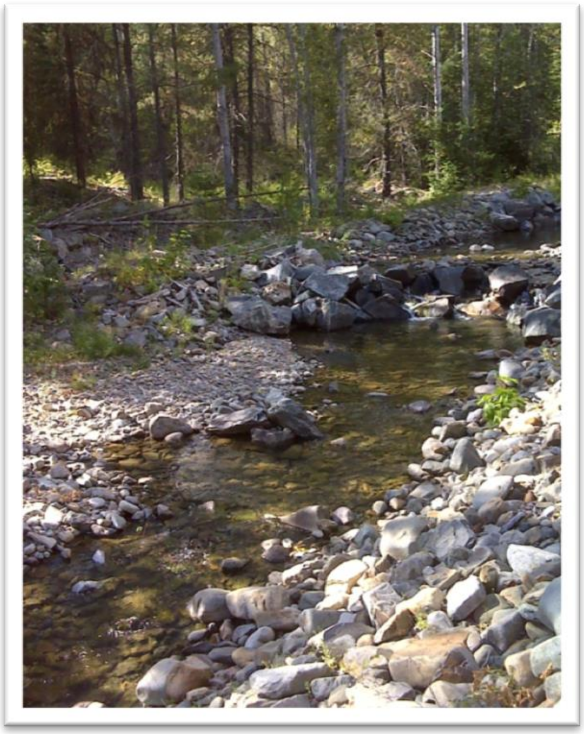
Reassessment of High Conservation Value (3) Forests For Canadian Forest Product's Operating Area in the Rocky Mountain and Kootenay Lake TSA

(Apex File CF-14-LL-01)



Englishman Creek at CP Rail bridge

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INTRODUCTION:

High Conservation Value Forests (HCVF) are defined as forest areas of exceptional ecological or social value. The identification of HCVFs advances sustainable forest management by providing certainty regarding the location of forest stands of exceptional conservation value, and leads to the development of management strategies that ensure these values are maintained or enhanced. This assessment focuses on the identification of HCVFs associated with Category 3 attributes.

HCVFs under Category 3 in the FSC-BC Standard (2005) are defined as 'Forest areas that provide basic services of nature in critical situations (e.g., watershed protection, erosion control). There are three points under this definition:

> **3.1** Where downslope or downstream consequences of landslides, sediment production, or snow avalanches are significant (e.g., spawning habitat, transportation or communication infrastructure), forest areas associated with unstable terrain (Class 4, 5), highly erodible soils, or snow avalanche starting zones.
>
> **3.2** Forest areas that protect the water supply of the community and individual water users identified through licencing data and consultation.
>
> **3.3** Forests required for the maintenance of flow regimes and/or flow protection in other critical watersheds (e.g., riparian stands, forest stands above the H60 line in snowmelt-dominated watersheds).

The assessment of HCVF3 forests in the Kootenay Lake and Rocky Mountain timber supply areas was initially undertaken in 2005 for Tembec Forest Industries and in 2009 for Canadian Forest Products (Radium). This report presents the outcome of a reassessment of the original HCVF3 polygons. The reassessment provides an opportunity to evaluate existing HCVF3 polygons within the context of new information from recent scientific studies concerning the effect of forests on terrestrial and aquatic environments. The study area for this reassessment includes Canfor's operating area in the East Kootenay as of January 2014, including TFL 14, MF27, MF471 (Teck) and MF471 (Nature Conservancy of Canada). The operating areas covered by BCTS or other licensees are not included.

TERMS OF REFERENCE

The overall goals of this project are to:

1. review existing HCVF3 polygons in the East Kootenay to determine if polygon boundaries require adjustment, based on new information obtained since the last assessment,
2. undertake an HCVF3 assessment within TFL 14,
3. review and update the management strategies for the HCVF3 polygons, linking them to new information and other forestry requirements and assessments such as ECA assessments, and
4. compile the results from the above 3 components into a single report and single shape-file covering all of Canfor's operating area in the East Kootenay.

The project has been undertaken as two main phases: mapping (goals 1 and 2) and management strategies (goal 3). This report (Goal 4) presents the results of Goals 1 to 3 in report format.

IDENTIFICATION OF HIGH CONSERVATION VALUES (HCV3)

The rationale used for the delineation of HCV3 forests in Canfor's Kootenay Lake and Rocky Mountain operating areas (the study area) is described in Table 1 and is consistent with the *Precautionary Approach* and the methods suggested in the *Checklist for Identification of HCV forests* in the guidance material provided in Appendix D of the FSC BC Standards (Oct, 2005).

Table 1. Rationale for delineation of HCVF 3 polygons in Canfor's TSA

Category	Appendix D Guidance	Forest Areas considered HCV 3 in Canfor's Kootenay Lake and Rocky Mountain Operating Areas
3.1	**Forests critical to erosion control:** Forest areas where the degree of slope carries a high risk of erosion, landslides and avalanches. (For the purpose of this assessment a 'risk' is consistent with the definition in Wise et al. (2004) where Risk = Hazard x Consequence and 'high' risk is the product of a 'moderate' to 'high' hazard and a high' to 'moderate' consequence respectively)	• Forests upslope from private land with dwellings or structures that includes terrain identified as having a moderate or high hazard of instability (Class P, U and IV and V) or potential snow avalanche initiation hazard. • Forests upslope from public and high-use transportation corridors including public roads, high-use Forest Service roads and railways that includes terrain identified as having a moderate or high hazard of instability (Class P, U and IV and V) or potential snow avalanche initiation hazard. • Forests upslope from riparian areas and stream channels identified as high-value fish spawning habitat that includes terrain identified as having a moderate or high hazard of instability (Class P, U and IV and V).
3.2	**Forests that contribute to maintaining the quality, quantity and seasonal timing for water flows that are a source of drinking water, irrigation water or water for a critical economic activity:** The potential impact to human communities is so significant as to be 'catastrophic' leading to significant loss of productivity, or sickness and death, and there are no alternative sources of drinking water. Availability of high quality water may be critical to agriculture or other economic activities.	• Community watersheds and high-use domestic and/or irrigation watersheds, where forests provide a critical service in maintaining the flow regime and water quality and where no economically viable alternative water supplies exist (the provision of bottled water is not considered economically viable).
3.3	**Forests that provide a significant ecological service in mediating flooding and/or drought, controlling stream flow regulation, and water quality:** Forest areas play a critical role in maintaining water quantity and quality and the service breakdown has catastrophic impacts or is irreplaceable.	• Watersheds (<100km^2) upstream from alluvial and colluvial fans with identified flooding and debris flow hazards that have private land with dwellings/structures, public/ high-use roads or railways.

Utility corridors (electrical transmission lines, below ground gas pipelines) were not considered conservation attributes in this assessment because short-term cessation of these services is unlikely to result in serious cumulative or catastrophic impacts to human life. In this assessment 'high-risk' is consistent with the definition in Wise et al. (2004) where Risk = Hazard x Consequence and 'high' risk is the product of a 'moderate' to ‘high’ hazard and a high’ to ‘moderate’ consequence respectively. ‘Moderate’ to ‘High’ consequence refers to areas where there is at least a moderate likelihood of impact to human life, human structures or high-value spawning habit from upslope or upstream hazards. ‘High-value’ as defined by Westover (2005) implies, long-term, high-density spawning habitat for Bull Trout, Kokanee and Westslope Cutthroat Trout.

Sources of Information

Information used to update HCVF 3 polygons came from:

- Canfor’s GIS databases.
- Input from Canfor’s Forest Supervisors and Forest Scientist.
- Information from Regional District of East Kootenay planning staff.
- B.C.’s Water License Web Query (http://a100.gov.bc.ca/pub/wtrwhse/water_licences.input).
- imapBC and GeoBC databases (http://maps.gov.bc.ca/ess/sv/imapbc/, https://apps.gov.bc.ca/pub/dwds/home)
- Google Earth imagery

Information in the databases included the location and number of licensed water intakes, community watersheds, roads, and private land boundaries as well as information on fish occurrence.

Information on terrain stability hazards came from Canfor in house databases. High resolution Google Earth images provided additional information regarding areas with potentially unstable or unstable terrain and areas with potential for snow avalanche hazards.

High-value spawning areas for Bull Trout (*Salvelinus confluentus)*, Cutthroat Trout (*Oncorhynchus clarki lewisi*) and Kokanee (*Oncorhynchus nerka*) were originally identified by Mr. Bill Westover (B.C. MoE, Senior Fisheries Biologist, May 2005) for the area previously under license to Tembec. These areas were confirmed as high value by Mr Herb Tepper (B.C. MFLNRO, Senior fisheries biologist Kootenay region, March 2014)

Information on high-value spawning areas for the flathead was provided by Montana Fish Wildlife and Parks via Erin Sexton (Research Assistant, Flathead Lake Biological Station, University of Montana)

Google Earth images from 2010 or later were used to confirm the locations of human dwellings and transportation corridors. HCVF polygon boundaries were delineated visually with the aid of 1:20k shaded DEM, TRIM contours and stream network databases in ArcGIS.

Information from previously completed watershed-level hydrogeomorphic assessments was also considered in the delineation of HCVF 3 polygons in the following areas;

- Russell Creek
- Hawkins Creek
- Tributaries to Moyie Lake and Moyie River
- Englishman Creek
- Etna, NoName and Braunagle Creeks
- Cotton Creek and Barkshanty Creeks
- Perry Creek
- Angus Creek
- Matthew Creek
- Kimberley Creek
- Mather Creek
- Lussier River
- Wigwam River
- Sparwood Face
- Lladner-McCool Face
- Littlemoor Cr. area
- Elk and Fording Rivers
- Boivin Creek
- Greenhills Creek
- Forster Creek
- Timber Forest License 14

Canfor's Forestry Supervisors and Regional District of East Kootenay (RDEK) planning staff were consulted to gain additional information about areas where there has been possible changes in conservation values (i.e. private land development and water intakes) in the ten years since the previous assessment.

The science behind HCVF3:

<u>How do forests protect from soil erosion and terrain instability?</u>

In the Kootenay region of B.C. forest roads are the primary factor responsible for soil erosion and sediment delivery to stream channels. A detailed sediment budget study undertaken in the Kootenay region by Jordan (2001) determined that surface soil erosion along forest roads resulted in erosion of between 0.008 tonnes/km/year to 1.68 tonnes/km/year depending on the road, soil texture, local geology and the annual meteorology. Jordan (2001) estimates that roughly 36% of the sediment eroded from the road prism was delivered to the stream channel on an annual basis, while the majority of the sediment is stored in ditchlines or between the road prism and the stream. The largest annual sediment yields were determined to be due to inadequate control of surface runoff along road surfaces, ditchlines and cut slopes (Jordan, 2001).

Over the longer term, majority of sediment delivery to stream channels associated with forest development occurs through mass wasting processes such as landslides and debris flows (Jordan et al., 2009). Sediment delivery from landslides can typically exceed 1000 tonnes/year (Jordan, 2001). Landslides that occur naturally are usually caused by the buildup of subsurface water during intense rainstorms and rain-on-snow events. In the Kootenay Columbia region high hazard areas, or those areas with a high likelihood of landslides, are most likely to occur on steep slopes (i.e., > 40%) with deposits of glacial sediments (Jordan, 2002). The highest hazard areas often have hollows or depressions that collect water during storms.

Most research indicates that logging can increase the hazard of landslides, especially in high hazard areas during the first ten years or so after harvest. This increase in the frequency of landslides following logging has been linked to (1) loss of soil cohesion as root systems from logged trees decompose (Schmidt et al., 2001; Sidle and Ochiai, 2006; Ammann et al., 2009), (2) increased soil water due to substantially decreased evapotranspiration and increased snowmelt following logging (Jordan et al., 2009), and (3) interception and concentration of subsurface and surface flow along roads and trails that is subsequently discharged onto potentially unstable or unstable slopes (Jordan, 2002, Jordan et al., 2009).

