Thompson Plateau Risk Analysis

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EXECUTIVE SUMMARY

Forsite Consultants Ltd. was retained by Weyerhaeuser Vavenby Forestlands to carry out an overview risk analysis for the Thompson Plateau Area. The objective of this project is to provide a risk assessment for forest roads in the study area, in order to prioritize road sections or sites for deactivation or repair. Risk in the context of this project pertains to landslides resulting from forest or other resource development, surface erosion and sediment delivery to streams as a result of landslides or erosion events. The study area is located west of the North Thompson River between Clearwater and Barriere and includes Eakin, Montigny, Thuya, Darlington, Powder, and Peterson Creek watersheds and adjacent face units. The study involved an overview assessment based on a review of air photos followed by a detailed field assessment of identified moderate and high risk sites.

Generally it was found that past forest harvesting practices have not resulted in significant risk to other resources in the area. Forest development has taken place on the plateau areas where roads are primarily constructed on moderate gradient slopes. Harvesting has excluded most riparian areas of larger streams.

We have identified several road sections located on steeper terrain that present a moderate to high risk to downslope resources (primarily fish habitat) as well as several stream crossing structures that presently present a moderate to high risk to downslope resources.

Additionally, the fan areas of Montigny and Thuya Creeks have been identified as moderate risk areas due to the potential for water flood and/or debris flood events. The present highway culverts are in good condition and no residential structures appeared to be at high risk. A more thorough investigation of the fan areas for evidence of historic debris flow activity and a detailed hydrologic analysis for design flood estimate would be required to quantify this risk further. While it is not expected that any works will be conducted to reduce this risk, for completeness it has been identified as part of this study.

The results of this analysis are being incorporated into an access management plan for the area. For road sections where access is no longer required, permanent deactivation has been recommended for moderate to high risk sites. Where access is needed, it has been recommended that the road sections be upgraded. In areas where it is decided that a road section will be upgraded or permanently deactivated it is recommended that detailed prescriptions be prepared.
1.0 INTRODUCTION

At the request of Mr. Wes Bieber, RPF of Weyerhaeuser - Vavenby Forestlands (Weyco), Forsite Consultants Ltd. (Forsite) was retained to carry out an overview risk analysis for the Thompson Plateau Area. The objective of this project is to complete a risk assessment for each road segment in the study area. Risk in the context of this project pertains to landslides resulting from forest or other resource development, surface erosion and sediment delivery to streams as a result of landslides or erosion events.

The study area is located west of the North Thompson River between Clearwater and Barriere. The study area includes the Eakin, Montigny, Thuya, Darlington, Powder, and Peterson Creek watersheds and adjacent face units. The study involved an overview assessment based on a review of air photos followed by a detailed field assessment of moderate and high risk sites. The results of this risk analysis will be used to prioritize road segments or sites for deactivation or repair through the Forest Investment Account (FIA) program. Funding for this project was provided through the FIA program.

2.0 METHODOLOGY

This study was completed in four phases. The first phase involved a review of an orthophoto based map to identify large or obvious sediment sources as well as identification of road sections located on terrain mapped as potentially unstable or unstable. The review of orthophotos was also completed in order to produce a preliminary report while we waited for the air photo order. The second phase involved a review of approximately 1:15000 scale air photos (stereo coverage) of the study area. Sites identified on the orthophoto were confirmed and new sites were added. Long profiles of the major streams in the area were developed concurrent with the air photo study to gain an understanding of stream channel geometry and identify stream reaches where sediment sources would have the largest impact in terms of downstream transport. Past assessments and background information on geology and climate were also researched during the office based assessment.

Following the office based assessment, the field review involved an overview helicopter flight as well as detailed reviews of any identified sites or road sections. The field work was timed to occur close to peak runoff timing for the area. Further, much of the fieldwork was completed during days with and following heavy rainfall. This aided in identifying areas of road drainage concerns. During the ground truthing many sites identified in the overview assessment were dropped and additional new sites were added. It was found that in this particular area many of the existing landslides or sediment sources were too small to be recognizable on the air photos. The air photo review however provided a good background of the study area and helped identify downslope elements at risk for the various hazards identified.

The air photo review part of this study identified both naturally occurring sediment sources or potential areas of instability and those attributable to forest development. However, for the purposes of the risk assessment, only those sediment sources or potential areas of instability related to forestry or other land use development are assessed as these are the only sites where restoration work will eventually be proposed. However, the existence of natural sediment sources within a particular drainage was considered when assessing the risk to a stream from forest development related sediment sources or landslide hazards.
3.0 TERAIN CHARACTERISTICS AND GEOMORPHOLOGICAL PROCESSES

3.1 PHYSIOGRAPHY

The study area is located near the town of Barriere, west of the Thompson River within the Thompson Plateau Physiographic Region (Holland 1964). The Thompson Plateau has a gently rolling upland of low relief for the most part lying between 1100 and 1500 metres elevation but with more resistant rock rising up 2100 metres elevation. This upland represents the late Tertiary erosion surface that has been dissected by the Thompson River and its tributaries. The Pleistocene epoch ended (∼10 000 ybp) with a gradual stagnation and a wasting of ice in place, this resulted in ice marginal meltwater channels that were quickly made, used temporarily, and then abandoned (Holland 1964). In our study area the main stream channels are the remnants of these older meltwater channels and the numerous lakes in the upper part of the study area represent areas where ice wasted away in place. The deeply incised stream channels of Eakin and Peterson and to a lesser extent Montigny and Thuya were likely formed by glacial meltwater and not by the modern day hydrologic regime in those channels.

