General Disclaimer

The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the Government of British Columbia of any product or service to the exclusion of any others that may also be suitable. Contents of this report are presented as information only. Funding assistance does not imply endorsement of any statements or information contained herein by the Government of British Columbia. Uniform Resource Locators (URLs), addresses, and contact information contained in this document are current at the time of printing unless otherwise noted.

Disclaimer of Liability

With respect to documents available from this server, neither the Government of British Columbia nor any of their employees, makes any warranty, express or implied, including the warranties of merchantability and fitness for a particular purpose, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

Results of the Interior Watershed Assessment Procedure

for the

WAP CREEK WATERSHED

(Salmon Arm/Vernon Forest Districts)

Prepared for
FEDERATED CO-OPERATIVES LIMITED
Canoe Division

and

RIVERSIDE FOREST PRODUCTS LIMITED
Armstrong Division

By
DOBSON ENGINEERING LTD.
#4, 1960 Springfield Road
Kelowna, BC
V1Y 5V7

June 2000

TABLE OF CONTENTS

TABLES

APPENDICES

Appendix A
Watershed Assessment Committee Members
and Initial Round Table Meeting Minutes

Appendix B
Maps

Appendix C
Hydrometric Data

Appendix D
Watershed Report Cards

Appendix E
Field Photographs

Appendix F
Sediment Source Survey Table

Appendix G
Historic Time Series Analysis

Appendix H
Longitudinal Profiles

FEDERATED CO-OPERATIVES LIMITED
Canoe Division

RIVERSIDE FOREST PRODUCTS LIMITED
Armstrong Division

Results of the Interior Watershed Assessment Procedure

for the

WAP CREEK WATERSHED

1.0 INTRODUCTION

This Interior Watershed Assessment Procedure (IWAP) report for the Wap Creek watershed has been completed for Federated Co-operatives Limited (FCL) and Riverside Forest Products Limited (RFPL). Wap Creek flows west and south into Mabel Lake approximately 30 km east of Enderby, B.C. *[Figure 1]*.

The Watershed Assessment Committee (WAC) for this project included representatives from both FCL and RFPL, BC Environment (BCE), Ministry of Forests (MoF), Department of Fisheries and Oceans (DFO) and members of the Spallumcheen Indian Band *[Appendix A – WAC Members/Minutes]*. Based on an initial round table discussion the watershed was divided into seven sub-basins (Iron, Devil, Un-named, Dale, Derry, Cavanaugh and Backyard Creeks), one residual (Wap residual) downstream of Wap Lake, and one large sub-basin and residual upstream of Wap Lake *[Appendix B - Maps]*. Further division of the large upper sub-basin was made into two distinct basins (Upper Wap and Joss Creeks) and a residual area (residual above Frog Falls). The entire watershed is covered by this assessment. Points of interest located at the mouth on Mabel Lake, at the inlet to Wap Lake and at Frog Falls were used for the project.

The purpose of this report is to:

- Document historic land-use and past forest development practices in the watershed.
- Determine the current watershed condition with respect to past and present land-use practice.
- Review any noted disturbance in the watershed that might explain recent reductions in coho and sockeye salmon stocks.
- Review 2000 to 2005 forest development plans to determine any potential detrimental effects on current watershed conditions.
- Summarize watershed restoration opportunities to improve water quality and/or fish habitat.

FIGURE 1
Location Map for the Wap Creek Watershed (Scale 1:250 000).

2.0 METHOD

This report is based on the *Interior Watershed Assessment Procedure –dated April 1999.* Historic land-use information was gathered through informal interviews with active and retired forestry workers, and local residents familiar with the watershed. Fixed wing overviews were conducted during and immediately following freshet to determine active sediment sources, and develop a field reconnaissance plan. An historical aerial photograph reconstruction of the mainstem channel from Frog Falls to Mabel Lake was completed using 1959, 1984 and 1997 flight lines. Ground reconnaissance was completed of all accessible roads and mainstem stream channels with an emphasis on problem sites identified during the initial overview. GIS analyses for watershed report card calculations were completed by Forsite Consulting Limited and Landmark Forest Management Ltd. A field review in the fall of 1999 was also completed with FCL and RFPL staff, and representatives from DFO and MoF. Representatives from BCE did not attend the fall field review.

3.0 BACKGROUND INFORMATION

3.1 Physical Characteristics

Wap Creek is a fifth order stream at the mouth at Mabel Lake (POI 1) with a watershed area of 35,574 ha. Runoff is dominated by spring snowmelt with peak flows occurring from late May to early July. The H60 line, that estimates the extent of contributing snowpack at peak flow, is located at 1,240 m. Rain-on-snow events do occur in the late spring particularly along the east side of the lower watershed from Derry Creek to Mabel Lake[1]. These events appear to occur as a result of warm moist air moving through the Enderby-Kingfisher valley from the north Okanagan area that is forced up and over the Mabel range leading to strong orographic precipitation. High snowpack depths are realized at upper elevations throughout the watershed[2].

Hydrometric data is not available for Wap Creek. The closest Water Survey of Canada gauge is located on the Eagle River at Malakwa (WSC 08LE024) where the second highest flood on record occurred on July 8, 1999. An above average flood was also recorded in the spring of 1997 *[Appendix C]*. Similar runoff conditions likely existed on Wap Creek based on similar terrain types and elevation. Natural channel disturbance that includes bank erosion, woody debris input from riparian areas and extensive flooding of low-lying areas would normally occur during floods of this magnitude.

The Wap Creek watershed is dominated by a broad "U" shaped glacial valley with lesser-defined tributary basins from Frog Falls to Mabel Lake. Upstream of Frog Falls

[1] Observations based on Dobson Engineering Ltd. field experience.
[2] Based on watershed comments received from FCL and RFPL field staff.

the drainage is well incised with localized kame terrace[3] deposits along the mainstem downstream of the Joss Creek confluence. Much of the watershed was completely overridden to the 2,160 m elevation nearing during the last glaciation. Above this elevation rugged peaks are present to a maximum elevation of approximately 2,750 m.

High-grade metamorphic rocks of the Monashee formation underlie the entire watershed[4]. Small pegmatite intrusions are present in the formation. Stability of the formation appears to be good with gradual weathering to fine sand and silt size sediment and infrequent hillslope failure. Hillslope movements in the watershed appear to be associated mainly with fine textured surficial deposits[5].

A deep valley fill comprised mainly of glacio-fluvial outwash deposits[6] is present from Frog Falls to Mabel Lake. Several terrace levels[7] are visible along the valley margins deposited during periods of higher sediment load and possibly higher stands of Mabel Lake. Alluvial fan deposits from all of the tributary basins downstream of Wap Lake occur on the broad valley flat. Most tributaries show evidence of at least one higher fan deposition level that has been truncated to reach current deposition levels. An extensive sand plain is present on the plateau along the north side of Wap Lake that spans portions of the Backyard Creek sub-basin and the residual above Wap Lake.

At least two large fans are present on the upper Wap Creek system upstream of Wap Lake. The first is located immediately downstream of Frog Falls and the second approximately one kilometre upstream of the falls. From the lower the mainstem channel meanders on a very low gradient alluvial plain with adjacent marsh and wetland complexes to Wap Lake. Downstream of Wap Lake the mainstem has a single thread meandering pattern to the Derry Creek confluence beyond which the channel becomes braided to the mouth at Mabel Lake.

Other surficial materials in the watershed include glacial till and colluvial blankets and veneers covering the majority of lower, middle and upper slopes.

[3] Kame Terrace – Refers to remnant stream beds that formed along a valley wall at an ice margin normally during glacial retreat. A large range of particles are normally found from both talus slope and glacial till transport, sorting and deposition.

[4] Jones, A.G. 1959. Vernon Map Area British Columbia, Geological Survey of Canada, Memoir 296, 186 p.

[5] Based on observed landslide activity in the watershed and an overview of localized surficial materials in and about the slides.

[6] Glacio-fluvial Outwash Deposits– Refers to sediment that is transported and deposited by glacial meltwater into a broad flat plane of fan depending on valley confinement.

[7] Terrace Levels – Refer to elevated benchland features normally adjacent to the active floodplain that represent historic floodplain or outwash levels that have been abandoned through river incision that follows from a reduction in sediment load.

3.2 First Nations Use

A summary of First Nations use in the Wap Creek area was to be provided by Spallumcheen Band members present in the WAC. Unfortunately no summary was available for the draft report. Based on information gathered for other assessments within Spallumcheen Band traditional territory, the Wap Creek watershed may have represented a significant travel corridor between the upper Okanagan and Eagle River valleys. Fisheries resources in the Shuswap River system, including Mabel Lake and Wap Creek were relied upon for food and ceremonial purposes. Information presented at the initial round table meeting indicated that chinook salmon were the target species for members of the Spallumcheen Band. Based on the extensive floodplain through the Wap watershed, access for hunting and gathering would have been good.

3.3 Forest Development History

Forest harvesting began in the Wap Creek watershed in the late 1800s and early 1900s to provide building materials for the Canadian Pacific Railway (CPR). The watershed was accessed by a narrow gauge railway system from Three Valley Lake[8]. Lumber was transported to Munday's millsite at the north-west end of Three Valley Lake where it was loaded onto railcars on the main CPR line. Munday's mill burned in 1913 and was never re-built. The narrow gauge railway in the Wap watershed extended along the lower valley beyond Wap Lake to approximately the upper crossing on the current Wap Forest Service Road (FSR). Red cedar was targeted on the Wap floodplain and on tributary fans. The narrow gauge railway was removed and sold for scrap metal around 1940[9]. Many of the lower valley forest roads have since been constructed on the old rail grades.

A large fire occurred in approximately 1915 that burned the majority of the Wap floodplain from Frog Falls to Dale Creek. The fire extended part way up the west side of the residual above Frog Falls, along the main valley walls and into the lower Cavanaugh and Dale Creek sub-basins. Fires were a regular occurrence in and around the CPR line while wood-fired locomotives were being used (early 1900s).

Early logging also took place on lower Wap Creek accessed via Mabel Lake. Selective harvest of cedar occurred on the floodplain up to at least Derry Creek. Some selective harvesting may have also occurred from Derry Creek to Wap Lake using the rail system and log drives on the Wap mainstem channel. A short section of mainstem channel immediately downstream of Wap Lake was channelized using wood cribbing. It is possible that this reach was used as a log dump from the railway for the drive to Mabel Lake.

[8] Pat Mills, Personal Communication, September 1999.
[9] Gordon Bell, Personal Communication, November 1999.

In the 1950s and early 1960s several other large wildfires occurred in the Backyard sub-basin and residual areas around Wap Lake. Lower watershed timber harvesting from around 1950 to 1980 focused on large cutblocks along the lower Wap mainstem channel, and dispersed smaller blocks in Cavanaugh, Dale, Devil and Un-named Creeks. In the upper watershed, harvesting focused on lower slopes in the residuals above Wap Lake and Frog Falls in addition to lower valley blocks along Upper Wap Creek. A large spruce bark beetle salvage program was undertaken on the plateau in Backyard Creek between 1970 and 1980.

More recent development (post 1980) has moved into middle and upper slope areas throughout the watershed. Large aggregate clearcuts have recently been harvested along the Wap mainstem valley in an effort to minimize road length, and additional proposals are in place with both forest licensees throughout the watershed (Appendix B).

3.4 Other Land-use Activity

Three private hydroelectric power diversions have been built on the mainstem in the residual above Frog Falls. A water license was granted to the Three Valley Gap Motel in 1963 but the diversion structures were not built until 1982[10]. The first structure is located at the top of Frog Falls and second and third structures at approximately 1.5 and 2.5 kilometres upstream of the falls, respectively. Flooding and debris accumulation in the spring of 1997 caused the channel to avulse around the upper structure forming a large side channel through the upper alluvial fan approximately 800 m long. The second structure failed during the same flood and has not been re-commissioned. Annual occurrence of frazzle ice[11] in the fall and flooding in the spring continues to restrict flow through and over the diversions. The lower diversion on Frog Falls has remained in tact since construction.

Other land-use in the watershed includes hunting, fishing, hiking, and all terrain vehicle use. Forest Service Recreation Sites are present on Wap and Caribou Lakes where fishing, camping and picnicking are the primary activities. Sport fishing has been noted as an increasing recreational activity in the watershed.

The Mount Griffin Ecological Reserve covers an area north and east of Wap Lake including portions of the Backyard Creek sub-basin and residual above Wap Lake. A proposal is in place for an additional reserve (Goal 2 Protected Area) paralleling Wap Creek upstream of Wap Lake including the adjacent marshlands to the fan below Frog Falls.

[10] Gordon Bell, Personal Communication, November 1999.

[11] Frazzle Ice – Ice crystals that form and grow within the channel during periods of rapid cooling in the late fall before continuous areas of sheet ice form along the channel.

3.5 Previous Assessments

An Integrated Watershed Restoration Plan (IWRP) was completed in the Derry, Dale, Un-named, Devil and Iron Creek sub-basins in 1997 and 1998 by Wildstone Consulting Ltd. Completed Sediment Source Survey (SSS) and Channel Assessment Procedures (CAP) in the IWRP provided a series of restoration recommendations for both past forest development related and natural disturbances.

Follow-up hydrologic assessment works (Watershed Condition Reports) were commissioned by RFPL in the Dale, Un-named, Devil and Iron Creek sub-basins. The purpose of the work completed by Dobson Engineering Ltd. was to review the completed IWRP report and provide recommendations on priority restoration work and the potential effects of proposed forest development on existing sub-basin conditions. Recommendations for high priority earth works in Upper Dale and Devil Creeks were implemented by RFPL in the fall of 1998. Lower priority restoration sites were deferred based on funding constraints but have been included in this report. Operational upgrading of roads under permit to access proposed development was suggested for several stream crossings in the upper Devil Creek sub-basin.

Portions of the Wap watershed have terrain mapping at Terrain Survey Intensity Levels C and D. Level D mapping covers the lower east side of the watershed including the Derry, Dale, Un-named, Devil and Iron Creek sub-basins. Level C mapping covers all of FCL holdings upstream of Wap Lake. No mapping has been completed for the Backyard sub-basin, Cavanaugh sub-basin or Wap residual area downstream of Wap Lake. Terrain stability information is shown on the project maps in Appendix B.

3.6 Agency and First Nations Concerns

The following points were noted during the initial round table meeting and in follow-up discussions with agency and First Nations representatives *[Appendix A]*.

Department of Fisheries and Oceans (DFO)

Coho and sockeye salmon stocks in Wap Creek have been declining since the late 1970s. Chinook salmon began to utilize the Wap system around 1988 and are increasing in number. The concentration of spawning and rearing habitat for salmon appears to be within 5.0 km upstream and downstream of Wap Lake. Spawning may occur in other watershed areas that are currently unknown to DFO staff. Significant channel disturbance has been noted by DFO in the western portion of the watershed including Cavanaugh Creek, the lower Wap mainstem and fans on Dale and Devil Creeks. The cause of the decline in coho and sockeye escapement is not well known.

A primary DFO concern also relates to the division of the watershed among two forest districts and two forest licensees. This division appears to have lead to fragmented management rather than an integrated watershed approach. An assessment of the entire

watershed was supported by DFO to develop effective forest development plans that are sensitive to fisheries resources.

Spallumcheen Indian Band

Comments received at the initial meeting related to salmon stocks on the Shuswap River system generally and were not specific to Wap Creek. The traditional salmon fishery on the larger Shuswap River system was largely for food and ceremonial purposes, and the focus was on chinook. Salmon spawning and escapement was noted to be declining from historic levels[12].

BC Environment (BCE)

Little information is available on the resident trout fishery but anecdotal reports from anglers suggest a decline in rainbow and bull trout, dolly varden, and kokanee populations. BCE was in agreement with DFO and other WAC members, that an assessment of the entire watershed (as planned with this IWAP) would be useful to both the licensees and agencies in developing future resource management plans.

Ministry of Forests (MoF)

The MoF also supported an integrated watershed assessment. High fisheries values have been realized in the watershed and it is possible that Wap Creek may receive a "sensitive watershed" designation from the Ministry of Forests in 2000.

4.0 ASSESSMENT

The results of the aerial overview, field reconnaissance and historic aerial photograph reconstruction are presented in the following sections. A unique rain-on-snow event was experienced during the initial aerial overview that supported an assumed sensitivity to these types of events along the lower east side of the watershed. Active sediment sources and disturbed channel reaches were easily identified during the event and ensuing flood.

Watershed report card calculations have been completed for 2000, 2005 and 2006 *[Appendix D - Watershed Report Cards]*, and current watershed hazards are discussed with respect to peak flows, surface erosion, riparian function, landslides and channel stability. Terrain related calculations utilized level C and D terrain mapping where available, and where not available slope gradients in excess of 60% were used to indicate areas of potentially unstable terrain. The 2000 report card includes all forest development completed up to and including December 1999. The 2005 report card includes all category A, Forest Development Plan (FDP) and Cutting Permit (CP) approved development. The 2006 report card includes category I (information) blocks that are planned beyond 2005.

[12] Based on direct observations made by members of the Spallumcheen Indian Band.

Watershed hazard ratings have been derived from both office and field assessment procedures in addition to field experience in similar watersheds throughout the province. For this purpose a "hazard" is defined to be a danger of current or future water resource impairment under present watershed conditions and hydrologic function (i.e. climate, runoff and streamflow regimes). The hazard ratings in each category refer to the observed detrimental effects from past forest harvesting and other land-use on the water resource *[Table 1]*.

Table 1
Watershed Hazard Rating Definition

Hazard Rating	Definition
Low	Little to no detectable effect on the water resource.
Moderate	Detectable effect on the water resource that should be considered in restoration and future land-use development planning.
High	Significant detrimental effect on the water resource that requires remediation either through site rehabilitation, or future land-use constraints.

Equivalent clearcut area (ECA) calculations were completed using silviculture opening file information, stocking densities and growth rates developed by biogeoclimatic zone. Green-up heights produced through this process should represent the best possible hydrologic recovery calculations available.

4.1 Peak Flows

Approximately 16.5% of the Wap Creek watershed has been either harvested or burnt in recent history (last 50 years) and the current road density is 0.8 km/km^2. The watershed ECA is 11.6% and the ECA for the watershed above the H60 line is 6.1% *[Table 2][Appendix D]*. Isolated peak flow concerns resulting from wildfire and past forest harvesting were noted in several sub-basins and are discussed in the respective sub-basin hazard descriptions. Peak flows at POI 1 at Mabel Lake have likely been unaffected by forest development to date and are not the current concern in the lower mainstem channel. Localized sediment sources and riparian stability along the lower mainstem are the concerns that are discussed in detail in the channel and riparian hazard section using the historic aerial photograph review. It is unlikely that the effects of forest harvesting in the sub-basins and residual areas of the watershed have manifested themselves in the form of increased peak flows for the following reasons. The broad floodplain and associated lakes, marshes and wetlands that occupy the elongated residual areas from Mabel Lake to Frog Falls provide an effective buffer and dispersal

mechanism for hillslope drainage, flood flows and flooding related sediment. The configuration and location of sub-basins in the watershed also provides for a natural de-synchronization of runoff as peak flows can occur in the lower sub-basins up to weeks before peak flows occur in the Backyard Creek and Frog Falls areas. These characteristics highlight the importance of managing at the sub-basin level regarding runoff and sedimentation, rather than focusing on the mainstem channel. Based on the observed cause of lower mainstem disturbance in the Wap watershed, peak flows levels are not the current concern and the current peak flow hazard rating is considered low *[Table 3]*.

A similar situation exists for the watershed upstream of Wap Lake (POI 2). The broad valley and associated wetlands from Wap Lake to Frog Falls provide an effective buffer to peak flows and sedimentation generated by sub-basin runoff. Past forest harvesting upstream of POI 2 has amounted to 10.4% and the current ECA for the entire drainage area and drainage area above the H60 line is 9.5% and 5.2% respectively *[Table 2]*. The road density upstream of POI 2 is 0.8 km/km^2. Isolated areas with road drainage concerns were noted and are discussed in the context of their respective residual areas or sub-basins. The cumulative effect of these isolated drainage concerns on peak flows at POI 2 is considered negligible. Any mainstem channel disturbance noted upstream of POI 2 appears to be related to sediment loading from landslides and riparian disturbance. Based on the site-specific nature of road drainage concern and characteristics of the drainage upstream of POI 2, the peak flow hazard rating is considered low *[Table 3]*.

There are no low gradient floodplains or marshlands upstream of POI 3 that could effectively buffer flood flows and flood related sedimentation. Hill slopes upstream of POI 3 are directly coupled to the mainstem channel, and the likelihood of sub-basin and other small drainage related disturbances affecting the mainstem channel are considered high. Limited past harvesting has occurred upstream of POI 3 (9.6% of the drainage area), but site specific road drainage concentration and diversion concerns noted in the residual above Frog Falls may be affecting discharge in the mainstem channel. Several road systems have been constructed in this location at various elevations on the slope and drainage in the established gullies has been affected. The diversions appear to be in part responsible for several gully torrents and open slope failures that have occurred. Based on these observations the peak flow hazard rating for the area upstream of POI 3 is considered moderate *[Table 3]* until such time as the road drainage concerns are either remedied, or their effect on discharge is determined to be less important.

In the sub-basins, small increases in peak flow have likely occurred in Devil, Un-named, Dale and Backyard Creeks based on the levels of past harvesting, road densities and/or wildfire effects *[Table 2]*. Stream flows observed during a 1999 spring rain-on-snow event was noticeably higher in Devil, Un-named and Backyard Creeks than that observed in the other lower sub-basins. Flows in Dale Creek appeared to have returned to near natural levels through hydrologic recovery on blocks in the upper sub-basin. Based on this observation the peak flow hazard rating for Dale Creek is considered low

[Table 3]. Road drainage concentration and diversions were observed in Devil and Un-named Creeks, and are considered to be a major contributor to observed increased peak flow impacts. These concerns should be addressed through increased cross-drain frequencies and strategic culvert placement in existing draws along the Iron and Iron Spur 1 roads. There is a current Watershed Restoration Program (WRP) proposal to restore drainage along many of the older spur roads in upper Dale, Un-named and Devil Creeks, which will be beneficial but will not address the Iron and Iron Spur 1 roads. The WRP works and operational drainage upgrading should collectively reduce the peak flow hazards in Devil and Un-named Creek that are currently considered high *[Table 3].* In Backyard Creek, extensive wildfire and beetle salvage efforts, combined with a unique plateau snow accumulation area and limited area below the H60 line, appear to have lead to significant peak flow and sediment/debris related disturbance on the fan. No road related drainage concerns were noted in the Backyard sub-basin. Hydrologic recovery of old burns and cutblocks in Backyard Creek appears to be the only way to reduce peak flows, that are currently considered to be at high hazard levels *[Table 3].*

The remaining sub-basins, Joss, Upper Wap, Derry, Cavanaugh and Iron, showed no evidence of elevated peak flow conditions either in the aerial overview or ground reconnaissance. These sub-basins have low past harvest levels and ECA's both for the entire drainage areas and drainage areas above the H60 elevation *[Table 2].* Road drainage effects on local and sub-basin peak flows appeared minimal and sites were noted where drainage improvement would be required. Based on these observations the peak flow hazard ratings for the Joss, Upper Wap, Derry, Cavanaugh and Iron sub-basins are all considered low *[Table 3].*

4.2 Surface Erosion

During the observed rain-on-snow event in 1999, obvious turbidity was noted in Devil Creek, Dale Creek, the residual above Wap Lake, the residual above Frog Falls, and Upper Wap Creek. The remaining tributaries were flowing relatively clear indicating limited surface erosion concern. A general concern noted throughout the watershed is the practice of ditchline grading on climbing road sections with fine textured soils. In many cases, observed chronic sources of sediment derived from running surface and ditch erosion could be avoided with alternative site-specific maintenance practices.

Devil Creek is the largest source of fine sediment to the lower Wap Creek system. Continual raveling and surface erosion on old bank failures created by a 1980s debris torrent, and the occurrence of new bank failures in 1999, are the main concerns in the sub-basin *[Photo 1 – Appendix E].* Minor surface erosion on the Iron Road system is also a concern that could be addressed with drainage improvements noted in section 4.1. Rehabilitation of the numerous old bank failures along the Devil Creek channel would be very difficult, and may not have a worthwhile effect in reducing sediment load. Natural recovery is occurring where residual soil depth has permitted but the time frame for recovery appears to be approximately 20 years (based on the torrent occurrence in or around 1980 and recovery in upper mainstem locations). Grass seeding efforts on the

recent bank failures located approximately 200 m upstream of the fan could reduce sediment input to the channel over the short term and should be considered based on accessibility. The cause of the recent failures and possible mitigation alternatives to avoid similar events is discussed in section 4.3. Based on the turbidity observed during the aerial overview the surface erosion hazard rating for Devil Creek is high *[Table 3]*. Natural recovery on exposed soils combined with road drainage improvements could reduce this hazard.

Dale Creek was also turbid during the rain-on-snow event but to a lesser degree than Devil Creek. Secondary erosion and raveling is occurring on bank failures that were caused by mainstem debris flows in the late 1970's and early 1990's *[Photo 2]*. Limited re-vegetation has occurred on the failures following the latest debris flow, but no new bank failures were noted. Fill failures from the Bunny road system in the upper sub-basin, that initiated the debris flows, were rehabilitated as much as possible in the fall of 1998. A short section of the Iron Road in the lower sub-basin is delivering fine sediment to the channel via landslide track number 10 *[Appendix A]*. A 2000 WRP proposal is in place for this site to move the road away from the break in slope and pullback over-steepened fill materials. These works should address this sedimentation concern. As in Devil Creek, the numerous bank failures along the mainstem channel will continue to produce fine sediment until natural re-vegetation occurs (potentially 20 years). Based on the level of turbidity observed during the aerial overview, the surface erosion hazard rating for Dale Creek is considered moderate *[Table 3]*. Proposed road works at landslide 10 will have a minor effect in reducing sedimentation, but natural recovery will be the only way to reduce the hazard over the long-term.

In Un-named Creek, minor turbidity was noted originating from a short section of the Iron Road beyond the lower crossing on the mainstem channel *[Appendix B]*. At this location a long uninterrupted ditchline is transporting sediment from the raveling and slumping cutslope beyond the crossing. In this case it appears that several old landslides that occurred below opening 24 may have been caused by ditchflow concentration and diversion into the opening and onto an old landing below the road. Increased culvert frequencies on the Iron Road beyond the cutslope should reduce ditchflow concentration into this area and along the base of the eroding cutslope. The remaining ditchflow may then need to be carried along the entire length of road from the opening to Un-named Creek in order to prevent additional failures below the road. A drainage assessment of this area should be completed to determine a feasible mitigation plan. The observed sediment input at the Iron Road crossing is a concern but is having only a minor effect on local turbidity levels. Flows were clear at the mouth of Un-named Creek during the rain-on-snow event and the current surface erosion hazard rating for the sub-basin is considered low *[Table 3]*.

TABLE 2
Historic Harvest/Burn and Current ECA Levels

Watershed/Sub-basin	Total Area Harvested or Burnt (%)	Current ECA (%)	ECA Above the H60 Line (%)
Wap Watershed (POI 1)	16.5	11.6	6.1
Iron Creek	3.4	3.2	0.0
Devil Creek	28.0	21.4	19.5
Un-named Creek	59.7	36.7	30.3
Dale Creek	23.6	18.5	18.5
Cavanaugh Creek	30.1	17.5	2.8
Derry Creek	4.3	3.7	1.8
Backyard Creek	23.9	21.1	21.0
Wap Creek U/S of Wap Lake (POI 2)	10.4	9.5	5.2
Residual Above Wap Lake	11.5	11.1	6.7
Wap Creek U/S of Frog Falls (POI 3)	9.6	8.2	4.0
Residual Above Frog Falls	26.6	21.6	9.1
Upper Wap Creek	2.4	2.2	0.4
Joss Creek	7.8	7.8	6.8

Turbidity was low during the aerial overview (June 18, 1999) in small tributaries throughout the Wap residual, and Cavanaugh, Derry and Backyard Creeks. No site-specific surface erosion concerns were noted in these areas and all surface erosion hazard ratings for the respective sub-basins are considered low *[Table 3]*.

