Perry Ridge, an Example of a Risk Assessment for Forestry Planning

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Abstract

Perry Ridge is located in southeastern B.C. Most of its uplands is Crown land, and private lands extend along its eastern base. The authors carried out a consensus overview assessment of risk to life/limb, property and water supply on the private land from proposed road building and logging on the Crown land. Geologic hazards, as assessed by others, were grouped into 9 types and a hazard rating system was developed. Elements at risk were identified and grouped into 3 categories (life/limb; property; and water supply), and a consequence rating system was developed. For each of the 32 hydrological units identified, existing risks were assessed by combining the hazard rating for each of the 9 types of hazardous events with the consequence rating for each of the 3 groupings of elements at risk. The anticipated risks following proposed logging activities were then assessed, and alternatives suggested. This is the first time in B.C. that such a risk assessment has been carried out as part of forest development planning.

Introduction

Perry Ridge is located in the Slocan Valley in the West Kootenay region of British Columbia. The relatively flat-topped ridge is approximately 25 km long, 9 km wide and ranges in elevation from 500 m to 2,100 m. Most of its uplands is Crown land and is included in the B.C. Ministry of Forests (MOF), Arrow Forest District, Small Business development area. (Under the “Small Business” program, provincial forest land is managed directly by the MOF, which conducts all planning, road-building, and silviculture activities, and makes individual timber sales available by bid.)

Privately owned land extends along the base of, and in places part way up, the east side of Perry Ridge. Much of the private land has been cleared for pasture or cultivation, or has been logged, and numerous residences, with associated water supply intakes, are located along the base of the ridge.

Forest development in the Slocan Valley is an unusually contentious issue. Some well-publicized anti-logging protests have occurred at Perry Ridge and elsewhere in the Slocan Valley. Residents’ concerns include possible impacts on water quality, and risks from landslides from logged areas and roads.

The Arrow Forest District is undertaking a comprehensive planning process for forest development on Perry Ridge, which significantly exceeds the requirements of the Forest Practices Code. This has included several mapping projects which addressed geologic and hydrologic hazards both on the ridge and within the adjacent populated valley bottom. To facilitate public participation, an advisory committee, the Perry Ridge Local Resource Use Planning Table (the Table) was set up, including representatives from various interest groups in the community. The risk assessment described in this paper was conducted for the Table as part of this planning process. The Arrow Forest District made an effort to keep the Table involved at every step of the study, and to make the results of the risk assessment and the underlying hazard studies accessible to the public.

The authors of this paper were asked to form the Perry Ridge Technical Review Panel (the Panel). The purpose of the Panel was to use the results of the geologic hazard studies, and other information, to carry out an overview geologic and hydrologic assessment of existing risk to life/limb, property and water supply and anticipated risks from road building and logging on Crown land as proposed in a Total Chance Plan (TCP). Based on the results of the risk assessment, and to the level of information available, the Panel was asked to suggest alternatives to the TCP and to make any other relevant recommendations.

For practical purposes, forest planning for a new development area has three stages:

1. An overview or Total Chance Plan (TCP) stage. A TCP is a hypothetical forest engineering plan to efficiently develop the timber in a planning area, over the entire period of rotation of the forest. It is based on existing inventory information, such as forest cover and topographic maps, and air photo interpretation. It may be prepared several years or decades before development.

2. A Forest Development Plan (FDP) is an operational plan which identifies specific roads and cutblocks, to be constructed and harvested over the next several years, for a single development area. It is based primarily on field work. The content and information requirements of a FDP are specified in detail by the Forest Practices Code.

3. Road designs and logging plans, for individual road permits and cutting permits issued by the MOF.

Most mapping and watershed-scale assessment of geologic and hydrologic hazards and related environmental concerns is done at the FDP stage, including terrain stability mapping and watershed assessments as required by the Forest Practices Code. Although risk assessments are not required by the Code, in theory they could be part of any of the three planning stages. In practice, simple risk assessments are commonly carried out during the third stage, as part of engineering work on individual high-hazard road segments or stream crossings.

The Perry Ridge Risk Assessment was done during the initial stage of planning. Its main objectives were to identify, at the scale of watersheds or other suitable geographic units (from about 1 to 13 km²), existing geologic and hydrologic risks or risks that would result from proposed forest development; to identify constraints to development which would be imposed by these risks; and to suggest alternatives and recommendations to the TCP to reduce these risks.

