	
A	n/a	SBFEP	North	28.3	40-60% removal	14.2	1859	extensive drainage diversions below block
B	n/a	SBFEP	Residual	46.4	40% removal	18.6	780	block extends below break in slope onto area of high hazard of sediment delivery
C	24-1,2	KLC	Residual	138.4	30% removal	41.5	1106	high erosion potential in 24-1; high sediment delivery hazard in major portions of 24-2

SBFEP – Small Business Forest Enterprise Program KLC – Kalesnikoff Lumber Company Ltd.

5.2.2 Risk Assessment

Table 5.4 provides the level of risk associated with the proposed development by hazard class. (All proposed development is information blocks.) The increase in the risk of peak flows is rated as significant as a result of the increase in weighted ECA to almost 25% in addition to the new road construction. The increase would result in a moderate-to-high hazard rating with the proposed development. Channel stability hazard is high and would increase, but not significantly, with the proposed development. The riparian hazard is moderate-high and would be unchanged with the proposed development because the proposed development is expected to pose no risk to riparian values. The risk for sediment sources associated with the proposed development cannot be known without detailed layout and harvest information.

Table 5.4. Risk due to development proposed for the Falls Creek drainage.

Indicator	Existing Hazard	Proposed Development	
		Associated Risk[2]	Resulting Hazard
Sediment Sources	M-H	unknown[1]	unknown
Peak Flow	M	+	**M-H**
Channel Stability	H	(+)	H
Riparian Function	M-H	o	M-H

[1] Requires field determination.
[2] Associated risk: o – none; (+) – insignificant increase; + – significant increase; ++ – major increase; (-) – insignificant decrease; "-" – significant decrease; "- -" – major decrease

5.2.3 Specific Recommendations Concerning Proposed Development

The following comments are provided in relation to the four blocks and the roads currently under consideration in the Falls Creek watershed. Table 5.3 provided highlights of the main points.

The area below Block A contains drainage diversions which have resulted in erosion gullies and sediment delivery to Falls Creek (see Sediment Source #34). The surface drainage in this area has been heavily modified by skid roads. Therefore, it is recommended (see sections 7.4.2) that this area be field reviewed in the spring to prescribe drainage installations. If Block A were pursued, this field review should also consider the block's potential drainage implications in increasing runoff below the block.

Block B impinges on the steep ground below the break in slope (immediately to the northeast of Falls Creek). It would be preferable to avoid this steep area (due to its very-high hazard of sediment delivery to Falls Creek) by relocating the block boundary above this break in slope. There may also be mitigation opportunities that a Level A Terrain Stability Field Assessment could provide.

Block C (FDP Block 24) contains two parts. The southwest corner of Block 24-1 is very wet and may, at times, flow outside of the Falls watershed and into Smokey Creek. Due to its high erosion potential (both in terms of surface erosion and road/ditchline erosion) and to avoid conflicts in management of the Smokey Creek watershed, it is preferable to reserve this southwest corner. In addition, this sub-irrigated active fluvial fan is an unusual and fragile hydrologic feature which warrants protection. A considerable percentage of Block 24-2 is in Class IV terrain including a large component of very-high sediment delivery hazard. A road is indicated for construction above these areas. A Terrain Stability Field Assessment is required to prescribe mitigative measures which avoid sedimentation of the Falls Creek mainstem. In addition, consideration should be given to reducing the extent of harvest on the Class IV terrain and very-high sediment delivery. Careful planning (or avoidance) of road construction immediately above these and other high-hazard areas is recommended.

5.2.4 Development Opportunities and Limitations

Given the results of this study's assessment, development proposals which possess some or all of the following characteristics are preferred:

- non-riparian areas
- dry areas with limited linkage to stream channel network
- single-tree or group selection (preferably with >70% retention to limit ECA increments)
- winter logging
- harvest below the H60 line (to limit the ECA contribution)
- long forwarding trails
- rocky ridges (road building)

In addition, the Level B terrain mapping should be used to best locate development proposals in order to emphasise terrain outside areas of high and very high hazard of sediment yield and to avoid stream crossings in areas of high and very-high potential of sediment delivery or of landslide-induced stream sedimentation (or of both). Where it is not possible to avoid these areas, Level A Terrain Stability Field Assessments should be carried out to confirm the terrain mapping and prescribe detailed mitigation measures which prevent sediment delivery to the channel network.

Assuming that recovery of the channel is the highest priority and assuming that channel recovery will be the fastest without additional stress due to higher peak flows, it is suggested that an objective of maintaining weighted ECA as low as possible (15-20%) would allow maximum speed of channel recovery. (Under 15%, significant changes to peak flows are not expected. At 20%, changes to peak flows are often measurable.)

In the meantime, it is recommended that rehabilitation work be initiated. As the risks to Falls Creek decline with the completion of hillslope (and riparian) remediation, additional development may be appropriate. Development possibilities can be discussed in light of channel recovery. For instance, with improved access, it may be possible to pursue targeted channel rehabilitation (e.g., the removal of selected sediment wedges if access is sufficient) to speed recovery, thereby facilitating further forest development.

6.0 REHABILITATION OPPORTUNITIES

Potential rehabilitation work in the Falls Creek drainage includes road deactivation, landslide rehabilitation, and channel and riparian restoration. All possibilities are complicated by poor access. The sediment source survey (section 4.1) has shown that road-related sediment sources are the most frequent sediment concern. As a result, road deactivation options are presented in detail in this section. Landslide, channel, and riparian rehabilitation options are reviewed briefly.

6.1 Description of Applicable Rehabilitation Techniques

6.1.1 Road Deactivation

Four approaches to road deactivation are considered in relation to their ability to address the moderate- and high-hazard road sections (including most of the significant sediment sources in the drainage – see section 4.1). The key strengths and weaknesses of each approach are identified as follows:

1) No action

This option leaves recovery to natural processes. Significant surface erosion and landslide activity will continue, particularly on and below the North Main Road.

2) Hand labour/tools

A range of handwork can be used effectively to address sedimentation hazards – e.g., cross-ditch installation, removal of metal/wooden culverts and small bridges, and armouring, control, and diversion of small stream channels. At a few sites, it is likely that handwork would be very time consuming. Brushing would be required in some areas (especially beyond 4+600 on the Main Road) to reduce costly transit times. Handwork would be less efficient at the north end of the drainage where access time by foot would be time consuming even with sufficient brushing. Blasting is a possibility as an adjunct to hand work but it has not been found to be cost effective in nearby, similar drainages.

3) Mini-excavator

A mini-excavator allows for pullback and resloping of landslide headwalls in addition to the placement of larger rock (in comparison to handwork) for control and diversion of channel avulsions. A small Kubota excavator requires a width of only one metre to provide access thereby limiting its disturbance potential. However, mini-excavator access would be slow where the road is washed out leaving a surface of only very coarse rock. Where the road has collapsed, it would be necessary and sufficient to excavate a narrow path. Trail brushing north of Main 3+866 would be required. A mini-excavator was very successfully used in the Queens Bay area (in conjunction with handwork) and resulted in only minimal new disturbance. Access time would be reasonable in the lower-to-middle part of the drainage but would be costly in the northern section.

