Terrain Management Code of Practice

Glynnis Horel and Shelley Higman

Introduction

The *Forest Practices Code Act of BC* (the Code) prescribed that terrain be managed for landslides. Terrain Stability Field Assessments (TSFAs) were required for unstable or potentially unstable terrain. Road designs, harvest, and silviculture plans were required to be consistent with the recommendations in TSFAs. By approving assessment reports, plans, and documents submitted by licensees, government assumed much of the responsibility for landslide hazard management. Under the Code, due diligence was not a defense available to licensees for landslides that occurred as a consequence of forest development.

Under the new *Forest and Range Practices Act* (FRPA), the government sets objectives for the protection of soil and water. As the new act is results-based, a licensee is not required to submit road designs for approval, undertake TSFAs for harvest areas, or hire professionals to carry out assessments. Instead, the licensee decides who to consult and what assessments to complete. Section 37 of the Forest Planning and Practices Regulation states:

An authorized person who carries out a primary forest activity must ensure that the primary forest activity does not cause a landslide that has a material adverse effect in relation to one or more of the subjects listed in section 149 (1) of the Act.

This section of the regulation shifts the responsibility for landslide hazard management from government to licensees (Chatwin 2005). Under FRPA, due diligence is a defense. It is also a defense under the *Private Managed Forest Lands Act* (PMFLA) and the federal *Fisheries Act*. What constitutes due diligence, however, is the subject of ongoing discussions among many professionals in BC and is beyond the scope of this article.

In response to this shift in responsibility, Weyerhaeuser Company Limited implemented a Terrain Management Code of Practice (CoP) for its BC Coastal Timberlands (BCCT) operations in January 2005. The CoP was developed as part of the due diligence process to demonstrate how the organization is meeting the objectives set out under FRPA, PMFLA, and other environmental legislation. Following Brascan Corporation's acquisition of BCCT in June 2005, the private land portion of BCCT became Island Timberlands Limited Partnership (ITLP). As part of its continuing operations, ITLP adopted the CoP. This article describes the CoP and its effectiveness as a tool for managing corporate liability.

What is the Code of Practice (CoP)?

A long-standing difficulty with terrain stability assessments and risk management has been the lack of consistent, *quantitative* definitions of hazard and consequence. (Refer to RIC 1996 for background descriptions of the terms "hazard," "consequence," and "risk" relating to landslides.) This has resulted in inconsistent interpretation of hazard levels, and different levels of tolerable risk in different timberlands operations. The CoP addresses these issues by providing definitions and strategies that:

- provide consistency in interpretation of hazard and risk across ITLP operations;
- promote consistency for all company and contractor professionals in establishing a level of tolerable risk; and
- create opportunities to control costs, manage liability, and improve predictions and outcomes.

Elements of the CoP

The framework for the CoP comprises the following elements:

1. descriptions of the roles and responsibilities within ITLP's organization;
2. definitions for landslides, steep terrain, landslide hazard, and consequence;
3. tools to assist in landslide prediction;
4. triggers for terrain specialist involvement, and quality control of specialist's work;
5. risk matrices incorporating landslide hazard and consequence levels, and harvest and road construction strategies for each risk category; and
6. provision for continual improvement.

Roles and Responsibilities

This element of the CoP defines responsibilities within the ITLP corporate structure, and sets expectations for business leaders, employees, and consultants in implementing the CoP. Other organizations could adapt a similar structure.

Definitions

For the CoP, a vegetated or non-vegetated landslide must cover 0.05 ha (500 m^2) or more. This is consistent with general practice for landslide inventories on the BC Coast because it is about the smallest size of

Continued on page 8

Continued from page 7

landslide that can be identified on 1:20,000 scale air photos.

Steep terrain is defined as Class IV and V, environmentally sensitive terrain (Es1 and Es2), potentially unstable and unstable (P and U) terrain stability units, and/or slopes steeper than 60%, depending on the mapping available for a given area.

Landslide hazard definitions are based on post-harvest landslide densities, expressed quantitatively as the number of landslides per 100 ha of logged steep terrain (Table 1). These values derive from recent landslide hazard mapping carried out by Weyerhaeuser (Rollerson *et al.* 2005) and from landslide inventories that have been done by consulting professionals as part of watershed assessments on Weyerhaeuser's tenure.

Landslide size classes are defined to compile and analyze landslide inventories (Table 2).

