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# Natural hazards in British Columbia: an interdisciplinary and inter-institutional challenge

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**Abstract** Although British Columbia experiences many natural hazards, there is as yet no unified policy to promote natural hazard management in the province. The problem is not in the quantity and quality of geoscience assessment of natural hazards, but instead, it is suggested, in the isolation of that work from broader risk perspectives and in the lack of clarity of division of responsibilities between various levels of government. The example of recent changes in perception of the terrain stability problem illustrates how natural hazard problems are driven by social and political priorities rather than by geoscience priorities.

**Key words** Natural hazards · Risk studies · Floods · Slope failures · Snow avalanches · Earthquakes · Management, multi-institutional, interdisciplinary

## Introduction

The earth sciences have a major stake in the interpretation and solving of natural hazard problems. But we are not the only scientists who are central to such problems. This paper attempts to define the complexity of the natural hazards problem and, with the aid of examples drawn primarily from British Columbia, indicates the role of interdisciplinary research and multi-institutional initiatives in light of mounting social costs associated with this problem area.

British Columbia is a province approximately the same size as the combined areas of Germany, France and Switzerland, yet with a population of fewer than 4 million. Of the provincial area, 18% is alpine tundra, snow and ice, and approximately 64% is mountainous (Fig. 1). It is located in a geologically active zone of interaction between the convergent North America plate and the Pacific plate and, generally, the Pacific plate subducts below the North America plate. Problems associated with seismicity, flooding, snow avalanching and slope failure are therefore widespread.

In 1992 three of the provincial ministries (Energy, Mines and Petroleum Resources; Transportation and Highways; and Environment, Lands and Parks) determined to establish the following:

1. The state of geologic hazard programs in British Columbia
2. What legislation was available
3. Which agencies were responsible for the coordination and implementation of geologic hazards research
4. What were the perceived research and monitoring needs and priorities
5. How a geologic hazards information and research database could be established

A conference was held (Bobrowsky 1992) and three kinds of recommendations were made:

1. Immediate steps for the protection of people
2. Scientific recommendations
3. Ways of incorporating geologic hazards databases into urban and regional planning

A number of these recommendations have been implemented, but extreme difficulty has been experienced with those of the third kind, namely the incorporation of the geological data base into urban and regional planning. Reasons for this difficulty point to the heart of the thesis of this paper. There are three specific reasons:

1. The mind set of the earth science community is commonly that it alone has the expertise on natural hazards and that the problem is at most a two-part one, involving hazard assessment and hazard management.
2. In reality, the role of earth scientists, though crucial, is only one component in at least a four-part process of hazard assessment, hazard perception, hazard

