Appendix 3

Interior Watershed Assessment Procedure

Results for Sub-Basins in W1832 for which Development is Proposed

Prepared by Woodlot Licence W1832 Staff

Interior Watershed Assessment Procedure

Results for Sub-Basins in W1832 for which Development is Proposed

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List of Figures and Tables

1 Introduction

This Appendix presents the results of Interior Watershed Assessment Procedure (IWAP) assessments of the four watersheds impacted by development activities proposed in the first Forest Development Plan for W1832. These watersheds are

- Dumont Creek
- Winlaw Creek – North Fork Sub-Unit
- Slocan River Watershed – Woodward Face Sub-Unit
- Winlaw Creek – Lower Main Watershed Sub-Unit

Portions of the Trozzo Creek – Lower Main Sub-Unit and Dunn Creek watersheds are also contained in W1832, but these areas are not affected by proposed development activities and were not assessed at this time.

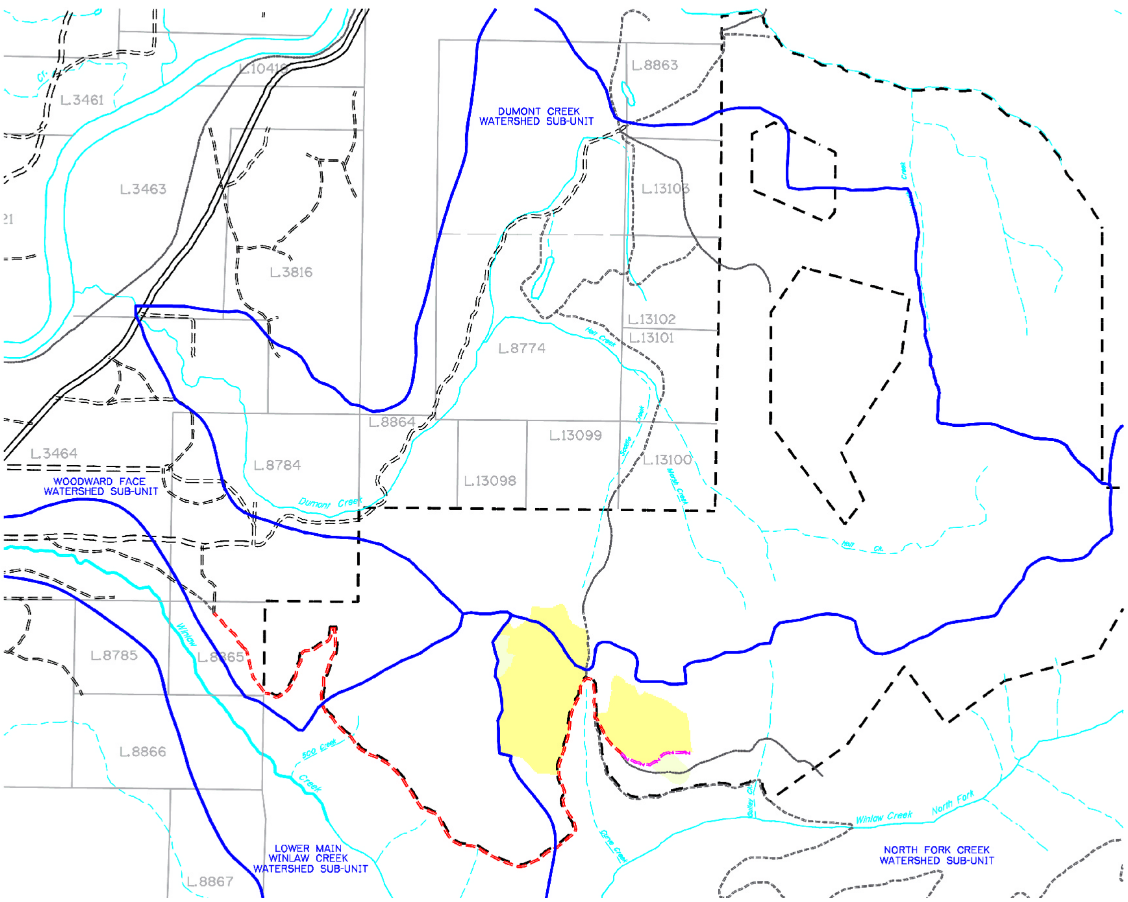

Figure 1: Map of Watershed Boundaries and Proposed Development in W1832 Crown Portion. Watershed boundaries shown in dark blue. Proposed road modification shown in red, proposed new road construction shown in magenta. Proposed partial cutting shown in yellow. W1832 boundary is black dashed line.

Sections 2 through 10 following present:

- standard assessment tables prepared per the Forest Practices Code Interior Watershed Assessment Procedure Guidebook (Level 1 Analysis), published September 1995 by the B.C. Ministry of Forests, and

- relevant sections of the Code Interior Watershed Assessment Procedure Guidebook which explain the derivation of the tables and which suggest interpretations of the tables.

Section 11 contains comments and assessments from the Licencee.

2 Determination of the H60 elevation

In much of the British Columbia interior, snow typically covers the upper 60% of a watershed when streamflow levels begin to rise in the spring. The H60 is the elevation for which 60% of the watershed area is above.

To estimate the elevation of this snowline (H60), draw a hypsometric (area-elevation) curve for the watershed. A hypsometric curve is constructed by calculating the area between contours (use 100 m) on a topographic map and plotting the cumulative area above a given elevation versus that elevation. If the difference between the highest and lowest elevation in the watershed is less than 300 m, use the entire watershed to estimate the equivalent clearcut area.

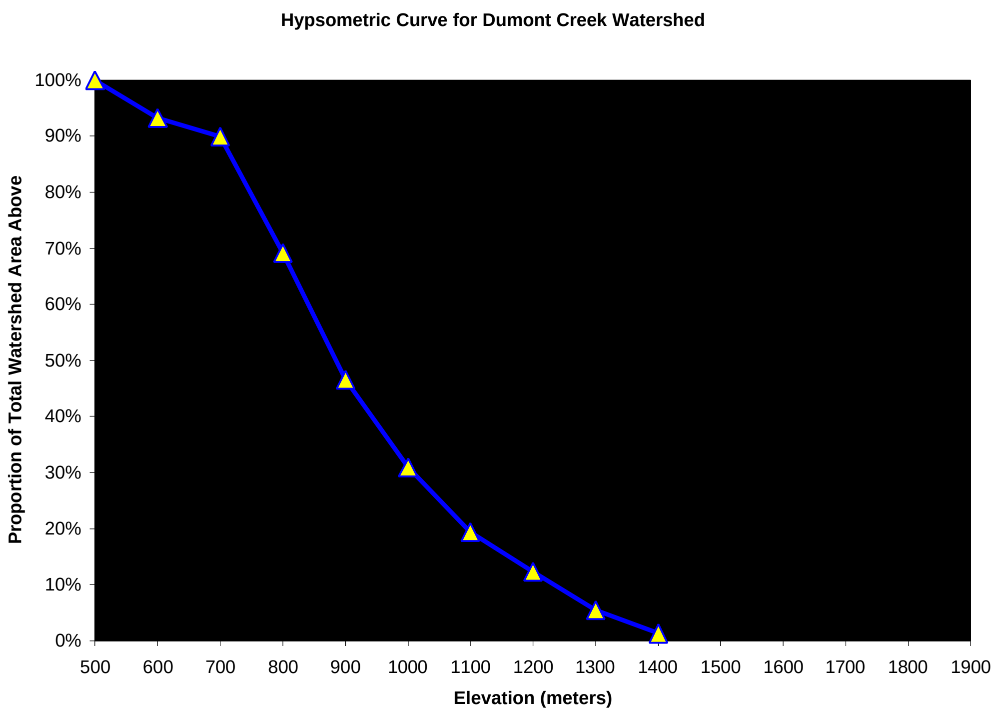

Figure 2: Hypsometric Curve for Dumont Creek Watershed.

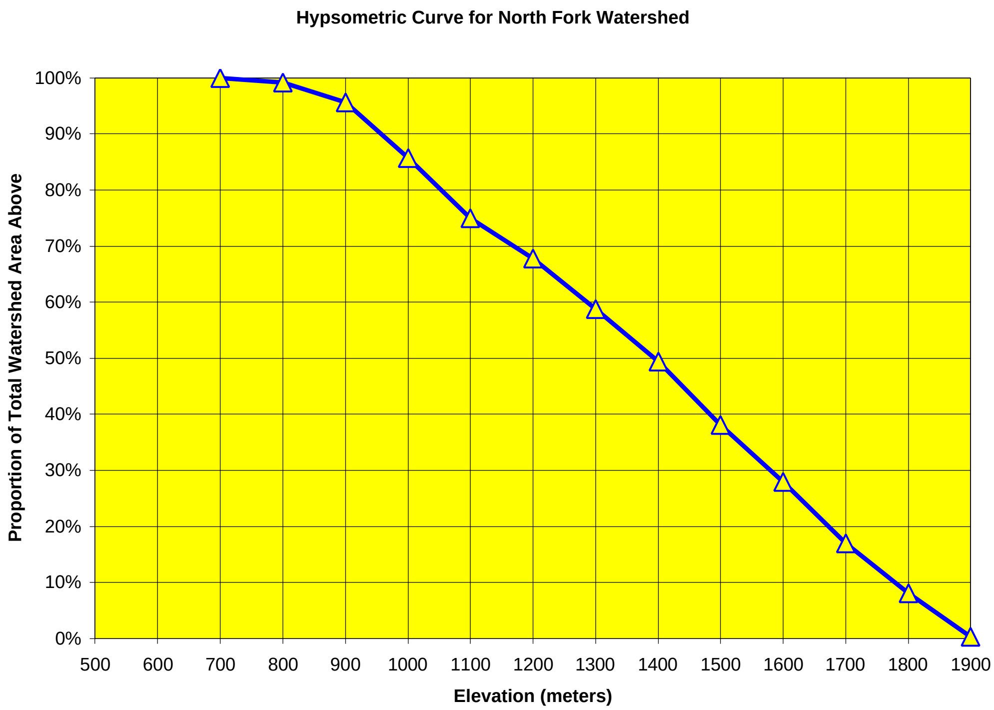

Figure 3: Hypsometric Curve for North Fork Watershed.