The Thompson Plateau is underlain by a variety of bedrock types. Stocks of granitic rock intrude sedimentary and volcanic formations of Palaeozoic age. Bedrock in our study area is mapped primarily as intrusive igneous rock with volcanic rock present in the northern part of the study area and fine clastic sedimentary rock present in the southern part of the study area. The deeply incised draw of Eakin Creek is mapped as being partially underlain by volcaniclastic rock. This rock is more erodable than the intrusive igneous rock mapped in the lower part of the study area and may explain the distinct differences in stream incision between the watersheds of Eakin Creek and Darlington Creek further south. Peterson Creek is again deeply incised into fine clastic sedimentary rock.

3.2 CLIMATE AND HYDROLOGY

The climate in this region is relatively dry with moderate precipitation as rain or snow. Barriere receives approximately 485mm of precipitation each year with approximately 25% falling as snow. Precipitation amounts will be much higher in the upper part of the study area due to higher elevations and more of the precipitation will fall as snow. Similar to many areas in the southern interior the area does receive infrequent intense spring and summer convective rainstorm events. The highest extreme daily rainfall event for Barriere was on June 30, 1982 when 48.8mm of rain fell in 24hours. In the southern interior these rainfall events result in a significant portion of the forest development related landslides and sediment delivery to streams.

The drainages in this study area have numerous lakes in the upper part of their watersheds. These lakes act as buffers for snowmelt and rainfall runoff spikes associated with climatic events. When considering the potential for increases in peak flow in the watershed as a result of forest development (ie increased ECA) the areas of the watershed upslope of the lakes can be effectively excluded from the watershed area. These areas would not contribute to runoff spikes from short duration intense climatic events such as high intensity short duration rainfall or rapid snowmelt as a result of unusually high spring temperatures coupled with large snowpacks.

3.3 NATURAL SLOPE INSTABILITY

Existing stability concerns are not widespread in the study area. Several small landslides related to road construction were observed and some reported in previous studies. Much of the harvesting has taken place in
the upland areas and not on the steeper terrain of the face units or the incised stream draws.

The intrusive granitic rock in the southern part of the study area has produced very sandy soils. These soils are poorly consolidated and are likely derived from an ablation till deposit or glaciofluvial origin. Road cuts through this material result in significant surface erosion from ditches and the road surface. The sandy material is quite coarse grained and therefore transport beyond the road right of way is rare except where the road crosses streams. Escarpment slopes composed of this material are sensitive to increases in groundwater and surface runoff and are a frequent site of drainage concentration related landslide events such as those observed in the upper Powder Creek watershed.

The drainages with the steeper gradient channels in their lower reaches such as Thuya, Montigny, and to a lesser extent Darlington Creek likely experience infrequent debris flood or debris flow events in the lower channel reaches on the fans. Peak discharge events from the upper watershed have the potential to mobilize stored sediment in the channels as well as sediment derived from hillslope failures on the terrace slopes in the lower reaches.

3.3.1 Effects of the Fire on Watershed Hydrology and Slope Processes

As discussed further in Section 4.10 Peterson Creek was extensively burned during the McLure fire of 2003. The following section was taken from a terrain assessment report completed by Forsite for the Dickey Creek Fire near Lillooet (Forsite 2004). This section explains the impacts of a wildfire event on sediment production and mass wasting hazards in a watershed. Grainger and Associates Consulting Ltd assisted with preparation of this section in the original report.

Depending on its severity, a burn can remove the tree canopy and destroy the litter, duff and upper mineral soil structure. Canopy removal results in decreased evapotranspiration and interception losses, and soil exposure to rain splash. Destruction of the organic and upper mineral soil layers results in decreased infiltration and exposure of mineral soil to erosion from rain splash and surface runoff. All these effects combine to cause increases in runoff, peak flows, water yield, surface erosion, landslides and sediment delivery to downslope and downstream resources.

During high intensity wildfires organic compounds on the forest floor are vaporized and diffuse into air spaces in the soil where they cool and precipitate, coating mineral particles with hydrophobic (water repellent) hydrocarbons and forming a hydrophobic soil layer. This results in a greatly reduced infiltration rate through the hydrophobic layer, saturation of the soil above the hydrophobic layer and greatly increased surface runoff (overland flow) and soil erosion. Peak flow increases related to hydrophobic soils effects have been recorded that were 2 to 8 times (800%) greater than pre-fire flows, with four-fold (400%) increases in sediment yield (Scott and Van Wyk 1990). By way of comparison, maximum peak flow increases from clearcut harvesting of 100% of a small watershed in the dry southern interior of B.C. will probably not exceed 50% (Schnorbus, et al 2004).

Hydrophobicity can last for 2-6 years, but its effect is thought to decrease as sites revegetate and the forest organic layers build up. It is recommended to manage for a significant hydrophobic effect for 3 years (Dobson Engineering Ltd., 2003.)

Hydrophobic effects are most pronounced shortly after a fire or after prolonged dry periods. As soils moisten, inter-particle surface tension and water repellency break down, and therefore soil hydrophobicity is not as great a concern during spring snowmelt. Hydrophobic soil effects on hillslope runoff, erosion and downslope processes...
flooding and landslides from 2003 burned sites elsewhere in Southern Interior of B.C. were observed after intense rains following up to a month of dry weather (Jordan et al 2004).