This is the first time in British Columbia that such an overview risk assessment has been carried out as part of the forest development planning process. As such, the purpose of this paper is not to present the results of the risk assessment (those are presented elsewhere, refer to Boyer, Jordan and VanDine, 1999), but to describe in some detail the method the Panel used to carry out its assignment.

Over the past two decades, a number of risk assessment studies have been conducted in British Columbia, primarily for highways and other transportation planning, hydroelectric development, and municipal planning. The theoretical basis of these studies, and some examples, are reviewed by Morgan (1991), Morgan et al. (1992), and Cave (1992). Although past studies have been done for industries or activities other than forestry, the basic principles are applicable to forestry planning. In the literature on risk assessment, there is some variability in the details of the methodology used, particularly in the definitions used for “High”, “Moderate”, and “Low” hazards and consequences. In this study, the Panel attempted to apply definitions consistent with past studies, with due consideration to the variety of hazards examined, and the differences in scale of planning unit to which the past studies were applied.

Risk is the product of hazard and consequence, where hazard is the probability or likelihood of a hazardous event occurring, and consequence is the effect of that event. Consequence is a combination of the elements at risk and the severity and/or frequency of the hazardous event on those elements at risk. For hazardous events that occur frequently in the same location, such as floods and snow avalanches, and where historical data exists, quantitative risk assessments may be appropriate. For Perry Ridge, however, the hazardous events are relatively infrequent and/or the historical data is lacking. To accommodate this difficulty the Panel carried out a consensual qualitative risk assessment based on available information and empirical evidence combined with the experience and judgement of the Panel. The consensual aspect of this risk assessment was intended to minimize any biases, and to provide an “average” of three people’s qualitative judgments.

**Background Data and Methodology**

The study area covered approximately 70 km² composed of approximately 44 km² of Crown land and 26 km² of private land along the east side of Perry Ridge.

In general, on most of the ridge, the level of geomorphic activity is low. Landslides and other sediment sources are scarce. However, many creeks are deeply incised in bedrock, and their channels
and fans have debris flow deposits. In the valley bottom, there are extensive deep glacial deposits, which are subject to a variety of potentially hazardous processes, including slumps, debris slides, and sinkholes.

No forest development has taken place on Crown land on the upper part or east side of Perry Ridge, although construction of a road into the area from the north has begun. Most of the ridge was burned by large fires 80 to 100 years ago, and timber in the burned areas is now nearing maturity.

**Hydrologic Units, Zones of Influence, and Forest Development Areas**

To relate the risks to the geography, the Panel divided the study area into 16 watershed units and 16 “face” units, a total of 32 hydrologic units. The latter are located between the watersheds, and most do not contain obvious surface watercourses. The lowermost point of the watershed units was generally located at the furthest upstream water intake. The lower boundary of the face units was assumed to be the topographic break between the Perry Ridge slope and the valley bottom, which is also typically the boundary between forest and agricultural land. For each hydrologic unit the watershed/face area was calculated and the H60 elevation determined. This is the elevation above which 60% of the watershed lies. It is used to give greater weight to forestry operations at higher elevations which receive greater snowfall.

The approximate areas downslope of the hydrologic units that could potentially be affected by surface water, groundwater, and runout resulting from various events originating upslope were delineated by the Panel and referred to as zones of influence. The zones of influence were delineated manually using 1:10,000 scale, 1:5,000 scale, 2 m contour valley bottom floodplain maps and 1998 air photos. In the absence of other information, groundwater flow was approximated from surface contours. The zones of influence between adjacent watershed and face units commonly overlap.

The Total Chance Plan (D. S. Spencer Forestry Consulting Ltd., 1998) extended the traditional TCP such that development of the timber also considered methods to partially reduce effects on some non-timber resources. The Perry Ridge TCP identified over 300 hypothetical cutblocks and over 100 km of logging roads. To simplify this TCP, the Panel divided the plan into 18 forest development areas based primarily on access, so that conceivably each area could be developed independently.