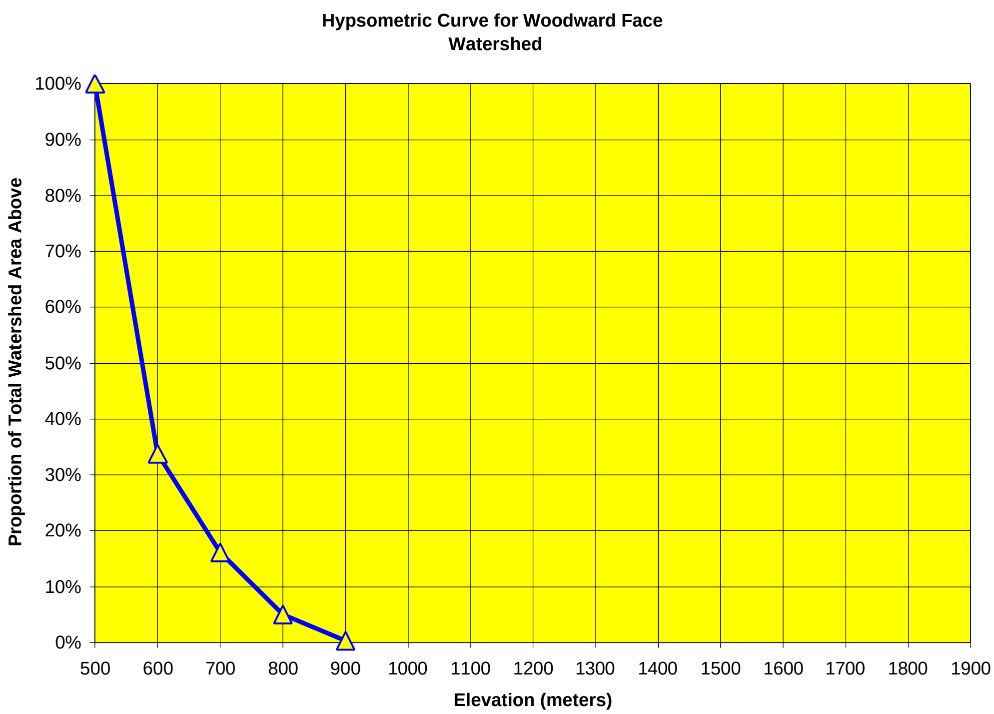

Figure 4: Hypsometric curve for Woodward Face Watershed.

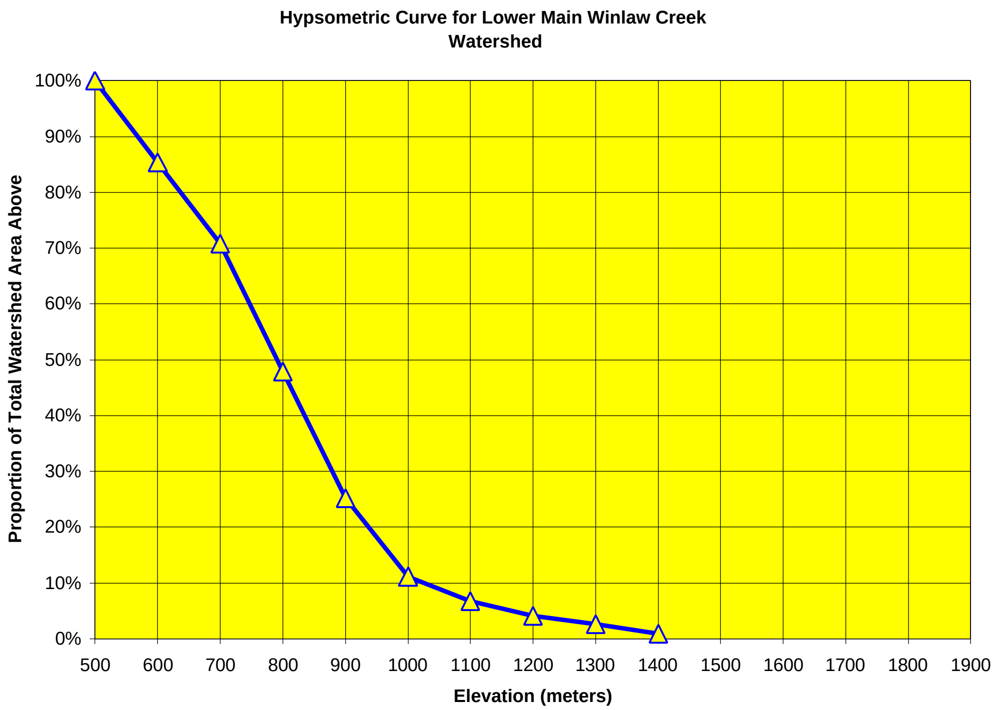

Figure 5: Hypsometric Curve for Lower Main Winlaw Creek Watershed.

Sub-Basin Name	H60 Elevation (meters)	Area Below H60 Line		Area Above H60 Line		Total Area of Sub-basin
		Hectares	Percent	Hectares	Percent	Hectares
Dumont Creek	840	249	42%	340	58%	589
North Fork Creek	1,300	329	41%	468	59%	798
Woodward Face	560	90	50%	90	50%	180
Lower Main Winlaw Creek	750	117	43%	154	57%	271

Form 1: Area Measurements by Elevation Band and Sub-Basin.

(Note: The H60 area in the smaller watersheds deviates from a 40/60 split because of the large area between each two 20 meter contours in relation to the small total area of the watersheds.)

3 Effects of Harvesting on Stream Flow

3.1 Peak Flows

Most hydrologic impacts occur during periods of the peak stream flow in a watershed. Stream flow is defined as the channelized flow of water at the earth's surface. Peak flow is the maximum flow rate that occurs within a specified period of time, usually on an annual or event basis. In the interior of British Columbia, peak flows occur as the snowpack melts in the spring. Occasionally, periods of high stream flow can be caused by rainstorms and rain-on-snow events, particularly in the coast transition zone.

Snow melts from a watershed in a predictable pattern. Melt begins earlier in the season at lower elevations and proceeds upslope. Snow has generally disappeared from the lower elevations some time before the spring stream flows peak. During peak flow, snow is beginning to disappear from the mid-elevations and is actively melting at the higher elevations of a watershed.

After an area has been harvested, both winter snow accumulation and spring melt rates increase. This effect is less important at lower elevations, since the snow disappears before peak flow. At mid-elevations, the additional melt may or may not be important, depending on seasonal variations. Harvesting at high elevations will have the greatest impact and is, therefore, of most concern.

The changes in snow accumulation and melt brought about by forest harvesting are reduced as new forests grow. This is commonly referred to as hydrologic recovery.

3.2 Hydrologic Recovery

Second-growth forests are said to be hydrologically recovered when snowpack conditions approximate those prior to logging and, as a result, any impact on stream flow is minimized. The most important influence of vegetation on snow accumulation is the interception of snow by the forest canopy and the subsequent loss of this snow to the atmosphere. This interception effect is a result of the combined effects of tree height and canopy closure. The rate at which the snowpack melts is affected by the extent to which the snowpack is exposed to solar radiation which, like interception, is also controlled by the canopy. Consequently, canopy closure is one of the main stand characteristics affecting snow accumulation and melt.

The degree of canopy closure is determined by tree species, height, and stocking density. Since tree height data is readily available and is closely correlated with canopy closure, it is the variable used to evaluate hydrologic recovery.

The first approximation of hydrologic recovery (Table 8-1) for the southern interior is based on theoretical estimates of the effects of canopy closure on radiation penetration and snow interception, stand growth curves relating tree height and canopy closure, and snow data from studies in the Okanagan and Kootenays. The recovery estimates apply to fully stocked stands that reach a maximum crown closure of 50-70% and height of 20-30 m when mature. The growth curves used to convert crown closure to tree height assume a stand density of 1500 stems per hectare when the main canopy is 3 m in height. Tree heights refer to the average height of the main canopy (that is, co-dominant and intermediate trees, not dominant and suppressed stems).

Average Height of the Main Canopy (meters)	Percentage of Hydrologic Recovery
0 to <3	0%
3 to <5	25%
5 to <7	50%
7 to <9	75%
9+	90%

Table 8-1. First approximation of snow recovery in the southern interior for fully stocked stands in the snow zone that reach a maximum crown closure of 50-70%

3.3 Low Flow

In the interior of British Columbia, the lowest stream flows normally occur in late summer. Summer low flows are significant to both human use and fish habitat. During late summer, water demands for irrigation and domestic use tend to be high and supply limited.

Low flows in summer or winter can harm fish populations by reducing the amount of available habitat. During the summer, this is exacerbated by the added stress of higher oxygen needs of fish and lower dissolved oxygen concentrations when the water is warmer. During the winter, low flows cause less oxygen stress, but overwintering eggs can be damaged by freezing or ice movement.

Both summer and winter low flows result from long periods during which the water being discharged from soils and bedrock is not replenished by rain or snowmelt. Trees affect low flows by intercepting rain and snow, by reducing the amount of water entering the soil and, through transpiration, by removing water from the soil.

Transpiration, however, is directly related to moisture availability. Consider what happens in a clearcut under different conditions. During a wet summer, interception loss in a clearcut is low, resulting in more water entering the soil than would occur under a forest canopy. In addition, the water that would have been transpired from the soil by trees is available for groundwater recharge and stream flow. As a result, under wet conditions, the summertime low flow after clearcutting is greater than the low flow that would have occurred in the forest.