4) Mid-sized excavator

A mid-sized excavator (John Deere 490 or similar) can accomplish a complete range of work including full pullback of slide headwalls, recontouring of roads, placement of large rock and cleanout or diversion of channels involving movement of large rock. However, there are few locations in the drainage where work of this scale is necessary. An excavator this size could walk over most of the grown-in roads without brushing, leaving pedestrian access essentially unchanged in brushy sections however, in other locations, such an excavator would require that the road be widened thereby slightly increasing pedestrian access. Because this machine is faster than the mini-excavator or hand work the proportion of time spent for foot access by the operator would be less than for other options. In narrow road sections, road widening would be needed – these temporarily excavated road sections could be recontoured on completion of the work. The risk of oil pollution to streams can be avoided through the use of vegetable-based hydraulic oil. Although effective at controlling sediment production in the long term, this method would result in the highest short-term sedimentation increase.

Short-term sedimentation disturbance tends to increase with option number (least for no action; greatest for mini- and mid-sized excavators). Pedestrian access is slightly increased with the use of a mid-sized excavator and slightly more increased with the handwork and mini-excavator options. The cost-benefit ratio and total cost vary in a complex way in relation to the specific nature and location of the sedimentation hazards under consideration. These trade-offs are discussed in detail in section 6.2.

6.1.2 Landslide Rehabilitation

Although there have been many landslides which have been important sediment sources in this drainage, most have now stabilized due to natural recovery. Further slide rehabilitation on most sites would result in only marginal decreases in erosion and sedimentation. One recent large slide (Sediment Source 32 – below the North Main Road) continues to deliver significant amounts of material to the creek by erosion from the slide path in addition to further potential failures at the headwall. Bioengineering techniques could stabilize this slide, however the remote location and lack of available willow would result in a costly project. Helicopter use would not be cost effective. The limited available resources are better spent on road deactivation including the prevention of drainage concentration from the roads upslope of this site (the probable cause of the slide).

6.1.3 Stream Channel Restoration

Falls Creek and its main tributaries are severely aggraded and disturbed, with bank erosion, channel diversions and numerous avulsions occurring over much of the creek length. The creek could be effectively stabilized by stream channel rehabilitation work only with a comprehensive and expensive programme such as could be done using a 'spider' excavator: to reduce channel avulsions, to armour banks, to dismantle woody debris jams, to place woody debris, etc. Sites were not identified where targeted work (using a conventional excavator or using bio-rehabilitation techniques) is likely to make a significant, cost effective, long-term difference in the stability of the main creek channel. There are several locations where there have been major avulsions of the creek down roads where work is warranted to contain the creek in the new avulsion channel or divert stream flow back to the main channel. These sites (Sediment Sources 16 through 22) are addressed in the road-deactivation options outlined in section 6.2 ("Main Road 3+866 to 4+600"). Highly-tergeted restoration possibilities may be warranted once the hillslope and avulsion issues are addressed (see section 7.3).

6.1.4 Riparian Restoration

The extensive disturbance of the riparian zone has been described in section 4.3. In many reaches, most conifers have been removed contributing to frequent channel avulsions and an almost complete lack of functional wood in the channel. The riparian zone has revegetated extensively with brush and deciduous tree species. Brush control is unlikely to be effective because the conditions for continued brush growth are ideal. It may be possible to interplant shade tolerant conifer species in the brushed areas to help speed the return to a natural forest succession thereby also providing a long-term source of woody debris to the channel. Major interventions to stabilize the riparian – e.g., the placement of large woody debris - are possible but are not feasible.

6.2 Consideration of Road-Deactivation Techniques by Road Section

The road-deactivation techniques described in section 6.1.1 can be compared for the specific hazardous road segments identified in Chapters 4 and 5 of this study. For the Main and North Main Roads respectively, Table 6.1 provides crude relative cost estimates and estimates of residual hazards of applying each technique. Estimates for the Northwest Main Road are not included as there was not the time in this study to carry out sufficient reconnaissance review in that area. Deactivation work may be of value on parts of the Northwest Main and its associated spur-road network but this is contingent on decisions about deactivation in other parts of the drainage.

Detailed prescriptions and work cost estimates are provided in Appendix A4 for deactivation of the first section of the Main Road (from the Crown boundary with Lot 8053 to 2+172 on Main Road). The prescription illustrates the typical kinds of structures and work involved if road deactivation were to be carried out in the other parts of the Falls drainage. Crude cost estimates for other deactivation options (outlined in Chapter 7) are shown in Appendix A5.

Table 6.1 Estimated costs and residual risk of deactivation techniques by road section.

Option	Key Benefits	Approximate Cost ($)	Outcome if Implemented: Long-Term Residual Sedimentation Hazard+	Outcome if Implemented: Short-term Sedimentation Hazard+	Pedestrian Access
Main Road: North boundary of private land to 2+172					
The cost estimates for this first road section (only) exclude cost of preparing detailed prescriptions because this has been completed in this study.					
no action	no cost, no change in pedestrian access	N	high hazard of further landslides with sediment delivery to creek at some slide sites; moderate-to-high hazard of future slides because of drainage diversion	N	unchanged
hand tools & labour	minimal disturbance; good drainage control; control of most slide hazards	L	continued high hazard of landslides **(sources a,b,c)** but with low-to-moderate delivery	L	unchanged
mini-excavator	good control of almost all sediment sources	L	low-to-moderate hazard of further (small) landslides at some sites	L	minor increase
mid-sized excavator	good control of almost all sediment sources with maxim mum control of slide sites	L	low hazard of further landslides	M	minor increase
Main Road: 2+172 to 3+866					
no action	no cost, no change in pedestrian access	N	significant drainage diversion and continued sediment delivery at some sites	N	unchanged
hand tools & labour	significant reduction in sediment delivery hazard and drainage diversion	L	low landslide and erosion hazard	L	unchanged
mini-excavator	significant reduction in sediment delivery hazard and drainage diversion	L	low landslide and erosion hazard	L (requires 1-m wide ramps in/out of creek)	minor increase
mid-sized excavator	significant reduction in sediment delivery hazard and drainage diversion	L	low landslide and erosion hazard	L-M (requires 3.5-m wide ramps in/out of creek)	minor increase
Main Road: 3+866 to 4+600					
no action	no cost, no change in pedestrian access	N	significant road erosion and continued channel avulsion especially in the road section from 4+350 to 4+457	N	unchanged
hand tools & labour	effective control of avulsion channels	M	low-to-moderate sediment delivery hazard; cannot dismantle bridge approach and woody debris jam at 4+250 (a minor source)	L	unchanged
mini-excavator	effective control of avulsion channels	M	low sediment delivery hazard; difficult to completely dismantle woody debris at 4+250 (east side) but this is a minor source	L	minor increase
mid-sized excavator	effective control of avulsion channels; allows dismantling of woody debris jam and bridge abutments at 4+250 if needed	M	low sediment delivery hazard	L-M	minor increase
North Main Road: POC to 2+214					
no action	no cost, no change in pedestrian access	N	high hazard of major landslides especially in road section from 0+200 to 0+600 and 1+485 to 1+620.	N	unchanged
hand tools & labour	control of drainage diversions; significant reduction in landslide risk	H	high hazard of further small fill and headwall failures at 0+357 and 0+457; elsewhere low-to-moderate landslide hazard	L	some increase
mini-excavator	good control of drainage diversions; significant reduction in landslide risk	M-H	low-to-moderate landslide hazard	L	some increase
mid-sized excavator	good control of drainage diversions; significant reduction in landslide risk	M	low-to-moderate landslide hazard	L-M (road widening required at several locations)	minor increase (higher if widened road sections are not recontoured upon completion of work)