There may also be post-fire hazards unrelated to hydrophobic soils and/or intense summer convective storms. Where the canopy has been removed increased snow accumulation and melt rate, elevated late spring and early summer ground water levels and decreased interception losses during late spring and early summer frontal storms can be expected. These can result in elevated spring freshet and early summer frontal storm peak flows. While these increases will be less than those associated with hydrophobic soils, they could still be greater than any experienced in recent memory prior to the fire. The recovery period for these conditions can be years to decades and will depend on the rate of stand recovery. Serious post-fire debris flow and debris flood events have been reported up to a decade after wildfire in the Southern Interior of B.C. (Cheng and Bondar, 1984).

4.0 W ATERSHED GENERAL OBSERVATIONS

4.1 E A K I N C R E E K WATERSHED

Eakin Creek flows within a deeply incised valley for most of its length from the plateau down to Lemieux Creek. Channel gradients are generally moderate, between 5 and 10% for most of the channel. Steeper reaches are present in the upper watershed between the lakes (see Appendix B-1).

Valley sidewalls are primarily overlain by deep till deposits with areas of steep rock and colluvial materials also present. Hillslopes are not directly coupled to the stream channel in the upper watershed where the stream flows on a wide valley flat. However lower in the watershed the stream is more incised and steep gradient slopes extend right down to the active floodplain. The riparian zone along Eakin Creek is for the most part undisturbed with the exception of the Eakin Creek road corridor. The Eakin Creek Road is the historic route to the Nehalliston Plateau Area and has been in place for at least 40 years. Although the road is located directly adjacent to the stream in several areas it does not appear to be having a significant impact on the stream. This is due to the generally robust nature of the channel, the bedload is primarily cobbles and gravel and the fact that the road prism where adjacent to the stream is well armoured with angular rubble material that is generally resistant to erosion (see Photo Plate 54). Small road fill failures and erosional events are contributing relatively minor amounts of sediment at localized points along the road (Photo Plates 12 and 13). The Eakin Creek road is also located very close to and not very high above the highwater level of Phinetta Creek, a major tributary to Eakin Creek in the northeast part of the study area.

Natural sediment sources are not widespread in the Eakin Creek watershed. Several slides coupled to the stream are present in the lower reach and in several areas the stream flows adjacent to talus or scree slopes. The channel is generally stable or at equilibrium with the natural sediment supply. Generally the channel of Eakin Creek appears in good condition with the exception of several sections where the Eakin Creek Road has encroached on the channel (Summit 1999).

Eakin Creek has resident fish populations and is also used by anadromous fish in the lower reaches. Several water licenses (Points of Diversion) are present on the lower reach of Eakin Creek.
4.2 EAKIN–MONTIGNY FACE UNIT

The Eakin Montigny face unit is located directly upslope of the Town of Little Fort and the lower reach of Lemieux Creek. Several small S6 and NCD drainages are located on the face unit. The largest of the creeks has several water licenses located on it.

Numerous old logging roads/trails are located on the lower slopes with two road systems that ascend to the plateau. One of these roads is the historic access to the Dum Lakes area. This road is now only used by the woodlot on the lower valley slopes and for recreational use higher up. Industrial access to the plateau in the area of Dum Lakes is via the Golden Loon FSR which branches off the Thuya FSR.

No recent landslides or areas of surface erosion were detectible on the air photos of the area. Access into this area for ground assessment was restricted by the private property in the lower valley. No areas of significant concern were noted during the overview flight.

4.3 MONTIGNY CREEK WATERSHED

The majority of the area of the Montigny Creek watershed is on the plateau. Montigny Creek starts in a series of lakes and wetland areas. The upper stream channel has an average gradient of less than 5% (see Appendix B-2). The creek has a riffle pool channel morphology with numerous wetlands and flooded areas in this reach. The upper watershed has been extensively harvested and is proposed for more harvesting to manage the mountain pine beetle. Generally, the past harvesting has been restricted to moderate slopes and the steep slopes adjacent to riparian areas have not been harvested. The on-site impact of the harvesting on fish habitat and stream morphology is judged to be low.

The lower middle reach of the stream channel has a steep gradient (see Appendix B-2) within a confined draw. In this reach the stream has a cascade pool channel morphology and flows through coarse colluvial materials and flows entirely subsurface in some sections. Harvesting is restricted to the upper moderate slopes outside of this draw.

The lower reach of Montigny Creek is deeply incised into an elevated glacial fan deposit. Sideslopes in this draw are very steep and some recent sloughing was observed. The sloughing on the sidewalls is likely due to the steep gradient of the sidewalls and possibly erosion at the toe of the slope by the stream channel. The channel occupies an oversized meltwater channel and a modern fan has developed on the Thompson River valley bottom. The creek has a cascade pool channel morphology with sand to cobble bedload and wood debris. Flows at the apex of the fan appeared to be greater than at the culvert outlet on the highway indicating that much of the streamflow likely flows subsurface in the fluvial sediments on the fan or is drawn off at licensed points of diversion. No evidence of recent debris flood or water flood events was observed on the fan. A local rancher living adjacent to the stream for many years commented that no significant flood events have occurred in the last ~20 years.

Numerous blocks are proposed in the upper part of the watershed and due to the relatively small size of this watershed the ECA value will likely be increased to greater than 30%. ECA values of greater than 30% have been known to result in increased peak flows in watersheds. However, in this watershed the lakes present in the upper watershed will likely store rainfall or snowmelt runoff for a period of time and moderate the hydrograph peaks associated runoff events. This may help to reduce the potential impact of increased ECA on peakflows. Further, the channel downslope of the plateau is robust and likely able to handle moderate increases in peak flow without significant changes in channel morphology. The potential for increased peak
flows was considered when assessing the hazard at the crossings lower down in this watershed. Channel morphology and crossings were examined with the potential for increases in seasonal peak flow taken into consideration. However, this project did not involve a detailed analysis of ECA or look at the proposed harvesting in detail.