In contrast, during a summer without rain, water input to the soil is zero regardless of whether the site is forested or not. Transpiration losses in the clearcut would probably be less than in the forest, but the forested site would have very low transpiration losses anyway. Consequently, stream flow from both sites would be very low and clearcutting would have little effect on the water balance.

There is a general public perception that clearcutting dries out soils. This is probably because the top layers of soil do, in fact, become drier upon exposure to stronger sunlight and wind. However, the deeper soil layers in the rooting zone of trees have been shown to have higher moisture content after clearcutting. The net effect is that total soil moisture tends to increase after clearcutting. This effect diminishes as a site becomes revegetated until there is no detectable difference within 10 to 15 years after logging.

Low flows may occasionally also be observed to decrease as a result of channel aggradation. In some cases, water continues to be discharged from a basin. However, it moves below the surface through the stream bed where channel aggradation has occurred.

Watershed studies have shown that tree removal tends to result in increasing mean monthly flows in August, September, and October by a moderate amount during the 10- to 15-year revegetation period. This is probably beneficial in cases where water can be impounded for human use or for delayed release downstream. However, in most cases, there may be no benefit to fish, since the very lowest flows are not increased by harvesting.

In summary, timber harvesting appears to have a negligible, or slightly positive, effect on summer low flows in most cases. Winter low flows are probably not affected by forestry activities.

3.4 Annual Water Yield

In the United States, where most forestry-related watershed runoff studies have been done, harvesting has been found to increase annual water yield by 100-500 mm per year. The smallest increases have occurred on warmer, drier sites where soil moisture is limited. In these areas, the removal of trees does not make much more water available to streams. The largest increases have been observed in the Oregon Cascades where rainfall is high. Under these conditions, trees intercept a considerable portion of rainfall, allowing it to evaporate. The high rainfall also enables trees to take up and transpire large amounts of soil water. Timber harvesting reduces these large water losses and makes more available to streams.

In the Alberta Rockies and the interior of British Columbia, research has also shown increases in water yield after timber removal. In an Alberta study, harvesting 50% of the forested area resulted in a water yield increase of 27%, or 40 mm. In a paired watershed study in British Columbia’s southern interior, clearcutting 30% of a watershed resulted in a 21% increase in yield.

The 1973 Eden fire near Salmon Arm burned 50% of a watershed and caused a 24% increase in the April to August runoff. The effects of this fire on water yield are assumed to be similar to those that would result from timber harvesting.

One difference between the studies in the U.S. and the ones in western Canada is that most runoff in the British Columbia interior and Alberta Rockies occurs during spring snowmelt. Because of the snow-dominated regime in these areas, tree removal effects on the annual water balance are not limited to changes in evapotranspiration, but include increases in snow accumulation and spring discharge levels.

In summary, timber harvesting can be expected to produce the largest increases in water yield in areas that have an ample supply of moisture during the growing season. In areas where runoff is dominated by snowmelt, a large part of the annual yield increase can be associated with increased snow storage in openings, faster snowmelt, and thus an increase in spring runoff volume.

3.5 Peak Flow Index Tables

The equivalent clearcut area (ECA) is defined as the area that has been clearcut, with a reduction factor to account for the hydrological recovery due to forest regeneration. To estimate this value, determine the height of regeneration in each logged polygon below the H60 line on the 1:20 000 forest cover map. Heights may need to be extrapolated if reference material is not up-to-date. The area of each opening will then have to be reduced by the appropriate percent hydrological recovery, as shown below.

The following assumptions can be made for the ECA calculations:

- NSR (not sufficiently restocked): - clearcut with 0% recovery
- Partial cutting:
  - <30% basal area removal - expect 100% recovery
  - 30-60% basal area removal - clearcut x 0.5
  - 60% basal area removal - clearcut with 0% recovery
  - clusters of trees - apply appropriate recovery to area occupied by clusters
- Private land:
  - The Guidebook indicates that private land should be excluded from total sub-basin area (Form 1) and ECA calculations (Form 2) where it forms <15% of total sub-basin area.
  - This is overridden by the District Guidance which indicates that private land should be included in the IWAP.
- Cultivated land: - same as for private land
- Open range: - include in total sub-basin area (Form 1) but exclude from ECA calculations (Form 2)
- Burn sites: - clearcut with 0% recovery; extrapolate if regeneration
- Large slides: - clearcut with 0% recovery
- Hydro line: - clearcut with 0% recovery

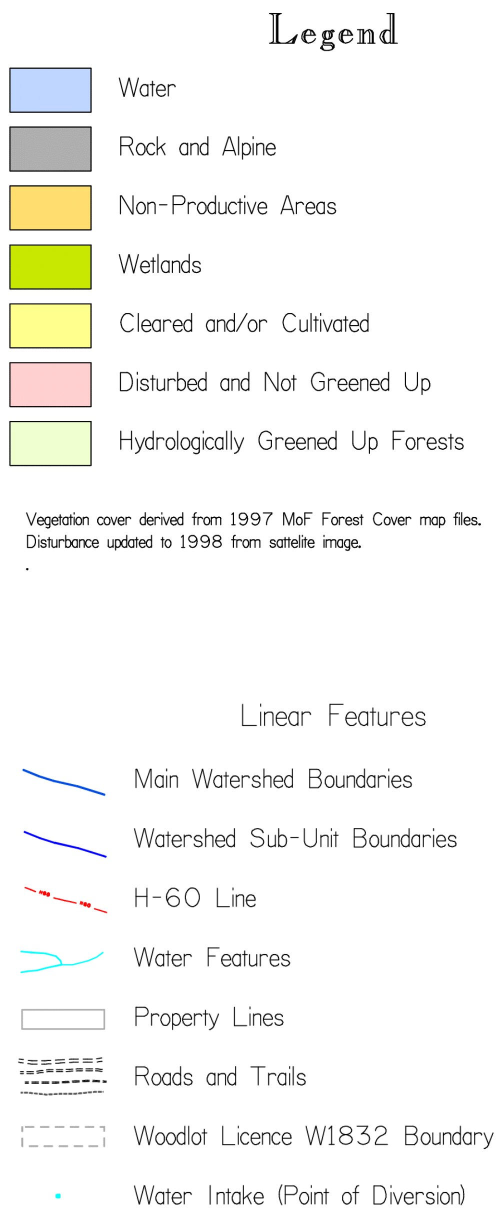

Figure 6: Legend for cover class maps in Figure 7 to Figure 10.

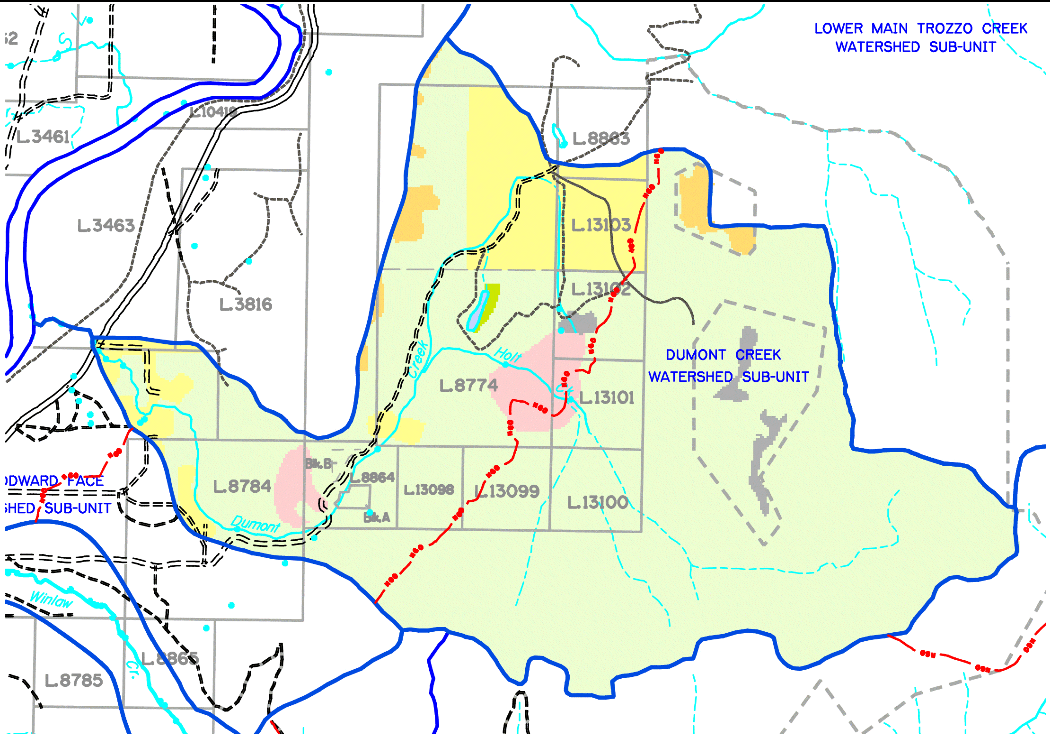

Figure 7: Map of Hydrologic cover classes in Dumont Creek Watershed.