+ In this table, hazard provides the "relative measure of expected occurrence." N – None L – Low M – Moderate H – High
Costs: Low <$2500; Moderate $2500-5000; High >$5000.

7.0 RISK-REDUCTION STRATEGIES & RECOMMENDATIONS

Chapter 5 identified significant existing hazards in all assessed categories. This chapter outlines strategies for reducing the risks associated with these hazards using the detailed discussion of rehabilitation options presented in Chapter 6. Comments are provided concerning the proposed and other potential forest development. Recommendations are provided.

7.1 Overview

The assessments and interpretations in chapters 4 and 5 reveal hazards ranging from hillslope sediment source issues through riparian and channel concerns. The spatial layout of the specific sites of concern and the variable degree of access present challenges in defining a best course of action. Hillslope issues should, in general, be addressed in advance of channel concerns so that investments in the channel are not undermined by further sediment delivery. In addition, budgets remain undefined and will have a large effect on what course of action is preferred. As a result, a variety of rehabilitation options is presented so that the Watershed Assessment Committee may determine which approach best suits the situation.

In general, the strategy of rehabilitation presented here is consistent with the following order of activities:

1. Address readily accessible sediment sources (including stream channel avulsions) to limit additional inputs to the channel system.
2. Consider other (less accessible) high-priority sediment sources in relation to available funding.
3. Examine and monitor channel once hillslope issues are addressed.
4. Initiate long-term riparian restoration – e.g., tree planting in selected areas.

In a longer-term framework, channel rehabilitation may be justified. In the future, improved access may become available in addition to a more stable regime of sediment generation. These factors will help to improve the benefit-cost ratio of channel rehabilitation. When this will occur cannot be known at present and suggests a role for monitoring.

Note on Use of Mid-Sized Excavator

Given the unavoidably crude nature of the costing, the lack of detailed prescriptions for some of the areas, and the concern expressed by some water users about the use of large equipment, the "mid-sized excavator" technique is not pursued further in the discussion of options/costs provided in section 7.2. This technique is likely to be slightly less expensive than the mini-excavator because the brushing costs would be less. However, short-term sedimentation is expected to be higher. Once complete prescriptions are available, detailed cost estimates can be developed for the mid-sized excavator technique. At present, depending on the perspectives present within the Watershed Assessment Committee, it may be appropriate to continue to build this technique into the options.

7.2 Risk Reduction: Sediment Sources

Road deactivation (including the prevention of further channel avulsions *onto* roads) and landslide rehabilitation address the large majority of sediment-source concerns. A few other sites are discussed separately in section 7.2.3.

The relative effectiveness of each technique in dealing with the sediment sources varies somewhat in relation to the location of the site under consideration. (See Table 4.2 for crude estimates of what may yet be delivered to Falls Creek.) In addition, the large-machine option may be able to address better a few situations in comparison with the small machine however, it may also cause greater disturbance to provide access to all locations. Overall, it is expected that the difference in effectiveness between the two machine options may not be great. It is also reasonable to say that the difference in effectiveness between the machine options would be less than the difference between them and the handwork option.

Note: In the following discussion, the sections of the North Main Road from 0+200 to 0+800 and from 1+485 to 1+620 are described as very-high hazard to distinguish their importance. They appear as high hazard road sections on Map 1.

7.2.1 Road Deactivation

It is suggested that most of the low-hazard road sections should not be deactivated because the reduction in sediment production would not justify the deactivation cost. Where machine access over low-hazard sections is required to get to higher-hazard sections, limited deactivation work to control drainage diversion is warranted.

For the road sections of moderate, high, and very-high hazard, four options are considered, each having a different level of intervention:

1. Do no road deactivation.
2. Deactivate all moderate, high and very-high hazard road sections regardless of access cost.
3. Deactivate only very-high hazard road sections.
4. Deactivate all moderate and high hazard sections for which there is relatively low cost access; deactivate all very-high hazard road sections.

Note that options 2 through 4 could include deactivation of selected low-hazard sections which must be crossed to gain access. Option 3 includes deactivation of various segments of road to gain access.

Discussion of Options in Terms of Residual Sedimentation Hazard

Option 1 is likely to result in large landslides due to the very-high hazard road sections in addition to continued significant sediment delivery from the moderate- and high-hazard road sections. If this option were chosen, there would be slow natural stabilization of present and future slide and erosion sites with channel recovery over a period of 50-100 years.

Option 2 would result in the least risk of sedimentation but is unlikely to be financially feasible.

Option 3 would result in a significant reduction in landslide hazard in the very-high hazard road sections with a good economy in sediment reduction. Access across the moderate- and high-hazard road sections could be accomplished at relatively low cost, as necessary.

Option 4 would result in the largest reduction in sedimentation risk at costs that are likely to be economically feasible. The moderate- and high-hazard sections (additional to option 3) could be addressed with little extra funding because many of the access-related costs would already be incurred.

It is assumed that options 3 or 4 are the most likely to be implemented. To help evaluate the implications of these two options, their components are priorised by road section according to their costs/benefits in relation to sediment source control.

Rating of Components within Options 3 and 4

<u>1. Very High priority</u>

<u>a.</u> *Deactivate the North Main Road from 0+200 to 1+620*

This work requires preparation of deactivation prescriptions. This deactivation can be done in isolation using hand work only. It could also be done as part of a larger programme in combination with hand and mini-excavator work on the Main Road.

<u>2. High Priority</u>

<u>a.</u> *Deactivate the Main road up to 2+172 using a mini-excavator or hand work.*

This work can be done at a low cost because the road is already brushed and a prescription for deactivation using a mini-excavator is complete.

3. <u>Moderate Priority</u>

a. Deactivate the Main Road from 2+172 to 4+660 using a combination of hand work and mini-excavator.

This work requires preparation of deactivation prescriptions.

b. Carry out a ground reconnaissance review of hazards on the Northwest Main road.