How much does the hazard (i.e. likelihood) of landslides increase following logging? The answer to this question depends on many variables, such as geology, weather, and logging practices. Meehan (1991) who's study focused on the Pacific Northwest, found that the increase in frequency of landslides due to logging varies widely, ranging from 2-4 times in Oregon and Washington to 31 times in the Queen Charlotte Islands. Meehan (1991) suggests that an increase in the frequency of landslides of 6.6 times is probably more representative. This increase in landslide frequency agrees closely with an increase of 6.4 times which was determined in a study of landslides in the west Kootenay Region (Jordan, 2002). Jordan's study of the causes of landslides in the West Kootenay found that, while some development related landslides appear to be associated solely with loss of soil strength on steep slopes, the majority (i.e. > 90%) of forest development-caused landslides could be linked to water concentration and diversion along roads and trails.

How do forests protect from changes in quantity, quality and timing of flows (i.e. flooding and the flow regime)?

Physical and biological sustainability of headwater streams depends on the natural variability of hydrologic and geomorphic processes that control sediment and nutrient flux as well as the temporal and spatial complexity of aquatic ecosystems (Poff et al., 1997; Meyer and Wallace, 2001; Gomi et al., 2001; Richardson et al., 2005). In headwater streams where mass wasting is infrequent, which is typical in the Kootenay – Columbia region, disturbance events leading to the episodic influx of sediment and nutrients and the mobility of the channel bed, are closely linked to a flood regime comprising a range of flood magnitudes and durations reflective of regional hydro-climate and physiographic controls (Resh et al., 1988; Poff et al., 1997).

In Kootenay-Columbia headwater streams flows begin to rise in early April as snowmelt is transferred to from hillsides to stream networks and remain elevated throughout May and June receding back to low flows during late June or early July. Snowmelt hydrographs of interior headwater streams typically display several independent peak flows associated with isolated periods of exceptional warm spring temperatures and/or rain-on-snow events. The largest peak flow of the spring snowmelt period corresponds to the annual maximum flood peak. The long-term time series of annual maximum peak flows is characterized by a range of flood magnitudes that have a probability of occurrence described by a cumulative frequency distribution (a.k.a. flood frequency curve).

Stream channels display geometries that are adjusted to the long-term frequency distribution of floods (Leopold and Maddock, 1953; Andrews and Nankerviz, 1995; Dodov and Foufoula-Georgiou, 2005). The average annual flood, that occurs approximately once every 1.5 to 3 years (avg. 2 yr return period), is referred to as the 'effective' discharge that mobilizes the majority of bedload sediment and maintains channel morphology over the long-term (Wolman and Miller, 1960). The effective discharge typically corresponds to the bankfull flood which just fills the active channel (Andrew, 1980).

Changes in the flood regime have the potential to cause long-term changes to sediment transport dynamics, sediment yield and morphology of stream channels (Knox, 1977; Gordon and Meetenmeyer, 2006; Kiss and Blanka, 2012). Changes in channel cross-sectional area of rainfall-dominated low-land alluvial streams have been linked to increases in both the frequency and magnitude of floods following the conversion of forests to pastures or urban areas (Booth, 1990; Fitzpatrick et al., 1999). In upland headwater streams, fining of surface textures has been documented as a result of decreases in the magnitude of floods associated with flood water extraction (Parker et al., 2003; Gordon and Meetenmeyer, 2006). Two studies investigating the influence of forest removal-related changes in flood response on sediment yield in snowmelt dominated headwater streams determined that increases in sediment yield can be linked to increases in the magnitude and duration of sediment transporting discharges following harvesting (Troendle and Olsen, 1994; Troendle et al. 2001).

A recent analysis of four snowmelt catchments with moderate harvest levels (30% to 40%) utilizing a frequency-based approach demonstrates that harvesting increases the magnitude and frequency of all floods on record including the largest floods (R.I. = 1:50 yrs., Green and Alila, 2012). Additionally, the study revealed new insights concerning the physical processes governing the relation between forests and floods in snowmelt environments. Specifically the study determined that the dominant process responsible for flood regime changes following harvesting is the increase in basin-average snowmelt rates that are amplified or mitigated by physical characteristics such as aspect distribution, elevation range, slope gradient and amount of alpine area. The study found that the greatest impacts to the flood regime occurred in moderate gradient, fully forested watersheds with a predominance of south aspect slopes while the smallest impacts were observed in steep, north-west aspect, alpine dominated watersheds.

In addition to changes to the frequency and magnitude of floods, forest harvesting in snowmelt regions has also been found to alter the timing of runoff. Following moderate levels of harvesting peak flows occur on average one to two weeks earlier compared to the unharvested condtion (MacDonald and Stednick, 2003; Moore and Scott, 2005; NRC, 2008).

In smaller watersheds earlier peak runoff can lead to stream flow deficits during the summer low flow months. Winkler (personal communication, April, 2014) has determined through an analysis using pre- and post-harvesting flow duration curves that harvesting of approximately 50% of a small (5 km^2) forested watershed with predominantly south-aspect slopes has resulted in substantial decreases in late summer (i.e., July through October) daily discharges. In addition, the removal of forest canopy along the riparian areas of small forested stream channels has been shown to locally increase stream temperature (Moore et al., 2005; MacDonald et al., 2014). Projected changes in climate over the next several decades for the Columbia Basin, which include earlier spring snowmelt and warmer summer temperatures (Hamlet et al., 2012), could compound forestry related changes in the timing, duration and temperatures of low flows, particularly in small, low elevation, forested watersheds along the Rocky Mountain Trench, Moyie Valley and Elk Valley.

Assessment of HCVF3s:

Forests within Canfor’s operating areas were assessed for the potential hazards[1] that forestry activities could pose to each HCV3. The potential hazards considered are;

- likelihood of landslides

[1] Hazard- a harmful or potentially harmful event.

- likelihood of snow avalanches
- likelihood of flooding
- likelihood of impacts to water quality and quantity

HCVF3 polygons were delineated in ArcGIS using Google Earth^{tm} digital orthophotographs and DEM-derived hillshade imagery basemaps (downloaded from GeoBC) by Kim Green, PhD., P.Geo., and Will Halleran, P.Geo., L.Eng., on the basis of professional expertise. Polygons were identified around forest areas that were deemed to present a high likelihood of a hazard having significant consequences (i.e. cause serious cumulative or catastrophic impacts) on an identified value. For each HCVF3 polygon, a primary 'service of nature' is identified based on the potential consequences to the identified HCV. In polygons where HCVs overlap (eg, landslides and water quality), a secondary 'service of nature' is also identified. The primary service of nature represents the greatest risk to human life. For example, in polygons where both 'flooding' and 'water quality' are identified, 'flooding', which represents the greatest risk to human life, is identified as the primary service of nature.

Scale considerations in the delineation of HCV3 forests

Watershed scale is an important consideration in the delineation of HCVF3 forests. The potential for 'serious cumulative or catastrophic impacts' will change with watershed size (NCASI 1999; MacDonald, 2000). For example, a landslide of several hundred cubic meters of material is likely to have long-term detrimental impacts to water quality in a small watershed of 1 to 10 km^2 but will have much less of an impact to water quality in a 100 km^2 or larger watershed where daily discharge is one to two orders of magnitude greater. The influence of scale is particularly relevant in mountainous watersheds of the Columbia and Rocky Mountains that have naturally high rates of sediment delivery. In these regions thick, fine-textured glacial deposits along major valleys supply high sediment loads to the large streams and rivers during annual spring freshet periods (Church et al., 1989). An extensive review of the scientific literature found no published studies that define a specific upper threshold of basin size for detecting cumulative impacts to peak flows associated with forest development in snowmelt-dominated hydrological regimes. Studies on the influence of forest removal on the flood regime have identified changes related to harvesting or forest removal in mountainous watersheds that are several 10's of square kilometers in size (Green and Alila, 2012) and in gentler gradient watersheds up to 120 km^2 in size (Fitzpatrick et al., 1999). Several investigations into scaling effects of watersheds have determined that the transition from transport-dominated to deposition-dominated systems (i.e. from confined headwaters to unconfined floodplain-bound streams) also marks the point of a substantial drop in annual variability in sediment and water discharge (Benda and Miller, 2001; Miller et al., 2003; Benda et al., 2005; Dodov and Foufoula Georgiou, 2005). At this hydrological breakpoint annual floods are comprised of both surface and subsurface runoff contributions and are less affected by spatially isolated precipitation/runoff events within the catchment area. It follows that watersheds larger than this threshold are also likely to be less responsive to development-related perturbations in runoff processes and sediment flux. The scale at which this transition occurs varies across hydroclimate regions. In the mountainous Appalachian region this transition was found to occur at approximately 100km^2 while in the gentle terrain of the U.S. Mid-West the hydrological threshold occurs at a scale of 700km^2 (Dodov and Foufoula Georgiou, 2005).

For the purpose of this HCVF3 assessment in the Kootenay-Coumbia headwater regions a scale of 100 km^2 was selected as the upper watershed limit for evaluating the potential for 'serious cumulative or catastrophic impacts' related to forest harvesting. The 100 km^2 threshold generally corresponds to the scale at which Kootenay and Columbia watersheds transition from steeper transport dominated headwater systems to lower gradient depositional systems with well-developed floodplains. In addition, watersheds of 100km^2 in the Kootenay Columbia region typically contain 4th to 5th order main stem channels which correspond to the upper limit for detecting sedimentary cumulative impacts associated with upstream development (NCASI, 1999, See Appendix 1 for an explanation of stream order). It is recommended that this 100km^2 upper limit be reviewed in the next HCVF3 re-assessment in case new studies are available that reveal harvesting effects in larger watersheds.

Delineation of HCVF3s

In the case of terrain stability and snow avalanche hazards HCVF3 polygons encompass the area directly upslope from the conservation value (e.g. private land with dwellings). In the case of flooding hazard, the entire catchment upstream from the conservation value is included within the polygon. This difference in area delineated for terrain stability and flooding is due to the fact that changes in the flood regime (i.e frequency of flooding) of a stream occur as a result of cumulative levels of harvesting within a catchment (Alila et al., 2009; Green and Alila, 2012) while changes to terrain and avalanche hazards are due to localized resource road and cutblock-related alterations to slope conditions. Similarly, the likelihood of impacts to water quality in Kootenay and Columbia watersheds is primarily associated with increased sediment delivery from landslides and for this reason, HCVF3 polygons delineated for water quality are located around unstable and potentially unstable terrain likely to contribute to degradation in water quality at the water intake.

Where high-value spawning habitat is the conservation value of concern, HCVF3 polygon delineation considers the influence of the physical catchment characteristics on the likelihood of negative impacts to the spawning habitat. In large watersheds (i.e., > 100 km^2), where a wide elevation and aspect distribution naturally limits the potential for cumulative impacts from forest development, polygons are delineated around riparian forests that provide immediate protection to channel banks and floodplains and, where necessary, around valley-side forests that limit local sediment delivery hazards (i.e., landslides) on adjacent slopes. In these large systems the root systems of mature coniferous and deciduous forests protect the banks and adjacent floodplains and forest floor from erosion during large flood events when the stream overflows its banks. In watersheds with substantial alpine/subalpine component (i.e., approx. > 30%), where the flow regime is controlled by high-elevation snowmelt, HCVF3 polygons are also limited to riparian forests necessary for maintaining channel stability. In small and moderate sized watersheds (i.e., < 100 km^2) without substantial alpine/subalpine component, the full catchment area is delineated as HCVF. In these smaller forested watersheds harvesting situated throughout the catchment area has the potential to influence the streamflow regime that can cause long-term degradation to spawning habitat (Green and Alila, 2012; Green et al., 2013).

The spatial extent of forests that protect channel stability and limit the likelihood of sediment delivery to riparian areas and high value fish spawning habitat was assessed using 1:20.000 digital elevation model (DEM) data downloaded from GeoBC together with high resolution Google Earth images.

HCV3.1 Forests critical to landslides, sediment production and snow avalanches.

HCV3.1 forests are delineated where there is a high likelihood of a landslide, debris flow, or snow avalanche (i.e. high hazard) and a moderate to high likelihood of catastrophic impacts to an HCV (i.e. moderate to high consequence to human dwelling, private land with structures, transportation corridors, consumptive use water supplies or high-value spawning habitat).