### 4.4 Montigny - Thuya Face Unit

The Montigny-Thuya face unit is the smallest unit in this study area but has a relatively high density of old roads and/or trails. Several road systems to access the upper Thuya watershed were constructed up this face unit. Only one S6 drainage is mapped on the face unit.

No recent landslides or areas of surface erosion were detectible on the air photos of the area or observed during the overview flight.

Highway 5 is located at the toe of the steep terrain of this face unit however no past or proposed harvesting is located on this slope and a prominent bench separates this slope from the area of harvesting upslope.

### 4.5 Thuya Creek Watershed

Thuya Creek watershed has a similar channel geometry and morphology to Montigny Creek watershed (see Appendix B-3) but with a much larger upper watershed area on the plateau. The lower 2-3 km of the stream channel are steep gradient and within a confined draw. A fan is located at the base of this steep reach adjacent the Thompson River floodplain. The presence of this fan indicates a relatively high energy stream in the lower reaches.

Existing forest development in the watershed has generally been confined to areas of gentle to moderate gradient slopes. Very few bladed trails were visible in the recent blocks. It is likely that the existing blocks have no significant impact on steeper terrain downslope of them. The upper canyon reach of the creek is very rocky, talus slopes on either side and a coarse rock stream channel (see Photo Plate 51). Much of the flow through these reaches is sub surface.

Numerous blocks are proposed in the upper part of the watershed and due to the relatively small size of this watershed the ECA value will likely be increased to greater than 30%. ECA values of greater than 30% have been known to result in increased peak flows in watersheds. However, in this watershed the lakes present in the upper watershed will likely store rainfall or snowmelt runoff for a period of time and moderate the hydrograph peaks associated runoff events. This may help to reduce the potential impact of increased ECA on peakflows. Further, the channel downslope of the plateau is robust and likely able to handle moderate increases in peak flow without significant changes in channel morphology. The potential for increased peak flows was considered when assessing the hazard at the crossings lower down in this watershed. Channel morphology and crossings were examined with the potential for increases in seasonal peak flow taken into consideration. However, this project did not involve a detailed analysis of ECA or look at the proposed harvesting in detail.

### 4.6 Thuya - Darlington Face Unit

This face unit is not as steep as the areas between Thuya, Montigny, and Eakin Creeks. The lower slopes where private land is present consist of gentle gradient rolling terrain. Very little commercial forest development has occurred in this area however older selective logging on private land is evident.
A recent debris flow event occurred in this area in May 2005. This event was reportedly caused by a broken beaver dam. The sudden pulse of streamflow resulted in a debris flow where the channel is deeply incised into till and glaciofluvial materials. The debris flow impacted the highway and the road crossing upslope of the road on private land. This event initiated on private land well downslope of forest development.

4.7 Darlington Creek Watershed

Darlington Creek has a more constant gradient than Thuya or Montigny (see Appendix B-4). The gradient does increase in the lower reaches but not to as steep of a gradient or as abruptly as Thuya or Montigny.

No recent landslides or areas of surface erosion were detectible on the air photos of this watershed. Only the mainstem and lower reaches of Darlington Creek are clearly visible on the air photos. The remaining channels in the watershed are small with a lot of the drainage subsurface, particularly in the many dry rocky draws present within the watershed (see Photo Plate 50). Current harvesting in the upper watershed has retained adequate riparian management zones (see Photo Plate 49).

Several lower gradient reaches are present in the lower part of the watershed. These reaches exhibit fan like features of abandoned channels and floodplain vegetation (cedar and cottonwood) see Photo Plate 53. These reaches represent areas of past deposition and are controlled by the underlying bedrock. These lower gradient reaches are visible on the stream profile.

The lower reaches of Darlington Creek are deeply incised into till and glaciofluvial material. Near the confluence of Darlington Creek with the Thompson River the stream channel is meandering with wetland areas adjacent indicating a relatively low energy stream. Darlington Creek joins up with Powder Creek in a wetland area near the confluence with the North Thompson River (see Photo Plate 48). No modern fan deposits are visible.

Numerous blocks are proposed in the upper part of the watershed and the ECA value will likely be increased to greater than 30%. ECA values of greater than 30% have been known to result in increased peak flows in watersheds. However, in the upper watershed adequate riparian reserve areas have been retained that will help maintain channel stability and the numerous wetland areas and lakes present will likely store rainfall or snowmelt runoff for a period of time and moderate the hydrograph peaks associated runoff events. This may help to reduce the potential impact of increased ECA on peakflows. Further, the channel downslope of the plateau is robust and likely able to handle moderate increases in peak flow without significant changes in channel morphology. Most of the lower reaches are timbered and no development is planned within the RMA. This retention of riparian vegetation will help to maintain channel stability if harvesting results in changes to peak flows. The potential for increased peak flows was considered when assessing the hazard at the crossings lower down in this watershed. Channel morphology and crossings were examined with the potential for increases in seasonal peak flow taken into consideration. However, this project did not involve a detailed analysis of ECA or look at the proposed harvesting in detail.

4.8 Powder Creek Watershed

Our delineation of Powder Creek includes the Lindquist Creek watershed. Powder Creek has the lowest relief of any of the watersheds in this study (see Appendix B-5). Slope gradients within the watershed are generally moderate and the stream is generally not deeply incised in the upper reaches. The lower reaches of Powder Creek are deeply incised into till and glaciofluvial material. Near the confluence of Powder Creek with the
Thompson River the stream channel is meandering with wetland areas adjacent to the channel indicating a relatively low energy stream. No modern fan deposits are visible.