Costs and Evaluation

Appendix A5 presents crude preliminary cost estimates for each of these four priority actions using the hand-work and mini-excavator approaches. Consistent with above comments (section 7.1), the mid-sized excavator costs are not shown (and the no-action approach clearly has zero cost). The Watershed Assessment Committee can consider these costs and other factors (pedestrian access, etc.), as appropriate, to reach a final determination of the work to be completed.

7.2.2 Landslide Rehabilitation

Difficult access to most landslide sites and lack of local willow sources make extensive landslide rehabilitation work prohibitively costly. Most landslides have revegetated naturally and this process should continue so long as the slide sites remain stable. However, it is prudent and feasible to hand seed (grass/legume mix) selected landslide paths (and run-out zones) which continue to be active sediment sources. These include Sediment Sources 23, 24, 26, and 33.

Given the current access and as discussed in section 6.1.2, it is not feasible at this time to consider more detailed landslide-rehabilitation work (*e.g.*, stabilisation of scarp at Sediment Source 32.)

7.2.3 Rehabilitation of Other Sediment Sources

During the course of field work, remediation options were noted where they appeared straightforward. The ones not included in Appendix A4 are provided separately in Appendix A6.

7.3 Other Risk-Reduction Opportunities

Once the hillslope sediment inputs to the channel have been stabilised, further risk-reduction opportunities may be available in the channel and floodplain areas. It should be emphasised, however, that these potential actions would be costly – at this point, an estimate cannot be made of their success until the hillslope issues have been addressed.

Selective excavation of sediment wedges would be the most useful channel intervention. Unfortunately, this action would be costly and dependent on sufficient access at propitious locations. Until the access opportunities are clearly known, it is difficult to confidently identify the likely benefits of such an intervention because it depends entirely on the mobility/accessibility of the sediment wedges chosen. If this option were pursued, it would be necessary to walk the channel to identify candidate locations (knowing the budget constraints) noting the following:

- the access availability resulting from the hillslope rehabilitation
- sediment wedge characteristics (especially their amount and mobility)
- sediment wedge locations (especially their integration into the channel)

Although it could be expensive, if good sites are found then there could be gains for downstream users in the longer-term (ie, for water users and for the Ministry of Transportation and Highways both of whom may incur lower maintenance costs) in addition to a faster return to improved channel stability.

It may also be warranted to address stringers on some collapsed bridge crossings.

Riparian rehabilitation could take the form of targeted planting at channel margins. In the long-term, interplanting of shade tolerant conifers (cedar, spruce, hemlock) would be helpful to re-establish the supply of large woody debris which has been reduced by the interruption of the natural stand succession.

Ultimately, this will be required by the channel for maintaining long-term channel stability. Costs for these measures will be highly variable depending on ease of access.

In the long-term, improved monitoring of both channel condition (especially its lateral and vertical stability) and water quality would be helpful in evaluating the success and advisability of any further interventions.

Note that there is little that can be done to reduce the risk associated with the peak flow hazard (except maintaining a low ECA). Road deactivation may be helpful in reducing the peak flow hazard, however its significance depends on both the extent and location of such interventions.

7.4 Recommendations

7.4.1 Risk Reduction

1) Choose one of options 3 or 4 with detailed implementation dependent on discussion of concerns by the Watershed Assessment Committee.

2) Deal with other described sites that are significant sediment producers and can be accessed in the context of Options 3 and 4 and available budget.

3) Carry out a ground reconnaissance of the moderate and high hazard road sections off the Northwest Main Road (see "moderate priority 3b" in section 7.2.1).

4) Hand seed exposed materials on stable areas of existing slide paths. Candidates include sites 3, 6, 8, 23, 24, 26, and 33.

5) If new road construction is planned, pursue "best pratices" for road location and construction to minimize the risk posed by new roads. For example:

- avoid locating roads and stream crossings in areas of high and very-high potential of either sediment delivery, or landslide-induced stream sedimentation, or both
- avoid locating roads in riparian areas
- avoid drainage interception and diversion
- minimize soil disturbance & revegetate promptly
- maintain roads or "put-them-to-bed"

6) Consider comprehensive monitoring (and appropriate data analysis) especially in relation to hillslope rehabilitation. For example, detailed assessment (CAP) on selected disturbed reaches - e.g., Reach 2 (deposition) and Reach 4 (transport) - can be used to monitor creek recovery through time. Other approaches such as that employed by Steve Bird can be considered.

7) In the future, consider looking for channel rehabilitation opportunities once the hillslope issues have been addressed. This could include removal of sediment accumulations and old bridges in some locations.

7.4.2 Proposed Development (summarised from 5.2.3 and 5.2.4)

General recommendations regarding future development

Given the extensive damage to the mainstem channel, a precautionary approach is recommended in relation to further development. This would imply harvest management which minimises ECA increases and limits road development, especially in areas with a high or very high hazard of sediment delivery and in areas which will contribute to increased peak flows (e.g., cuts into seepage areas). Once rehabilitation work is implemented and/or as the risks to Falls Creek decline, there should be signs of improvement in the condition of the mainstem.

Development proposals which possess some or all of the following characteristics are preferred:

- non-riparian areas
- dry areas with limited linkage to stream channel network
- single-tree or group selection (preferably with >70% retention to limit ECA increments)
- winter logging
- harvest below the H60 line (to limit the ECA contribution)
- long forwarding trails
- rocky ridges (road building)

In addition, the Level B terrain mapping should be used to best locate development proposals in order to emphasise terrain outside of areas with high and very high hazard of sediment yield and to avoid stream crossings in areas of high and very-high potential of sediment delivery or of landslide-induced stream sedimentation (or of both). Where it is not possible to avoid these areas, Level A Terrain Stability Field Assessments should be carried out to confirm the terrain mapping and prescribe detailed mitigation measures which prevent sediment delivery to the channel network.

Assuming that recovery of the channel is the highest priority and assuming that channel recovery will be the fastest without additional stress due to higher peak flows, it is suggested that an objective of maintaining weighted ECA as low as possible (15-20%) would allow maximum speed of channel recovery. (Under 15%, significant changes to peak flows are not expected. At 20%, changes to peak flows are often measurable.) Additional development may be supported once improved channel stability is observed – for example, when there is a limited amount of "severely disturbed" sections (say less than 25% of each reach).

In the meantime, it is recommended that rehabilitation work be initiated. As the risks to Falls Creek decline and/or with the completion of hillslope (and riparian) remediation, additional development may be appropriate. Development possibilities can be discussed in light of channel recovery. For instance, with improved access, it may be possible to pursue targeted channel rehabilitation (e.g., the removal of selected sediment wedges if access is sufficient) to speed recovery, thereby facilitating further forest development.