No HCVF3 polygons have been delineated based on snow avalanche hazard alone. In all areas with potential snow avalanche hazards terrain stability hazards also exist. HCV3.1 forests are also delineated where there is a high likelihood of sediment delivery by landslides and/or through impacts to riparian areas adjacent to high value spawning habitat.

HCV3.2 Forests critical to water supplies:

A forest is considered to have a high conservation value when it provides protection to:

- water quality values (quality, quantity and timing of flow) in Community Watersheds, and
- high-use domestic, industrial and/or irrigation watersheds or intakes that supply campgrounds, industry or other sites with multiple water users.

Detrimental impacts to water quality of these water supplies could result in widespread and potentially costly consequences. For watersheds less than approximately 100 km^2 and which have a naturally low rates of sediment delivery, the entire forested catchment upstream from the water system intake is identified as the HCVF3 polygon and more detailed level of assessment is required to identify specific forest areas that contribute towards the protection of water quality (see management strategies). For watersheds greater than 100 km^2 only the riparian forests of the main stem channel(s) and any class IV or V (P or U) terrain immediately adjacent to the lower main stem channel within 5 km of the intake is considered a HCVF3 (e.g., Matthew Creek, Hawkins Creek).

Designated Community Watersheds that are maintained only as back-up systems and where the primary water supply is groundwater sourced (e.g. Boivin Creek, Cummings Creek, Glencairn Creek) do not meet the criteria for HCVF 3.2 designation for water quality. In addition, forests upstream/upslope from streams with less than 4 individual water intakes did not meet the criteria of HCV3.2 for water quality because this would not represent a 'widespread loss' of a value. In these cases it would be feasible to establish alternative sources of drinking or irrigation water for a small number of individual dwellings. A threshold of four licensed intakes on a single water source was considered as the point at which establishing an alternative water source would be economically and logistically limiting.

HCV3.3 Forests required for the maintenance of flow regimes/flood control:

A forest is considered to have a high conservation value when it mitigates potential changes to the flood regime that could affect flooding hazards on alluvial fans with human dwellings, private land or public transportation corridors and summer low flows in drought-prone domestic, consumptive and irrigation watersheds. Alluvial fans that have potential flooding hazards were identified using the Alluvial Fans Hazard Map produced by the Ministry of Water, Land and Air Protection (B.C. M.WLAP in-house database, 2003). The Alluvial Fans Hazard Map identifies the general area on a fan that may be affected by a flood event (debris floods or debris flows). In addition, high resolution Google Earth images were reviewed in densely populated areas to more accurately identify the potential flooding risk to HCVs located on an alluvial fan.

Forests that did not meet the criteria of HCV3.3 for flooding included:

1. Forests in watersheds that have an annual peak discharge dominated by snow melt from alpine (non-forest) areas, and

2. Forests in very large watersheds (larger than about 100 km^2).

In alpine dominated watersheds, where the alpine/subalpine area accounts for at least 30 percent of the drainage area, there is a low likelihood that moderate levels of timber harvesting on lower elevation, forested slopes below the alpine areas will substantially affect peak discharge (Schnorbus and Alila, 2004; Green and Alila, 2012).

To date there are no studies that connect forest harvesting to changes in peak flows in large, mountainous watersheds. As watershed size increases to roughly greater than $100km^2$, the natural variability in peak flow magnitude decreases (Dodov and Foufoula-Georgiou, 2005). This is due to a number of factors including (1) increased effects of desynchronized runoff of rainfall and snowmelt on peak stream flow with increased distribution of aspects and elevations as basin size increases and (2) the larger proportion of subsurface flow in total stream flow.

Watersheds with a high likelihood of changes in low flows are typically small (10’s of square kilometers or smaller) and have no alpine component. These

ASSESSMENT RESULTS

As a result of this re-assessment of HCVF3 in Canfor’s forest license, 79 polygons have been delineated. This represents a decrease of 14 HCVF3 polygons compared to the 93 polygons originally defined for Tembec and Canfor Radium. The decrease in polygons is primarily due to improved air photo imagery that enables better assessment of the presence of private land structures. Despite the improved imagery, The HCVF3 polygons delineated through this reconnaissance-level assessment are general and may include areas with no hazards or potential consequences to downslope or downstream values. Further detailed level assessments and risk analysis are required in each polygon to specifically identify areas that could pose a high risk to an identified value. In addition, polygons boundaries edited or created as part of this re-assessment have been delineated using TRIM contour and shaded 1:20,000 DEM layers within ArcGIS on a NAD 83 UTM 11N projection and subsequently compared against Google Earth imagery. These boundaries may shift when presented on base maps in different projections. For this reason, polygon boundaries should not be considered exact and professional judgment should be used when evaluating whether proposed forest development situated near a boundary falls within an HCVF3 polygon.

Where forests provide more than one ‘basic services of nature in critical situations’ the ‘service’ that has the greatest potential impact to human life and property is identified as the ‘primary service’. For example a Community Watershed that also has an identified flooding hazard will have ‘Flooding’ identified as the Primary Service and ‘Water Quality’ identified as the Secondary Service (e.g., Kimberley Creek and Russell Creek).

The numbering of HCVF 3 polygons is according to the following system;
Canfor’s HCVF numbering standard is a 4 digit number.

i. The first number corresponds to the area
    1. TFL 14 = 1
    2. Invermere TSA = 2
    3. Cranbrook TSA = 3
    4. Kootenay Lake TSA = 4
ii. The second number corresponds to the HCV Category. Since these are all HCV3 polygons this number is 3.
iii. The last 2 numbers correspond to the unique number given each HCVF polygon, within each area/category, starting at 01 and going up to 99.

Table 2. HCVF3 polygons where forests may moderate terrain instability, snow avalanche, sediment and flooding hazards.

HCVF_ NUM	Location	High Conservation Value	Primary_Mngmt	Secondary_ Mngmt	Req. Assess	Management Strategies (see also detailed strategies pgs 26-31)	Comments
1301	Casals Creek	Private Land Dwellings	Flooding		HRA	Undertake field assessment to determine catchment boundary. HRA to assess channel stability, flood hazard to dwelling and assess increased risk of flooding associated with harvesting.	1 POD House is situated on fan of Casal Creek.
1302	Billy Goat Creek	Private Land Dwellings/High-use Watershed	Flooding	Water Quality	HRA	Undertake field assessment to determine catchment boundary. Undertake HRA to assess flood risk to development on fan. Apply BMP's for erosion control (See Appendix 4) on roads and trails	6 POD, 3 consumptive use POD
1303	Thomas Face	Private Land Dwellings	Terrain Stability (Gentle over Steep)		DTSFA, DP	DTSFA required with drainage plan (Appendix 2) to avoid surface water concentration in gentle-over-steep conditions and above unstable or potentially unstable slopes.	
1304	Bobby Burns Lodge	Private Land Dwellings	Snow Avalanche, terrain stability		DTSFA, AA	DTSFA and Avalanche Assessments required to guide forest development. Utilize assessment results in harvest systems/road building practices to minimize snow avalanche and debris flow risks.	Bobby Burns Lodge at toe of slope.
1305	Mad Trapper Springs	High-use watershed	Water Quality	Avalanche	HRA, AA	HRA required to provide recommendations to minimize impacts to water quality/quantity. Apply BMP's for erosion control, manage surface drainage on roads and trails to minimize surface erosion	4 PODS
2301	Brisco Face	Private Land Dwellings, Transportation Corridor	Flooding		HRA	Undertake HRA to assess risk of debris floods to dwellings on private land.	Many dwellings along base of debris flow/flood gullies

HCVF_ NUM	Location	High Conservation Value	Primary_Mngmt	Secondary_ Mngmt	Req. Assess	Management Strategies (see also detailed strategies pgs 26-31)	Comments
		Hwy 95				Utilize harvest/road strategies to avoid increasing the frequency of debris floods and flows– especially in forested catchments.	
2302	Marion Creek	High-use watershed	Water Quality		HRA, DTSFA	Undertake HRA and DTSFA recommendations to avoid increasing risk of debris floods and flows in steep headwater channels. Use BMPs for erosion control on roads and trails.	6 licenses
2303	Goldie Creek	Community Watershed	Water Quality		HRA, DTSFA, DP	HRA is required prior to harvesting to provide guidance for forest development. DTSFA must consider the potential for existing drainage diversions along extensive old skidtrail network. Drainage plans are required where roads are proposed on or above potentially unstable or unstable slopes with old trail networks.	Extensive skid trail network from old logging exists in southern half of watershed.
2304	Windermere Creek	High-use watershed	Water Quality		HRA, RA,	HRA is required prior to logging or road building to provide guidance for forest development. Use BMP's in road and trail construction to minimize surface erosion. Harvest prescriptions need to incorporate riparian management strategies to ensure riparian function is sufficiently maintained.	>40 licenses, No IRA completed
2305	Burnaise Creek	Private Land Dwellings, Transportation Corridor, Hwy 95, rural roads	Flooding		HRA	HRA to assess hydrogeomorphic risk on fan (Highway 95 and dwellings).	No Licensed POD
2306	Shuswap Creek	Private Land Dwellings, high-use watershed, Transportation Corridor	Flooding	Water Quality	HRA, RA	HRA to assess hydrogeomorphic risk on fan (Highway 95 and dwellings). Harvest prescriptions need to	9 licenses, No terrain Mapping

HCVF_ NUM	Location	High Conservation Value	Primary_Mngmt	Secondary_ Mngmt	Req. Assess	Management Strategies (see also detailed strategies pgs 26-31)	Comments
		Hwy 95				incorporate riparian management strategies to ensure riparian function is sufficiently maintained along mainstem. BMPs for roads and trails to manage for surface erosion.	
2307	Stoddart Creek	Private Land Dwellings, high-use watershed, Transportation Corridor Hwy 95	Flooding	Water Quality	HRA, DTSFA	HRA to assess hydrogeomorphic risk on fan (Highway 95 and dwellings). DTSFA are necessary for all proposed roads and blocks on or above potentially unstable and unstable slopes.	30 licenses, no terrain mapping
2308	Macaulay Creek	Private Land Dwellings, high-use watershed, Transportation Corridor, Hwy 95	Flooding	Water Quality	HRA, DTSFA,	HRA to assess hydrogeomorphic risk on fan (Highway 95 and dwellings). DTSFA are necessary for all proposed roads and blocks on or above potentially unstable and unstable slopes.	20+ licenses for consumptive use, irrigation and power generation
2309	Luxor Creek	Community Watershed, Private Land Dwellings, Fish Spawning	Flooding	Water Quality, Fisheries	DTSFA, HRA, RA	Use BMPs to minimize surface erosion on roads and trails. HRA and RA required to provide strategies to maintain channel stability through lower reaches. DTSFA's required on all proposed roads and blocks on or above potentially unstable and unstable slopes	Steep side slopes, soil erosion, IRA not completed.
2310	Fraling Creek	Private Land Dwellings, high-use watershed, Transportation Corridor hwy 95,Rail line	Flooding	Water Quality	HRA, DTSFA	HRA required prior to proposing harvesting to document hydrogeomorphic condition, provide strategies to maintain channel stability through lower reaches and assess debris flood risk on fan (Highway 95 and dwellings). BMPs for erosion control on roads and trails	12 licenses for consumptive use and irrigation. Debris flood reached lower fan-Rail line