One small slide was identified in the upper reaches of Powder Creek (Site PL1) that was likely caused by drainage diversion by a block road upslope. That road has since been deactivated reducing the drainage delivery to the site. The slide may continue to produce small volumes of sediment as the headscarp stabilizes but the likelihood of a larger failure has been reduced.

Large riparian buffers have generally been retained along the Powder and Lindquist mainstem channels as well as any fish bearing tributaries. Most of the harvesting appears to be post Forest Practices Code with the older harvesting being mostly selective ground based. Only two road crossings were identified on Powder Creek. None of which were impacting the channel in any significant way. Lindquist Creek has two crossings on the mainstem and several more in the upper part of the watershed where the flow splits into numerous tributaries. No concerns were identified with these crossings.

4.9 Peterson Creek Watershed

Peterson Creek watershed was burned extensively by the recent McLure fire event in 2003. IWS 2003 reports that approximately 49% of the watershed was burnt to varying degrees. However there will likely be some survival of trees in that area. During our field review it was noted that most of the survival will be on the north side of the creek and in valley bottom areas where the fire was not as intense.

Several recent assessment reports (Landmark 2001, IWS 2003) provide extensive background information on the Peterson Creek watershed. In addition Forsite has completed several recent terrain stability assessments for timber salvage activities in the area of the Peterson Creek watershed burned by the recent McLure fire event in 2003.

Peterson Creek begins in a series of lakes in the upper watershed and then descends in a deep canyon or valley to the Thompson River valley bottom. Terrain within the incised reach of Peterson Creek consists of both steep bedrock slopes with talus and scree deposits and steep fluvial terrace slopes where the stream has downcut through glacial till and glaciofluvial sediments. An extensive gentle gradient alluvial fan has been built out into the Thompson River valley by Peterson Creek since deglaciation.

Prior to the fire event there were very few concerns with regards to sediment sources and landslide hazards; however, the burn has increased the hazard in some areas by burning out old wood culverts and wood support for fill slopes. Further the soils following the burn are much more susceptible to surface erosion.

The recent fire will have the largest impact on watershed hydrology in Peterson Creek. Although further harvesting of unburned timber is planned in the upper watershed most of the areas proposed for harvesting are upstream of Allan Lake which has considerable potential to moderate peak flow impacts associated with harvesting.
5.0 **RISK ANALYSIS RESULTS**

5.1 **RISK ASSESSMENT PROCEDURE**

This project involved the completion of a partial risk analysis (MOF 2004). Partial risk analysis involves determining the likelihood of occurrence of a landslide or erosion event and that event being a hazard to and directly or indirectly reaching or otherwise affecting a specific value at risk. Partial risk analysis is not a measure of the expected degree of damage to a specific value. For example where we have identified a landslide hazard from a particular road section we have estimated the potential runout of such a slide. If it is likely that that slide may runout to a stream with known fish habitat we have assigned a high consequence rating for that particular hazard. We have not determined the degree of damage that such a landslide would have on the fish habitat, only that the slide may impact it.

In some cases to make informed decisions, it may be necessary to also consider the value or cost of values at risk. Specific or total risk analysis involves partial risk analysis, together with estimates of the degree of harm or loss to a given value or set of values if the landslide or erosional event does occur. For the purposes of this risk assessment (prioritizing sites for FIA funded deactivation or environmental maintenance) a partial risk analysis was determined to be suitable.

Consequence ratings have been estimated based on standard practice and identification of downslope resources in the area. All of the main streams in the study area have domestic water intakes located on them. Intakes are typically located on the lower reaches of these streams. Sediment delivery to a stream with a domestic water intake is considered a moderate to high consequence dependent on the magnitude of the hazard and location of the identified site in relation to the intake. Private property and dwellings are located on the lower slopes of the study area. Impact to private property and dwellings as the result of a landslide or debris flow/flood event in one of the stream channels is considered a high consequence. A landslide or erosion event that results only in local site degradation and possible loss of forest productivity is considered a low to moderate consequence dependent on landslide size.

The results of the risk analysis are presented in tabular format in Tables 5.1 through 5.10, and a map of the study area is attached as Figure 2.
<table>
<thead>
<tr>
<th>Site Location</th>
<th>Site Characteristics</th>
<th>Hazard</th>
<th>Consequence</th>
<th>Risk = H x C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eakin</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eakin</td>
<td>South Eakin FSR</td>
<td>E1</td>
<td>Section of South Eakin FSR that ascends up valley sidewall from valley flat. Numerous streams and NC drainages are intercepted by the road, most are adequately culverted but several result in long ditch runs. Several old slides are present that initiated from the road prism. Several sections of oversteepened fill slopes likely supported by wood debris are present. Photo Plates 1-4</td>
<td>Landslides initiated due to drainage structure failure or failure of the overly steep fill slopes.</td>
</tr>
<tr>
<td>Eakin</td>
<td>Block Roads off the 2375 Road system</td>
<td>E2</td>
<td>Area of recent harvest. Slumping cut slopes have infilled the ditchline. Steep gradient slopes of deeply incised draw of Eakin Creek downslope. Slumping cut slopes have filled in the ditchline resulting in water on the road surface. Photo Plate 5</td>
<td>Road prism failure due to saturation of road prism. Potential for significant runout due to steep terrain downslope of the block.</td>
</tr>
<tr>
<td>Eakin</td>
<td>Eakin Creek Road</td>
<td>E3</td>
<td>Existing slide upslope of mainline and downslope of recent block. Photo Plates 6</td>
<td>Minor sediment delivery from the site. Unlikely to reach Eakin Creek</td>
</tr>
<tr>
<td>Eakin</td>
<td>2057 Road</td>
<td>E4</td>
<td>Road climbs up steep escarpment slopes in cutblock, S6 trib to Eakin Creek (S3) located downslope. Numerous cut slope failures have occurred along the road section. Ditchline is infilled and water is running down the road. Culvert at beginning of road section has an infilled sump and sediment laden water is flowing through the culvert into the S6 stream downslope. Photo Plates 7-11</td>
<td>Cut slope failures and significant sediment production from this road section.</td>
</tr>
<tr>
<td>Eakin</td>
<td>Eakin Creek Road MOTH</td>
<td>E5</td>
<td>Site identified originally identified (#4) in 1999 IFAP by Summit Environmental Consultants. Although the Eakin Creek Road has affected several locations along Eakin Creek, three sections of road (collectively termed Site 4) are most crucial. At each section, the road has slumped into Eakin Creek as a result of undercutting and/or road drainage problems. Small fill slope failure, 4 to 5 metres long and less than 2 metres high. Photo Plates 12,13</td>
<td>Continued erosion of the road fillslope</td>
</tr>
</tbody>
</table>
### Table 5.1 Eakin Creek Watershed - Risk Assessment