Recommendations regarding the proposed development

The following recommendations are provided, consistent with the comments presented in section 5.4:

Block A. Conduct a spring field review to fully map the drainage network between the block and Falls creek and prescribe drainage installations necessary to stabilize the drainage network below this block. This field review should also consider the block's potential to increase runoff..

Block B. Relocate the block boundary above the break in slope. Consider a Level A Terrain Stability Field Assessment to prescribe measures to avoid mainstem sedimentation.

Block C (24-1). Reserve the wet southwest corner where the potential for surface erosion and drainage interception/diversion is high.

Block C (24-2). Conduct a Terrain Stability Field Assessment to prescribe mitigative measures which avoid sedimentation of the Falls Creek mainstem. Consider reducing the extent of harvest on the Class IV terrain and very-high sediment delivery. Carefully plan (or avoid) road construction immediately above these and other high-hazard areas.

8.0 REFERENCES

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Respectfully submitted, (July 31, 2000)

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APPENDIX A1. LICENSED WATER SOURCES

Table A1.1 Water license information for Falls Creek.

Intake Code	Licence No.	Purpose	Quantity	Unit	Licence Status	Process Status	Priority Date	Issue Date
N7	C111411	Irrigation Local Auth	6.25	AF	Current	Not Applicable	19770315	19961026
N7	C111412	Waterworks Local Auth	54750000	GY	Current	Not Applicable	19810716	19961026
S6	C102045	Domestic	500	GD	Current	Not Applicable	19791009	19910827
S6	C110189	Irrigation	3.66	AF	Pending	Apportionment F	19940709	19960326
S6	C113617	Domestic	500	GD	Awaiting Sign	Not Applicable	19720203	0
S6	C102229	Domestic	500	GD	Current	Not Applicable	19720203	19910827
S6	C110190	Domestic	500	GD	Current	Not Applicable	19720203	19960326
S6	C053271	Domestic	1000	GD	Current	Not Applicable	19720203	0
S6	C062518	Domestic	500	GD	Current	Not Applicable	19791009	0
S6	C113613	Domestic	500	GD	Awaiting Sign	Not Applicable	19720203	0
WW	C056943	Irrigation Local Auth	1.875	AF	Current	Not Applicable	19050525	0
WW	C056943	Waterworks Local Auth	182500	GY	Current	Not Applicable	19050525	0
WW	C063097	Storage	2	AF	Current	Not Applicable	19300825	0
WW	C063097	Waterworks (Other)	10000	GD	Current	Not Applicable	19300825	0
X7	C111909	Domestic	500	GD	Current	Not Applicable	19770223	19970210
X7	C111910	Irrigation	3.75	AF	Current	Not Applicable	19730806	19970210
X7	C111918	Domestic	500	GD	Current	Not Applicable	19770530	19970210
X7	C111903	Domestic	1000	GD	Current	Not Applicable	19730816	19970210
X7	C111908	Domestic	500	GD	Current	Not Applicable	19770404	19970210
X7	C111914	Domestic	500	GD	Current	Not Applicable	19730728	19970210
X7	C111914	Irrigation	5	AF	Current	Not Applicable	19730728	19970210
X7	C111917	Domestic	1000	GD	Current	Not Applicable	19770519	19970210
X7	C111917	Irrigation	7	AF	Current	Not Applicable	19770519	19970210
X7	C109436	Domestic	1000	GD	Current	Not Applicable	19730816	19950424
X7	C111919	Domestic	500	GD	Current	Not Applicable	19770223	19970210
X7	C111913	Domestic	1000	GD	Current	Not Applicable	19730806	19970210
X7	C111913	Irrigation	8.75	AF	Current	Not Applicable	19730806	19970210

All licenses appear on Water Rights Map 5301B
All licenses are within the Nelson-Slocan Junction Water Management Precinct

Table A1.1 (continued). Water license information for Falls Creek.

Intake Code	Licence No.	Licensee
N7	C111411	BONNINGTON IMPROVEMENT DISTRICT C/O DAVID TACON RR 1 COMP 14 SITE 12 SOUTH SLOCAN BC V0G2G0
N7	C111412	BONNINGTON IMPROVEMENT DISTRICT C/O DAVID TACON RR 1 COMP 14 SITE 12 SOUTH SLOCAN BC V0G2G0
S6	C102045	ACHSEN MICHEL C SITE 7 COMP 9 RR 1 SOUTH SLOCAN BC V0G2G0
S6	C110189	BARABONOFF CLARENCE & STEVE & PAUL C/O PO BOX 309 ROBSON BC V0G1X0
S6	C113617	BARABONOFF NATALIE SUSAN RR 1 SITE 7 COMP 9 SOUTH SLOCAN BC V0G2G0
S6	C102229	ELLIS ELIZABETH D RR 1 4683 BAINES RD SOUTH SLOCAN BC V0G2G0
S6	C110190	FORSYTH KEVIN F SITE 7 COMP 41 RR 1 SOUTH SLOCAN BC V0G2G0
S6	C053271	HALL THEODORE A & NADJA 1009 OBSERVATORY ST NELSON BC V1L4Z7
S6	C062518	JENSEN KIRK E & COLETTE M RR 1 SITE 7 COMP 13 SOUTH SLOCAN BC V0G2G0
S6	C113613	RONDPRE ETHEL M RR 1 SITE 7 BOX 23 SOUTH SLOCAN BC V0G2G0
WW	C056943	BONNINGTON IMPROVEMENT DISTRICT C/O DAVID TACON RR 1 COMP 14 SITE 12 SOUTH SLOCAN BC V0G2G0
WW	C056943	BONNINGTON IMPROVEMENT DISTRICT C/O DAVID TACON RR 1 COMP 14 SITE 12 SOUTH SLOCAN BC V0G2G0
WW	C063097	WEST KOOTENAY POWER LIMITED PO BOX 130 TRAIL BC V1R4L4
WW	C063097	WEST KOOTENAY POWER LIMITED PO BOX 130 TRAIL BC V1R4L4
X7	C111909	BRONAUGH JOHN M & BIGGIN JUDITH H 712 CARBONATE ST NELSON BC V1L4P8
X7	C111910	FRANSEN THOR N & JUDY V RR 1 SITE 7 COMP 6 SOUTH SLOCAN BC V0G2G0
X7	C111918	FUHR BRUCE W & DEBORAH A RR 1 SITE 6 COMP 18 SOUTH SLOCAN BC V0G2G0
X7	C111903	JENNINGS LINDA J BOX 76 CRESCENT VALLEY BC V0G1H0
X7	C111908	KING JOHN G AND COLLEEN LB RR 1 SITE 6 COMP 1 SOUTH SLOCAN BC V0G2G0
X7	C111914	KING JOHN G AND COLLEEN LB RR 1 SITE 6 COMP 1 SOUTH SLOCAN BC V0G2G0
X7	C111914	KING JOHN G AND COLLEEN LB RR 1 SITE 6 COMP 1 SOUTH SLOCAN BC V0G2G0
X7	C111917	KING JOHN G AND COLLEEN LB RR 1 SITE 6 COMP 1 SOUTH SLOCAN BC V0G2G0
X7	C111917	KING JOHN G AND COLLEEN LB RR 1 SITE 6 COMP 1 SOUTH SLOCAN BC V0G2G0
X7	C109436	MOREAU JOSEPH D P & MARIANNE 625 12 ST COLD LAKE AB T9M1B1
X7	C111919	PHELAN BRIAN J & DEBORAH E RR 1 SITE 7 COMP 46 SOUTH SLOCAN BC V0G2G0
X7	C111913	SWETLISHOFF WILLIAM & OLGA ET AL RR 1 SITE 6 COMP 11 SOUTH SLOCAN BC V0G2G0
X7	C111913	SWETLISHOFF WILLIAM & OLGA ET AL RR 1 SITE 6 COMP 11 SOUTH SLOCAN BC V0G2G0