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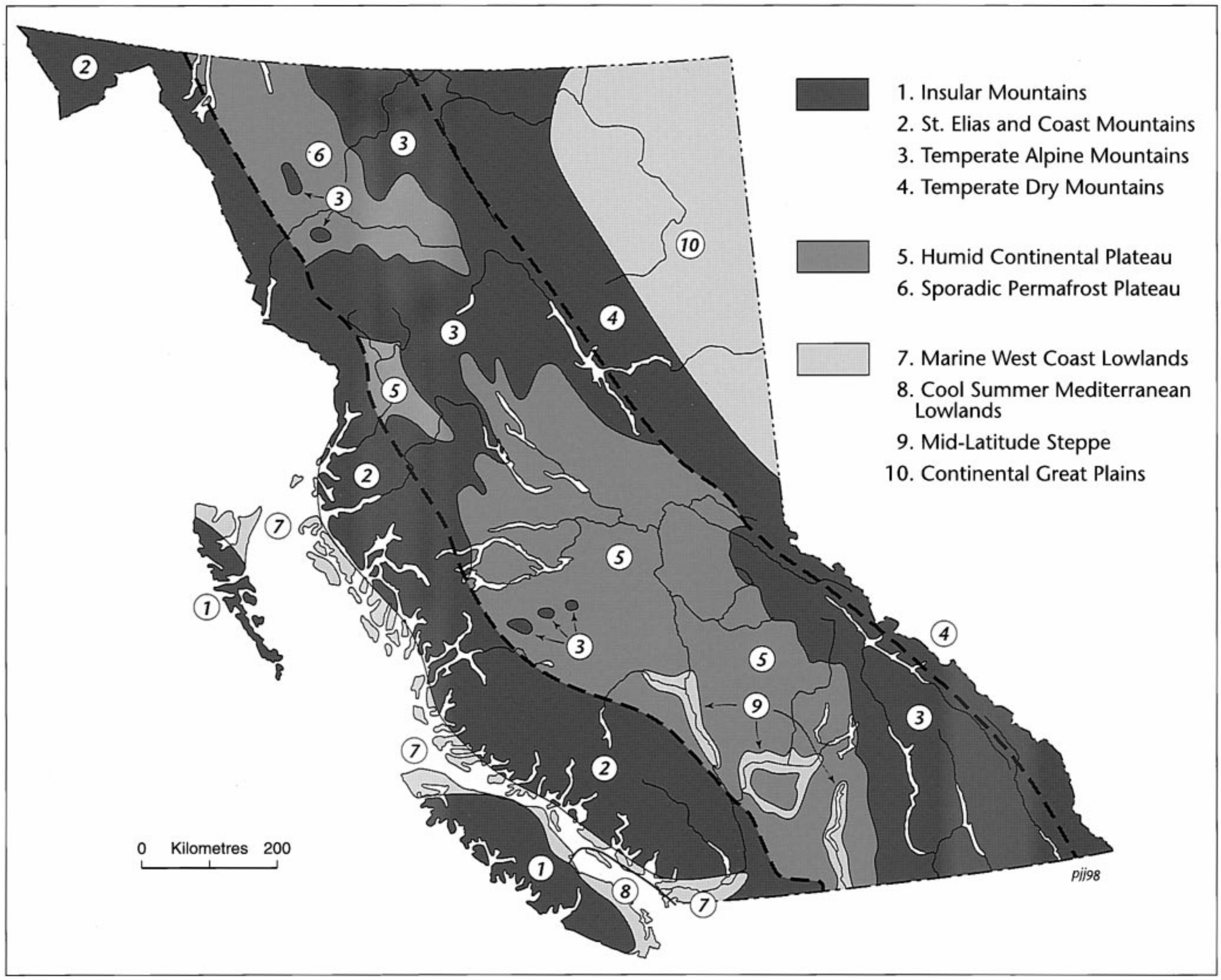


**Fig. 1** Physical geographic regions of British Columbia

communication and hazard management (Slovic 1986; Slaymaker 1996).
3. Urban and regional planners were not present at the meeting where these recommendations were made.

More generally, natural hazards (White 1974; Clague 1991) are best considered within a broader context of management for sustainable development; this, in turn, leads to a focus on decision making under conditions of uncertainty (Morgan and Herrion 1992).

## Componentsof the problem

If it is agreed that decision making under uncertainty is a focal concern, then it is necessary to look to the field of risk studies for assistance (Slovic 1986). A second component of the problem is a clear identification of the categories of natural hazard and the differences between them (Slaymaker 1996). A third component is to identify available mechanisms, agencies and policies for dealing with the problem.

### Risk studies

There are four well-recognised areas of the risk-studies field: risk assessment, risk perception, risk communication and risk management and/or mitigation. Risk assessment seeks to give precise description of the nature of the hazard and the extent and type of exposure to the hazard in various populations. Risk is commonly described as the product of probability of occurrence of a natural hazard and its societal consequences (Whyte and Burton 1980). Risk perception is the common sense understanding of hazards, exposure and risk, arrived at by a community through intuitive reasoning. Public policy decisions are almost always driven by perceived risk among the population affected and among decision makers, and they are commonly at variance with technical risk assessments. Risk communication is the social dialogue about risk by a variety of parties. It has the practical objective of searching for consensus on how to assess and manage hazards. It also includes a process of overcoming misperceptions through public education policy. Risk management is the process of determining an adequate response to hazards which, ideally, incorporates risk assessment, risk perception and risk communication. Strategies include controlling, mitigating or sharing the adverse impact of hazards and indeed can include enhancing the beneficial outcomes of hazards. Educational, economic and regulatory approaches to hazards can also generate benefits that outweigh the adverse impacts of hazards.