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Hazard</th>
<th>Consequence</th>
<th>Risk = H x C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub Basin</td>
<td>Site Characteristics</td>
<td>Hazard Type</td>
<td>Rating</td>
</tr>
<tr>
<td>Eakin</td>
<td>Road Number</td>
<td>Site Number</td>
<td>Surficial Materials and Slope Morphology</td>
</tr>
<tr>
<td>Eakin Creek</td>
<td>E6</td>
<td>Site identified (#5) in 1999 IWAP by Summit Environmental Consultants. Two road fill failures were identified. Each failure was approximately 12 m along the road by 4 m high (from road surface to creek level).</td>
<td>Moderate</td>
</tr>
<tr>
<td>MOTH</td>
<td></td>
<td>Continued erosion of the road fillslope</td>
<td></td>
</tr>
</tbody>
</table>

### Table 5.2 Eakin Montigny Face Unit - Risk Assessment

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Hazard</th>
<th>Consequence</th>
<th>Risk = H x C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub Basin</td>
<td>Site Characteristics</td>
<td>Hazard Type</td>
<td>Rating</td>
</tr>
<tr>
<td>Eakin</td>
<td>Road Number</td>
<td>Site Number</td>
<td>Surficial Materials and Slope Morphology</td>
</tr>
<tr>
<td>Montigny</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No sites identified
### Table 5.3 Montigny Creek Watershed - Risk Assessment

<table>
<thead>
<tr>
<th>Sub Basin</th>
<th>Road Number</th>
<th>Site Number</th>
<th>Site Characteristics</th>
<th>Hazard</th>
<th>Consequence</th>
<th>Risk = H x C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montigny</td>
<td>Highway and Frontage Road</td>
<td>M1</td>
<td>Highway crossing of Montigny Creek, 800mm CMP Creek currently flowing along the southern margin of the fan. No evidence of recent debris flow or debris flood events was observed on the fan.</td>
<td>Debris flood or water flood events on the fan Channel avulsions</td>
<td>Low</td>
<td>Damage to crossing structures during debris flood or water flood events. Flooding of residential structures</td>
</tr>
<tr>
<td>Montigny</td>
<td>Powerline Road</td>
<td>M2</td>
<td>Old powerline access road bridge No longer passable by vehicle, partially collapsed into creek Low probability of stream diversion if bridge does collapse</td>
<td>Collapse of bridge structure into creek may result in mobilization of stored bedload and/or bank erosion.</td>
<td>Moderate</td>
<td>Relatively minor sediment delivery to Montigny Creek</td>
</tr>
<tr>
<td>Montigny</td>
<td>Thuya FSR</td>
<td>M3</td>
<td>Thuya FSR crossing over Montigny Creek. 1200mm Culvert Stream channel consists of cobble and boulders Moderate stream gradient</td>
<td>Culvert plugging and diversion of streamflow</td>
<td>Low</td>
<td>Impact to Montigny FSR Relatively minor sediment delivery to Montigny Creek</td>
</tr>
<tr>
<td>Montigny</td>
<td>2325.05</td>
<td>M4</td>
<td>Old skid trails in block diverting drainage. Flowing and ponded water observed on trail during field review. Gentle gradient slopes and wetland areas present between trail and Montigny Creek. This drainage is not likely resulting in significant sediment delivery to Montigny Creek.</td>
<td>Diversion and concentration of surface flows Erosion of the trail surface to the extent that sediment is mobilized to Montigny Creek</td>
<td>Low</td>
<td>Relatively minor sediment delivery to Montigny Creek</td>
</tr>
</tbody>
</table>

### Table 5.4 Montigny – Thuya Face Unit - Risk Assessment

<table>
<thead>
<tr>
<th>Sub Basin</th>
<th>Road Number</th>
<th>Site Number</th>
<th>Site Characteristics</th>
<th>Hazard</th>
<th>Consequence</th>
<th>Risk = H x C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montigny</td>
<td>2325.05</td>
<td>M4</td>
<td>Old skid trails in block diverting drainage. Flowing and ponded water observed on trail during field review. Gentle gradient slopes and wetland areas present between trail and Montigny Creek. This drainage is not likely resulting in significant sediment delivery to Montigny Creek.</td>
<td>Diversion and concentration of surface flows Erosion of the trail surface to the extent that sediment is mobilized to Montigny Creek</td>
<td>Low</td>
<td>Relatively minor sediment delivery to Montigny Creek</td>
</tr>
</tbody>
</table>