HCVF_ NUM	Location	High Conservation Value	Primary_Mngmt	Secondary_ Mngmt	Req. Assess	Management Strategies (see also detailed strategies pgs 26-31)	Comments
2311	Spillamcheen face, McIntosh Spring	Private Land Dwellings	Flooding	Water Quality	DTSFA, HRA,	HRA to assess hydrogeomorphic risk on fan and determine strategies to maintain channel stability through lower reaches. DTSFA required on roads and blocks situated on or above potentially unstable/unstable terrain. BMPs for surface erosion on roads and trails.	McIntosh Spring
2312	Beard Creek	High-use watershed	Water Quality		HRA	Steep watershed with frequent avalanches and debris flows in headwaters. Use BMPs for erosion control. Undertake HRA to provide guidance for forest development and identify where DTSFA's are required.	4+ POD
2313	Hogranch and Paddy Creek	High-use watershed	Water Quality		HRA	Use BMP for erosion control. Undertake HRA to identify processes of sediment delivery and provide guidance for minimizing water quality/quantity and timing of flow impacts.	> 6 POD
2314	Witness Creek	Private Land Dwellings	Flooding		HRA	HRA to assess for the potential for increasing risk of flooding and debris flows on fan due to harvesting and road building	Domestic Watershed
2315	Yearling Creek	Private Land Dwellings	Flooding	Water Quality	HRA	HRA to assess for the potential for increasing risk of flooding and debris flows on fan due to harvesting and road building	3 POD's
2316	Palliser/Albert River	Spawning Habitat	Water quality -Riparian function		RA		
2317	Face north of Canal Flats	Private Land Dwellings	Terrain Stability		DTSFA	Manage surface runoff on roads and trails	

HCVF_ NUM	Location	High Conservation Value	Primary_Mngmt	Secondary_ Mngmt	Req. Assess	Management Strategies (see also detailed strategies pgs 26-31)	Comments
2318	Lussier River	Spawning Habitat Kokanee	Water quality -Riparian function		IRA	Establish adequate riparian buffers along channel to allow lateral migration over active floodplain.	Information in the IRA provides Management strategy guidance for riparian reserves and Management zones around streams.
2319	Middle White River	Spawning Habitat	Water quality -Riparian function		RA	Undertake RA to provide guidance for harvesting to avoid impacting riparian function.	IRA not completed.
2320	Findlay Creek	Spawning Habitat Kokanee	Water quality -Riparian function		IRA	Undertake RA to provide guidance for harvesting to avoid impacting riparian function.	No IRA done for Lower Findlay RAU
2321	Sandown Creek	Spawning Habitat Cutthroat, Bull trout	Flood regime for Fisheries		IRA, HRA	Locate cutblocks to minimize hydrological impacts. Last HRA completed in 2007. Update to HRA required prior to additional harvesting. See recommendations in IRA (Central Purcell) for riparian management.	Flood regime and riparian values for fisheries
2322	Skookumchuck Creek	High-use watershed	Water Quality		DTSFA	Gentle over steep conditions exist along lower reaches. DTSFA required for roads and trails situated on or above the unstable and potentially unstable slopes along Skookumchuck. DTSFA to determine if drainage plans are required	2 Domestic, 1 industrial, 1 irrigation license
3301	Face NW side of Hwy 3. Between Irishman and Moyie Lake and along west side of Moyie Lake.	Private Land Dwellings/Transportation Corridor Hwy 3, Rail line	Flooding / Terrain Stability (df)		DTSFA, HRA	Limit harvesting in upper elevations (above H60) follow recommendations of HRA (completed in 2012). Undertake DTSFA's on proposed roads and trails and propose blocks. DTSFA's should provide prescriptions to manage harvesting related increases in slope runoff and identify where	Avalanche chutes/debris flows/ floods to Hwy 3

HCVF_ NUM	Location	High Conservation Value	Primary_Mngmt	Secondary_ Mngmt	Req. Assess	Management Strategies (see also detailed strategies pgs 26-31)	Comments
						drainage plans are required.	
3302	Face units from south of Barkshanty to south of Glencairn Creek	Private Land Dwellings/ Transportation Corridor Hwy 3	Terrain Stability		DTSFA	DTSFAs are required on proposed roads, trails and blocks to manage drainage. Gentle-over-steep conditions exist along here. DTSFA's may identify where Drainage plans are required.	
3303	Glencairn	Private Land Dwellings/ Transportation Corridor Hwy 3 / Community Watershed	Flooding	Water Quality	HRA,	Level of harvest is of concern here due to the high hazard of flooding and debris floods on Glencairn fan. Refer to guidance in existing HRA (2010)	Town of Moyie back-up water supply
3304	Barkshanty	Private Land Dwellings/Transportation Corridor Hwy 3	Flooding	Water Quality	HRA	Level of harvest is of concern here due to the high hazard of flooding on Barkshanty fan. Need to update existing HRA (2002) if additional harvesting is proposed	4+ Pods
3305	Cotton Creek	Private Land Dwellings/ Transportation Corridor Hwy 3	Flooding		HRA	High hazard for increased flooding due to forest harvesting. Will need to update HRA if additional harvest is proposed	4 Pods
3306	Prudhomme Creek	Private Land Dwellings	Flooding		HRA	High risk for increased flooding due to forest harvesting. HRA required	3 Pods
3307	Linklater-Purcell Cr	Private Land Dwellings	Flooding		HRA	High risk for increased flooding due to forest harvesting. HRA required to assess risk to private land, dwellings and roads and provide guidance for level of harvest to minimize risk of increased frequency of flooding.	
3308	Wait Creek	High-use watershed	Water Quality/Quantity		HRA	HRA required prior to proposed development to determine hydrogeomorphic characteristics of watershed. High harvest levels could potentially alter low flows. Does	POD's downstream on private land

HCVF_ NUM	Location	High Conservation Value	Primary_Mngmt	Secondary_ Mngmt	Req. Assess	Management Strategies (see also detailed strategies pgs 26-31)	Comments
						perennial stream exist?	
3309	Wildhorse River	Spawning Habitat Kokanee	Water quality -Riparian function		IRA	Refer to existing IRA for guidance on riparian management strategies.	Kokanee spawning
3310	Lewis face/Lazy Lake	Private Land Dwellings / Spawning habitat	Terrain Stability / Snow	Terrain Stability / Snow	DTSFA, AA	DTSFA's required on proposed roads and blocks. Drainage plans may be required as per DTSFA recommendations to manage surface runoff to avoid concentrating and diverting runoff on roads and trails.	
3311	Lakit	Private Land Dwellings	Terrain Stability (df)	Water Quality	DTSFA, AA	Very active debris flows and snow avalanche area. Use recommendations in DTSFA and AA to guide forest development	4+ Pods Fort Steele
3312	Lewis Creek	High use Rec. Site / Private Land Dwellings	Terrain Stability / Snow	Water Quality	DTSA, HRA, AA	Very active debris flows and snow avalanche area. Use recommendations in DTSFA and AA to guide forest development. HRA to assess for hydrogeomorphic risk on fan and increased risk associated with forest development.	4+ Pods Wasa
3313	Upper Mather Cr	High-use watershed	Water Quality		HRA	Use guidance provided in HRA (2011) and IRA (2010)	Numerous POD`s just downstream.
3314	Kimberley	Private Land Dwellings/ Community Watershed	Flooding	Water Quality	HRA	High risk of flooding in Morrisey subdivision. HRA completed in 2013. Recommendations in HRA include limiting harvest level to avoid increasing frequency of flooding.	Kimberley/Meadowbrook CW
3315	Matthew Creek	Community Watershed	Water Quality	Fisheries	DTSFA, HRA, DP	Watershed assessment updated last in 2005. Needs to be updated using HRA method if more development proposed. Drainage plans exist for roads along Matthew main stem on	Kimberley CW

HCVF_ NUM	Location	High Conservation Value	Primary_Mngmt	Secondary_ Mngmt	Req. Assess	Management Strategies (see also detailed strategies pgs 26-31)	Comments
						both Bootleg and Lowpass sides. Any additional roads must have drainage plans	
3316	Perry Creek	Private Land Dwellings/Spawning Habitat Cutthroat	Flooding	Flood regime for Fisheries	HRA, IRA	Update to HRA (2003) needed if more development proposed. See existing IRA for guidance on riparian buffers.	Cutthroat Wycliffe
3317	Lower St. Mary above Perry	Spawning habitat	Water quality -Riparian function		IRA	See existing IRA for guidance on riparian buffers. BMP for roads and trails to manage for surface erosion	
3318	Denver (St Mary Lake)	Private Land Dwellings / High-use watershed/Transportation Corridor	Terrain Stability, Flooding	Water Quality	DTSFA, HRA,	DTSFA's required on proposed blocks and roads. HRA required to assess for risk of increasing frequency of flooding/debris floods. Use BMP for surface erosion to avoid concentrating and diverting runoff on roads and trails.	9 Pods on Face. 4+ on Denver, fan avulsion hazard
3319	Redding/St. Mary	Spawning Habitat Cutthroat	Water quality -Riparian function		IRA	See existing IRA for guidance on riparian buffers.	Cutthroat spawning
3320	Upper St. Mary	Spawning Habitat Cutthroat	Water quality -Riparian function		IRA	See existing IRA for guidance on riparian buffers.	Cutthroat Spawning
3321	Baker Cr.	Spawning Habitat Bull Trout	Water quality -Riparian function		IRA	See existing IRA for guidance on riparian buffers.	Bull Trout
3322	Flathead Couldrey	Spawning Habitat Bull Trout	Water quality -Riparian function		IRA	See existing IRA for guidance on riparian buffers.	Bull Trout Spawning
3323	Flathead Howell	Spawning Habitat Bull Trout	Water quality -Riparian function		IRA	See existing IRA for guidance on riparian buffers.	Bull Trout Spawning
3324	Upper	Spawning Habitat Bull	Water quality		IRA	See existing IRA for guidance on	Bull Trout Spawning

HCVF_ NUM	Location	High Conservation Value	Primary_Mngmt	Secondary_ Mngmt	Req. Assess	Management Strategies (see also detailed strategies pgs 26-31)	Comments
	Flathead	Trout	-Riparian function			riparian buffers.	
3325	Wigwam/Lodgepole/Lower Elk	Spawning Habitat Bull Trout	Water quality -Riparian function		IRA	See existing IRA for guidance on riparian buffers.	Bull Trout Cutthroat Kokanee
3326	Caithness Creek	Transportation Corridor Hwy 3 / Private Land	Flooding	Water Quality	HRA	Undertake HRA to provide recommendations to limit impacts to water quality/quantity/timing of flows and hydrogeomorphic risk on fan	4+ Pods
3327	Morrisey Cr	Spawning Habitat Cutthroat	Water quality -Riparian function		IRA	See existing IRA for guidance on riparian buffers. Use BMP's to limit surface erosion along roads and trails.	Cutthroat
3328	Cocato/Morrisey Face	Transportation Corridor Cocato Rd. River Rd.	Terrain Stability / Snow		DTSFA, AA	Use guidance from DTSFA and Avalanche assessments to avoid increasing the likelihood of instability	Proposed development
3329	Slopes west of Elk R. between Fernie Resort and Elko including Tunnel Cr.	Transportation Corridor Hwy 3 / Private Land	Terrain Stability / Snow		DTSFA, AA	Use guidance from DTSFA and Avalanche assessments to avoid increasing the likelihood of instability	Avalanche/ debris flow chutes
3330	Coal Creek	Transportation Corridor Cocato Rd. River Rd.	Flooding		HRA	HRA required prior to proposed development to minimize likelihood of development related increases in flood frequency.	Fernie
3331	Hartley/Mutz/ Face between Hartley and Fairy Creek	Transportation Corridor Hwy 3 / Private Land	Terrain Stability / Snow	Water Quality	DTSFA, HRA, AA	Use guidance from DTSFA and Avalanche assessments to avoid increasing the likelihood of instability. Undertake HRA's to provide guidance for forest development to minimize impacts to water quality/quantity and timing of flows. Use BMP's on roads and trails to limit surface erosion.	Many Pods, High density of dwellings