Consequence definitions are based on likelihood of sediment delivery to specified resources. Criteria are developed for:

- Key public resources:
  - domestic water quality
  - fish and fish habitat
  - public safety and infrastructure
- Other resources:
  - Wildlife Habitat Areas, Old Growth Management Areas
  - Culturally Modified Tree reserves and other areas of cultural significance
  - visual quality
  - soil productivity
  - forest resources

Tools for Landslide Hazard Prediction

Predicting where and when a landslide will occur is an inexact science. Equally difficult to predict are the size and direction of the landslide. Emerging research and modelling are helping practitioners better understand the dynamic nature of

Table 1. Landslide hazard definitions

High (H)	**>5 landslides per 100 ha logged on steep terrain**
Moderate (M)	**3 to 5 landslides per 100 ha logged on steep terrain**
Low (L)	**1 to <3 landslides per 100 ha logged on steep terrain**
Very Low (VL)	**<1 landslide per 100 ha logged on steep terrain**

Landslide = ≥0.05-ha event (smallest inventoried and smallest visible on air photos).
Steep terrain = Class IV/V; Es1/Es2; P/U; slope > 60%.

Table 2. Landslide size classes

Landslide size class	Landslide size (ha)	Description
1	**0.05–0.1**	**Very small**
2	**0.1–0.25**	**Small**
3	**0.25–0.5**	**Medium**
4	**0.5–1.0**	**Large**
5	**>1.0**	**Very large**

landslides. In developing the CoP, the forest company compiled and analyzed data on natural and development-related landslides in many watersheds. Landslide inventories and analyses are ongoing, but results to date have produced the framework for some CoP tools:

- analysis of landslide inventory data including frequency, correlations to slopes and bedrock types, and runout for the watersheds where these data exist;
- regional landslide frequency maps; and
- terrain vulnerability maps.

Biogeoclimatic mapping and precipitation data are used to extrapolate landslide inventory data from individual watersheds to produce regional landslide frequency maps that cover all ITLP's landbase. These maps are used for strategic planning and comparisons of watershed sensitivities.

We use regional landslide frequencies, slope gradient, and terrain stability mapping to produce terrain vulnerability maps. Specific regional criteria are incorporated into the terrain vulnerability maps for Haida Gwaii (Queen Charlotte Islands) because of its different glacial history and climate, and higher landslide rates than other coastal areas. Terrain vulnerability maps are used for planning cutblock and road locations, as well as determining when professional assessment is required. Terrain vulnerability maps also incorporate regional rainfall criteria for operational shutdown for landslides.

Terrain Specialist Involvement

The CoP includes triggers for retaining a specialist to conduct terrain stability assessments. It defines the role of the terrain specialist, and outlines the professional qualifications that ITLP requires for its specialist consultants. For quality control, ITLP also regularly commissions confidential, independent peer reviews of a sample of reports completed for ITLP by its terrain consultants.

ITLP will request an assessment by a terrain specialist based on the following criteria:

- watershed use (e.g., community watershed);
- hydrologic region (wet or dry), and regional landslide frequency;

- the site is on vulnerable terrain, as determined from the Terrain Vulnerability maps, and/or on-site indicators of sensitive terrain; and
- consequence, in terms of potential effects on specified resources such as fish habitat, public infrastructure, or private property.

The specialist's role as defined in the CoP focuses on evaluation of landslide hazard levels using the definitions in Table 1, and probable runout and geomorphic consequences in assessments of roads, cutblocks, and areas surrounding cutblocks. This information can assist forest managers to make appropriate land use decisions. In the CoP, company forest managers, not terrain specialists, are responsible for recommendations for harvesting strategies and silvicultural systems.

Table 3. Risk matrix

		Consequence			
		H	M	L	VL
Landslide hazard	H	H	H	M-H	M-H
	M	H	M	M	L
	L	M	M	L	L
	VL	L	L	L	VL

Terrain Management Strategies

Consequence is the sediment delivery potential to a specified resource. Examples of specified resources are public safety, private property water intakes, and fish habitat. The CoP provides overview-level definitions for sediment delivery potential by slope angle and runout distance between landslide initiation and the resource. However, terrain specialists are expected to use professional judgment when estimating sediment delivery potential for a specific site. For example, a high consequence would be a high sediment delivery potential to a specified resource. A very low consequence would be no possibility of a slide reaching that resource because of very long runout distances or terrain features that would contain the slide debris.

A matrix combining landslide hazard categories with consequence categories for roads and for cutblocks defines the risk categories (Table 3). Example strategies are given in Table 4 for different risk categories, ranging from conventional harvesting or road construction in low-risk categories to highly restricted harvest or road construction in high-risk categories. In the mid-range of risk, specific strategies are not prescribed and give company forest managers flexibility.