No sites identified
### TABLE 5.5 THUYA CREEK WATERSHED - RISK ASSESSMENT

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Site Characteristics</th>
<th>Hazard</th>
<th>Consequence</th>
<th>Risk = H x C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thuya Highway and Frontage Road</td>
<td>T1</td>
<td>Highway 5 and frontage road crossing on lower reaches of Thuya Creek. Culverts appear to be of suitable size. Stream channel consists of boulders. High energy stream on large fan. Likely experiences infrequent debris flood events. [Photo Plates 21-23]</td>
<td>Debris flood or flood events on the fan Channel avulsions of sufficient size to impact the highway or residential structures</td>
<td>Low</td>
</tr>
<tr>
<td>Thuya NA</td>
<td>T2</td>
<td>Water intake on Thuya Creek [Photo Plate 24]</td>
<td>No hazard at site</td>
<td>NA</td>
</tr>
<tr>
<td>Thuya 2305.40</td>
<td>T3</td>
<td>Bridge on lower Thuya Creek No significant concerns</td>
<td>Sediment delivery from the road prism Impact to the stream from the crossing structure</td>
<td>Low</td>
</tr>
<tr>
<td>Thuya 2340.03</td>
<td>T4</td>
<td>Bridge on lower Thuya Creek No significant concerns [Photo Plate 25]</td>
<td>Sediment delivery from the road prism Impact to the stream from the crossing structure</td>
<td>Low</td>
</tr>
<tr>
<td>Thuya 2300.00</td>
<td>T5</td>
<td>Old wood culvert on upper Thuya Creek Resulting in significant ponding back of the culvert Wetland/take area has formed Installation of a new crossing would likely result in draining of that area. [Photo Plates 26-29]</td>
<td>Failure of the crossing. Road would be completely washed out in the event of a failure. Resulting pulse of water would result in bedload movement and possible channel instability downstream.</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

- **Site Location**: Highway and Frontage Road, Water intake on Thuya Creek, Bridge on lower Thuya Creek, Old wood culvert on upper Thuya Creek.
- **Site Characteristics**:
  - T1: Highway 5 and frontage road crossing on lower reaches of Thuya Creek. Culverts appear to be of suitable size. Stream channel consists of boulders. High energy stream on large fan. Likely experiences infrequent debris flood events.
  - T2: Water intake on Thuya Creek.
  - T3: Bridge on lower Thuya Creek.
  - T4: Bridge on lower Thuya Creek. Installation of a new crossing would likely result in draining of that area.
  - T5: Old wood culvert on upper Thuya Creek. Resulting in significant ponding back of the culvert. Wetland/take area has formed.

- **Hazard**: Debris flood or flood events on the fan, Channel avulsions of sufficient size to impact the highway or residential structures, Sediment delivery from the road prism, Impact to the stream from the crossing structure.

- **Consequence**: Damage to crossing structures during debris flood or flood events. Flooding of residential structures, Minor sediment delivery to S3 stream, Significant sediment delivery to Thuya Creek, Loss of road access.

- **Risk**: Moderate, Low, High.
### Table 5.6 Thuya - Darlington Face Unit - Risk Assessment

<table>
<thead>
<tr>
<th>Sub Basin</th>
<th>Road Number</th>
<th>Site Number</th>
<th>Site Characteristics</th>
<th>Hazard</th>
<th>Consequence</th>
<th>Risk = H x C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thuya - Darlington Face</td>
<td>Private Access Road</td>
<td>TD 1</td>
<td>Recent debris flow (May 2005) in S6 Stream channel Reportedly caused by broken beaver dam in small pond. Pond located on terrace slope, downslope of face unit. Debris flow ran out to and impacted the highway and deposited significant material downslope of the highway. Event occurred on private land. Further similar events in this channel.</td>
<td>Moderate</td>
<td>Impact to highway Impact to fish habitat Impact to private land</td>
<td>High</td>
</tr>
</tbody>
</table>

### Table 5.7 Darlington Creek Watershed - Risk Assessment

<table>
<thead>
<tr>
<th>Sub Basin</th>
<th>Road Number</th>
<th>Site Number</th>
<th>Site Characteristics</th>
<th>Hazard</th>
<th>Consequence</th>
<th>Risk = H x C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darlington Creek</td>
<td>2205.00</td>
<td>D1</td>
<td>Old log stringer bridge on spur road off the Darlington FSR. Deck is damaged, only pickup or ATV access. Bridge not impacting stream in any significant way. Stream well confined, low likelihood of a channel avulsion in the event of structure collapse.</td>
<td>Collapse of bridge</td>
<td>Relatively minor sediment delivery to Darlington Creek</td>
<td>Moderate</td>
</tr>
<tr>
<td>Darlington Creek</td>
<td>2217.00</td>
<td>D2</td>
<td>Section of road with severe rutting. Possible source of fine grain sediment to S6 tributary of Darlington Creek. Continued surface erosion from the road prism.</td>
<td>High</td>
<td>Fine grain sediment delivery to S6 tributary to Darlington Creek.</td>
<td>Low</td>
</tr>
</tbody>
</table>
TABLE 5.8 POWDER – LINDQUIST CREEK WATERSHED - RISK ASSESSMENT