The earth science community has the expertise and experience to make the best assessments of the hazard. But it is not at all clear that earth scientists have the lead expertise in the other three components of the hazard problem. Information processing with respect to people's attitudes and behaviour towards impending disasters and changes in risk-taking behaviour over human life spans, as researched in developmental psychology, have given rise to a distinct sub-field of hazard communication. In part, this field deals with disparities between the meaning of risks as assessed by experts and as understood by the general public. Given that these disparities exist, how can the quality of dialogue about hazards across the gap that separates the experts from the general public be improved? Secondly, how can this improved dialogue about hazards be applied towards achieving a higher degree of social consensus on the inherently controversial aspect of managing environmental hazards? (Leiss 1990). A classification of firmly held perspectives on hazards, following the discussion of Krimsky and Golding (1992), is helpful (Table 1).

With respect to hazard assessment, the earth scientist will assess the absolute magnitude and frequency characteristics of the event, the social scientist will assess the magnitude of the disruption of the regional development plans, and the applied scientist, earth scientist and social scientist should ideally communicate over the range of alternative responses. With respect to hazard perception and communication, this has, until recently, been the exclusive domain of the social scientist (Wynne 1991) and has been ignored by earth scientists. "The barriers that inhibit communication between our profession and the public must be broken down to convey the critical importance of earth science to society" (Clague et al. 1997). In a similar vein, it can be said that it is of critical importance that we also learn from citizens and from social scientists about society. We are not alone in providing primary data about natural hazards. With respect to hazard management and mitigation, much has been written by earth scientists and engineers. Ultimately, however, it seems clear that this phase of the natural hazard problem depends for its implementation on political will at municipal, regional, provincial, national and even global scale. Academics, their institutions and individual developers can apply pressure, but ultimately, in a democratic society, natural hazards will be reduced by broader societal involvement in decision making. This is then a further argument for not only interdisciplinary and multi-institutional activity, but also for a broad educational commitment to sustainability.

The earth science community, at least in British Columbia, is still struggling to come to grips with hazard perception and communication. The essence of the argument advanced here is that at each stage of the natural hazards problem there needs to be interdisciplinary and multi-institutional involvement. The precise details will vary from country to country and in relation to different hazards. The most important, and, up until now, the least palatable point for earth scientists, is that population pressure, not geoscience, is the driver in natural hazard problems. Hence, mutual respect among

**Table 1** Classification of risk perspectives. (Modified from Krimsky and Golding 1992)

| | Geoscience | Engineering | Economics | Psychology | Social geography, sociology | Cultural geography, anthropology |
|---|---|---|---|---|---|---|
| Input term | Mapped/ Modelled value | Expected value (synthesised) | Expected utility | Subjective expected utility | Perceived fairness | Shared values |
| Methodology | Historical record Experiments | Event analysis | Risk/benefit analysis | Psychometrics | Surveys/ structured analysis | Grid group analysis |
| Scope | Environment | Safety | Fiscal viability | Individual | Social interest | Cultural cluster |
| Application | Science and protection of the environment; | Safety engineering; | Decision making; | Policy making and regulations; conflict resolution and mediation | | |
| | Risk assessment | Risk mitigation | Risk assessment | Risk perception | Risk communication | |
| Function (instrumental) | Standard setting for early warning system | Improving early warning system | Resource allocation | Individual assessment | Fairness, equity, political acceptance | Cultural identity |
| Function (social) | Assessment | | Coping with uncertainty | | Political legitimation | |
| | | | Risk reduction and policy selection | | | |