Equivalent Clearcut Area (ECA) is a concept widely used in forest hydrology to estimate the percent of a watershed that has been clearcut or is equivalent to the clearcut condition. ECA calculations consider silvicultural system (clearcut or partial cut), harvesting system, and amount and density of regeneration (Interior Watershed Assessment Procedure Guidebook, MOF and MELP, 1995). For each hydrologic unit, the Panel estimated an ECA Index, which is an indicator of the extent of existing and proposed logging and its hydrologic effect. The following assumptions were made: the areas above H60 were weighted 50% higher than the areas below H60; between 40% and 80% of the private land had been logged, based on estimates made from air photos; on Crown land it was assumed that 30% of the volume of timber in the development area would be logged during the initial development; logging would not be concentrated in any one hydrologic unit; logging a given volume of timber would have the same effect whether it is clearcut or selectively logged; and reserves identified in the TCP would not be logged.

**Geological Hazards**

Key documents used for the hazard assessment included: Detailed Terrain Stability Map at 1:20,000 scale (Wehr, 1985; updated by S. Chatwin Geoscience Ltd., 1998b); Stream Channel Assessments at a scale of 1:10,000, for 14 of the 16 streams (S. Chatwin Geoscience, 1998a); Geological Hazards Mapping on the private land at a scale of 1:25,000 scale (Apex Geoscience, 1998); Floodplain Mapping along the Slocan River at 1:5000; and 1:15,000 scale 1998 air photos. Using this information the geological hazardous events were grouped into nine different types, in three categories:

- **Primarily water related events:** peak flow/flood, sediment yield
- **Primarily slope/channel related events**: debris slide into a stream, debris flow down a stream, debris flood/avulsion along stream channel, open slope landslide (any type of landslide that occurs on an open slope above the valley bottom and does not enter a stream), snow avalanche.

- **Primarily valley bottom related events**: valley bottom landslide, sinkhole development.

In each of the above categories, the likelihood or probability of a particular event occurring was rated somewhat differently, although all were rated strictly on the occurrence of an event and independent of the magnitude of the event. One of the challenges of the Panel was to establish a common hazard rating system for all nine event types that could be applied to an entire hydrologic unit. Hazards were relatively rated as “High”, “Moderate”, “Low”, “Very Low” and “None”.

The anticipated hazard with logging on Crown land as proposed by the TCP was then assessed, based on the existing hazard plus an inferred linkage to forest development. This linkage was subjectively determined from the TCP, including the proposed road system, harvesting system, the estimated ECA Index as a result of logging, and the location of roads or logging with respect to mapped hazard polygons. The linkage was relatively rated as “Low”, “Moderate” and “High”. Assumptions included the 30% removal of timber in development areas, as discussed above, road building and logging in accordance with the Forest Practices Code, and the fact that adjacent zones of influence often overlap. The effects of present and/or future land use activities on the private land were not considered.

An example summary of existing hazards, inferred linkage to forest development, and the anticipated hazards after logging as proposed by the TCP is

<table>
<thead>
<tr>
<th>No.</th>
<th>Event type</th>
<th>Existing hazard</th>
<th>Linkage to forest development</th>
<th>Hazard with TCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Peak flow/flood</td>
<td>Moderate</td>
<td>+++</td>
<td>High</td>
</tr>
<tr>
<td>2</td>
<td>Sediment yield</td>
<td>Very Low</td>
<td>++++++</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>Debris slide into stream</td>
<td>Moderate</td>
<td>+++</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>Debris flow down stream</td>
<td>Moderate</td>
<td>+++</td>
<td>High</td>
</tr>
<tr>
<td>5</td>
<td>Debris flood/avulsion along stream</td>
<td>Low</td>
<td>+++</td>
<td>Moderate</td>
</tr>
<tr>
<td>6</td>
<td>Open slope landslide</td>
<td>Low</td>
<td>+</td>
<td>Low</td>
</tr>
<tr>
<td>7</td>
<td>Snow avalanche</td>
<td>None</td>
<td></td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>Valley bottom landslide</td>
<td>High</td>
<td>+</td>
<td>High</td>
</tr>
<tr>
<td>9</td>
<td>Sinkhole</td>
<td>None</td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>

*Notes: Linkage to forest development: + (Low); +++ (Moderate); ++++++++ (High)*
shown in Table 1. To illustrate the concept of linkage, using this example: the linkage of “valley bottom landslide” to forest development is low because the proposed development does not occur where it could affect the polygons mapped high for this hazard; and the linkage of “sediment yield” is high because there are seven proposed road crossings of the creek. Low, moderate, and high linkages increase the hazard class by zero, one, or two classes respectively. (The series of +’s are graphic symbols equivalent to arrows of various lengths.)