APPENDIX A2. DETAILED SEDIMENT SOURCE DESCRIPTIONS

This appendix contains three tables. Tables A2.1 and A2.2 describe the sediment sources which continue to have the potential to deliver sediment to the Falls Creek channel. Where any of these sediment sources have delivered material to the channel in the past, these details are provided. Table A2.3 summarises sediment source information for those sources which are not expected to be active at any time in the future.

The following abbreviations are used in these tables:

Types

BD Bed Destabilisation

CA Channel Avulsion

DS Debris Slide

EG Erosion Gully

BE Bank Erosion

HF Headwall Failure

RE Road Erosion

SE Surface Erosion (landslide paths)

SL Slump

Causes

AR Avulsion onto Road

BC Bridge Collapse

CF Cutbank Failure

CB Culvert Blockage

DC Drainage Concentration

DD Drainage Diversion

FF Fillslope Failure

MC Machinery in Channel

NA Natural

SE Seepage

SP Slide Path erosion (existing landslide)

UT Undercut Toe

Table A2.1 Present/Future Sediment Sources – Sources 1 through 17.

No	Observer	Present/Future Sediment Production					Associated Past Production (if applicable)				Debris Slides Only	
		type	cause	conn	size	P/F+	type	cause	conn	size	area (m^2)	% reveg
1	MC	DS	OF/DD	VH	H	F-M						
2	MC	DS	OF/DD/SE	VH	M	F-H						
3	MC	HF/SE	SP	H	H	P	DS	NA	VH	VH	750	60
4	DP			L	M	P	DS	CF	L	M	75	
5	MC	EG	DC	VH	M	P	EG	DC	VH	M		
6	MC	HF	SP	VH	M	P	DS	DD	VH	H	200	65
7	CW	BD	MC	VH	L	P	BD	MC	VH	L		
8	MC	HF	SP	VH	L	P	BE	NA/DD	VH	M	80	50
9	MC	DS	OF/DD/SE	H	H	F-M						
10	MC	EG	DD	VH	M	P	EG	DD/DC/AR	VH	M		
11	CW	BD	MC	VH	L	P	BD	MC	VH	L		
12	MC	DS	OF	VH	H	F-M						
13	MC	DS	OF	H	H	F-M						
14	CW	BD	MC	VH	L	P	BD	MC	VH	L		
15	MC	DS	OF	M	M	F						
16	DP	BD	CA	VH	L	F-M	CA	BC	VH	H		
17	DP	BD/EG	CA	VH	M	P	CA	BC	VH	M		

+ M – moderate likelihood H – High Likelihood Most past sources vary in age between 5 and 60 years old.

Table A2.2 Present/Future Sediment Sources – Sources 18 through 34.

No	Observer	Present/Future Sediment Production					Associated Past Production (if applicable)				Debris Slides Only	
		type	cause	conn	size	P/F*	type	cause	conn	size	area (m^2)	% reveg
18	DP	BD	CA	VH	H	P	CA	BC	VH	H		
19	DP	BD	CA	VH	H	P	CA	BC	VH	H		
20	DP	BD	CA	VH	M	P	CA	BC	VH	M		
21	DP	BD	CA	VH	H	P	CA	BC	VH	H		
22	DP/CW	BE	CA	VH	H	P	CA	BC	VH	H		
23	CW	SE/RE	DD/SE	VH	L	P	DS	OF/DD	VH	L	15	0
24	CW	SE	DD/SE	VH	L	P	DS	OF/DD	VH	L	~18	0
25	CW	EG	DD	VH	L	P	EG	DD	VH	L		
26	CW	SL	FF	VH	L	P	DS	UT/CA	VH	L	6	60
27	CW	DS	OF/SE/DD	H	H	F-H						
28	DP	HF/SE	SP	H	M	F-M	DS	OF	M	VH	1000	98
29	DP	DS	DD/SE/OF	M	H	F-H						
30	DP	DS	OF/DD/SE	M	M	F-H	DS	OF/DD	M	H	300	99
31	DP	DS		M	L	F-M	DS	DD	M	H	900	100
32	MC	DS	DD/OF	VH	VH	F-H	DS	OF/DD/CF	VH	VH	1000	~100
33	MC	SE/HF	DD/SP	VH	H	P	DS/SE	DD	VH	VH	800	0
34	MC	EG	DC	VH	M	F-M	EG	DC	VH	M		

* M – moderate likelihood H – High Likelihood Most past sources vary in age between 5 and 60 years old.

Table A2.3 Past Sediment Sources.

No	Observer	Past Production				Debris Slides Only	
		type	cause	conn	size	area (m^2)	% reveg
1	MC	DS	DD	VH	M	150	90
2	MC	DS	DD/OF	H	H	300	90
3	MC	DS	DD/SE	VH	H	400	100
4	MC	EG	CB/AR	VH	H		
5	MC	EG	DD	VH	H		
6	MC	EG	DD	VH	M		
7	MC	EG	DD/DC	VH	M		
8	CW	DS	DD/SE	M	H	600	70
9	CW	SL	UT	M	H	200	98
10	MC	EG	NA	VH	L		
11	CW	DS	CF/SE	M	M	200	75
12	MC	DS	DD	VH	H	750	100
13	MC	EG	DC	H	H		
14	MC	DS	DC	VH	VH	600	100
15	MC	DS	DC	VH	H	120	100
16	MC	DS	DC	VH	H	480	95
17	MC	DS	DC	VH	H	150	100

Most sources vary in age between 10 and 50 years old.

APPENDIX A3. RECONNAISSANCE CHANNEL ASSESSMENT

The content of this appendix is taken from Utzig and Carver (1999).

A3.1 Overview of Approach

A hybrid approach to reconnaissance channel assessment was developed by supplementing BC's Channel Assessment Procedure (Anonymous 1996) with additional observations and definitions. The approach involves three steps: identifying reach breaks, conducting field observations, and carrying out interpretations.