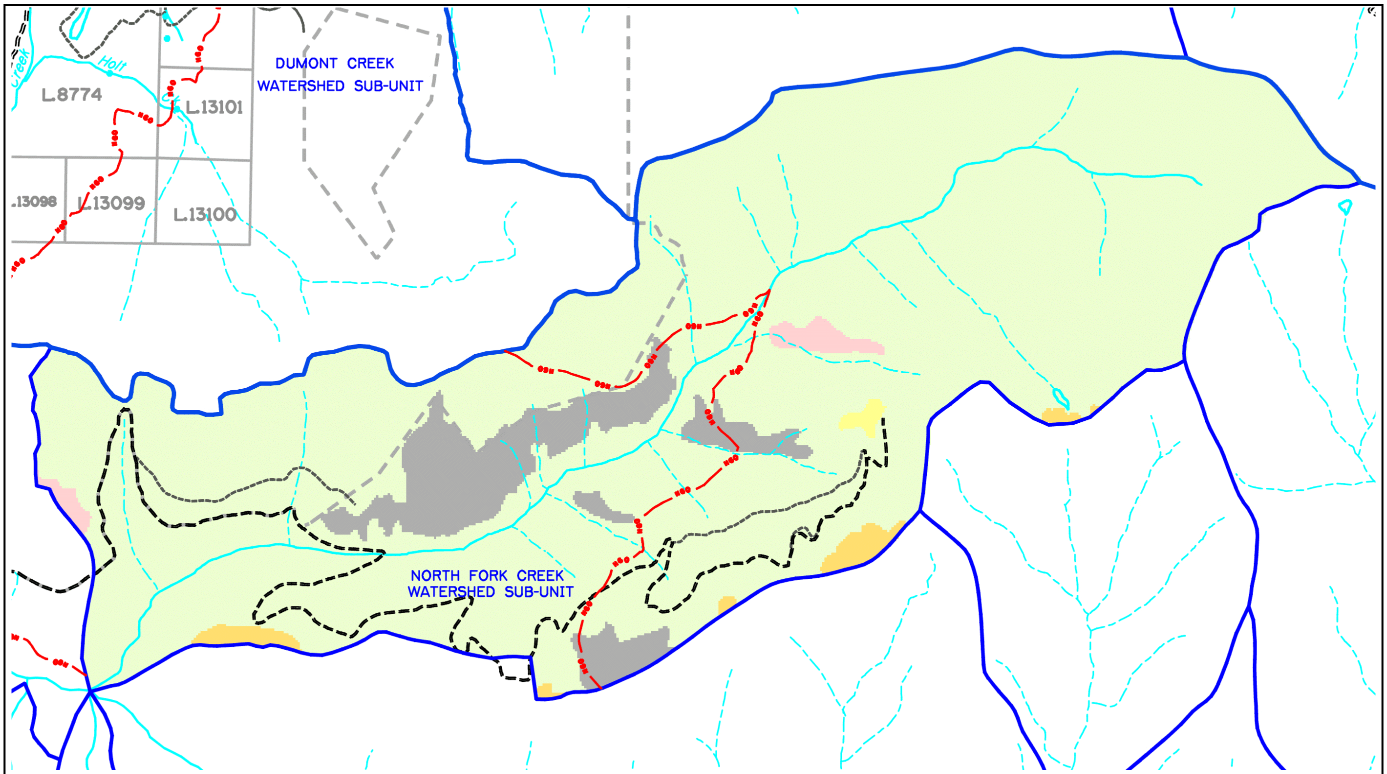

Figure 8: Map of Hydrologic cover classes in North Fork Watershed.

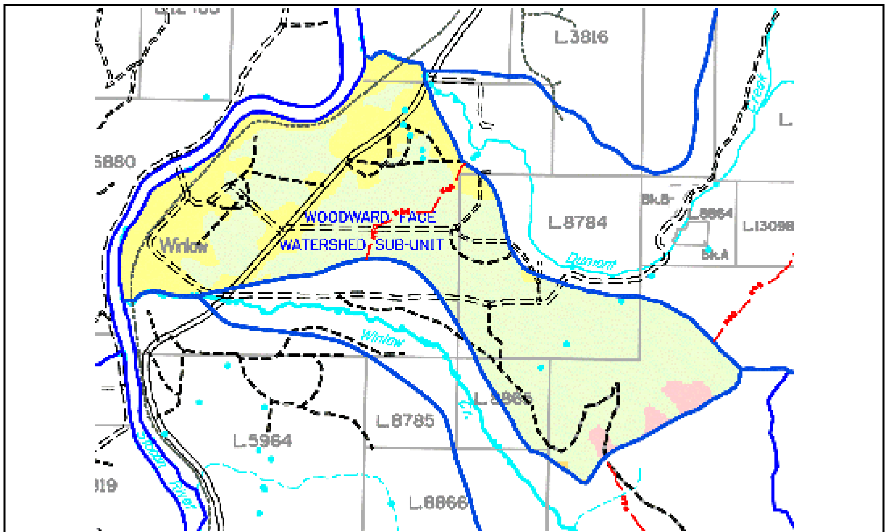

Figure 9: Map of Hydrologic cover classes in Woodward Face Watershed.

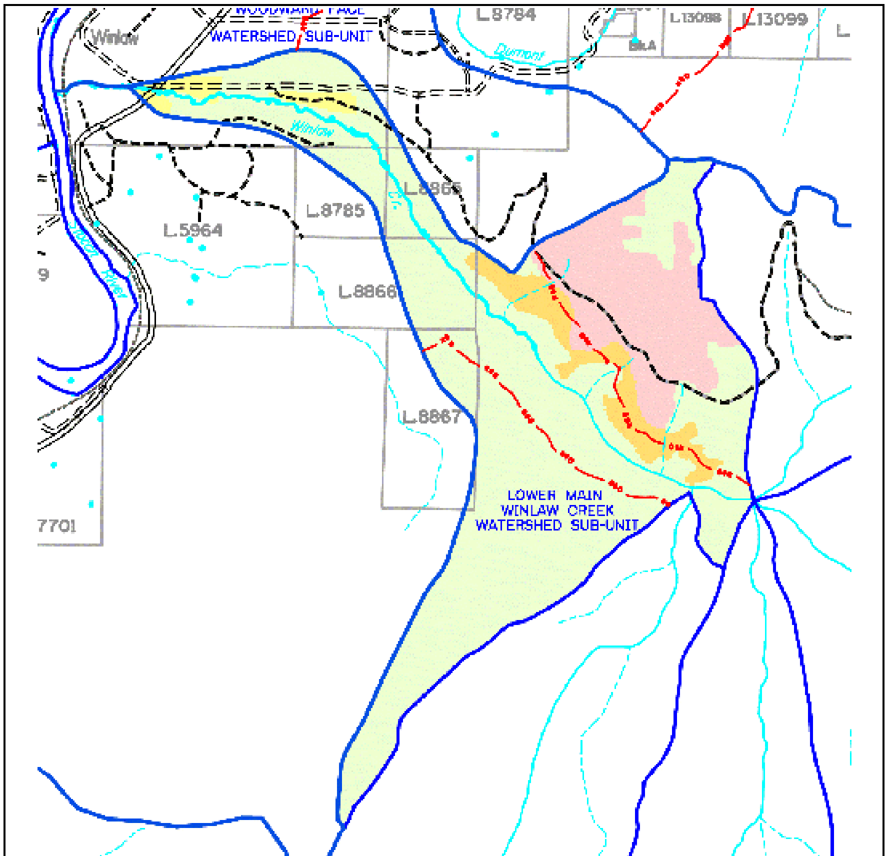

Figure 10: Map of Hydrologic cover classes in Lower Main Winlaw Creek Watershed.

Sub-Basin Name	Sub-Basin Area (hectares)	Area Below H60 Line			Area Above H60 Line			Peak Flow Index
		A ECA (hectares)	B ECA ÷ Total Sub-basin Area	C Weighted ECA (B x 1)	D ECA (hectares)	E ECA ÷ Total Sub-basin Area	F Weighted ECA (E x 1.5)	***Indicator #1*** (C + F)
Dumont Creek	589	78.4	0.13	0.13	5.0	0.01	0.01	0.15
North Fork Creek	798	2.1	0.00	0.00	6.4	0.01	0.01	0.01
Woodward Face	180	49.9	0.28	0.28	6.5	0.04	0.05	0.33
Lower Main Winlaw Creek	271	7.8	0.03	0.03	43.5	0.16	0.24	0.27

Form 2: Peak Flow Index Calculation by Sub-Basin.

During peak flow, snow is beginning to disappear from the mid-elevations and is actively melting at the higher elevations of a watershed. Therefore, harvesting at high elevations will have the greatest impact and is, hence, of greater concern than at lower elevations. Therefor, additional emphasis is applied to ECA above the H60 line (column E) by multiplying column E by an ECA weighting factor of 1.5.

4 Forestry Impacts on Surface Erosion

4.1 Surface Erosion

Increases in suspended sediment concentrations above natural levels have a detrimental impact on fish and fish habitat. High levels of suspended sediment can abrade and clog fish gills, reduce feeding and survival, and decrease overall stream productivity. Deposition of fine sediment on the stream bottom eliminates living space for juvenile trout and salmon and reduces populations of important fish food organisms. Sedimentation also degrades spawning habitat by filling in the spaces between the gravel particles where fish deposit their eggs, thereby reducing water percolation and oxygen levels and smothering the eggs.

Increases in suspended sediment concentrations can also reduce the value of water for domestic and agricultural use. High suspended sediment levels can reduce the effectiveness of treatment processes and increase maintenance costs by clogging or reducing the capacity of filtration systems. Visible turbidity is aesthetically undesirable for domestic use and can be associated with higher bacterial concentrations. Suspended sediment can also be deposited in, and reduce, the capacity of irrigation ditches, storage ponds, and water tanks.

Most of the time, streams are capable of carrying more suspended sediment than they actually contain. In such cases sediment concentration is "supply limited" and an increase in erosion by running water anywhere in a watershed will usually cause an increase in suspended sediment load downstream. In studies where researchers have considered the effects of both increased peak flows and increased sediment supply, the increases in sediment supply have been consistently judged to be more important in causing an increase in suspended sediment concentrations.

Roads are one of the most significant causes of increased erosion. Road construction exposes large areas of mineral soil to removal by rainwater and snowmelt. Sediment is easily delivered to water courses during wet periods because roads and their drainage ditches frequently intersect stream channels. Generally, the greater the number of stream crossings, the greater the number of sites where sediment can readily be delivered to channels. Fine-grained soils are particularly sensitive to such surface erosion.