Elements at Risk and Consequences

The elements at risk that the Panel were asked to consider were: life and limb, property and water supply. They were mapped as follows: residences and other buildings were located from a high-resolution satellite photo, 1998 air photos, and 1:5,000 floodplain maps; roads, utilities, and agricultural land were obtained from forest cover maps; and water license locations were obtained from the Ministry of Environment, lands and Parks water rights maps (excluding water wells, as they are usually not recorded).

This mapping was accompanied by several stated assumptions and limitations. The intent was to have a uniform level of information across the study area (and within each zone of influence), rather than to accurately map each element at risk. Only existing elements at risk were considered; possible future elements such as new subdivisions were not.

Consequences were rated by the Panel as “High”, “Moderate”, and “Low” based upon the elements at risk and the inferred severity/frequency of the type of events to which these elements at risk are, or may be, exposed. If the consequences were assessed to be “Very Low”, they were not noted. The relative ratings were not intended to be compared among the three groupings of elements at risk. Some examples of consequences are as follows (this is a partial list only):

- Consequence to life and limb: High - death; Moderate - serious injury; Low - minor injury.
- Consequence to property: High - destruction of multiple residences; Moderate - destruction of single residence, or damage to multiple residences; Low - damage to single residence.
- Consequence to water supply: High - destruction of multiple water intakes, or very high increase in turbidity; Moderate - destruction of a single water intake, or high increase in turbidity; Low - damage to a single water intakes, or moderate or low increase in turbidity.

Risk Assessment

The risk assessments for each of the 32 hydrologic units were carried out with the help of three 3 X 4 risk matrices: one relating to life and limb, one relating to property and one relating to water supply. Example risk matrices for one hydrologic unit are shown in Table 2.

The numbers in Table 2, correspond to the nine types of hazardous events (see Table 1). The location of the numbers indicate the existing risk rating (that is, with no logging on Crown land). Event numbers appearing in Table 2 but not in Table 1 indicate consequences that were assessed to be “Very Low”.

The risks with logging activities on Crown land as proposed by the TCP were then assessed and entered in the matrices. It was assumed that the consequences would not change after logging, only the hazards, and the amount the hazards would change was related to the linkage to forest development. The changes to the existing hazard, and therefore risk, are shown graphically in the risk matrices by a series of ascending “+’s”, as explained for Table 1. Note that as for consequences, relative risks were not to be compared among the three groupings of elements at risk.

It is important to note that the risk ratings are applied conservatively across an entire hydrologic zone of influence, and do not necessarily apply to an individual element of risk within that zone. The risk ratings are relative terms only, and cannot be translated into a numerical probability of a consequence occurring at any particular location. Several things would have to occur, and several conditions would have to be met, before these risks are actually realized.

Take, for example, a house located in a zone of influence near the base of the east side of Perry Ridge. Assume the hazard of an open slope landslide in the hydrologic unit above the zone of influence is rated as “High” (although the “High” open slope landslide hazard has been applied to the entire unit, it
<table>
<thead>
<tr>
<th>Hazard</th>
<th>Consequence to Life and Limb</th>
<th>Consequence to Property</th>
<th>Consequence to Water Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Mod</td>
<td>Low</td>
</tr>
<tr>
<td>High</td>
<td>VH</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>Mod</td>
<td>H</td>
<td>+</td>
<td>4M</td>
</tr>
<tr>
<td>Low</td>
<td>M</td>
<td>+</td>
<td>5</td>
</tr>
<tr>
<td>Very Low</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(probably only refers to a portion of that hydrologic unit, and the remainder has a lower hazard rating). For a “Moderate” property consequence to occur, and hence the house to be at “High” risk: the open slope landslide has to occur; it has to occur at a location above the house; it has to travel far enough down the slope to reach the house; its flow path has to be in line with the house; and it has to have enough energy when it reaches the house to destroy it. For a “High” consequence to life and limb to occur, and hence life and limb to be at “Very High” risk, in addition to the above occurrences and conditions: someone has to be in the house at the time it is destroyed; and the open slope landslide has to have enough energy to not only destroy the house but to kill the person in the house.