**Table 2A** Province of British Columbia: role in natural hazards

| | Flooding | Tsunami | Landslide | Avalanche | Earthquake |
|---|---|---|---|---|---|
| Identification | ENV (1)[a] | IOS[a] | – | – | Building code[a] |
| Management | | | | | |
| Subdivsions | ENV (2) | ENV (2) | HWY/Local (3) | HWY/Local (3) | – |
| By-laws | Local (5, 6)<br>ENV<br>MARC | Local (5, 6)<br>ENV<br>MARC | (5) | – (5) | Building code |
| Community plans | Local (5)<br>ENV<br>MARC | Local (5)<br>ENV<br>MARC | Local (5)<br>HWY<br>MARC | Local (5)<br>HWY<br>MARC | – |
| Building inspection | | | | | |
| Building code | – | – | – | – | Local |
| Geotech report | Local (7) | Local (7) | Local (7) | Local (7) | |
| Crown lands | Hazards Identified by referral to provincial agencies and local authorities (8) | | | | |
| Mitigation | | | | | |
| Forecast/monitor | ENV[a] | IOS/PEP[a] | – | – | PGC[a] |
| Works | ENV (10)[a]<br>Local | – | – | – | – |
| Operation and maintenance | ENV (9)[a]<br>Local | – | – | – | – |
| Disaster response | | | | | |
| Preparedness | Local<br>PEP<br>ENV | Local<br>PEP | Local<br>PEP | Local<br>PEP | Local<br>PEP |
| Response | Local<br>PEP (11)[a]<br>ENV/HWY | Local<br>PEP (11)[a] | Local<br>PEP (11)[a] | Local<br>PEP (11)[a] | Local<br>PEP (11)[a] |
| | Response involvement by all provincial agencies as required | | | | |
| Recovery | Local<br>PEP (11)[a]<br>ENV | Local<br>PEP (11)[a] | Local<br>PEP (11)[a] | Local<br>PEP (11)[a] | Local<br>PEP (11)[a] |
| | Recovery involvement by all provincial agencies as required | | | | |
| Research/information | ENV | IOS[a] | Forests<br>Mines<br>HWY<br>ENV | HWY | PGC[a] |
| | Research/information universities, NRC, GSC and federal agencies[a] | | | | |
| Operational | Individual provincial agencies within area of operation | | | | |

all scientists and between all levels of action is a necessary precondition to success. It is inappropriate to think that earth scientists should be given the lead role solely by virtue of their expertise in geoscience.

## Categories of natural hazard

In this paper only four categories of natural hazard are differentiated; there are of course many more (e.g. Smith 1996). Firstly, flood hazards are considered. In British Columbia coastal flooding, river floods and local flooding are differentiated. Coastal flooding is driven principally by either tsunami or storm surge events. River floods characteristically are either snowmelt or rainfall events. The large river basins produce snowmelt floods that last for days or even weeks, but which are predictable. Rainfall events produce flashier and less predictable floods, either from intense rainstorms or from rain-on-snow events in the fall. Local flooding may result from ice build-up or from blocked drainage. Secondly, mass movements constitute significant hazards in mountainous regions. These hazards are usually divided into two categories of high-magnitude, low-frequency events, incorporating more than a million cubic metres of material and low-magnitude, high-frequency events. In the former category belong rock avalanches from mountain slopes, debris avalanches from volcanoes and massive retrogressive spreading failures. By contrast, rock falls, rock, debris and earth slides, and debris flows and debris torrents incorporate less material but are a regularly occurring phenomenon. Indeed, this latter category has been attracting much more attention recently. Thirdly, snow avalanching is a significant hazard. The traditional distinction is one between loose avalanches, which usually involve surface or near surface snow, and slab avalanches, which are initiated by failure at depth in the snow cover. Dry slab avalanches are responsible for most of the damage and fatalities from avalanches. Ice, slush and roof avalanches are local hazards. The fourth category of hazard that is particularly important in British Columbia is that of earthquakes. There are three major factors that are considered with respect to the seriousness of the hazard: intensity of shaking, type of structure and foundation soils. Deep deposits of

**Table 2B** Relevant British Columbia government legislation and programs respecting natural hazards (after Bobrowsky 1992). *MCL* Ministry of Crown Lands; *ENV* BC Ministry of Environment; *HWY* BC Ministry of Transportation and Highways; *MARC* Ministry of Municipal Affairs, Recreation and Culture; *PEP* Provincial Emergency Program; *IOS* Institute of Ocean Sciences; *PGC* Pacific Geoscience Centre; *Local* Local Authorities, Regional District, Municipality, City, Town, etc.