In the residual above Wap Lake the main source of turbidity to the low gradient mainstem and wetlands is the upper watershed, particularly the Upper Wap mainstem channel. However, there are several sites in the residual above Wap Lake that are contributing fine sediment to the wetland system and could be addressed. Two small tributary channel crossings in the residual were also observed to be initiating localized

turbidity from the erosion of exposed soils. The first site is located on the lower road access to opening 226 on the south slope where landslides 20 and 21 have occurred. Re-contouring of the road was completed at this location in 1997 to prevent additional landslides, and grass is not yet well established *[Photo 3]*. The crossing was constructed in sandy glacial till that is moderately erodable. Follow-up hand seeding of this crossing may reduce sediment input. The second site is a raveling and slumping cutslope on the 9019 road before the crossing on largest northeast tributary channel *[Photo 4]*. In this case fine sediment is being transported by the ditch at the base of the slope and into the channel. Drainage improvements or sediment control use on this site could reduce sediment input. Evidence of annual road flooding and erosion was also noted on two short sections of the Wap FSR between 6.5 and 7.5 km, and 10 and 12 km. The licensees have noted these flooding concerns and new road locations are planned for 2000. The surface erosion concerns in the residual above Wap Lake are considered in the hazard rating for the larger Wap above Wap Lake drainage area.

In the residual above Frog Falls sediment input from old landslide scars and road running surfaces constructed in fine textured surficial materials are the primary surface erosion concerns. Road cut and fillslopes along Branch 4 leading up to and beyond the crossing on Wap Creek are chronic sources of fine sediment *[Appendix B]*. This road has been constructed in fine textured kame terrace material that is highly erodable. Road improvements were made throughout this area in 1998 and 1999 to reduce cutslope slumping and fillslope raveling. Vegetation cover is poor on exposed soils and may need to be enhanced with follow-up grass-seeding or further improvements to cut and fillslope stability. A short section of the 200 Road leading up from the Joss sub-basin is also a source of fine sediment (approximately 2.4 km to 2.6 km)*[Appendix B]*. This road was built in the last two to three years and exposed soils are also not well vegetated. Ditchline grading was observed along this road section that is exacerbating sedimentation concerns. Follow-up seeding of exposed soils and avoidance of ditch grading where possible should reduce sediment input to channels. Secondary erosion of old landslide scars 22 through 28 in the residual is also a concern that will be difficult to address. There may be some risk of future hillslope failures in this area related to road drainage that will need to be addressed prior to any attempts being made to stabilize the landslide scars. If stability can be restored then re-vegetation should be considered where possible. The surface erosion concerns in the residual above Frog Falls are considered in the hazard rating for the larger Wap above Frog Falls drainage.

In the Joss Creek sub-basin, the climbing section of the 200 road from approximately 2.1 km to 2.4 km is also fine textured and eroding *[Appendix B]*. The concerns on this road section are the same as mentioned above and could also be addressed through seeding of exposed soils and avoidance of ditchline grading. Ditchline maintenance may be possible on a site-specific basis at culvert inlets and small cutslope slump areas, rather than widespread disturbance along the entire road length. A second area of concern is the road cut and fills on the 200 road at the Joss Creek crossing. Some upgrading work has been completed in this area but sediment transport to the channel is still occurring. As above, follow-up grass seeding or further improvements to cut and

fillslope stability could reduce sedimentation in this location. Due to the fine textured road materials and observed erosion concerns, the surface erosion hazard rating for the Joss Creek sub-basin is considered moderate *[Table 3]*. Demonstrated success in stabilizing exposed soils could reduce this hazard.

In the Upper Wap sub-basin, observed turbidity is related to bank erosion and riparian disturbance, not road surface erosion. Channel concerns are discussed in section 4.4. Several drainage structures on the old trail along the north side of the sub-basin have failed diverting two tributaries down the running surface. These diversions are old and do not pose surface erosion concerns. Ideally these diversions would be corrected through deactivation or upgrading to access proposed development in the upper basin. Based on these road observations and the cause of turbidity in the upper channel, the surface erosion hazard rating for the Upper Wap sub-basin is considered low *[Table 3]*.

In summary, based on the presence of active sediment sources from Joss Creek to Devil Creek, the surface erosion hazard ratings at all points of interest from Mabel Lake to Frog Falls are considered moderate *[Table 3]*. As discussed in the previous residual and sub-basin sections, site specific rehabilitation and maintenance efforts with demonstrated success in stabilizing exposed soils could reduce these hazards throughout the watershed. The effect of completed works could be easily assessed in future watershed assessments through the use of aerial overviews during spring freshet.

4.3 Landslides

Thirty landslides have occurred in the watershed that were either identified from current aerial photography or field reconnaissance *[Appendix F]*. Twenty-five of the landslides impacted either tributary or mainstem channels, twenty-four of which are related to past forest development. Existing landslides are concentrated in the lower portions of the Derry, Dale, Un-named, Devil and Iron Creek sub-basins, and in the residual above Frog Falls in the upper watershed. Numerous bank failures have also occurred along the Dale and Devil Creek mainstem channels that are associated with debris torrents initiated from upslope road fill failures. Landslides and bank failures have been differentiated on the basis of their cause. Bank failures are caused primarily by stream channel erosion and gully sidewall undercutting, where upslope processes such as drainage concentration and diversion on roads normally cause landslides. Debris torrents and debris flows are included in the landslide count based on their significant watershed impact, and usual origin as open slope or gully sidewall slides that initiate larger events in the recipient channels. Bank failures are normally smaller events and as such are difficult to map. The extent and impact of both landslides and bank failures on the watershed is discussed by sub-basin in the following paragraphs. All landslides noted in the watershed have been mapped and their approximate size noted *[Appendices B and F]*.

All of the landslides in the Iron, Devil, Un-named and Dale sub-basins appear to have been caused by hillslope drainage interception along the Iron, Iron Spur 2 (as defined in the 1997 IWRP) and IceBox Road systems with ditchline diversion onto the steep gully

sidewalls of the mainstem channels. Three of the larger slides initiated debris flows in Dale and Devil Creeks that traveled the length of the mainstem channel terminating on the fans. Both channels were scoured to bedrock during these events and numerous bank failures were caused by the scour along the base of the gully sidewalls *[Photos 1 and 2]*. As noted above, these old bank failures continue to produce fine sediment through secondary erosion, and in the case of Devil Creek continue to occur in some locations. A debris flood on lower Devil Creek was observed in progress during the aerial overview as a result of a two recent bank failure impacts. These recent failures may also be related to drainage along the Iron Road and old trail in openings 23 and 24 and should be investigated. Upslope road concerns were addressed in Dale Creek in the fall of 1998 and the works appear to have reduced the risk of additional debris flows as much as possible. Planned WRP works on the lower Iron Road adjacent to Dale Creek will further reduce the risk of additional bank slumping. Debris flows have not occurred in Iron and Un-named Creeks even through each has been impacted by road drainage diversion related landslides *[Photos 5 and 6]*. Debris flows are likely to occur in these channels if drainage improvements are not made on the Iron, Iron Spur 2 and Ice Box Roads. Based on the observed road drainage concerns in Iron, Devil and Un-named Creeks, and recently completed landslide and road rehabilitation in upper Dale Creek, the landslide hazard ratings in each sub-basin are considered moderate *[Table 3]*. The completion of the above noted road drainage improvements across all of the sub-basins, and demonstrated stability of the deactivated Bunny Spur 2 road in upper Dale Creek could reduce these hazards.

Two road drainage related gully sidewall slides have occurred below the Kingfisher FSR in Cavanaugh Creek. The drainage on the road above the slides appears to have been restored and no residual landslide risks were observed (such as tension cracks or road flooding). No other hillslope stability concerns were noted and the landslide hazard rating in Cavanaugh Creek is considered low *[Table 3]*.

In Derry Creek several bank failures have been initiated by drainage concentration along the Derry FSR *[Photo 7]*. Wood culverts along the road are overloaded and rotting *[Photos 8 and 9]*, and cut and fill slope stability is a concern. Major road failures with subsequent downstream effects are imminent along this road if it is not either upgraded or deactivated. A 2000 WRP plan is in place to improve crossing stability on the Derry FSR up to the Bunny Road, and deactivate the remainder of the road leading into the upper sub-basin. At least one small landslide was also initiated from a switchback on the Bunny Road. Drainage and fillslope stability improvements were made on the Bunny Road in the last two or three years that appear to have reduced the risk of additional slides. Access to the Bunny Road will need to be considered in the deactivation and upgrading plans on the Derry FSR. The mapped landslide that occurred in opening 8 did not impact any channels and is not a concern. Based on the condition of the Derry FSR the landslide hazard rating for Derry Creek is considered high *[Table 3]*. Planned deactivation and drainage upgrading should reduce this hazard.

The majority of the Backyard Creek sub-basin is located on low rolling terrain with moderate slopes in the upper drainage *[Photo 10]*. No hillslope failures or hillslope concerns with existing roads and cutblocks were observed in the sub-basin. The landslide hazard rating in Backyard Creek is low *[Table 3]*.

In the residual above Wap Lake, landslides have occurred in the same areas where active surface erosion was noted. On the lower access to opening 226, road re-contouring appears to have reduced the risk of additional failures *[Photo 3]*. On the 9019 Road, landslide 19 originated in a saturated road fill *[Photo 11]* that has recently been used as a spoil site for road improvements *[Photo 12]*. Drainage improvements on the road appear to have reduced the risk of additional landslides, but the remaining headscarp is still unstable and may continue to ravel or slide. Additional fill deposition at this location has not improved stability and should be transported to a more stable site. Beyond the large northwest tributary crossing on the 9019 Road, a second oversteepened fillslope is present *[Photo 13]*. This site has also been used for road improvement spoils that could fail into the tributary. Relocation of some fill and spoil material could reduce the risk of failure. There are no other landslide concerns in the residual above Wap Lake.

The highest density of landslides in the watershed occurs from Frog Falls to the Joss Creek confluence. A series of fine textured glacio-fluvial terraces are present along the lower slopes and roads have been constructed both within and above these deposits. An old section of Branch 4 that continued upstream beyond the first Wap Creek crossing was abandoned for stability reasons. Landslides 26, 27 and 28 have been in part caused by the construction of this old road along the base of the slope. Much of the old road grade has failed into the channel and little can now be done to improve stability. Several other road systems are present upslope of the slides where drainage concentration into unconditioned gullies is presumed. A review of road drainage upslope of the slides may reveal valuable improvements that could be made to reduce the risk of additional slides. Landslides 22, 23 and 24 all originated from the 100 Road and others upslope that are all located downstream of the Branch 4 crossing. Again, road drainage concentration is suspected on old roads above the 100 Road that should be assessed and improved where required. Old crib works and other organics found in the 100 Road have begun to fail and should also be addressed *[Photo 14]*. Observed cribbing on the 100 Road does not appear to be extensive, so site specific improvements may suffice. Landslide 25 is an area along the Branch 4 road before the Wap Creek crossing where fillslope raveling and slides have impacted the channel. Improvements have been made along this road section and it remains to be seen if further efforts are required. Ongoing observations of this road section and others constructed in fine textured terrace deposits throughout the residual above Frog Falls is required to enable a timely response to potential landslide risks. The landslide hazard rating for this residual is considered in the larger Wap above Frog Falls sub-basin rating.

No landslide occurrences were observed in either the Joss or Upper Wap sub-basins. Numerous avalanche tracks are present in the Upper Wap sub-basin that should not be confused with landslides. Some fillslope raveling was observed on the 200 Road at the

Joss Creek crossing that could be addressed through regular maintenance to prevent surface erosion. Based on observations of overall stability in the upper watershed the landslide hazard ratings for the Joss and Upper Wap sub-basins are considered low.

In summary the effect of the lower watershed slides on the mainstem channel downstream of Wap Lake has been minimal. Two slides that occurred in the Wap residual were natural occurrences that are assumed to be the result of 1960s wildfires on the steep slopes. Slides in the residual above Frog Falls have contributed significant amounts of sediment to the channels in part causing aggradation and infilling from their initial impact point to Wap Lake. Based on the concern for additional landslides in the residual above Frog Falls and the potential impact on sensitive channels downstream to Wap Lake, the landslide hazard ratings for POI's 2 and 3 are considered high. Based on the isolation of major landslide effects on the channels to areas upstream of Wap Lake, the landslide hazard rating for the larger watershed is considered moderate (POI 1) *[Table 3]*. Attention to the above suggestions for reducing landslide risks in the upper and lower watershed could reduce these hazards.

4.4 Channels and Riparian Function

4.4.1 Wap Residual

The lower Wap Creek mainstem channel (reaches A and B) is highly disturbed from sediment loading and past harvesting on the floodplain *[Appendix G – Historic Aerial Photograph Review]*. The lower channel is a gravel bed river that displayed evidence of natural lateral migration and bar development. Following the harvest of opening 203 on the large glacio-fluvial terrace in the mid-1960s, large bank failures were initiated by channel undercutting on the steep terrace slope. Significant volumes of sediment have since been input to the channel from the failures that are approximately 50 m high and cumulatively over 150 m wide *[Photos 15, 16 and 17]*. Riparian regeneration on the old cutblock is unable to protect the toe of the slope and the failures are increasing in size. Downstream of the failures the channel has widened by up to 200% in an attempt to compensate for the increased sediment load. Riparian regeneration has been incapable of maintaining bank stability exacerbating the erosion and widening process. The riparian zone along reaches A and B is currently non-functional *[Photo 18]*. Reaches A and B are considered highly sensitive to further sediment loading. A field review of the area around the bank failures was conducted to determine any feasible restoration strategies. No obvious side channels are present that would be suitable for mainstem diversion around the failures. Protection of the toe of the slope at the base of the failures with re-vegetation of the raveling terrace slopes is therefore the most feasible restoration opportunity. An application for restoration funding has been made under the Watershed Restoration Program (WRP) and Habitat Restoration and Habitat Enhancement Program (HRSEP).

Upstream of the large bank failures the mainstem appears to be transporting or dispersing a sediment wave from late 1950s and early 1960s wildfire disturbance along the main valley and in the Backyard Creek sub-basin *[Appendix G]*. This type of disturbance following large fires is common where runoff becomes "flashy" and the channels are loaded with burnt timber and sediment from bank failures. Reach C remains moderately disturbed with a functioning riparian zone. Recovery should continue as the sediment wave either disperses throughout the active floodplain area or is transported into reaches A and B, but that may take between 10 and 30 years.

Reach D upstream of the Backyard Creek fan was channelized in the early 1900s for what is thought to be a dumping location for log drives to Mabel Lake. This channel is stable with remnant crib walls along much of its length. The riparian zone is functioning.

4.4.2 Iron Creek

The Iron Creek mainstem channel is stable with minor sediment loading from one road related gully sidewall slide into reach I2. Additional slides into the mainstem are a concern from the Ice Box road system if drainage is not improved. The Iron Creek channel has similar characteristics to Devil and Dale Creeks, and is susceptible to debris flows if sediment loading continues. A short section of the fan channel (reach I1) was harvested to the banks with little or no disturbance. All mainstem riparian zones are fully functioning. The current channel and riparian hazard ratings in Iron Creek are low *[Table 3]*.

4.4.3 Devil Creek

A debris flow occurred in the Devil Creek mainstem channel in the late 1970s from a large road fillslope failure into the northern tributary channel. Natural recovery on the slide scar and along the mainstem is occurring but several bank failures along the channel remain active. Woody debris is lacking throughout the channel limiting any ability to trap and store introduced sediment. Two new bank failures occurred in the spring of 1999 that triggered a debris flood in the lower channel *[Photo 1]*. It is likely that peak flows in the channel will remain above normal levels due to past harvesting and road diversions in the upper watershed, and may be in part responsible for the recent failures. Drainage along the Iron Road and trail in openings 23 and 24 may also be connected to the recent failures and remain a concern until follow-up reviews are completed. The Devil Creek mainstem channel is highly disturbed with a non-functioning riparian zone. The current channel and riparian hazard ratings are considered high *[Table 3]*. Recommended road drainage improvements may reduce this hazard.

4.4.4 Un-named Creek

The Un-named mainstem channel has been impacted by several road and cutblock related debris slides along the incised valley walls. These failures appear to be related to drainage interception and diversion from the Iron and Iron Spur 2 roads onto the unconditioned slopes. It is possible that these failures could have been avoided with improved water management. A minor increase in sediment load is visible in the mainstem channel but the system is otherwise un-disturbed. The Un-named channel is identical to Devil and Dale Creeks and debris flows are likely with further sediment loading. The entire mainstem channel is currently considered stable with a functioning riparian zone. The channel and riparian hazard ratings in Un-named Creek are low *[Table 3]*.

4.4.5 Dale Creek

Debris flows have occurred in the late 1970s and early 1990s in Dale Creek that were triggered by road fill failures from a spur on the Bunny Road system. Road deactivation was completed on the spur in the fall of 1998 that appears to have reduced the risk of additional failures as much as possible. The entire Dale Creek mainstem was scoured to bedrock by the flow events leading to numerous bank failures and disturbance on the fan *[Photo 2]*. The majority of coarse sediment and debris was deposited on the fan and did not reach Wap Creek. The entire Dale Creek mainstem channel remains highly disturbed with no instream woody debris to trap sediment. The riparian zone is currently non-functioning but should recover slowly barring additional debris flow occurrence. The channel and riparian hazard ratings for Dale Creek are currently considered high *[Table 3]*, but could be reduced with demonstrated stability of completed deactivation works at the debris flow initiation sites and recommended drainage improvements on the Iron and Iron Spur 2 roads.

4.4.6 Cavanaugh Creek

The channels in the Cavanaugh Creek sub-basin show very limited disturbance from past forest development and BC Hydro right-of-way clearing. The lower channels (reaches C1, C2, C3, C4 and C5) are all stable showing only minor increases in sediment load from upstream disturbance. Windthrow into reach C4 was noted but has not caused major disturbance *[Photo 19]*. Two abandoned bridges were found on reaches C2 and C4 that should be addressed before failure and channel obstruction occurs. Reaches C1 through C5 have functional riparian zones.

Past harvesting in the riparian zone and BC Hydro right-of-way clearing along reach C6 has reduced bank stability and increased erosion *[Photo 20]*. This reach is low gradient and recovering with alder and conifer regeneration in the riparian zone *[Photo 21]*. Reach C6 will remain moderately disturbed with a non-

functioning riparian zone until regeneration has stabilized the banks is capable of providing channel controlling large woody debris (LWD). Channel restoration is not required on reach C6.

Reach C7 has recovered from past harvesting in the riparian zone and is now stable. The riparian zone is considered to be functioning. Several old bridge crossings on tributaries to reach C7 were noted as concerns that will require either upgrading or removal to prevent channel disturbance. Two old crossings are located on the Ohashi Road in opening 42 *[Photo 22]*, and a third crossing is located on a trail system between openings 41 and 43 *[Photo 23]*. These sites should be reviewed to determine appropriate rehabilitation measures.

In summary, mainstem channels in the Cavanaugh Creek sub-basin are in good condition with recovery occurring in harvested riparian areas. Based on limited overall disturbance from past forest development and BC Hydro right-of-way clearing the channel and riparian hazard ratings for Cavanaugh Creek are considered low *[Table 3]*. Old road structure concerns noted above should be addressed to maintain low hazard levels.

4.4.7 Derry Creek

Past harvesting on the Derry Creek fan (reach D1), impact of several road drainage related slides and bank failures into reaches D2 and D3, and past harvesting in the riparian zone along reach D4 has caused minor channel aggradation and bank erosion on the fan. Only one side of the fan channel was harvested to the bank, which has maintained a source of LWD and riparian function to the channel. Increased sediment loads have effectively been dispersed through the fan channel causing only low levels of disturbance. Reaches C2 and C3 are sediment transport channels with low disturbance levels and functioning riparian zones.

Reach C4 is recovering from past riparian harvesting with alder and some conifer regeneration on the banks *[Photo 24]*. This reach remains moderately disturbed with a non-functioning riparian zone. An adequate riparian reserve was left during harvesting in opening number seven along Reach C5, and landslide 15 did not affect any channels *[Photo 25]*. Reach C5 is stable with a functioning riparian zone.

In summary the effects of past forest development on Derry Creek have been minimal to date, and site specific concerns are recovering. There remains a significant concern with respect to the stability of the Derry FSR that could have considerable detrimental effect the channel if failures occur. The current channel and riparian hazard ratings are considered low *[Table 3]*, and road improvements and deactivation on the Derry FSR should be completed to maintain this low hazard condition.

4.4.8 Backyard Creek

The Backyard Creek fan has been recovering from large wildfire disturbance since the earliest available aerial photography (1959)*[Appendix G]*. Much of the upper sub-basin and slopes adjacent to reaches BY1 and BY2 were burned in the late 1950s and early 1960s. Extreme sediment loading from bank failures and woody debris input appears to have occurred in reach BY2 and on the fan following the fires. A large spruce bark beetle salvage effort was also undertaken between the 1970s and mid-1980s. Peak flows in the Backyard sub-basin have likely been above normal for at least 50 years. Recovery on the fan has been slow, and the channel remains moderately disturbed with a non-functioning riparian zone *[Photos 26 and 27]*. Future forest harvesting in this sub-basin will need to consider fan channel stability so as not to delay recovery. Reach BY2 is a steep sediment and debris transport reach that has recovered from past disturbance and now has a functioning riparian zone.

On the plateau, reaches BY3 and BY4, and major tributary channels are stable with little evidence of past disturbance *[Photo 10]*. Complete riparian recovery appears to have occurred following the wildfires and very limited riparian harvesting was done during the 1970s and early 1980s beetle salvage effort. Reach BY5 was not assessed on the ground but no disturbance was noted during the aerial overview or aerial photograph review. Two old tributary channel crossings were observed between openings 22 and 26, and 204 and 206 that were rotting and in need of either removal or replacement. These crossings should be assessed to prevent channel disturbance. All plateau mainstem and major tributaries currently have low disturbance levels and functioning riparian zones.

Based on continued channel stabilty concerns on the Backyard Creek fan the channel and riparian hazard ratings for the sub-basin remain moderate *[Table 3]*. Further fan recovery and green-up on old beetle salvage blocks and burns could reduce these hazards.

4.4.9 Residual Above Wap Lake

The mainstem channel upstream of Wap Lake is low gradient with adjacent marsh and wetland complexes. The channel has been infilled with fine sediment from landslides and private hydroelectric diversion structure disturbance upstream of Frog Falls. Increased bar development is visible throughout Reach E and an avulsion occurred between 1959 and 1984 on the Wap delta building into Wap Lake *[Appendix G]*. Avulsions on these types of deltas are common occurrences but can be exacerbated by sediment loading. The input of fine sediment to Reach E has caused a decline in instream complexity and pool depth, and the observed effects constitute a moderate level of disturbance. The riparian zone along Reach E has remained in tact and functioning.

Reach F is a high energy fan with a moderate level of disturbance from upstream sediment loading *[Appendix G]*. The channel above and below the Wap FSR crossing has straightened and widened in an effort to disperse the sediment load, with a decline in instream LWD and complexity. The riparian zone has remained functional despite increased bank erosion and widening.

4.4.10 Residual Above Frog Falls

Reach G that contains Frog Falls is a relatively stable bedload transport channel with localized disturbance immediately downstream of the second private hydroelectric diversion *[Appendix G]*. The channel is constricted by concrete retaining walls at this location, increasing flow velocity and stream power below structure *[Photo 28]*. The resulting change in stream power has caused localized scour and bank erosion, increasing sediment transport into disturbed reaches E and F *[Photo 29]*. The second diversion is inactive and the license holder has no intention of reactivation[13]. Removal of the structure and re-establishment of the original channel pattern through the diversion site would improve long-term stability.

Reach H is located on an historic fan deposit where a third private hydroelectric diversion was constructed at the apex of the fan *[Photo 30]*. A side or overflow channel is visible to the east of the active channel in the 1959 and 1984 aerial photographs *[Appendix G]*. The centre and east side of the fan, including the riparian area along the side channel was logged between 1984 and 1997. During the spring flood of 1997, a large debris jam formed in the diversion pond causing a major avulsion around the structure and down the side channel[14]. High levels of channel scour and bank erosion occurred in the side channel during the avulsion increasing sediment transport to downstream reaches *[Photo 31]*. Past harvesting on the fan where the new channel became established exacerbated the disturbance resulting from failure of the diversion structure. The mainstem channel below the diversion exhibits similar disturbance to that observed at the second structure *[Photo 32]*. Stream power is increased below the structure and the channel is scoured and eroded. The permit holder for the diversion structure reported annual problems during periods of frazzle ice formation (late fall and early spring) and debris accumulation at the diversion pond. Each occurrence plugs the spillways and intake resulting in flows overtopping the structure. Frazzle ice formation in November 1999 caused the flow to overtop the structure, re-activating the overflow channel. Continual channel disturbance can be expected at and downstream of the third diversion structure. Design improvements or structure removal could reduce channel disturbance and sediment transport to disturbed reaches E and F.

[13] Gordon Bell, Personal Communication, November 1999.
[14] Gordon Bell, Personal Communication, November 1999.

Upstream of the diversions, reach I is a stable boulder and bedrock controlled sediment and debris transport channel. The BC Hydro transmission right-of-way crosses the mainstem channel at a stable location and no obvious disturbance was noted. Reach I was impacted by landslides 22 through 28 that have increased the level of sediment and woody debris transport. Localized woody debris accumulations were noted in the channel but no obvious disturbance has occurred from the landslides. Additional landslides into reach I are concern for the downstream effects of sediment deposition.

4.4.11 Upper Wap Creek

Upstream of the Joss Creek confluence, Wap Creek is a stable sediment and debris transport reach (J). No disturbance was noted from past forest development and the riparian zone is intact and functional. In the mid-sub-basin area, reach K has been moderately disturbed by a sequence of hydrologic events initiated by an old trail crossing between openings 201 and 202. It appears that a debris accumulation at the crossing caused a sediment wedge to form upstream. The accumulation of sediment in the channel subsequently raised local water table levels drowning adjacent riparian vegetation. The old structure released during the spring of 1997 initiating scour, bank erosion and localized aggradation downstream of the crossing *[Photo 33]*. Surficial materials in the local area appear to be composed mainly of compacted glacial till, but some erodable glacio-fluvial outwash material was observed. Much of the riparian vegetation died under elevated water table conditions, reducing its ability to maintain bank stability. The riparian zone along reach I is considered to be non-functioning. A portion of the old bridge remains in place that should be removed, and several sites downstream of the crossing could be restored and protected from further erosion *[Photo 34]*. A proposal for site restoration under the WRP and HRSEP programs has been made for 2000.

The upper mainstem channel (reach L) has not been disturbed by past forest development and has a functional riparian zone. Avalanche tracks are visible throughout the upper sub-basin that indicate annual inputs of slide debris. Some debris jams were observed in the upper reaches that were composed of avalanche material. This type of disturbance is natural and should not be associated with past forest development.

Based on channel disturbance and a section of non-functioning riparian zone in Reach K, the channel and riparian hazard ratings for the Upper Wap sub-basin are considered moderate *[Table 3]*. Successful restoration works on Reach K could reduce these hazards.

4.4.12 Joss Creek

Lower Joss Creek (reach J1) is a steep sediment and debris transport channel with a minor increase in sediment load and debris from sidecast at the 200 Road crossing. The input of sediment and debris has had little effect on the channel locally, but is a concern with respect to downstream channel stability. Additional sediment input from this site could be avoided with regular road observations and maintenance as detailed in section 4.2. Lower Joss Creek currently has a low disturbance level and a functioning riparian zone.

Upper Joss Creek (reach J2) has a low level of disturbance from past forest development. Minor sediment input was observed at an old ford on the access to opening 221 that could be addressed with a small amount of armouring. The riparian zone along reach J2 is in tact and functioning.

Based on the limited amount of past forest development related disturbance, the channel and riparian hazard ratings in Joss Creek are low *[Table 3]*.

