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Prior to Watershed Advisory Committee
Technical Meeting #1

LEMPRIERE and MANTEAU CREEK Watershed Assessments

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EXECUTIVE SUMMARY

Weyerhaeuser Company Limited (Vavenby Division) contracted *Integrated* Woods Services Ltd. to complete watershed assessments for the Lempriere and Manteau Creek watersheds. The Clearwater Forest District classified (October 19, 1999) the Lempriere Creek watershed as requiring a Watershed Assessment Procedure (WAP) with no channel assessment, if recommended by a hydrologist. The Clearwater Forest District classified (October 19, 1999) the Manteau Creek watershed as requiring only a road round table. Field assessments of channel conditions were completed for both Lempriere and Manteau Creeks, to provide an increased degree of certainty regarding stream channel conditions and channel sensitivities. Weyerhaeuser Company Limited (Vavenby Division) contributed Forest Renewal British Columbia funding for this project.

The objectives of the Lempriere and Manteau Creek watershed assessments are to:

1. Field assess the current stream channel conditions within the watersheds,
2. Assess the sensitivity of the stream channels to impacts from forestry activities,
3. Identify opportunities for upslope and in-stream watershed restoration activities,
4. Provide recommendations regarding future forestry development within these watersheds.

The Lempriere and Manteau Creek watersheds are located approximately 220 kilometres (km) north-northeast of Kamloops, British Columbia. Both streams flow in a northerly direction and are tributary to the upper North Thompson River. Hydrologic watershed boundaries, as defined from 1: 20 000 TRIM data, were utilized for the completion of the watershed assessment procedures. Issues of importance in these watersheds include fisheries values, channel stability concerns and pre-Forest Practices Code road construction techniques.

The conclusions of the Lempriere and Manteau Creek watershed assessments are as follows:

1. The existing levels of forest harvesting are low in the Lempriere and Manteau Creek watersheds, with current (Fall 2000) ECA's of 14.4% and 5.9%, respectively. ECA's below 20% suggest that there should be no detectable change in annual run-off in these streams, as a result of forestry activities. The risk associated with increased peak flows is considered low for these watersheds.
2. Accelerated sediment production and delivery to stream channels is a primary concern in both the Lempriere and Manteau Creek watersheds. Road construction techniques and on-going road maintenance are the principal management issues. Forest development strategies that minimize road densities and the "life span" of newly constructed roads should be considered, to reduce risks associated with sediment supply increases to stream channels in these watersheds. Rate of cut (i.e. ECA) and impacts to riparian function are currently considered secondary concerns in these watersheds.
3. The current channel disturbance levels vary from undisturbed to moderate in the assessed stream reaches within the Lempriere and Manteau watersheds. Moderate levels of disturbance exist on the two alluvial fans (reaches 1 and 4c) situated within the Manteau watershed. Moderate levels of disturbance also occur within segments of reach 1 of Lempriere Creek and reach 2 of both streams. These levels of disturbance are predominantly associated with natural sediment sources and/or avalanche tracks within these watersheds.
4. Forestry-related mass wasting events and an associated debris torrent have occurred on an unnamed[1] tributary (slide #27/priority site #8) to reach 2 of Lempriere Creek. Disturbance levels in this tributary stream increased due to this event(s), but no readily detectable changes in channel attributes in the mainstem of Lempriere Creek were apparent in the review of aerial photographs from different years.
5. In-stream works to improve channel conditions in reaches 1 and 4c of Manteau Creek are not recommended due to the unstable characteristics of the alluvial fans. Reach 1 of Lempriere Creek is not recommended for restoration as it displayed some disturbance indicators in the pre-development aerial photographs and because the disturbed segment is located within the floodplain of the North Thompson

[1] referred to as Dawn Creek in the North Thompson EMRA (IWS, 1999)

River. Reach 2 of both Lempriere and Manteau Creeks are not considered moderate or high priorities for in-stream works, as the disturbance in these reaches appears to be largely related to natural sediment sources and episodic events associated with avalanche tracks.

6. There are many opportunities to complete watershed restoration activities within the upland portions of the watersheds. Moderate and high risk road segments totaling 23.1 km and 14.4 km were identified in the Lempriere and Manteau watersheds. Two priority road sites are outstanding in the Manteau watershed and six priority road sites are outstanding in the Lempriere watershed. Two new priority sites (sites A and B) have been identified in the Lempriere watershed.

The recommendations to the Watershed Advisory Committee are as follows:

1. In regard to proposed development, the selection of material used to construct the fill slopes or to protect exposed soils from surface erosion, should be based on the risk of sediment delivery to adjacent watercourses. Suitable erosion and sediment control strategies should be incorporated into the road construction and deactivation plan throughout the watersheds.
2. Riparian areas managed in accordance with Clearwater Forest District Riparian Management Area Policy should be adequate to protect aquatic resources. Windthrow hazard assessments will need to be completed in the proposed blocks to ensure that the riparian reserves are windfirm. Windthrown trees can result in channel disturbance, can expose erodible soils and potentially initiate mass wasting events. Appropriate strategies will need to be developed to reduce any concerns identified in the windthrow hazard assessment.
3. Road deactivation and/or hillslope stabilization activities need to be scheduled and completed for the ten priority sites identified in the Lempriere and Manteau Creek watersheds (see Section 7.3). Availability of funding will likely limit the number of sites deactivated in 2001 and some sites may therefore need to be re-scheduled for 2002. Priority site 15 (including slides 6, 7 and 8) in the Manteau watershed was completed in 1999.

Watershed	Priority Site	Road	Slide No.	Risk	Scheduled for Completion
Lempriere	6	1500.12	S16, S17, S18	moderate	2001
Lempriere	7	1300	S15	high	FSR
Lempriere	8	1300.04	S27	high	2001
Lempriere	9	1303	S29, S31	high	road permit
Lempriere	10	1300	S25, S26	high	FSR
Lempriere	11	1303.02	S30	high	2001
Lempriere	A	trail	a, b, c, d	high	2001
Lempriere	B	1300	e	moderate	2001
Manteau	14	1200	n/a	moderate	2001
Manteau	16	1200	S9, S10	high	2001

4. Kilometres 11 to 15.5 of the Lempriere FSR should be deactivated and the alternative access through the Miledge and Chappell drainages should be utilized. This section of the Lempriere FSR is considered a high risk and has several mass wasting events coupled to stream channels. The alternative access through the neighbouring drainages is considered a lower risk.
5. Proposed forestry development in the Manteau watershed must take into consideration the effects of changes in water, sediment and/or debris supply on the inherently unstable alluvial fans that the stream flows across in reaches 1 and 4c.
6. Prior to developing any proposed roads or cutblocks within the catchment area of the unnamed tributary[2] to reach 2 of Lempriere Creek, road deactivation or upgrade activities need to be planned and/or

[2] referred to as Dawn Creek in the North Thompson EMRA (IWS, 1999)

completed. A Terrain Stability Field Assessment also needs to be completed for any proposed roads or cutblocks, with consideration for the channel condition of the tributary stream.

7. Red Flag ECA's of 25% and 20% are recommended for the Lempriere and Manteau Creek watersheds. The lower Red Flag ECA in the Manteau Creek watershed reflects the unstable nature of the two alluvial fans that the stream flows across.
8. The watersheds should be re-assessed if there is a concern with the level of proposed development or when proposed forestry development approaches the Red Flag ECA's.
9. Refer to the Watershed Advisory Committee recommendations in Appendix J.

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1.0 INTRODUCTION

Weyerhaeuser Company Limited (Vavenby Division) contracted *Integrated* Woods Services Ltd. to complete watershed assessments for the Lempriere and Manteau Creek watersheds. The Clearwater Forest District classified (October 19, 1999) the Lempriere Creek watershed as requiring a Watershed Assessment Procedure (WAP) with no channel assessment, if recommended by a hydrologist. The Clearwater Forest District classified (October 19, 1999) the Manteau Creek watershed as requiring only a road round table. Field assessments of channel conditions were completed for both Lempriere and Manteau Creeks, to provide an increased degree of certainty regarding stream channel conditions and channel sensitivities. Weyerhaeuser Company Limited (Vavenby Division) contributed Forest Renewal British Columbia funding for this project.

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4. Provide recommendations regarding future forestry development within the watershed.

2.0 METHODOLOGY

The watershed assessment was completed utilizing methodologies that satisfy the requirements of the most recent Watershed Assessment Procedure (Government of British Columbia, 1999). This newest Watershed Assessment Procedure (WAP) is intended to "consider the cumulative effects of forest practices on the aquatic environment" and includes a field verification component. The procedure combines analysis of stream channel and upslope watershed conditions with an assessment of stream channel sensitivities and provides recommendations regarding proposed forestry development.

Background information reviewed during these watershed assessments included the: *Upper North Thompson River, Chappell Creek and Miledge Creek Watersheds Erosion and Mass Wasting Risk Assessment and Access Management Map* (IWS, 1999), *Manteau Road 1210 Road Deactivation Prescription and Completion Report* (IWS, 1998), *Gosnell Watershed Assessment Procedure* (IWS, 2001) and the *Kamloops Land and Resource Management Plan* (1995). Level 'C' terrain stability maps, terrain resource inventory maps, forest cover maps and aerial photographs were used as

information sources (see Appendix B). Available fisheries and water license data was obtained from the Ministry of Environment, Lands and Parks to provide a comprehensive source of background information for the project.

Field assessments were conducted throughout the watersheds where road access permitted. A helicopter overview flight was conducted on September 28, 2000, to assess channel conditions and to identify large sediment sources in portions of the watersheds with limited access. The risk ratings identified in the Erosion and Mass Wasting Risk Assessment (EMRA) were utilized in the sediment source survey for the watershed assessments.

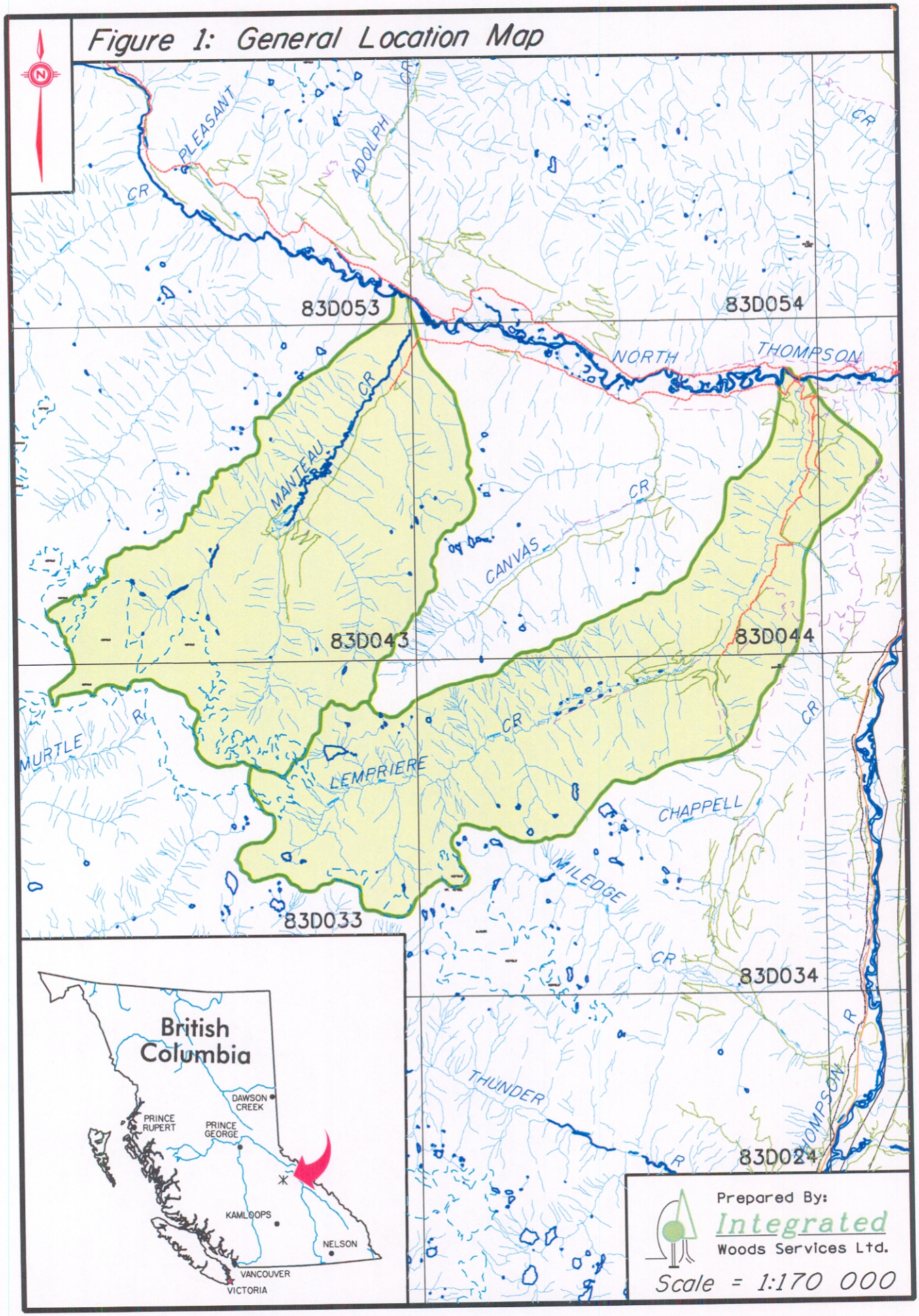
The stream reaches to be assessed in the field were determined by channel characteristics, riparian condition, proximity to known or suspected sediment sources and/or accessibility. The Channel Assessment Procedure (Government of BC, 1996) and the Rosgen (1996) classification system (see Appendix C) were utilized to classify stream channel morphology and to evaluate channel sensitivity, while the Channel Assessment Procedure (CAP) was used to classify the stream channel disturbance levels. A "risk assessment approach" (see Appendix D) was developed and utilized to provide an assessment of the level of risk that forestry activities have had on the aquatic resources within the specified watersheds. The longitudinal profiles, watershed report cards, selected aerial photographs, watershed assessment maps (including priority road sites and photograph locations) and ECA maps are presented in Appendices E, F, G, H and I, respectively.

3.0 WATERSHED LOCATIONS AND GENERAL INFORMATION

The Lempriere and Manteau Creek watersheds are located approximately 220 kilometres (km) north-northeast of Kamloops, British Columbia (see Figure 1). Both streams flow in a northerly direction and are tributary to the right[3] bank of the upper North Thompson River. Hydrologic watershed boundaries, as defined from 1: 20 000 TRIM data, were utilized for the completion of the watershed assessment procedures. Issues of importance in these watersheds include fisheries values, channel stability concerns and pre-Forest Practices Code road construction techniques.

[3] as viewed downstream

Figure 1: General Location Map



Bull trout (*Salvelinus confluentus*), a red-listed species, and mountain whitefish (*Prosopium williamsoni*) are documented[4] in the Lempriere system. The presence of bull trout is documented in the Manteau Creek system. As coho salmon (*Oncorhynchus kisutch*) spawning is documented in the North Thompson River upstream of these tributaries, juvenile coho salmon may utilize available habitat in the lower reach of each stream.

A western hemlock looper (*Lambdina fiscellaria lugubrosa*) outbreak occurred in the local geographic area during the late 1980's. Recent forest health concerns in these watersheds have not been identified by the Ministry of Forests or by Weyerhaeuser Company Limited. Critical moose winter range is located adjacent to the North Thompson River in these drainages and late winter North Thompson caribou habitat is situated at high elevations (Kamloops LRMP, 1995). No water withdrawals are currently licensed on either stream[5].

The watershed areas, minimum elevations, maximum elevations and elevation of H_{60} lines[6] are presented in Table 1.

Table 1: Watershed Areas, Minimum and Maximum Elevations, H_{60} Lines

Watershed	Area (ha)	Minimum Elevation (m)	Maximum Elevation (m)	H_{60} Line (m)
Lempriere Creek	12 645	767	2566	1518
Manteau Creek	10 977	806	2624	1710

4.0 WATERSHED CHARACTERISTICS

4.1 Physiography and Hydrology

Both of the watersheds are situated within the Cariboo Mountains physiographic region of British Columbia (Holland, 1976) and the Columbia Mountains hydrologic zone (Coulson and Obedkoff, 1998). The annual peak flow regimens of watersheds in this hydrologic zone are generated by nival

[4] from BC Fisheries, Fisheries Inventory Summary System (FISS)
[5] as determined by query of the MoELP water licence database
[6] H_{60} line = the elevation isoline above which 60% of the watershed is situated

flows (i.e. spring snowmelt), though intense rainfall events can also contribute significant amounts of water to these watersheds. The H_{60} lines for these watersheds were determined from a digital terrain model (using Arc/Info) for their respective drainage.

Water Survey of Canada (WSC) stream gauge data are not currently available for either of the streams being assessed. Significant flood events are known to have occurred in the local geographic area in both 1997 and 1999.

4.2 Slopes and Aspect

Aspect varies greatly with location within both the Lempriere and Manteau Creek watersheds. The main valley in the upper two-thirds of the Lempriere watershed is oriented in a southwest to northeast direction. The main valley is aligned in a south to north direction in the lower watershed. Aspect in the Lempriere Creek watershed therefore generally has a strong north or south component in the upper watershed and a strong east or west component in the lower watershed. The main valleys in the Manteau watershed are oriented in a generally north to northeast direction. Aspect generally has a strong east or west component in the Manteau Creek watershed.

Slope classes, by area (ha) and percentage of drainage, for the Lempriere and Manteau watersheds are presented in Table 2. Slopes are gentle (<26%) to moderate (27-49%) in 47% and 37% of the Lempriere and Manteau Creek watersheds, respectively. The gentle slopes predominantly occur at lower elevations in the main valley bottoms of the Lempriere and Manteau watersheds.

Table 2: Slope Class by Area (ha) and Percentage of Watershed Area

Watershed	Slope Class (%)				
	0-26%	**27-49%**	**50-70%**	**>70%**	**Total Area**
Lempriere Creek	1 873 (15%)	4 002 (32%)	3 728 (29%)	3 042 (24%)	12 645 ha (100%)
Manteau Creek	1 537 (14%)	2 576 (23%)	3 264 (30%)	3 600 (33%)	10 977 ha (100%)

4.3 Surficial Materials

Lempriere Watershed

Fluvial deposits are the predominant surficial material mapped[7] adjacent to the stream channel in the lower and middle portions of the Lempriere watershed. Adjacent to reach 1 of Lempriere Creek, the surficial materials and expression are mapped as fluvial terraces and fluvial plain[8]. A fluvial plain is predominantly (~80%) mapped adjacent to the channel throughout reach 2 and lower reach 3. The predominant surficial materials and expressions mapped adjacent to reach 3 are fluvial plain and fluvial terraces. Colluvial materials are located adjacent to the channel in reach 4. Fluvial materials (plain or terrace) are the predominant materials mapped adjacent to reach 5. Organic materials exist adjacent to the channel in segments of reaches 2, 3 and 5. In the upper Lempriere watershed, surficial materials adjacent to the channel vary between morainal, fluvial, organic and colluvial deposits. Glaciofluvial materials are mapped on the lower valley sidewalls throughout lower reach 2 and adjacent to many tributary streams throughout the watershed.

Manteau Watershed

Fluvial materials are located adjacent to the channel in reach 1 of Manteau Creek. A fluvial fan (with a debris torrent modifier) is mapped adjacent to this reach. Undifferentiated materials (gullied) with a much lower occurrence of colluvium are mapped downstream of the bridge crossing over lower reach 2. Colluvial materials are predominant adjacent to the channel upstream of the bridge in reach 2 but fluvial terraces are mapped in four locations also. Morainal and colluvial materials are located adjacent to the stream channel in much of reach 3. Fluvial materials are also mapped adjacent to the channel in some locations. Fluvial materials (fans, plains and terraces) are predominant adjacent to lower reach 4a. Organic (dominant material) and fluvial materials are located adjacent to the upper two-thirds of reach 4a and reach 4b. Reach 4c is located on a fluvial fan and major avalanche activity is listed as a modifying process for portions of all sub-reaches comprising reach 4. Undifferentiated materials, with modifying processes of gullying, snow avalanche and rapid mass movement, are mapped adjacent to the lower 40% of reach 5. Fluvial plain, morainal and colluvial materials are mapped at different locations adjacent to upper reach 5.

[7] from Upper North Thompson Terrain Stability Maps (Quaterra, 2000)
[8] fluvial plain is considered an active process while fluvial terraces are considered an inactive process

Fluvial plain is mapped adjacent to reaches 6 and 8 and colluvial materials and bedrock are located adjacent to reach 7. Reach 1 of the east fork of Manteau Creek is located on a fluvial fan. Undifferentiated materials, with modifying processes of gullying and rapid mass movement, are located adjacent to reach 2 and the lower 60% of reach 3. Fluvial materials (terrace and plain) are mapped adjacent to much of upper reach 3, with colluvium also located adjacent to the most upstream portion of the reach. Reach 4 has fluvial deposits mapped as the predominant surficial materials.

4.4 Other Watershed Attributes

Wildfire, pests, pathogens and windthrow are natural disturbance regimens associated with the forested ecosystems found within these watersheds. Any of these disturbances can potentially affect stream channels via changes in rates of watershed run-off, large woody debris recruitment to the channel and/or sediment production/delivery. Three different biogeoclimatic zones[9] are present in the Lempriere and Manteau watersheds. The Interior Cedar-Hemlock (ICH) zone includes two different variants and occurs at lower elevations. The Engelmann Spruce-Subalpine Fir (ESSF) zone occurs at higher elevations. The Alpine-Tundra (AT) zone occurs at the highest elevations in these watersheds. The ICHwk1, ICHvk1 and ESSFwc2 variants historically experienced rare, stand-initiating disturbances[10] (e.g. wildfire, wind, pests, landslides). Uneven-aged or multi-storied even-aged stands were typical, with disturbances generally resulting in the death of individual trees or small patches of trees. Natural stand-initiating disturbances have affected larger areas in both watersheds, however.

In the forest cover database, 418 ha of the Lempriere watershed is labeled as burned by wildfire (and not salvaged). The burns on the east side of the valley occurred in 1960 while the remaining burns are not dated. A wildfire burned approximately 270 ha of forested land in the Manteau watershed in 1998. A number of relatively small wildfires also occurred in the Lempriere and Manteau watersheds in 1998 (J. Jones, pers. comm., 2001). These wildfires are currently being incorporated into the forest cover database (D. Kehler, pers. comm., 2001) but only the largest fire in the Manteau

[9] from Ministry of Forests FC1 database
[10] all three variants are identified as Natural Disturbance Type 1 in the Biodiversity Guidebook (Government of BC, 1995a)

watershed was included in the current ECA calculations. Changes in watershed hydrology and sediment production have been documented in a number of watersheds, following the occurrence of wildfires (Cheng, 1980; Cheng and Bondar, 1984).