| Notes | Agency | Hazard | Aspect | |
|---|---|---|---|---|
| (1) | Agreement respecting floodplain mapping in BC | ENV | Flooding | Identification |
| (2) | Sect. 82–85 Land Titles Act | ENV | Flooding | Management |
| | | | Erosion | Management |
| (3) | Sect. 86 Land Titles Act | HWY | All | Management |
| | | Local | All | Management |
| (4) | Municipality Enabling and Validating Act | MARC | Flooding | Management |
| (5) | Municipal Act Sect. 945, community plans | | All | Management |
| | Municipal Act Sect. 952, rural land use | MARC | All | Management |
| | Municipal Act Sect. 970, non-conforming | | All | Management |
| | MunicipalAct Sect. 976, development permit | | All | Management |
| | Municipal Act Sect. 978, tree cutting | | All | Management |
| (6) | Municipal Act Sect. 969, floodplain elevation | MARC | | |
| | | ENV | Flooding | Management |
| (7) | Municipal Act Sect. 734, geotechnical report | Building inspector | All | Management |
| (8) | Land Act Sect. 8 (inter-agency referral) | MCL | All | Management |
| (9) | Dyke Maintenance Act | ENV | Flooding | Mitigation |
| (10) | Flood Protection Program | ENV | Flooding | Mitigation |
| | River Protection Assistance Program | ENV | Flooding | Mitigation |
| | Fraser River Flood Control Program | ENV[a] | Flooding | Mitigation |
| (11) | Disaster Financial Assistance Program | PEP[a] | Flood/landslide | Response/recovery |
| | Environment Management Act | ENV | All | Response |

Dash indicates no designated agency
[a] Federal government participation

loose and soft soils, such as those underlying the Fraser delta, can amplify the shaking and cause a shift in the predominant period and induce liquefaction.

## Mechanisms, agencies and policies available

Table 2A provides a matrix identifying the agencies involved with hazard management in British Columbia. The implication from this table is that hazard identification, where it is actively undertaken, is a responsibility of the senior levels of government. It is worth noting that other than in the cases of flooding and tsunami, hazard identification relies on a reactive rather than a proactive mechanism. On the other hand, management of development impacted by natural hazards is the responsibility of local governments. While local government may be a reluctant partner in hazard management, it has a large responsibility.

Local government is initially involved through the development of Official Community Plans. The Municipal Act requires a written statement including restrictions on the use of land subject to hazardous conditions or that is environmentally sensitive to development. The OCP also utilises Development Permit Areas under the Municipal Act to designate areas for the protection of development from hazards. Local governments have access to many provincial agencies for hazard identification. Hazard mitigation which involves the forecasting and monitoring of hazards and the development of engineering works to mitigate the impacts of the hazard has largely been the responsibility of the senior levels of government. This responsibility is associated with the level of professional staff required to forecast and monitor hazards and the significant investment required to develop engineering works, both of which are beyond the capacity of local government. Operation and maintenance is undertaken by local authorities.

Notwithstanding the significant developments that have been made by geoscientists and engineers in identifying and mitigating natural hazards, there is yet to be identified a unified process for hazard management at any level of government in British Columbia. Table 2B also shows significant areas where no responsible agency has been identified.

Floodplain management is perhaps the most advanced area of hazard management in the province. Due to the frequency of flooding, the potential for loss of life, property damage and the trauma associated with river flooding, a partnership between all levels of government has evolved to address floodplain management, including identification, management, mitigation and disaster response. This program has evolved since the 1948 Fraser flood (Fig. 2) which caused significant damage in the lower Fraser valley, costing approximately US$20 million. A similar flood in the Fraser River valley today would translate into billions of dollars of damage were it not for existing floodplain management and protective works.