4.4.13 Watershed Channel Summary

Based on the direct channel disturbance from past forest development related landslides, riparian harvesting and private hydroelectric diversions, the channel disturbance hazard ratings at each of the POI's are considered high. Efforts to reduce sediment input from identified road, landslide and bank failure sources can reduce these hazards. Restoration efforts should focus on areas that are tributary to or within high value fish streams particularly reaches A and B in the Wap residual, and Reaches E and F in the residual above Wap Lake.

Based on the contribution of non-functioning riparian zones to channel disturbance in the sensitive lower watershed reaches (A and B), the riparian hazard rating for the watershed is considered moderate. Successful restoration of the large bank failures on Reach B could reduce this riparian hazard. Due to lesser channel disturbance associated with non-functioning riparian zones in the watershed upstream of Wap Lake, the riparian hazard ratings at POIs 2 and 3 are both considered low *[Table 3]*.

TABLE 3
2000 Watershed Hazard Ratings for Wap Creek

Watershed/ Sub-basin	HAZARD CATEGORY				
	Peak Flows	Surface Erosion	Landslides	Riparian	Channel Disturbance
Iron Creek	Low	Low	Moderate	Low	Low
Devil Creek	High	High	Moderate	High	High
Un-named Creek	High	Low	Moderate	Low	Low
Dale Creek	Low	Moderate	Moderate	High	High
Cavanaugh Creek	Low	Low	Low	Low	Low
Derry Creek	Low	Low	High	Low	Low
Backyard Creek	High	Low	Low	Moderate	Moderate
Wap Creek U/S of Wap Lake (POI 2)	Low	Moderate	High	Low	High
Wap Creek U/S of Frog Falls (POI 3)	Moderate	Moderate	High	Low	High
Upper Wap Creek	Low	Low	Low	Moderate	Moderate
Joss Creek	Low	Low	Low	Low	Low
Wap Watershed (POI 1)	Low	Moderate	Moderate	Moderate	High

5.0 PROPOSED FOREST DEVELOPMENT

Proposed forest development has been mapped according to planned silviculture system, year of harvest and forest development approval category *[Appendix B]*. All blocks on the current forest development plan (2000 – 2005 FDP) are shown in purple with hatching for those planned with partial cut systems. All proposed roads are shown in red, and category I or "information" blocks are shown in crimson. Watershed report card calculations have been completed for 2005 that include all blocks and roads in the current development plan (2000 – 2005), and 2006 that include category I blocks and their associated roads. Harvest dates for

category I blocks have not been determined at this time, therefore all category I development was simply included in the 2006 calculations for information purposes.

Forest development is planned from 2000 to 2006 for all sub-basins and residual areas in the Wap Creek watershed. In total, planned development amounts to approximately 1,467 ha from 2000 to 2005 (4.1% of the watershed), with an additional 148 ha planned as category I development (0.4% of the watershed)(labeled as 2006 on the watershed maps).

As discussed in the assessment section of this report, future forest development planning and management should focus on sub-basin characteristics and concerns to avoid cumulative effects on the mainstem of Wap Creek. In this context, proposed development is discussed in the following sections with respect to specific sub-basin and residual area concerns. A summary discussion of the potential for cumulative mainstem channel effects at the three points of interest follows the sub-basin discussions. Where possible, comments are provided on the opportunities and constraints for future forest development by sub-basin.

5.1 Iron Creek

Four current FDP and two category I blocks are planned in the Iron Creek sub-basin. Road access to these blocks is planned from both the Ice Box and Iron road systems with three major tributary crossings (as determined from 1:30,000 mapping). The total area proposed for harvest amounts to 171 ha or 13.5% of the drainage area.

Past forest harvesting has been limited in the Iron sub-basin and the channel system was observed to be in good condition. The main concern with proposed development is water management both within blocks and on existing and proposed roads. Bank failures along the steep incised channels of Iron Creek are likely if drainage concentration and diversion occurs during or after road construction and harvesting. Natural hillslope drainage will need to be maintained. One road related failure that illustrates this concern has already occurred on the Ice Box road as a result of infrequent culvert placement (landslide #1). The mainstem channel of Iron Creek is susceptible to debris flows with sediment loading from these types of events, as evidenced by three road related debris flow events in the adjacent drainages of Devil and Dale Creeks. Natural debris flows do not appear to be common occurrences.

If hillslope drainage can be managed to prevent development related bank failures along the channels, there should be no other hydrologic concerns with current FDP or category I development in Iron Creek.

5.2 Devil Creek

Two current FDP blocks are proposed in the Devil Creek sub-basin with a total area of 30.9 ha. The majority of development is planned below the H60 elevation (25.3 ha). One short section of new road will be required to access one block with remaining development accessible from existing roads. 1999 spring runoff was observed to be

high in Devil Creek and very turbid relative to adjacent sub-basins. The turbidity is resulting from secondary erosion on existing bank failures, and the occurrence of a new bank failure in the spring of 1999. Little can be done to stabilize the existing bank failures along the mainstem channel and the effects of planned development on these features will likely be very limited. However, discharge concerns that appear to be related to hillslope drainage concentration and diversion by the Iron Road system could be addressed through planned WRP deactivation in the upper sub-basin, and operational drainage upgrading along the remaining roads required to access development in both Devil and Iron Creeks. These efforts should be focused on restoring natural hillslope drainage and avoiding concentration off of switchbacks onto the steep incised gully walls of the main channels. The maintenance of natural drainage along the proposed road and within the proposed blocks will also be important to prevent further alteration.

The mainstem channel of Devil Creek remains highly disturbed from the 1970s debris flow and ongoing bank failures and surface erosion. Small increases in peak discharge could be a concern in the watershed with harvesting above the H60 line. Development planned from 2000 to 2005 is primarily located below the H60 elevation therefore should not affect peak discharges in Devil Creek. The equivalent clearcut area (ECA) above the H60 elevation will remain constant through hydrologic recovery over the development plan period. Future development planning should be sensitive to channel stability, and additional harvesting above the H60 should be based on observed recovery in the mainstem that can be anticipated with completed road drainage improvement and natural re-vegetation in the riparian zones.

5.3 Un-named Creek

Approximately 60% of the Un-named Creek sub-basin has been harvested since the mid-1960s with no obvious effects on channel stability. Hydrologic recovery on old cutblocks has effectively reduced the ECA for the sub-basin to 36.7%. Planned development includes four blocks with a total area of 44.7 ha or 4.7% of the sub-basin, and no roads. Most of the planned development (28.5 ha) is located below the H60 line where the effects on spring runoff should be minimal. Based on past harvest levels, stream discharge effects from harvesting do not appear to be the concern. However, several bank failures into the mainstem channel have occurred as a result of drainage concentration and diversion on the Iron Road system. Additional failures of this nature, either from road or in block drainage diversions, are the concern in the sub-basin that would likely trigger a debris flow. This concern can be addressed through a drainage review and upgrade on the Iron and Iron Spur 2 roads, and a concerted effort to maintain natural drainage patterns within the proposed blocks both during and after harvesting. Planned WRP deactivation works on the old road systems in the upper watershed will have a positive affect on restoring hillslope drainage, but should not be relied upon to address drainage concerns on the active roads (Iron and Iron Spur 2).

In summary, the effects of planned forest harvesting in the Un-named Creek sub-basin are expected to be negligible if efforts are made to maintain natural drainage within

blocks, and improve drainage on the active Iron and Iron Spur 2 roads. The mainstem and tributary channels of Un-named Creek are stable and do not show any disturbance from past harvesting. The main concern with ongoing development is additional sediment loading from drainage related bank failures that could trigger a debris flow similar to the events in adjacent sub-basins.

5.4 Dale Creek

One cutblock with an area of 11.2 ha is proposed in Dale Creek from 2000 to 2005. Road access is in place for the block. The only concern with planned development is the potential for a bank failure along the channel below the northern falling boundary of the proposed block. Natural hillslope drainage will need to be maintained both during and after harvest to prevent any occurrence. If drainage is maintained, planned development should not affect channel stability or sedimentation levels in Dale Creek.

5.5 Derry Creek

Ten blocks with a total area of 194 ha are proposed in the Derry Creek sub-basin from 2000 to 2005. Limited past harvesting has taken place in Derry Creek and the effects on channel stability and sedimentation levels have been minimal. The main concern in Derry Creek is the stability of the Derry FSR beyond the Bunny Road intersection. This concern is unrelated to proposed development and will be addressed under RFPL's 2000 WRP works.

There should be no detrimental effect on sub-basin hydrology with proposed development under current Forest Practices Code guidelines. As an extra precaution against development related bank failures and sediment input, care should be taken to maintain natural hillslope drainage on all blocks and roads in and around the incised Fennel Creek tributary. This tributary has similar characteristics to Dale, Devil, Un-named and Iron Creeks where the likelihood of debris flow initiation with bank failure impact is high.

5.6 Cavanaugh Creek

Six blocks with a total area of 104 ha are proposed from 2000 to 2005 in the Cavanaugh Creek sub-basin. Five of the six blocks are located below the H60 line on well drained southeast and east facing slopes. Several short spur roads will be required, but the majority of planned development is accessible from existing roads or old trails that will require some upgrading. The condition of the Cavanaugh Creek sub-basin is considered good and planned development does not pose any hydrologic concern with the application of current Forest Practices Code standards.

5.7 Backyard Creek

One cutblock is proposed as category I on the Backyard Creek fan. This particular block will need to be sensitive to the current unstable state of the mainstem channel on the fan. Standard Forest Practices Code riparian requirements that consider the entire active floodplain of the channel (i.e. bankfull width) should be adequate to permit natural lateral migration while protecting bank stability as much as possible. Some retention within the Riparian Management Zone (RMZ) along the mainstem could reduce the long-term risk of fan destabilization should active bank erosion continue. The actual harvesting of the block on the fan should have no effect on stream discharge in the mainstem of Backyard Creek.

Future development in the Backyard sub-basin will also need to be sensitive to potential stream discharge increases with harvesting and channel stability on the fan. This sub-basin has a broad plateau area above the H60 elevation where natural snow accumulation levels are high, and the potential effects of forest harvesting and wildfire on discharge levels appear to be greater than in other Wap Creek sub-basins. The unique topography may require alternative harvesting proposals above the H60 elevation that minimize increased snow accumulation with harvesting, at least until channel stability can be regained on the fan.

5.8 Wap Residual

Twenty-five blocks with a total area of 524.8 ha are proposed in the residual area downstream of Wap Lake. No specific concerns were noted in any of the small tributaries draining the slopes of the residual area and all residual area slopes are either partly coupled or de-coupled from the mainstem of Wap Creek. This characteristic as provided by the broad floodplain of the Wap reduces the potential for direct effects on the mainstem from forest harvesting and road construction on the valley slopes. This should not downplay the significance of these small tributaries, but rather focus management attention on the control of finer sediment that is capable of being transported into the lower gradient tributary reaches on the Wap floodplain or Wap mainstem itself. These low gradient reaches provide both refuge for fish during high flows in the mainstem, and spawning and rearing habitat throughout the year. Proposed development in the Wap residual should not affect tributary or Wap mainstem conditions with the application of current Forest Practices Code standards, and attention to the control fine sediment erosion during road construction and active use.

5.9 Residual Above Wap Lake

Fourteen current FDP and two category I blocks are proposed on both the north and south sides of the residual above Wap Lake. Proposed development amounts to 300 ha or 5.3% of the drainage area. New roads will be required on both sides of the valley with several crossings on tributary streams. New crossings appear to be located either

on lower slopes or in upper plateau areas where tributary stream gradients are low. All crossings on steep incised tributaries are in place.

Hill slopes in the residual above Wap Lake are partially coupled to the mainstem system that includes extensive marsh and wetland complexes along the entire valley bottom. This mainstem and wetland area is the most valuable rearing and holding habitat for both resident and migratory fish species in the Wap watershed. Past forest development and private hydroelectric related sediment input to this area has visibly reduced channel complexity and infilled much of the pool and adjacent wetland habitat. Further input of fine sediment to this system is the main concern with proposed development.

The steep incised tributary channels in the residual above Wap Lake are capable of transporting all sediment up to cobble in size to the fan areas adjacent to the wetlands, which are likely used for spawning. Existing road crossings on these incised tributaries are the main source of fine sediment introduced by ditchflow and both cut and fillslope failures. Regular maintenance of existing drainage structures and an effort to prevent sediment input at new crossings should help to minimize unnecessary input to the wetland system. The actual harvesting in the residual above Wap Lake is not expected to have a detrimental effect on tributary stability or wetland function.

5.10 Residual Above Frog Falls

Thirteen blocks with an area of 60 ha are proposed in the residual above Frog Falls. Road access to the blocks will be mainly achieved via new routes that were constructed in 1998 and 1999. Mid-slope blocks on the east side of the valley will utilize existing old roads that will require some upgrading.

Private hydroelectric dam disturbance and past road related landslides and surface erosion have input a large volume of sediment to the channels in the residual above Frog Falls, leading to significant disturbance in the downstream reaches in the residual above Wap Lake. Much of the lower valley slopes appear to be covered by historic kame terrace deposits that have proven to be difficult to work in. Regardless of further development in this area there will continue to be extensive surface erosion and possibly additional landslides that occur from the existing old road network. Proposed development, particularly in areas where there are old road and trail concerns may actually provide an opportunity to improve the drainage situation and reduce the risk of additional slides and fine sediment input.

A thorough review of existing drainage on the stacked road system along the east side of the valley was recommended in the assessment section of this report. This review with upgrading to restore natural drainage patterns and improve overall road stability is the most important activity in this area to reduce further impact on the channel system. It is possible that this work could be completed under the FRBC program, but

in the event that funding is not available the work will need to be completed operationally.

Surface erosion was also noted as a concern on the Branch 4, 100 and 200 road systems that will also need to be monitored by field staff to permit a quick response to any noted slumping, drainage diversions or fillslope failures. Site specific maintenance was recommended on fine textured road sections to maintain vegetative cover in ditches and cut and fillslopes, rather than widespread grading. This practice could greatly reduce overall sediment input from the road system in this area.

If the hillslope drainage review on the east side of the valley can be completed in the 2000 season and efforts are made wherever possible to prevent fine sediment input to streams, the effects of proposed harvesting on the channel system is expected to be negligible.

5.11 Joss Creek

Six blocks with an area of 37 ha are proposed from 2000 to 2005 in the Joss sub-basin. Short extensions to existing roads will be required to access the blocks with no new stream crossings visible on 1:30,000 maps.

The main concern in the Joss sub-basin is fine sediment input to tributaries and the mainstem from the 200 road. This road was built in fine textured erodable soils and is a chronic source of sediment. Efforts to employ site-specific maintenance with grass seeding of exposed soils should greatly reduce sediment movement. Proposed road extensions appear to be located on less erodable soils and should not be a problem with regular Forest Practices Code construction and maintenance standards.

Access to the N23 and 881-2 blocks on the east side of the mainstem will require the reconstruction of a crossing where sediment input was observed from eroding fill materials. This upgrade will provide an opportunity to improve crossing stability when the new bridge abutments are armoured. The bridge approaches in this location are steep and will need to be waterbarred or deactivated following harvest.

With attention to erosion control on existing roads, proposed development is not expected to have a detrimental effect on the Joss Creek system.

5.12 Upper Wap Creek

Seven blocks with an area of 125 ha are proposed along the north side of the Upper Wap sub-basin. Access to the blocks will be via the existing road and trail system along the lower slope with several short spurs where required to reach the lower falling boundaries. Access to the two uppermost blocks (916-1 and 916-2) has not yet been determined, but an extension from the existing trail system would seem appropriate.

The concerns in the Upper Wap sub-basin relate to channel disturbance from an old trail crossing and drainage diversions along the old trail on the north side of the mainstem. Development will not affect the disturbed channel reach and proposed trail upgrading required to access the blocks will address the drainage diversion concern.

Terrain mapping does not extend into the middle or upper portion of the sub-basin, and the mapping for the lower basin would indicate that there might be stability concerns in the area of the proposed blocks. As a preventative measure it would be prudent to either extend the terrain map coverage into the upper basin or complete terrain stability field assessments (TSFA) on the blocks (877-1, 2, 3 and 916-1, 2). There are no other concerns with development in the Upper Wap sub-basin.

5.13 Proposed Development Summary

The anticipated hydrologic effects of proposed development at the POI's in the Wap watershed can be managed at the sub-basin and residual area level through the implementation of the above suggestions. Observed channel disturbance in the upper and lower watershed has resulted from site-specific hydroelectric structure failure, and past forest management practices such as harvesting in the riparian zone on mainstem channels and road construction on steep unstable slopes. These noted channel disturbances can be mitigated through planned WRP works and either improvement or decommissioning of the upper two hydroelectric diversion structures. Road related drainage concerns could also be managed through the recommended drainage improvements and site-specific maintenance practices.

There should be no unusual hydrologic constraints on future forest development in the Wap watershed if the potential effects of planned development are minimized through the recommended sub-basin and residual area management suggestions. The Devil Creek sub-basin, Backyard Creek sub-basin and residual area above Frog Falls are considered the most sensitive areas at this time for future development, where plans will need to be reviewed in the context of future channel and hillslope stability.

6.0 SUMMARY

6.1 Watershed Assessment Results

The Wap Creek watershed is characterized by a broad low gradient floodplain stretching from the mouth on Mabel Lake to approximately Frog Falls. Sub-basins typically have steeper gradient mainstem and tributary channels that are capable of transporting up to cobble sized sediment onto the broad floodplain area. An extensive marsh and wetland complex, including Wap Lake, is present on the upper floodplain. This low gradient region effectively buffers the lower watershed from any sedimentation effects that have been realized from past land-use in the upper watershed.

This division will be used as the basis for the assessment summary as stream sedimentation is the main concern in the Wap watershed.

6.1.1 Wap Creek Downstream of Wap Lake

In the lower watershed, mainstem channel disturbance has occurred from both sub-basin and localized floodplain disturbance. Past wildfire and beetle salvage efforts in Backyard Creek appear to have destabilized the fan introducing significant volumes of fine and coarse sediment to the mainstem immediately downstream of Wap Lake. Natural recovery is occurring on the Backyard fan but there is a concern that future forest development above the H60 elevation could delay recovery.

Farther downstream, past harvesting in the riparian zone along the mainstem has lead to bank destabilization and considerable erosion of an historic glacio-fluvial outwash terrace. The volume of sediment introduced from two large bank failures on the terrace has straightened and widened the mainstem from Derry Creek to Mabel Lake. This mainstem disturbance has reduced fish access to upstream spawning reaches and represents the largest instream restoration opportunity in the watershed. Other disturbance in the lower watershed includes three debris flow events in the Dale and Devil Creek sub-basins, all induced by road drainage related landslide or bank failure impact on the channels. The debris flows scoured each mainstem to bedrock and initiated numerous bank failures along the channels that continue to provide significant fine sediment to Wap Creek through secondary erosion. A new bank failure was observed on lower Devil Creek during the aerial overview phase of the project supporting the concern for road related drainage diversions. The majority of coarse sediment and debris from the debris flow events in Dale and Devil Creeks was deposited on the respective fans and did not reach Wap Creek. Stabilization of the bank failures along these channels is not an option leaving the focus on the prevention of additional bank failures and debris flow events. The active roads (Iron, Iron Spur 2, and Icebox) in the Dale, Un-named, Devil and Iron Creek sub-basins are all a concern with respect to hillslope drainage alteration and additional bank failure or landslide initiation. Road drainage related bank failures have occurred in the Un-named and Iron Creek sub-basins and future debris flows are likely with continued failure impact.

Other lower watershed disturbance is isolated to several alluvial reaches in Derry and Cavanaugh Creeks where past harvesting or clearing for the BC Hydro transmission line has occurred in the riparian zone. Minor bank erosion and widening was noted in these areas but natural recovery is occurring and restoration attention is not warranted. Several old road crossings were also identified in the Cavanaugh and Backyard Creek sub-basins that should be removed or repaired before downstream channel effects are realized. The Derry FSR was noted to be in poor condition and in need of either upgrading or

deactivation to prevent imminent failure into the mainstem and tributary channels.

Most of the disturbance that has occurred in the lower mainstem of Wap Creek has resulted from the fan destabilization on Backyard Creek and the destabilization of the large glacio-fluvial terrace at the Derry Creek confluence. The effects on the mainstem from other sub-basin disturbances would rank at least one order of magnitude less than those realized from these two sites. Instream restoration at the eroding terrace, and road drainage improvements in Iron, Devil, Un-named, Dale and Derry Creeks can minimize further disturbance.

6.1.2 Wap Creek Upstream of Wap Lake

Wap Lake and the wetland/marsh complex that stretches to approximately Frog Falls has been noticeably infilled with fine sediment from road-related landslides and private hydroelectric diversion structure disturbance in the residual above Frog Falls. Channel complexity and pool depth has been reduced by fine sediment input, and a known coho salmon spawning reach downstream of Frog Falls is now aggraded and straightened as a result of the increased sediment load. Several site-specific road surface erosion concerns were noted on tributary crossings in the residual above Wap Lake. The volume of sediment introduced at these sites is relatively small and can be addressed through minor upgrading and soil stabilization.

In the residual above Frog Falls, extensive erodable kame terrace deposits appear to be present on the lower slopes. Road construction in these soil types has created chronic running surface, and cut and fillslope erosion concerns that can only be addressed through continual monitoring by field staff and site-specific maintenance efforts. On the east side of the residual a "stacked" road system is present that appears to have significantly altered natural hillslope drainage resulting in numerous landslides, gully torrents and bank failures in the terrace deposits below. A comprehensive review of hillslope drainage with restoration where required will need to be completed on these road systems to reduce the risk of additional failures and ongoing slide erosion. Organic cribbing was also observed along portions of the 100 road that is linked to the occurrence of several landslides and debris flows.

In the lower residual above Frog Falls there are three private hydroelectric diversion structures, two of which have and continue to cause considerable channel disturbance. The lowermost structure is located atop the falls and has not affected channel stability. The second structure is no longer active but has and continues to cause unnecessary bank erosion below the structure resulting from channel constriction and an increase in stream power. The third structure was built at the apex of an historic fan deposit and is currently active. Flows overtop the upper structure on at least an annual basis eroding fill materials and

increasing downstream sedimentation. In the spring of 1997 it appears that the entire flow of Upper Wap Creek avulsed around the structure and formed a new channel through the fan. Sediment transported downstream by this event likely amounted to that of approximately 10 of the upstream road related landslides combined.

In the Joss sub-basin, surface erosion on the 200 road is the main concern. This road has been recently upgraded and extended along the upper slopes leading back into the residual above Frog Falls. Sediment input to both Joss Creek and several tributaries was noted from this road section that could be addressed through site-specific maintenance and soil stabilization efforts. Minor fillslope erosion at a ford on Joss Creek was also noted. Development proposed in the current FDP will require a new crossing that should address this concern.

Channel disturbance has occurred in the middle reaches of Upper Wap Creek from the failure of a bridge on an old trail crossing. Extensive bank erosion is occurring at the site that could be reduced with minor instream works. Several old trail related drainage diversions were also noted that would be addressed by development proposed in the current FDP.

Elevated sedimentation levels in fish-bearing reaches upstream of Wap Lake is the main concern in the upper watershed. The private hydroelectric diversions, road surface erosion, road drainage diversion and instream disturbances are all contributing factors to the sedimentation issue. Attention to all areas of concern is necessary to reduce the impact on the fisheries resources.

6.2 Proposed Forest Development

Development is proposed from 2000 to 2006 in all areas of the Wap Creek watershed. In total, planned development amounts to approximately 1,467 ha from 2000 to 2005 (4.1% of the watershed), with an additional 148 ha planned as category I development (0.4% of the watershed). The main concern with development as proposed is not the actual harvesting itself but rather the management of surface water within blocks draining onto steep valley slopes, and on existing and proposed road systems. Reduced sedimentation, primarily from road related sources, should be the main watershed management objective with ongoing forest development. As a general watershed wide strategy to achieve this end, road maintenance should be done on a site-specific basis where sediment delivery to channels is possible, rather than widespread grading of ditchlines and running surfaces. This practice would retain as much established vegetation in ditchlines and on cut and fillslopes as possible, reducing the total area of exposed soils in the watershed.

6.2.1 Wap Creek Downstream of Wap Lake

In the lower watershed there are concerns with respect to drainage diversion on the Iron, Iron Spur 2 and Ice Box road systems that have and may continue to cause bank failures into the steep incised channels of Dale, Un-named, Devil and Iron Creeks. Potential drainage diversions within the proposed blocks in these sub-basins and the Fennell Creek tributary in Derry Creek are also a concern that will need to be addressed. These channels are susceptible to debris flow initiation with abnormal sediment loading that has been demonstrated on three separate occurrences. The current levels of development and proposed block locations in these sub-basins should not have a detrimental effect if natural hillslope drainage can be maintained. Future development, particularly in the Devil Creek sub-basin, will need to be sensitive to mainstem channel and bank stability.

Development as proposed in the Derry and Cavanaugh Creek sub-basins, as well as the Wap residual area downstream of Wap Lake is not a concern with the implementation of current Forest Practices Code standards. Channel stability on the fan of Backyard Creek could be a concern with future development in the sub-basin. Natural recovery on the fan is occurring but stability should be reviewed prior to the formation of any plans. Delayed recovery could occur with any changes in runoff timing, runoff magnitude or sedimentation.

6.2.2 Wap Creek Upstream of Wap Lake

Upstream of Wap Lake the concern with proposed development also relates to the management of hillslope drainage and control of sedimentation from existing and proposed roads. Road upgrading to access development and planned WRP works should address drainage diversion and minor sedimentation issues observed in the residual above Wap Lake, and Joss and Upper Wap sub-basins. Development on the east side of the residual above Frog Falls could be a concern if hillslope drainage is not reviewed and improved from the BC Hydro right-of-way to the Upper Wap sub-basin. Harvesting in the residual above Frog Falls should not have a detrimental effect if these drainage improvements are made. Existing roads that have been constructed in fine textured kame terrace deposits will generate sediment during active hauling and routine maintenance. Efforts by FCL staff to monitor erosion on roads in the these areas (Branch 4, lower 100 and 200 systems), combined with site-specific maintenance and ongoing re-vegetation effort on exposed soils can greatly reduce sediment delivery to the channels.

Terrain mapping is not available for the middle and upper portions of the Upper Wap sub-basin where several blocks are proposed. Judging from the extent of potentially unstable terrain mapped in the lower sub-basin, an extension of the map coverage or completion of terrain stability field assessments to cover these blocks could reduce the risk of hillslope failure.

There are no other concerns with development upstream of Wap Lake.

6.2.3 Watershed Development Summary

Development proposed throughout the watershed should not have a detrimental effect on channel stability or sedimentation levels in the Wap Creek mainstem if the road related drainage and sedimentation concerns identified in this report are addressed, and development adheres to current Forest Practices Code standards. Future forest development that recognizes the watershed goal to reduce and minimize sedimentation from road related sources should also be appropriate. Backyard and Devil Creeks are the only areas in the watershed where channel recovery should be reviewed prior to future development plan formation.

7.0 RECOMMENDATIONS

7.1 Forest Development Plan Recommendations (RFPL).

- Inspect and upgrade road drainage as required on the Iron and Iron Spur 2 Roads in the Dale, Un-named and Devil Creek sub-basins to prevent hillslope drainage concentration and diversion onto the steep gully sidewalls of the mainstem channels.
- Maintain natural hillslope drainage within all blocks that drain onto the steep slopes adjacent to the channels in the Iron, Devil, Un-named and Dale Creek sub-basins, and Fennell Creek tributary drainage in the Derry Creek sub-basin.
- Review drainage on the Iron Road and trail in openings 23 and 24 to determine any connection to the recent bank failures on lower Devil Creek. If a connection can be made to the failures, improve drainage where required to prevent further occurrence.
- Improve road drainage on the IceBox road beyond opening 42 to avoid additional landslides into Iron Creek.
- Complete plans for road relocation or upgrading on the Wap FSR between 6.5 and 7.5 km, and 10 and 12 km to reduce flooding and surface erosion.
- Where possible avoid widespread road and ditchline grading throughout the watershed where sediment delivery to channels is possible. Maintain these areas in a site-specific manner such that disturbance to any established ditchline, cutslope or fillslope vegetation is minimized.
- Review the Iron Road beyond the lower Un-named Creek crossing (where mapped as a moderate sediment source) to determine if improvements can be made to reduce sediment input to the channel. In this location additional cross-drains to interrupt ditchflow before the eroding cutslope may not be appropriate as two drainage related landslides have already occurred below opening 24.
- Insure that the entire active floodplain width of the mainstem channel on the Backyard Creek fan is considered in any applicable stream and riparian classifications for proposed block AS9013. Consider retaining additional stems in the riparian management zone for this block along Backyard Creek to provide additional long-term bank stability should active erosion continue on the fan.
- Review channel stability and the success of recommended road drainage improvements prior to forming any future development plans in the Devil Creek sub-basin.
- Review channel recovery on the fan of Backyard Creek prior to forming any additional forest development plans, particularly above the H60 elevation.