Where “High”, “Very High”, and “Moderate” risks were identified, and based on the information contained in the background documents and the experience of the Panel, alternatives to the logging or road building on Crown Land as proposed in the TCP were suggested and recommendations made to reduce the effects of the proposed forest development on life/limb, property and water supply. The effect of the alternatives on the feasibility (economic or otherwise) of the development plan was not considered.

The difference between alternatives and recommendations, is that the alternatives were suggestions to be considered by the Table at subsequent planning meetings, while the recommendations should be carried out, in many cases prior to logging, regardless of the details of the final forest development plan.

Examples of suggested alternatives are: eliminate logging in specific areas; limit the ECA in specific areas (equivalent to reducing the rate of cut); add riparian reserve zones; modify road locations; eliminate specific stream crossings; eliminate specific roads and instead consider skyline logging, helicopter logging, or no logging.

Examples of recommendations are: extend geological hazard mapping in specific areas; carry out stream channel assessments on specific streams not already assessed; determine stream courses or watershed boundaries in some locations where they are poorly mapped; do Terrain Stability Field Assessments to address specific hazards; pay special attention to the location, design and construction of specific logging roads and creek crossings; design and construct specific logging roads to higher drainage control standards than normal; minimize ground disturbance associated with skidding in specific areas. Most recommendations were aimed at doing further geotechnical studies, or detailed planning or design in excess of minimum Forest Practices Code standards, to reduce identified hazards such as sediment production or landslides.

This risk assessment did not address the acceptability of risk. Thresholds of risk acceptability should be established by government, which must incor-
porate appropriate socio-economic and environmental factors into its decision making.

Conclusions and Discussion

Obvious questions to ask at the conclusion of such a study are: Was the process useful? Is it applicable to other forest planning areas? And considering that this was the first such study done for forestry purposes, should any major changes in the methodology be made for future studies?

Having a risk assessment study such as this done at the initial, or TCP, stage of planning helps identify major constraints, and set priorities for further mapping and information gathering for specific Forest Development Plans.

In considering possible future studies elsewhere, one should keep in mind that the information used in the Perry Ridge Risk Assessment exceeded what is normally available at this stage of planning, especially the stream channel assessments and hazard mapping on private land. The methodology we used, therefore, may be more applicable to studies for smaller, high-risk areas (such as populated alluvial fans) done at the FDP stage. At this stage, field work should be an important component of the study, and would be targeted at specific roads and harvesting areas. Future studies at the overview level are likely to be simpler, commensurate with the information available.

We found the consensual approach, using a threemember panel, to be useful in dealing with the inevitable lack of quantitative hazard data. However, the process is time consuming and expensive. We found the level of information available for the study, and its consistency and quality, to be suitable for the purpose of this study. However, future risk assessments in other areas are likely to have less rather than more information available. Considering the large areas of land with which forestry planning deals, it is unlikely that the routine collection of more detailed geologic and hydrologic information would be affordable for most planning studies.

We found that dealing with the public involvement aspects of this study introduced an unexpected amount of additional time (and therefore cost to the proponent, the Arrow Forest District). We found that the public, and even some forestry and engineering professionals with an interest in the process, had difficulty understanding the concepts of probability on which risk assessment is based, and the limitations of such a study. We also found that some sectors of the public had a very low tolerance for any risks associated with proposed development, and that they did not understand the concept that damage to a single property, which to them personally is of very high consequence if it is their own property, might be considered only a "Moderate" consequence in the context of a larger planning unit. This is not unexpected, and it is probably inevitable in any such study that attempts to keep citizens informed about risks that affect them locally.

A change that might reduce some of these problems is to develop consistent and accepted definitions of what types, magnitudes, and frequencies of hazard constitute "High", "Moderate", and "Low", and similarly, definitions for consequences. This change can only come about from the accumulated professional experience of doing a number of such studies.

References


———. 1998b. *Upgrade of TSIL C mapping and surface soil erosion hazard mapping for the east side of Perry Ridge*. Maps prepared for MOF Arrow Forest District, Castlegar, B.C.