Recent research suggests that climatic and hydrologic patterns have been significantly changing over the last 25 years (Whitfield and Cannon, 2000). Trends in climatic and hydrologic variation across Canada were evaluated by a number of authors for the decades 1976-1985 and 1986-1995. The following trends were observed in the south-central interior of British Columbia: 1) higher temperatures in all months except February, 2) increases in spring precipitation and decreases in summer precipitation, 3) higher spring stream flows with lower summer and fall flows, 4) an earlier onset of spring run-off (Whitfield and Cannon, 2000).

5.0 WATERSHED RISK ASSESSMENT WORKSHEETS

Table 3: Characteristics of the Assessed Stream Reach Segments

Stream & Reach	Dominant morphology and CAP disturbance levels	Dominant Level 1 Rosgen stream type	Stream reach sensitivity to:			Hillslope connectivity
			Increased peak flows (1 to 5)	Increased sediment supply (1 to 5)	Decreased large woody debris supply (1 to 5)	
Lempriere - 1	RP-CP: 1-2	B-Bc	3	3	3	Low- Mod.
Lempriere - 2	CP-SP: 0-2	B	2	2	2	High
Lempriere - 3	RP: 0	C	3	4	4	Low
Lempriere - 4	not field assessed	-	-	-	-	-
Manteau - 1	CP: 2	Da	4	5	3	Low
Manteau - 2	CP-SP: 1-2	B	2	2	2	High
Manteau - 3	RP: 0-1	C	3	3	3	Mod.-High
Manteau - 4a	RP: 0-1	C	3	4	4	Low
Manteau - 4b	RP: 0-1	C	3	4	4	Low
Manteau - 4c	RP-CP-SP: 2	D/Da	4	5	4	Low
Manteau - 5	not field assessed	-	-	-	-	-
East Fork - 1	RP: 1	C	3	4	4	Low
East Fork - 2	SP: O	A	2	2	2	High
East Fork - 3	CP: 0-1	B	2	2	2	High

Disturbance Levels
0 = Undisturbed
1 = Partial disturbance
2 = Moderate disturbance
3 = Severe disturbance

Channel Sensitivity
1 = Very low sensitivity
2 = Low sensitivity
3 = Moderate sensitivity
4 = High sensitivity
5 = Very high sensitivity

Refer to Appendix D and Section 6.3 to assist in interpreting Tables 3 and 4.

Table 4: Effects of Forestry Activities in the Watershed and Risk to Aquatic Resources

Stream & Reach	Probability that past forestry activities have caused changes to[1]:			LEVEL OF RISK to the aquatic environment caused by changes to[2]:			Dominant land use activity[3]
	Peak flows (1 to 5)	Sediment supply (1 to 5)	LWD supply (1 to 5)	Peak flows	Sediment supply	LWD supply	
Lempriere - 1	2	3	2	B	C	B	FH
Lempriere - 2	2	3	2	B	B	B	FH
Lempriere - 3	2	2	2	B	B	B	FH
Lempriere - 4	-	-	-	-	-	-	-
Manteau - 1	1	2	2	A	C	B	HL, FH
Manteau - 2	1	2	1	A	B	A	FH
Manteau - 3	1	2	1	A	B	A	FH
Manteau - 4a	1	2	2	A	B	B	FH
Manteau - 4b	1	2	2	A	B	B	FH
Manteau - 4c	1	2	2	A	C	B	FH
Manteau - 5	-	-	-	-	-	-	-
East Fork - 1	1	2	2	A	B	B	FH
East Fork - 2	1	1	1	A	A	A	FH
East Fork - 3	1	1	1	A	A	A	FH

[1] Probability of change = The probability that past forestry activities have caused changes to the supply of water, sediment or large woody debris

i.e. 1 = "Very Low" probability of change
5 = "Very High" probability of change

[2] Level of risk: A = Very Low, B = Low, C = Moderate, D = High, E = Very High

[3] Land-use: A/R = agriculture/ranching
FH = forest harvesting
HL = historical logging (pre-1975)
LG = light grazing

6.0 PROFESSIONAL INTERPRETATIONS

6.1 Watershed Management Objectives

Maintaining water quality, quantity and timing are considered the primary management objectives in the Lempriere and Manteau Creek watersheds. These management objectives include maintaining the fish habitat that currently exists in these watersheds.

6.2 Governing Conditions for Stream Channels

Church (2000) identifies a number of primary conditions governing stream channel morphology. These primary conditions governing stream channel morphology are: 1) the amount and timing of water delivered to the channel, 2) the amount and calibre of sediment delivered to the channel, 3) the supply of wood to the channel (in forested ecosystems), 4) the condition of the stream banks (including riparian vegetation), and 5) the gradient over which the stream flows. Secondary factors governing stream channel morphology are streambed materials, local climate, watershed geomorphology and land-use activities. Changes in stream channel morphology will occur over time in response to natural or human-influenced variations in bank conditions and supply of water, sediment and/or debris. Streams are dynamic systems and change is constantly occurring, however natural events or land-use activities can affect the rate of change.

6.3 Existing Channel Conditions

Lempriere Creek - reach 1

Reach 1 of Lempriere Creek extends upstream from the North Thompson River for approximately 650 metres. The channel has a moderate degree of entrenchment, with a sinuous pattern (plan form) and rapids dominated morphology (see photo 1 in Appendix A). The measured channel gradient is less than 2.5% throughout the reach. Terraces are coupled to the channel in some locations in this reach.

Stream bank materials and degree of moss cover vary with location in the reach. Banks formed predominantly from: 1) sand, 2) gravel and cobble or 3) cobble and boulder were observed in different areas. Sand is the predominant texture within the floodplain of the North Thompson River. Cobble was the predominant bed material (visual estimate) observed within the reach, with gravel

and boulder being sub-dominant textures in the surface layer of the bed. Gravel was generally noted within pools and boulder was present in varying frequency in pools, riffles and rapids.

Large woody debris (LWD) does not occur frequently in the channel in this stream reach. The majority of the LWD is clumped in a debris jam approximately 50 m upstream of the North Thompson River. Only a few logs with saw-cut ends were observed in the debris jam. The composition and age of riparian vegetation varies along the stream reach. Alder (*Alnus* sp.) forms dense cover immediately adjacent to the channel in some locales, while mixed or conifer dominated riparian buffers are common (see photo 1).

Disturbance levels are moderate for approximately 100 m upstream of the confluence with the North Thompson River. Elevated mid-channel sediment bars, channel braiding and a debris jam were noted in this stream segment (see photo 2). Disturbance indicators noted in other segments of this reach included bank erosion, pool in-filling, extended riffles or cascades, LWD frequency and LWD distribution. Upstream of the moderately disturbed segment, disturbance levels (both aggradation and degradation) are generally low (see photo 3). Characteristics of cascade-pool morphology become evident in the upper stream reach (see photo 4).

Aerial photograph review of reach 1 included photographs from 1966 (pre-development), 1975 (post-development), 1997 and 2000. Road construction across natural sediment sources (SS) occurred in two locations adjacent to the channel in reach 1 of Lempriere Creek. Sand and fine-textures are the dominant materials being eroded, slumping and/or raveling at SS #1 and #2 (see photo 2). Both sites are revegetating but continue to contribute sediment to the channel. The current risk to aquatic resources associated with these sediment sources is considered low.

Riparian harvesting occurred in a number of locations adjacent to the reach. From the aerial photograph review, the length of riparian forest affected by harvesting is estimated to be 350 m. A riparian buffer (<20 m wide) was left adjacent to the channel in most areas and regeneration of trees within the block has occurred (see photo 1). Impacts to riparian function are currently considered to be low in the previously harvested block (opening 7, polygon 93).

Some changes in channel attributes were apparent on the aerial photographs. The majority of flow around an island upstream of SS #2 switched from the right bank to the left bank. The right channel now appears to flow water at only at the highest flows (see photo 5). Channel migration toward the right bank occurred just downstream of SS #2 between 1966 and 1975. A vegetated floodplain area was re-incorporated into the active channel, with corresponding bar deposition on the left channel margin. The size of the bars at the mouth of the stream increased between 1966 and 1975. Channel widening, due to erosion of the right bank at the mouth of the stream, also occurred between 1966 and 1975. Further widening at this site is likely related to the debris jam located to the left channel margin in the lower reach (see photo 2). This reach was assessed as having a moderate sensitivity to changes in supply of water, sediment and/or large woody debris.

Lempriere Creek - reach 2

Reach 2 is approximately 11.8 km in length and the channel pattern varies from sinuous to regular meandering. A moderate degree of entrenchment and cascade-pool morphology was observed in the field assessed segment. Step-pool morphology was observed in some locations during the helicopter overview flight. Valley sidewalls are generally coupled or partly coupled to the stream channel throughout the reach (see photo 6). Islands occur only occasionally within the reach. The stream channel was field assessed within the upper third of the stream reach and measured channel gradients ranged from 3.5%-4%. The average channel gradient calculated from the longitudinal profile is 2.8%.

Boulder and cobble were the predominant stream bank materials observed within the assessed segment (see photo 7). These larger clasts form a surface layer on the banks, with smaller calibres occurring beneath the surface layer. Cobble and boulder are the predominant textures present in the surface layer of the stream bed (visual estimate). Boulders frequently have a "b" axis measurement greater than 80 centimetres (cm).

The frequency of LWD in the channel was low in the assessed segment and LWD was often oriented parallel to the streamflow or elevated above the channel. Mature coniferous forest stands occur adjacent to most of the stream reach and a well-developed shrub layer is also commonly present. Forest harvesting within riparian areas is restricted to the upper stream reach. Approximately 750 m

of riparian forest adjacent to the left[11] stream bank was harvested with little or no riparian leave strip. Six avalanche tracks are coupled to the left bank of the stream in the mid-reach. Three large[12] natural sediment sources are apparent adjacent to the lower stream reach, in the pre-development (1966) aerial photos. One of these sediment sources (SS #3) is still evident on the 2000 aerial photos while the two others appear to have revegetated. SS #4 is located just upstream of the confluence with an unnamed[13] tributary (see photo 8). Two landslide scars are mapped in close proximity to SS #4 (see map in Appendix H). SS #5 is a natural source located at the toe of an avalanche track (see photo 9), approximately 3 km downstream of reach 3. Thirteen potential natural sediment sources or revegetating sediment sources are coupled to the channel in this reach (see map in Appendix H). Six road-related mass wasting events are identified upslope of lower reach 2. A 4.5 km segment of high risk road (Road 1300) occurs in the mid-watershed with numerous associated failures and a debris torrent (see sections 6.4 and 6.5.2 for further discussion of sediment sources and risks). Class IV and V terrain occurs adjacent to the channel throughout the lower two-thirds of the reach.

Disturbance levels are low throughout the assessed segment of reach 2 (see photo 10). The disturbance indicators observed during the field assessment included disturbed stone lines and LWD orientation. Disturbance indicators observed during the helicopter overview flight included widening of the channel in depositional areas, eroding banks, channel braiding and LWD jams. The frequency of these indicators is relatively low and disturbance levels are considered low (see photo 11). The channel appeared to be stable throughout much of the stream reach. Channel widening, extensive bars and braiding were observed adjacent to and between four avalanche tracks that are in close proximity to one another in the middle of the reach. These avalanche tracks and disturbance indicators are also apparent on the pre-development aerial photographs (1966). Extensive road-related slope failures (Roads 1300 and 1300.04) coupled to an unnamed[14] tributary to Lempriere Creek (see photos 12 & 13) have resulted in an increased sediment supply to both stream channels. A sediment fan now exists at the confluence of this tributary and Lempriere Creek (see photo 8).

[11] left or right stream bank - as viewed in downstream direction
[12] large sediment sources are greater than 0.05 hectares (500 m^2) in size
[13] referred to as Dawn Creek in the North Thompson EMRA (IWS, 1999)
[14] referred to as Dawn Creek in the North Thompson EMRA (IWS, 1999)

No readily detectable changes in channel attributes in the mainstem of Lempriere Creek were apparent in the review of aerial photographs from different years. This stream reach was assessed as having a low sensitivity to changes in the supply of water, sediment and/or LWD to the stream channel.

Lempriere Creek - reach 3

Reach 3 is approximately 10 km in length, with an irregular to tortuous meandering plan form. This low gradient reach has a low degree of entrenchment and riffle-pool morphology (see photo 14). Numerous wetland areas, meander cut-offs and oxbow lakes occur adjacent to this stream reach. Valley sidewalls are generally decoupled from the stream channel. Measured channel gradients of less than 0.5% were recorded in the field assessment. The average channel gradient, determined from the longitudinal profile, is approximately 0.15%.

Within the assessed segment, the stream banks are comprised predominantly of fine sand with lesser amounts of fine-textures. The banks were generally stable and well vegetated with moss, grass and/or herbs and shrubs. Sand and gravel are the dominant surface layer bed materials (visual estimate) in the assessed segment of this reach (see photo 15).

LWD occurs frequently in the stream channel and is generally functional[15] within the assessed segment. LWD is often oriented parallel or diagonal to streamflow but still provides a degree of function (see photo 14). Natural riparian vegetation communities are predominantly non-forested adjacent to the upper 60% of the reach. Selective harvesting occurred adjacent to approximately 650 m of the lower stream reach in 1982. Riparian leave strips of varying width and density were left in harvested areas. Current impacts to riparian function are considered to be moderate within the affected segments, based on the aerial photograph review of riparian conditions.

Review of the 1975 and 1997 aerial photographs indicated no readily detectable changes in channel attributes such as channel width, sinuosity, island or bar frequency. The stream channel was assessed as stable in the field reviewed segment of this reach (see photo 14) with occasional bank

[15] in-stream LWD functions include sediment storage, energy dissipation, localized bed and bank scour

erosion noted (see photo 16). Stable channel conditions were also observed in this reach during the helicopter overview flight (see photo 17). This stream reach was assessed as having a moderate to high sensitivity to stream bank disturbance or changes in water, sediment and/or debris supply.

No forestry development has occurred upstream of reach 3 in the Lempriere Creek watershed and fish distribution[16] is limited by two 8.0 m high waterfalls in reach 4 (see photo 18). No field assessments were completed upstream of reach 3 in the Lempriere Creek watershed.

Manteau Creek – reach 1

Reach 1 of Manteau Creek occurs on an alluvial fan and is approximately 350 m in length. The channel has a low to moderate degree of entrenchment and a multi-channel and braided pattern. The average gradient is approximately 4.5%, as determined from the longitudinal profile. Due to limited access, this stream reach was not field assessed. Channel characteristics were determined from TRIM data, Level C terrain mapping, aerial photograph review and the overview flight.

Bank materials are non-cohesive fluvial materials and textures range from sand to boulder. Cobble and boulder appear to be the dominant bed materials (surface layer) in the avulsed channel. Selective logging on the alluvial fan occurred adjacent to both stream banks between 1963-1966. Due to the selective nature of harvest, functional riparian buffers were left in the riparian areas (see photo 19). The riparian area associated with an old crossing of Manteau Creek in reach 1 has regenerated with deciduous species (see photo 19).

Changes in channel characteristics were determined from aerial photographs (1966, 1975, 1985, 1997 and 2000) and disturbance levels were determined during the overview flight. Disturbance levels currently appear to be moderate throughout most of the stream reach. Disturbance indicators observed include channel avulsions, channel braiding and multiple channels, bank erosion and LWD jams (see photos 19 & 20). A single braided channel is predominant in the 1966, 1975 and 1985 photographs (see aerial photographs in Appendix G). It appears that a disturbance event occurred between 1975 and 1985 (pre-development) that affected lower reach 2 and reach 1. The most

[16] from the Upper North Thompson River Watershed Fish and Fish Habitat Inventory Procedure (ARC, 1999)

downstream avalanche track (in reach 2) on the left bank is the initiation zone for increased channel disturbance downstream. Channel widening is apparent in a segment of reach 2 and on the alluvial fan. A single, highly braided channel is still evident on the 1985 aerial photographs. An avulsion occurred near the apex of the fan prior to 1997 and a channel located to the east of the original channel now carries the main streamflow. The channel that now carries the majority of the streamflow begins near the terminus of an old skid trail. The original channel likely still carries water at higher flows. Sediment deposition has occurred in forested areas on the fan and a number of smaller channels transport water. Revegetation of sediment deposits to the left channel margin, adjacent to the avulsion, is evident on the 1997 and 2000 aerial photographs. There is a low probability that forestry activities on the fan initiated or accelerated the avulsion of the channel. Aerial photograph review reveals no readily detectable changes in channel characteristics in the North Thompson River immediately downstream of the confluence of the two streams.

The channel flows across an alluvial fan in reach 1 of Manteau Creek. The channel is both laterally and vertically unstable and was assessed as having a high sensitivity to changes in the supply of water, a very high sensitivity to changes in sediment supply and a moderate sensitivity to changes in large woody debris supply.

Manteau Creek – reach 2

Reach 2 of Manteau Creek is approximately 3.5 km in length and has an irregular wandering to sinuous plan form. The channel appears to be highly entrenched throughout the reach and a single-thread channel is predominant. Cascade-pool and step-pool morphology were both observed in the assessed segments and rapids are a predominant morphologic feature. Measured channel gradients ranged from 3.5 to 7.5%, though most measurements were greater than 5%. The average channel gradient determined from the longitudinal profile is 5.6%. Valley sidewalls are generally coupled to the channel in this reach.

Bank materials within the assessed segments are predominantly comprised of a surface layer of cobble and boulder (see photo 21). The stream banks were generally well vegetated with moss and/or shrub species. Bedrock outcrops and sediment sources of varied textures also form the stream banks in places. Bank erosion was generally limited to areas where streamflow is deflected directly

into the stream bank. Bed materials vary from sand to boulder, with cobble and boulder being the predominant clasts observed in the surface layer (visual estimate). Gravel and sand are generally restricted to the lowest velocity areas and the deepest pools are often associated with large boulders or boulder clusters.

Within the assessed segment located downstream of an avalanche chute, LWD is often clumped into small jams on the channel margins (see photo 22). These jams generally have a zone of influence (on sediment storage and hydraulics) that does not extend upstream or downstream for a linear distance greater than one bankfull stream width. Individual pieces of wood are often oriented parallel to stream flow or are elevated above the channel at lower flows. The riparian forest adjacent to reach 2 has not been affected by harvesting, except at a major road crossing in the lower reach. The riparian forest stands are generally comprised of mature conifer species or are areas labeled as non-productive brush in the forest cover database. A wildfire (1998) came in close proximity to the left bank of the stream in the mid-reach, over a distance of about 500 m. While aerial photograph review indicates that the fire boundary comes close to the stream, few fire-killed trees were observed immediately adjacent to the channel during the overview flight (see photo 23).

Disturbance indicators noted within the assessed segments of reach 2 included disturbed stone lines, extensive cascades, channel braiding, bank erosion, LWD jams and LWD function. Disturbance levels within the assessed segments are generally low with few disturbance indicators noted at any one location (see photo 24). Downstream of the avalanche chute in upper reach 2, the channel disturbance indicators noted appear to be related to a pulse event rather than an on-going trend of aggradation or degradation (see photo 22). Mid-channel deposits and channel braiding were also observed in segments of the lower and mid-reach during the overview flight (see photo 25). From aerial photograph review and observations made during the overview flight, it appears that moderate disturbance levels occur over a distance of about 700 m in reach 2. Episodic events associated with the avalanche tracks appear to be a common disturbance mechanism in this stream reach. This stream reach is considered to have a low sensitivity to changes in the supply of water, sediment and/or LWD to the channel.

Manteau Creek – reach 3

Reach 3 is a low gradient reach approximately 2.1 km in length, with an irregular wandering plan form and riffle-pool morphology. The reach has an average channel gradient of 0.6%, as determined from the longitudinal profile. Valley sidewalls are generally coupled to the stream channel on the left bank and partially coupled on the right bank in this reach. Riparian vegetation communities are predominantly labeled[17] as non-productive brush on the left bank and approximately 40% of the right bank. The remainder of the riparian area on the right bank is dominated by mature conifer stands. Disturbance levels in this reach appear very low in the recent aerial photographs (1997 and 2000) and no readily detectable changes in channel attributes are evident in the comparison of newer and older (1975) aerial photographs. This stream reach is considered to have a moderate to high sensitivity to changes in the supply of water, sediment and LWD to the channel.

Manteau Creek – reach 4a

Reach 4a is a low gradient reach approximately 4.5 km in length. The channel has a low degree of entrenchment with a tortuous meandering pattern and riffle-pool morphology. A single-thread channel is predominant and the average channel gradient is approximately 0.5%. Infrequent, irregular islands are situated within the reach. Valley sidewalls are generally decoupled from the stream channel and numerous wetlands and small lakes occur adjacent to the channel in the valley bottom. Riparian vegetation communities are predominantly labeled as swamp throughout the reach, though coniferous forest stands occur in some areas. Review of the aerial photographs indicates that there has been no change in sediment supply phase or channel pattern. The location and size of sediment bars has shifted between 1975 and 2000, however quantification of the magnitude of change is difficult with unrectified aerial photographs of considerably different scales. Diagonal, point and medial bars are evident in both sets of photographs, however. The aerial photograph review revealed no readily detectable change in disturbance levels between the pre-development and post-development years. Channel sensitivity to changes in water, sediment and/or debris supply is considered moderate to high in this reach.

[17] from forest cover database

Manteau Creek – reach 4b

Reach 4b is a low gradient reach approximately 1.4 km in length, with a low degree of entrenchment and riffle-pool morphology. This reach was separated from reach 4a based largely on differences in channel pattern. This reach is situated on a fluvial plain downstream of an alluvial fan and is multi-thread throughout the reach. Numerous small distributary channels (see photo 26) occur within the reach although a main channel still exists throughout most of the reach. About 100 m of the reach is situated upstream of the confluence of the east and west[18] forks of Manteau Creek. Measured channel gradients of less than 0.5% were recorded downstream of the confluence of the east and west forks of the stream. The average channel gradient is 0.6%, as determined from the longitudinal profile. Valley sidewalls are generally decoupled from the stream channel.

Within the assessed stream segments, stream bank materials and bank stability vary with location. Near the toe of the alluvial fan, stream bank materials are stratified into a layer of sand and gravel overlying a layer of gravel and small cobble (see photo 27). Downstream of the east fork of Manteau Creek, fine sand is the predominant bank material and the stream banks are generally well vegetated and stable (see photo 28). Localized bank erosion was noted in conjunction with sediment deposition. Riparian areas are mostly identified as swamp or non-productive forest, though mature coniferous forest occurs adjacent to the upper reach (see photo 28).