7.2 Forest Development Plan Recommendations (FCL).

- Where possible avoid widespread road and ditchline grading throughout the watershed where sediment delivery to channels is possible, particularly on roads mapped with moderate or high surface erosion contributions. Maintain roads in these areas in a site-specific manner such that disturbance to any established ditchline, cutslope or fillslope vegetation is minimized.
- Inspect road conditions regularly in the residual above Frog Falls and on the 200 road in the Joss sub-basin, and initiate improvements where and when required to minimize surface erosion and reduce the risk of additional landslides.
- Consider extending terrain stability map coverage into the Upper Wap Creek sub-basin or complete terrain stability field assessments on blocks 877-1, 2, 3 and 916-1 and 2 to minimize the risk of hillslope failure.
- If FRBC funding is not available to complete a hillslope drainage review on the east side of the residual above Frog Falls, consider undertaking the work on an operational basis.

7.3 Watershed Restoration Program Recommendations (RFPL).

- Review the Iron Road in lower Dale Creek where it is mapped as a moderate sediment source (upslope of landslide 10). Modify road drainage to avoid surface erosion on the existing bank failures into Dale Creek.
- Upgrade or deactivate the Derry FSR to prevent imminent failures into Derry Creek. Access to the Bunny Road system will need to be considered in any works planned on the Derry FSR.
- Assess old road and trail crossings on reaches C2, C4 (Ohashi Road) and tributaries to reach C7 (trail between openings 41 and 43) in the Cavanaugh sub-basin. Upgrade or deactivate the crossings to prevent further channel disturbance.
- Assess old road crossings between openings 22 and 26, and 204 and 206 in the Backyard Creek sub-basin to determine appropriate deactivation or upgrade measures.
- Implement planned restoration for the large eroding bank failures and extensive mid and lateral channel bars on the lower Wap mainstem channel (Reach B) if HRSEP and WRP funding becomes available. Re-apply for WRP, Fisheries Renewal BC and/or HRSEP funding for these sites in 2000 and 2001 if the current project is not accepted.

7.4 Watershed Restoration Program Recommendations (FCL).

- Improve vegetation coverage on exposed soils at the lower deactivated road crossing before opening 226 in the residual above Wap Lake.
- Assess oversteepened fillslopes at the headscarp of landslide 19, and immediately beyond the main northwest tributary crossing on the 9019 Road in the residual above Wap Lake to determine appropriate measures to reduce the risk of hillslope failures.
- Assess road drainage on the east side of the residual above Frog Falls to determine any potential connection to downslope gully failures and landslides. Improve drainage or deactivate roads where required to reduce the risk of future failures.
- If hillslope drainage upslope of the slides in the residual above Frog Falls can be improved, consider a landslide rehabilitation program in the area that may include headscarp stabilization and slide scar re-vegetation.
- Assess the 100 Road from the Branch 4 intersection to the BC Hydro transmission line to determine the extent of organic material that has been used to support the road. Replace organics with competent fill material in areas where there is a risk of failure.
- Implement planned in-stream and cutbank restoration on the Upper Wap mainstem channel between openings 201 and 202 if WRP and HRSEP funding becomes available. Re-apply for funding in 2000 if this project is not accepted.

7.5 Other Recommendations

- Contact the permit holder for the private hydroelectric diversions on the Wap mainstem upstream of Frog Falls and communicate the current concerns with degraded fish habitat in Wap Creek upstream of Wap Lake. Recommend the removal of the second inactive structure with re-establishment of natural channel morphology as much as possible through the site. Also recommend either removal or upgrading of the upper structure to reduce the ongoing risk of avulsion with detrimental downstream channel effects.

MM/dd

APPENDICES

APPENDIX A

Watershed Assessment Committee Members and Initial Round Table Meeting Minutes

Watershed Assessment Committee – Wap River
April 1999

Bob Harding
Department of Fisheries and Oceans
P.O. Box 1160
Salmon Arm, BC V1E 4P3
(250) 832-8037

Michael Milne
Dobson Engineering Ltd.
4-1960 Springfield Rd.
Kelowna, BC V1Y 5V7
(250) 861-5595

Greg Hislop
Federated Co-operatives Ltd.
P.O. Box 70
Canoe, BC V0E 1K0
(250) 833-1200

Jeff Lipsett
Federated Co-operatives Ltd.
P.O. Box 70
Canoe, BC V0E 1K0
(250) 833-1200

Pat Mills
Federated Co-operatives Ltd.
P.O. Box 70
Canoe, BC V0E 1K0
(250) 833-1200

Rob Udy
Landmark Forest Management Ltd.
P.O. Box 87
Salmon Arm, BC V1E 4N2
(250) 804-0332

Des Anderson
Ministry of Environment, Lands & Parks
Regional Office – Southern Interior
1259 Dalhousie Drive
Kamloops, BC V2C 5Z5
(250) 371-6314

Pierre Rossouw
Ministry of Forests
Salmon Arm Forest District
850 16th Street N.E.
Salmon Arm, BC V1E 4S4
(250) 833-3433

Ron Beals
Ministry of Forests
Salmon Arm Forest District
850 16th Street N.E.
Salmon Arm, BC V1E 4S4
(250) 833-3440

Rita Winkler
Ministry of Forests
Kamloops Forest Region
515 Columbia Street
Kamloops, BC V2C 2T7
(250) 828-4169

Murray Wilson
Riverside Forest Products Ltd.
Armstrong Division
Bag Service 5000
Armstrong, BC V0E 1B0
(250) 546-2255

Mike Christian
Spallumcheen Indian Band
P.O. Box 3010
Enderby, BC V0E 1V0
(250) 838-6496

Eric Goodman
Ministry of Forests
Vernon Forest District
2501 14th Avenue
Vernon, BC V1T 8Z1
(250) 558-1747

Rob Kennett
Riverside Forest Products Ltd.
Armstrong Division
Bag Service 5000
Armstrong, BC V0E 1B0
(250) 546-2304

memorandum

to:	**Watershed Assessment Committee**
from:	**Karin Janzen, Silvatech Consulting Ltd.**
date:	**April 14, 1999**
re:	**Upper Wap River IWAP - Minutes of Watershed Assessment Committee Meeting**

Meeting was convened at 1:15 p.m. on Wednesday, April 14, 1999, at the offices of the Ministry of Forests, Salmon Arm Forest District, 790 16th Street NE, Salmon Arm, BC. This meeting was chaired by Pierre Rossouw of the Ministry of Forests (MOF).

Committee includes:
Pierre Rossouw, Ministry of Forests;
Ron Beals, Ministry of Forests;
Rita Winkler, Ministry of Forests;
Des Anderson, Ministry of Environment, Lands and Parks;
Jeff Lipsett, Federated Co-operatives Ltd.;
Greg Hislop, Federated Co-operatives Ltd.;
Pat Mills, Federated Co-operatives Ltd.;
Rob Udy, High Country Forestry Consulting Ltd.;
Michael Milne, Dobson Engineering Ltd.;
Bob Harding, Department of Fisheries and Oceans;
Jim DeCoffe, Riverside Forest Products;
Stuart Lee, Spallumcheen Indian Band;
Morgan Felix, Spallumcheen Indian Band.

Introduction of Attendees:

Pierre Rossouw, MOF, welcomed the committee members, who then introduced themselves, to this initial Watershed Assessment Committee (WAC) meeting for the Upper Wap River Watershed Assessment Procedure (WAP). Rossouw reminded the participants that by attending this meeting, they have, in effect, made a commitment to the procedure. He went on to stress that committee members have an obligation now to attend subsequent meetings and, if unable to do so, to ensure that a replacement representative is found and briefed. He emphasized that it was important to the function of the committee that each representative's views and recommendations be included in the final report.

Discussion of IWAP Procedure and Role of the Watershed Assessment Committee:

Rossouw pointed out that since guidelines for a new Watershed Assessment Procedure were still in draft form, the assessment of the Upper Wap River would be based on interim guidelines provided by the Ministry of Forests, Kamloops Region, in a memorandum dated September 2, 1998. He went on to detail the differences between the old watershed assessment procedure and the format that will be followed for this project. He described the previous procedure as a number-based review of the watershed that essentially provided a statistical overview of watershed conditions. The interim procedure, which is modelled somewhat on the proposed new procedure guidelines, is more focused on field assessments and results in a more realistic overview of watershed conditions.

Rossouw noted that most of the group had participated in other WAC meetings and were familiar with the intent of the meeting and their role in it; however, he asked if anyone was unsure of the purpose of a watershed assessment committee. Chief Stuart Lee, representing the Spallumcheen Band, indicated that he needed more detailed information than he had received to this point.

In response, Rossouw gave an overview of the WAP process outlining the steps necessary to complete a watershed assessment. He noted that there is an initial meeting of representatives of parties who might have an interest in the watershed. The purpose of this meeting is to raise and discuss issues of concern, provide direction to the hydrologist conducting the assessments, divide the watershed into logical sub-basins and determine a point of interest for the study. The hydrologist will then complete his field work in the study area based on the issues raised at the first meeting and provide a draft report of his findings to the members of the watershed committee for their consideration. A second meeting will be held and the committee members will discuss the report and determine their recommendations which will be forwarded to the statutory decision makers along with the final report.

Summary of Previous Assessment Work and Current Fisheries and Water Quality Concerns:

Jim DeCoffe, representing Riverside Forest Products Limited, Armstrong Division, asked for some background as to why this Watershed Assessment Procedure for the Upper Wap River was being initiated at this time.

Rossouw provided some background information, noting that two types of watershed were likely to be the subjects of WAPs: the community watershed and any watershed designated as sensitive. The Wap River, Rossouw said, was very likely to be listed as sensitive in the near future. For that reason, he noted, Federated Co-operatives Ltd. decided to take the initiative and proceed with a WAP at this time. He commented that Forest Renewal BC was putting some pressure on to get these assessments underway. Riverside, said Rossouw, had been invited to participate in initiating the assessment but had declined. Rossouw noted that if Riverside were to agree to complete an IWAP in their portion of the watershed it may be possible for the cost to be covered by Forest Renewal BC. The fact that this IWAP was initiated prior to the FRBC fiscal year end, makes the project eligible for carry over FRBC funding that will not be available for IWAPs beyond this year. The fact that the watershed will likely be designated as "sensitive" in the upcoming year or years, Riverside will be directed to complete an IWAP by the District Manager which will not be eligible for FRBC funding if initiated beyond 1999. Citing, in particular, high fisheries values in this watershed, Rossouw commended Federated for taking the initiative in getting the WAP underway.

DeCoffe stated that Riverside was willing to complete ECA calculations on their portion of the watershed prior to considering the IWAP further. Rita Winkler, Ministry of Forests, observed that ECA calculations were no longer the prime trigger for pursuing a WAP within a watershed. She noted that ECA numbers were a useful tool but that consideration for the various values present, including fisheries, domestic water supply and life and property, were key in determining if a watershed assessment was necessary.

Rossouw went on to describe the Wap River as a low-energy system. He pointed out that the mainstem is extremely flat while the tributaries are very steep. He added that degraded tributary conditions can initiate or exacerbate channel disturbance in the low gradient mainstem, and for that reason he felt that the entire watershed should be the subject of this WAP rather than just portions of it. He pointed out that he has worked for the past three or four years towards having an assessment of the total system.

Michael Milne of Dobson Engineering Ltd., hydrologist for this WAP, suggested that perhaps DeCoffe could take the information from this meeting back to Riverside for further consideration. Milne offered to discuss the situation with Riverside staff after they had time to consider the meeting minutes and their proposed level of development within their operating area. Milne then went on to note that IWRP assessments had been completed by Wildstone Consulting in 1996 and 1997 on Derry, Dale, Devil, Un-named and Iron Creeks which are tributaries to the lower Wap River system. The Dale, Devil, Iron and Un-named tributaries had been subjected to detailed hydrologic assessment by Dobson Engineering Ltd. in 1998 which led to works being carried out at high priority sites in the same year. He noted these detailed hydrologic assessments were more detailed than the IWAP and that the results

could easily be incorporated into an overall WAP without any further field assessment. These creeks, said Milne, represented approximately 20 to 25% of Riverside's area in the total Wap River basin. Derry, Cavanaugh and another un-named western tributary downstream of Wap Lake (named "Backyard" Creek for this discussion), were described by Milne as the two biggest tributaries in the Wap system downstream of Wap Lake. No assessment work has been completed in the Cavanaugh or "Backyard" Creek drainages.

Rossouw noted that Level C terrain mapping was available from the Salmon Arm Forest District for a portion of the Wap watershed, to which Milne added that some Level D mapping was also available at Riverside for the Derry, Dale, Devil, Un-named and Iron Creeks.

Milne provided some details of the 1996 and 1997 IWRPs, which included a sediment source survey, channel assessment and fish habitat assessment, carried out on the east side of Mabel Lake which was largely a Riverside Armstrong holding. This overall assessment came back with a large number of recommendations that tended to be somewhat "overwhelming" in their scope. The decision by Riverside to complete follow-up assessments in several of the IWRP tributaries represented an effective way to address IWRP and proposed development concerns in a time and cost effective fashion.

Milne went on to say that the lower Wap River has been disturbed by 50 year old riparian harvesting on the broad alluvial floodplain. The channel is now much wider and shallower with limited regeneration in the riparian zone. He added that this type of alluvial, low-gradient channel is very difficult to restore and that management should strive to limit any increases in peak flows or sediment introduction from the tributary channels. The mainstem channel will regain its stability through debris jam formation and mid and lateral bar accumulation. These deposits will vegetate naturally and the channel will slowly return to its original width and depth dimensions. Milne mentioned that the detailed assessments and works in the Dale, Devil, Un-named and Iron Creeks had addressed current flow and sediment input concerns. In some instances, if a crisis situation was determined in the field, then works were carried out even before the report was finalized. He noted that in general there were many IWRP road and channel sites found that didn't warrant immediate action.

Bob Harding of the Department of Fisheries and Oceans then outlined the known fisheries situation in the Wap River system. He noted that there were sockeye in the Wap River as well as coho of the Thompson Basin group. The numbers of these coho, he pointed out, were neither holding nor increasing but were dropping instead. Chinook, however, were increasing, said Harding. In addition, the system supported rainbow trout, dolly varden, bull trout, kokanee and whitefish. Frog Falls was noted as the barrier to upstream movement. The concentration of fish, said Harding, occurred approximately 5 km above and 5 km below Wap Lake.

Harding pointed out that some of the greatest concerns in the watershed, from his point of view, arise from the fact that the area comes under the jurisdiction of two forest districts and, until recently, two divisions of the same forest company. The western portion of the watershed has seen a lot of historical development and there is a lot of channel instability, he noted. Harding went on to say that he would also like to see the entire watershed dealt with in this assessment. He felt that while previous work in portions of the watershed was producing some site specific rehabilitation, assessing the watershed in a piecemeal manner was really just "fire fighting". He commented that it would certainly be necessary to keep all parties with interests in the watershed involved and aware.

Milne asked Harding if DFO anticipated any enhancement works in the watershed. Harding answered that none were planned at the moment but that if any works targeting coho were proposed, then there might be some fisheries renewal money available. Greg Hislop, representing Federated Co-operatives Ltd, asked if fish ladders might be constructed around any barriers. Harding noted that fish are not fully utilizing the system now and that there were no plans to open new areas just to circumvent any bottlenecks.

Milne went on to say that the situation in the Wap River seemed to relate to those in the Coastal systems in that the floodplain along the mainstem had been logged historically. He observed that the active channel in the lower system was almost as wide as the floodplain. While stabilizing the channel was desirable, the question, of course, he said, was whether or not anything could really be done to improve the situation. He termed restoration of the lower mainstem a "real challenge" and for the most part "futile." The most strategic way to restore channel functions

in the mainstem is to manage sediment and peak flows in the major tributaries. Milne commented that it could be hundreds of years before the lower mainstem channel stabilized. Harding agreed with the intent to manage sediment and flows, but emphasized a need to look at the big picture in this watershed. Winkler and Anderson both concurred with Harding's statement. Anderson went on to say that an assessment of the whole system was needed in order to come up with integrated plans for future development.

Harding asked what plans had been made to communicate with the Vernon Forest District on this matter. Rossouw pointed out that Vernon had been invited to send a representative to this meeting but had declined due to other commitments. Ron Beals, Ministry of Forests, said that the non-participation of the Vernon Forest District in the process shouldn't hamper this assessment.

At this point, Lipsett reminded the committee that Federated only had funding for assessment of the area immediately above and below Wap Lake. If the area to be assessed was to be increased, then Riverside's participation was necessary. He added that it was not Federated's intention to try to force Riverside to participate in this WAP, but available funding would determine the scope of the study area and Federated already had its limits. Rossouw noted that if Riverside were to participate, then there was a real opportunity for additional Forest Renewal BC-funding to be applied. Anderson agreed with this and reiterated the general consensus that the entire watershed needed to be assessed in order to give the necessary tools to those who managed its resources.

Lipsett then went on to say that both Riverside and Federated had forest licence and timber licence in the watershed. Although there had been lots of historical logging, there was an ample supply of 90 - 100 year old trees. He called the Wap River watershed a "very important" timber supply. Anderson questioned whether there was much logging planned over the next five years. Lipsett answered that there had been a lot of logging approved and proposed throughout the area. Milne asked if there was much road development proposed, to which Lipsett responded that the roads were, for the most part, already in place. Pat Mills of Federated Co-operatives Ltd. pointed out that he was aware of 14 km of new construction on mapsheet 88. Lipsett went on to say that an agreement was in place for an ecological reserve paralleling the channel and marshlands upstream of Wap Lake.

Anderson questioned DeCoffe on Riverside's logging plans. DeCoffe noted that there is quite a lot of logging planned for 1999 and the next five years. SP's, he noted, have already been submitted. Anderson asked if there was any sense of the ECA's in areas proposed for logging. Lipsett said that he did not have that information. DeCoffe said that he though ECA's in the Cavanaugh Creek sub-basin were approximately 30%, but did not have any numbers for other areas. Milne reported that some of the numbers reported in the IWRP for the lower eastern tributaries were inflated and incorrect. He went on to say that the H60 line used in the IWRP was wrong and that some of the sub-basin boundaries were incorrect. These inconsistencies were rectified in the follow-up detailed hydrologic assessments with reported ECAs between 5 and 30% for the tributaries assessed. ,

Rossouw then asked Chief Stuart Lee of the Spallumcheen Band to present the Band's perspective on current watershed conditions. Lee noted that he had not personally been involved in any process up to this point but that the Band had worked with DFO on fisheries management concerns. He pointed out that the Band has had meetings with all forest companies harvesting in the Band's traditional areas. He told the committee that the traditional fishery was largely for food and ceremonial purposes and that the focus was on chinook. When asked by Lipsett whether this fish stock was in good shape, Lee responded that it was certainly not as good as in the past. Milne asked Lee if he could provide him with some input on traditional use of the watershed to include in the WAP report.

The committee then touched briefly on other issues concerning the watershed. Harding noted that sport fishing in the area was a growing activity. Lipsett observed that he was not aware of any active mining in the watershed. Rossouw questioned whether there were any real wildlife issues in the watershed. Milne observed that this was really beyond the scope of the WAP. Lipsett wondered if wildlife concerns could be loosely addressed. Beals noted that there were some caribou and moose in the watershed, while Mills added that goats, grizzly bear and mule deer had been occasionally observed. Harding questioned whether BC hydro was a contributor to the problems in the Wap watershed. Rob Udy, of High Country Forestry Consulting Ltd., said that this could be looked into. Hislop noted that the dam at Frog Falls was a private dam and served the Three Valley Gap establishment.

Rossouw added that there had been problems caused by power lines in the Kingfisher area and it is possible that some channel concerns may be present on the Wap River where the line cross the floodplain.

Break for coffee.

Review of Watershed Boundaries and Point of Interest Location:

Following a brief coffee break, discussion turned to the location of the point of interest and sub-basin delineation for the purposes of this WAP. Initially the point of interest suggested was at the inlet of Wap Lake. Maps of the watershed were spread out and the committee broke into informal groups. (Discussion on the topic was considerable; however, because of the various discussions taking place simultaneously, individual comments and observations were not recorded.) It was confirmed at the end of this discussion period that there would be three points of interest for this study, these being: the mouth of Wap River at Mabel Lake, the inlet to Wap Lake and Frog Falls. In addition, sub-basins within the watershed were determined to be: Iron Creek, Devil Creek, Unnamed Creek, Dale Creek, Cavanaugh Creek, Dairy Creek, "Backyard Creek," Wap River above Frog Falls, Joss Creek and the Begbie Basin. Udy suggested that a key map be prepared to accompany the minutes of this meeting as a reference for committee members.

It was agreed by the group that at present the IWAP was to be completed for only Federated Co-op's operating area, but that the hydrologist would discuss the situation and concerns with Riverside staff and the Armstrong Division.

Terms of Reference for Hydrologist:

Milne noted that his first course of action would be discuss the meeting results and agency concerns with Riverside. Rossouw observed that this would certainly provide an opportunity to piggyback some of the costs. He added that he would like to see a ReCAP of the lower mainstem channel system. Milne noted that he already had a good understanding of the issues pertaining to the lower mainstem and would consider the current state of the system in any assessments of tributaries or the upper watershed above Wap Lake. Milne felt that a ReCAP of the lower system would not necessarily tell us anything that we didn't already know. He said that it may be more advantageous to look at the tributaries in context with the mainstem and identify high priority sediment source concerns. He pointed out that the committee already knew that the channel was severely degraded and not easily recovered.

The topic of ECA's came up again and Milne noted that knowing these for the entire watershed and sub-basins could provide some useful direction for future assessment and development. Udy concurred. Winkler questioned how the H60 line sat in relation to the watershed. Milne replied that he estimated that the H60 elevation in the watershed lay at approximately 1500 m. Udy asked if the H60 line would be developed for the watershed as a whole. Milne noted that he would prefer to apply one H60 elevation for the basin as a whole even if only the area upstream of Wap Lake was to be assessed. Udy then observed that he felt that separate H60s for certain basins only would not be particularly useful.

Discussion ensued regarding the impact of peak flows. Milne pointed out that problems in the watershed were not really a flow issue but mainly the result of historic riparian harvesting along the lower floodplain. Consensus of the group supported this statement and it was agreed that peak flows were not always the issue and riparian conditions and sediment budgets were just as much a problem.

Anderson asked whether it had been agreed that a ReCAP would be done on the main channel. Milne said that it would depend on whether Riverside participated and that he would get back to the committee on that matter once he has had an opportunity to sit down and discuss the issues with Riverside.

Winkler wondered whether Milne should be given the flexibility to change a point of interest if he determined there were more suitable locations. Rossouw emphasized that in that case, Milne should come back to the group first to clear any changes. Anderson questioned whether it would be necessary to subdivide the Cavanaugh and Unnamed Creek sub-basins if Riverside joined the project and the study area was expanded. Rossouw noted that there would be no need to do this unless some specific reason was identified.

Action Items/Closing Remarks:

In response to Rossouw's question about time lines for the project, Milne noted that he would not get into the watershed until sometime in July. He anticipated that he would be in a position to table his draft report in mid to late August. Rossouw reminded the committee that most parties preferred 30 days to study the report before the final meeting. He said that, on that basis, the committee members could expect the last meeting to be called for sometime in mid-September.

Milne confirmed that he would be approaching Riverside to discuss assessment of the lower watershed.

Meeting was concluded at 4:00 p.m.

Prepared and Submitted By:
Karin Janzen

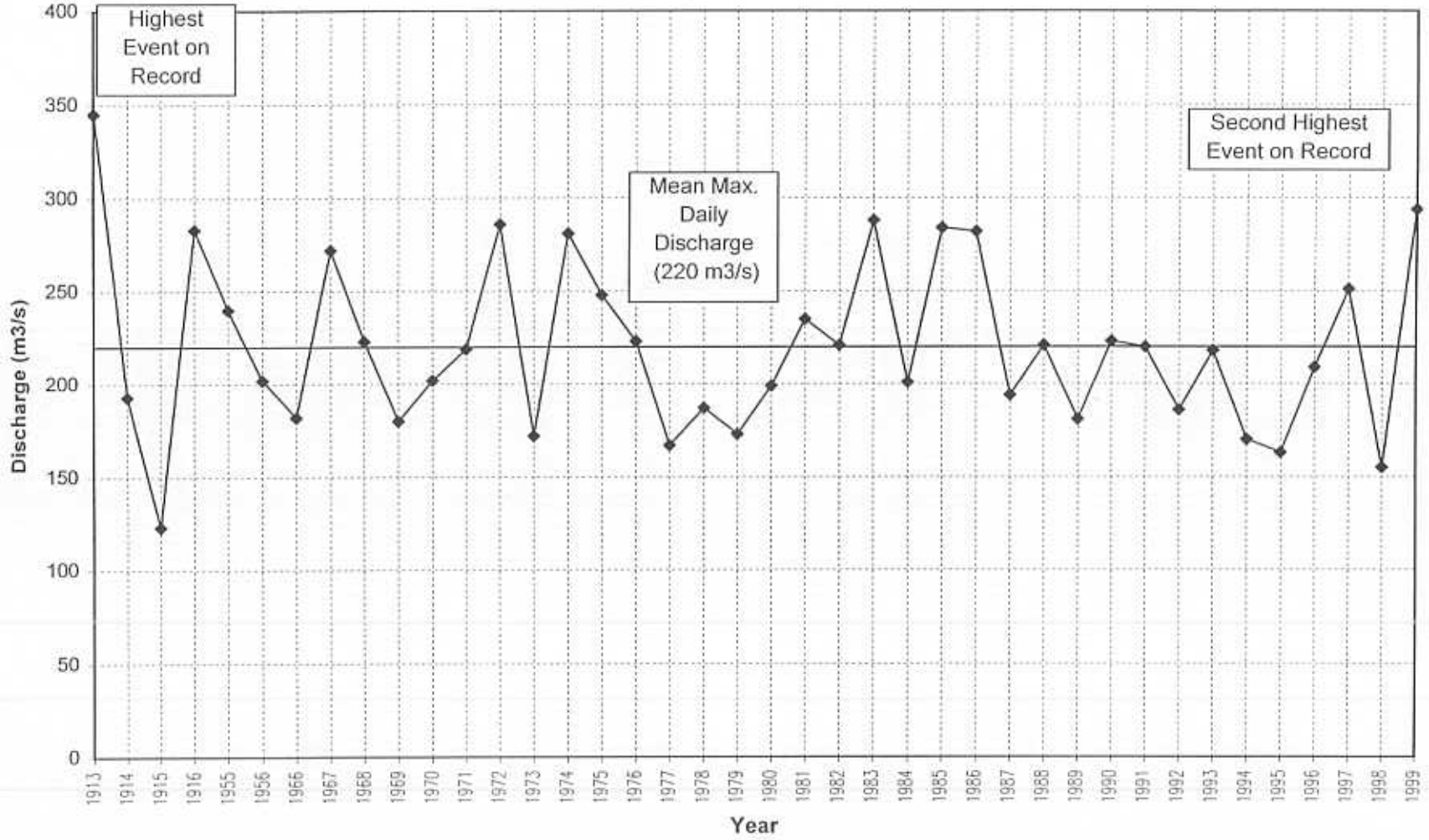
APPENDIX B

Maps

APPENDIX C

Hydrometric Data

Maximum Daily Discharges for WSC Station #08LE024
Eagle River Near Malakwa



APPENDIX D

Watershed Report Cards

Wap Creek IWAP Report Card - 2000

Sub Drainage / POI	Wap Watershed												Watershed	Above Wap Lake	Upper Wap
									Above Wap Lake						
										Upper Wap					
Watershed Inventory Category	Wap Residual	Iron	Devil	Unnamed	Dale	Derry	Cavanaugh	Backyard	Residual Above Wap Lake	Residual Above Frog Falls	Joss	Upper Wap	POI 1	POI 2	POI 3
Area (ha)	8722	1260	968	949	596	4710	2843	2836	5568	1747	1603	3772	35574	12690	7122
H60 Elevation (m)	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240
Total Area Harvested/Burned (ha)	1785.2	42.5	270.9	566.3	140.9	201.8	854.7	676.9	641.7	464.6	124.7	91.7	5861.9	1322.7	681.0
Percent Area Harvested/Burned (%)	20.5%	3.4%	28.0%	59.7%	23.6%	4.3%	30.1%	23.9%	11.5%	26.6%	7.8%	2.4%	16.5%	10.4%	9.6%
Equivalent Clearcut Area (ECA) (ha)	952.8	40.8	207.1	348.7	110.4	172.6	498.9	597.7	618.4	376.6	124.7	83.7	4132.4	1203.4	585.0
Equivalent Clearcut Area (ECA) (%)	10.9%	3.2%	21.4%	36.7%	18.5%	3.7%	17.5%	21.1%	11.1%	21.6%	7.8%	2.2%	11.6%	9.5%	8.2%
ECA Above H60 (ha)	161.1	0.0	189.1	287.9	110.0	65.3	79.5	596.2	374.8	159.2	109.8	15.2	2168.1	659.0	284.2
ECA Above H60 (%)	1.8%	0.0%	19.5%	30.3%	18.5%	1.8%	2.8%	21.0%	6.7%	9.1%	6.8%	0.4%	6.1%	5.2%	4.0%
Road Density (km/km2)*	0.5	0.9	2.1	3.5	1.9	0.5	1.1	0.8	0.8	2.0	0.7	0.2	0.8	0.8	0.8
Total Road Length (km)	41.9	11.3	20.5	33.2	11.4	22.6	30.8	22.3	43.2	35.0	11.6	7.9	291.7	97.7	54.5
Semi Perm Deactivation (km)	0.6	0.0	0.0	0.0	0.0	0.0	4.6	0.0	16.4	3.6	0.0	0.0	25.2	20.0	3.6
Permanent Deactivation (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Moderate and High Sediment Source Roads (km)	0.0	0.0	0.0	0.4	0.3	0.0	0.0	0.0	0.3	2.4	1.0	0.0	4.4	3.7	3.4
Landslides (#)	4.0	1.0	1.0	5.0	3.0	3.0	2.0	0.0	4.0	7.0	0.0	0.0	30.0	11.0	7.0
Road on Potentially Unstable Terrain	3.7	0.0	1.0	1.8	4.5	6.6	0.0	0.4	6.1	11.8	3.9	2.2	42.0	24.0	17.9
Stream Crossings (#)	42	1	14	13	2	17	13	13	34	31	10	18	208	93	59
Stream Logged to the Bank (km)	22.0	0.4	3.9	7.0	0.2	5.5	15.3	2.7	4.4	9	1.7	7.1	79.2	22.2	17.8
Mainstem With Non-Functional Riparian Zone (km)	8.4	0.0	1.8	0.0	3.2	1.1	1.5	0.7	0	0.9	0	1.5	19.1	2.4	2.4
Disturbed Mainstem Channel (km)	20.4	0.0	1.8	0.0	3.2	1.1	1.5	0.7	8.8	1.3	0	1.5	40.3	11.6	2.8

*Permanently deactivated roads are not included in the road density calculation.