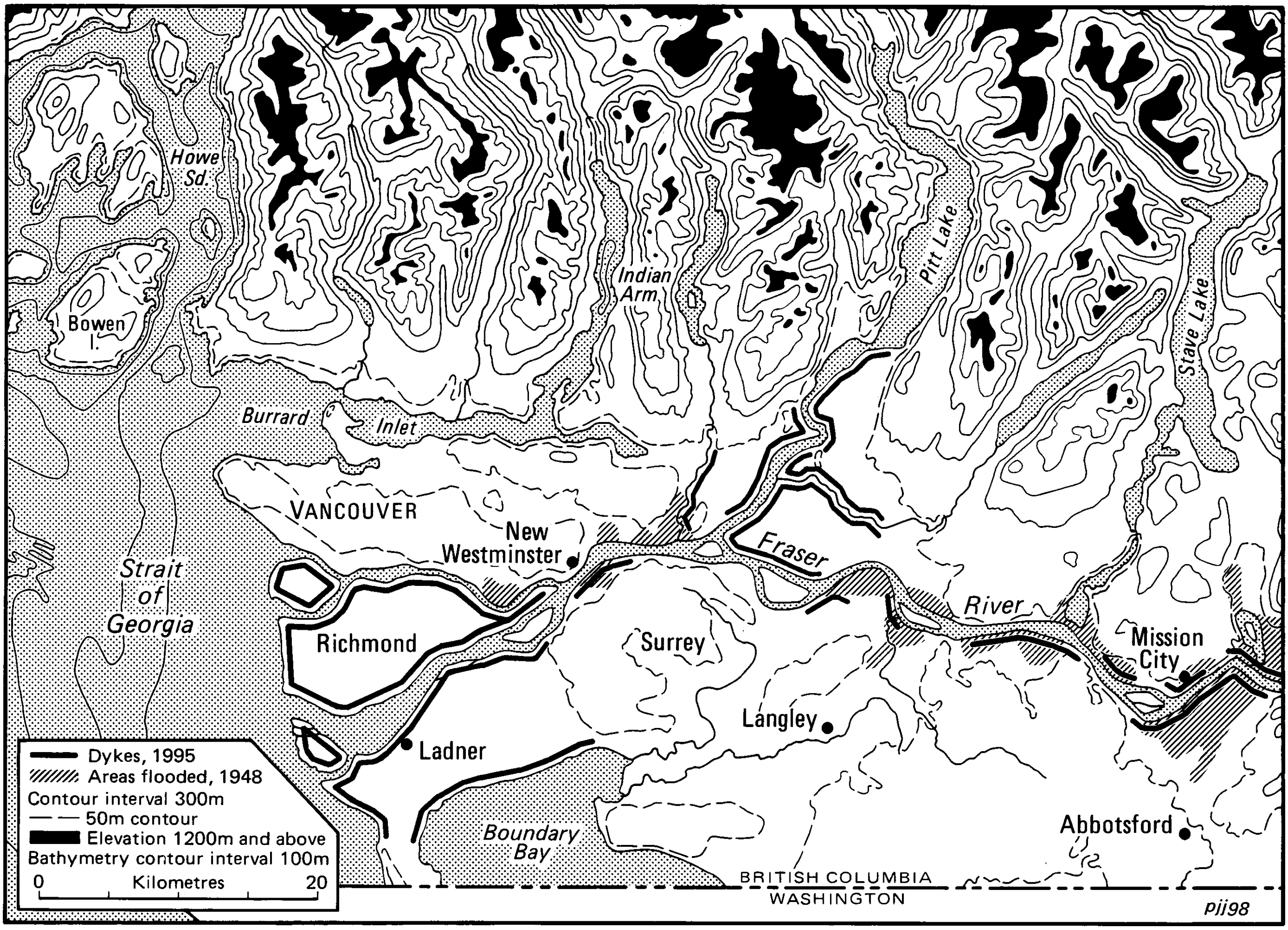


**Fig. 2** The flood hazard in the lower Fraser valley: extent of dyking (1995) and areas flooded in 1948, the year of the most recent extensive flooding