Low levels of channel disturbance were observed in this reach (see photo 29 & 30). Disturbance indicators noted within the reach included extensive lateral bars, mid-channel bars, LWD frequency and LWD orientation. Upstream of the confluence of the east and west forks of Manteau Creek, increased levels of bank erosion and overbank sediment deposition were observed (see photo 31). This reach is considered to be moderately to highly sensitive to changes in the processes controlling channel morphology.

[18] the west fork of the stream is considered the mainstem

Manteau Creek – reach 4c

Reach 4c of Manteau Creek is situated on an alluvial fan[19] and this reach encompasses the mainstem of the stream, from the apex to the toe of the fan (see aerial photographs in Appendix G). The mainstem channel is approximately 600 m in length and channel morphology varies from step-pool to riffle-pool, moving downstream in the reach. The channel is multi-thread on the fan and the channel pattern varies from straight to sinuous. Measured channel gradients ranged from less than 1% (at the toe of the fan) to 16% (at the apex of the fan). The valley sidewalls are decoupled from the stream on the alluvial fan.

Stream bank materials and bank stability vary with location within the reach. Stream banks are mostly comprised of cobble and/or boulder in the upper reach and the banks are generally stable (see photo 32). Some banks are composed of bedrock outcrops in the upper reach. Stream banks in the lower and middle reach are comprised of: 1) sand and gravel, 2) cobble, or 3) cobble and boulder. The banks are often unstable and eroding in the middle and lower reach where channel braiding and avulsions are occurring. Stream bed materials in the upper reach are heterogeneous (sand to boulder), with boulder and cobble being the dominant clasts observed in the surface layer. Stone lines are generally formed by large boulders. The percentage of gravel and cobble in the stream bed increases moving downstream in the reach. Very little moss was observed on in-channel sediment.

Riparian vegetation communities adjacent to this reach are varied. Non-productive brush is mapped adjacent to the upper reach, mature conifer stands are located in the mid-reach and swamp or non-productive forest is mapped adjacent to the lower reach. LWD is present in the channel in this reach with some LWD functioning to trap the larger calibres of sediment.

Upstream of the confluence of the east and west forks of Manteau Creek, disturbance levels are mostly moderate. Disturbance indicators noted in this channel segment included numerous avulsions, bank erosion, mid-channel sediment deposition, channel braiding and sediment deposition into riparian areas (see photos 33 & 34). Disturbance levels generally decrease from moderate to low in the lower stream reach (see photo 35).

[19] mapsheet 83D.043, terrain polygon 882

Aerial photographs for 1975, 1985, 1997 and 2000 were reviewed for this stream reach (see aerial photographs in Appendix G). The 1985 photographs provide the most recent pre-development coverage of this reach and the upstream reaches of the east and west forks of Manteau Creek. A stream crossing was constructed near the apex of the fan and harvesting on portions of the fan occurred in 1990-1991. Indicators[20] of instability on the alluvial fan are evident on the 1985 photographs, prior to any development in the watershed. These indicators include: 1) multiple channels on the fan, 2) changes in channel form upstream and downstream of the fan, and 3) coupling of large sediment sources to upstream reaches with no sediment traps (i.e. lakes, wetlands or low gradient stream reaches) located downstream.

A shift in the main channel location on the alluvial fan occurred between 1985 and 1997, however this shift cannot be conclusively tied to a particular natural event or to forestry development. The main channel of the west fork of Manteau Creek (reach 4c) now flows into the east fork (reach 1) of the stream approximately 400 m upstream of the location visible on the 1985 photographs. This reach is considered to be highly sensitive to changes in water, sediment and/or debris supply.

Manteau Creek – reach 5

Reach 5 is situated upstream of the alluvial fan and extends upstream for approximately 2.4 km. The channel is single-thread through most of the reach, with the channel pattern varying from straight to sinuous. The channel is highly entrenched throughout the reach and step-pool morphology is predominant. The average channel gradient is about 13.5% in the upper and lower reach and approximately 5% in the middle of the reach (from longitudinal profile). The valley sidewall is coupled to the channel on the left bank and five avalanche tracks are coupled directly to the stream. The valley sidewall is generally decoupled from the stream on the right bank. Non-productive brush is mapped adjacent to approximately 1100 m of channel (both banks) and mature conifer stands are the predominant riparian vegetation elsewhere.

The most downstream avalanche track is coupled to the stream channel approximately 300 m upstream of the lower reach break (see photo 36). A large sediment source is located at the toe of

[20] from Wilford, 1998

this avalanche track and it appears to be the source of resultant channel disturbance downstream in reaches 5 and 4c. The mainstem channel of Manteau Creek downstream (in reach 5) of this avalanche track appears to be wider and less sinuous in the 1985 aerial photographs than in the 1975 photos. Disturbance indicators observed in the aerial photographs include extensive bars, mid-channel deposits and channel braids.

East Fork Manteau Creek – reach 1

Reach 1 of the east fork of Manteau Creek extends approximately 425 m upstream of the confluence with the west fork. The channel has a low to moderate degree of entrenchment, a regular meandering channel pattern and riffle-pool morphology. This reach is located on an alluvial fan, measured channel gradients ranged from 1% to 3% and a single-thread channel is predominant. Stream bank materials are generally comprised of sand overlying gravel and the banks were quite stable and vegetated through most of the reach. Stream bed materials were heterogeneous (sand to boulder) with gravel and cobble being the most common surface textures (visual estimate).

LWD is frequently present in the reach but is often oriented parallel to the streamflow. Riparian vegetation immediately adjacent to the channel is often dominated by alder (*Alnus* sp.) or willow (*Salix* spp.). The mapped riparian polygons are labeled as productive or non-productive mature coniferous forest stands and swamp is mapped adjacent to the channel in the lower reach. Modifications to riparian structure are limited to a 50 m channel segment adjacent to Road 1200 in the upper reach.

Disturbance levels throughout the reach are generally low (see photo 37) but observed disturbance indicators included extended riffles, infrequent elevated mid-channel deposition and LWD orientation. Channel disturbance has occurred downstream of the Road 1211 bridge, where a berm has been constructed adjacent to the channel (see photo 38). The berm appears to have been constructed to protect the road prism at the west end of the bridge. The berm has been breached for approximately 1.5 m at the upstream end and water can now flow between the berm and the road. Overall, disturbance levels in this reach are low and the channel is considered to be moderately sensitive to changes in the supply of water, sediment and/or LWD. While this fork of Manteau

Creek is located on an alluvial fan, there is an absence of instability indicators in the pre and post-harvest aerial photographs.

East Fork Manteau Creek – reach 2

Reach 2 of the east fork of Manteau Creek is high gradient and approximately 700 m in length. The channel is single-thread, has a high degree of entrenchment, a straight to sinuous pattern and step-pool morphology is predominant (see photo 39). Class IV and V terrain (glaciofluvial materials) comprise the valley sidewalls, which are coupled to the stream channel. The average channel gradient for the reach is close to 11%. Stream banks in the lower reach are comprised of cobble, boulder and/or bedrock and are well mossed. Within the assessed segment, the stream bed materials are heterogeneous but boulder is predominant in the surface layer (visual estimate). The riparian forest stands are labeled as mature (age-class 8 or 9)[21] conifer types and no harvesting of riparian buffers has occurred. Review of the aerial photographs revealed no apparent changes in channel characteristics or disturbance levels. Disturbance levels appear to be low and channel sensitivity is considered to be low.

East Fork Manteau Creek – reach 3

Reach 3 of the east fork of Manteau Creek is approximately 4.6 km in length and is predominantly a single-thread channel. The channel has a moderate degree of entrenchment, a sinuous pattern and cascade-pool morphology (see photo 40). Measured channel gradients ranged from 3-5% and the average channel gradient calculated from the longitudinal profile is about 3%.

Stream bank materials within the assessed segment varied with location. Banks comprised of moss covered cobble and/or boulder are common but old bar material (sand to cobble) also formed the banks in some areas. Banks were generally stable within the assessed segment but slumping is occurring in some locations where the banks are comprised of gravelly loam material. Stream bed materials are heterogeneous, with gravel and cobble being the predominant surface textures

[21] age-class 8 = 141-250 years old and age-class 9 = 250+ years old

observed. Stone lines are generally formed by boulders and sand occurs in lee areas and to the channel margins.

The frequency of LWD within the assessed segment is relatively low and most of the debris in the channel is functional only on the channel margins (see photo 40). Avalanche tracks are coupled to the left bank of the stream for approximately 2 km of the channel length. These polygons are labeled as non-productive-brush and are dominated by shrub species such as alder and willow (see photo 41). The avalanches generally have impacted the riparian vegetation on the opposite side of the stream also. Coniferous forest stands older than 141 years are the predominant riparian vegetation communities in the remainder of the reach.

Disturbance levels observed within the assessed segment of the stream were generally low. Disturbance indicators noted include disturbed stone lines, pool in-filling (with gravel and cobble) and LWD function. This reach is considered to have a low sensitivity to changes in the supply of water, sediment and/or debris.

6.4 Sediment Source Survey

An Erosion and Mass Wasting Risk Assessment (EMRA) of the road network in these drainages was previously completed (IWS, 1999). The EMRA was utilized for the sediment source survey (SSS) in the Lempriere and Manteau Creek watersheds. The purpose of the EMRA was to identify those portions of the road network that are considered a moderate or high risk to forestry and/or aquatic resources. The total length[22] of moderate and high risk road within the two watersheds is approximately 23.1 km and 14.4 km, respectively (see Table 5). A total of nine priority sites (see map in Appendix H) were identified in the watersheds during completion of the EMRA (IWS, 1999). Rehabilitation of priority site #15 in the Manteau watershed was completed in 1999, leaving eight outstanding priority road segments. The numbers and lengths of outstanding priority road segments identified in the EMRA are presented in Table 5, as are the total lengths of moderate and high risk road in the watersheds.

[22] includes previously and recently identified moderate and high risk road segments

Table 5: Summary of Outstanding Priority Road Sites and Moderate and High Risk Road

Watershed	Number of Outstanding Priority Sites (from EMRA)	Length of Outstanding Priority Road Sites (km)	Total Length of Moderate Risk Road (km)	Total Length of High Risk Road (km)
Lempriere Creek	6	10.7	17.6	11.7
Manteau Creek	2	6.9	5.5	2.7

A road was constructed through class V terrain during the late 1960's, in the lower Lempriere watershed. This road, mapped as a trail downslope of the 1300 Road, is now included as a high risk road segment and labeled priority site "A"(see photo 42). Review of pre-development (1966) and post-development (1975) aerial photographs indicates that six mass wasting sites located downslope of this road pre-date the road construction. However, the road prism became the initiation zone for further mass wasting (slides a, b, c and d).

To eliminate discrepancies between different documents, the numbering scheme developed for the EMRA (IWS, 1999) was utilized to label priority road sites and landslides on the maps accompanying this report. Additionally, the Gosnell Watershed Assessment Procedure (IWS, 2001) identifies that Road 1303.02 should be considered as a higher priority site.

Five forestry-related landslides were identified in the Manteau watershed and twelve were identified in the Lempriere drainage in the EMRA (see map in Appendix H and photos 43-45). Fifteen of the seventeen forestry-related landslides in these drainages are associated with the priority sites. An inventory of the landslides identified in the EMRA in the Lempriere and Manteau watersheds is presented in Table 6 (see EMRA for full details regarding each landslide). The five additional slides identified in the Lempriere watershed (slides a-e) are also presented in Table 6.

Table 6: Inventory of Landslides in the Lempriere and Manteau Watersheds

No.	Size (ha)	Initiation Point	Sediment Delivery	Road No.	Rehab. Priority	Priority Site No.	Watershed
S5	0.10	natural	open slope	n/a	low	n/a	Manteau
S6	0.10	cutblock	open slope/bench	1210.00	completed	15	Manteau
S7	0.80	cutblock	road/gully	1210.00	completed	15	Manteau
S8	0.70	cutblock	road/open slope	1210.00	completed	15	Manteau
S9	1.00	cutblock	road/slope	1200.00	high	16	Manteau
S10	1.60	road	slope/floodplain	1200.00	high	16	Manteau
S14	0.10	cutblock	slope	1306.00	low	n/a	Lempriere
S15	0.05	cutblock	road	1300.00	moderate	7	Lempriere
S16	0.05	road	slope	1500.12	moderate	6	Lempriere
S17	0.05	landing	slope	1500.12	moderate	6	Lempriere
S18	0.05	landing	slope/creek	1500.12	moderate	6	Lempriere
S25	0.90	road	slope/creek	1300.00	high	10	Lempriere
S26	0.05	cut slope	road	1300.00	high	10	Lempriere
S27	2.60	landing	road/creek	1300.04	high	8	Lempriere
S28	0.15	cutblock	bench	1300.00	moderate	n/a	Lempriere
S29	0.10	road	road/slope	1300.00 1300.03	moderate	9	Lempriere
S30	0.25	road	open slope	1303.02	high	11	Lempriere
S31	0.10	road	slope	1303.00	moderate	9	Lempriere
a	0.06	road	slope/creek	trail	low	A	Lempriere
b	0.15	road	slope/creek	trail	moderate	A	Lempriere
c	0.10	road	slope/creek	trail	low	A	Lempriere
d	0.10	road	slope/creek	trail	low	A	Lempriere
e	0.20	road	slope/creek	1300.00	moderate	B	Lempriere

Large (>0.05 ha), natural sediment sources coupled to the mainstem stream channels occur in both the Lempriere and Manteau watersheds. Five large, natural sediment sources adjacent to reaches 1 and 2 of Lempriere Creek were identified during the field assessment or from the aerial photographs. Thirteen potential, natural sediment sources were also noted on the aerial photographs, coupled to

the channel in reach 2 of Lempriere Creek. These thirteen sites appear to be sources of sediment on the 1966 and/or 1975 photos but have since revegetated. Four mass wasting sites (slides a-d) were identified during the air photo review, adjacent to the trail (priority site A) upslope of reach 2. Another mass wasting site (slide e - priority site B) was identified adjacent to the 1300 Road approximately 500 m north of priority site #10. Additionally, two landslide scars are identified adjacent to reach 2 of Lempriere Creek in the terrain stability mapping. This inventory of large sediment sources (see Tables 7 and 8) does not include avalanche tracks that are coupled to the channel and which contribute sediment to the channels episodically.

Table 7: Large, Natural Sediment Sources in the Lempriere Watershed

SS No.	Approx. Size (ha)	Origin	Coupling	Surficial Materials	Revegetation	Survey Method
1	0.05	natural	coupled	fluvial	~75%	field
2	0.05	natural	coupled	fluvial	~60%	field
3	0.07	natural	coupled	glaciofluvial	~20%	air photo
4	0.25	natural	coupled	glaciofluvial	~75%	air photo
5	0.10	natural	coupled	glaciofluvial	very little	field

Three large, natural sediment sources coupled to the stream channel were identified in the Manteau watershed (see Table 8). Two sediment sources (SS#1 and #2) were observed in the field downstream of the reach 2-3 break (see photo 46). The third sediment source is coupled to reach 5 at the toe of a large avalanche track. The effects of the third sediment source are discussed further in section 6.3 (Manteau Creek - reach 5).

Table 8: Large, Natural Sediment Sources in the Manteau Watershed

SS No.	Approx. Size (ha)	Origin	Coupling	Surficial Materials	Revegetation	Survey Method
1	0.06	natural	coupled	glaciofluvial	~80%	field
2	0.10	natural	coupled	glaciofluvial	~50%	field
3	0.40	natural	coupled	glaciofluvial	~20%	air photo

6.5 Potential Risks Associated with Forestry Development

6.5.1 Peak flow risks

There are currently few concerns related to potential peak flow increases in these watersheds. It is generally accepted that detectable changes in annual run-off do not occur until greater than 20% of a forested watershed is disturbed or harvested (Rekston, 1991). The probability that detectable changes in peak flows have occurred within the watersheds is low or very low at the existing harvesting levels (refer to Appendix D). The low or very low probabilities result from the relatively low equivalent clearcut areas and their corresponding peak flow indices for Lempriere and Manteau Creeks (see Table 9). Approximately 3.3% of the ECA in the Lempriere watershed is derived from areas burned by wildfire.

Table 9: Equivalent Clearcut Areas and Peak Flow Indices (Fall 2000)

Watershed	Equivalent Clearcut Area (%)			Peak Flow Index
	Below H_{60}	Above H_{60}	Total	
Lempriere Creek	11.6	2.8	14.4	0.16
Manteau Creek	5.4	0.5	5.9	0.06

The most significant concern related to potential peak flow increases is the sensitivity of some stream reaches to increases in flow regimens. While the levels of stream channel disturbance observed in the watersheds were generally low, moderate disturbance levels do exist in some stream segments. Segments of reaches 1 and 2 in the Lempriere watershed and reaches 1, 2, and 4c in the Manteau watershed have moderate disturbance levels (whether natural or influenced by forestry activities), rendering these reaches more sensitive to changes in the supply of water. Nonetheless, the risk associated with peak flow increases related to past forestry development is **low** or **very low** in both watersheds.

Potential changes in natural drainage patterns and run-off rates are a concern when high road densities exist within a watershed. Current total road densities are relatively low in both the Lempriere and Manteau watersheds. The road density above the H_{60} line is also low in these watersheds.

From the perspective of managing for peak flow increases and accelerated stream bank erosion, current risk levels related to peak flow increases are **low** and **very low** in the Lempriere and Manteau Creek watersheds, respectively (refer to Appendix D).

6.5.2 Sediment supply risks

Eight of the assessed stream reaches within the Lempriere and Manteau watersheds are moderately to very highly sensitive to an increased sediment supply. The inherent sensitivity of these channels is largely due to the nature of the streambed and bank materials, channel hydraulic properties and/or the topography in these watersheds. Existing channel disturbance can also increase the sensitivity rating of a stream reach.

Natural sediment sources and avalanche tracks are coupled to the channels of both streams. Episodic mass wasting events are a natural process supplying sediment to the stream channels in these watersheds. Analysis of sediment supply risks does not consider the natural sediment sources unless accelerated erosion related to forestry development has occurred at a particular site.

Road densities, road locations and stream crossing densities can influence the sediment supply to the stream channels. The existing road and stream crossing information is summarized in Table 10.

Table 10: Existing Road and Stream Crossing Summary

Watershed	Length of Existing Road (km)	Existing Road Density (km/km^2)	Existing Stream Crossings	Existing Density ($No./km^2$)
Lempriere Creek	65.018	0.514	54	0.43
Manteau Creek	22.033	0.201	17	0.15

The current road densities (km of road /km^2 of area) in the Lempriere and Manteau Creek watersheds are relatively low, in relation to surface erosion hazard. The *potential* hazard of surface erosion associated with the current stream crossing densities is moderate in the Lempriere Creek watershed and low in the Manteau Creek watershed. Only four existing stream crossings occur on the

mainstem(s) of Manteau Creek and two crossings are located on the mainstem of Lempriere Creek. The remainder of the crossings in these watersheds occur on mapped tributaries to Lempriere and Manteau Creeks. Five crossings of unnamed tributaries were identified as problems while accessing the upper Lempriere Creek watershed via the 1300 Road. Four of these crossings are included within the priority sites or the high risk road segments. At the site that is not within a priority or high risk segment, water was observed ponding on the 1300 Road, approximately 700 m south of the junction with the 1303 Road.

The mass wasting hazard associated with the density of road on unstable soils is currently low in the Lempriere and Manteau Creek watersheds. Overall, the probability that sediment supply to the stream channels has been increased from forestry-related mass wasting events is judged to be low in the Manteau watershed. This probability is moderate for reaches 1 and 2 of Lempriere Creek and low in the remainder of the Lempriere watershed.

Within the Lempriere and Manteau Creek watersheds, the levels of risk to aquatic resources associated with forestry-related increases in coarse-textured sediment supply are generally **low**. A **moderate** level of risk has been determined for reach 1 of Lempriere Creek and reaches 1 and 4c (alluvial fans) of Manteau Creek. The **moderate** risk rating for reach 1 of Lempriere results from a moderate probability of a sediment supply increase and a moderate channel sensitivity rating. The **moderate** risk ratings for reaches 1 and 4c of Manteau Creek result from a low probability of a sediment supply increase and a very high channel sensitivity rating.

6.5.3 LWD supply risks

Large woody debris is important in portions of both watersheds for controlling sediment storage, energy dissipation and stable channel morphologies. Fisheries values in many stream reaches are also dependent on an adequate supply of LWD over the long-term. It is for these reasons that many stream reaches have been rated as having a moderate to high sensitivity to a reduction in LWD supply. Full removal of the riparian forest is considered to highly modify[23] riparian function. Retention of a riparian buffer of less than ~20 m width is considered a moderate modification of

[23] only human-caused modifications to riparian structure and function are considered in the risk analysis

riparian function. Numerous avalanche tracks, swamps and naturally non-productive areas occur within the Lempriere and Manteau watersheds. As these areas are non-forested due to natural processes, reduced riparian function in these areas is not considered in the risk analysis.

Human-caused modifications to the riparian forests adjacent to the mainstem channel of Lempriere Creek are generally restricted to the upper watershed. Approximately 350 m of forest adjacent to the channel in reach 1 was harvested in 1969. A variable width (< 20 m) buffer was left in most areas and regeneration of trees is occurring within the block. Current impacts to riparian function are considered low within this reach.

Harvesting of riparian forest adjacent to reach 2 of Lempriere Creek has occurred only at the most upstream end of the stream reach. The single-bank areas affected by riparian harvesting are located within opening 2, polygon 533. Approximately 150 m (~0.6% of the total[24] reach length) of moderately modified and 600 m (~2.5% of the total reach length) of highly modified riparian forest currently exist adjacent to reach 2. Human-caused modifications to riparian structure have occurred over a distance (both banks) of about 650 m (~6.5% of the total reach length) adjacent to reach 3 of Lempriere Creek. This area is considered moderately modified in regard to riparian function. As these areas are all labeled as sufficiently restocked, recovery of the arboreal component of the riparian vegetation will continue to occur. Recruitment of LWD to the stream channels within the harvested areas will be affected for a period of many decades.

The only moderately or highly modified (by humans) riparian buffers in the Manteau watershed are situated adjacent to reach 3 of Manteau Creek. Approximately 150 m (~1.6% of the total reach length) of riparian forest has been highly modified by forest harvesting. Overall, the impacts from this level of riparian disturbance are considered to be low.

