Landslide Hazards in BC

Achieving Balance in Risk Assessment

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British Columbia's mountainous and geologically diverse terrain, and the variety of landslide hazards that come with it, pose a continuing challenge to geotechnical engineers and geoscientists who specialize in this field. Population centres, transportation routes, utilities and natural resources all have been significantly affected by landslides over the past century. As a result, Canadian landslide hazards experts are among the world leaders in their field, and many BC professionals play an important role in consulting assignments abroad.

Perhaps surprisingly, BC has experienced (comparatively speaking) fairly limited impacts from landslides despite its steep terrain, for various reasons. However, increasing development pressures into areas of unstable slopes that are susceptible to landslides means there is a potential for much greater losses in the future. Therefore, the careful assessment and management of landslide hazards and risks by qualified specialists, based on scientific principles, must continue.

In particular, the expert faces the difficult task of maintaining a rational balance between overestimating or underestimating landslide risks: both can be very costly to society. Yet risk management decisions involve other stakeholders in addition to professional specialists. Facilitating interaction between, and sharing of responsibility with, other parties involved in the development process will require the adoption of a risk-based approach to landslide hazards management, as well as corresponding changes in applicable provincial legislation.

The Human Costs

A review of landslide accidents with three or more fatalities in Canada between 1880 and 2001 prepared by Evans (2003) showed that four major BC incidents occurred at a cost of 126 lives. This includes the 1915 rock slide near Britannia, the second most lethal landslide in Canadian history. Over the last 50 year period in BC, Evans lists 13 incidents with a cumulative cost of 59 lives. Another 16 fatalities can be added from the author's personal knowledge of small-scale accidents over the last 25 years.

Combining these records, the average human cost of landslides in BC amounts to about three lives per year. At least one-third is due to debris flows with the remainder divided between rock slides, rock falls and flow slides. The average annual risk of death by a landslide for a BC citizen is about 1 in one million — only slightly more than the chance of being killed by lightning.

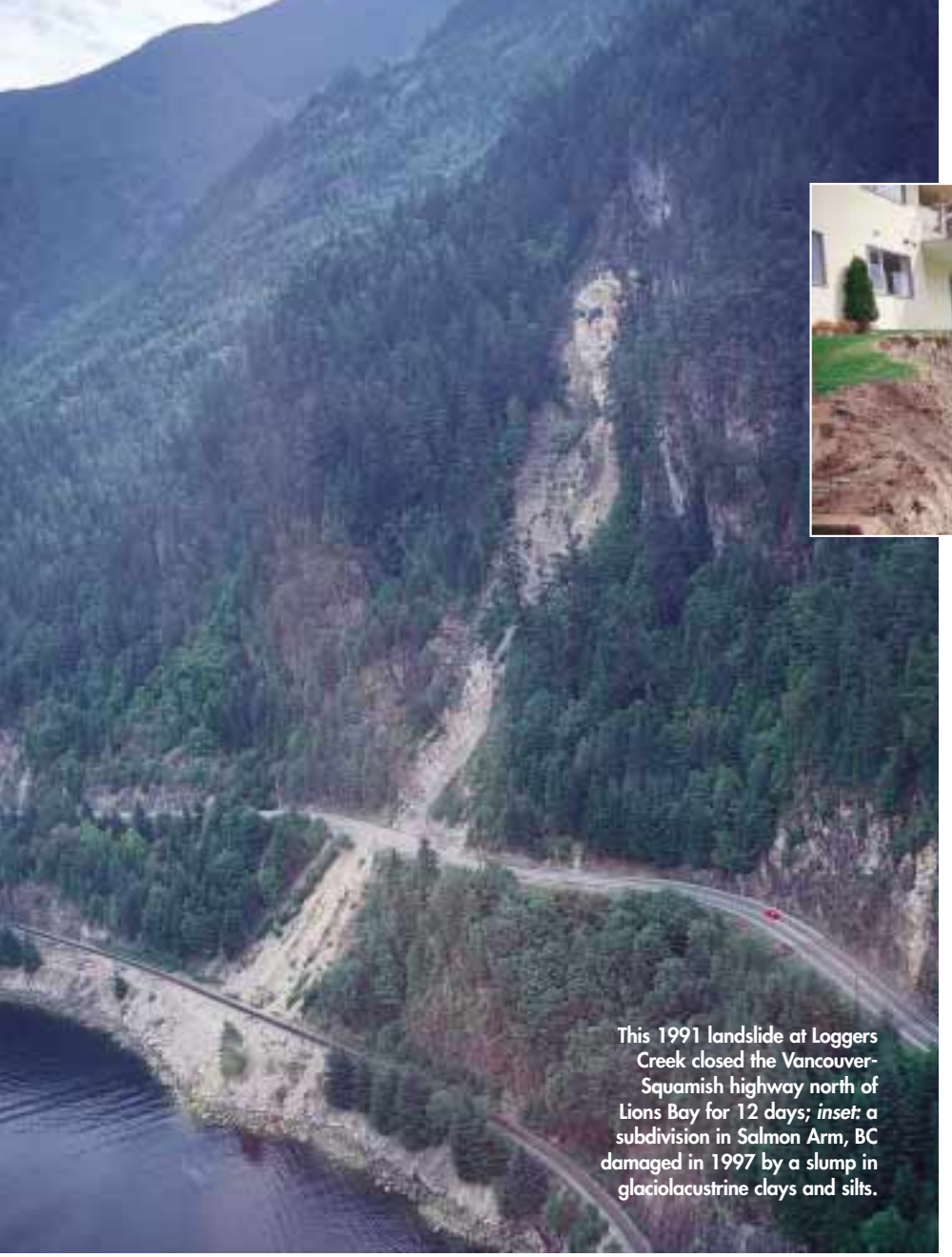
These numbers pale in comparison with the 25,000 persons killed by a debris flow cluster in Venezuela in December 1999; the 30,000 buried by a lahar at Armero, Colombia in 1996; or the 15,000 engulfed in a rock avalanche at Huascaran, Peru in 1970; not to mention the 250,000 lives destroyed by earthquake-triggered flow slides in the Loess Plateau, China in 1921.