The erosion and transport of sediment from roads is exacerbated by the greatly reduced infiltration capacity of mineral soils on cut banks, running surfaces, and fill slopes, caused by compaction and the loss of organic horizons. Roads and skid trails also intercept and concentrate surface runoff so that it has more energy to erode even stable soils. Roads in areas with higher rainfall and snowmelt rates tend to exhibit higher levels of erosion than roads in drier areas. Roads can also cause rapid mass movements and result in very large increases in sediment loads.

The negative effects of roads and skid trails can be moderated by laying them out to avoid the more sensitive sites, using appropriate road and drainage structure construction techniques, installing waterbars on non-permanent roads, and adopting a variety of other erosion control techniques.

4.2 Road Inventory

Road density above H60 (Indicator #2): To obtain this value, measure the total length of all roads above the H60 line and divide by the total sub-basin area. Roads include all hauling and in-block roads.

Road density for total sub-basin (Indicator #3 and #8): Measure the total length of all roads in the watershed[1] and divide by the total sub-basin area.

Sub-Basin Name	Sub-Basin Area (hectares)	Road Above 60 Line		Road for Entire Sub-Basin	
		Length (meters)	**Indicator #2** Density (km/km2)	Length (meters)	**Indicator #3 and #8** Density (km/km2)
Dumont Creek	589	421	0.07	6,769	1.15
North Fork Creek	798	3,835	0.48	10,176	1.28
Woodward Face	180	3,758	2.09	10,999	6.12
Lower Main Winlaw Creek	271	1,299	0.48	3,588	1.32

Form 3: Road Inventory and Density.

4.3 Surface Erosion Hazard

Density of roads on erodible soils (Indicator #4): Measure the total length of all roads located on erodible soils[2] and divide by the total sub-basin area.

Road density within 100 m of a stream (Indicator #5): Measure the total length of all roads located within 100 m of any stream identified on the TRIM or forest cover maps and divide by the total sub-basin area.

Road density within 100 m of a stream and on erodible soils (Indicator # 6): This is probably the most important indicator in the surface erosion section. The two most important factors in determining how much fine sediment will be delivered to streams from road running surfaces are the proximity of the road to the stream and the parent material on which the road was built. This indicator attempts to quantify this hazard.

To obtain this value, measure the total length of roads that are located within 100 m of any stream and on erodible soils and divide by the total watershed area.

Density of active stream crossings (Indicator # 7): It has been frequently documented that stream crossing are often a chronic source of fine-textured material to streams. This can be either directly from the building of the stream crossing or indirectly from delivery of fine sediments along road ditches that empty directly into a stream. To obtain this value, count the total number of stream crossings in the watershed (of all streams visible on TRIM or forest cover maps) and divide by the total watershed area. Active stream crossings are

[1] All roads shown on forest cover mapping were used. This excludes private driveways in settled areas and some overgrown, old trails in forested areas.

[2] Identified as slopes over 60% in this assessment because sufficient coverage of terrain assessment data is not available.

defined as those crossings that are still presently being used or will be maintained in a coordinated access management plan.

Sub-Basin Name	Sub-Basin Area (hectares)	Road on Erodible Soils		Road within 100 m of a Stream	
		Length (meters)	**Indicator #4** Density (km/km2)	Length (meters)	**Indicator #5** Density (km/km2)
Dumont Creek	589	394	0.07	5,259	0.89
North Fork Creek	798	1,353	0.17	3,039	0.38
Woodward Face	180	394	0.22	2,245	1.25
Lower Main Winlaw Creek	271	0	0.00	2,343	0.87

Sub-Basin Name	Sub-Basin Area (hectares)	Road within 100 m of a Stream on Erodible Soils		Density of Stream Crossings	
		Length (meters)	**Indicator #6** Density (km/km2)	Number	**Indicator #7** Density (number/km2)
Dumont Creek	589	394	0.07	5	0.85
North Fork Creek	798	349	0.04	4	0.50
Woodward Face	180	24	0.01	0	0.00
Lower Main Winlaw Creek	271	0	0.00	3	1.11

Form 4: Roads Adjacent to Streams.

5 Riparian Buffers

Riparian zones are defined in the Forest Practices Code as the land adjacent to the normal high water line in a stream, river, lake, or pond and extending to the portion of land influenced by the presence of the adjacent ponded or channeled water.

The riparian zone is of critical importance to stream ecosystems. The riparian vegetation: contributes nutrients and fish food by providing plant material and insects to the stream, regulates stream water temperatures (tree canopy shading), and delivers large woody debris (LWD) to the stream. The LWD provides much of the fish habitat and also contributes to stream channel stability. The roots of streamside vegetation tend to resist stream erosion by helping to hold the bank materials together. Streamside vegetation promotes overbank sediment deposition and also provides hiding cover or refuge for fish.

Logging in riparian zones has led to increased bank erosion, loss of in-channel islands, increased size and frequency of sediment wedges, and altered stream shape. Logging camps, storage areas, and dumps are commonly located in floodplain areas because of the relative ease of access and construction and the readily available source of drinking water. These facilities have caused stream pollution problems, as well as changes to the stream channel itself.

Forestry activities influence some, but not all, factors that control channel conditions. Logging can influence flood characteristics, sediment delivery, and the nature and extent of riparian vegetation. Typically, if stream flows and sediment delivery to the channel are increased, it is expected that the channel would become wider, shallower, less sinuous, and steeper (within limits, depending on sinuosity). Changes in sediment supply to the channel can have a major influence on in-stream biological conditions. For instance, increased sediment supply can result in reduced fish rearing and overwintering habitats (loss of pools and underbank areas), decreased juvenile fish survival and smolt production, and impaired spawning and incubation environments (degraded riffle sites). Changes in the species, size, amount, distribution, and orientation of LWD also have a significant effect on stream channel conditions (e.g., pools can infill and riffles can become more extensive).

The influence of logging will also vary depending on stream size. Small streams can be affected directly by landslides, particularly in headwater areas, and this can result in complete disruption of the normal shape of the channel. Medium-sized channels are usually influenced strongly by in-stream woody debris. The LWD characteristics are influenced by both streamside and upslope logging. Altered LWD characteristics have been shown to lead to changed channel morphology, sediment characteristics, and hydrologic conditions. Logging activities have less obvious direct influence on the larger stream channels. Exceptions include direct disturbances of streambanks (crossings, streamside logging, yarding, etc.), bed conditions (obstructions, sediment, and debris removal), and mid-channel islands.

Sub-Basin Name	Length of Stream Logged (meters)	Total Stream Length (meters)	**Indicator #4** Proportion of Stream Logged	Length of Fish-Bearing Stream Logged (meters)	Total Fish Bearing Stream Length (meters)	**Indicator #5** Proportion of Fish Bearing Stream Logged
Dumont Creek	300	10,018	0.03	0	0	0
North Fork Creek	0	15,704	0	0	0	0
Woodward Face	0	322	0	0	0	0
Lower Main Winlaw Creek	0	4,193	0	0	3,500	0

Form 5: Riparian Buffer Impacts.

6 Landslide Hazard

6.1 Definition of Unstable Slopes

The potential for slopes to experience landsliding is determined by terrain (surficial geology) mapping, and the subsequent interpretation of the terrain mapping information into slope stability classes using, as defining criteria, slope angle, materials and landforms, material texture, active geomorphological processes, and soil drainage.

Terrain maps provide information about the distribution and characteristics of surficial materials, landforms, and geological processes in an area. The terrain classification system used for mapping in British Columbia is defined in Howes and Kenk (1988). The Resources Inventory Committee (1994) provides additional important information, including that on terrain survey intensity levels and interpretive products such as slope stability classification. The Mapping and Assessing Terrain Stability Guidebook provides detailed information on the standard procedures to be used for forestry-related purposes in British Columbia.

Terrain mapping and slope stability classification must be done by a registered professional who has extensive experience in terrain mapping and landslide hazard interpretations. Junior mappers can do this work under the close supervision of such an individual.

In British Columbia a five-class slope stability classification is most commonly used. The slope stability classes are as follows:

I. No significant stability problems exist.

II. There is a very low likelihood of landslides following harvesting or road construction.

III. Minor stability problems may develop in some areas.

IV. Terrain polygons contain areas with a moderate likelihood of landslide initiation following harvesting or road construction.

V. Terrain polygons contain areas with a high likelihood of landslide initiation following harvesting or road construction.

6.2 Locating Areas of Potential Slope Instability

Slope stability Class IV and V are used as indicators of potentially unstable terrain. If slope stability maps are available for the watershed of concern, then the polygons identified as Class IV and V should be indicated on the overlay or entered into a GIS.

Where terrain mapping or slope stability classification is not available for a watershed, the potentially unstable terrain may be assessed as (in order of reliability):

1. Areas properly defined as Es1 and Es2, in environmental sensitivity mapping done as part of forest development planning, where the mapping was done by a registered professional with extensive experience in terrain mapping and landslide interpretation.

There are a large number of Es1 and Es2 maps in existence that were not produced by such individuals. These are not acceptable for use in IWAP, as there is no certainty that all areas of potentially unstable or unstable terrain have been identified.

2. Areas with slopes greater than 60% (31 degrees). In most cases, using a slope angle classification alone will largely over-estimate the area of potentially unstable terrain.

(Note: Complete coverage of terrain mapping is not available for any of the watersheds affected by this Forest Development Plan at the time of writing. Terrain stability mapping was used to identify unstable terrain where it is available, and slope greater than 60% based on analysis of the TRIM I digital terrain model was used to identify potentially unstable terrain in areas where mapping is not available.)