HCVF_ NUM	Location	High Conservation Value	Primary_Mng mt	Secondary_ Mngmt	Req. Assess	Management Strategies (see also detailed strategies pgs 26-31)	Comments
3332	Fernie to Sparwood Sparwood Ridge & Hosmer Ridge	Private Land Dwellings/ Transportation Corridor Hwy 3, Rail Line	Terrain Stability / Snow		DTSA, AA	Use guidance from DTSFA and Avalanche assessments to avoid increasing the likelihood of instability	
3333	Lladnar Face and north to Littlemoor including Hollow Cr.	Private Land Dwellings/ Transportation Corridor Hwy 43	Terrain Stability / Snow	Water quality	DTSFA, HRA, AA	Hydrological assessments completed for Littlemoore and Lladnar Creeks. Will need updating using HRA methodology if more development proposed. Use guidance from DTSFA and Avalanche assessments to avoid increasing the likelihood of instability. Use BMP's on roads and trails to limit surface erosion.	Avalanche Chutes, numerous pods
3334	Fernie to Sparwood Sparwood Ridge & Hosmer Ridge.	Private Land Dwellings/ Transportation Corridor Hwy 3, Rail Line	Terrain Stability / Snow		DTSFA, AA	Use guidance from DTSFA and Avalanche assessments to avoid increasing the likelihood of instability	
3335	Fording Dr. W. side of Hwy.	Private Land Dwellings/ Transportation Corridor Hwy 43	Terrain Stability		DTSFA	Use guidance from DTSFA to avoid increasing the likelihood of instability	Elkford
3336	Face above Fording Mine road	Transportation Corridor Fording Mine Rd	Terrain Stability / Snow		DTSFA, AA	Use guidance from DTSFA and Avalanche assessments to avoid increasing the likelihood of instability	
3337	Ewin/Chaucey	Transportation Corridor Fording Mine Rd	Terrain Stability / Snow		DTSFA, AA	Use guidance from DTSFA and Avalanche assessments to avoid increasing the likelihood of instability	
3338	N. Elk River	Spawning Habitat Cutthroat	Water quality -Riparian function		IRA	See existing IRA for riparian management strategies.	Cutthroat Spawning
3339	Elk R. at Elkford	Spawning habitat Cutthroat	Water quality -Riparian		IRA	See existing IRA for riparian management strategies.	Cutthroat Spawning

HCVF_ NUM	Location	High Conservation Value	Primary_Mngmt	Secondary_ Mngmt	Req. Assess	Management Strategies (see also detailed strategies pgs 26-31)	Comments
			function				
4301	Thompson Creek	High-use watershed / Transportation Corridor Hwy 3	Flooding	Water Quality	HRA, DTSFA	HRA required prior to development to assess for flood risk associated with harvesting and provide guidance for level of harvest. DTSFAs required on proposed roads and blocks situated on or above potentially unstable and unstable terrain.	Creston
4302	Russell Creek	Community Watershed / Transportation Corridor Hwy 3	Flooding	Water Quality	HRA, DTSFA	Existing HRA will need to be updated if additional harvesting proposed. DTSFAs required on proposed roads and blocks situated on or above potentially unstable and unstable terrain. DTSFA will need to identify if drainage plans are required.	Kitchener Community watershed. Past slides in watershed due to poor drainage control on roads and increased runoff from harvesting.
4303	Face between Russell & Thompson	Private Land Dwellings/ Transportation Corridor Hwy 3	Terrain Stability		DTSFA	Use guidance from DTSFA to avoid increasing the likelihood of instability	1 Pod on Map. No Name.
4304	Kidd Creek	Private Land Dwellings	Flooding		HRA	HRA to assess for hydrogeomorphic risk on fan.	
4305	Hazel/Jensen/ Kristina/Kitchener Creeks	Private Land Dwellings/ Transportation Corridor Hwy 3	Flooding / Terrain Stability (df)		DTSFA, HRA	DTSFA's required for roads and blocks situated on or above potentially unstable or unstable terrain. HRA to provide guidance to limit increases in frequency of flooding/debris floods.	2 Pods Hazel Past road-related slides
4306	Kitchener Face	Private Land Dwellings/ Transportation Corridor Hwy 3	Terrain Stability (df)		DTSFA	DTSFA's required for roads and blocks situated on or above potentially unstable or unstable terrain.	
4307	Little Moyie River	Private Land Dwellings	Flooding		HRA	Harvesting poses increased risk of flooding to development on fan. See guidance in HRA completed in 2007. Update HRA if new development proposed.	2 Pods

HCVF_ NUM	Location	High Conservation Value	Primary_Mng mt	Secondary_ Mngmt	Req. Assess	Management Strategies (see also detailed strategies pgs 26-31)	Comments
4308	Glenlily	Private Land Dwellings	Terrain Stability		DTSFA, HRA	These assessments may have been completed by Sitkum Consulting	1 Pod registered. 2 Pods on map.
4309	Kingsgate West	Transportation Corridor Rail Line	Terrain Stability		DTSFA	DTSFA's required for roads and blocks situated on or above potentially unstable and unstable terrain.	
4310	Christopher/ Ryan Face	Private Land Dwellings / Transportation Corridor Hwy 3	Terrain Stability		DTSFA	History of landslides caused by drainage diversions. Use guidance from DTSFA and to avoid increasing the likelihood of instability. Drainage plans may be necessary as per DTSFA's on proposed roads	Yahk
4311	Englishman Creek	Transportation Corridor Rail Line	Flooding		HRA	Channel still stabilizing following high levels of harvesting and riparian disturbance from early 1900's. See guidance for forest management provided in HRA completed in 2012.	Bull Trout Spawning
4312	Hawkins Creek	High-use Watershed	Flooding	Water Quality	DTSFA, HRA	HRA completed in 2005. Requires updating. Level of harvest a concern in Cold Creek.	Residential area of Yahk is located on the fan of Hawkins Creek which is subject to flood hazards. 7 PODs Watershed Overview Assessment Completed, terrain stabililty concerns on north side of creek above intake.
4313	Irishman/ Colleen	Spawning Habitat	Water quality -Riparian function		IRA	See guidance for riparian provided in IRA	Bull Trout Spawning

Assessment codes (See Management Strategies and Appendices for more information regarding these assessments):

AA	Avalanche Asssessment	DTSFA	Detailed Terrain Stability Field Assessment
HRA	Hydrogeomorphic risk assessment	IRA	Integrated Riparian Assessment –existing assessment conducted for Tembec
RA	Riparian Assessment	DP	Drainage plan

MANAGEMENT STRATEGIES:

High conservation values, and associated primary and secondary (if applicable) 'services of nature' (i.e. erosion control, protection of water quality and moderating flood hazards) provided by the forest are identified for each HCV3 polygon in Table 2. Management strategies recommended in Table 2 to ensure the protection and maintenance of these critical 'services of nature' are consistent with or exceed Provincial guidelines.

HCV 3.1.Forests Critical to Erosion Control (Landslides, sediment production, snow avalanches)

Studies by Nelson Forest Region research staff (Jordan, 2002) have determined that most landslides and erosion related to forest development in the Nelson Forest Region are the result of water diversion and concentration along roads, trails, and ditchlines. Landslides occur when concentrated runoff is discharged above or onto potentially unstable or unstable terrain. In streams with high value spawning habitat, sedimentation can also occur as a result of inadequate riparian buffers that do not account for lateral channel migration on active floodplains.

The recommended management strategies in HCVF3s to limit landslides, sedimentation and snow avalanche hazards associated with forestry activities include;

- Careful development and annual maintenance of surface drainage management systems. As a minimum, undertake detailed terrain stability field assessments (DTSFA) (APEGBC, 2003) and drainage plans (Green and Halleran, 2002, Appendix 2) for proposed roads and bladed trails situated on Gentle-over-Steep terrain (See Appendix 3 for definition of GoS) or on or above potentially unstable or unstable terrain.

- Snow avalanche risk assessments (LMH 55, Weir, 2002) must be completed on proposed block situated on terrain assessed as having a potential snow avalanche initiation hazard and a high like likelihood of impacting down slope development. Where proposed development is situated adjacent to existing avalanche paths harvest prescriptions must include measures to minimize the potential for avalanche paths to expand laterally.

- For areas with high value spawning habitat, in addition to following BMPs for minimizing soil erosion on forest roads (See Appendix 4), proposed forest development must incorporate riparian management strategies contained in existing Integrated Riparian Assessment (IRA) reports completed for Tembec in 2007-2009 (Green et al., 2009). Where these studies have not been done, proposed development must incorporate either;
    - Recommendations from site specific Riparian Assessments conducted by Qualified Registered Professionals (i.e. RPF, PGeo, RPBio, registered to practice in B.C.) that document measures to protect spatial and temporal attributes of riparian function that contribute to maintenance of channel morphology (i.e. LWD and sediment inputs), aquatic habitat (i.e. LWD, stream temperature), and terrestrial habitat (i.e. wildlife corridors, nesting tree and shrubs, ungulate habitat, etc.), or,
    - Guidance provided in Appendix B of the FSC-BC (2005) standards for riparian retention around streams, lakes and wetlands.

HCV3.2 Forests Critical to Water Supplies (water quality, quantity, timing of flow)

In the mountainous East Kootenay region of BC stream flow (i.e. total water yield and timing of flow) is dominated by spring snowmelt. Risks to water supplies from forestry activities include impacts to water quality from road-related landslides and changes to the timing and magnitude of peak flows.

Risks to water quality associated with development related landslides are influenced by basin scale. In larger watersheds (i.e., > 100km^2), although landslide-related stream sedimentation can affect water quality (suspended sediment, turbidity) for several days, it generally does not constitute “serious cumulative or catastrophic impacts” to the water supply. In smaller watersheds (i.e., <10 km^2) a similar sized landslide can result in highly turbid water for upwards of three years or more until the deposit becomes stabilized and vegetated.

Longer-term cumulative impacts to water supplies from forestry harvesting include changes to water quality and quantity associated with changes to the flood regime. Increased risks to water quality associated with moderate to high levels of forest harvesting are due to the increased frequency of floods capable of transporting sediment. Recent studies indicate that the frequency of bankfull floods capable of mobilizing sediment are increased by over 50% in non-alpine dominated watersheds[2] following moderate levels of harvest (i.e. >30%) (Green and Alila, 2012), which can result in sustained increases in sediment yield and turbidity (Green et al., 2013). In addition, moderate levels of harvest (i.e. > 30%) in small (i.e. 5 km^2), forested watersheds have been found to shift the timing of runoff resulting in increases in water yield early in the snowmelt period and subsequent decreases in water yield through the mid and late summer months (Winkler, 2014). This change in the timing and volume of runoff can have long-term detrimental impacts to surface water availability for domestic and agriculture supplies in the late summer months when it is most needed.

Changes to both the frequency of floods and the timing of runoff associated with moderate levels of forest harvesting can last for many decades until forest stands are hydrologically recovered.

Forestry-related sedimentation can be minimized by employing measures to maintain (1) surface water drainage patterns on and above unstable and potentially unstable terrain and (2) riparian function along active floodplains. The recommended management strategies in HCVF3s to limit hazards to water quality, quantity and timing of flows associated with forestry activities include;

- Employ best management practices (BMPs) for road and trail construction (see Appendix 4),
- Undertake Hydrogeomorphic Risk Assessment (HRA) following the methodology described in BCFLNR Land Management Handbook 61(Wilford et al, 2009) completed by QRP's (Registered professionals in B.C qualified to assess geomorphic and hydrological processes of stream channels and watersheds) that assess the increase in risk of impacts to channel stability, water quality and quantity and timing of flows at the intakes associated with existing and proposed

[2] Forested watersheds with minimal alpine area (i.e. <20% alpine area).

development and provide recommendations to minimize forestry related impacts to water quality and the frequency, magnitude and timing of peak flows and lowflows. Appendix 5 includes minimum requirements for an HRA in HCVF3 polygons.

- Recommended activities to reduce hydrological impacts in HCVF3 watersheds could include;
  - limiting the ECA's to less than 30% and distributing cut blocks across different elevations and aspects,
  - Deactivating roads and trails immediately after logging and/or silviculture activities to reduce the rapid delivery of runoff to stream channels.
  - Applying partial cut treatments in mixed species stands where retained mature and understory stems maintain a significant (>50% of pre-harvest) shade cover for the snowpack.