There are three probable reasons for the modest losses in BC: a) low population

Table 1: Landslide damage in Western Canada (1880-2001)

Sector and Landslide Types	Estimated Annualized Losses ($ million/year)	
	Direct Damage[1]	Prevention
Residential (debris flows, slides)	2.5 - 3.5	1 - 2
Roads and bridges (debris flows, rock fall, slides)	4	5.5
Railways (debris flows, rock fall, slides)	2.5 - 3.5	2 - 4
Hydro power network (rock slides)	1	4
Pipelines (earth and rock slides)	1 - 2	2 - 4
Forestry[1] (debris avalanches and flows)	2 - 3	1
Subtotal	**12 - 16**	**16 - 21**
Residential land sterilization		10 - 50
Forest harvestable land loss	16 - 48	
Total	**28 - 64**	**26 - 71**

[1] Exclusive of environmental and fisheries losses



This 1991 landslide at Loggers Creek closed the Vancouver-Squamish highway north of Lions Bay for 12 days; *inset:* a subdivision in Salmon Arm, BC damaged in 1997 by a slump in glaciolacustrine clays and silts.

density, which still allows us to avoid the development of the most exposed lands, b) lack of widespread weathering thanks to scouring of the landscape by Pleistocene glaciers, and c) relatively rational and safety-conscious government policies relating to development.

The Material Costs

No detailed compilation of material losses from BC landslides has been completed to date. The author has made estimates based on advice from a number of individuals involved first-hand in landslide study and management (as listed at the end of this article). The estimates, shown in 2004 Canadian dollars, are very approximate but in the correct order of magnitude:

Housing. The author is aware of 23 houses destroyed by BC landslides over the last 25 years. At an estimated cost of $200,000 each this amounts to about $0.5 million per year (M/y), allowing for an incomplete record. Damage to structures located on unstable terrain was $40-60 million over the last 20 years ($2-3 M/y).

Preventive construction, mainly debris flow barriers, has cost $1-2 M/y over the last few decades. Preventive cost also includes the value of development land that has been sterilized due to perception of hazard, which is very difficult to quantify. On the assumption that each of 10 geotechnical companies designates 10 ha per year as hazard zones, this amounts to 100 ha, worth $10-50 M/y.

Transportation. Road reconstruction or stabilization costs $1-15 million each year, averaging about $3 M/y. Court settlements due to rockfall accidents have amounted to about $1 M/y. The yearly budget for rock slope maintenance and landslide stabilization on highways is $3.5 and $2 M/y respectively.

Six train derailments in the last two decades add up to about $30 million, or $1.5 M/y. Track repair and stabilization on the three railway lines costs approximately $1-2 M/y and rock and soil slope maintenance adds another $2-4 M/y.

Hydro power. During the last 30 years, BC Hydro completed three major stabilization projects on landslides threatening reservoirs with a total cost of about $60 million ($2 M/y). Various dam design changes and operational restrictions due to landslide hazards amount to another $1 M/y. Their ongoing landslide monitoring program costs about $1 M/y. Apart from a powerhouse damage incident in 1953, the only direct landslide damage involves transmission towers, probably less than $1 M/y on average.

Pipelines. Significant pipeline failures occur in BC at a rate of once every 1-2 years, causing direct losses in the order of $1-2 M/y. This includes last year's pipe rupture in the Skeena region, caused by a clay flow slide, which interrupted gas service to the City of Prince Rupert for over a week. Preventive stabilization and rerouting costs $2-4 M/y.