Table 4. Example strategies

Risk	Strategy number	Strategy description
High	**1**	Harvest: • Limit to single stem or small patches (i.e., keep canopy density high). Road Construction: • Avoid conventional construction. If non-conventional[1] methods do not reduce risk to low (i.e., green level), then avoid building the road.
Moderate-High	**2**	Harvest: • Harvest when expected size of the landslide < 0.1 ha and is consistent with other planning processes; or apply Strategy (1). Road Construction: • Avoid conventional construction. If non-conventional methods reduce risk to low (i.e., green level), then build when expected size of the landslide < 0.1 ha and is consistent with other planning constraints.
Moderate	**3**	Harvest: • Strategy depends on values at risk. RPF applies professional expertise to the area to define how to harvest (e.g., silvicultural system, seasonal constraints, maximize lift); or apply Strategy (1) or (2). Road Construction: • Build conventionally if the size of the landslide < 0.1 ha; otherwise, use non-conventional methods.
Low or Very Low	**4**	Harvest: • Conventional harvesting and silvicultural strategies (or any of Strategies 1, 2, or 3) unless constrained by other planning processes. Road Construction: • Conventional road construction methods. Use specific designs for road drainage in terrain rated as ≥ M hazard (below road).

[1] Non-conventional = either non-standard construction techniques, or temporary road, or both.

Continual Improvement

The CoP requires an annual inventory of landslides, and periodic re-analysis of landslide data to check for changes in landslide trends. The intent is that terrain management strategies will be adapted in response to trends (if applicable). In addition, ITLP plans to hold an annual terrain management workshop for its company and consulting professionals to convey information and improvements.

Continued on page 10

Continued from page 9

Concluding Remarks

The CoP is a decision-making framework for managing steep coastal terrain. Its flexible framework allows for practicing of due diligence when managing landslide risks in forest operations. One of the strengths of the framework is that it focuses on the principles of risk, not hazard. Organizations that use this approach can define for themselves what constitutes a material adverse effect and acceptable levels of risk. The CoP demonstrates that without legislative requirements, terrain mapping and terrain stability assessment remain key tools in the management of steep coastal terrain.

For further information, contact:

Glynnis Horel, P.Eng.
Ostapowich Engineering Services Ltd.
227 Horel Road
Salt Spring Island, BC V8K 2A4
Email: oesl@shaw.ca

Shelley Higman, P.Eng., P.Geo.
Island Timberlands Limited Partnership
1420 East Island Highway
Nanoose Bay, BC V9P 9A3
Email: shigman@islandtimberlands.com

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Stream Shade as a Function of Channel Width and Riparian Vegetation in the BC Southern Interior

Pat Teti

Since the pioneering stream temperature work by George Brown (1970), ecologists and hydrologists have recognized that reducing shade is the main mechanism by which timber harvesting can increase the temperature of small streams. Therefore, the retention and recovery of shade are logical management objectives on streams in which high summer temperature is an issue.

Guidelines for the retention of stream shade and the protection of riparian areas vary considerably between jurisdictions and between agencies within the same jurisdiction. The state of Oregon requires the retention of all trees within 6.5 m (20 feet) of the high water mark of all streams with domestic or fish use (Robison *et al.* 1999). The state of Washington's watershed analysis manual (Washington Department of Natural Resources 1997) specifies target values for percentage shade for different types of streams. For stream temperature protection, British Columbia's *Forest Planning and Practices Regulation* simply calls for the retention of sufficient shade to prevent a material adverse impact on fish in streams that have been designated as temperature sensitive.

It is recognized that riparian areas are managed for many purposes other than stream temperature and that it is possible for stream temperature to be protected with simple reserves without reference to quantitative shade or temperature criteria. However, increasing emphasis on environmental indicators suggests that forest professionals should have a quantitative understanding of shade on streams where shade is important.

The ability of forest professionals to manage stream temperature in BC is limited by the relative novelty of appropriate shade measurement methods, a lack of baseline shade data, and an absence of quantitative shade guidelines. This paper addresses the first two deficiencies by describing a practical sampling procedure and by quantifying how stream shade varies as a function of simple riparian characteristics.

Methods

Many researchers have developed a variety of stream shade parameters and methods to measure them. Brazier and Brown (1973) described a user-made instrument for making ocular estimates of "angular canopy density" or ACD which they defined as percentage shade during the 4 hours at mid-day. They and other authors (Wooldridge and Stern 1979; Beschta *et al.* 1987) argued that shade, or the lack of it, was overwhelmingly important during this period of highest solar irradiance and incident angle. Davies-Colley and Payne (1998) adapted the LAI-2000