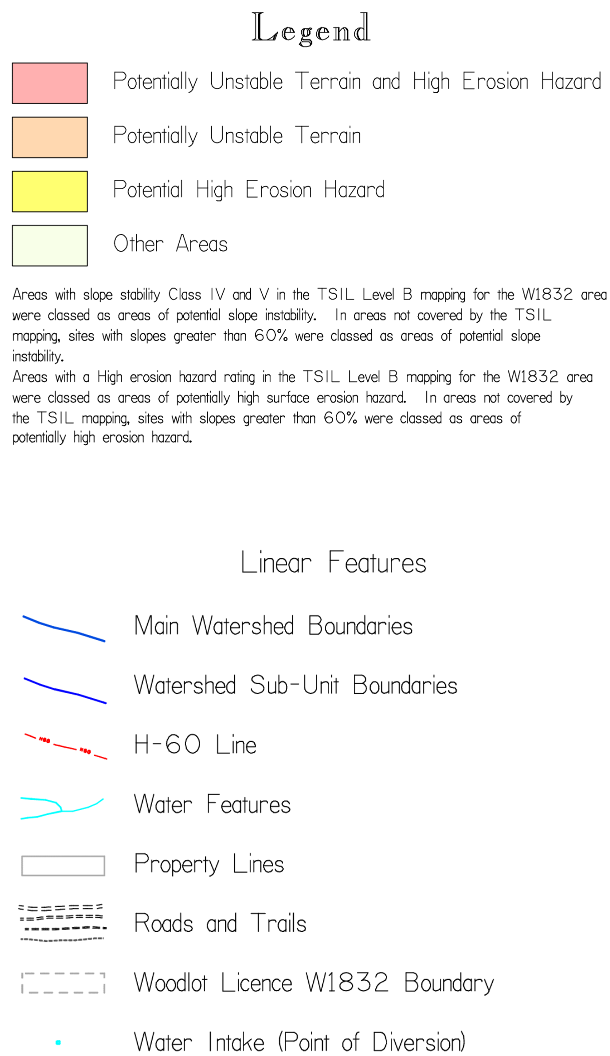

Figure 11: Legend for terrain class maps in Figure 13 to Figure 15.

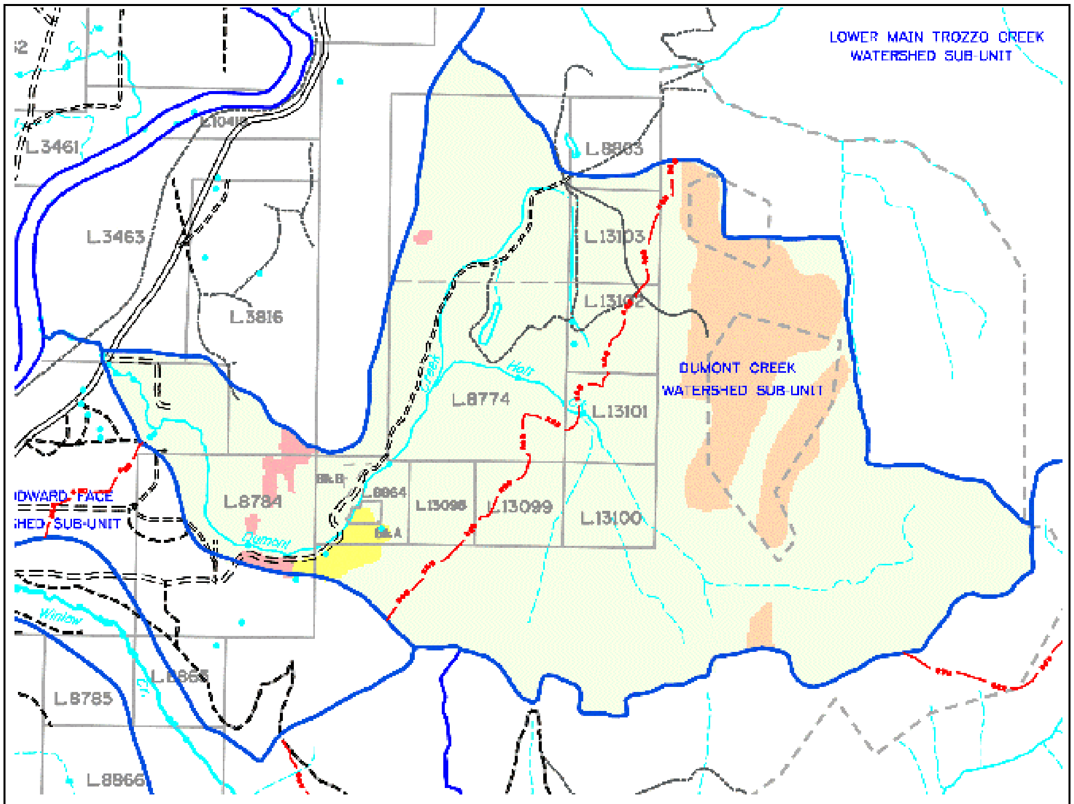

Figure 12: Map of Terrain classes in Dumont Creek Watershed.

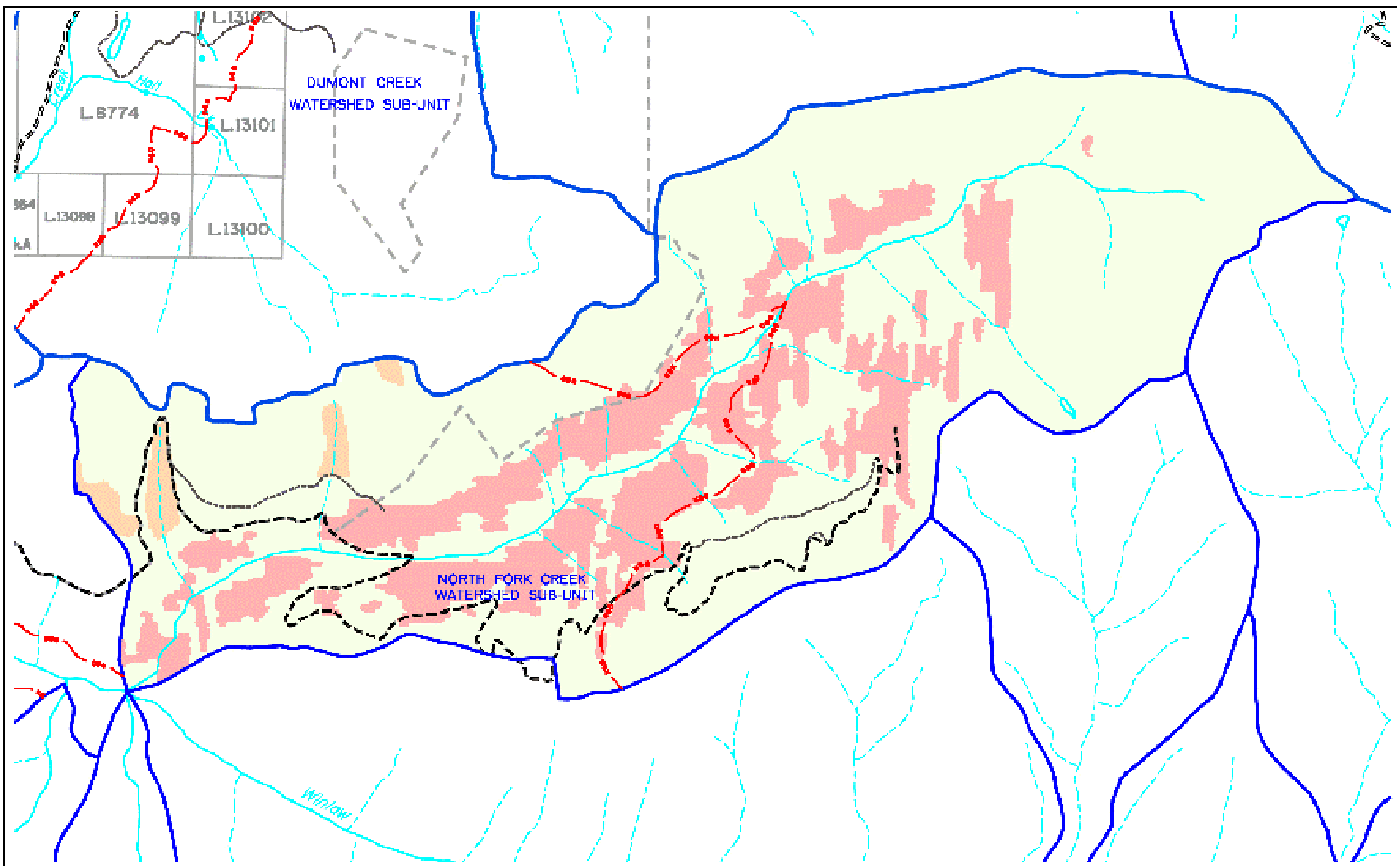

Figure 13: Map of Terrain classes in North Fork Watershed.

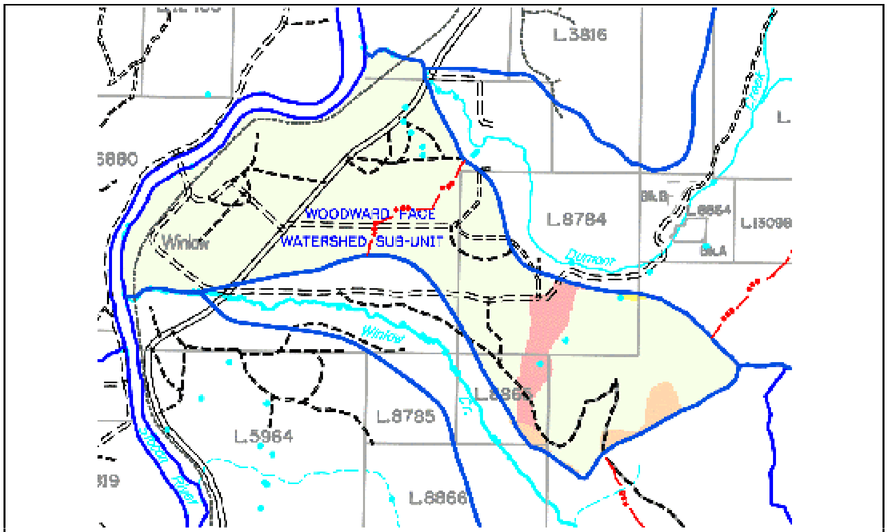

Figure 14: Map of Terrain classes in Woodward Face Watershed.