Reach breaks were established in the office based on the TRIM maps and air photos. Reaches are sections of channel homogeneous in their physical characteristics – these characteristics include gradient, channel form, riparian vegetation, bed materials, bank materials, confinement, and hillslope-to-channel coupling. In addition, confluences and changes in sediment supply can result in reach breaks. Although tentative reach breaks can be defined in advance of field work, they are expected to be substantially revised as a result of field observations.

Field observations included an assessment of channel disturbance according to the indicators provided in the CAP and additional observations in the form of detailed channel descriptions for selected reaches. All observations were carried out by foot traverse due to poor access to Falls Creek. A significant majority of the channel was traversed – enough that each reach could be characterized as to its level of disturbance. The field work was carried out On October 9, October 16 and November 11, 1998. The frequency of disturbance indicators and the detailed descriptions were used to identify the extent of disturbance existing in each reach.

A3.2 Results

Ten reaches were identified between Kootenay River and the basin headwaters. The characteristics of each reach are provided in Table A3.1 along with their disturbance ratings. Figure 4.1 provides this information on a longitudinal profile of Falls Creek. These results show that 89% of surveyed reaches are moderately or severely aggraded. Stable and degraded reaches were not observed. Table A3.2 provides details on the presence/absence of disturbance indicators as recorded in the field. The channel was observed to have very high width-to-depth ratios (10 to 50) indicative of a lack of storage capacity due to aggradation. The stream is expected to have SP_b-w and CP_b-w morphology though functioning wood was almost entirely absent from the channel.

A3.3 Discussion

Logging and road building during the 1960s have caused extensive damage to the mainstem and riparian areas of Falls Creek. Collapsed road crossings have caused avulsions creating major new channels on old road beds. In addition, a number of road-related landslides has deposited directly into the creek. Reaches 8 through 10 are in better condition than the lower reaches – these reaches were not as affected by such disturbance and have recovered somewhat from the riparian logging. In reach 7, evidence of landsliding is common. Below this, reaches 5 and 4 have been destabilized by collapsed road crossings both on the mainstem and on the major headwater tributary (reach 11 in Table 1). Channel condition worsens steadily downstream with long sections rated as A3. Prominent in the channel are frequent debris jams retaining massive sediment wedges of up to 500 m^3. A large majority of the bed is active annually and elevated bars occur throughout reaches 1 through 7. (Typically 80% of the bed was observed to be annually mobile – see Appendix A5 of Utzig and Carver (1999) for the detailed data.) Avulsions are common in reaches 3 and 4. Long-term wood recruitment has been impaired by the widespread removal of riparian vegetation. As a result, wood is rarely present in the channel and almost never functioning.

There are some limited signs of recovery. Pools exist especially in the upper reaches however they are limited in extent presumably due to annual infilling during the freshet. The large boulders are typically stable and provide important anchoring to the bed.

Table A3.1. Summary of reach characteristics and disturbance levels.

Reach	Length, m (slope distance)	Reach Elevation		Gradient, % (min,max)	Width, m (min,max)	Disturbance Rating			Descriptions Available
		lower	upper			A1	A2	A3	
1	1700	540	725	not surveyed					
2	2550	725	880	5 (4,8)	14 (7,40)		10	90	
3	1600	880	975	6 (3,7)	14 (7,25)		15	85	M9
4	800	975	1020	6.5 (5,8)	10 (7.5,18)		65	35	M8
5	300	1020	1040	7 (5,10)	7.5 (6,9.5)		90	10	M6
6	350	1040	1060	3.5	n/a	10	60	30	
7	1450	1060	1200	8(5,11)	3.8 (3,5)		30	70	M3
8	200	1200	1240	11	n/a	80	20		
9	500	1240	1280	9 (8,10)	3.5 (1.8,7)	55	35	10	M2
10	~750	1280	1355	11(10,14)	2.6 (2,3.4)	90	10		M1
11	Trib	1060	1140	9 (6,18)	7 (4.5,10)	20	60	20	M4,M5

See Utzig and Carver (1999) for the detailed channel description data for sites M1 through M9.

Table A3.2. Indicators of disturbance as observed in the field.

Reach	Location	S1	S2	S3	S4	S5	C1	C2	C3	C4	C5	B1	B2	B3	D1	D2	D3
2	0-2450	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓			✓	✓
2	2450-2550																
3	0-400				✓			✓			✓					✓	
3	400-1300	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
3	1300-1600				✓			✓	✓	✓	✓					✓	
4	0-500			✓	✓			✓	✓	✓			✓			✓	✓
4	500-650			✓	✓			✓	✓	✓			✓			✓	
4	650-800			✓	✓		✓	✓	✓	✓			✓			✓	✓
5	M6				✓			✓	✓		✓		✚			✓	
6	0-350				✓		✓	✓	✓	✓	✓	✓				✓	✓
7	0-700(&M3)	✓		✓	✓		✓	✓	✓	✓	✓	✓				✓	
8	0-200			✓				✓					✓				
9	0-500			✓	✓								✓			✓	✓
10	0-150			✓				✓					✓		✓	✓	
11	above Xsing			✓				✚	✚	✓	✓		✓	✓		✓	✓
11	below Xsing				✓				✓	✓	✚	✓	✚			✓	
11	M4(400-500)				✚			✚			✚	✓				✓	

✓ - active indicator; ✚ recovering indicator; locations within a reach begin at bottom of reach

S1	homogeneous bed texture	C1	extensive cascades	B1	abandoned channels
S2	sediment fingers	C2	minimal pool area	B2	eroding banks
S3	sediment wedges	C3	elevated mid-channel bars	B3	avulsions
S4	extensive bars	C4	multiple channels or braids	D1	small woody debris
S5	extensively scoured zones	C5	disturbed stone lines	D2	LWD function
				D3	LWD jams

See Anonymous (1996) for detailed definitions of these disturbance indicators.

APPENDIX A4. ROAD DEACTIVATION PRESCRIPTIONS – FALLS MAIN

NOTE: *The Point of Commencement (POC) used for this table is that used by Kokanee Forest Consulting Ltd. (1998) in their deactivation review. It is at the junction with the trail to the community water intake on Falls Creek. See Map 1. That POC is north of the private/Crown boundary. In order to avoid confusion which might be caused by introducing a new POC for this study (and which would result in two sets of stations for the same locations), all stations and locations used in the present study are tied to the earlier POC. This results in 'negative numbered'" stations in the first portion of the survey from the 'Temp' POC up to the location of the old POC.*

Table A4.1 Road deactivation prescriptions for Falls Main Road.