The levels of risk to aquatic resources associated with forestry-related LWD supply decreases are currently **very low** or **low** in all of the assessed stream reaches within the Lempriere and Manteau Creek watersheds. Localized modifications to riparian structure have occurred in some areas of each watershed, but the overall impacts to riparian function are considered low.

[24] total length includes both banks (i.e. reach length x 2)

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Cumulative Effects and Summary of Risks

Fisheries are the primary aquatic resource value identified in these watersheds. Protection of aquatic resource values in these watersheds is dependent on the minimization of accelerated stream channel disturbance. The current ECA's are 14.4% and 5.9% in the Lempriere and Manteau Creek watersheds, respectively. Overall, the current levels of forest harvesting activities do not generate a level of risk to aquatic resources greater than **low** in the peak flow risk category in either of the watersheds.

The level of risk to aquatic resources associated with an increase in the supply of coarse-textured sediment is generally **very low** or **low** in the Lempriere and Manteau Creek watersheds. A **moderate** level of risk exists for reach 1 of Lempriere Creek. This risk rating results from a moderate probability of a forestry-related sediment supply increase and a moderate channel sensitivity. A **moderate** level of risk exists for reaches 1 and 4c of the Manteau Creek watershed. This risk level reflects a low probability of a forestry-related sediment supply increase and a very high channel sensitivity for the alluvial fans.

The calculated risk to aquatic resources resulting from a decreased LWD supply is **low** or **very low** in all of the assessed stream reaches in the Lempriere and Manteau Creek watersheds. Localized modifications to riparian structure have occurred in some areas of each watershed, but the overall impacts to riparian function are considered low.

7.2 In-Stream Works

No moderate or high priority opportunities for in-stream works were identified within the Lempriere and Manteau Creek watersheds. Moderate disturbance levels exist within reaches 1 and 4c of Manteau Creek and in some segments of reaches 2 and 5 of Manteau Creek. Moderate disturbance levels occur within some segments of reaches 1 and 2 of Lempriere Creek. Reaches 1 and 4c of Manteau Creek are not considered a moderate or high priority for in-stream restoration works, due to the unstable nature of the alluvial fans. Reach 1 of Lempriere Creek is not recommended for restoration as it displayed some disturbance indicators in the pre-development aerial photographs and because the disturbed segment is located within the floodplain of the North Thompson River.

The remaining reaches are not considered moderate or high priorities, as the disturbance levels in these reaches are largely related to natural sediment sources and/or episodic events related to avalanche tracks.

7.3 Upslope Works

There are many opportunities to complete watershed restoration activities within the upland portions of the watersheds. Moderate and high risk road segments totaling 23.1 km and 14.4 km were identified in the Lempriere and Manteau watersheds in the SSS. The eight outstanding priority road sites identified in the EMRA (IWS, 1999) total 17.6 km of road length. Two additional priority sites (1 road and 1 slide) in the Lempriere watershed are included in the SSS. The road site (site A) is approximately 1.6 km in length, it is situated upslope of lower reach 2 of Lempriere Creek and it begins and terminates at the 1300 Road. Site B is a mass wasting event located adjacent to the 1300 Road.

Watershed	Number of Outstanding Priority Sites (from EMRA)	Length of Outstanding Priority Road Sites (km)	Total Length of Moderate Risk Road (km)	Total Length of High Risk Road (km)
Lempriere Creek	6	10.7	17.6	11.7
Manteau Creek	2	6.9	5.5	2.7

Minimization of accelerated coarse-textured sediment input to stream channels in the watersheds is necessary to maintain channel stability and protect aquatic resources. Minimization of fine-textured sediment input to stream channels in the watersheds is also necessary to protect water quality. Road deactivation and hillslope stabilization activities need to be scheduled and completed to reduce the risks to aquatic resources associated with past forestry development.

7.4 Conclusions

The conclusions of the Lempriere and Manteau Creek watershed assessments are as follows:

1. The existing levels of forest harvesting are low in the Lempriere and Manteau Creek watersheds, with current (Fall 2000) ECA's of 14.4% and 5.9%, respectively. ECA's below 20% suggest that there should be no detectable change in annual run-off in these streams, as a result of forestry activities. The risk associated with increased peak flows is considered low for these watersheds.
2. Accelerated sediment production and delivery to stream channels is a primary concern in both the Lempriere and Manteau Creek watersheds. Road construction techniques and on-going road maintenance are the principal management issues. Forest development strategies that minimize road densities and the "life span" of newly constructed roads should be considered, to reduce risks associated with sediment supply increases to stream channels in these watersheds. Rate of cut (i.e. ECA) and impacts to riparian function are currently considered secondary concerns in these watersheds.
3. The current channel disturbance levels vary from undisturbed to moderate in the assessed stream reaches within the Lempriere and Manteau watersheds. Moderate levels of disturbance exist on the two alluvial fans (reaches 1 and 4c) situated within the Manteau watershed. Moderate levels of disturbance also occur within segments of reach 1 of Lempriere Creek and reach 2 of both streams. These levels of disturbance are predominantly associated with natural sediment sources and/or avalanche tracks within these watersheds.
4. Forestry-related mass wasting events and an associated debris torrent have occurred on an unnamed[25] tributary (slide #27/priority site #8) to reach 2 of Lempriere Creek. Disturbance levels in this tributary stream increased due to this event(s), but no readily detectable changes in channel attributes in the mainstem of Lempriere Creek were apparent in the review of aerial photographs from different years.
5. In-stream works to improve channel conditions in reaches 1 and 4c of Manteau Creek are not recommended due to the unstable characteristics of the alluvial fans. Reach 1 of Lempriere Creek is not recommended for restoration as it displayed some disturbance indicators in the pre-development aerial photographs and because the disturbed segment is located within the floodplain of the North Thompson River. Reach 2 of both Lempriere and Manteau Creeks are

[25] referred to as Dawn Creek in the North Thompson EMRA (IWS, 1999)

not considered moderate or high priorities for in-stream works, as the disturbance in these reaches appears to be largely related to natural sediment sources and episodic events associated with avalanche tracks.

6. There are many opportunities to complete watershed restoration activities within the upland portions of the watersheds. Moderate and high risk road segments totaling 23.1 km and 14.4 km were identified in the Lempriere and Manteau watersheds. Two priority road sites are outstanding in the Manteau watershed and six priority road sites are outstanding in the Lempriere watershed. Two new priority sites (sites A and B) have been identified in the Lempriere watershed.

7.5 Recommendations to the Watershed Advisory Committee

The recommendations to the Watershed Advisory Committee are as follows:

1. In regard to proposed development, the selection of material used to construct the fill slopes or to protect exposed soils from surface erosion, should be based on the risk of sediment delivery to adjacent watercourses. Suitable erosion and sediment control strategies should be incorporated into the road construction and deactivation plan throughout the watersheds.
2. Riparian areas managed in accordance with Clearwater Forest District Riparian Management Area Policy should be adequate to protect aquatic resources. Windthrow hazard assessments will need to be completed in the proposed blocks to ensure that the riparian reserves are windfirm. Windthrown trees can result in channel disturbance, can expose erodible soils and potentially initiate mass wasting events. Appropriate strategies will need to be developed to reduce any concerns identified in the windthrow hazard assessment.
3. Road deactivation and/or hillslope stabilization activities need to be scheduled and completed for the ten priority sites identified in the Lempriere and Manteau Creek watersheds (see Section 7.3). Availability of funding will likely limit the number of sites deactivated in 2001 and some sites may therefore need to be re-scheduled for 2002. Priority site 15 (including slides 6, 7 and 8) in the Manteau watershed was completed in 1999.

Watershed	Priority Site	Road	Slide No.	Risk	Scheduled for Completion
Lempriere	6	1500.12	S16, S17, S18	moderate	2001
Lempriere	7	1300	S15	high	FSR
Lempriere	8	1300.04	S27	high	2001
Lempriere	9	1303	S29, S31	high	road permit
Lempriere	10	1300	S25, S26	high	FSR
Lempriere	11	1303.02	S30	high	2001
Lempriere	A	trail	a, b, c, d	high	2001
Lempriere	B	1300	e	moderate	2001
Manteau	14	1200	n/a	moderate	2001
Manteau	16	1200	S9, S10	high	2001

4. Kilometres 11 to 15.5 of the Lempriere FSR should be deactivated and the alternative access through the Miledge and Chappell drainages should be utilized. This section of the Lempriere FSR is considered a high risk and has several mass wasting events coupled to stream channels. The alternative access through the neighboring drainages is considered a lower risk.
5. Proposed forestry development in the Manteau watershed must take into consideration the effects of changes in water, sediment and/or debris supply on the inherently unstable alluvial fans that the stream flows across in reaches 1 and 4c.
6. Prior to developing any proposed roads or cutblocks within the catchment area of the unnamed tributary[26] to reach 2 of Lempriere Creek, road deactivation and/or upgrade activities need to be planned and/or completed. A Terrain Stability Field Assessment also needs to be completed for any proposed roads or cutblocks, with consideration for the channel condition of the tributary stream.
7. Red Flag ECA's of 25% and 20% are recommended for the Lempriere and Manteau Creek watersheds. The lower Red Flag ECA in the Manteau Creek watershed reflects the unstable nature of the two alluvial fans that the stream flows across.
8. The watersheds should be re-assessed if there is a concern with the level of proposed development or when proposed forestry development approaches the Red Flag ECA's.
9. Refer to the Watershed Advisory Committee recommendations in Appendix J.

[26] referred to as Dawn Creek in the North Thompson EMRA (IWS, 1999)

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APPENDIX A

Photographs from the WAP

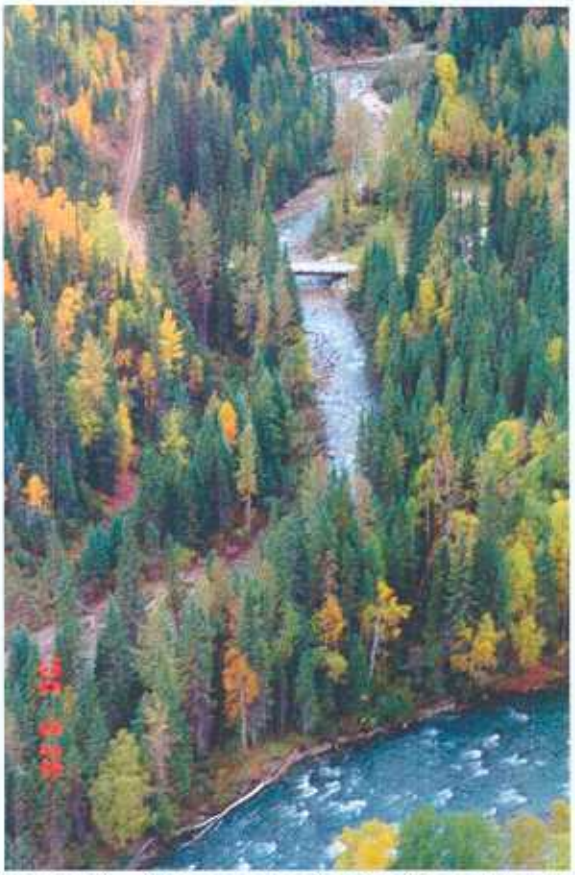


Photo 1: Lempriere Creek (reach 1) – Sinuous plan form with rapid dominated morphology. Conifer or mixed riparian forest adjacent to channel. SS #2 in background on outside of bend.

Photo 2: Lempriere Creek (reach 1) – Mid-channel sediment bars, channel braiding and LWD jam at confluence with N. Thompson River. SS #1 coupled to channel on right bank.

Photo 3: Lempriere Creek (reach 1) – Low level of channel disturbance in mid-reach. Dense alder adjacent to channel in some segments.

Photo 4: Lempriere Creek (reach 1) – Cascade-pool morphology in upper reach.

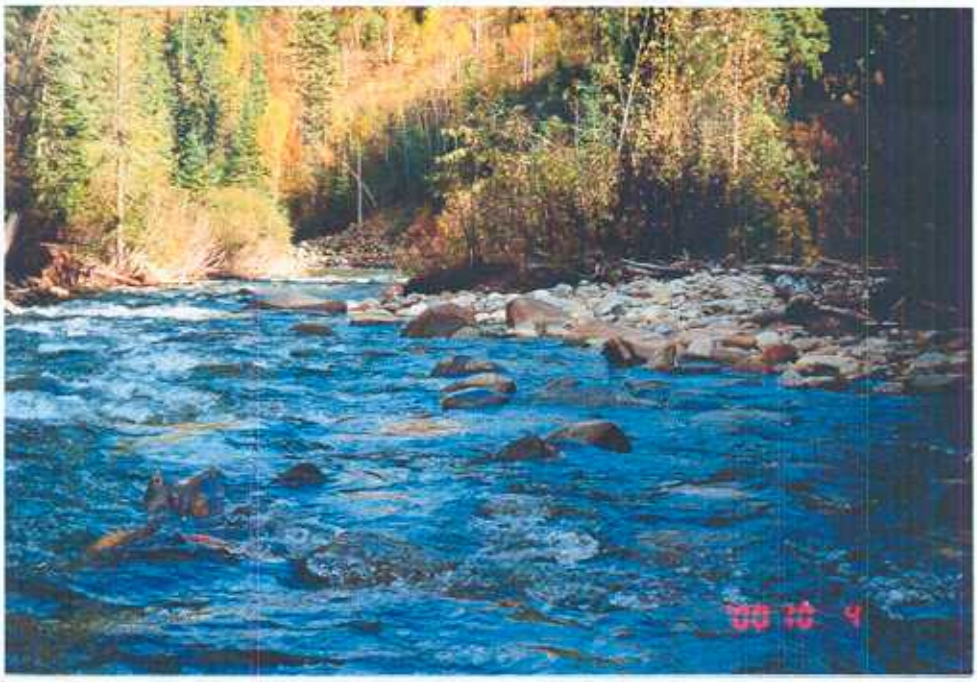


Photo 5: Lempriere Creek (reach 1) – Left channel now carries majority of flow.

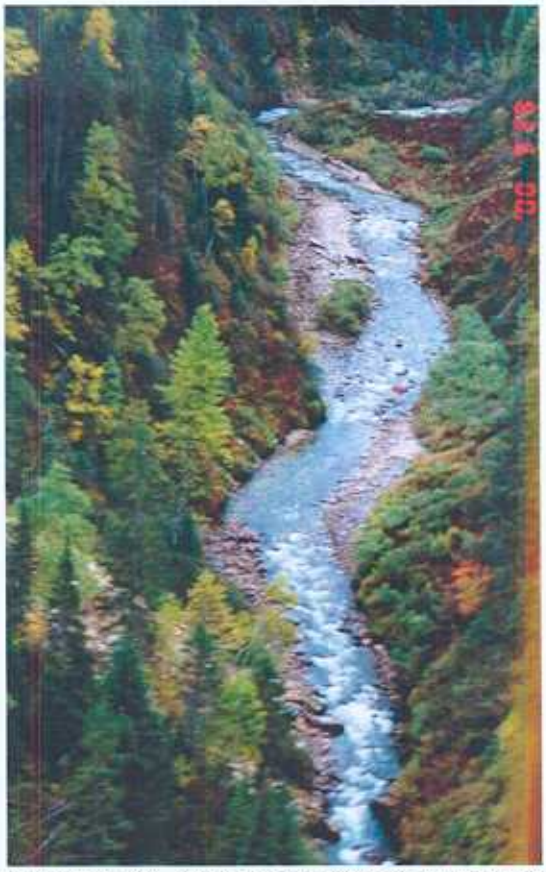


Photo 6: Lempriere Creek (reach 2) – Stable cascade-pool morphology with coupled valley sidewalls. Mass wasting event coupled to channel in foreground.

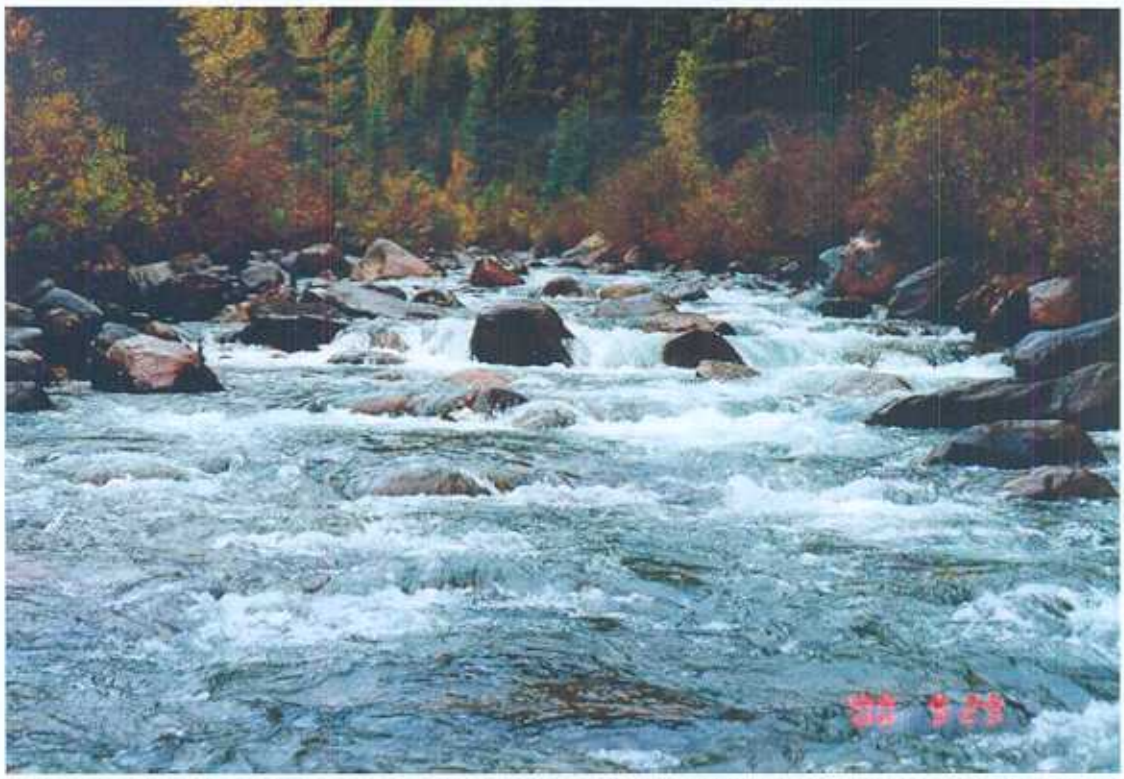


Photo 7: Lempriere Creek (reach 2) – Stable cascade-pool morphology. Note boulder and cobble bank materials and dense riparian shrub layer.

Photo 8: Lempriere Creek (reach 2) – Mouth of unnamed tributary affected by slide 27 and resultant debris torrent. SS #4 is located just upstream of the confluence.

Photo 9: Lempriere Creek (reach 2) – SS #5 at toe of avalanche track in upper reach.

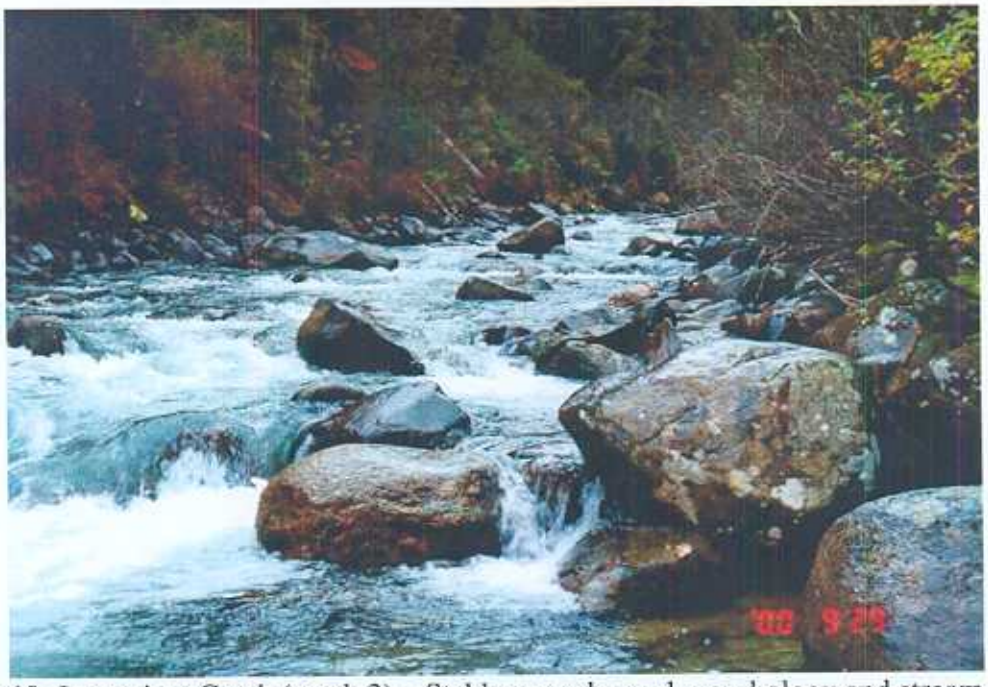


Photo 10: Lempriere Creek (reach 2) – Stable cascade-pool morphology and stream banks.

Photo 11: Lempriere Creek (reach 2) – Low level of disturbance. Disturbance indicators in this channel segment are mid-channel deposits and LWD orientation.

Photo 12: Slide #27 on tributary to Lempriere Creek. Initiation point for debris torrent down the stream. See photos 8 and 13 for effects further downstream on this tributary.

Photo 13: Tributary to Lempriere Creek. Torrented segment of stream between 1300 Road and Lempriere Creek. Initiation point was slide #27.

Photo 14: Lempriere Creek (reach 3) – Stable riffle-pool morphology with low degree of entrenchment.