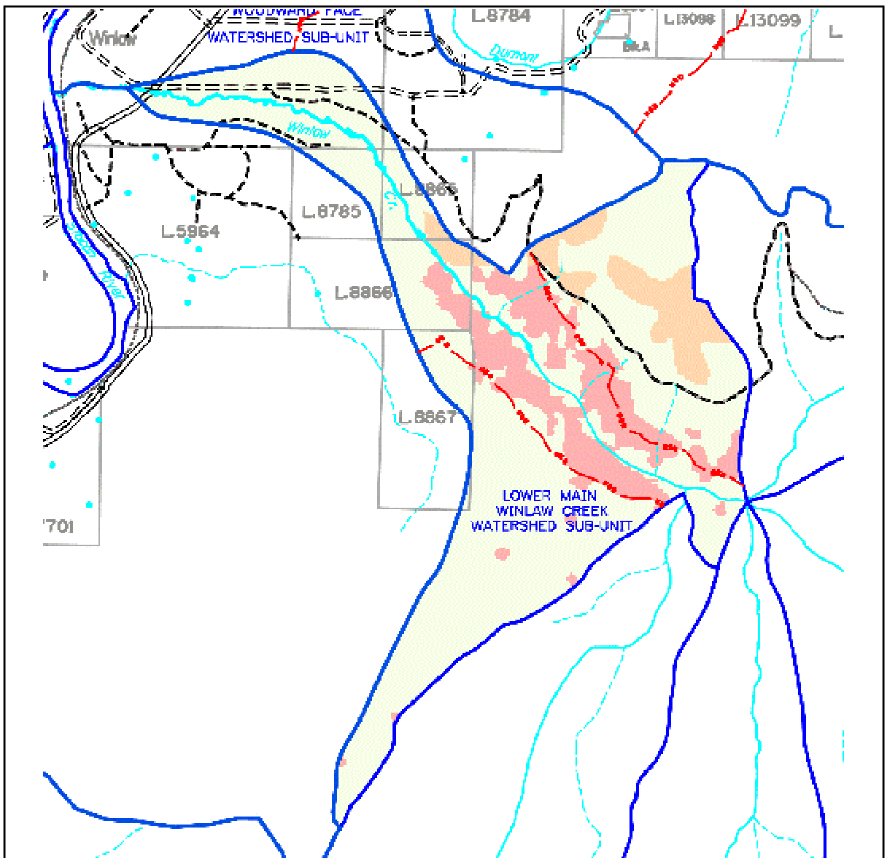

Figure 15: Map of Terrain classes in Lower Main Winlaw Creek Watershed.

6.3 Forestry Impacts on Landslides and Mass Wasting

Landslides indicate unstable terrain. The frequency of occurrence of landslides within a watershed is an indication of the presence of potentially unstable slopes. Forest development activities, particularly the construction of roads, can reduce slope stability and initiate slope failures. Impacts from a slide into a stream can range from minor water quality degradation to the initiation of a major debris torrent.

The increase in bedload and woody debris delivery to streams from mass wasting is probably the most important factor in creating stream channel change following logging.

Increased landslide rates are attributed to many factors. Road building disrupts and concentrates subsurface drainage, often creating points of water concentration. Road sidecast can overload and oversteepen already steep slopes. Tree removal increases the amount of rain that reaches the soil because of the loss of canopy interception, and also increases the rate at which snow melts during both rain-on-snow events and spring snowmelt. Soil strength is reduced by the decay of anchoring roots in the years following tree harvesting. Yarding operations can disrupt natural drainage pathways and can result in gullies infilled with woody slash, increasing the potential for or magnitude of debris torrents.

There are three landslide-related issues to be considered. The first issue is the potential for slides to occur in a particular area. This can be assessed on the basis of the number of events that has occurred both in natural settings and in association with forest development activities. The more slide sites there are, the greater the potential for future mass wasting events.

The second issue is that of delivery. Delivery is defined as the potential for the slide debris to enter a stream. The highest risk sites are those where there is a continuous slope to the edge of a stream. In these situations, opportunities to prevent a slide from impacting the stream are limited. The least risk sites are those where the stream is separated from the slope by a broad valley flat.

The final issue is the potential for transfer of material down the stream after it has entered a watercourse. Sediment transport, particularly of coarse material, is a function of stream gradient. The steeper the gradient, the more material moved and the greater the distance of travel. Low gradient sections of channel are typically braided (multi-channel) as a result of sediment deposition.

Sub-Basin Name	Sub-Basin Area (hectares)	Landslides		Road on Unstable Terrain		Streams with Logged Banks on Slopes > 60%	
		Number	**Indicator #11** Density (number/km2)	Length (meters)	**Indicator #12** Density (km/km2)	Length (meters)	**Indicator #13** Density (km/km2)
Dumont Creek	589	1	0.17	446	0.08	0	0
North Fork Creek	798	4	0.50	1,815	0.23	0	0
Woodward Face	180	1	0.56	485	0.27	0	0
Lower Main Winlaw Creek	271	1	0.37	252	0.09	0	0

Form 6: Landslide Hazard Assessment.

7 Watershed Characteristics

The watershed characteristics listed in Forms 8 and 9 are either required to derive one of the 13 impact indicators, or are otherwise easily acquired from a GIS analysis of digital watershed and forest cover data. The characteristics are not directly used to assess cumulative impacts in a watershed, but are valuable for use in assessing the impact results.

Sub-Basin Name	Sub-Basin Area	Crown Land		Private Land		Operable Land	
	Hectares	Hectares	Percent	Hectares	Percent	Hectares	Percent
Dumont Creek	589	422	72%	167	28%	0	0
North Fork Creek	798	798	100%	0	0%	0	0
Woodward Face	180	35	19%	145	81%	0	0
Lower Main Winlaw Creek	271	217	80%	54	20%	0	0

Form 7: Watershed Characteristics I.

Sub-Basin Name	Sub-Basin Area	Area with Unstable Slopes		Area with Erodible Soils		Are there fisheries temperature concerns?	Hydrological Zone	Dominant Bedrock Geology	Area there Glaciers in Sub-Basin?
	Hectares	Hectares	Percent	Hectares	Percent				
Dumont Creek	589	74	13%	13	2%	No	Southern Selkirk Mountains	Intrusive Granitic	No
North Fork Creek	798	183	23%	169	21%				
Woodward Face	180	13	7%	9	5%				
Lower Main Winlaw Creek	271	65	24%	43	16%				

Form 8: Watershed Characteristics II.

8 Other Land Uses That Potentially Affect Water Quality

In addition to forestry-related land uses, other activities on Crown land can potentially impact aquatic resources, and must be assessed as part of the IWAP. These include:

- livestock grazing
- all-terrain vehicle recreation (motorcycles and off-road trucks)
- mining (placer) activity.

Grazing animals affect water quality by trampling and disturbing streamside and lakeshore sediments, and by depositing fecal material in and adjacent to streams and lakes. As part of the level 1 IWAP, Forest Service range officers will provide an assessment of whether there are locations in a watershed where livestock potentially congregate near streams or lakes. If such locations exist, they must be examined in the field and assessed for sediment or fecal impacts. Where field assessment indicates that cattle congregation on Crown land could potentially affect water quality, prescriptions must be developed and implemented by the Forest Service and range licensees to reduce and eliminate the impacts.

All-terrain vehicle (ATV) recreation is not uncommon in interior watersheds. In forested watersheds, ATV use most commonly occurs along linear rights-of-way, such as for hydro or gas lines. Water quality is affected where ATVs expose mineral soil, allowing surface runoff of sediment-laden water to enter streams. As part of the level 1 IWAP, Forest Service recreation officers will provide an assessment of whether there are locations in a watershed where ATV recreation occurs. If such locations exist, they must be examined in the field and assessed for sediment impacts. Where field assessment indicates that ATV recreation on Crown land is contributing to water quality degradation in a watershed, the Forest Service should develop prescriptions to reduce and eliminate the impacts.

Placer mining can potentially have severe impacts on water quality. Where placer mining is occurring in a watershed, the specific locations must be assessed in the field for sediment impacts. Where impacts are found, the district inspector of mines, B.C. Ministry of Energy, Mines and Petroleum Resources (effective March 1996 - now Ministry of Employment and Investment - Energy and Minerals Division), should be notified and measures taken to reduce the placer impacts.

Sub Basin Name	Range Use Close to Streams?	Mining Close to Streams?	All Terrain Vehicles Close to Streams?
Dumont Creek	Yes	No	No
North Fork Creek	No	No	No
Woodward Face	No	No	No
Lower Main Winlaw Creek	No	No	Yes

Form 9: Other Land Uses which may impact water quality.

9 Watershed Report Cards

The preceding forms produce a set of raw data scores. The range of raw data for each indicator varies greatly from one indicator to another. Therefore, to make the indicators easier to interpret, the data are rescaled to fit between 0 and 1.0, with increments of 0.1. Zero means no impact, 0.5 means potential moderate impact, and 1.0 means potential high impact. This rescaling is performed automatically by the spreadsheet used to summarize the IWAP data.

The watershed report cards below present the raw data score for each indicator, the rescaled score for each indicator, and the hazard index for each of four impact categories for each sub-basin.

This report card is used as the basis for identifying watershed constraints and developing management recommendations.