## The emergence of terrain stability mapping as a central concern in the British Columbia natural hazards problematique

The past two decades, commencing perhaps with a controversial editorial in the B.C. Professional Engineer (Farquharson et al. 1976), have seen a dramatic increase in research and debate over natural hazards policy (or the absence of it) in British Columbia. Many factors have contributed to this, among them the high rate of population growth (Eisbacher 1982), the lively debate over resources and the environment that led to a demand for information about hazards and terrain stability (Ryder and Howes 1984), a recognition of ecological concerns associated with fish and forestry (Church 1983), an extreme climatic event on the Queen Charlotte Islands in 1978 (Schwab 1983), speculation over possible implications of climate change (Slaymaker 1990) and the international pressure brought to bear on our inefficient timber-harvesting practices (Ellis 1989). In other words, the social context has led to a total shift in emphasis within the British Columbian natural hazards community. As a result of these broad convergent factors, there has occurred an explosion of research activity on terrain stability. Because forestry, tourism, mining and fisheries are key elements in the provincial economy and the province's population is growing at a rate of 2.5–3% per annum, there is widespread pressure on the use of land. As indicated previously, land in British Columbia is generally mountainous and in many places is close to threshold conditions for slope failure. Slope failure, both naturally occurring and road-building related, causes productive forest site loss, increased industrial operating costs (to replace roads and bridges), interferes with fisheries by damaging habitat where fine sediment impinges on a productive watercourse and reinforces environmentalists' negative image of economic development activities in the province. Indeed, the whole concept of sustainable development may be viewed cynically by the public where there is lack of serious attention to sustaining the land base. The focus on terrain stability is therefore understandable in terms of: (a) its relevance to resource development planning; (b) its relevance to land use and development planning; and (c) its relevance to project planning (Resources Inventory Committee 1996).

It is in this sense that the natural hazard of slope failure has become a central concern and has generated implications for the whole natural hazards problem. A cursory glance at the topics of recent publications in the terrain stability field in British Columbia reveals the following:

1. Terrain stability mapping (Pack 1995)
2. Terraininventory (Howes and Kenk 1996)
3. Terrainengineering analysis (Broster and Bruce 1990)
4. Applications of Geographic Information Systems to terrain stability (Niemann and Howes 1992)
5. Guidebooks for the Forest Practices Code (B.C. Ministry of Forests 1995)
6. Watershed management and terrain stability (Chatwin and Smith 1992)
7. Terrain stability in sediment budget studies (Roberts and Church 1986)
8. River response to terrain instability (Hogan and Wilford 1989)
9. Effects of terrain instability on fish (Hartman and Scrivener 1990)
10. Slope instability predictive studies (Howes 1987)

These activities are now judged to be highly relevant to the economic and political future of the province. The B.C. Ministry of Transportation and Highways (1996) provides interesting perspectives on the developments of the past 15 years. As a result of this activity, there has been an increased focus on low-magnitude, high-frequency events (Fannin and Rollerson 1993). At the same time, recognition of the socio-economic context in which this work has been occurring has led to a gradual awareness of the importance of risk concepts (Fell 1994). These developments have led inexorably to involvement with the hazard communication field (Plough and Krimsky 1987). Clague et al. (1997) appear to be the first Canadian earth scientists to respond to this challenge.

## Conclusion

Excellent earth science and applied science have been practised for many years in British Columbia. Nevertheless, as in many administrations around the world, damages and costs from natural hazards have continued to escalate (Smith 1996). Environmental consultants, planners and other professionals need the geoscience information to make wise decisions; geoscientists need to respect the kinds of information provided by social scientists. The thesis suggested here is that lack of progress has resulted from the isolation of individual groups of scientists from each other and from the independence of various levels of government that have the legal responsibility for hazard management (Table 2). The example of the slope failure hazard demonstrates that the gap between geoscientists' understanding of the phenomenon, social scientists' understanding of the dimension of associated risk and government professionals lacking a consistent inter-agency policy continues to exist. The absence of a unified policy to promote natural hazard management in the province means that there remains an urgent challenge to define the dimensions of a genuinely interdisciplinary and multi-institutional emphasis. More progress could be made by having technical sessions attended by geoscientists, social scientists and laypersons who all have input into the decision-making process.

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