Wap Creek IWAP Report Card - 2005

Sub Drainage POI 1 POI 2 POI 3	Wap Watershed												Watershed	Above Wap Lake	Upper Wap
									Above Wap Lake						
										Upper Wap					
Watershed Inventory Category	Wap Residual	Iron	Devil	Unnamed	Dale	Derry	Cavanaugh	Backyard	Residual Above Wap Lake	Residual Above Frog Falls	Joss	Upper Wap	POI 1	POI 2	POI 3
Area (ha)	8722	1260	968	949	596	4710	2843	2836	5568	1747	1603	3772	35574	12690	7122
H60 Elevation (m)	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240
Total Area Harvested/Burned (ha)	2231.1	186.7	298.3	608.2	152.1	371.4	958.4	676.9	941.5	524.9	162.1	216.9	7328.5	1845.4	903.9
Percent Area Harvested/Burned (%)	25.6%	14.8%	30.8%	64.1%	25.5%	7.9%	33.7%	23.9%	16.9%	30.0%	10.1%	5.8%	20.6%	14.5%	12.7%
Equivalent Clearcut Area (ECA) (ha)	1292.2	185.0	229.5	370.0	115.4	318.0	540.0	486.1	678.4	407.8	156.8	192.8	5172.0	1635.8	757.4
Equivalent Clearcut Area (ECA) (%)	14.8%	14.7%	23.7%	39.0%	19.4%	6.8%	19.0%	17.1%	15.8%	23.3%	9.8%	5.1%	14.5%	12.9%	10.6%
ECA Above H60 (ha)	410.1	129.2	188.6	310.2	112.6	185.3	79.1	484.5	590.3	173.1	130.4	84.5	2877.9	978.3	388.0
ECA Above H60 (%)	4.7%	10.3%	19.5%	32.7%	18.9%	3.9%	2.8%	17.1%	10.6%	9.9%	8.1%	2.2%	8.1%	7.7%	5.4%
Road Density (km/km2)*	0.7	0.7	1.8	3.5	1.9	0.6	2.4	0.8	1.0	2.5	0.9	0.2	0.9	0.9	0.9
Total Road Length (km)	60.2	9.0	17.7	33.2	11.4	29.8	33.6	22.3	54.1	43.4	14.8	7.9	337.4	120.2	66.1
Semi Perm Deactivation (km)	0.6	0.0	0.0	0.0	0.0	0.0	4.6	0.0	16.4	19.9	0.0	0.0	41.5	36.3	19.9
Permanent Deactivation (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Moderate and High Sediment Source Roads (km)	0.0	0.0	0.0	0.4	0.3	0.0	0.0	0.0	0.3	2.4	1.0	0.0	4.4	3.7	3.4
Landslides (#)	4.0	1.0	1.0	5.0	3.0	3.0	2.0	0.0	4.0	7.0	0.0	0.0	30.0	11.0	7.0
Road on Potentially Unstable Terrain	3.7	0.0	1.0	1.8	4.5	6.6	0.0	0.4	9.0	15.2	4.3	2.2	48.7	30.7	21.7
Stream Crossings (#)	53	3	14	13	2	21	16	13	43	39	11	18	246	111	68
Stream Logged to the Bank (km)	22.5	1.5	4.0	7.5	0.2	7.2	15.3	2.7	8.4	9.2	1.9	6.7	89.1	26.2	19.8
Mainstem With Non-Functional Riparian Zone (km)	6.4	0.0	1.8	0.0	3.2	1.1	1.5	0.7	0	0.9	0	1.5	19.1	2.4	2.4
Disturbed Mainstem Channel (km)	20.4	0.0	1.8	0.0	3.2	1.1	1.5	0.7	8.8	1.3	0	1.5	40.3	11.6	2.8

*Permanently deactivated roads are not included in the road density calculation.

Wap Creek IWAP Report Card - 2006

Sub Drainage / POI	Wap Watershed												Watershed	Above Wap Lake	Upper Wap
									Above Wap Lake						
										Upper Wap					
Watershed Inventory Category	Wap Residual	Iron	Devil	Unnamed	Dale	Derry	Cavanaugh	Backyard	Residual Above Wap Lake	Residual Above Frog Falls	Joss	Upper Wap	POI 1	POI 2	POI 3
Area (ha)	8722	1260	968	949	596	4710	2843	2836	5568	1747	1603	3772	35574	12690	7122
H60 Elevation (m)	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240	1240
Total Area Harvested/Burned (ha)	2310.8	213.8	301.8	611.0	152.1	396.2	958.4	686.5	941.5	524.9	162.1	216.9	7476.0	1845.4	903.9
Percent Area Harvested/Burned (%)	26.5%	17.0%	31.2%	64.4%	25.5%	8.4%	33.7%	24.2%	16.9%	30.0%	10.1%	5.8%	21.0%	14.5%	12.7%
Equivalent Clearcut Area (ECA) (ha)	1358.0	203.2	217.8	276.3	99.5	329.6	503.4	495.7	866.7	402.4	156.8	188.0	5097.4	1613.9	747.2
Equivalent Clearcut Area (ECA) (%)	15.6%	16.1%	22.5%	29.1%	16.7%	7.0%	17.7%	17.5%	15.6%	23.0%	9.8%	5.0%	14.3%	12.7%	10.5%
ECA Above H60 (ha)	409.8	156.3	178.6	218.2	96.7	181.3	79.1	484.5	590.3	169.9	130.4	82.8	2777.9	973.4	383.1
ECA Above H60 (%)	4.7%	12.4%	18.5%	23.0%	16.2%	3.8%	2.8%	17.1%	10.6%	9.7%	8.1%	2.2%	7.8%	7.7%	5.4%
Road Density (km/km2)*	0.7	0.9	1.8	3.5	1.9	0.6	1.2	0.8	1.0	2.5	0.9	0.2	1.0	0.9	0.9
Total Road Length (km)	60.5	11.7	17.7	33.2	11.4	29.8	34.8	22.3	54.1	43.4	14.8	7.9	341.6	120.2	66.1
Semi Perm Deactivation (km)	0.6	0.0	0.0	0.0	0.0	0.0	0.5	0.0	16.4	3.6	0.0	0.0	21.1	20.0	3.6
Permanent Deactivation (km)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Moderate and High Sediment Source Roads (km)	0.0	0.0	0.0	0.4	0.3	0.0	0.0	0.0	0.3	2.4	1.0	0.0	4.4	3.7	3.4
Landslides (#)	4.0	1.0	1.0	5.0	3.0	3.0	2.0	0.0	4.0	7.0	0.0	0.0	30.0	11.0	7.0
Road on Potentially Unstable Terrain	3.7	0.0	1.0	1.8	4.5	6.6	0.0	0.4	9.0	15.2	4.3	2.2	48.7	30.7	21.7
Stream Crossings (#)	58	5	14	13	2	21	16	13	43	39	11	18	253	111	68
Stream Logged to the Bank (km)	22.5	1.9	4.0	7.5	0.2	7.3	15.3	2.7	8.4	9.2	1.9	8.7	89.6	28.2	19.8
Mainstem With Non-Functional Riparian Zone (km)	8.4	0.0	1.8	0.0	3.2	1.1	1.5	0.7	0	0.9	0	1.5	19.1	2.4	2.4
Disturbed Mainstem Channel (km)	20.4	0.0	1.8	0.0	3.2	1.1	1.5	0.7	8.8	1.3	0	1.5	40.3	11.6	2.8

*Permanently deactivated roads are not included in the road density calculation.

APPENDIX E

Field Photographs

PHOTO 1. Lower Devil Creek showing the bank failures that caused the debris flood onto the fan in the spring of 1999.

PHOTO 2. Dale Creek fan showing partial recovery from 1990s debris flow. Note limited recovery on bank failures upstream of the fan.

PHOTO 3. Lower road access to opening 226 on the south side of the residual above Wap Lake. The road was re-contoured following the occurrence of landslides 20 and 21 but remains a source of fine sediment to Wap Creek.

PHOTO 4. Eroding cutslope on the 9019 road before the first crossing on the largest northeast tributary channel in the residual above Wap Lake. Regular slumping with sediment transport through the ditch is causing turbidity in the tributary.

PHOTO 5. Iron Road crossing on Un-named Creek showing three old drainage related landslides into the channel and several road sections with unstable cutslopes.

PHOTO 6. Road drainage related landslide into Iron Creek from the IceBox Mainline. No cross-drains are present along the road section above the slide, allowing concentrated drainage to flow onto the steep gully sidewall of Iron Creek.

PHOTO 7. Road drainage related bank failures along Derry Creek below the Derry FSR. Note the discharge onto the bank failure shortly after a spring rainfall event.

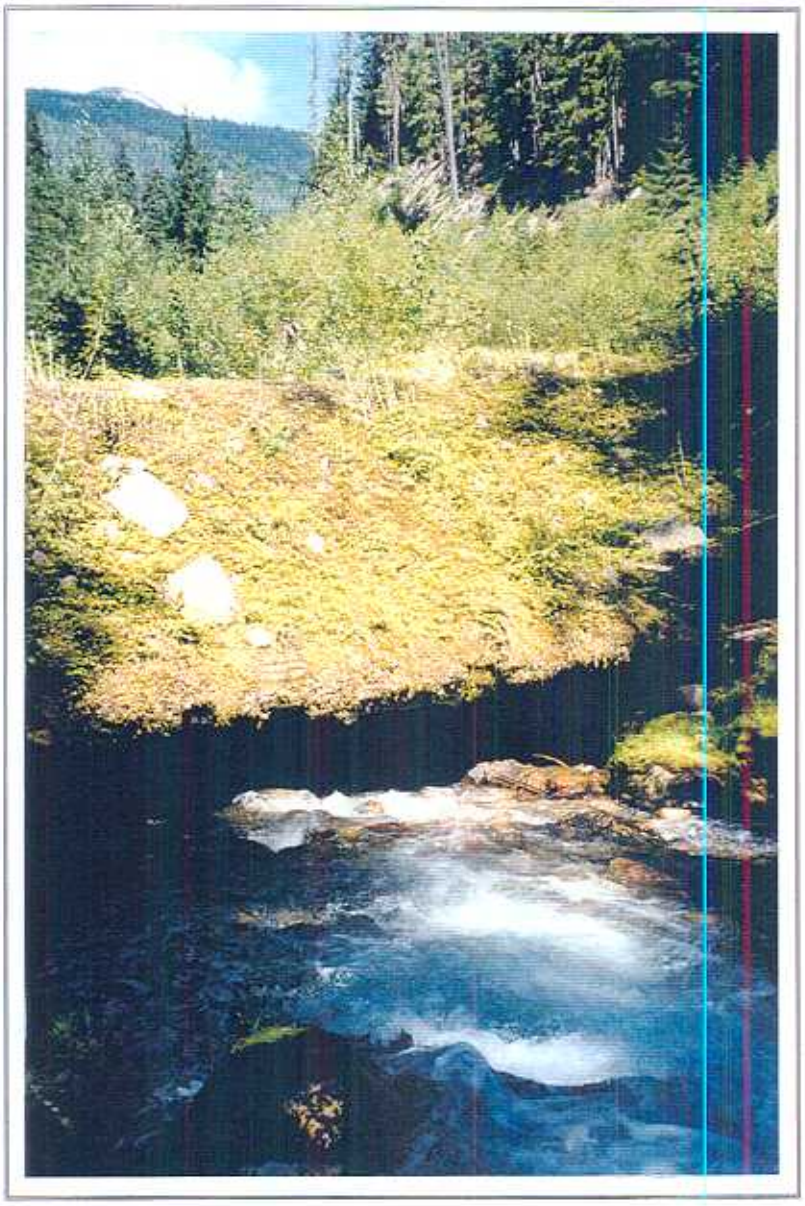


PHOTO 8. Fill loaded onto the wood culvert over Fennell Creek on the Derry FSR. The structure is rotting and may fail into the channel.

PHOTO 9. Old composite crossing on the 4th tributary beyond Fennell Creek on the Derry FSR. This structure should be removed or upgraded to prevent further sediment and debris input to the tributary channel.

PHOTO 10. Backyard Creek mainstem channel on the plateau above Wap Lake. Note the low rolling terrain dominated by sand and gravel outwash deposits. Channel stability is good on the plateau and no major sediment sources were noted.

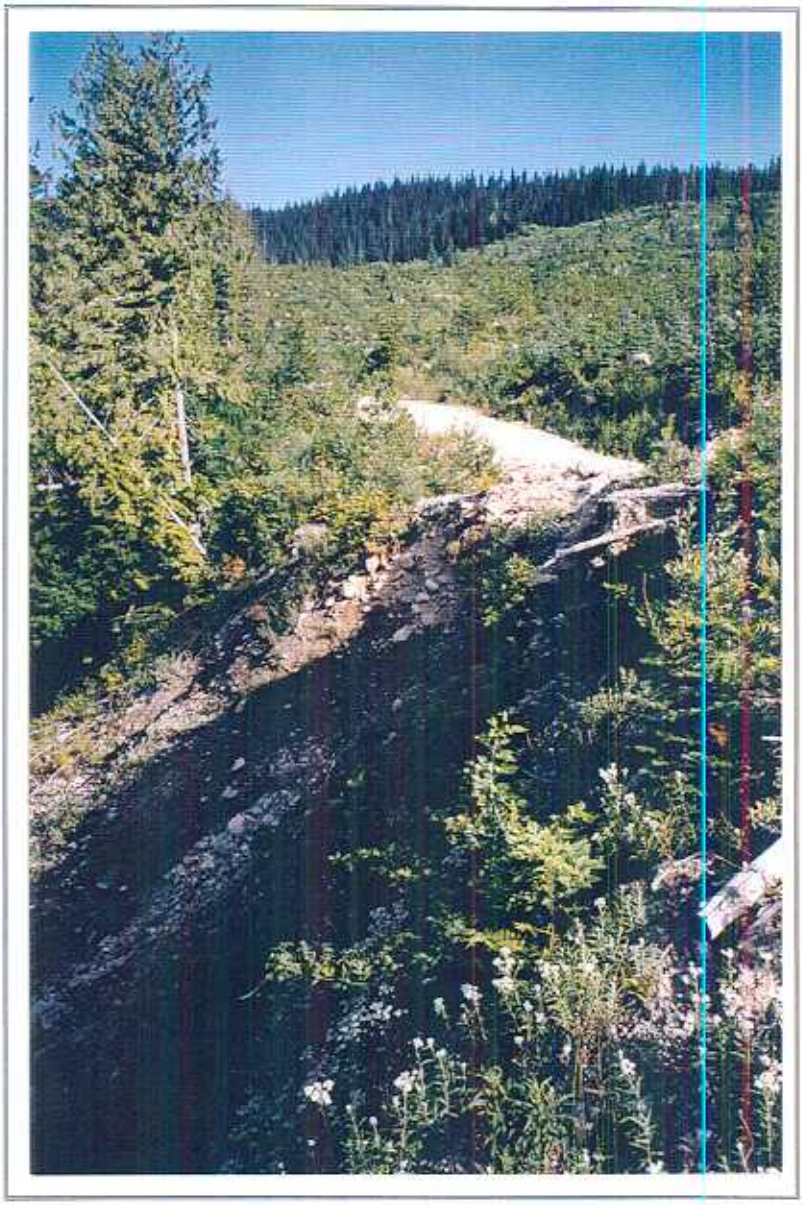


PHOTO 11. Landslide #19 from the 9019 road into the northeast tributary in the residual above Wap Lake. This slide was caused by drainage diversion onto an overloaded fillslope.

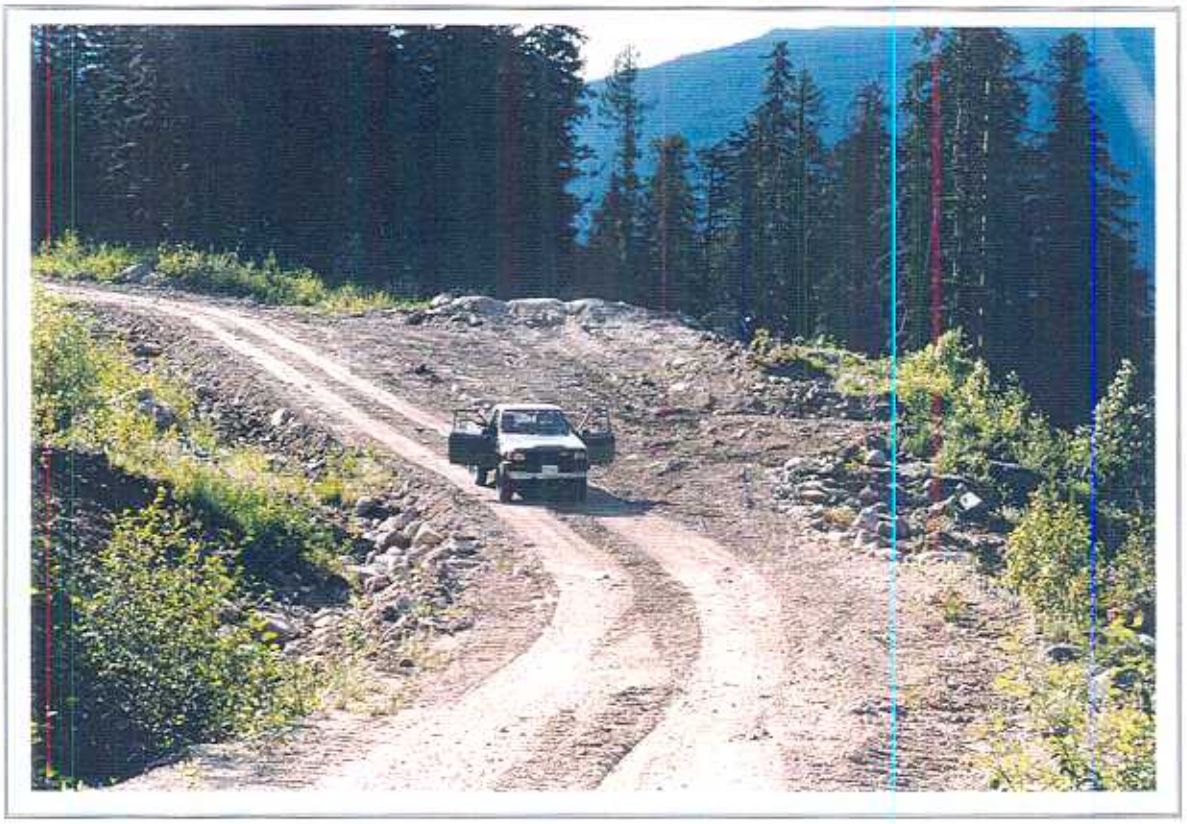


PHOTO 12. Recent fill material piled atop landslide #19. This site continues to be oversteepened which may lead to additional landslides into the tributary channel.

PHOTO 13. Recent road improvement spoils dumped onto an oversteepened fill draining into a small tributary beyond the large northeast tributary crossing on the 9019 road.

PHOTO 14. Failed crib wall on the 100 road that triggered a landslide into the Wap mainstem channel in the residual above Frog Falls. Similar cribbing structures are present along other portions of the 100 road in the general area.

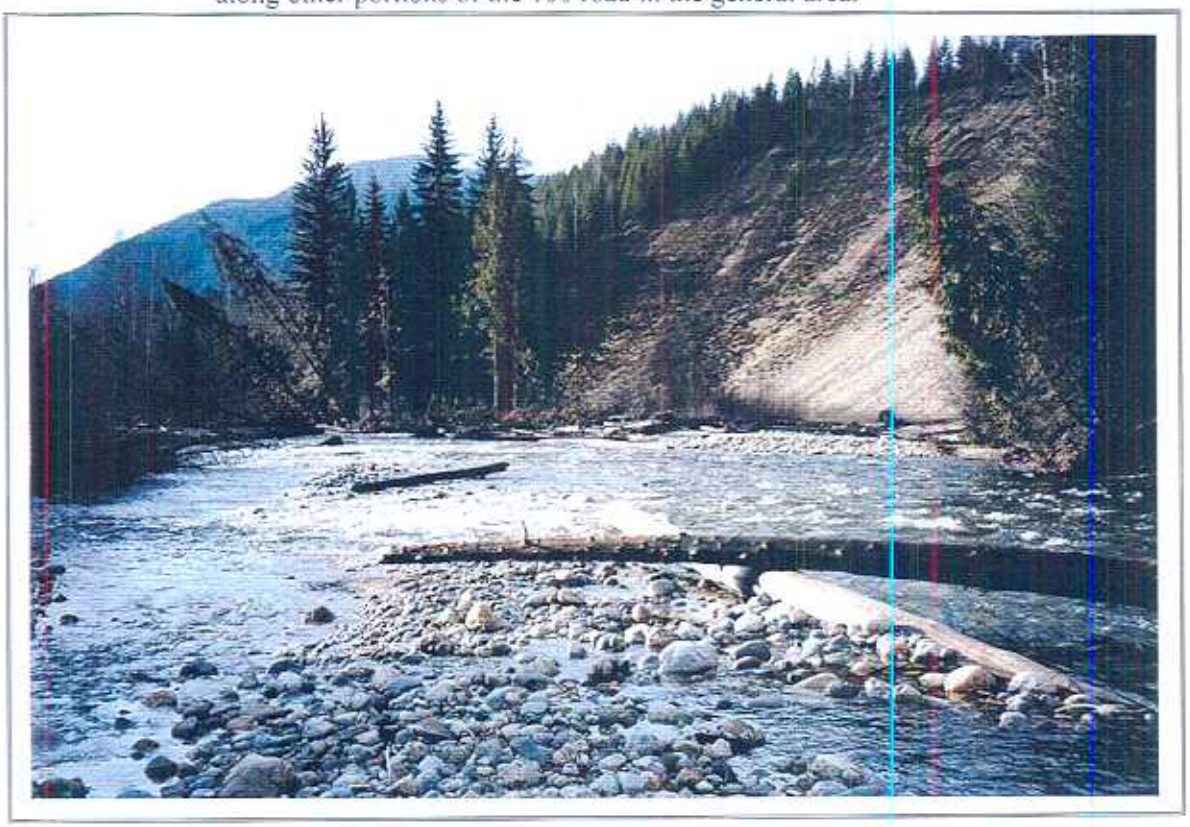


PHOTO 15. The lowermost large bank failure on Wap Creek immediately downstream of the Derry Creek confluence. The majority of flow has been diverted away from this lower failure by aggradation and debris accumulation in the side channel leading to the toe of the slope.

PHOTO 16. The second large bank failure on Wap Creek that is currently contributing sediment to the channel. The dimensions of the two failures are approximately 50 m high and cumulatively 150 to 200 m wide.

PHOTO 17. View upstream to the lower failure showing the active channel width and partial re-vegetation on the raveling slope.

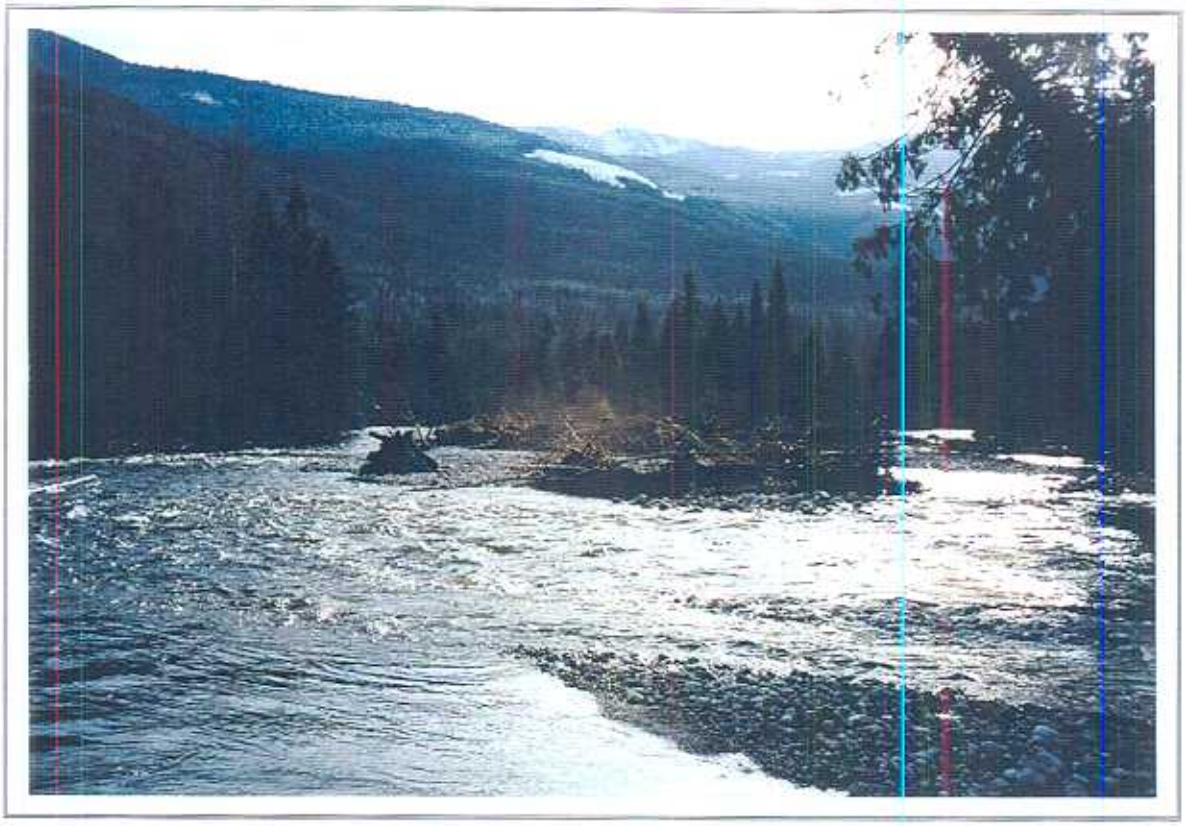


PHOTO 18. Wap mainstem channel downstream of the two large bank failures showing the active channel width and instream debris from the failures and bank erosion.