- Detailed Terrain Stability Field Assessments (DTSFA's) with drainage plans on proposed roads, bladed trails and blocks situated on or above potentially unstable or unstable terrain (i.e. 'P', 'U', or Class 'IV' or 'V') and for those roads and trails situated on GoS terrain (See also BMP's for erosion control in Appendix 4).

HCV3.3 Forests required for the maintenance of flow regimes - flooding/debris flow hazards on fans

Recent studies of the effects of forest development in mountainous watersheds of southern BC using hydrological modeling have begun to shed light on the influence of watershed physiography on stream flow response. These studies have determined that similar levels of forest development in physiographically different watersheds results in substantially different stream flow responses (Green and Alila, 2012; Schnorbus and Alila, 2013). The magnitude of streamflow response appears to relate primarily to the effect of harvesting on synchronization/desynchronization of runoff. Where harvesting increases the desynchronization of runoff changes in the frequency and magnitude of floods is minimized while increases in the synchronization of runoff increases changes in the peak flow regime (Figure 1).

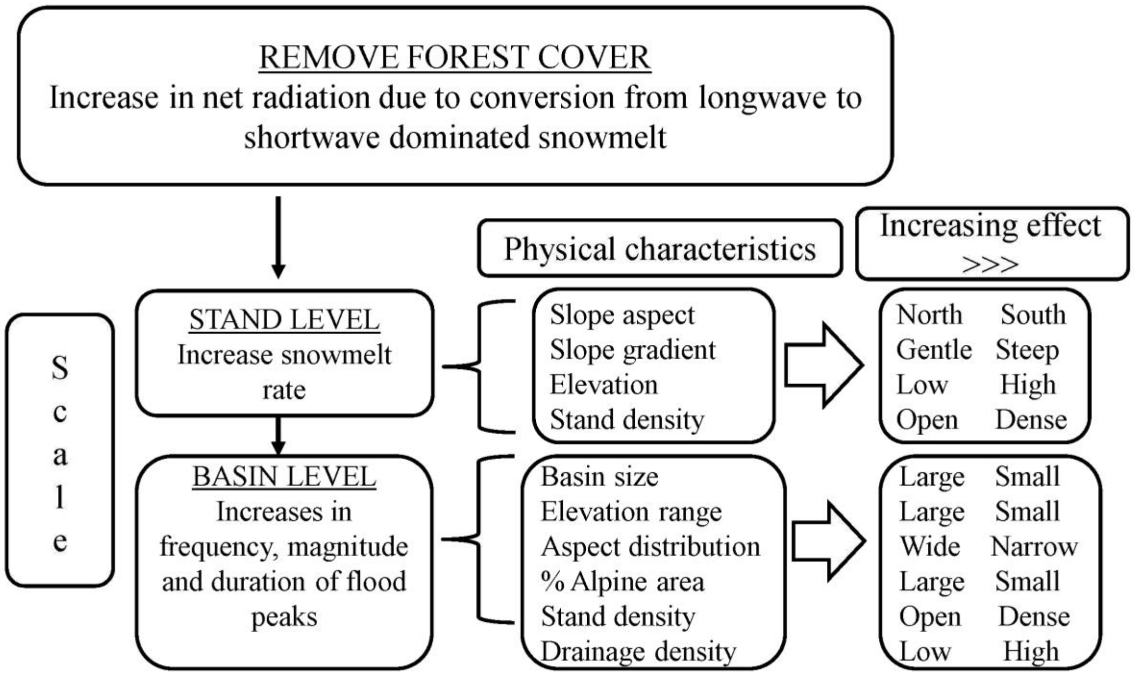

Figure 1. Conceptual model of the influence of basin physiography on flow regime response to harvesting (modified from Green and Alila, 2012).

The conceptual model of watershed response presented in Figure 1 is based on the findings of a meta-analysis investigation that compared the effects of similar levels of harvesting in four physiographically different snowmelt watersheds. The outcomes of this study found that in moderate sized (i.e., 20 km^2) steep, alpine-dominated watersheds (>30% alpine area) harvesting the lower-elevation forested slopes has less influence on flood magnitude/frequency than similar harvest levels in fully forested watersheds of comparable size. Watershed size, the amount of alpine area and the aspect and elevation range of slopes all play a role in determining the extent of change to the flow regime. Of the four watersheds investigated, the greatest change in frequency and magnitude of floods occurred in a fully forested watershed with limited slope aspect distribution. In this case the frequency of large, potentially damaging floods (i.e. 20 year to 50 year return period floods) increased by up to 3 times following harvesting (Green and Alila, 2012).

The alteration of the flood regime associated with moderate levels of harvesting caused 50 year return period floods to increase in frequency to become 20 to 30 year return period floods and 20 year floods to become 8 to 10 year return period floods (Green and Alila, 2012).

The recommended management strategies in HCVFs to minimize changes in the risk of flooding hazards on fans associated with forestry activities relies on guidance from QRP's regarding the location and level of harvest for individual watersheds.

- Hydrological risk analyses (HRA), following the methods of LMH 61 (Wilford et al., 2009) to assess the level of risk associated with proposed harvesting and recommend harvesting strategies to minimize increases in flooding hazards. The HRA should specifically provide guidance with respect to the distribution of cut blocks within a catchment to minimize synchronization of runoff in a basin (See also Appendix 5).
    - As discussed in above, harvesting strategies recommended to minimize increases in flooding hazards may include limiting harvest levels to 30% or less, distributing cutblocks over different elevations and aspects, using partial cut systems in mixed stands that retain species that provide shade to the snowpack and retains viable understory stems, and utilizing temporary road and skid trail systems that can be deactivated following logging and silviculture activities.

LIMITATIONS:

The HCV3 polygons delineated through this reconnaissance-level assessment are general and may include areas with no hazards or potential consequences to downslope or downstream values. Further detailed level assessments (i.e., DTSFA's or HRA's) are required in each polygon to specifically identify areas that could pose a high risk to an identified value. In addition, polygons boundaries edited or created as part of this re-assessment have been delineated using TRIM contour and shaded 1:20,000 DEM layers within ArcGIS on a NAD 83 UTM 11N projection and subsequently compared against Google Earth imagery. These boundaries may shift when presented on base maps in

different projections. For this reason, polygon boundaries should not be considered exact and professional judgment should be used when evaluating whether proposed forest development situated near a boundary falls within an HCVF3 polygon.
Information regarding the location of High Conservation Values collected from British Columbia Provincial GIS databases and Canfor's GIS databases (e.g., PODs, community watersheds, road information, private land boundaries) is assumed to be correct and up to date at the time of this assessment.

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APPENDIX 1 – DESIGNATION OF STREAM ORDER

Stream order is a surrogate measure of stream size. Watersheds are made up of networks of tributaries, each of which flows into a larger stream. Tributaries are identified by stream order, determined by the order of other tributaries that have contributed to their flow. The start or headwaters of a stream, with no other streams flowing into it, is called the first-order stream. Two first-order streams flow together to form a second-order stream. Second-order streams flow into a third-order stream. In general in the Kootenay – Columbia region, 4th and 5th order streams correspond to S2 and S1 stream classifications respectively.

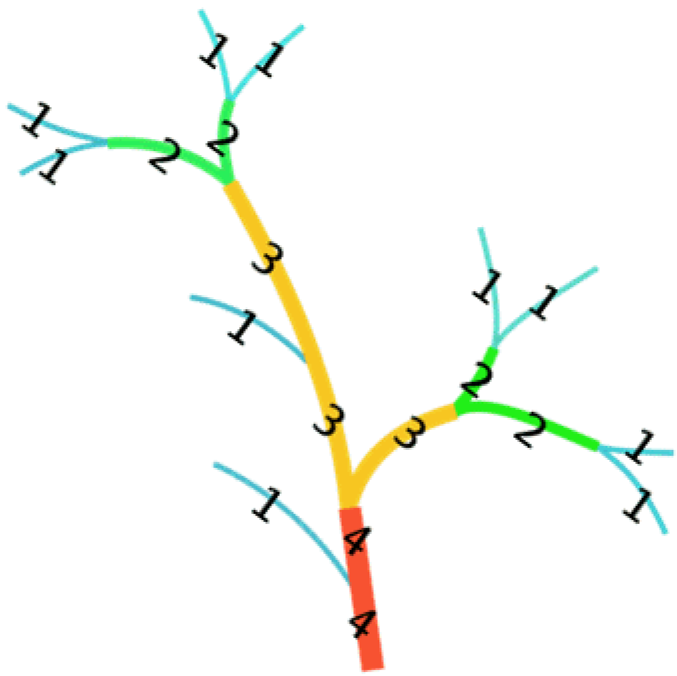

Figure 2. Example of stream order designation.

APPENDIX 2. DRAINAGE PLANS: A COMPREHENSIVE PLANNING TOOL IN HIGH RISK TERRAIN

(by Green and Halleran, 2002)

Downloaded from: www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr003/Green.pdf

Note: The methodology noted in this document is based on 1990's technology. The use of high resolution DEM (e.g. 5m or better or Lidar) to define catchment boundaries is now a viable option instead of the use of air photographs but field verification of boundaries is still necessary.

ABSTRACT

Drainage plans can be a powerful tool in the proactive management of terrain instability events. The methodology used to undertake drainage plans is currently non-standardized, which results in products being submitted that vary greatly in quality and cost. To achieve some standardized approach, resource managers and the professionals who conduct the plans must agree on their objectives, components, application, and implementation. The drainage plans are used to delineate drainage patterns over a hillslope, including the location of drainage divides and watercourses (perennial and ephemeral). In addition, drainage plans are used to locate culverts or cross-ditches along high-risk road segments that will maintain or re-establish natural drainage patterns. It is suggested that a risk analysis approach (where Risk = Hazard × Consequence) be used by resource managers to determine where drainage plans are appropriate. Drainage plans should be considered where there is a high or very high risk (moderate or high-hazard and a high consequence) of a slide occurring on or below the area where development or deactivation is proposed. To accurately locate watercourses and drainage divides, a three-step methodology is suggested, which includes a preliminary air photograph review, detailed fieldwork, and accurate presentation of the information for easy incorporation into operational plans. As a minimum, the drainage plan deliverables should include watercourse and divide line work transferred onto an accurate topographic base map and flagged in the field. Experience indicates that incorporating information from a drainage plan into operational plans is the most difficult aspect of all. If drainage plans are to be successfully used as a tool for minimizing development- or deactivation-related slides in high-risk areas, all levels of management—from planners to operations supervisors to hoe operators—must be made aware of where and why the plans are being undertaken.

INTRODUCTION

Comprehensive study of landslides and their causes is ongoing in the Nelson Forest Region, located in southeastern British Columbia. Preliminary findings indicate that most development-related landslides (at least 33% and possibly as high as 69%; Table 1) in British Columbia's southern Interior occur as a result of drainage diversion and concentration along resource roads (Jordan 2001).

TABLE 1 *Landslide study data, Nelson Forest Region (Jordan 2001)*

Total number of landslides:	582
natural	135
development-related	447
Distribution by apparent cause:	
road fill[a]	36%
drainage diversion, road	25%
drainage diversion, skid trails	8%
road cut	2%
clearcut	2%
other	4%
natural	23%

a Many caused by water diversion flowing over and saturating fillslope.

In British Columbia, the Forest Practices Code regulations require road designs and prescriptions to maintain slope stability when roads are proposed on potentially unstable or unstable terrain. Drainage structures are prescribed as part of the road design to maintain natural drainage patterns along a proposed road right-of-way.

Although most road surveys locate drainage structures for permanent watercourses, the location of short-duration (ephemeral) watercourses, which often have no obvious channel (also referred to as non-classified drainages or NCDs), are commonly missed during road surveys that are undertaken after the freshet. Drainage divides that form the natural topographic separation between these small sub-basins may also be ignored. As a result, intercepted ditch water often flows across subtle drainage divides before being discharged from the road prism.

The location of ephemeral watercourses and the location of drainage divides are two pieces of information that are essential for reducing the number of resource road–related landslides in the southern Interior. These two pieces of information are also critical for maintaining slope stability where roads are proposed above potentially unstable or unstable terrain.