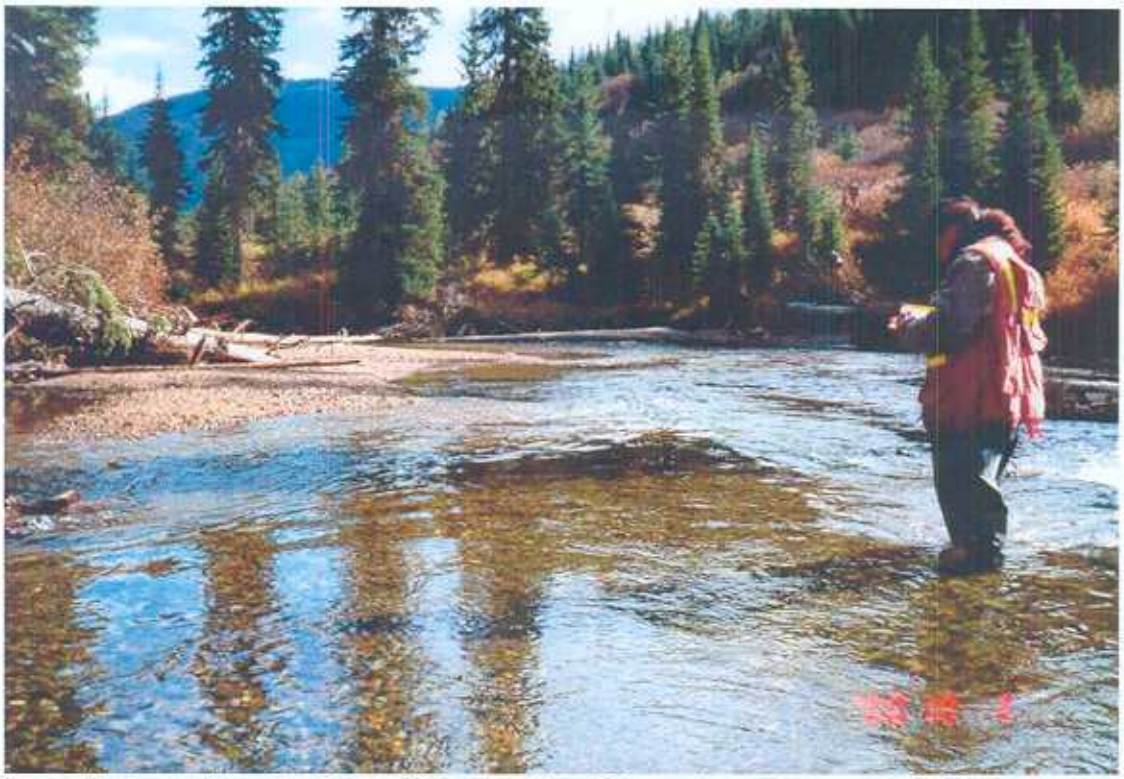


Photo 15: Lempriere Creek (reach 3) – Stable riffle-pool morphology with gravel and sand dominated stream bed.

Photo 16: Lempriere Creek (reach 3) – Example of eroding banks comprised predominantly of fine sand.

Photo 17: Lempriere Creek (reach 3) – Stable riffle-pool morphology with decoupled valley sidewalls, low degree of entrenchment and variable riparian vegetation.

Photo 18: Lempriere Creek (reach 4) – Series of cascades/waterfalls, upstream of existing forest development in watershed.

Photo 19: Manteau Creek (reach 1) – Multi-channel form on alluvial fan, with avulsed channel in background. Riparian buffers were left at time of harvest.

Photo 20: Manteau Creek (reach 1) – Avulsed channel to left side of photo was the original channel.

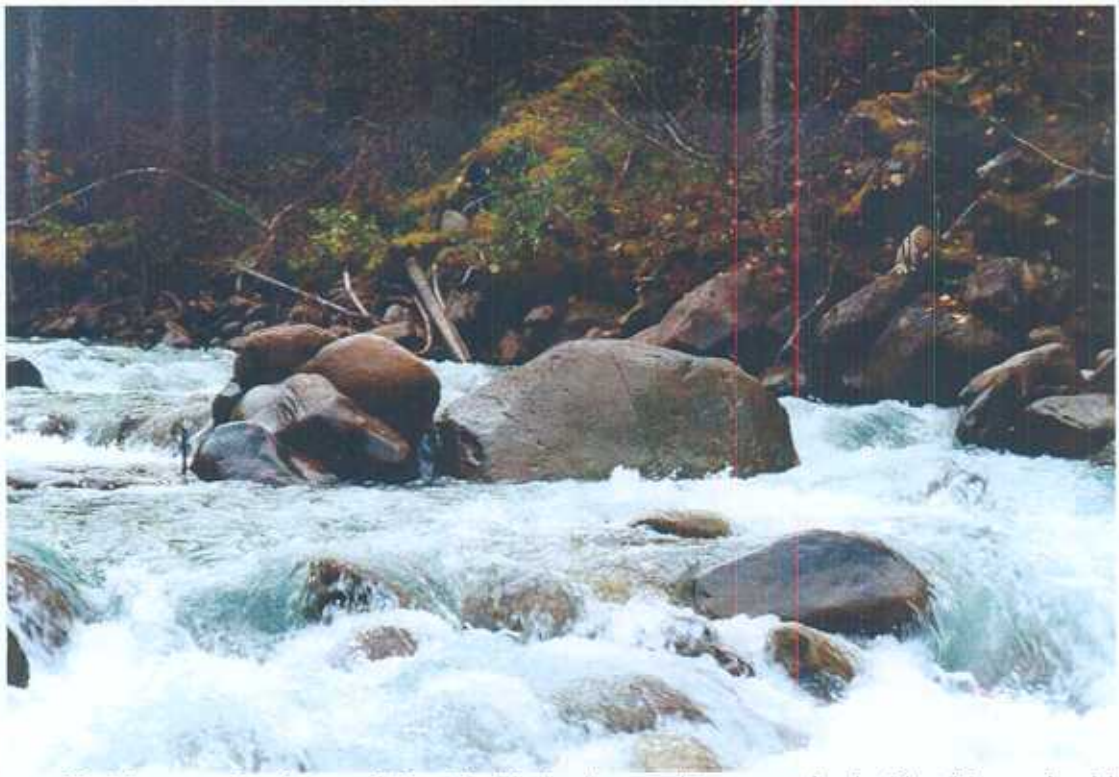


Photo 21: Manteau Creek (reach 2) – Stable bank materials comprised of boulder and cobble.

Photo 22: Manteau Creek (reach 2) – LWD clumped into small jams on channel margins downstream of avalanche track. Example of pulse disturbance event.

Photo 23: Manteau Creek (reach 2) – Wildfire (1998) came close to left bank of channel. Riparian areas were generally not affected by the wildfire.

Photo 24: Manteau Creek (reach 2) – Low level of disturbance with stable stream banks.

Photo 25: Manteau Creek (reach 2) – Example of bank erosion, mid-channel deposits and channel braiding in the middle of the reach.

Photo 26: Manteau Creek (reach 4b) – Example of distributary channel at confluence with mainstem channel. Low gradient channel with stable stream banks.

Photo 27: Manteau Creek (reach 4b) – Stratified bank material (sand/gravel over gravel/cobble) near the toe of the alluvial fan.

Photo 28: Manteau Creek (reach 4b) – Stable riffle-pool morphology and stream banks.

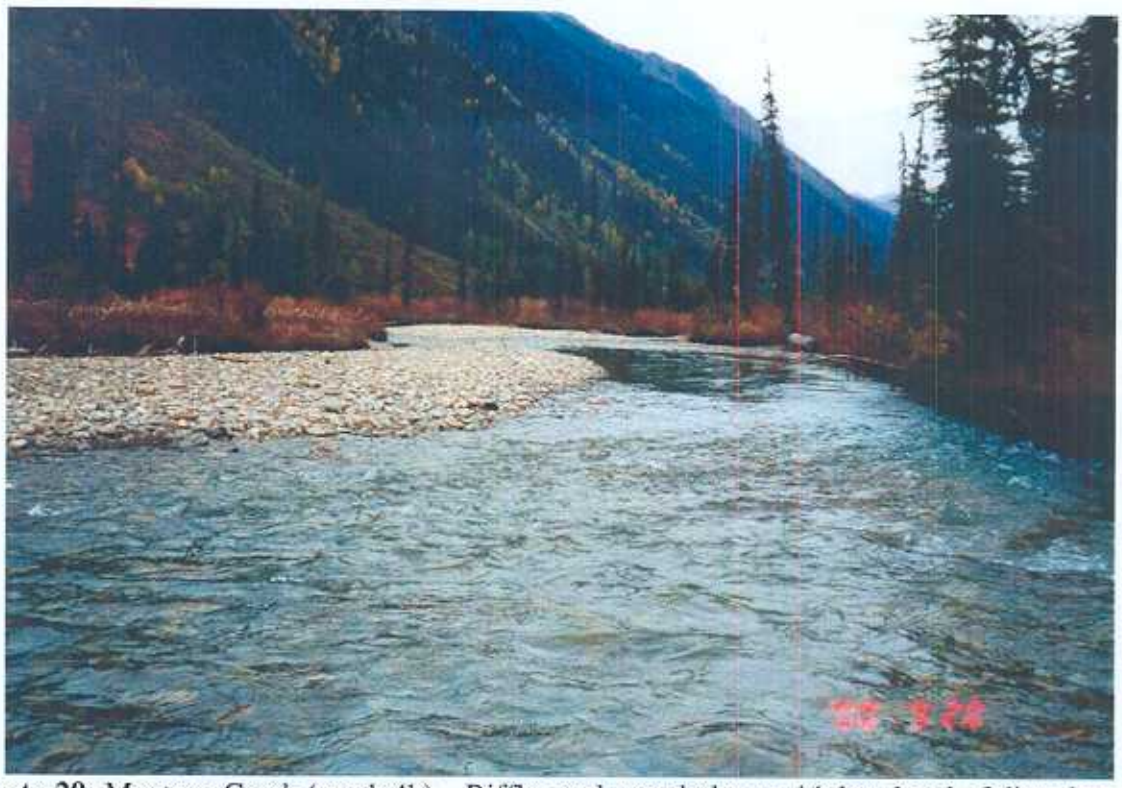


Photo 29: Manteau Creek (reach 4b) – Riffle-pool morphology with low level of disturbance. Extensive lateral bars are characteristic in segments of this reach.

Photo 30: Manteau Creek (reach 4b) – Riffle-pool morphology at confluence of east and west forks. Note erosion occurring on both stream banks.

Photo 31: Manteau Creek (reach 4b) – Mid-channel deposition and bank erosion, upstream of the confluence with the East Fork of Manteau.

Photo32: Manteau Creek (reach 4c) – Stable bank comprised of boulder and cobble in upper portion of reach (near apex of alluvial fan).

Photo 33: Manteau Creek (reach 4c) – Moderate disturbance level in mid-reach on alluvial fan. Disturbance indicators include avulsions, mid-channel deposits and braiding.

Photo 34: Manteau Creek (reach 4c) – Moderate disturbance level on lower alluvial fan. Disturbance indicators include avulsions, mid-channel deposits and braiding.

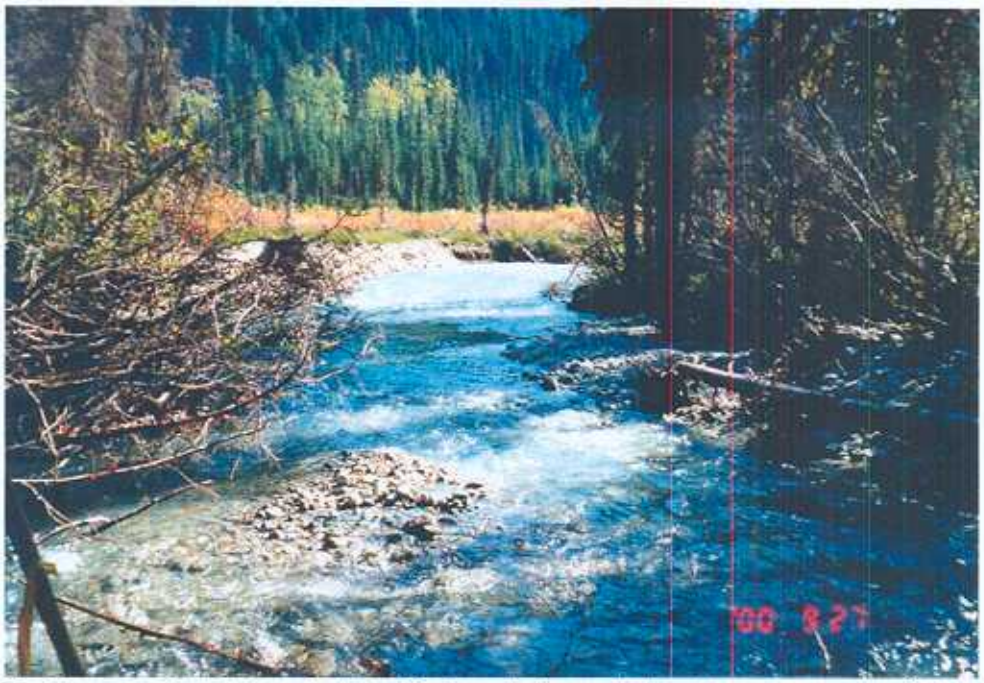


Photo 35: Manteau Creek (reach 4c) – Reduced channel disturbance near toe of alluvial fan.

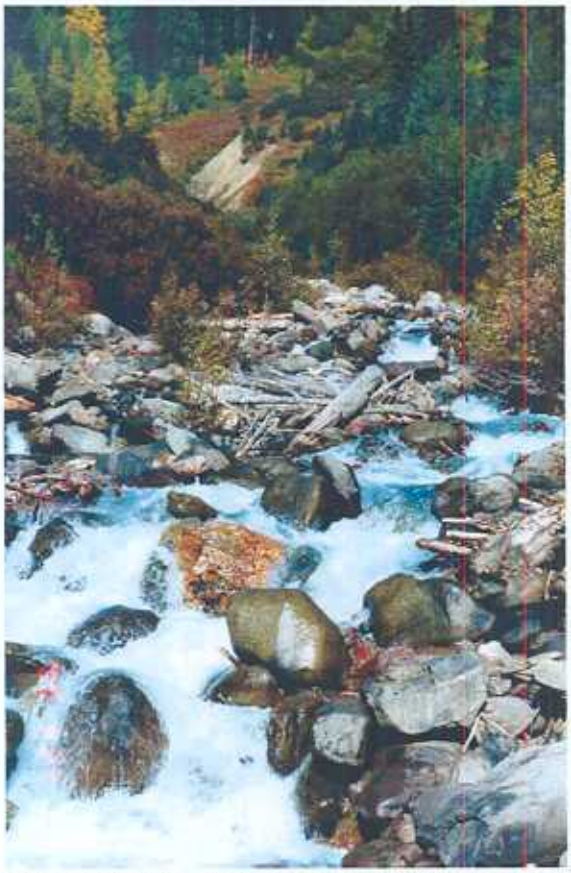


Photo 36: Manteau Creek (reach 4c/5) – Disturbed channel segment with SS #3 in background.

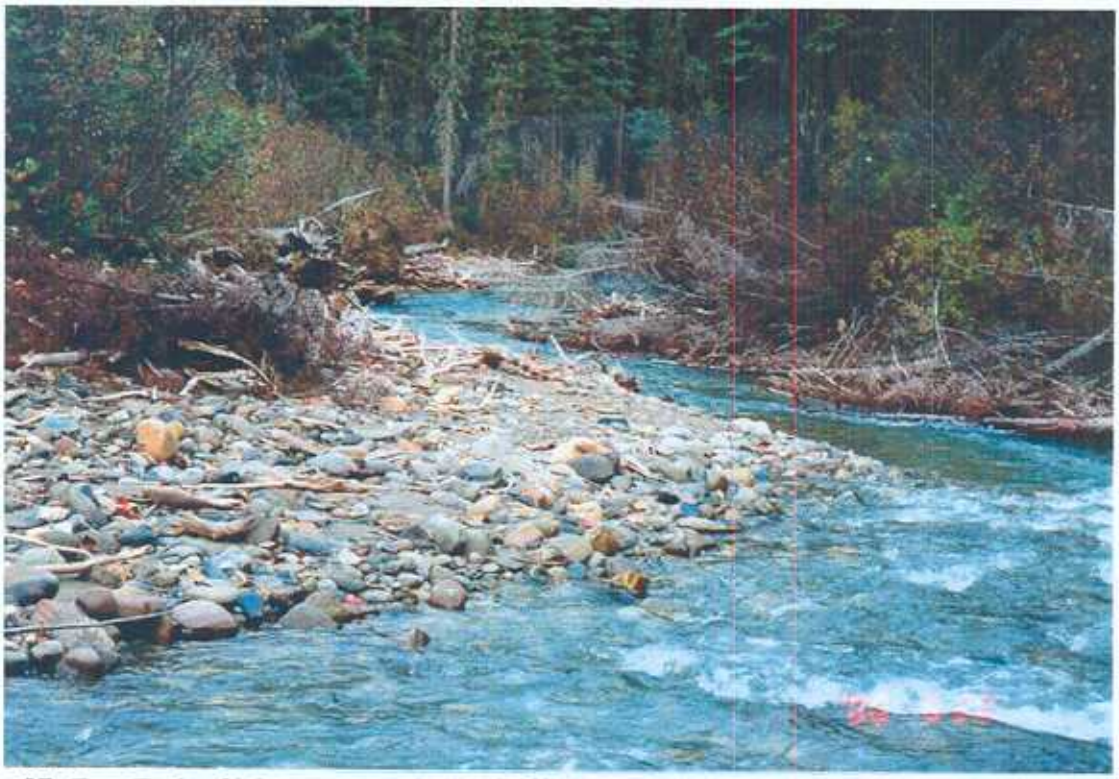


Photo 37: East Fork of Manteau (reach 1) – Riffle-pool morphology with low level of disturbance.

Photo 38: East Fork of Manteau (reach 1) – Berm constructed to protect road prism adjacent to bridge on Road 1211.

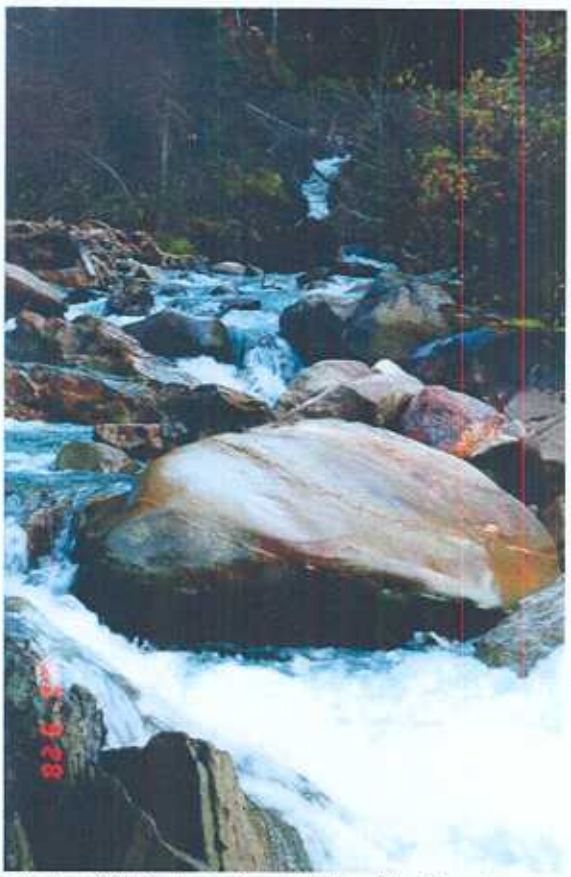


Photo 39: East Fork of Manteau (reach 2) – Stable step-pool morphology.

Photo 40: East Fork of Manteau (reach 3) – Stable cascade-pool morphology. Low frequency of LWD with function generally only on channel margins.

Photo 41: East Fork of Manteau (reach 3) – Stable cascade-pool morphology. Dense shrub layer occurs adjacent to much of the reach.

Photo 42: Lempriere watershed – Priority Site "A", slide "b". Road was built through class V terrain in the late 1960's.

Photo 43: Manteau watershed – Priority site 16, slide 10 on Road 1200.

Photo 44: Lempriere watershed – Priority site 10, slide 25 on Road 1300.

Photo 45: Lempriere watershed – Unnumbered slide initiated at Road 1303.02. Located within opening 18, polygon 167.

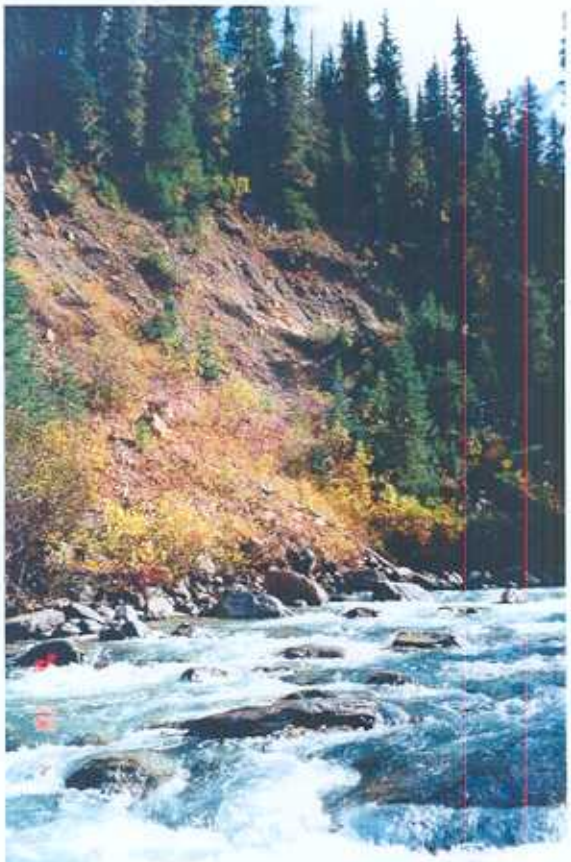


Photo 46: Manteau Creek (reach 2) – Natural sediment source (SS #2) with partial revegetation.