PHOTO 19. Blowdown into reach C4 of Cavanaugh Creek. No major channel obstructions caused by the blowdown were noted.

PHOTO 20. Cavanaugh Creek flowing under the BC Hydro transmission line. Some channel widening and bank erosion has occurred through this reach but regeneration of deciduous and coniferous species has limited long-term disturbance.

PHOTO 21. Riparian regeneration along Cavanaugh Creek beneath the BC Hydro line. Note old stumps on the banks and instream sediment bars from localized and upstream bank erosion.

PHOTO 22. Two washed out road crossings on the Ohashi Road through opening 42 in the Cavanaugh Creek sub-basin. The two structures have caused some localized disturbance and should be removed.

PHOTO 23. Failed road crossing on a trail between openings 41 and 43 in the upper Cavanaugh sub-basin. Bank erosion is occurring at this site which is the uppermost source of turbidity in the system.

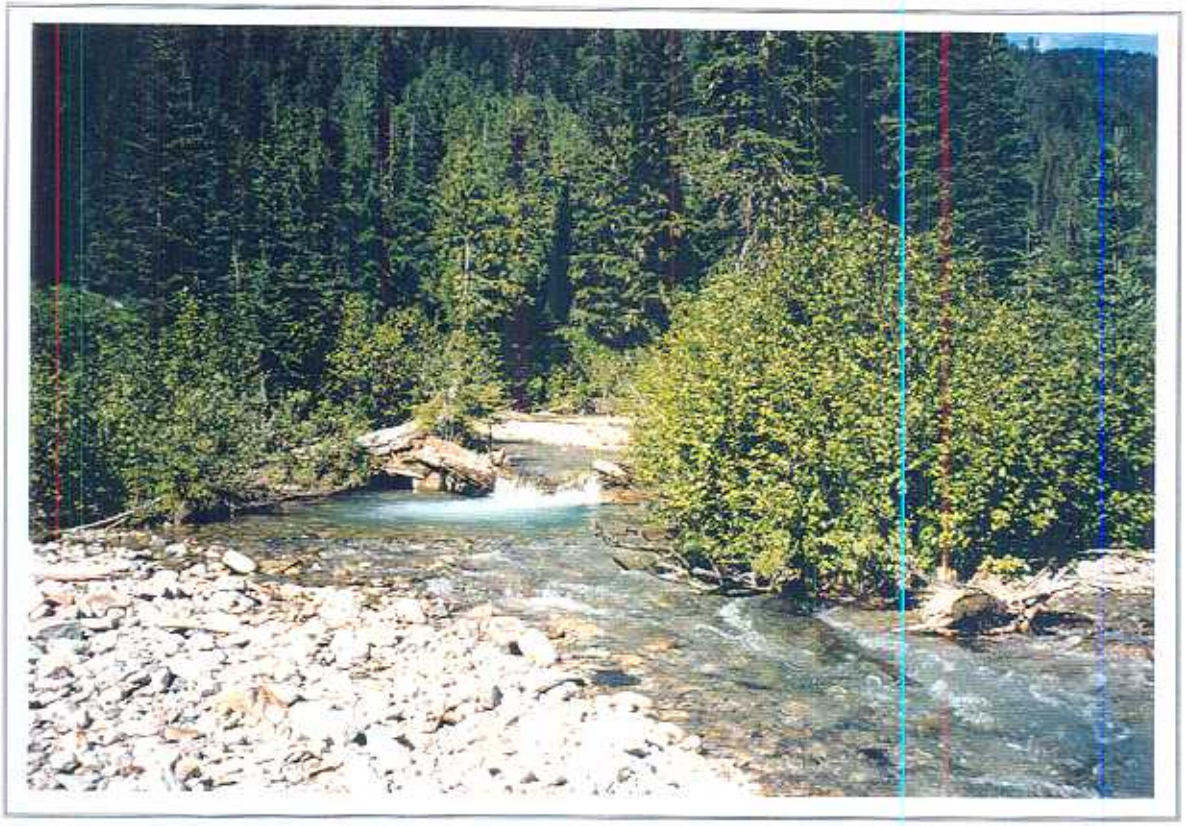


PHOTO 24. Reach D4 of Derry Creek flowing through opening 7. The channel was disturbed by past harvesting in the riparian zone but is recovering with deciduous and coniferous regeneration on the banks.

PHOTO 25. Reaches D4 and D5 of Derry Creek showing past riparian harvest, and landslide 15 that did not impact the channel.

PHOTO 26. Upper Backyard Creek fan showing disturbance that appears to be the result of increased discharge (peak flow) following wildfire and beetle salvage harvesting on the plateau.

PHOTO 27. Backyard Creek in the mid-fan area showing the active transport of large boulders and ongoing bank erosion and woody debris input.

PHOTO 28. The second hydro-electric diversion structure on Wap Creek upstream of Frog Falls. This structure is no longer active but has caused considerable channel disturbance by increasing velocity through the structure and into the alluvial channel downstream.

PHOTO 29. Channel disturbance downstream of the second diversion structure.

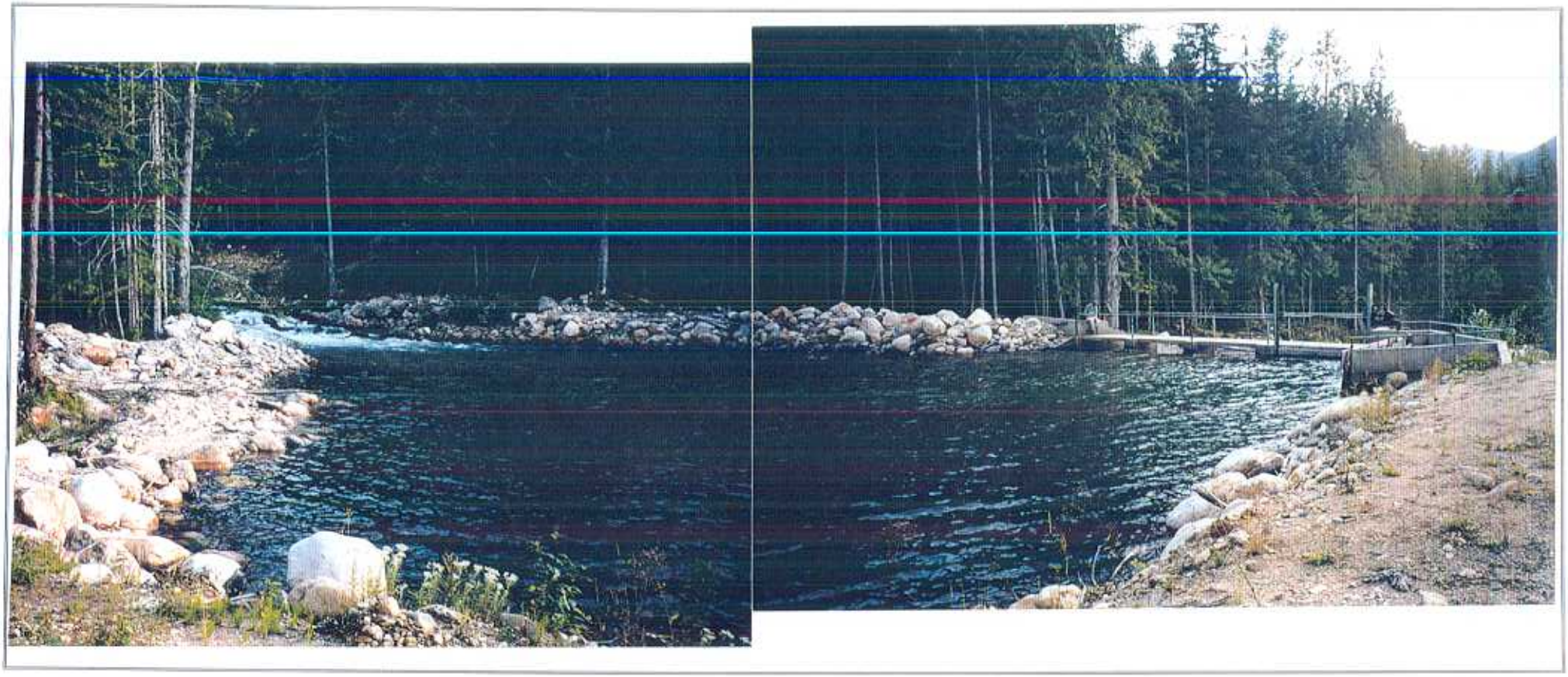


PHOTO 30. The third and uppermost hydro-electric diversion structure at the apex of the alluvial fan upstream of Frog Falls. Note the alluvial fill materials used to contain the small intake pond.

PHOTO 31. New channel formed by the 1997 avulsion around the third diversion structure. Overflow from the dam is reported to be a regular occurrence during periods of frazzle ice formation in the late fall or woody debris accumulation in the spring.

PHOTO 32. Channel disturbance immediately downstream of the outfall from the third diversion structure.

PHOTO 33. Channel disturbance downstream of the old crossing on Upper Wap Creek. Note the eroding cutbank in the centre of the photograph and increased channel width from aggradation downstream of the initial disturbance site.

PHOTO 34. View of the compacted glacial till and glacio-fluvial bank noted in photograph 33. This site represents the uppermost source of turbidity in the Wap Creek system.

APPENDIX F

Sediment Source Survey Table

Watershed Name: *Wap Creek*

Sub-Basin: *Entire Watershed*

Sediment Point Source Survey Inventory

#	*Type*	*Origin*	*Cause*	*Transport Route*	*Conectivity*	*Length (m)*	*Width (m)*	*Total Area (ha)*	*Comments*
1	DS	GS	R	GS	IM	150	15	0.225	From drainage diversion on last switchback on Ice Box M/L.
2	DF	FS	R	GC	IM	3960	10	3.96	Torrent to the mouth caused by early 70s fillslope failure.
3	DF	GH	N	GC	NC	200	3	0.06	Small natural gully torrent.
4	DF	GH	N	GC	NC	200	3	0.06	Small natural gully torrent.
5	DS	GS	CC	GS	IM	70	10	0.07	Approximately 15 to 20 years old. Partial revegetation.
6	DS	GS	CC	GS	IM	50	10	0.05	Approximatley 15 to 20 years old. Partially revegetated.
7	DS	GS	R	GS	IM	30	10	0.03	Approximately 15 to 20 years old. Partially revegetated.
8	DS	OS	R	OS	NC	75	20	0.15	Approximately 15 to 20 years old. Partially revegetated.
9	DS	GS	R	GS	IM	75	15	0.1125	Approximatley 10 to 15 years old. Drainage diversion from road.
10	DS	GS	R	GS	IM	45	20	0.09	Not revegetated. Road drainage onto gully sidewall.
11	DF	GH	R	GC	IM	4440	10	4.44	Torrent from fill failure to mouth late 80s or early 90s.
12	DF	GH	R	GC	IM	4440	10	4.44	Torrent from fill failure to mouth in early 90s.
13	DS	FS	R	GS	IM	50	20	0.1	Partially revegetated.
14	DS	GS	R	GS	IT	40	20	0.08	Partially revegetated.
15	DS	OS	CC	OS	NC	100	40	0.4	No sediment delivery.
16	DF	GC	N	GC	IT	1000	5	0.5	Small natural gullly torrent.
17	DS	OS	N	OS	NC	200	50	1	No sediment delivery.

Types: Falls (F), Creep (C), Slumps and Earthflows (S or EF), Bedrock Failure (BF), Debris Avalanch/Slide (DA or DS), Debris Flow/Torrent (DF)

Cause: Road (R), Clearcut (Cc), Natural (N), Other (O)

Origin/Transport Route: Open Slope (os), Fill slope (fs), Cut slope (cs), Gully headwall (gh), Gully channel (gc), Gully sidewall (gs)

Connectivity: Into Tributary (it), Into Mainstem (im), Not Connected (nc)

#	Type	Origin	Cause	Transport Route	Conectivity	Length (m)	Width (m)	Total Area (ha)	Comments
18	DS	FS	R	GS	IT	150	20	0.3	Partial revegetation, drainage corrected.
19	DS	FS	R	GS	IT	150	50	0.75	Oversteepened fill and landing, partial revegetation.
20	DS	OS	R	GS	IT	75	10	0.075	Not revegetated.
21	DS	FS	R	GS	IT	75	20	0.15	Not revegetated but road deactivated.
22	DS	OS	R	OS	IM	700	30	2.1	Revegetated.
23	DF	GH	R	GC	IM	900	10	0.9	Partial revegetation. Caused by upslope drainage diversion.
24	S	GH	CC	GC	IM	300	40	1.2	Slump from glacio-fluvial terrace.
25	DS	FS	R	OS	IM	150	250	3.75	Partial pull-back of fill and headscarp. Not revegetated.
26	DF	GH	R	GC	IM	200	15	0.3	Not revegetated.
27	DF	GH	R	GC	IM	200	15	0.3	Not revegetated.
28	DF	GH	R	GC	IM	200	15	0.3	Not revegetated.
29	DS	GS	R	GS	IM	60	15	0.09	Road drainage related. Partially revegetated.
30	DS	GS	R	GS	IM	60	15	0.09	Road drainage related. Partially revegetated.

Types: Falls (F), Creep (C), Slumps and Earthflows (S or EF), Bedrock Failure (BF), Debris Avalanch/Slide (DA or DS), Debris Flow/Torrent (DF)

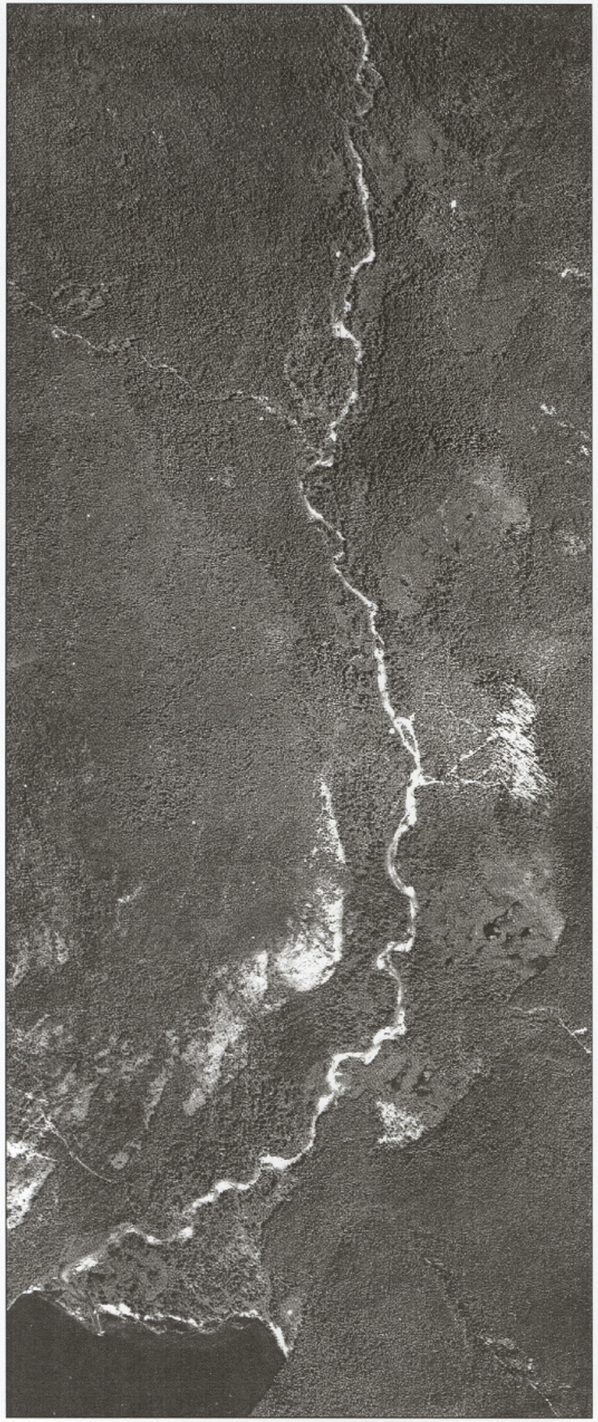
Cause: Road (R), Clearcut (Cc), Natural (N), Other (O)

Origin/Transport Route: Open Slope (os), Fill slope (fs), Cut slope (cs), Gully headwall (gh), Gully channel (gc), Gully sidewall (gs)

Connectivity: Into Tributary (it), Into Mainstem (im), Not Connected (nc)

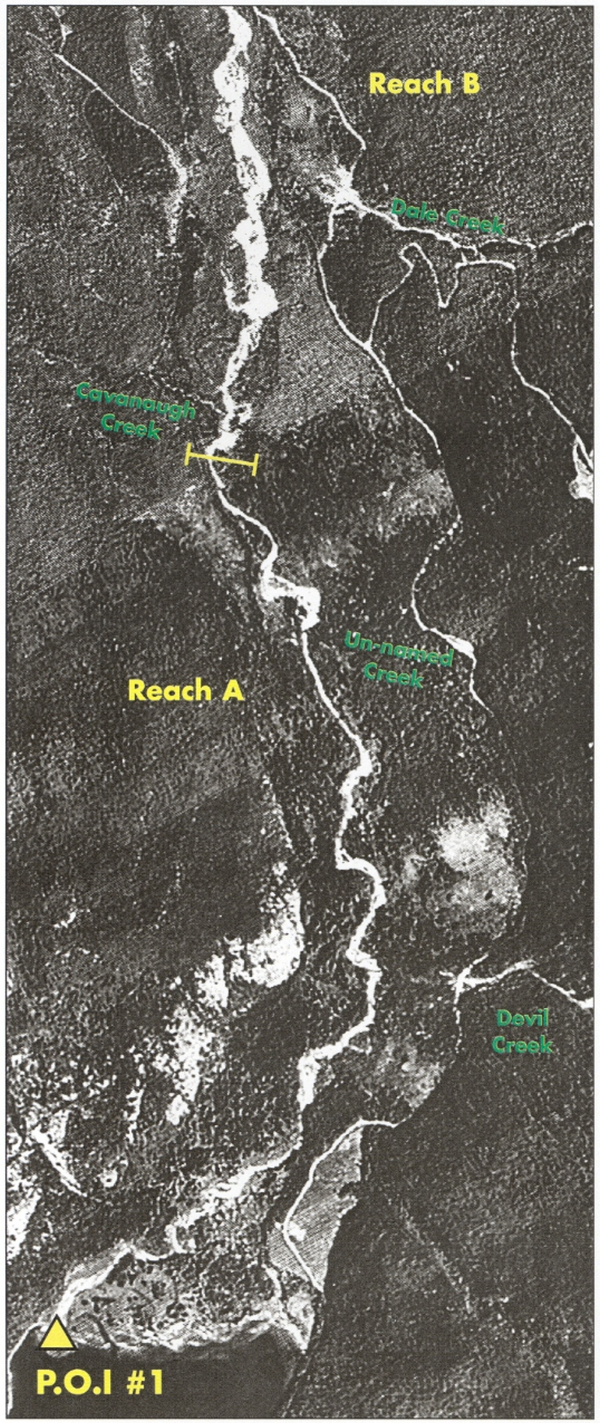
APPENDIX G

Historic Time Series Assessment

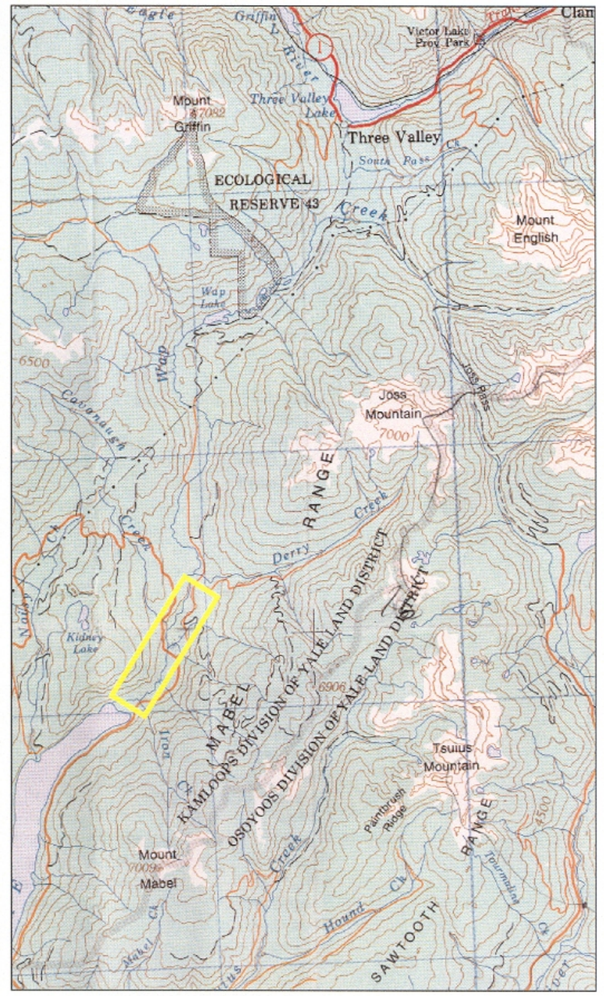


1959

1984



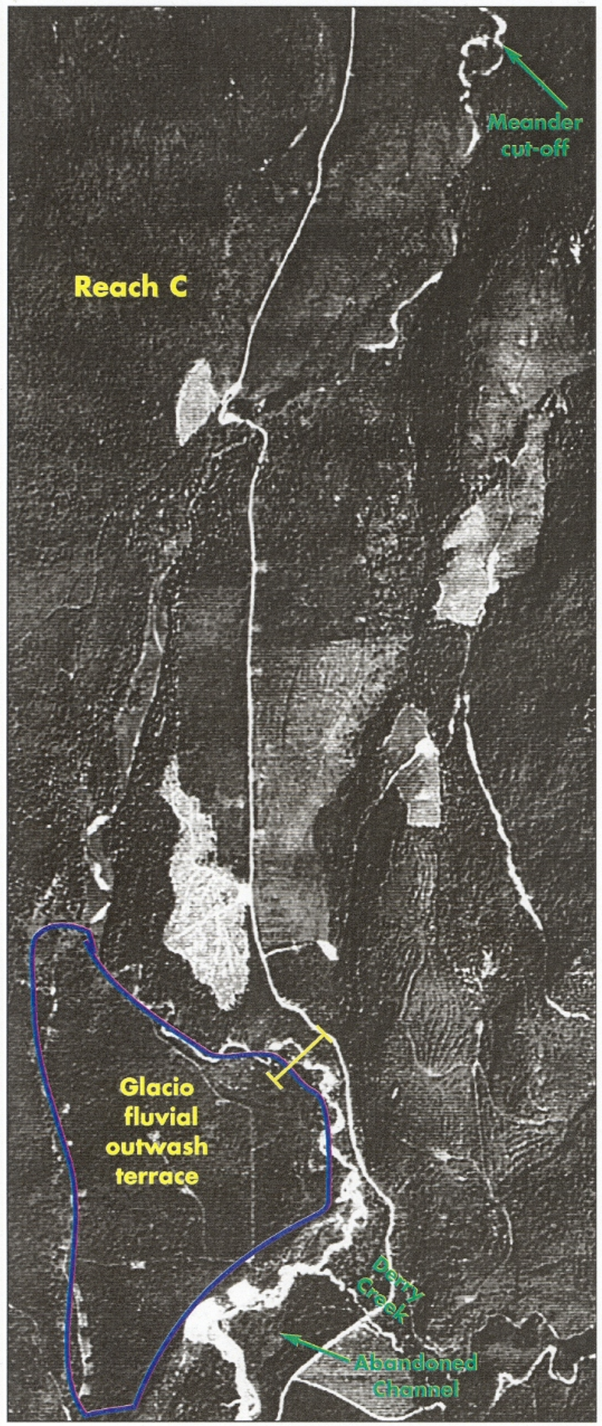
1997



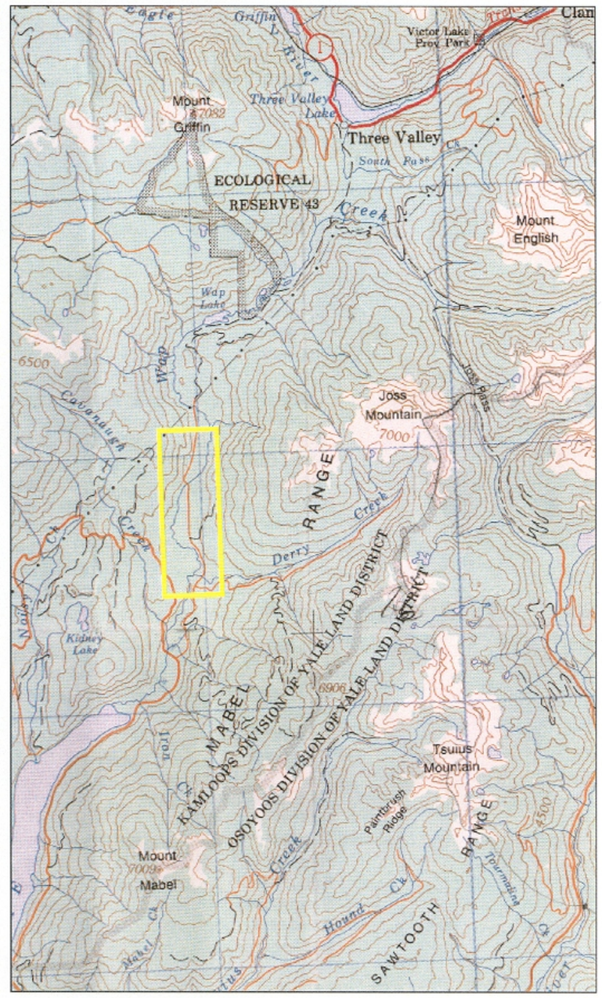
- Lower reaches of the Wap mainstem channel showing natural bar development and some side channels on the alluvial floodplain (1959).
- Significant disturbance is visible in 1984 and 1997 from very high sediment input from upstream bank failures and localized bank erosion. The active channel is up to 400% wider from sediment loading, the channel is straighter and mid channel bars are extensive.
- Much of the lower floodplain was selectively logged prior to 1959. The historic logging is not the cause of disturbance.
- Note the Dale and Devil Creek alluvial fans that dispersed the majority of sediment and debris from the road fill initiated debris flows. A minimal amount of coarse sediment from the debris flows actually reached the Wap mainstem channel.