Station Distance (m)	Prescription Symbol	Sideslope (%, down)	Road Gradient (%)	Recommendations/Comments (and Related Sediment Source # where Applicable[1])	Cost Estimate ($)
Temp POC 0-158				The 'temporary' POC is at the property boundary between Crown and private land	
0-125	X	20		Install crossditch and extend it across the skid road below the main road.	50
0-074	X			Install crossditch	35
POC 0+000					
0+038	X			Install cross ditch; swale in road	35
0+100				Swale in road	
0+110	X			Install crossditch	35
0+122	X				
0+185				Existing water bar	
0+201	X			Install cross ditch	35
0+240				Existing partial waterbar	
0+323				Road to major community water intake on west	
0+332	X	15	+12/-12	Deepen and armour existing cross ditch; build up the berm on south side; ephemeral stream?	50
0+402	X	15		Deepen existing cross ditch; seepage area	35
0+636				Concrete water box	
0+717				North end of road turnaround (limit of vehicle access)	
0+842				*Junction with spur road on east*	
			8-12		

Station Distance (m)	Prescription Symbol	Sideslope (%, down)	Road Gradient (%)	Recommendations/Comments (and Related Sediment Source # where Applicable[1])	Cost Estimate ($)
1+010				*Junction with spur road on west*	
1+079	X	20	9-12	Install cross ditch	35
				Cutbank seepage from 1+079 to 1+097	
1+120				**P1.** Start cleanout (0.5m wide) for a path for miniexcavator (south margin of old debris slide site)	
1+126				End cleanout for excavator path; 6 m total distance	15
1+202			3		
1+243		20-40	3	Install cross ditch on road, 8m long; extend ditch for 15m across the skid road below the main road. Armour fill slope where actively eroding. Ephemeral stream flow.	150
1+287			+16/-7		
1+338	Start PBH	75		**S1.** Start pullback of fill for width of 1-2m to a slope angle of 70% as far down as can be reached with excavator. Headwall of debris slide in fill slope.	
		75-90			
1+361	End PBH		12	**S1.** End pullback heavy; 23 m total distance	207
1+363				**P2.** South margin of fillslope debris slide.	
		60-75			
1+386				**P2.** North margin of slide.	
1+400				**S2.** Old fill slope slumping	
1+459			15-20		
1+550			3-5		
		70-100		Steep fill slope which has revegetated and has been stable. Leave as is, no pullback recommended	
1+579					
1+600				Check for cutbank seepage in May - June. Cross ditch?	

Station Distance (m)	Prescription Symbol	Sideslope (%, down)	Road Gradient (%)	Recommendations/Comments (and Related Sediment Source # where Applicable[1])	Cost Estimate ($)
1+652				**S4.** Recent cutbank debris slide. Seed this slide track.	
1+679				**P3.** North margin of old cutbank and fill slope slide	
1+750	X	25-45	3-5	Install cross ditch; seepage area	35
1+815				East bank of Falls Creek	
1+833				West bank of Falls Creek; eroding streambank, minor resloping required to stabilize cutbank and allow excavator access; seed	10
1+841	X	20-40	2	Install 9m long cross ditch; active spring in bank which is flowing (and eroding) down road to creek	45
1+911				Switchback; short spur road to south.	
2+056				**P4.** A small stream has been diverted down the road from 2+080 to 2+056 where the flow then continues downslope below the road. The section from 2+056 to 2+080 is not a natural channel. Clean out the channel from 2+056 to 2+080 and the road crossing at 2+056 with excavator; armour as needed (supervision required). Downslope below 2+056 the channel is stable.	150
2+072	EOT			End of Prescription Summary	
				Total Cost	922

[1] Sediment sources are differentiated according to:

S - Present/Future Sources (those expected to deliver material to Falls Creek in the near future)

P - Past Sources (those no longer expected to be of concern)

APPENDIX A5. COST SUMMARY OF REHABILITATION OPTIONS 3 AND 4

(see Section 7.2.1)

Table A5.1 Cost summary of rehabilitation options 3 and 4.

Priority	Road Section	Range in Estimated Costs ($)					
		Develop Prescription	Brushing	Hand Work	Small Machine Work	Seeding	Total
1. Very High	North Main 0+200 to 1+620	1500	1500	4000-6000	3000-5500	500	6500-9500
	Comment:	Costs are difficult to estimate until detailed prescriptions are complete and walk in access times are better known (I.e. after completion of brushing and prescriptions). Machine costs would be lower if work on this road section is combined with work on other sections.					
2. High	Main Road POC to 2+172	0	0	800	1500	100	2400
	Comment:	Supervisor to do the required seeding.					
3a. Moderate	Main Road 2+172 to 4+600	1500	300	2000-4000	2000-4000	400	4200-6200
	Comment:	Further brushing is required only if machine work is done. Machine costs are lower if work on this road section is combined with work on the road section from the POC to 2+172.					
3b. Moderate	Northwest Road	1800-3000	0	0	0	0	1800-3000
	Comment:	A more detailed cost estimate should be made after the reconnaissance checks are completed and priorities for the drainage are decided upon by Watershed Assessment Ctee.					

APPENDIX A6. OTHER SEDIMENT SOURCE REHABILITATION OPTIONS

In the course of field work, remediation options were noted for all current sediment sources wherever they were feasible and obvious. Those not already provided elsewhere (e.g., in Appendix A4) are listed below. Sediment sources listed in this table are those which have the potential now or in the near future to deliver sediment to Falls Creek ("Present/Future" on Map 1).

Note: These are not prescriptions. These were requested by Alan Davidson to give insight into the scope of the rehabilitation needed at each current sediment source.

Table A6.1 Other sediment source rehabilitation options.

Sediment Source No.	Location	Potential Rehabilitation Action – May Require Prescription
5	Below Main 2+128	Restore natural drainage at 2+080. If carried out, must also create channel for the flow to cross the road below: no easy solution for the lower road - hand tools may suffice but it may need machinery.
6	Below Main 2+140 (off road below Main)	Remove wooden culvert to restore the natural drainage - to do this, the lower-road crossing needs to be deactivated. Could be difficult with only hand tools; otherwise, could be left to re-armour but would need monitoring.
10	Main 3+335	Correct drainage diversion. Can consider hay bales in the erosion gully to prevent the scour from progressing further upstream.
12	Main 3+410	Pullback oversteepened fill.
13	Main 3+480	Pullback oversteepened fill.
15	Main 3+520	Install cross-ditch.
21	Main 4+457 to 4+530	Build up berm at 4+457 with hand tools to keep water in new active channel (and out of 4+357 to 4+457).
23	Northwest Main	Install cross-ditch with hand tools.
24	Northwest Main	Install cross-ditch with hand tools.
26	Northwest Main	Open up the channel with hand tools where the water comes out of the fill.
27	Northwest Main	Pullback fill and feather the top.
29	North Main 0+357	Install cross ditch; pull fill from outlet.
30	North Main 0+457 to 0+467	Install cross ditch; remove fill.
33	Below North Main 1+580	Fall the trees all around the scarp; address the drainage diversions onto the slide from the North Main Road.
34	North Main 2+260 to 2+540	Conduct assessment in the spring in conjunction with the drainage diversions on the slopes above – use hand tools to construct water bars and cross ditches. (40-65% slopes below)

Most sources which are not included in this table did not exhibit feasible options for rehabilitation.