Drainage plans that identify the location of watercourses and divides can be an effective tool in pre-emptive management of terrain instability events related to resource road construction or deactivation. This paper introduces the concept of drainage plans, presents methods and deliverables that have been used by the authors over the past 3 years, and discusses difficulties that have been encountered in the application and incorporation of drainage plan information into operational plans and activities.

DRAINAGE PLAN OBJECTIVES

A drainage plan is a map that delineates surface drainage features, including watercourses and divides over a hillslope. The primary objectives of a drainage plan are:

- to identify drainage features over a slope; and
- to locate drainage structures to minimize drainage diversion and concentration and reduce the occurrence of slides caused by drainage diversion and concentration.

Secondary objectives can include:

- locating drainage structures to avoid saturating areas were there is existing downslope instability; and
- delineating areas for hydrological risk assessment of proposed forest development activities.

Roads and trails constructed with cutslopes less than 0.5 m can intercept surface and subsurface flows. A road that traverses a slope at a constant grade cuts through gentle topographic swales and ridges that originally functioned to maintain disperse surface and subsurface flows. The identification of these subtle features allows for placement of drainage structures that reduce the opportunity for water carried in the ditch line to be diverted across divides. In addition, identification of ephemeral surface flows and the corresponding divides (micro-drainages) on the face of slopes allows for a more precise assessment of level of harvest within these micro-drainage basins where downslope terrain stability is a concern. Identification of these micro-drainages also allows drainage structures to be placed so that culvert discharge can be avoided or minimized on slopes where downslope terrain instability is identified.

INFORMATION REQUIREMENTS

The information required to complete a drainage plan includes an understanding of the nature of drainage over the hillslope, the location of permanent and seasonal watercourses, the location of drainage divides, and the location of existing drainage diversions.

Nature of Slope Drainage

Hillslope drainage patterns are dependent on cross-slope and longitudinal slope profiles, soil depth (i.e., depth to restricting layer), relic glacial landforms, and bedrock structure.

Slope Profile Slope profile generally plays the most significant role in controlling the overall drainage pattern (Figure 1). Convex slopes can have complex drainage patterns, including divergent drainage patterns that occur when small unconfined streams pool behind and split around obstructions such as bedrock knolls or overturned root wads. Drainage divides on convex slopes are subtle and often discontinuous. Convergent drainage patterns occur on concave slopes where ephemeral streams converge downslope, becoming larger and more entrenched. Drainage divides on convex slopes generally converge downslope and become more defined.

Soil Depth Groundwater and interflow in unsaturated soil (vadose zone) can play a significant role in slope drainage patterns in areas with shallow soils or restricting layers. These conditions often exist on convex slopes where the processes of glaciation have scraped the noses of the upper convex slopes bare of soil. Seeps and springs can develop where subsurface and groundwater flow is concentrated through shallow soils (Figure 2).

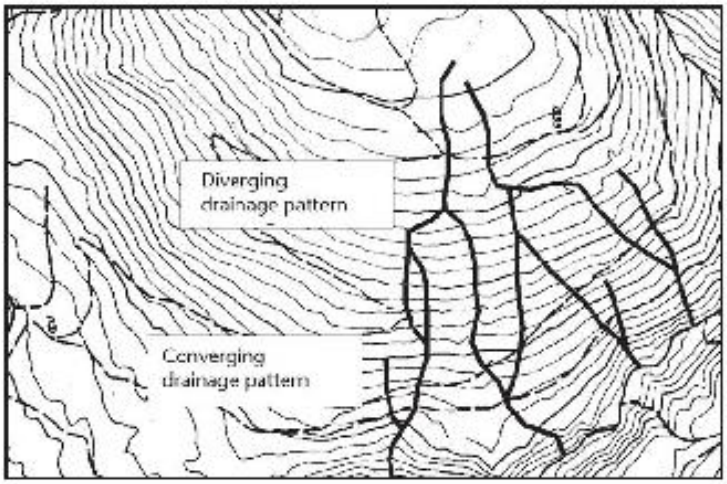

FIGURE 1 *Simplified representation of drainage patterns on convex and concave slopes.*

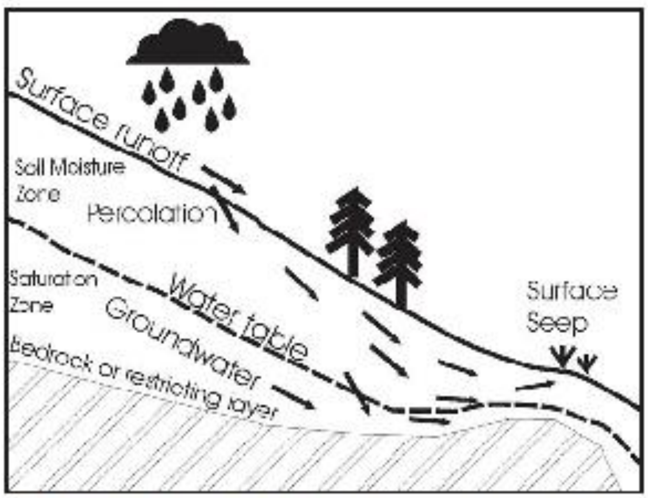

FIGURE 2 *Subsurface and groundwater flow can account for a significant proportion of slope drainage in some areas. Seeps develop where subsurface water is brought to surface.*

Glacial Landforms About 11 000–20 000 years ago, massive valley glaciers and ice sheets covered most of the lowland areas and occupied all of the large British Columbia Interior valleys. During deglaciation, rivers and streams flowed on top of and along the margins of the melting glaciers and from the toes of the glaciers. Sediment scoured from beneath the glacial ice was deposited over the landscape as the ice downwasted. A ridged and hummocky topography formed by the glacial sediments is often exposed at the mid-elevations along the main Interior valleys and on the valley sides and interfluves of larger tributary valleys. In some locations, these ridges and hummocks control surface drainage patterns (Figure 3).

FIGURE 3 *Relic glacial topography controlling surface drainage patterns.*

Bedrock Structure Faulted, jointed, and foliated metamorphic and sedimentary rocks and, to a lesser extent, intrusive rocks underlie much of the landscape throughout the southern Interior of British Columbia. Where soil is shallow and bedrock is exposed or close to the surface, joints and fractures in the rock can control surface and subsurface drainage patterns (Figure 4). Locating permanent and ephemeral streams and the divides that separate them is essential to maintaining natural drainage patterns over a hillslope. Permanent watercourses are usually identifiable on air photos and on the ground. However, the locations of permanent watercourses on digital base maps are often incorrect and need adjusting.

FIGURE 4 *Rectangular jointing in weakly foliated metamorphic rocks in the Castlegar area.*

FIGURE 5 *Ephemeral stream flowing over the forest floor.*

Location of Ephemeral and Permanent Watercourses and Divides

The location of ephemeral or seasonal streams may be identifiable on air photos but many are difficult to identify on the ground due to the lack of defined channels. In many cases, ephemeral streams flow over the forest floor (Figure 5), leaving little evidence of a channel once the flows cease.

Location of Existing Drainage Diversions

If natural drainage patterns have been previously disrupted by old roads and trails, additional road or trail construction can compound existing drainage diversion and concentration (Figure 6). Where there has been a significant amount of past road or trail development on a hillslope, it may be necessary to start at the top of a drainage basin and work downwards to identify the extent of existing diversions.

SUGGESTED METHOD AND OUTPUTS

Three steps are suggested to complete a drainage plan. The first step is to delineate all obvious watercourses and divides on recent 1:20 000 (or larger) air photos. Where significant development has occurred, older air photos can be used to help identify original drainage patterns.

The second step is to conduct fieldwork to verify and/or correct watercourse and divide locations on air photos and identify on the ground (at least along the proposed road right-of-way) with tags, paint, or flags. Fieldwork should be done during the spring freshet to aid in identifying the location of ephemeral watercourses.

The third step is to transfer information from the air photos onto accurate topographic base maps. The transferring can be done by hand or through stereo transfer methods.

Outputs

The outputs for a drainage plan project vary depending on the scope of the project. The basic product is a topographic map that identifies the location of watercourses, divides, and existing diversions (Figure 7).

Where a road is proposed, the location of any additional drainage struc-

FIGURE 6 *The location and extent of existing drainage diversions must be determined before new road construction occurs downslope to avoid compounding problems (existing road – pink; proposed road – yellow; drainage divides – red)*

tures required to maintain natural drainage patterns should also be presented on the topographic base map. Where plans and profiles exist, the locations of additional drainage structures should be presented directly on the plans and profiles.

Outputs for a drainage plan can also include a hydrological assessment of proposed harvesting and road construction activities for small face unit drainages adjacent to high-value streams.

Where drainage plans are conducted in conjunction with road deactivation activities, divide and watercourse information should be included on deactivation maps.

INCORPORATING DRAINAGE PLANS INTO OPERATIONS

Two main challenges have been encountered by the authors and resource managers who have undertaken drainage plans:

1. initial incorporation of the drainage plan information into operations; and
2. retaining the information through maintenance, reconstruction, and deactivation activities.

The initial incorporation of drainage plan data into operations has proven difficult in a number of road projects where plans and profiles (RPS) have

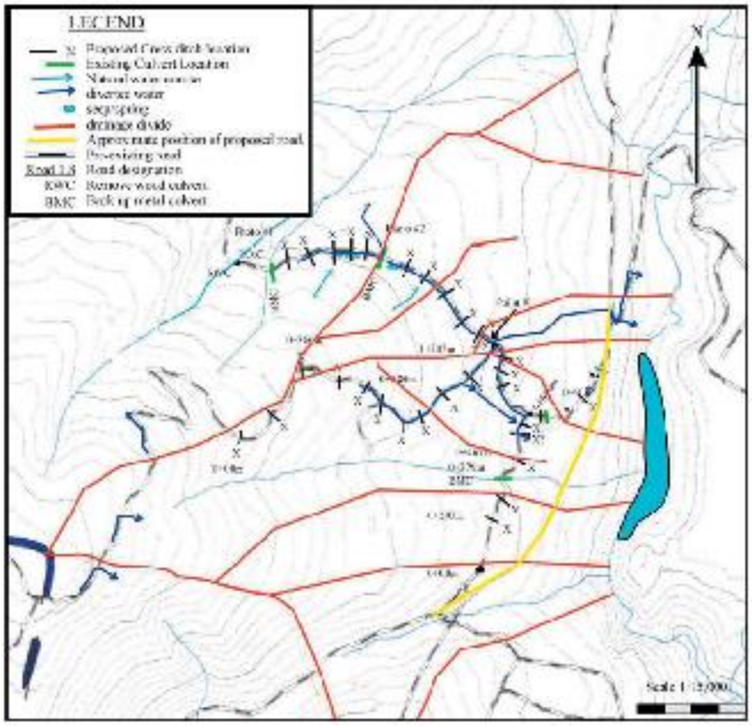

FIGURE 7 *Example of drainage plan map.*

been produced independently of drainage plans. Confusion due to overlapping prescriptions occurs where operations managers and equipment operators are trying to work with the information from two separate plans and field markers.

The most difficult challenge over the long term has been in retaining the information from drainage plans through maintenance, reconstruction, and deactivation activities. This is primarily due to the lack of a formal process for archiving and retaining information from drainage plans—particularly if the drainage plan has been produced as a stand-alone product.

Some suggestions to address these challenges include:

1. developing company protocols for dealing with drainage plans;
2. placing signs along road segments where water diversions pose a risk to downslope resources. Signs also provide a non-verbal means to communicate the existence of a drainage plan in multiple user group situations; and
3. incorporating drainage plans into Ministry of Forests road design and road deactivation requirements.

RECOMMENDED APPLICATIONS OF DRAINAGE PLANS

A simple risk analysis approach (where Risk = Hazard × Consequence) is suggested for identifying, at a reconnaissance level, areas where drainage plans should be undertaken (Table 2). Drainage plans are recommended

TABLE 2 *Risk determination matrix (Moore 1994)*

	Hazard		
Consequence	**Low**	**Moderate**	**High**
Low	Low	Low	Moderate
Moderate	Low	Moderate	High
High	Moderate	High	Very High

where development or deactivation activities are proposed *on or above* areas with moderate or high likelihood of a slide (i.e., Class IV or V, or "P" or "U" terrain) that are situated above areas where the consequence of a slide occurring would be moderate to high (e.g., settlement or transportation corridors, community watershed intakes, high-value fisheries streams).