1959

1984



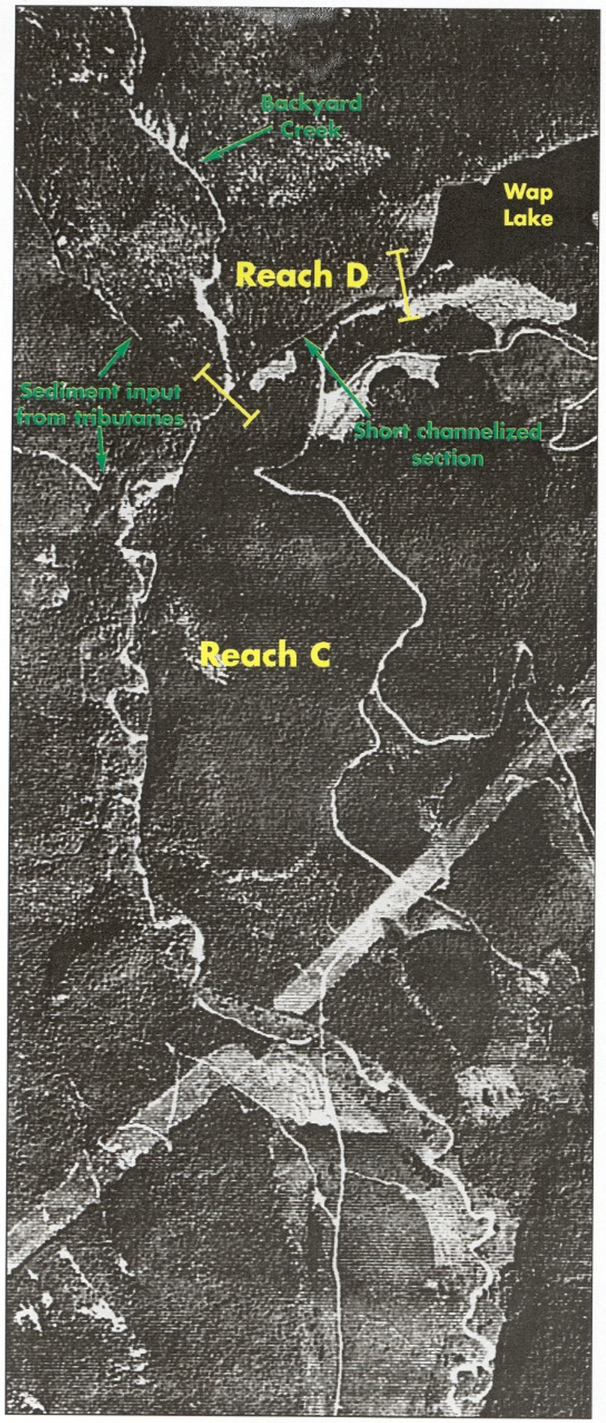
1997



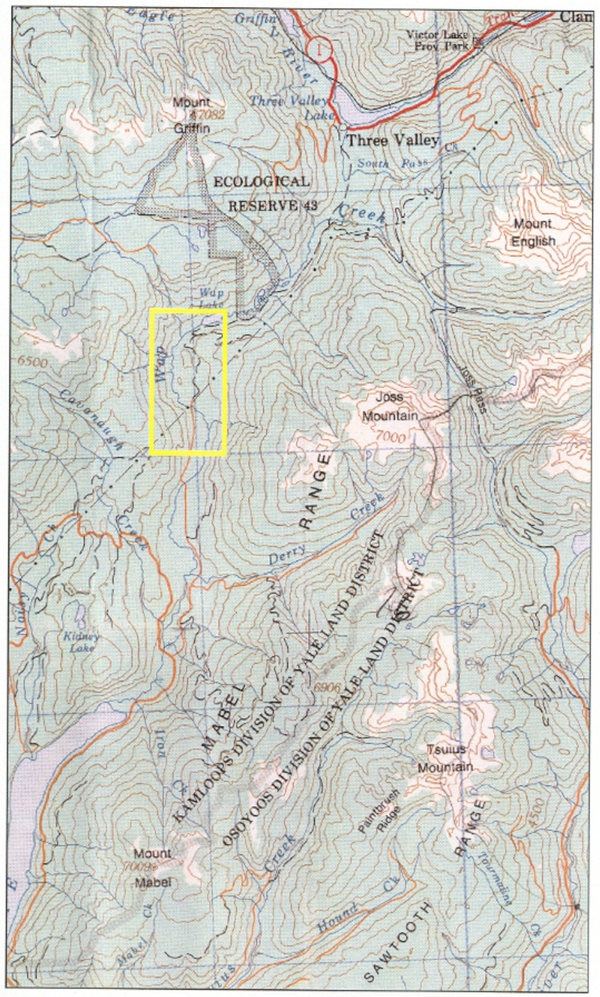
- Upper Reach B and lower Reach C showing the large bank failures that are occurring following harvest of the large block on an historic glacio-fluvial outwash terrace.
- Upstream of the large bank failures some increase in sediment load is visible with bar development and a meander cut-off. The increase in sediment load visible upstream of the bank failures is thought to be from natural tributary input following 1960's wildfires.
- Note evidence of an abandoned channel near the bank failures that could be used to divert flow away from the erodable outwash slope in order to revegetate and stabilize. Mature vegetation on the outwash slope was providing stability in 1959.
- Also note increased sediment load on the Derry Creek fan from upstream road sediment sources and harvesting on the south side of the fan.

1959

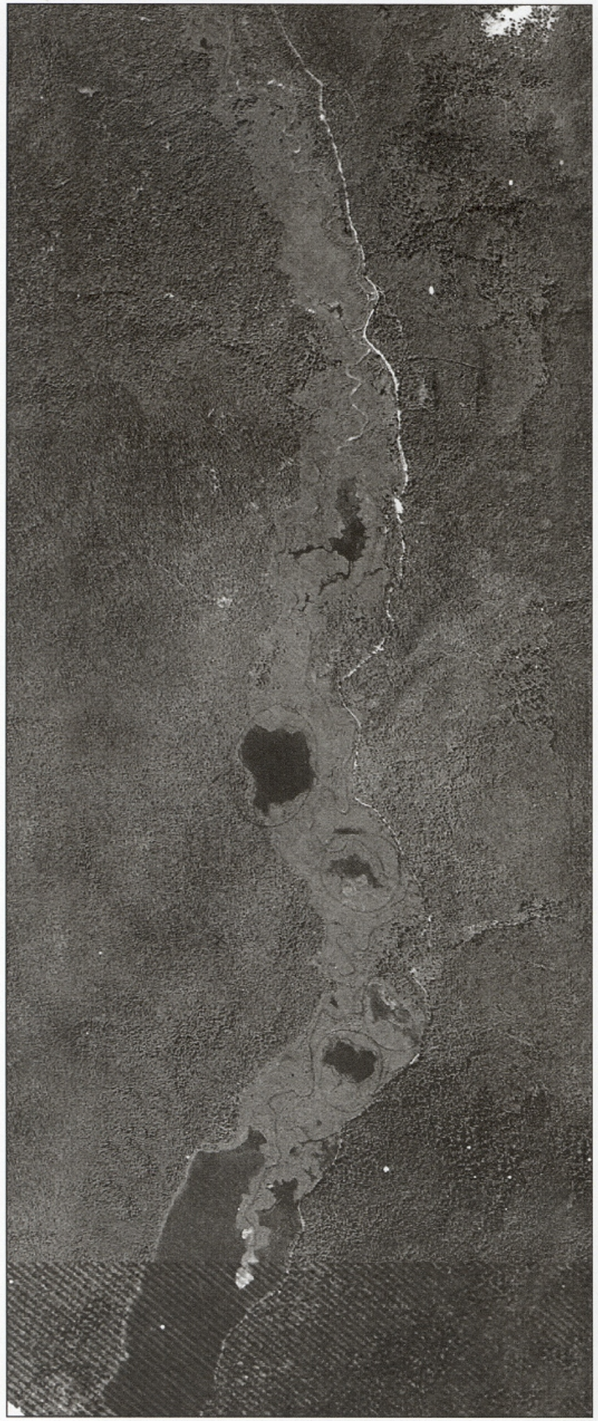
1984



1997

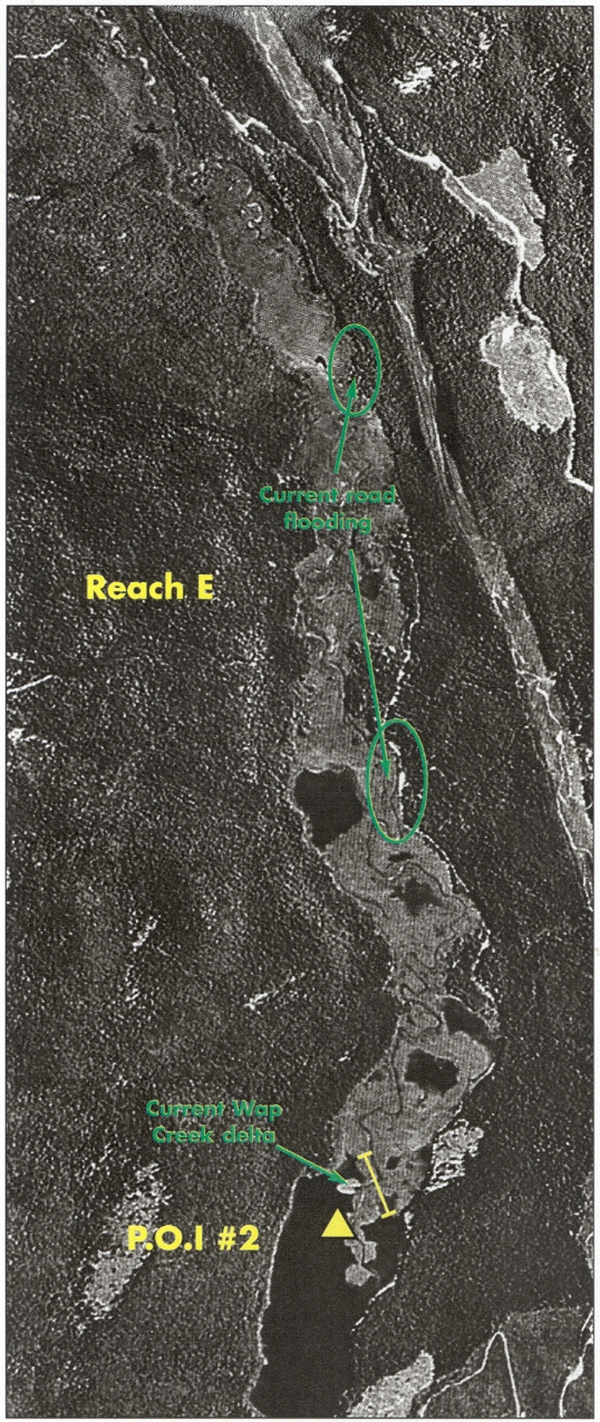


- Upper Reach C and Reach D downstream of Wap Lake. The mainstem channel morphology has remained unchanged with sediment loading from Backyard Creek and other small tributaries along the west and north side of the valley.
- Much of the upper Backyard Creek sub-basin and north valley wall between Wap Lake and the powerline burned between 1960 and 1965. Channel and gully destabilization in the small tributaries and steep reach of Backyard Creek appears to have transported a significant volume of sediment to the Wap mainstem. The two small tributaries and lower Backyard Creek remain unstable but are recovering.
- The transport of sediment in Reach C of Wap Creek is slow based on a very low gradient. Minor aggradation will persist in the channel until the tributaries recover and instream gravel and sand bars revegetate.

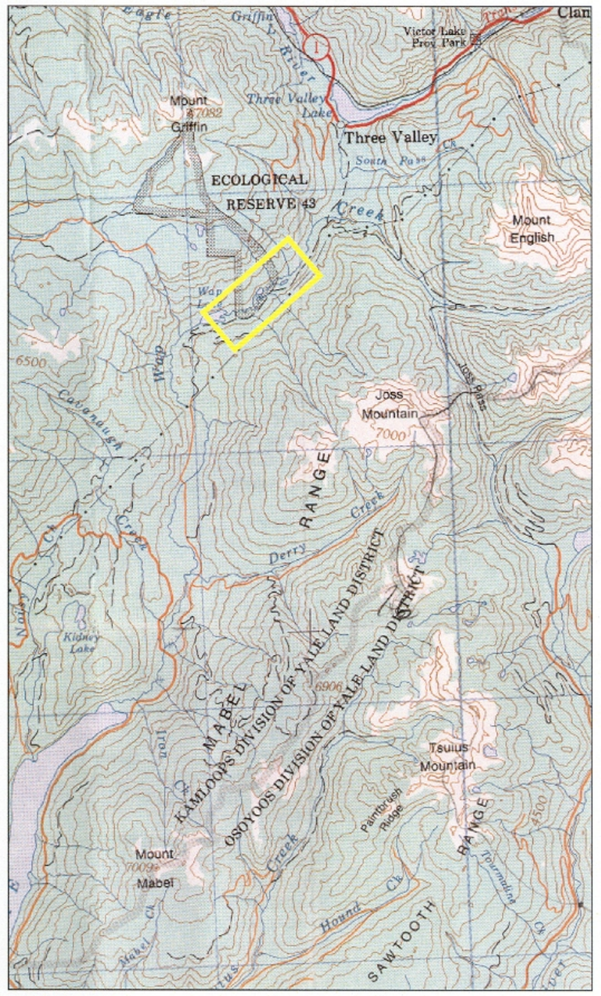


1959

1984

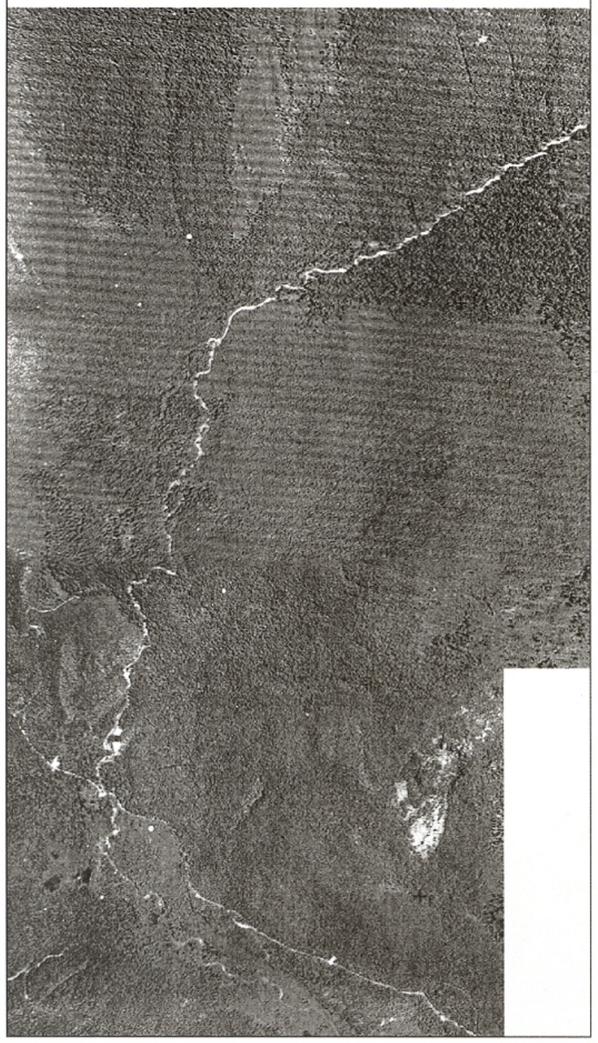


1997



- Reach E and lower Reach F upstream of Wap Lake. An increase in sediment supply has occurred in these reaches from upstream landslides. Lower reach F is a large fan that shows channel widening and lateral movement in response to the increase in sediment load.
- Some visible increase in channel bar area can be attributed to lower discharge in the 1984 and 1997 photos, but channel infilling with sand and small gravel has occurred throughout Reach E to Wap Lake.
- An avulsion did occur on the Wap delta building into Wap Lake between 1959 and 1984. The delta is a "birds foot" type with an elongated central deposition feature and small lateral lobes formed by natural avulsions. The most recent avulsion may have been partly caused by the increase in sediment load. No restoration is required.

Image Not Available

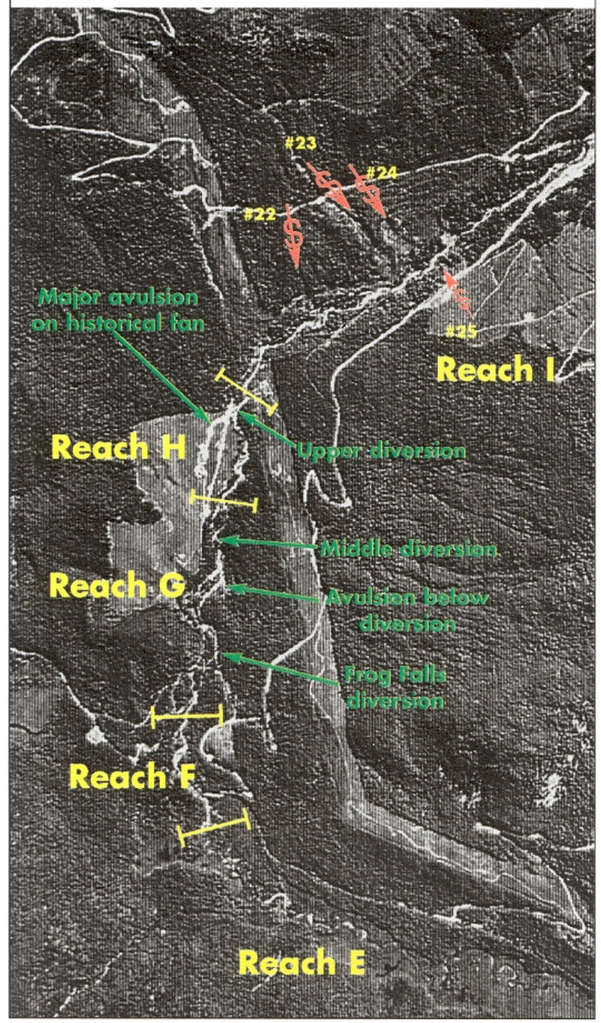


1959

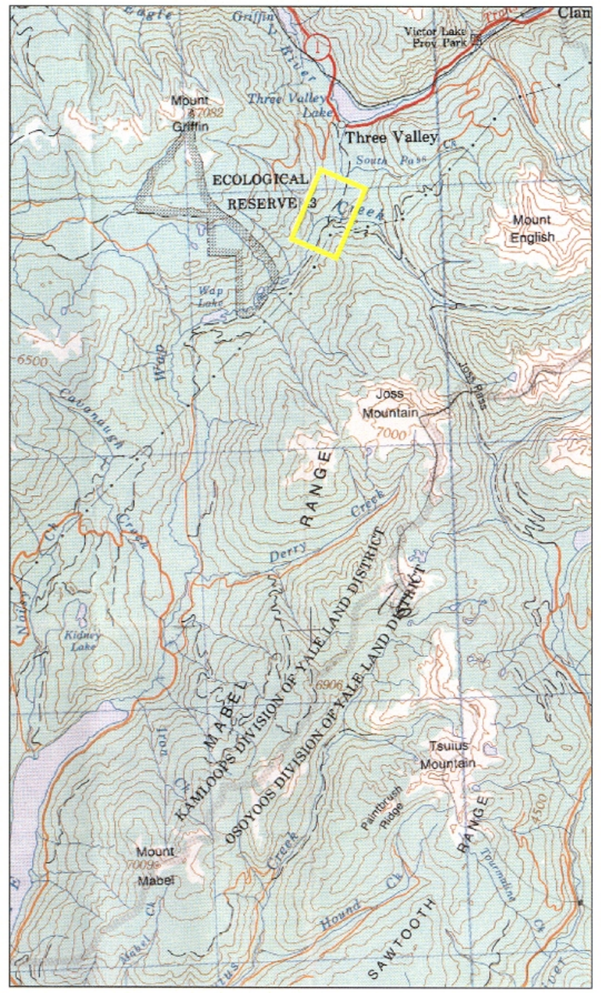
Image Not Available

1984

Image Not Available



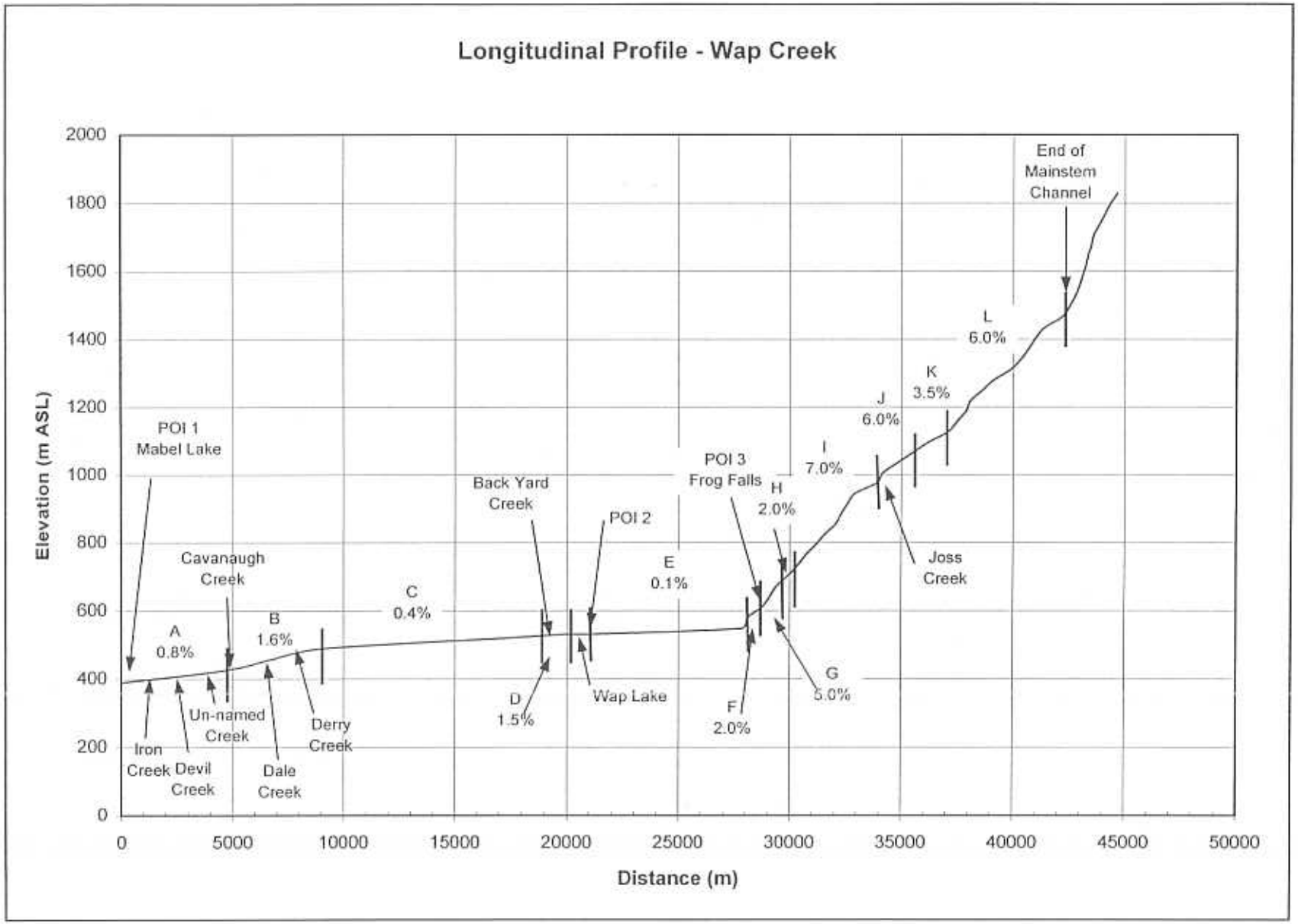
1997



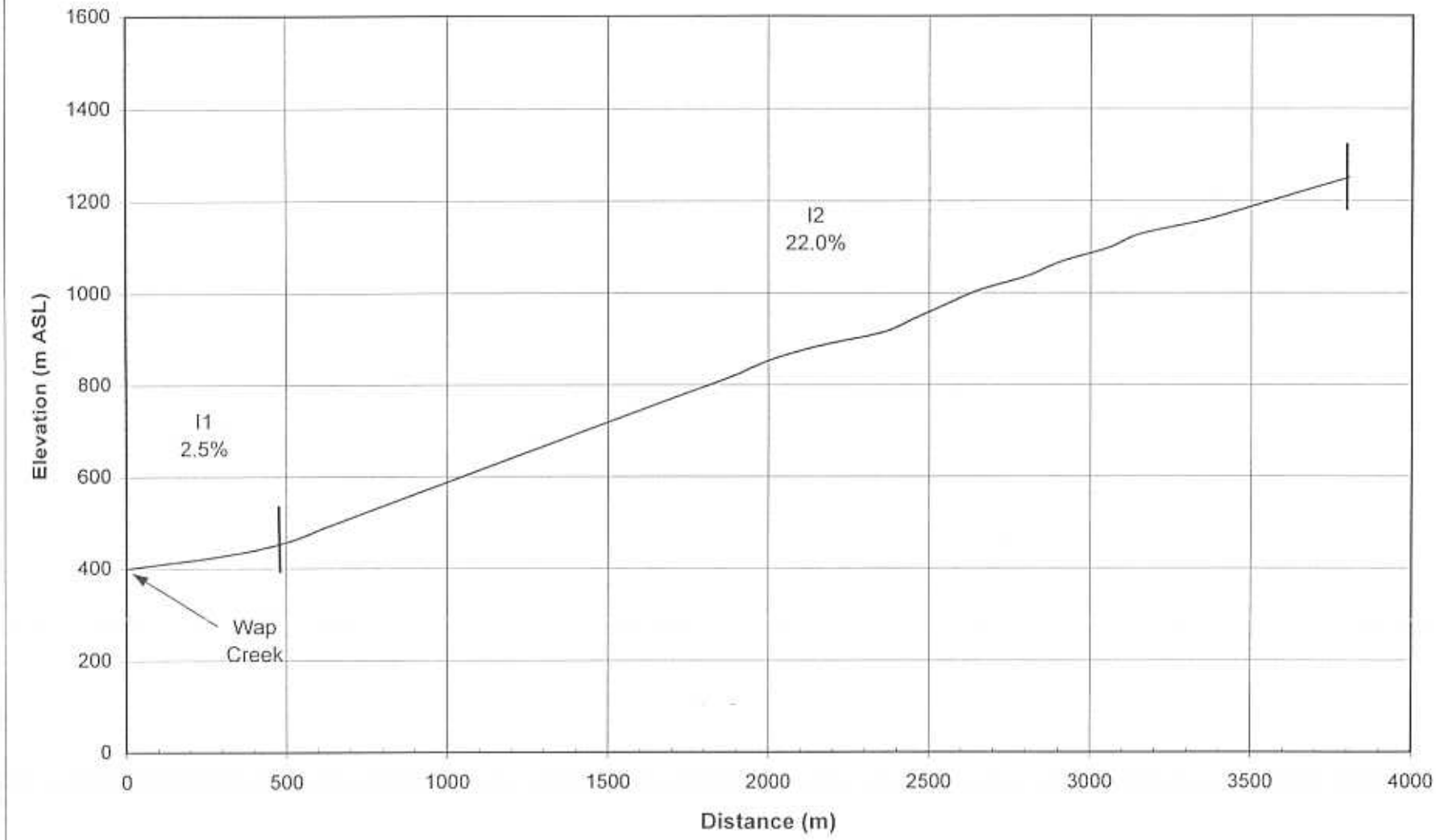
- Upper Reach E, Reaches F, G, H and lower I. The remainder of reach F is shown with disturbance from upstream landslide impact.
- Reach G is a bedrock and boulder controlled reach with limited disturbance. The Frog Falls hydro diversion is located at the top of the falls and has not caused any disturbance. Above the falls an avulsion is visible in 1984 that was reported to be caused by a large flood in 1983. The diversion is not currently active but still constricts flow increasing velocity and stream power.
- Reach H shows a major avulsion between 1984 and 1997 caused by flooding on the upper diversion at the apex of an historic fan.
- Sediment loading from landslides is visible through Reaches E, F, G and H from 1984 to present.