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Site Characteristics</th>
<th>Hazard</th>
<th>Consequence</th>
<th>Risk = H x C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sub Basin</td>
<td>Road Number</td>
<td>Site Number</td>
<td>Surficial Materials and Slope Morphology</td>
</tr>
<tr>
<td>Powder</td>
<td>Powder</td>
<td>BCTS</td>
<td>PL1</td>
<td>Small retrogressive slide</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Photo Plates 35,36</td>
</tr>
<tr>
<td>Powder</td>
<td>Powder</td>
<td>BCTS</td>
<td>PL2</td>
<td>Sloughing cut slopes on road</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Photo Plate 37</td>
</tr>
<tr>
<td>Lindquist</td>
<td>2200.00</td>
<td>2200.00</td>
<td>PL3</td>
<td>Darlington FSR crossing on Lindquist Creek</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Photo Plates 38,39</td>
</tr>
<tr>
<td>Lindquist</td>
<td>2225.00</td>
<td>2225.00</td>
<td>PL4</td>
<td>Ponded water on road surface due to drainage interception by skid trails within the block. Likely only a seasonal concern, field review was completed immediately following spring snow melt.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Photo Plate 40</td>
</tr>
</tbody>
</table>

TABLE 5.9 POWDER – PETERSON FACE UNIT - RISK ASSESSMENT

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Site Characteristics</th>
<th>Hazard</th>
<th>Consequence</th>
<th>Risk = H x C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sub Basin</td>
<td>Road Number</td>
<td>Site Number</td>
<td>Surficial Materials and Slope Morphology</td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

No Sites identified in this sub basin
## Table 5.10 Peterson Creek Watershed - Risk Assessment

<table>
<thead>
<tr>
<th>Sub Basin</th>
<th>Road Number</th>
<th>Site Number</th>
<th>Hazard Characteristic</th>
<th>Type of Hazard</th>
<th>Hazard Rating</th>
<th>Consequence Characteristic</th>
<th>Consequence Rating</th>
<th>Risk = H x C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peterson</td>
<td>P1</td>
<td></td>
<td>Old wood culvert</td>
<td>STILL functional but likely completely rotted out, acting as a soil arch. Not a significant concern for present use but would likely need to be replaced before any hauling activity.</td>
<td>Collapse of structure</td>
<td>Low</td>
<td>Sediment delivery to S6 stream Restriction of road access</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peterson</td>
<td>BCTS P2</td>
<td></td>
<td>Large cut slope in sandy terrace soils Revegetating slowly Sediment in ditchline just upslope of crossing over Peterson Creek. Most sediment appears to settle out before reaching Peterson Creek</td>
<td>Erosion of the cut slope and road surface.</td>
<td>Low</td>
<td>Indirect sediment delivery to Peterson Creek</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Peterson</td>
<td>2100.00 P3</td>
<td></td>
<td>50 metre section of road with steep wood supported fillslope upslope of steep draw of S7 tributary to Peterson Creek. Steep slope appears to be an old failure scarp Trees are burnt and likely to start losing root strength within 10-20 years, at that time fillslope may become unstable.</td>
<td>Road fill slope failure with the potential to runout to Peterson Creek tributary.</td>
<td>Low</td>
<td>Sediment delivery to S7 tributary to Peterson Creek</td>
<td>High</td>
<td>Moderate</td>
</tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peterson</td>
<td>2130.00 P4</td>
<td></td>
<td>Old skid trail with wood supported fillslopes Steep terrain downslope of the trail Potential for drainage concentration onto the steeper terrain downslope however ditchlines do not show signs of significant runoff.</td>
<td>Drainage concentration by the road prism resulting in a landslide on the terrain downslope with the potential to runout to Peterson Creek.</td>
<td>Low</td>
<td>Sediment delivery to Peterson Creek</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peterson</td>
<td>2130.00 P5</td>
<td></td>
<td>Old log box culvert, severely damaged by fire. Steep favourable road on the town side of the crossing. Potential for flow down the road if the structure were to collapse and block the channel. Steep escarpment slope downstream. Diversion of flows down the road and into the next stream channel would have the potential to initiate a debris flow or flood event in that channel that could runout to Peterson Creek.</td>
<td>Collapse of the log box structure resulting in a diversion of the stream and subsequent debris flow or flood event in the secondary channel back, along the road.</td>
<td>Moderate</td>
<td>Sediment delivery to Peterson Creek</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
6.0 CLOSURE

This risk analysis has been carried out in accordance with generally accepted engineering and geoscientific practice for the area. Conclusions and recommendations presented herein are based on air photo interpretation and visual site inspections of selected areas in each watershed. Due to the nature of this assessment procedure it is possible that some sites may have been missed that were not identifiable on air photos or located along the roads that we assessed in the field. Further, assessments of soils and slope stability are based on interpretation of surface features and limited sub-surface investigation; actual ground conditions may vary from those inferred.

This report provides a qualitative evaluation of potential landslide and erosion hazards associated with existing forest and other resource development in the study area, a description of the downslope landslide consequences, and recommendations to reduce the landslide hazards and associated risks. Acceptance of the qualitative consequence values and the subsequent risk analysis is the responsibility of the licensee or the regulatory authority, as is the determination of acceptable risk and the decision to proceed with any action based on that risk assessment.

We trust that this report satisfies your present requirements. Should you have any questions or comments, please contact our office at your convenience.

Sincerely,

Forsite Consultants Ltd.

Prepared by:

Rod Williams, P.Geo
Project Geoscientist
7.0 REFERENCES


Forsite Consultants Ltd. 2004 *CP 212 Town and Dickey Creek Fire Salvage Terrain Stability Assessment and Soil Erosion Hazard Assessment*. Prepared for Ainsworth Engineered Canada LP