Drainage plans are also useful in identifying and maintaining slope drainage in "gentle-over-steep" terrain, which has been identified in the southern Interior landslide study as accounting for a significant number of slide events, as indicated by the following quote from Jordan (2001).

> An important category of landslides occurs some distance below roads, below a culvert or a point of accidental drainage discharge. In many of these cases, the road itself is on gently-sloping, low-hazard terrain, and the landslide occurs on steeper terrain below. This is known as the "gentle-over-steep" situation.

Drainage conditions in gentle-over-steep terrain generally consist of numerous small ephemeral streams in a dispersed or divergent drainage pattern (Figure 8). Road construction in this situation can easily concentrate and divert numerous unrecognized ephemeral watercourses. Concentrated and diverted water is discharged from the road prism and flows downslope onto steeper terrain, triggering slides due to the significant increase in surface and subsurface runoff (Grainger 2002).

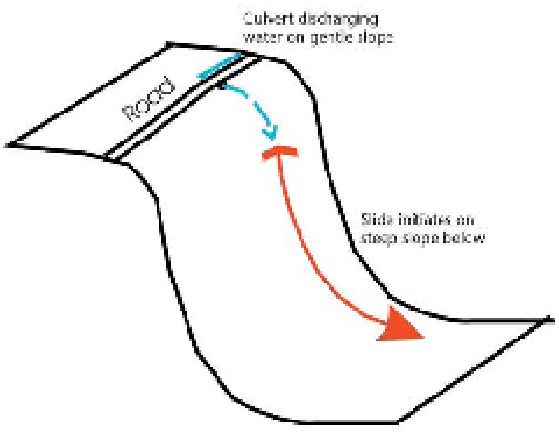

FIGURE 8 *The "gentle-over-steep" situation.*

CONCLUSIONS

Where development or deactivation activities are proposed on or above high-risk terrain, the placement of drainage structures based on road gradient or preliminary road location surveys alone is often insufficient to maintain natural drainage patterns and slope stability. Drainage plans can be effective tools in reducing the occurrence of terrain instability events associated with resource road construction and deactivation.

Professionals undertaking drainage plans should use similar survey methods and provide standard outputs to reduce confusion surrounding the definition and utility of drainage plans.

Forest managers, planners, technicians, and professionals involved in resource road construction and deactivation need to take the first step in identifying where drainage plans should be undertaken and conducting drainage plans as part of road designs and deactivation prescriptions in high-risk terrain.

Due to the liability associated with prescribing drainage structures in high-risk situations, drainage plans should be completed and signed off by qualified registered professionals who have a comprehensive knowledge of air photo interpretation, slope hydrology, and terrain stability analysis.

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APPENDIX 3 GENTLE-OVER-STEEP TERRAIN CONDITIONS

Excerpt from: Grainger, B., 2002

INTRODUCTION

This paper discusses the terrain, hydrologic and forest development factors that should be investigated as part of any Terrain Stability Field Assessment where there is the potential for the particular class of slope failures associated with forest industry practices known as "gentle-over-steep" (GoS) landslides. In the Southern Interior of British Columbia in the last several years there has been an increasing awareness that the majority of significant landslides related to forest industry practices in this region have been GoS type landslides. GoS landslides in the Shuswap and Okanagan Highlands have been responsible for the evacuation of residents, property damage and litigation (Anderson, et. al., 1997; Dobson Engineering Ltd. 1997), and loss of life (Schwab et. al., 1990).

Until recently there has been little discussion of the occurrence, processes and management implications of this class of landslides in the forestry geotechnical literature, or explicit recognition in forest practices regulations in British Columbia of the need to manage the risks associated with these slides.

GoS landslides are described as occurring "some distance below roads, below a culvert or a point of accidental drainage discharge [where] the road itself is on gently-sloping, low-hazard terrain, and the landslide occurs on steeper terrain below." (Jordan, 2001). Landslides generally occur near a slope gradient break between the flatter lying terrain on which the road is constructed, and steeper gradient terrain downslope. This may occur from several to several hundred metres downslope of the road, and the physical connection between the forestry development and off site landslide consists entirely of water movement between the two.

The Southern Interior of British Columbia is defined in this paper as the area covered by the Kamloops and Nelson Forest Regions. This paper builds on earlier work in the Nelson Forest Region (Jordan, 2001), which provided both landslide inventory data for the Slocan Valley in the southern Columbia Mountains, and discussed GoS landslide characteristics and processes. The Slocan study inventoried approximately 190 strictly drainage related failures, many of which were GoS landslides. Most of the conclusions are drawn from observations of about 100 GoS landslides in the Shuswap Highlands and, to a lesser degree, on the Kamloops Plateau, both in the Kamloops Forest Region.

This paper first discusses GoS landslide characteristics and processes, to provide the background for understanding the suggested hazard assessment procedures. GoS landslide risks in the Southern Interior are briefly discussed. The suggested procedure for conducting an assessment of GoS landslide hazard is broken down into five terrain and development factors, and each discussed with examples. Finally a framework for managing GoS landslide hazards is briefly presented.

GoS LANDSLIDE CHARACTERISTICS AND PROCESSES

Forest roads, and to a lesser extent trails, situated on gentle (6 to 26%) to moderately sloping (27 to 50%) terrain can intercept surface and subsurface hillslope drainage. Drainage accumulates or is concentrated down the ditch or road surface, and redirected to a single exit point from the road. This is usually a culvert, cross ditch or switchback, but can be a random point of discharge caused by road prism failure. This discharge then travels as either surface or subsurface flow, some distance across gentle to moderate gradient terrain downslope of the road. When it reaches a slope break to moderately steep (50 to 70%) to steep (>70%) gradient slopes, a landslide can occur.

Although deep-seated landslides have been observed downslope of the outlet of concentrated road drainage, most GoS landslides occur in shallow, relatively permeable weathered till or colluvium overlying relatively impermeable till or bedrock.
(For further information see: www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr003/Grainger.pdf)

APPENDIX 4. EROSION CONTROL ON FOREST ROADS – BEST MANAGEMENT PRACTICES

Soil erosion on forest roads and trails is caused by poor surface water management. BMPs to minimize sedimentation to streams associated with roads and trails include;

Road Location and Design

- Roll the road grade where possible (up to bridges and down to culverts) to reduce road surface erosion.
- Crown road surfaces to allow intercepted water to run off or, where prescribed by DTSFA, in-sloped. Avoid the creation of grader windrow (berms) along outer edge of road that inhibits runoff.
- Avoid the creation of long-ditchlines that discharge directly into creeks.
- Grass seed erodible cut/fill slopes and ditchlines along roads and landings to prevent erosion.
- Be aware that surface runoff on roads and trails in or below proposed blocks will INCREASE substantially following harvesting and design drainage systems accordingly. Plan for at least 2 times the pre-harvest volume of water in cross drains and culverts.

Road-building

- Felling and bunching the wood before new roads are built will be done whenever possible, rather than push-felling trees. This will help minimize the width of the road.

Timing of Road-building and Logging

- Canfor has a wet weather shut-down procedure that will be strictly followed.

- For roads that will be used for more than one year, efforts will be made to build the road at least one year before logging to allow the road time to set up before logging commences.
- Construct temporary roads just before logging, and deactivate immediately following logging to a hydrologically stable condition. Fully deactivate following planting.
- Timing of road building and logging will be scheduled for appropriate times of year based on site specific conditions. For example, do not undertake road building, harvesting or hauling during or immediately after periods of heavy rainfall when road surfaces are saturated and carrying high runoff volumes. In the east Kootenay – Columbia region these shut-down conditions will primarily be associated with spring break-up and early to mid-summer convective storm systems.

Stream Crossings and Bridge Design

- Conduct in-stream works only during Ministry of Environment approved fish stream timing windows. All in stream works will have on site spill kits and supervision.
- In-block stream crossings will be at designated crossing points utilizing wood or metal skid bridges or pipes. Once crossings are no longer in use ensure crossing will not contribute sediment to creek.
- When rock is being sourced for armoring of stream banks or sediment control in ditch line, find a rock source that is not prone to rapid weathering (e.g., Siltstones, black shales, argillites, carbonates). These rock types break down quickly and within a few years can add sediment to creeks rather that controlling it.
- Culverts for stream crossings must stretch 2 feet beyond the end of the bank. In some cases where there is lots of fill being used this will require a longer culvert. Fill slopes below culvert outlets must be armored with adequately sized, non-erodible rip-rap.

Further guidance regarding BMPs for reducing soil erosion can be found in Section 5.6 of the BCFLNR (2012) Fish-stream Crossing Guidebook (http://www.for.gov.bc.ca/HFP/Fish/Fish-Stream%20Crossing%20Print.pdf)

APPENDIX 5. HYDROGEOMORPHIC RISK ASSESSMENT (HRA) IN HCVF3 FORESTS.

Qualified professionals appropriately trained to undertake hydrogeomorphic assessments:
APEGBC and ABCFP have established the qualifications necessary for individuals undertaking DTSFA's in BC. To date the appropriate skills and training required for professionals undertaking HRA's has not been clearly established. The following excerpt from LMH 61 provides suggestions for the appropriate background of a professional undertaking such assessment in BC.

> *"This manuscript attempts to provide an understanding of watershed-fan processes and the planning and assessment of watershed activities to help better manage potential environmental, social, and economic risks. It also helps to identify when it is prudent to engage hydrogeomorphic specialists (i.e., hydrologists, terrain specialists, and others) in the process."*

Undertaking a hydrogeomophic assessment requires a comprehensive understanding of geological and hydrological processes. Specifically, to collect and interpret the data necessary to completing an HRA, the professional must have training in geology, fluvial geomorphology, hydrology and forest hydrology.

The resulting HRA document is intended to provide a record of current hydrological and geomorphological conditions of the stream channel. Data collected on channel morphology, hydraulic geometry and riparian condition will provide a baseline against which future survey data is compared. In this way channel conditions can be monitored over time. The professional conducting the channel survey must be sufficiently experience in collecting and documenting survey data. The survey must also be sufficiently detailed to capture spatial and temporal variability as well as to be useful for monitoring purposes.

Objectives of the HRA

The overall objective of the HRA is to identify watershed and stream channel processes and information on flood hazards and provide recommendations to minimize impact to these processes and hazards associated with forest development. The specific objectives (deliverables) of a hydrogeomorphic risk assessment (HRA) undertaken in HCVF3 forests include;

1. Document information about HCV(s) (e.g., number and location of water intakes, location of spawning habitat)
2. Document current hydrogeomorphic conditions of watershed including
    a. Channel hydraulic geometry and grain size characteristics across spatial scales (this information is collected to provide a baseline for future monitoring so must be sufficiently detailed and documented in table form and presented both graphically and in table form in the report).
    b. Detailed description of channel morphology across spatial scales.
    c. Hydrometric analysis providing information on the magnitude of bankfull and channel forming floods. A flood frequency analysis should be undertaken where archived hydrometric data is available
    d. Describe the frequency and mechanism of channel forming floods – including estimated time of last channel forming event, the impact this flood had on channel form and processes and likely mechanism
    e. Description of riparian function including source and recruitment mechanism of woody debris. Riparian stand characteristics – species mix and age class, disturbance mechanisms. Description of functioning LWD (size, density and spatial distribution along channel network).
3. A risk assessment of the impact of existing and proposed development on the hydrology and channel stability and flood frequency of the watershed using the framework outlined in LMH 61
4. Provide guidance for forest development to limit impacts to hydrogeomorphic processes based on field information and the most recent scientific and technical studies. The HRA should specifically provide guidance with respect to the distribution of cut blocks within a catchment to minimize synchronization of runoff in a basin.