Watershed Report Card for Dumont Creek Watershed

		Indicator		(5) Score	(6) Hazard Index
Peak Flow					
	Index above H60	0.01			
	Index below H60	0.13			
1	Total Peak Flow Index	0.15		0.24	
2	Road density above H60	0.07	km/sq.km.	0.07	
3	Total road density (See note below)	1.15	km/sq.km.	0.38	**0.24**
Surface Erosion					
4	Roads on erodable soils	0.07	km/sq.km.	0.13	
5	Roads within 100 m of a stream	0.89	km/sq.km.	1.00	
6	Roads that are both of the above	0.07	km/sq.km.	0.33	
7	Active stream crossings	0.85	no./sq.km.	0.95	
8	Total road density (See note below)	1.15	km/sq.km.	0.38	**0.97**
Riparian Buffer					
9	Portion of stream logged?	0.03	km/km.	0.10	
10	Portion of fish bearing streams logged?	0.00	km/km.	0.00	**0.10**
Landslides					
11	Landslide density	0.17	no./sq.km.	0.62	
12	Roads on unstable slopes	0.08	km/sq.km.	0.25	
13	Streams >60% and banks logged	0.00	km/sq.km.	0.00	**0.62**

Table 1: IWAP Report Card for Dumont Creek Watershed.

Watershed Report Card for North Fork Creek Watershed

		Indicator		(5) Score	(6) Hazard Index
Peak Flow					
	Index above H60	0.01			
	Index below H60	0.00			
1	Total Peak Flow Index	0.01		0.02	
2	Road density above H60	0.48	km/sq.km.	0.48	
3	Total road density (See note below)	1.28	km/sq.km.	0.43	**0.31**
Surface Erosion					
4	Roads on erodable soils	0.17	km/sq.km.	0.34	
5	Roads within 100 m of a stream	0.38	km/sq.km.	0.86	
6	Roads that are both of the above	0.04	km/sq.km.	0.22	
7	Active stream crossings	0.50	no./sq.km.	0.60	
8	Total road density (See note below)	1.28	km/sq.km.	0.43	**0.73**
Riparian Buffer					
9	Portion of stream logged?	0.00	km/km.	0.00	
10	Portion of fish bearing streams logged?	0.00	km/km.	0.00	**0.00**
Landslides					
11	Landslide density	0.50	no./sq.km.	1.00	
12	Roads on unstable slopes	0.23	km/sq.km.	0.66	
13	Streams >60% and banks logged	0.00	km/sq.km.	0.00	**1.00**

Table 2: IWAP Report Card for North Fork Creek Watershed.

Watershed Report Card for Woodward Face Watershed

		Indicator		(5) Score	(6) Hazard Index
Peak Flow					
	Index above H60	0.05			
	Index below H60	0.28			
1	Total Peak Flow Index	0.33		0.55	
2	Road density above H60	2.09	km/sq.km.	1.00	
3	Total road density (See note below)	6.12	km/sq.km.	1.00	**0.85**
Surface Erosion					
4	Roads on erodable soils	0.22	km/sq.km.	0.44	
5	Roads within 100 m of a stream	1.25	km/sq.km.	1.00	
6	Roads that are both of the above	0.01	km/sq.km.	0.07	
7	Active stream crossings	0.00	no./sq.km.	0.00	
8	Total road density (See note below)	6.12	km/sq.km.	1.00	**1.00**
Riparian Buffer					
9	Portion of stream logged?	0.00	km/km.	0.00	
10	Portion of fish bearing streams logged?	0.00	km/km.	0.00	**0.00**
Landslides					
11	Landslide density	0.56	no./sq.km.	1.00	
12	Roads on unstable slopes	0.27	km/sq.km.	0.74	
13	Streams >60% and banks logged	0.00	km/sq.km.	0.00	**1.00**

Table 3: IWAP Report Card for Woodward Face Watershed

Watershed Report Card for Lower Main Winlaw Creek Watershed

		Indicator		(5) Score	(6) Hazard Index
Peak Flow					
	Index above H60	0.24			
	Index below H60	0.03			
1	Total Peak Flow Index	0.27		0.45	
2	Road density above H60	0.48	km/sq.km.	0.48	
3	Total road density (See note below)	1.32	km/sq.km.	0.44	**0.46**
Surface Erosion					
4	Roads on erodable soils	0.00	km/sq.km.	0.00	
5	Roads within 100 m of a stream	0.87	km/sq.km.	1.00	
6	Roads that are both of the above	0.00	km/sq.km.	0.00	
7	Active stream crossings	1.11	no./sq.km.	1.00	
8	Total road density (See note below)	1.32	km/sq.km.	0.44	**1.00**
Riparian Buffer					
9	Portion of stream logged?	0.00	km/km.	0.00	
10	Portion of fish bearing streams logged?	0.00	km/km.	0.00	**0.00**
Landslides					
11	Landslide density	0.37	no./sq.km.	0.95	
12	Roads on unstable slopes	0.09	km/sq.km.	0.31	
13	Streams >60% and banks logged	0.00	km/sq.km.	0.00	**0.95**

Table 4: IWAP Report Card for Lower Main Winlaw Creek Watershed.

10 Level 2 Assessment

At this point in the Level 1 assessment, it must be decided whether further analyses on a particular watershed are required. As a rule of thumb:

- If all hazard indices (Form 11) are less than 0.5, there are no or limited perceived cumulative impacts and no further IWAP analysis is required to assess impacts of past forestry activity. However, if a forest development plan is proposed for the area, a second level 1 analysis must be completed to assess the potential impacts that may result from that forest development. The assessment can thus be used strategically to alter the plan, as necessary, to minimize watershed impacts.
- If the surface erosion hazard index is greater than or equal to 0.5, but all other hazard indices are less than 0.5, no further IWAP analysis is required.
- If any of the peak flow, mass wasting, or riparian buffer hazard indices are greater than or equal to 0.5, then a level 2 analysis (that is, a channel assessment) must be completed before the interpretations, as described, are developed. The results of the level 2 analysis should be used in the interpretation worksheets in the section “Making interpretations and recommendations,” under “channel instability.”

The level 2 WAP provides an overview assessment of stream channels in the watershed, and estimates the level of channel disturbance associated with forest practices for the most sensitive channel type within each watershed or sub-basin.

11 Interpretations

Previous text sections of this Appendix have been drawn from the IWAP manual. This section was written by the Licencees, and is not drawn from the IWAP manual, except for specific citations.

We have used the standard IWAP process to develop a series of measurements and assessments of human disturbance and associated risk to watersheds within which development activities are proposed. The next step is to interpret the results.

The first, most important, question to ask is “Are the assessments valid?”

Results from the Interior Watershed Assessment Procedure (IWAP) become less dependable in smaller watersheds, and the KBLUP IS notes that they should not be used by themselves to define hazards in watersheds under 500 hectares. KBLUP IS also notes:

> *IWAP is a very new procedure and will not be fully calibrated until many applications can be ground-truthed and analyzed. For example, current applications are experiencing numerous problems with “false highs”. This occurs when high hazard scores are registered on the report card but are not confirmed by field investigation. Studies are currently underway to calibrate the reconnaissance level hazard ratings with actual on-the-ground hazards.*
>
> *…Therefore it is important that hazard scores be used only as a course filter to help identify potential problem areas and/or to aide in the prioritization of watersheds for application of a full IWAP.*[3]

All of the watershed units under consideration are relatively small, ranging in size from 180 to 798 hectares. A careful examination of the results suggests that many of the hazard ratings are skewed to the “high” end of the scale by watershed size, rather than by watershed-wide high hazard conditions. This is because a single “event” in a small watershed will result in high “events per km^2” rating, which is the basis for many IWAP risk assessments.

For example, the Woodward Face Sub-Unit has a landslide density of 0.56 landslides per km^2 , which results in a mass wasting category hazard rating of 1.00, or very high. However, this hazard rating is caused by a single landslide, which has been attributed to improper road maintenance. The high rating is not sound evidence of widespread high hazard of landslides in this low elevation, low slope gradient unit. The landslide itself is a significant feature and was a significant event for water users, but it is not a reliable indicator of the level of landslide risk at a watershed scale for this unit.

A review of the Woodward Face Report Card (Table 3) shows that the sub-basin also has high hazard index ratings for peak flow (0.85) and surface erosion (1.00). These ratings are largely due to high road density in the settled portion of the watershed.

The IWAP Guidebook states:

> *If any of the peak flow, mass wasting, or riparian buffer hazard indices are greater than or equal to 0.5, then a level 2 analysis (that is, a channel assessment) must be completed…*

---

[3] KBLUP IS Chapter 3 Page 37 and 38.

Thus, technically speaking, a channel assessment is required for a watershed subunit which is largely devoid of surface water flow, due to a single landslide and established human use patterns. Neither of these factors is a sound indicator of widespread high geomorphological or forestry related hazard in this watershed, and a channel assessment appears spurious.

Examples of high hazard indexes which suggest that a stream channel stability assessment is required can be found in each watershed assessed. These high hazard ratings are generally related to high densities of old roads and suburban roads in the watersheds in question, not to alteration of forest cover. As the development activities proposed in this FDP are modification of an existing road and partial cutting of 27 hectares of forest, both activities largely in areas remote from surface water flow, a full channel assessment does not appear warranted at this time.

As an alternative to the full IWAP process, The Kootenay Boundary Land Use Plan Implementation Strategy suggests that a subset of IWAP variables on a Watershed Report Card be interpreted using the parameters set out in Table 5.

Impact Indicators	Hazard rating		
	low	medium	high
a) peak flow index	<0.3	0.3-0.42	>0.42
b) road density for entire sub-basin (km/km^2)	<1.5	1.5-2.1	>2.1
c) no. of stream crossings ($no./km^2$)	<0.4	0.4-0.6	>0.6
d) no. of landslides ($no./km^2$)	<0.1	0.1-0.18	>0.18
e) roads on unstable slopes (km/km^2)	<0.15	0.15-0.25	>0.25

Table 5: Interpretation Guide for IWAP Report Card Scores.

This appendix has provided the basic data input into the IWAP assessment, and basic summaries and interpretations of that data. The body of the Forest Development Plan contains:

- interpretations of the IWAP report card results,
- assessments of the relationship between hazards suggested by IWAP and hazards noted in the field, and
- discussion of the relationship between proposed development activities and watershed hazards.