APPENDIX B

List of Aerial Photographs and Maps Utilized

Aerial Photographs Utilized:

Lempriere Creek

1966
BC4396: No. 040-045

1975
BC7812: No. 68-74, 109-115, 134-139, 164-168, 196-198

1997
30BCC97117: No. 160-165
30BCC97118: No. 30-36, 153-163
30BCC97137: No. 26-28, 109-112
30BCC97214: No. 68-72, 156-163

2000
30BCC00095: No. 195-196

Manteau Creek

1966
BC4397: No. 152-154

1975
BC7812: No. 116-118, 126-133, 170-176, 186-191, 229-232

1985
30BC85024: No. 189-190, 212-214, 272-273
30BC85038: No. 152-154

1997
30BCC97118: No. 148-151
30BCC97137: No. 12-19, 78-81, 112-114
30BCC97186: No. 166-176
30BCC97214: No. 52-61, 119-126

2000
30BCC00095: No. 153-154, 205-206
30BCC00101: No. 48-49, 62-66, 118-121

Maps Utilized:

Forest Cover and TRIM Mapsheets

83D.033, 83D.034, 83D.043, 83D.044, 83D.045, 83D.053, 83D.054

Level C Terrain Mapping

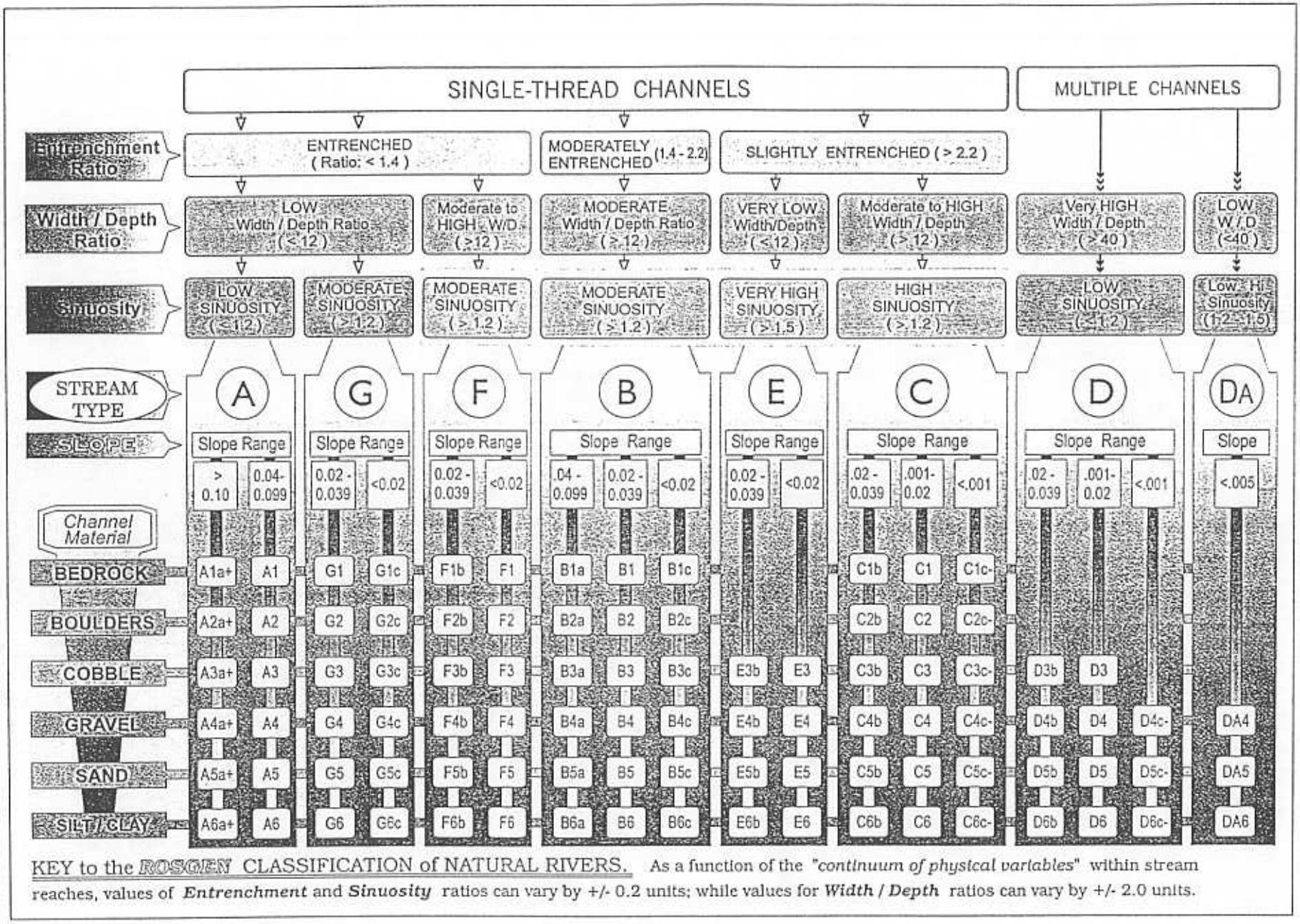
83D.033, 83D.034, 83D.043, 83D.044, 83D.053

APPENDIX C

Key to the Rosgen
Stream Classification System

Stream Type	General Description	Entrenchment Ratio	W/D Ratio	Sinuosity	Slope	Landform/ Soils/Features
Aa+	Very steep, deeply entrenched, debris transport, torrent streams.	<1.4	<12	1.0 to 1.1	>.10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with deep scour pools; waterfalls.
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.	<1.4	<12	1.0 to 1.2	.04 to .10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step/pool bed morphology.
B	Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4 to 2.2	>12	>1.2	.02 to .039	Moderate relief, colluvial deposition, and/or structural. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate w/scour pools.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains.	>2.2	>12	>1.4	<.02	Broad valleys w/terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/pool bed morphology.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	n/a	>40	n/a	<.04	Broad valleys with alluvium, steeper fans. Glacial debris and depositional features. Active lateral adjustment, w/abundance of sediment supply. Convergence/divergence bed features, aggradational processes, high bedload and bank erosion.
DA	Anastomosing (multiple channels) narrow and deep with extensive, well vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth ratios. Very stable streambanks.	>2.2	Highly variable	Highly variable	<.005	Broad, low-gradient valleys with fine alluvium and/or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition w/well-vegetated bars that are laterally stable with broad wetland floodplains. Very low bedload, high wash load sediment.
E	Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio.	>2.2	<12	>1.5	<.02	Broad valley/meadows. Alluvial materials with floodplains. Highly sinuous with stable, well-vegetated banks. Riffle/pool morphology with very low width/depth ratios.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio.	<1.4	>12	>1.4	<.02	Entrenched in highly weathered material. Gentle gradients, with a high width/depth ratio. Meandering, laterally unstable with high bank erosion rates. Riffle/pool morphology.
G	Entrenched "gully" step/pool and low width/depth ratio on moderate gradients.	<1.4	<12	>1.2	.02 to .039	Gullies, step/pool morphology w/moderate slopes and low width/depth ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials, i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates.

TABLE 4-1 General stream type descriptions and delineative criteria for broad-level classification (Level I).



KEY to the *ROSGEN* CLASSIFICATION of NATURAL RIVERS. As a function of the *"continuum of physical variables"* within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

FIGURE 5-3. Classification key for natural rivers.

Stream type	Sensitivity to disturbance[a]	Recovery potential[b]	Sediment supply[c]	Streambank erosion potential	Vegetation controlling influence[d]
A1	very low	excellent	very low	very low	negligible
A2	very low	excellent	very low	very low	negligible
A3	very high	very poor	very high	very high	negligible
A4	extreme	very poor	very high	very high	negligible
A5	extreme	very poor	very high	very high	negligible
A6	high	poor	high	high	negligible
B1	very low	excellent	very low	very low	negligible
B2	very low	excellent	very low	very low	negligible
B3	low	excellent	low	low	moderate
B4	moderate	excellent	moderate	low	moderate
B5	moderate	excellent	moderate	moderate	moderate
B6	moderate	excellent	moderate	low	moderate
C1	low	very good	very low	low	moderate
C2	low	very good	low	low	moderate
C3	moderate	good	moderate	moderate	very high
C4	very high	good	high	very high	very high
C5	very high	fair	very high	very high	very high
C6	very high	good	high	high	very high
D3	very high	poor	very high	very high	moderate
D4	very high	poor	very high	very high	moderate
D5	very high	poor	very high	very high	moderate
D6	high	poor	high	high	moderate
Da4	moderate	good	very low	low	very high
DA5	moderate	good	low	low	very high
DA6	moderate	good	very low	very low	very high
E3	high	good	low	moderate	very high
E4	very high	good	moderate	high	very high
E5	very high	good	moderate	high	very high
E6	very high	good	low	moderate	very high
F1	low	fair	low	moderate	low
F2	low	fair	moderate	moderate	low
F3	moderate	poor	very high	very high	moderate
F4	extreme	poor	very high	very high	moderate
F5	very high	poor	very high	very high	moderate
F6	very high	fair	high	very high	moderate
G1	low	good	low	low	low
G2	moderate	fair	moderate	moderate	low
G3	very high	poor	very high	very high	high
G4	extreme	very poor	very high	very high	high
G5	extreme	very poor	very high	very high	high
G6	very high	poor	high	high	high

a Includes increases in streamflow magnitude and timing and/or sediment increases.

b Assumes natural recovery once cause of instability is corrected.

c Includes suspended and bedload from channel derived sources and/or from stream adjacent slopes.

d Vegetation that influences width/depth ratio-stability.

TABLE 8-1. Management interpretations of various stream types (*Rosgen, 1994*)

APPENDIX D

Philosophy and Application of the Risk Assessment Approach

(Developed by Beaudry and Associates, 1999)

PHILOSOPHY AND APPLICATION OF THE RISK ASSESSMENT APPROACH

The risk assessment approach establishes a level of risk of detrimental impacts to the aquatic resources that may be caused by forestry activities. The risk assessment is based on the evaluation of two components and the use of a "Risk Matrix". The first component of the risk assessment evaluates the sensitivity of a particular stream reach to a change in a specific hydrologic or geomorphic process. This assessment is qualitative and is ranked on a scale of 1 to 5 (i.e. Very Low to Very High). An example would be that: "a bedrock-controlled channel has a 'Very Low' sensitivity to changes in peak flows".

The second component assesses the probability that forestry activities within the watershed will significantly change some specific hydrologic or geomorphic process. The assessment is also qualitative and the probability of change is ranked on a scale of 1 to 5 (i.e. Very Low to Very High). An example of this type would be: "there is a 'Very High' probability that there will be a significant increase in snowmelt generated peak flows if 100% of the forest above the H_{60} line is harvested in an Interior watershed".

The risk assessment value is generated by combining the "sensitivity" rating with the "probability of change" rating on the Risk Matrix. The risks are also scaled from Very Low to Very High. Risk matrices have been developed for three categories of watershed processes: 1) changes in peak flows, 2) changes to the sediment supply and 3) changes to the supply of large woody debris (LWD). The "sensitivity" and the "probability of change" ratings are established by analyzing the information collected from maps, aerial photographs, fieldwork and other relevant data.

This risk assessment procedure works very well to satisfy the requirements of the new Watershed Assessment Procedure (released April 1999). On page 11 of this document it states that: "the Hydrologist will use the report card, together with the field assessment maps, to develop hazard ratings for peak flow, sediment sources, riparian function and channel stability. He or she will then use these ratings in making specific recommendations for the Forest Development Plan".

The results of the risk matrix approach provide an assessment of the real level of risk to the aquatic resources in a specific watershed. This is very different than the original "hazard indices" provided by the Level 1 Watershed Assessment Procedure (Government of BC, 1995b). While the hazard

indices only assessed potential hazards, the risk matrix provides an assessment of the real level of risk that exists for a specific watershed. The real risk is based on detailed fieldwork, past and proposed forestry activities, specific characteristics of the watershed, the channel assessment and the local climate and hydrology. In the old Interior Watershed Assessment Procedure (IWAP), this type of detailed approach was intended to be used only on those watersheds that were identified as having a "medium" or "high" potential hazard (i.e. a Level 1 hazard index greater than 0.5) and disturbed stream channels. This type of detailed analysis was previously termed a Level 3 watershed assessment. The new WAP does not identify different levels of assessment, but rather directs the hydrologist to complete one comprehensive assessment (Government of BC, 1999). The field component of the new procedure is based on reconnaissance-level assessments, however.

Resource values and management objectives for the watershed will determine the level of risk that is acceptable. The acceptable level of risk is a management and socio-economic decision made by resource agencies, based on specific watershed management objectives that are set prior to beginning the assessment. The acceptable level of risk is not a technical decision made by the consulting hydrologist in isolation. However, in general, forest harvesting activities that generate "Very Low" or "Low" levels of risk should not negatively impact aquatic resources.

A "moderate" level of risk (i.e. the gray zone between low and high) needs to be carefully interpreted in the context of the management objectives. For example, if there are very high or unique fisheries values in the watershed (bull trout, for example) and the acceptable level of risk has been defined as low, then some changes to the Forest Development Plan should be considered. These changes should focus directly on the particular "hazard" that has been identified as creating the unacceptable level of risk. For example, if the LWD risk is moderate because of past forest harvesting activities, then the goal should be to reduce the LWD risk, but not necessarily by reducing harvesting. This may be achieved by initiating something like riparian area planting through the Watershed Restoration Program (WRP). If the peak flow risk is moderate then this may lead to specific rate of cut constraints, or possibly re-distribution of cutblocks within the watershed. It is important to remember that the type of constraint imposed must be directly related to the management objectives in the watershed and the acceptable level of risk identified by the resource agencies. Broad, non-specific constraints are generally not effective and may result in activities that don't necessarily protect the aquatic resources in an effective manner.

"High" or "Very High" levels of risk (in any one of the three particular categories) suggest that past and future harvesting activities could lead to significant negative impacts to the aquatic resources. In such cases, the Forest Development Plan may have to be re-designed, if the level of risk is deemed unacceptable to meet the specific management objectives for a particular watershed. Another possibility is to initiate restoration activities in older, harvested areas to mitigate the effects of proposed harvesting activities.

It is of the utmost importance to understand that the management decisions that are made relative to the results of the "risk assessment" must be made in the context of clear and specific watershed management objectives. These objectives are generally defined by the resource agencies (i.e. Ministry of Forests, Ministry of Environment, Lands and Parks, Department of Fisheries and Oceans, Ministry of Health).

Table 1: RISK MATRIX[1] for *PEAK FLOW CHANGES*

		Sensitivity of the stream reach to increases in peak flows				
		1	**2**	**3**	**4**	**5**
Potential for increased peak flows	**1**	A	A	A	A	B
	2	A	B	B	B	C
	3	A	B	C	D	D
	4	A	B	C	D	E
	5	B	C	D	E	E

[1] "Risk" refers to the level of risk imposed on aquatic resources from past and proposed forestry activities in the watershed. The risk matrix on this page only considers the risks associated with increases in snowmelt generated peak flows. These flows are the channel forming flows for most of the areas in the Interior region of British Columbia. The five levels of risk are defined as follows:

A = Very Low
B = Low
C = Moderate
D = High
E = Very High

- The sensitivity of the stream reach to increases in peak flows is a subjective designation. It is determined based on the results of the field-based channel assessments and the morphological characteristics of the reach such as stream gradient (s), stream width (W_b), bed and bank materials, size of largest stream bed particle (D), stream depth (d) and entrenchment ratio (ER). The level of disturbance in the reach is also assessed, using the methodology proposed by the Government of BC (1996). The reach is also classified using the system proposed by Rosgen (1996). The Rosgen classification system is also used to assist in the designation of the sensitivity of the stream reach.

- The potential for increased snowmelt generated peak flows was assessed based on the amount of forest harvesting and hydrological recovery in the watershed (i.e. ECA), the distribution of cutblocks within the watershed, the general aspect of the proposed cutblocks and the relative proximity of the cutblocks to a watercourse. Although no strict algorithm was developed to make this assessment, the following general rules and conceptual model were applied:

    a) A Peak Flow Index less than 25 yielded a "very low" potential for increased peak flows (i.e. a value of 1).

    b) A Peak Flow Index between 25 and 39 yielded a "low" potential for increased peak flows (i.e. a value of 2).

    c) A Peak Flow Index between 40 and 54 yielded a "moderate" potential for increased peak flows (i.e. a value of 3).

    d) A Peak Flow Index between 55 and 70 yielded a "high" potential for increased peak flows (i.e. a value of 4).

    e) A Peak Flow Index greater than 70 yielded a "very high" potential for increased peak flows (i.e. a value of 5).

    f) If most of the proposed cutblocks had a southerly aspect then the designation would be more conservative (e.g. an ECA of 25 with south aspect cutblocks could yield a "moderate" potential).

    g) Based on the concept of a "variable source area", if most of the cutblocks were located close to streams, then the designation would more conservative.

    h) The conceptual modeling is based on recent research results that have been obtained in watershed research trials in the Prince George Forest Region (Beaudry and Gottesfeld, in press; Beaudry and Floyd, 1999).

Table 2: RISK MATRIX[1] for *SEDIMENT SUPPLY CHANGES*

		Sensitivity of the stream reach to increases in sediment supply				
		1	**2**	**3**	**4**	**5**
Potential for increased delivery of sediment	**1**	A	A	A	A	B
	2	A	B	B	B	C
	3	A	B	C	D	D
	4	A	B	C	D	E
	5	B	C	D	E	E

[1] "Risk" refers to the level of risk imposed on aquatic resources from past and proposed forestry activities in the watershed. The risk matrix on this page only considers the risks associated with increases in sediment supply to the stream channel. The amount of sediment delivered to a stream channel can play a large role in shaping the channel, as it must respond to the amount of water and sediment it transports. Channels tend to become wider, shallower and less sinuous where the influx of coarse material has been appreciable (Knighton, 1984; Sullivan et al., 1987; Hogan et al., 1998). The five levels of risk have been defined as follows:

A = Very Low
B = Low
C = Moderate
D = High
E = Very High

- The sensitivity of the stream reach to increases in sediment supply is a subjective designation. It is determined based on the results of the field-based channel assessments and the morphological characteristics of the reach such as stream gradient (s), stream width (W_b), bed and bank materials, size of largest stream bed particle (D), stream depth (d) and degree of entrenchment. The level of disturbance in the reach is also assessed using the methodology proposed in Government of BC (1996). The reach is also classified using the system proposed by Rosgen

(1996). The Rosgen classification system is also used to assist in the designation of the sensitivity of the stream reach.

- The potential for increased delivery of sediment to the stream channel was assessed based on the density and location of roads, the number of stream crossings, the surficial materials in the watershed, the local climate, stream density and the level of coupling of the hillslopes to the stream channel.

Table 3: RISK MATRIX[1] for *LARGE WOODY DEBRIS SUPPLY CHANGES*

		Sensitivity of the stream reach to decreases in large woody debris supply				
		1	**2**	**3**	**4**	**5**
Potential for decreased supply of large woody debris	**1**	A	A	A	A	A
	2	A	B	B	B	C
	3	A	B	C	D	E
	4	A	C	D	D	E
	5	B	C	D	E	E

[1] "Risk" refers to the level of risk imposed on aquatic resources from past and proposed forestry activities in the watershed. The risk matrix on this page only considers the risks associated with decreases in the supply of large woody debris to the stream channel. Many stream channels are very dependent on the supply of Large Woody Debris (LWD) for the maintenance of stream channel diversity and complexity and ultimately maintaining good fish habitat. The removal of the riparian forest, either through forest harvesting, grazing or agriculture, can have a significant detrimental impact on the long-term stability and productivity of the stream channel. The five levels of risk have been defined as follows:

A = Very Low
B = Low
C = Moderate
D = High
E = Very High

- The sensitivity of the stream reach to decreases in the supply of LWD is a subjective designation. It is determined based on the results of the field-based channel assessments and the morphological characteristics of the reach such as stream gradient (s), stream width (W_b), bed and bank materials and stream depth (d). The methodology proposed in Government of BC (1996) and the stream classification system proposed by Rosgen (1996) are used as tools to help

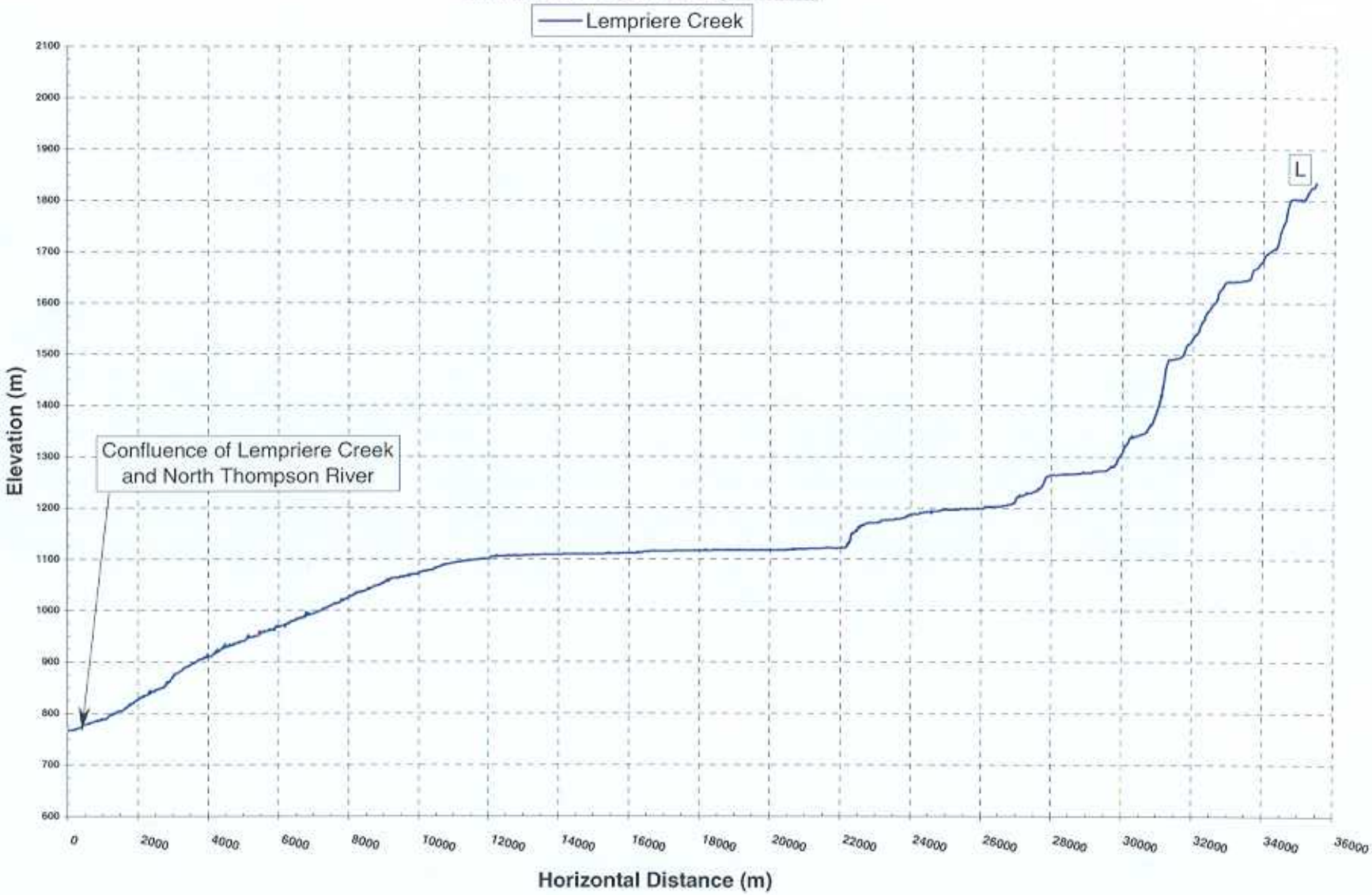
determine the level of sensitivity to a significant decrease in the supply of LWD to the stream channel.