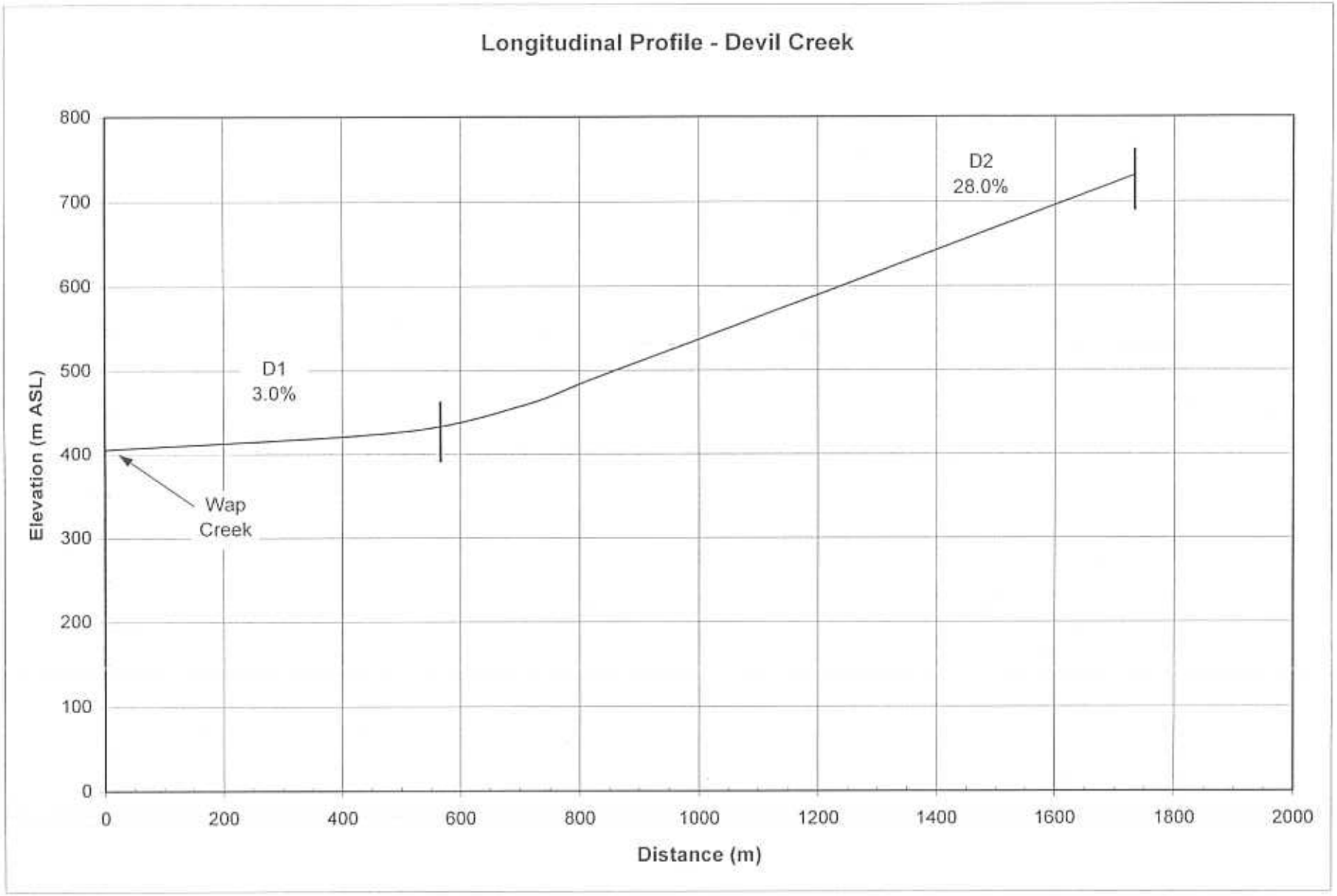
APPENDIX H

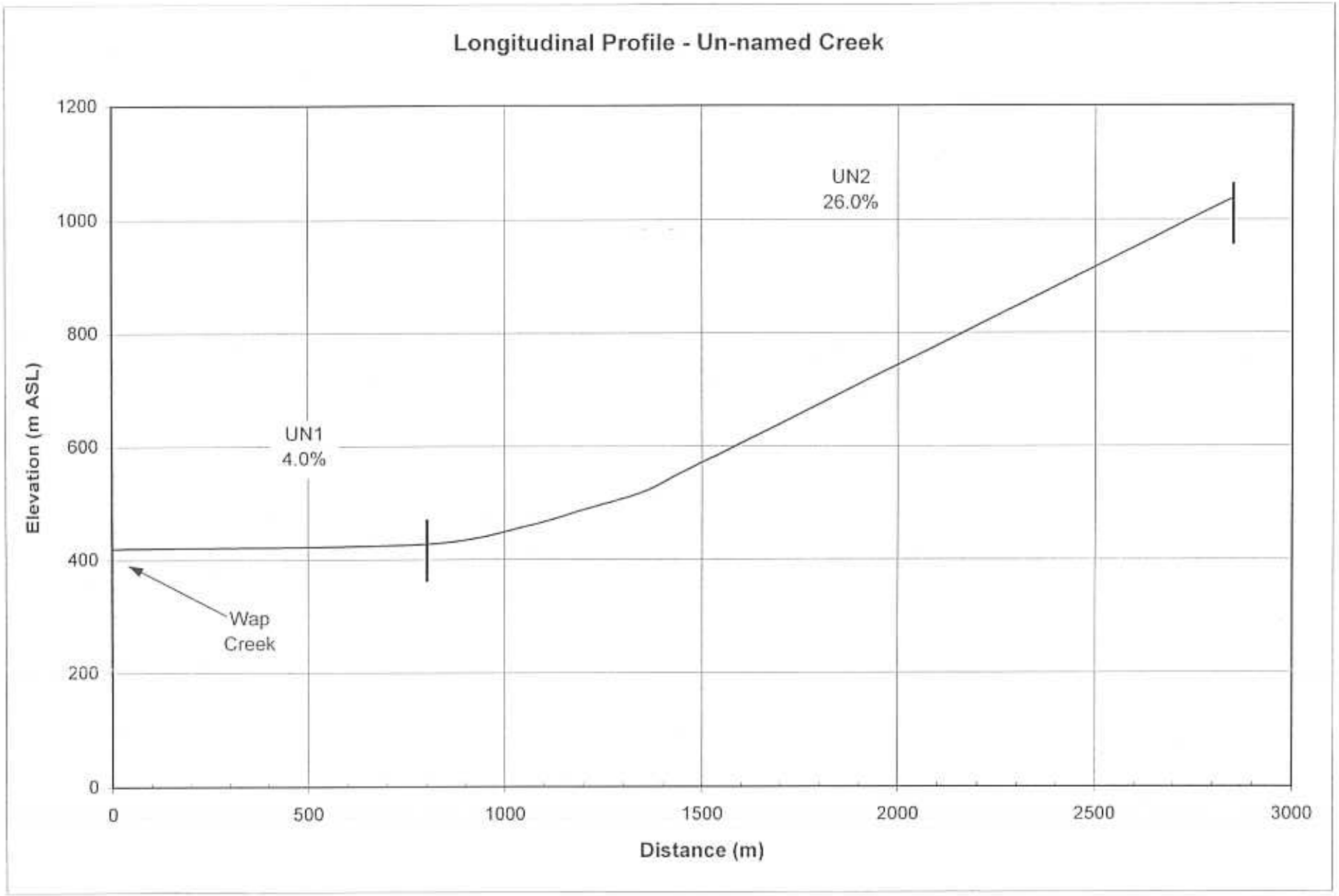
Longitudinal Profiles

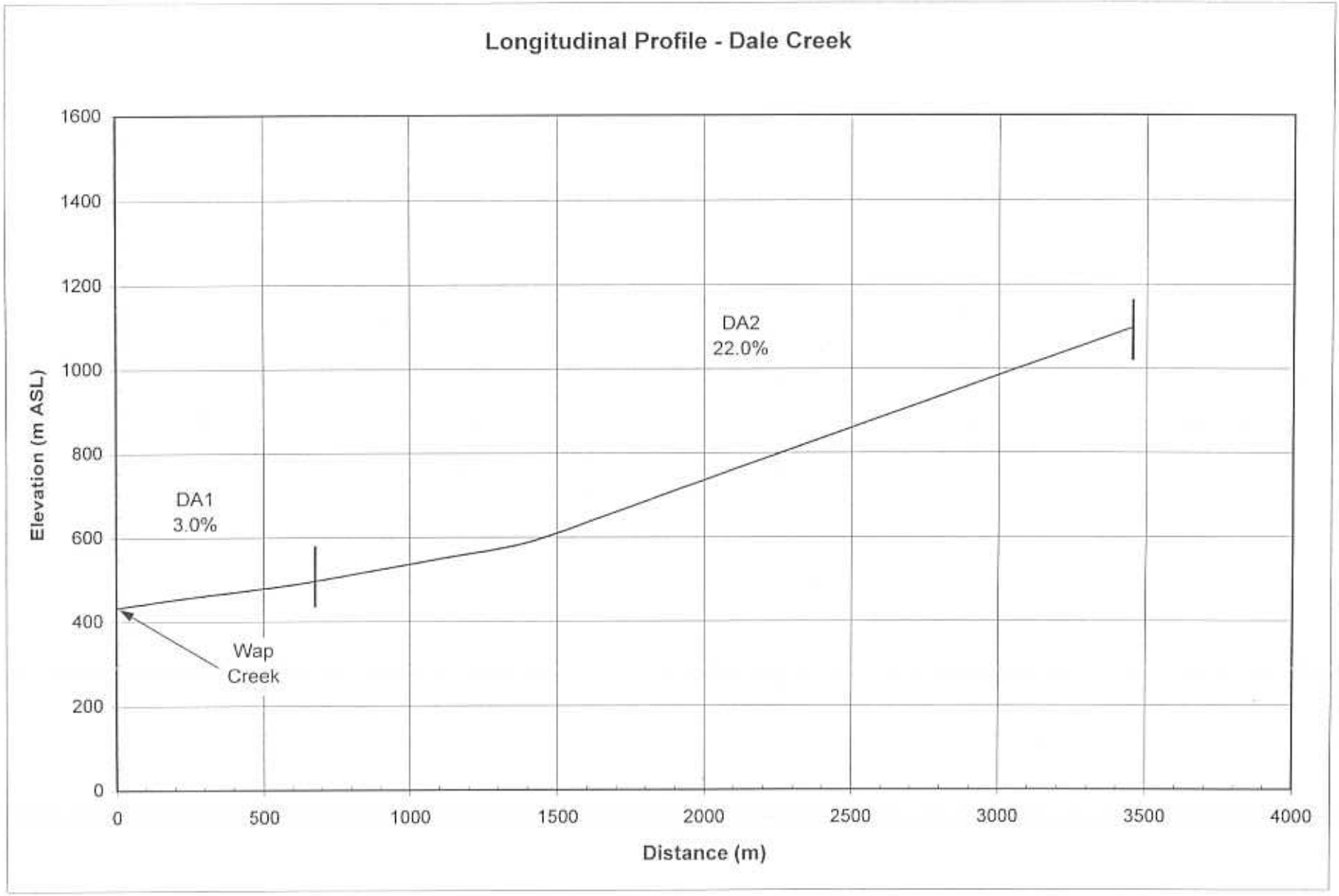

Longitudinal Profile - Wap Creek
Elevation (m ASL)
Distance (m)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
POI 1
Mabel Lake
Cavanaugh
Creek
A
0.8%
B
1.6%
C
0.4%
Back Yard
Creek
POI 2
D
1.5%
Wap Lake
E
0.1%
POI 3
Frog Falls
F
2.0%
G
5.0%
H
2.0%
I
7.0%
J
6.0%
K
3.5%
L
6.0%
End of
Mainstem
Channel
Joss
Creek
Iron
Creek
Devil
Creek
Un-named
Creek
Dale
Creek
Derry
Creek

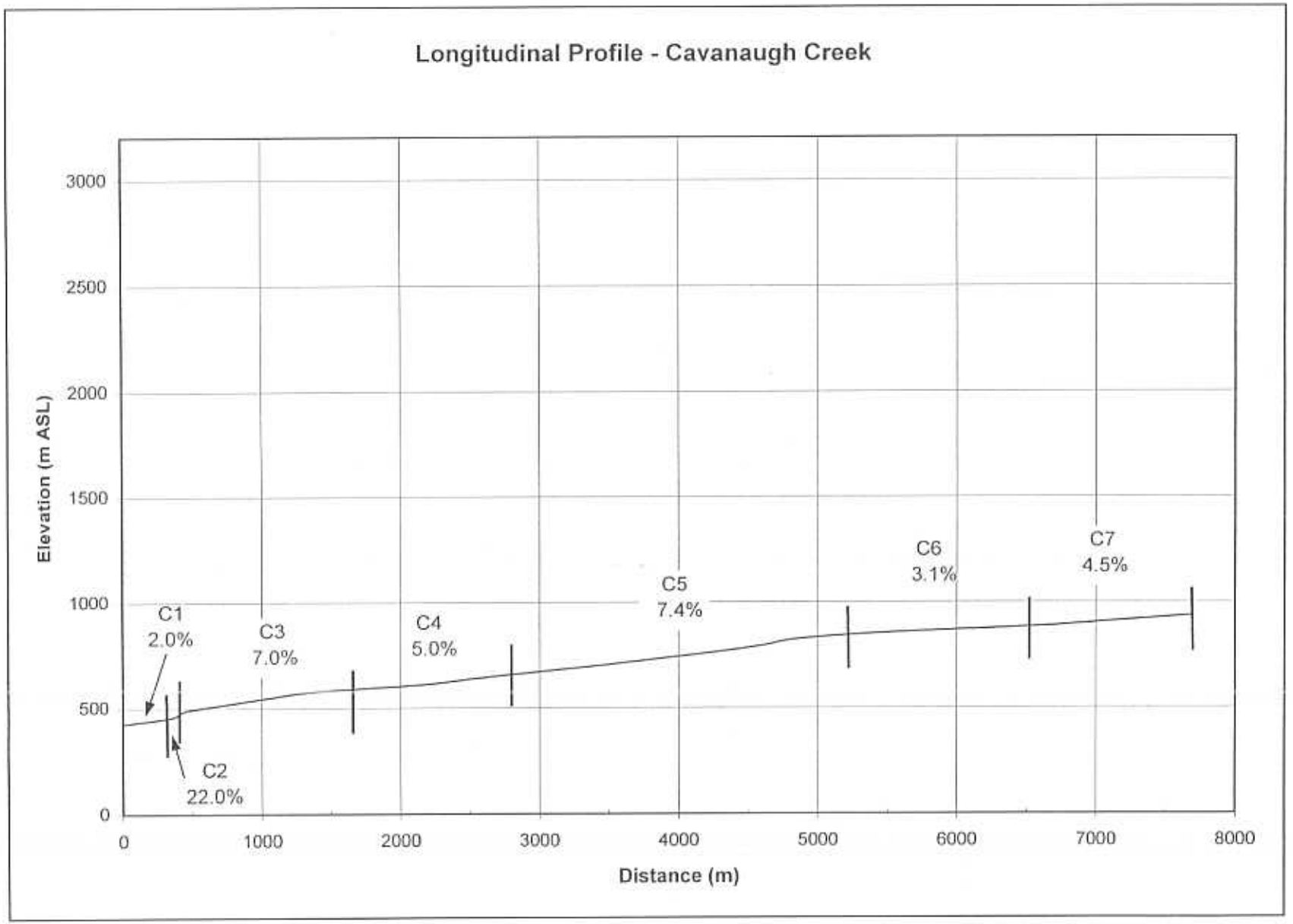
Longitudinal Profile - Iron Creek

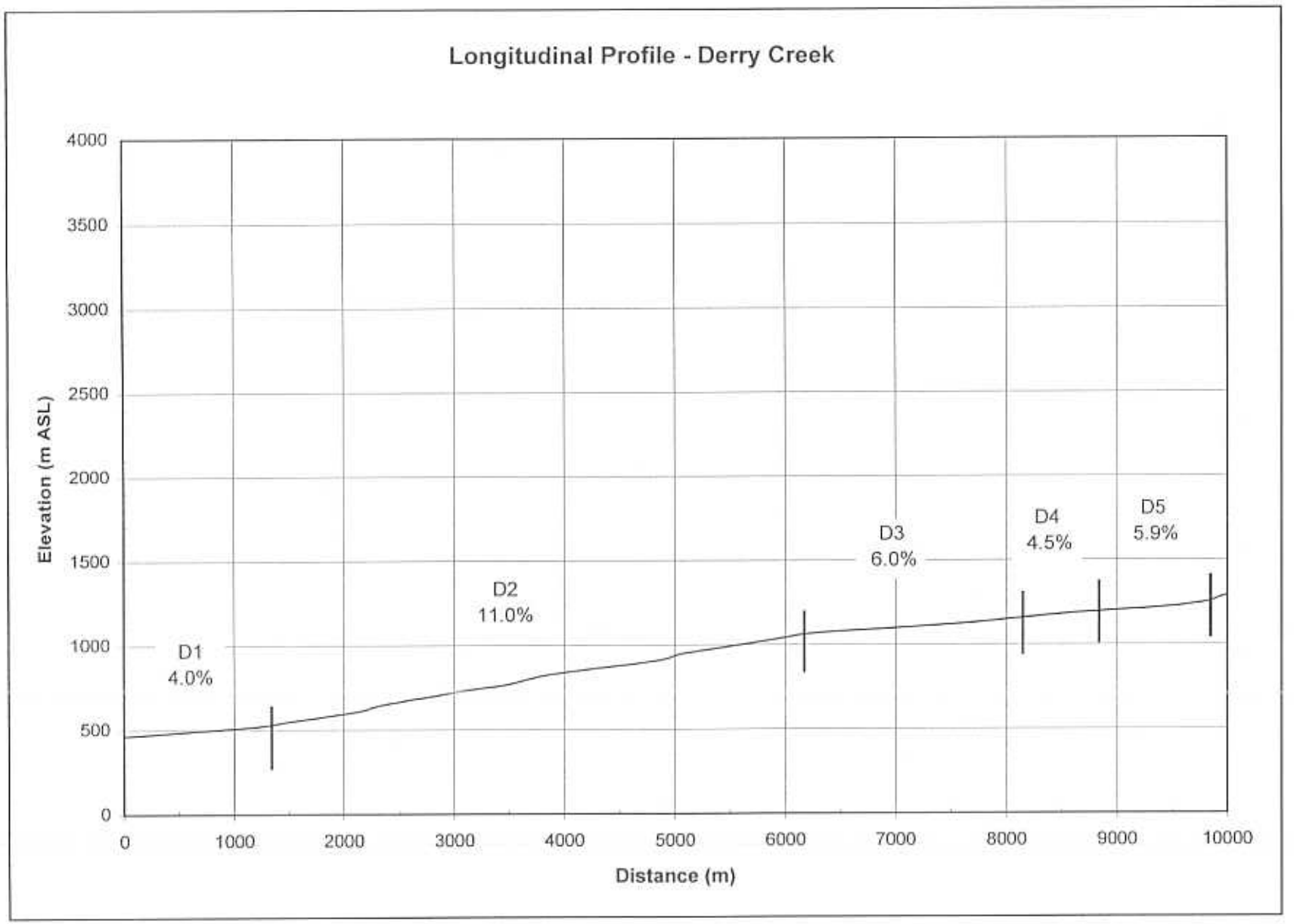



Longitudinal Profile - Devil Creek
Elevation (m ASL)
800
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance (m)
D1
3.0%
D2
28.0%
Wap
Creek

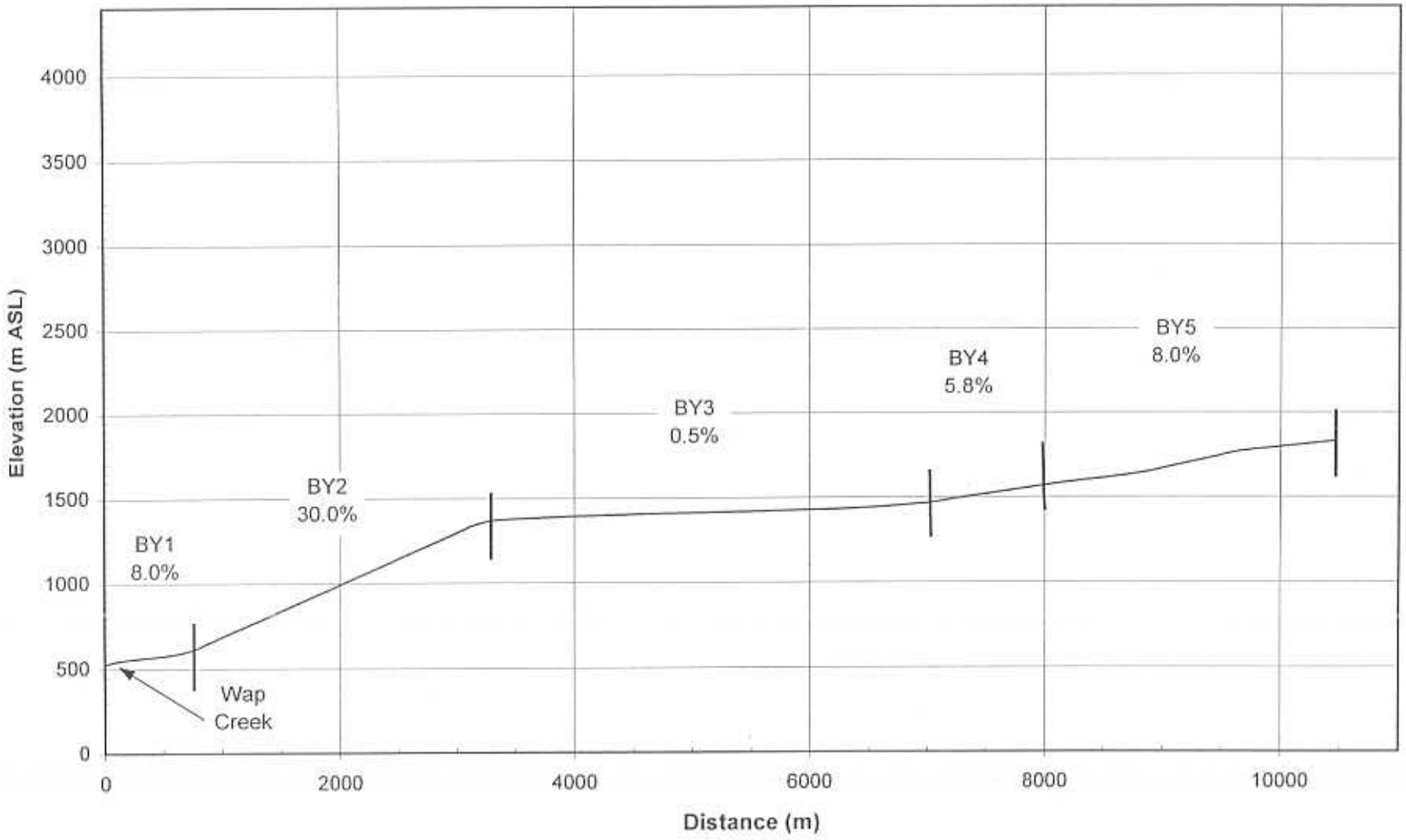

Longitudinal Profile - Un-named Creek
Elevation (m ASL)
1200
1000
800
600
400
200
0
0
500
1000
1500
2000
2500
3000
Distance (m)
UN1
4.0%
UN2
26.0%
Wap
Creek

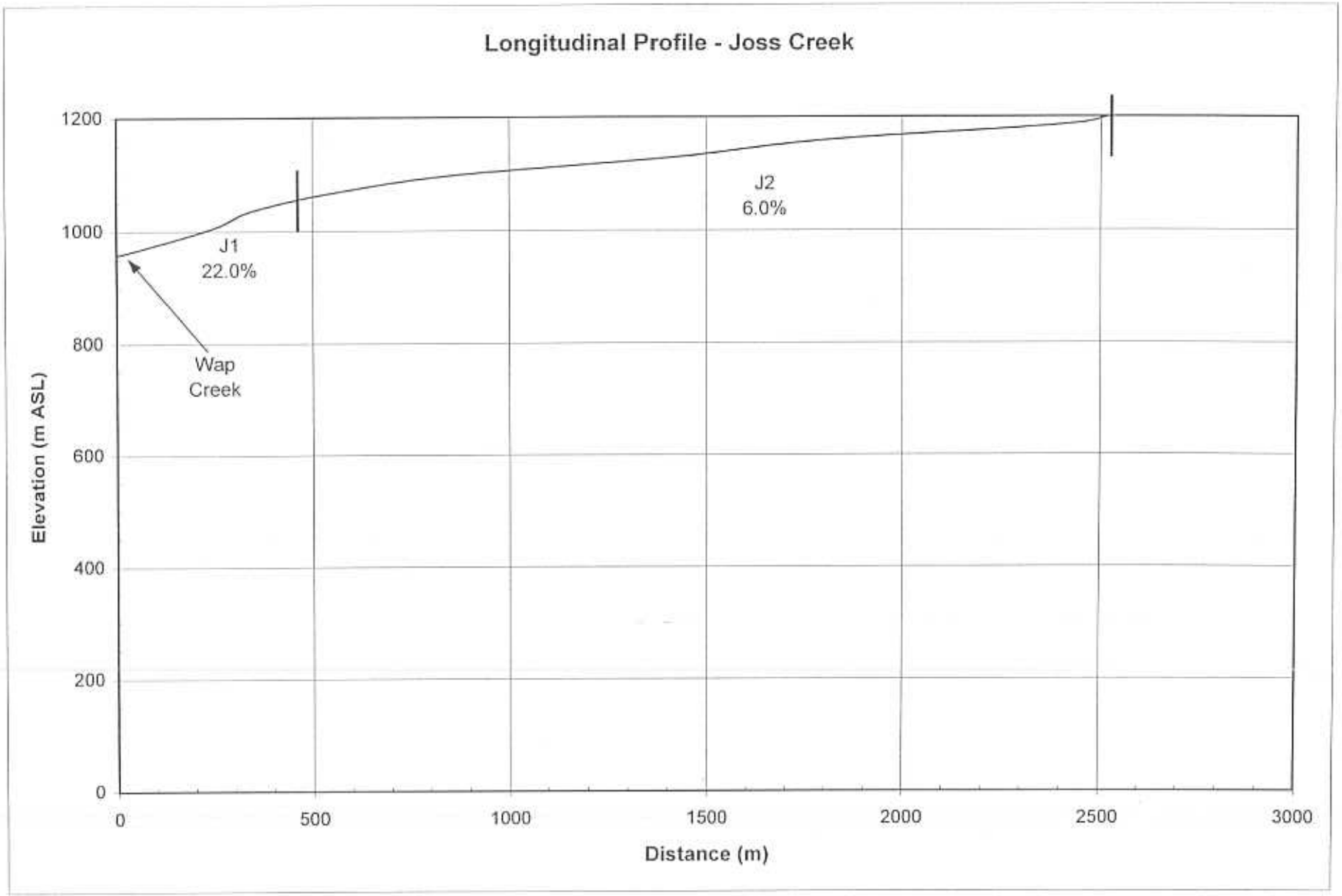

Longitudinal Profile - Dale Creek
Elevation (m ASL)
1600
1400
1200
1000
800
600
400
200
0
DA1
3.0%
DA2
22.0%
Wap
Creek
0
500
1000
1500
2000
2500
3000
3500
4000
Distance (m)


Longitudinal Profile - Cavanaugh Creek
Elevation (m ASL)
3000
2500
2000
1500
1000
500
0
0
1000
2000
3000
4000
5000
6000
7000
8000
Distance (m)
C1
2.0%
C2
22.0%
C3
7.0%
C4
5.0%
C5
7.4%
C6
3.1%
C7
4.5%


Longitudinal Profile - Derry Creek
Elevation (m ASL)
4000
3500
3000
2500
2000
1500
1000
500
0
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance (m)
D1
4.0%
D2
11.0%
D3
6.0%
D4
4.5%
D5
5.9%

Longitudinal Profile - Backyard Creek




Longitudinal Profile - Joss Creek
1200
1000
800
600
400
200
0
Elevation (m ASL)
0
500
1000
1500
2000
2500
3000
Distance (m)
J1
22.0%
J2
6.0%
Wap
Creek