Forestry. Direct costs in terms of road, bridge, camp and equipment damage are widely distributed and very difficult to estimate, probably in the range of $1-2 M/y, in addition to another $1 M/y for preventive work. Natural or artificially-caused landslides often destroy harvestable timber and render land unproductive. Assuming that only 400 ha of harvestable terrain are impacted annually, this amounts to a cost of $16-48 M/y.

Table 2: Estimated potential for major landslide damage

Possible Event	Potential Fatalities	Potential Cost ($ million CDN)
Landslide cutting a pipeline and causing an oil spill	0	30 - 50
Debris flow or rock fall impacting a bus or train	20 - 50	5 - 50
Cluster of debris flows impacting communities and transportation links in a region	10 - 50	10 - 50
Rock avalanche impacting a community	0 - 200	10 - 50
Rock and earth slides triggered by a major earthquake	0 - 200	10 -100
Rock avalanche destroying a major dam	Thousands	1,000

Rapid urbanization of sloping terrain in Coquitlam, BC reflects increasing development pressures.

Adding the Numbers

As summarized in Table 1, the total yearly cost of landslides in BC amounts to $28-37 M/y excluding the cost of land sterilization and forest harvest losses, which are extremely difficult to quantify. Rough estimates of these two items raises the total to $54-135 M/y. In either case, the cost of prevention exceeds the amount of direct losses by 30-150%.

Per capita cost of landslides in BC is $7 to $33. Landslide cost as a percentage of the provincial GNP is less than 0.2%, a very small figure compared to the 1-5% suffered by some South American and Asian countries.

The BC estimates do not include indirect costs such as disruption of major lifeline corridors (which could cost as much as $5-10 million per day) and the disruption of access or essential services to communities. Neither do they include environmental costs and losses suffered by fisheries, which may be very substantial.

The concern of landslide experts is that a single event, or an extraordinary cluster of landslide events, could easily upset these comfortable numbers. Some very arbitrary but not unrealistic estimates are shown in Table 2.

It must also be considered that landslide damage is narrowly focused and landslide accidents can have a profound effect on a community or a region even if they are unimportant on the provincial scale. Also, since landslide losses are not insurable in BC, they can have devastating impacts on individuals or families.

The conclusion from the above approximate estimates is that while landslides do not perhaps rank too highly in terms of directly experienced losses in Canada, they cannot be neglected in view of their high potential impact.

Professional Responsibility

Proposed residential housing developments located in hazardous areas in BC are subject to the provisions of the *Municipal Act,* one of which requires that a certificate be issued by a registered professional engineer to ensure that the land is "safe for the purposes intended."

There are significant problems with this legislation as currently written. First, it ignores the potential role played by professional geoscientists, many of whom are highly qualified to assess landslide hazards.

Second, both in a linguistic and legal sense, the word "safe" implies the complete absence of any hazard or risk. Those familiar with natural processes know that this is an impossible criterion. There is always some level of hazard and, when a structure is present, some level of risk. What the expert really means by "safe" is that he or she judges the perceived risk to be acceptable.

This begs the question as to whether it is realistic for a practising professional to declare acceptable risks on land owned by other parties and to assume full responsibility for any eventual loss. Typically, the practitioner may study tens of locations every year and many hundreds over a career. Even if the "acceptable" risk level on each site is very low, the professional will eventually accumulate enough liability to make a fatal error almost a certainty. This is a heavy burden to bear by a professional group that is among the least well compensated (Morgenstern, 2000).

Risk Level versus Acceptability

For the above reasons, there is a growing belief among landslide experts that the

current legislation should be modified to leave the decision on "acceptability" to the client and to limit the professional's role to determining the *level* of hazard or risk.

Under this scenario, the geotechnical study report would specify only the type, intensity and probability of the landslide hazard. Determining the level of risk often requires the involvement of other professionals such as structural engineers.

Determining whether the specified level of hazard or risk is *acceptable,* however, would rest with the owner in the case of single-family houses and other privately owned facilities, subject to laws and regulations to protect the third party. In the case of high-density housing and public property, the public authority would determine acceptability.

Certain municipalities and regions in BC have already adopted a risk-based approach to development approval. APEGBC has made recommendations to the provincial government to change the existing legislation in this regard. An ad hoc working group led by Dr Matthias Jakob PGeo was recently formed to propose professional practice guidelines for landslide hazard assessments.

Conclusion

Worldwide, landslides are one of the costliest natural hazards in terms of human and material losses. To date, BC has been fortunate to avoid the magnitude of losses experienced in other countries, but these statistics may change in the face of increasing development pressures. Modernization of existing legislation will provide a more equitable means of distributing liability between the various stakeholders involved in the development process.

Obviously, in order for a risk-based approach to landslide hazards management to be effective, practitioners must continue to strive to improve quantitative methods of hazard and risk assessment through practically-oriented research.

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