- The potential for a significant reduction in the supply of LWD to the stream channel was assessed based on the level of riparian harvesting that has occurred along the mainstem of the stream channel. This riparian harvesting could be as a result of past forest harvesting activities (i.e. prior to enactment of the Forest Practices Code of British Columbia Act) or agricultural practices.

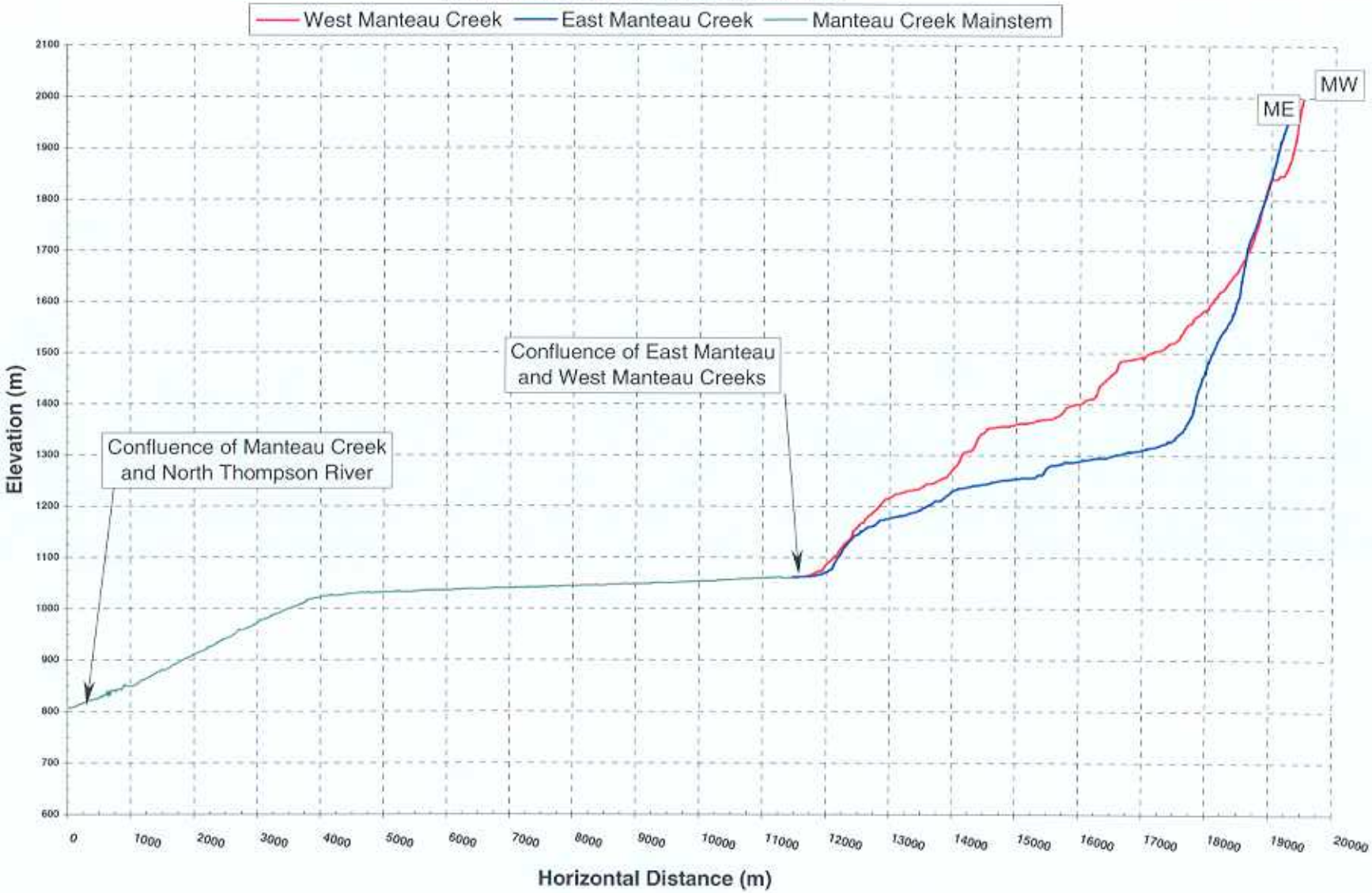
APPENDIX E

Longitudinal Profiles

Lempriere Creek Long Profile



Manteau Creek Multi-Long Profile



APPENDIX F

Watershed Report Cards

Watershed Report Card
(Fall 2000)

Watershed: Lempriere Creek Watershed (126.454 km^2)

1. Total Area Disturbed: 21.096 km^2 (16.7%)
2. Equivalent Clearcut Area: 18.205 km^2 (14.4%)
3. Equivalent Clearcut Area Above H_{60}: 3.582 km^2 (2.8%)
4. Total Road Length: 65.018 km
5. Total Road Density: 0.514 km/km^2
6. Total Road Length Above H_{60}: 8.009 km
7. Road Density Above H_{60} Line: 0.063 km/km^2
8. Length of Road on Unstable[1] Soils: 10.035 km
9. Density of Road on Unstable Soils: 0.079 km/km^2
10. Number of Stream Crossings: 54
11. Stream Crossing Density: 0.43/km^2
12. Length of High Risk Road: 11.7 km
13. Length[2] of Mainstem Channel with Moderately Modified[3] Riparian Forest: 1.450 km
14. Length of Mainstem Channel with Highly Modified Riparian Forest: 0.600 km
15. Length of Field Assessed Channel that is Moderately or Highly Disturbed: 0.100 km

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[1] unstable soils = slopes >60%, Es and E2s polygons in forest cover database
[2] includes linear total of all riparian harvesting (i.e. single bank and both banks)
[3] modified by forest harvesting

Watershed Report Card
(Fall 2000)

Watershed: Manteau Creek Watershed (109.767 km^2)

1. Total Area Disturbed: 2.515 km^2 (14.2%)
2. Equivalent Clearcut Area: 6.470 km^2 (5.9%)
3. Equivalent Clearcut Area Above H_{60}: 0.549 km^2 (0.5%)
4. Total Road Length: 22.033 km
5. Total Road Density: 0.201 km/km^2
6. Total Road Length Above H_{60}: 0 km
7. Road Density Above H_{60} Line: 0 km/km^2
8. Length of Road on Unstable[1] Soils: 2.457 km
9. Density of Road on Unstable Soils: 0.022 km/km^2
10. Number of Stream Crossings: 17
11. Stream Crossing Density: 0.15/km^2
12. Length of High Risk Road: 2.7 km
13. Length[2] of Mainstem Channel with Moderately Modified[3] Riparian Forest: 0 km
14. Length of Mainstem Channel with Highly Modified Riparian Forest: 0.150 km
15. Length of Field Assessed Channel that is Moderately or Highly Disturbed: 0.500 km

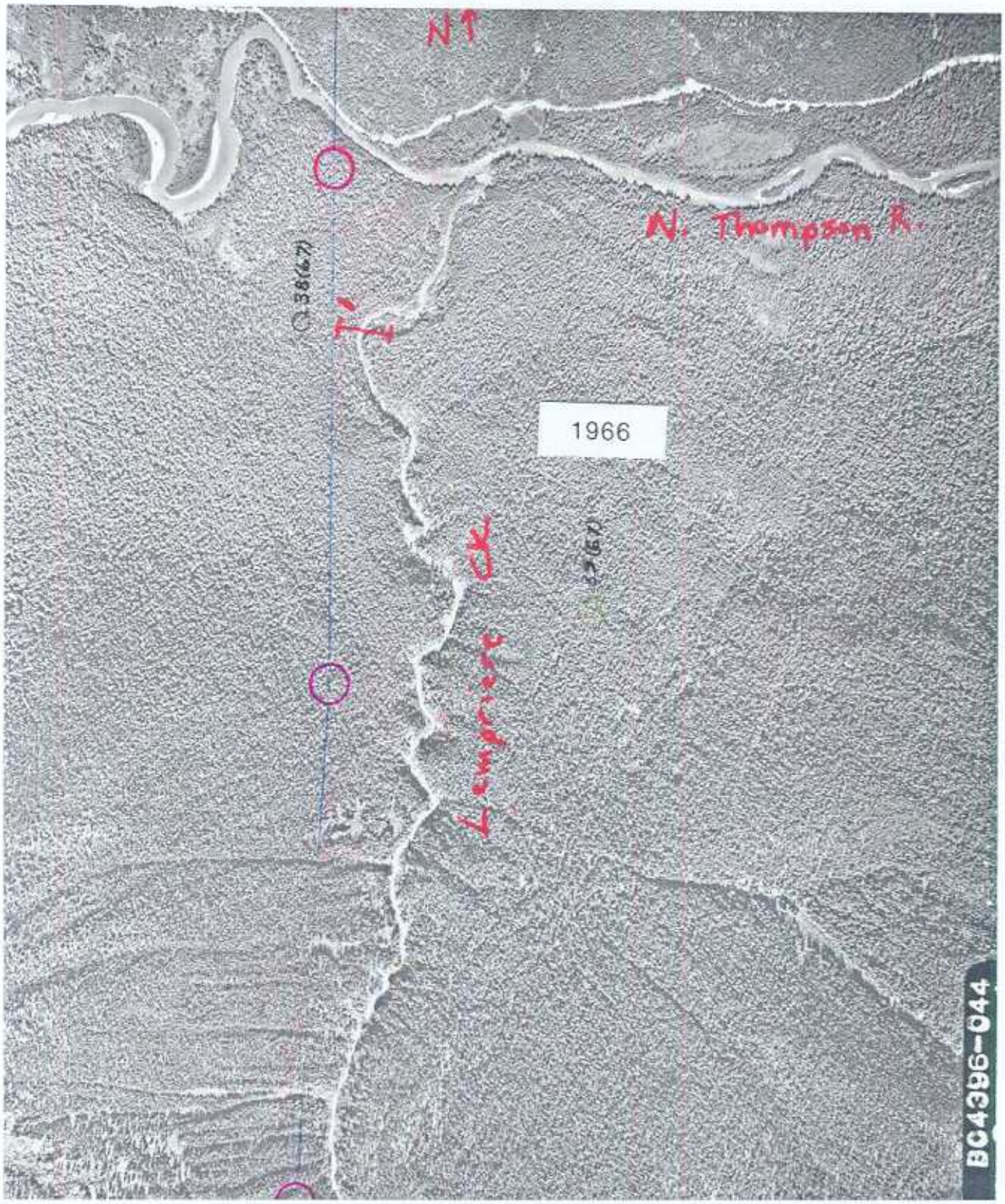
---

[1] unstable soils = slopes >60%, Es and E2s polygons in forest cover database
[2] includes linear total of all riparian harvesting (i.e. single bank and both banks)
[3] modified by forest harvesting

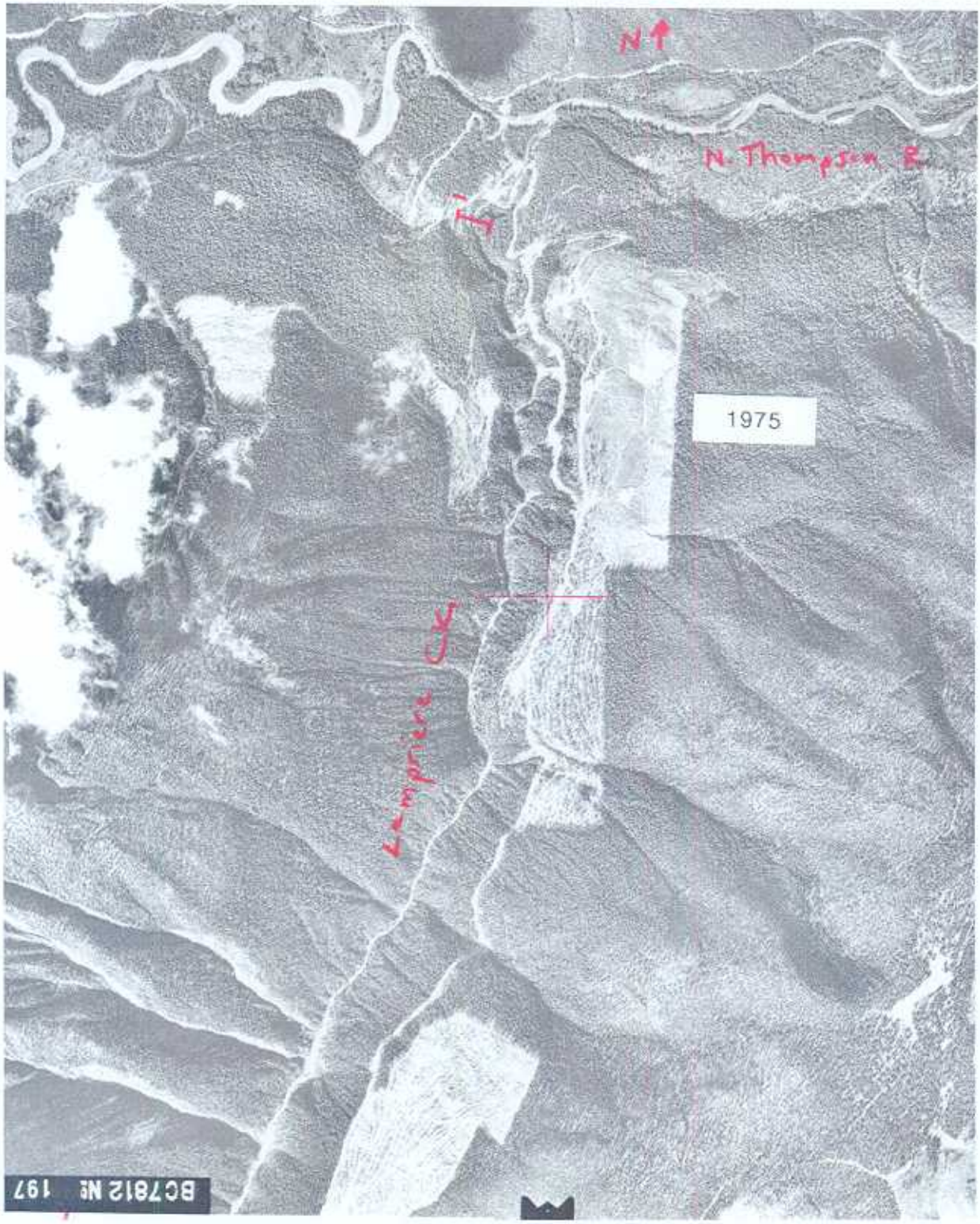
APPENDIX G

Selected Aerial Photographs

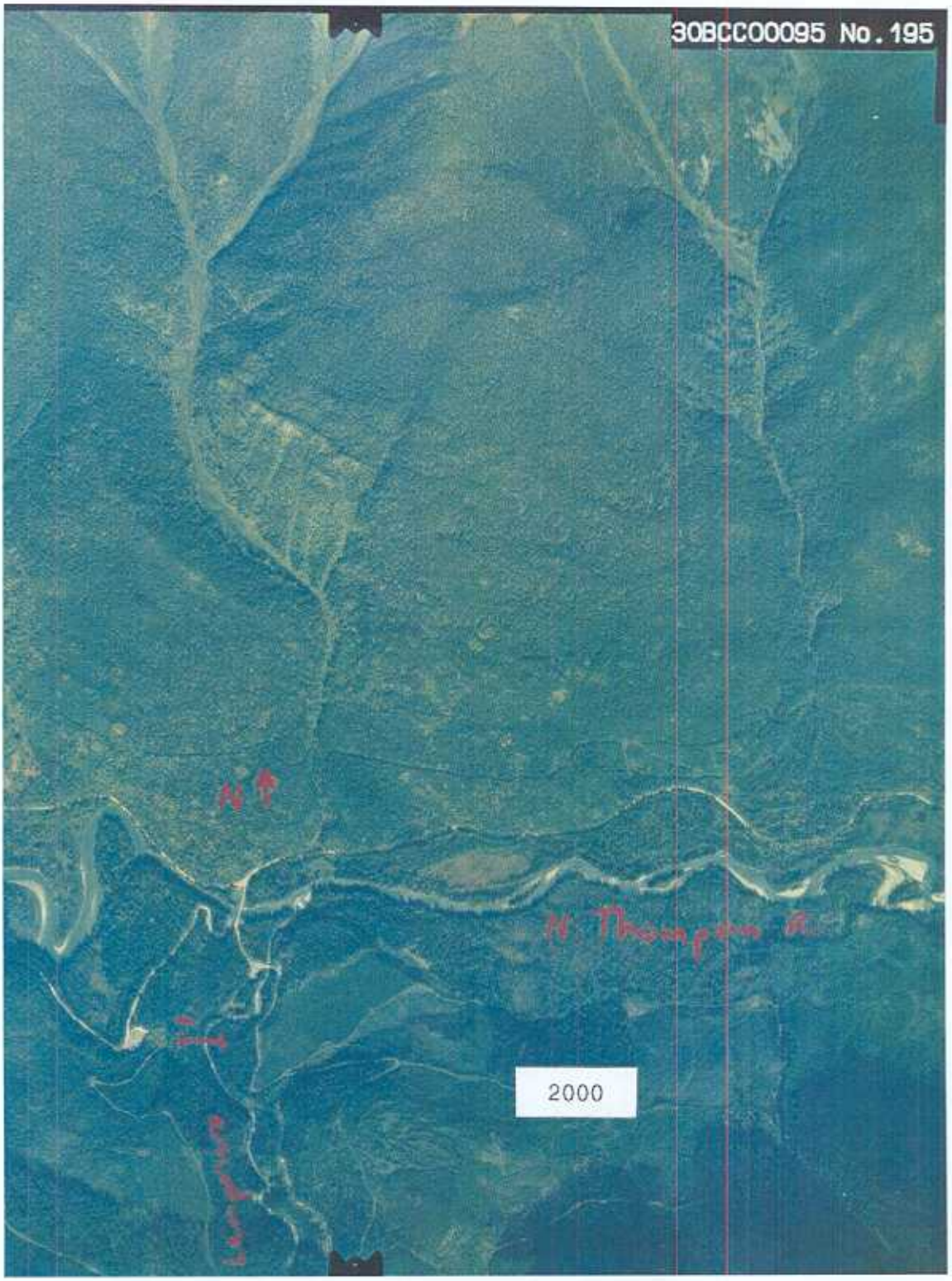
Lempriere Creek (1966)



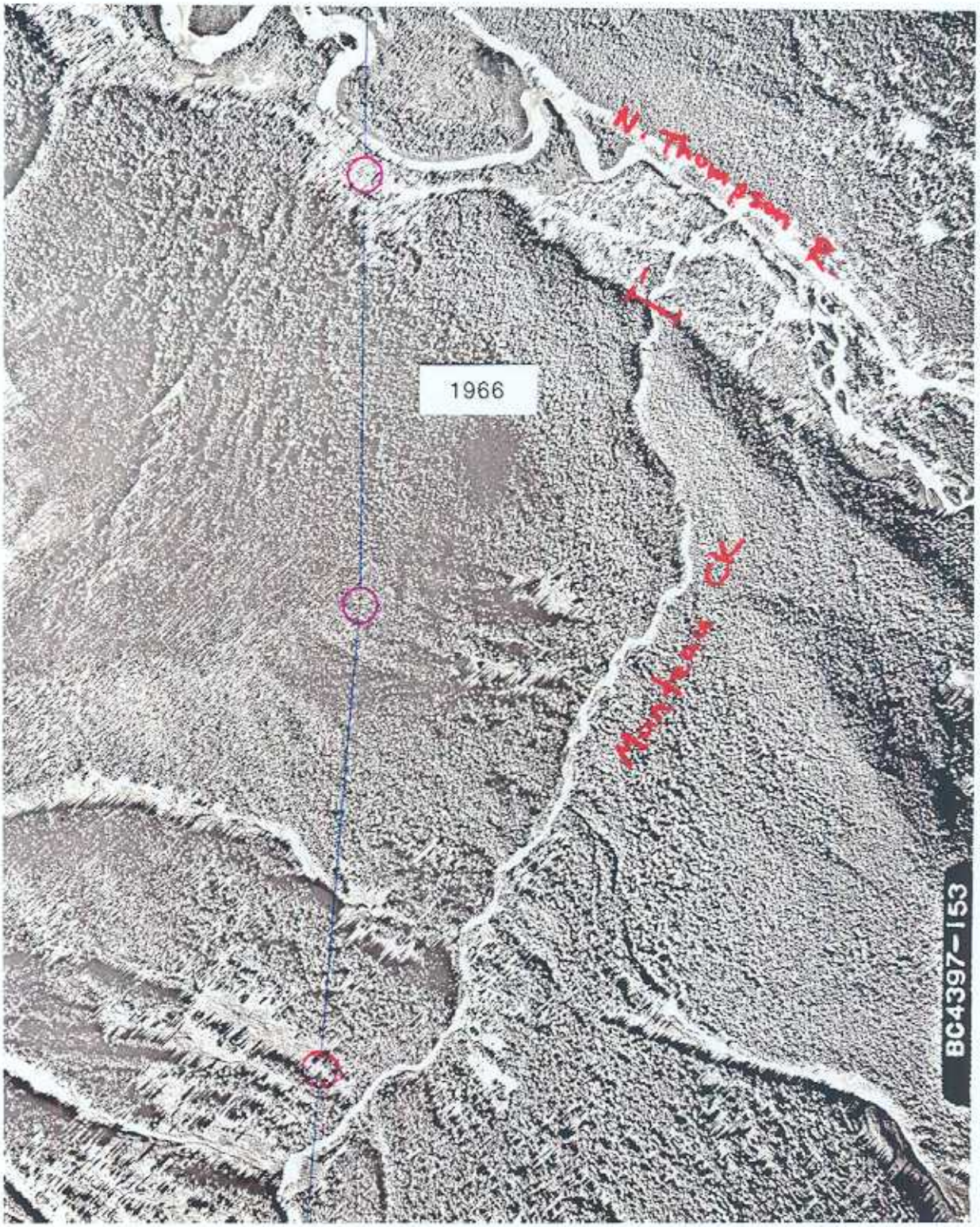
Lempriere Creek (1975)



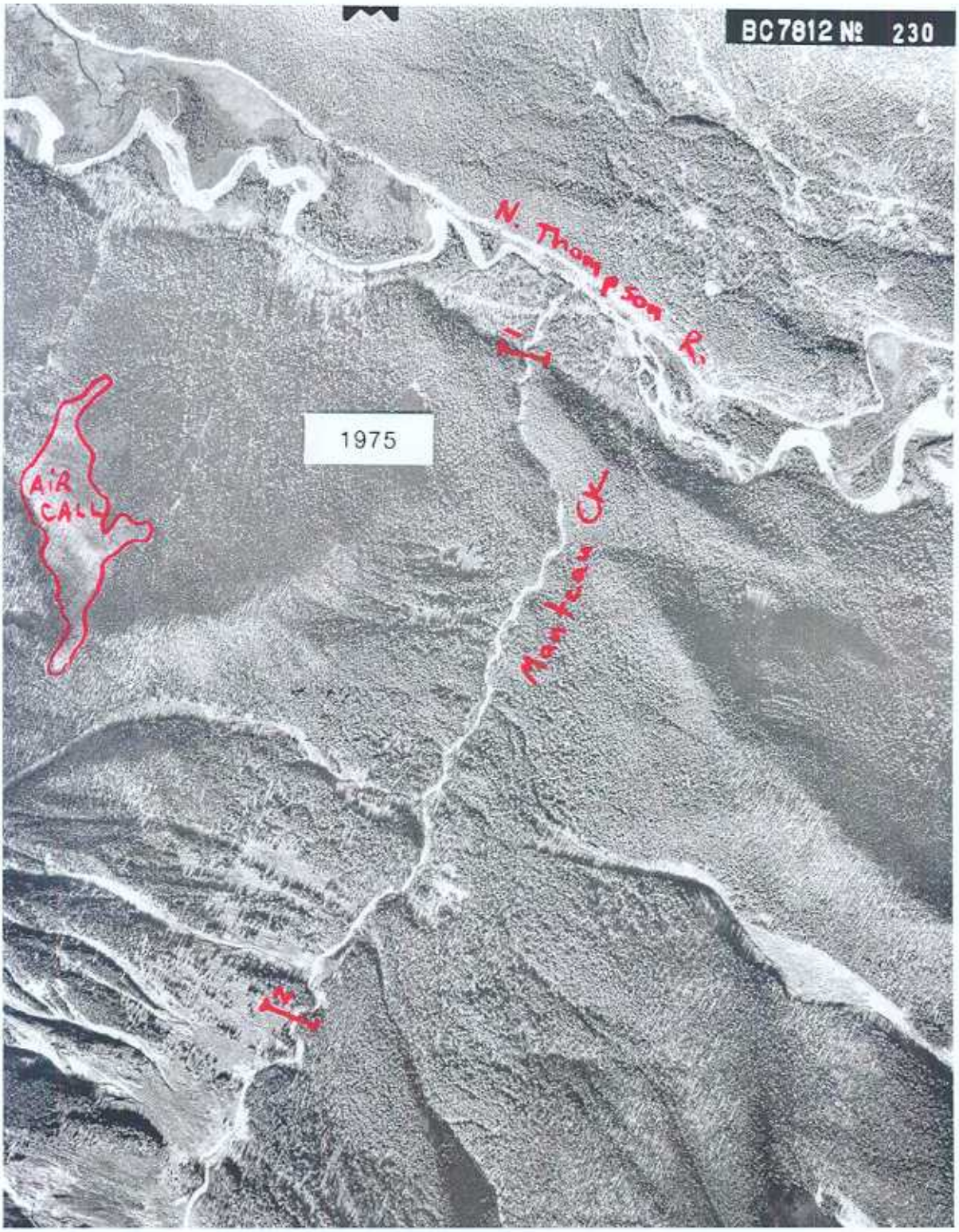
Lempriere Creek (2000)



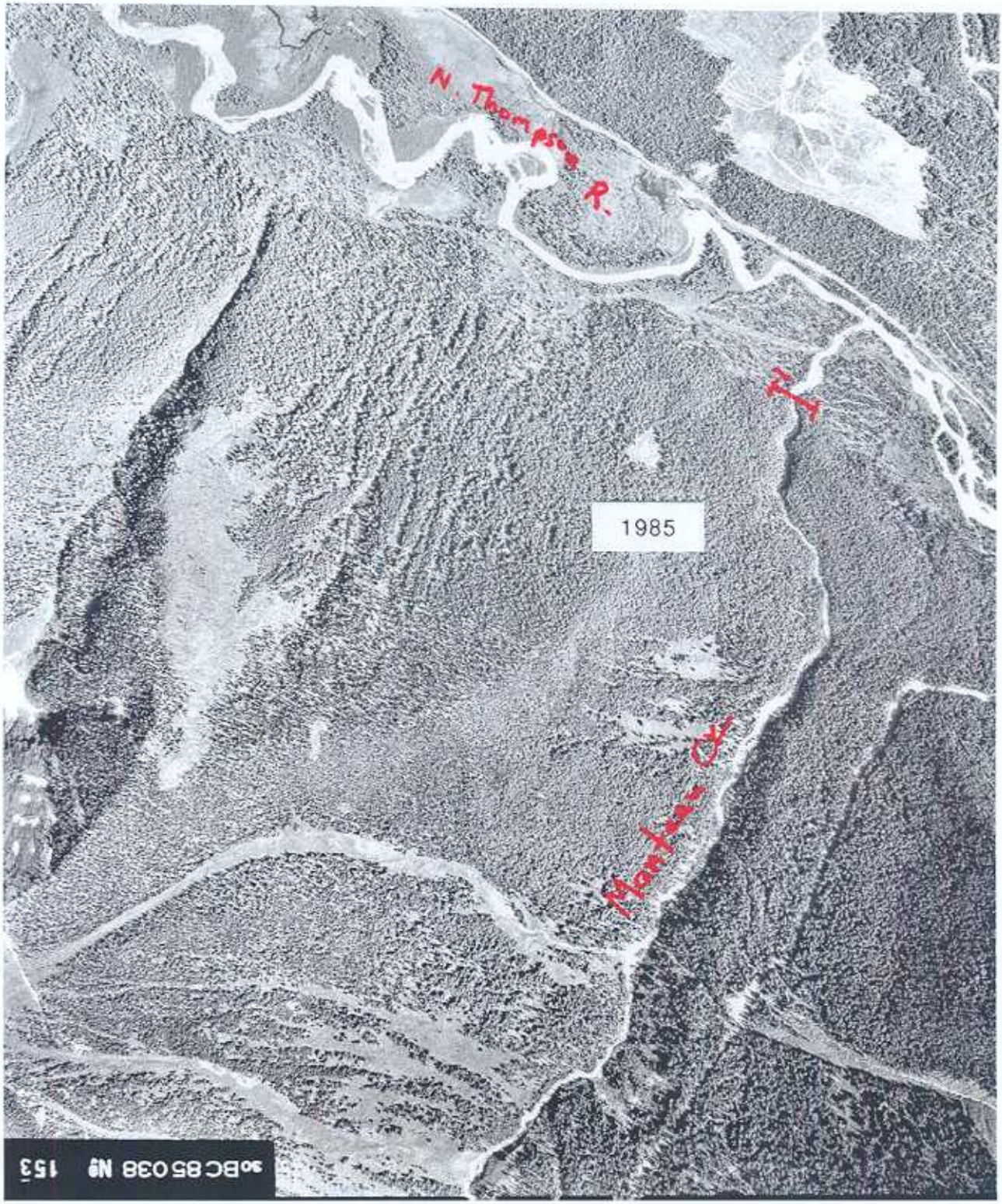
Manteau Creek (1966) – Lower Fan



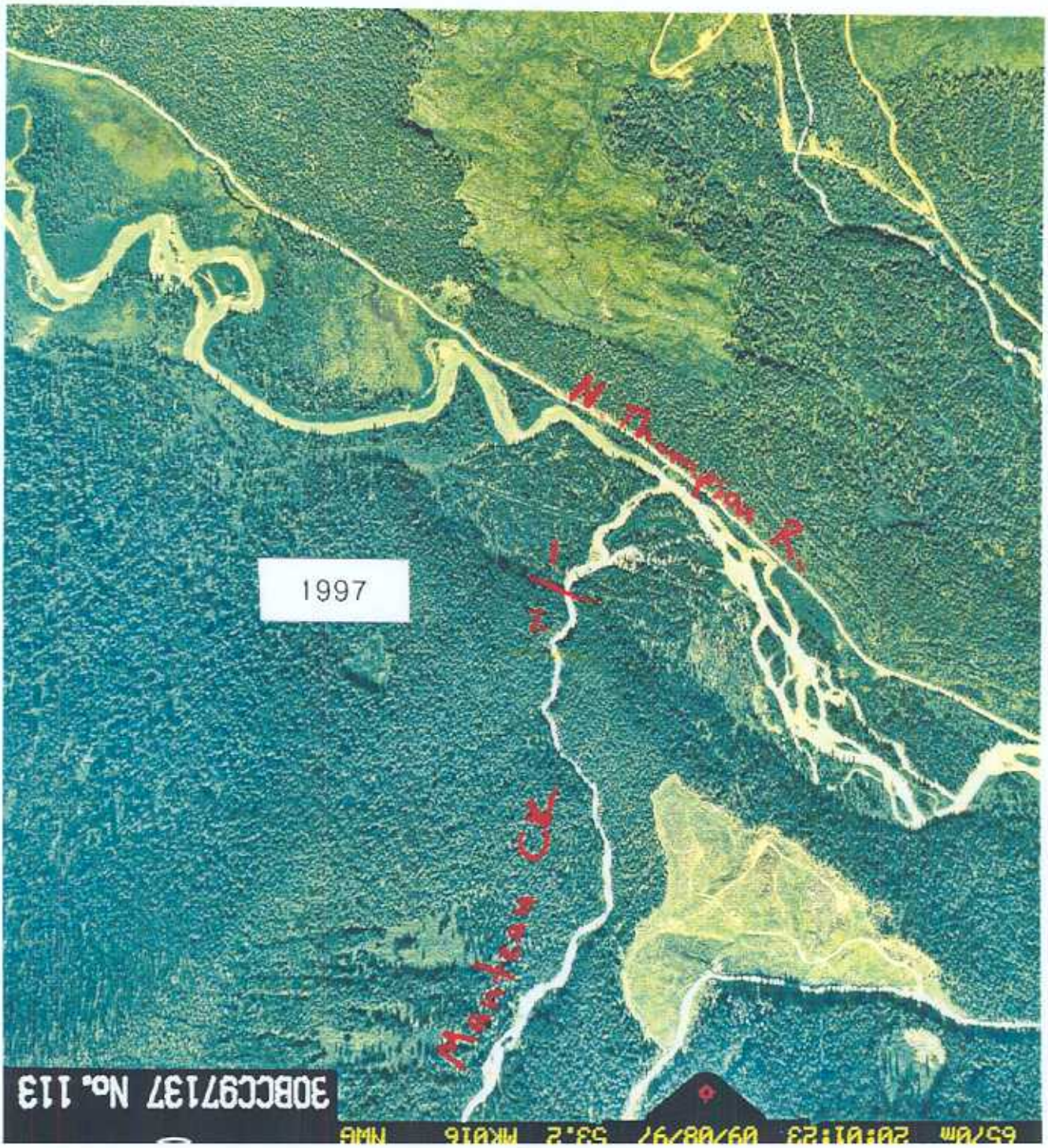
Manteau Creek (1975) – Lower Fan



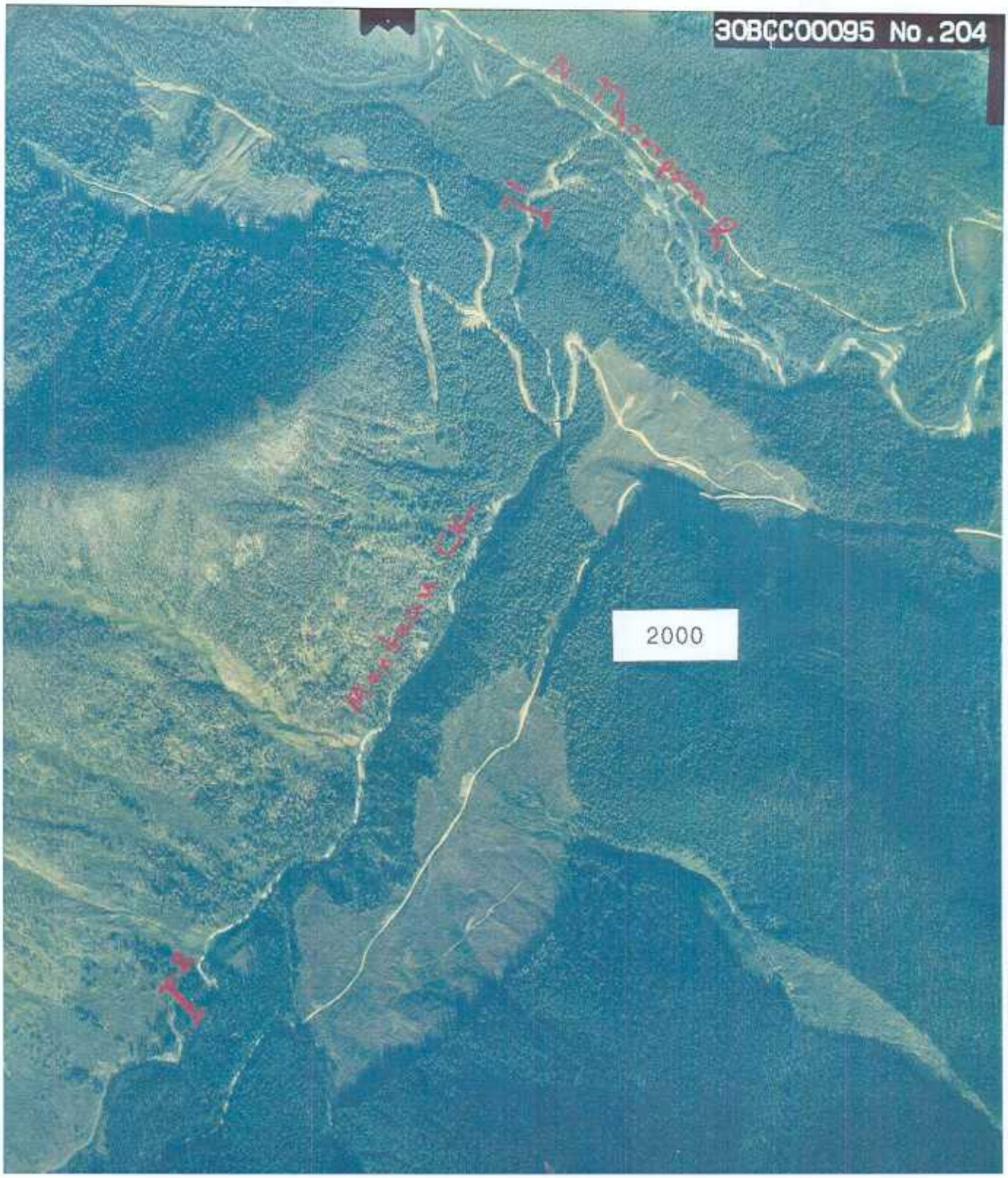
Manteau Creek (1985) – Lower Fan



Manteau Creek (1997) – Lower Fan

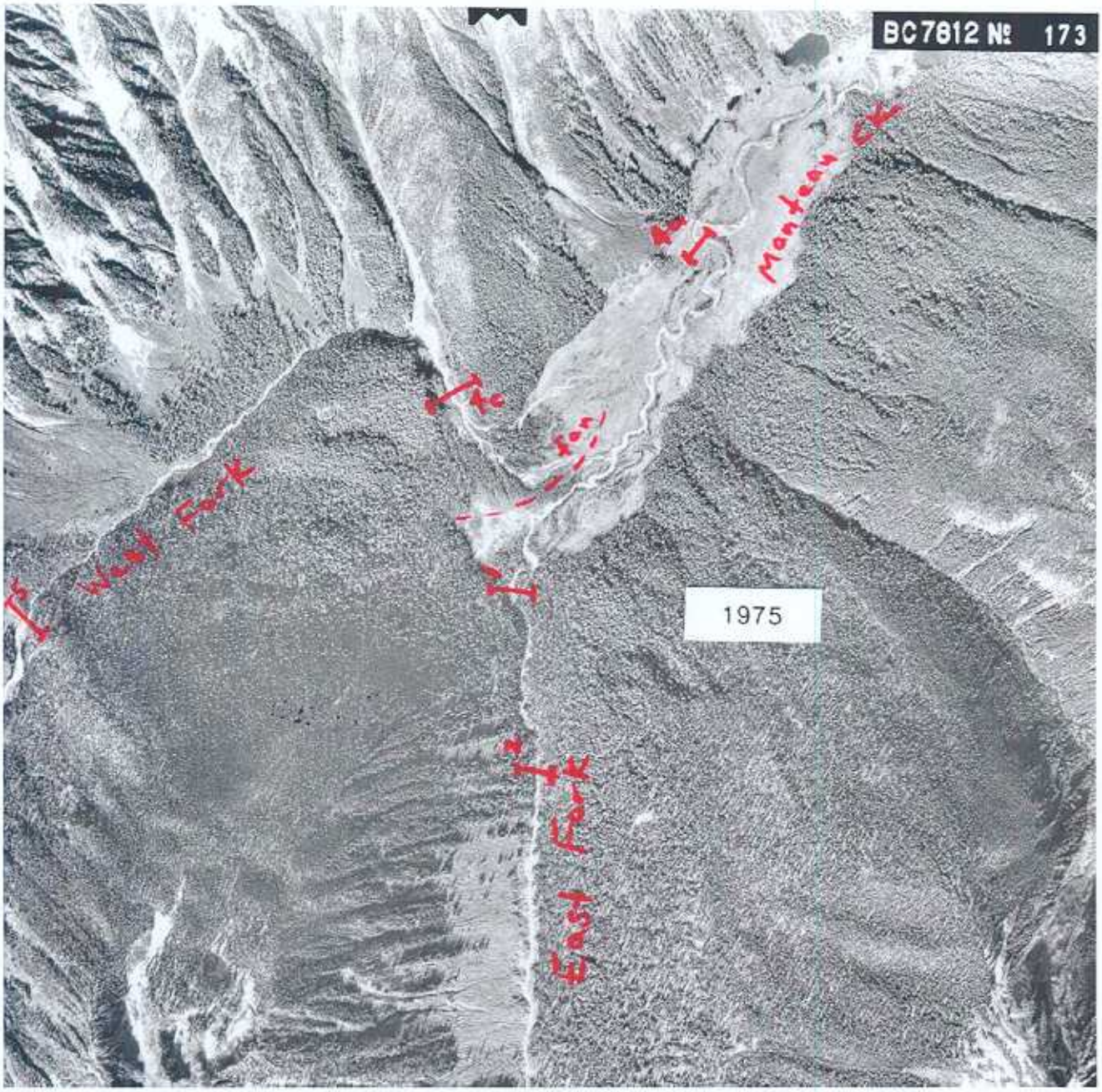


Manteau Creek (2000) – Lower Fan

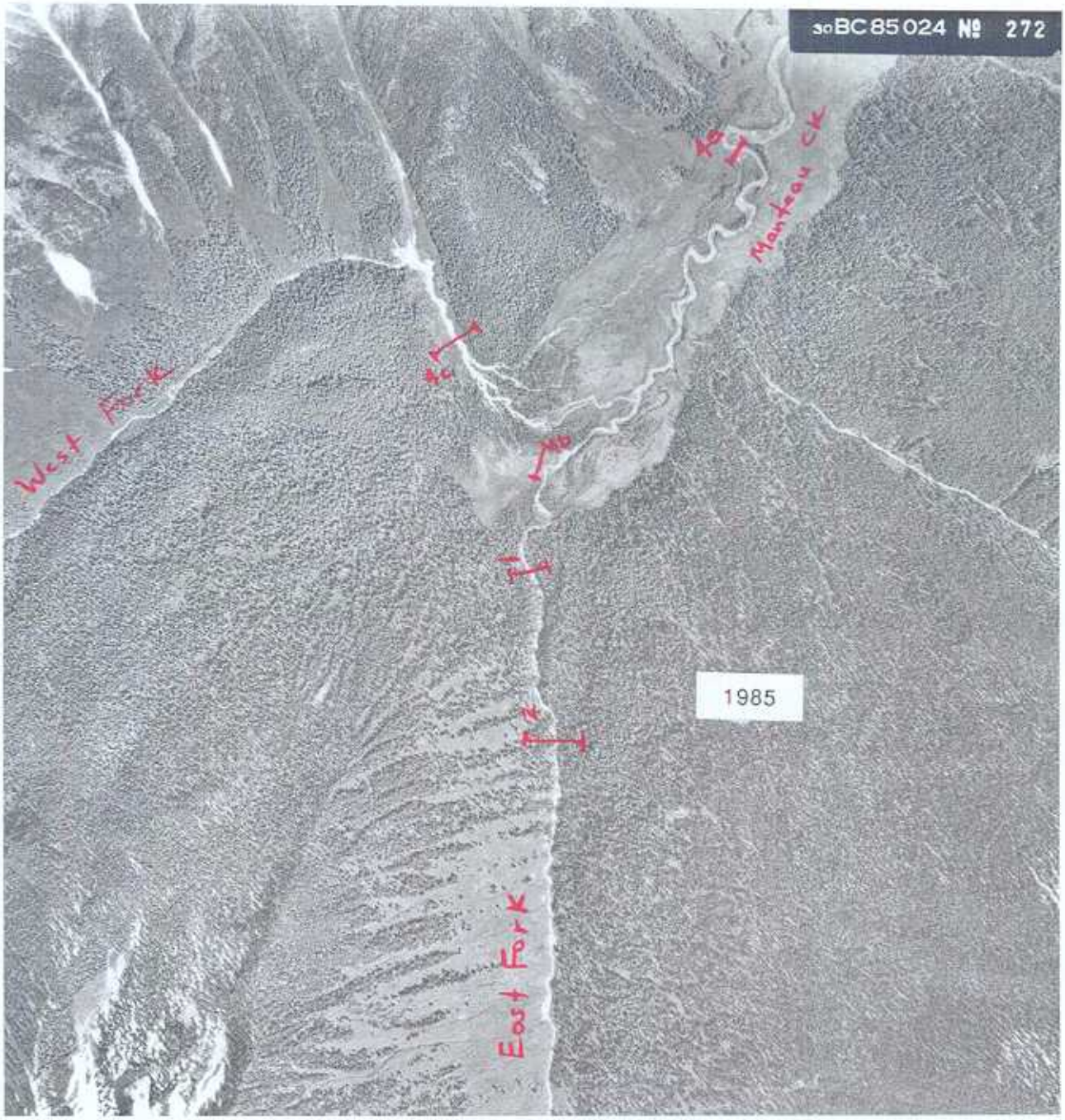


Manteau Creek (2000) – Area Burned by Wildfire in Lower Watershed

Manteau Creek (1975) – Upper Fan



Manteau Creek (1985) – Upper Fan



Manteau Creek (2000) – Upper Fan