AN ASSESSMENT OF NATURAL HAZARDS MANAGEMENT IN BRITISH COLUMBIA

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Natural hazards pose a serious threat to the people of British Columbia. As developments continue to encroach into areas of high risk, damage costs and the potential for further losses of property and lives increase. This thesis provides an introduction to hazards management in British Columbia and a review of programs employed in the reduction of damage losses. Several subject areas are examined, including decision-making under crisis; a situation often found in conjunction with hazardous events.

Ad hoc management during periods of crisis is no longer a viable method of reducing impacts from natural hazards. In exploring both the human and physical aspects of natural hazards in British Columbia, it becomes apparent that current programs do not provide the degree of protection necessary. Continued flooding of residential areas in southwest and central regions of the province are examples of events which demonstrate the need for new management alternatives. The Mount Garibaldi landslide case, which is examined in this theses, illustrates the adverse effects of ad hoc decision-making and lack of management programs.

Spatial distribution of natural hazards is such that few sites in British Columbia are free of risks. As a result, the provincial and Canadian federal governments have developed legislative and administrative frameworks for responding to hazardous events. Emphasis has been placed on response rather than protection. This tends to lead to decision-making in the face of crisis, where normally, decisions are made rapidly and immediately after a disaster. An alternative would be to prepare a planned approach to natural hazards management.

This study includes a preliminary assessment of the steps needed to establish a hazards program. Legal and administrative frameworks are assessed in detail, while physical and social factors are examined from a hazard or site-specific basis. The correlation between legislative acts and crisis is illustrated in Chapter 3 and the need for a comprehensive legal standing for risk reduction programs studied. British Columbia, in comparison with California and other american states, is significantly less advanced in the formulation of hazards legislation. This is, in part, responsible for the continued growth of development into areas of high risk, without consideration of alternatives or potential losses.

Administrative programs in British Columbia have developed into effective, but hazard specific systems. No coordinated approach to hazards delineation of land-use in areas of risk, however, has accompanied their evolution. Lack of a comprehensive hazards management program has led to overlapping data collection and in some cases, a conflict in requirements where development is approved. The need for a central entity to collect and disseminate information is apparent. It has been proposed that the Provincial Emergency Program currently in existence, could act as coordinator, if it was given the mandate. Creation of a new bureaucracy is not required, but a reorganization of the existing infrastructure is necessary, before an effective loss-reducing program will become effective.

Preparedness and cordination between agencies can also reduce the social impacts and stresses placed on individuals in areas of high risk. This has been made clear by the Mount Garibaldi case example examined in this study. In this example, a large developed area north of Squamish, British Columbia was considered to be in the path of a potential, catastrophic rockslide. To reduce the risks, the government decided to purchase all properties and return the area to a

natural setting. Lack of a planned or coordinated system to implement such a decision led to disfavour, misinterpretation and distrust by those individuals affected by the stress-generated programs introduced, in an effort to reduce the risk. Programs were implemented in an ad hoc manner and as a result, their effectivness was greatly reduced. An example being the program to relocate and compensate those individuals occupying lands within the designated hazard area. Under the terms of reference, only owners of improved lands could be compensated, establishing an inequity for those with undeveloped land. In addition, deadlines were established for vacating property when no area of relocation had as yet been established. Contributing to the general disorganization was the fact that responsibility for management of this problem was transferred from one government agency to another, because each agency had varying legal jurisdiction in reference to actions taken. The inadequacy of crisis generated decisions is clearly illustrated by this case example.

The thesis also highlights the need for a definitive policy on natural hazards. Legislation which consolidates present laws in regard to natural hazards is necessary to clarify the position of government agencies and to define the rights of victims. With the exception of flooding, no agency is legally designated to manage land use in areas susceptible to the other seven prominent hazards in British Columbia, except for post-event response. Jurisdictions are therefore unclear in some cases, creating a great deal of confusion for members of the public, who rely upon government agencies for guidance. A policy which clearly defines the needs of the public and goals of government, would probably substantially reduce misconceptions and agency overlaps. Public awareness of programs may also be advanced through presentation of a policy statement.

This study illustrates that a multi-level approach is necessary to manage natural hazards. Several examples of in-place, hazards

programs from the United States are examined in Chapter 6. To prevent, or at lease reduce the potential for disaster, British Columbia must follow the lead taken by many of these states, which have acknowledged the high risks involved, and implemented loss-reducing programs. A planned and orderly approach is suggested for the province. The initial step is to present a definitive policy statement, followed by a legislative act to provide the legal boundaries for implementing actions and meeting stated goals. Administrative boundaries must be clarified, so that areas of jurisdiction and function are clear. Public awareness of risk and actions to reduce losses should be promoted. Formation or designation of a central agency to act as collector and disseminator of data would probably improve awareness, by being accessable and capable of providing public information. The preparation of risk maps is seen as one means of informing the public of where and what risks are involved, and providing land-use managers with foreknowledge of hazardous areas.

British Columbia is facing disaster. Without a provincial program to reduce risks from natural hazards, it is likely that damage losses will rise in the future, possibly to levels unmanageable by existing provincial and federal agencies. This threat to life and property from natural hazards can be largely avoided. Alternative actions may significantly reduce losses. Many avenues still need to be examined before a comprehensive hazards program can be implemented in British Columbia. Compilation of data on natural hazards, such as provided here, will hopefully aid in the development of policies and programs to reduce risks faced by residents. Planning is mandatory if a reduction in crisis decision-making is to occur and the risks from natural hazards are to be avoided.

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Chapter 1
AN ASSESSMENT OF NATURAL HAZARDS MANAGEMENT IN BRITISH COLUMBIA

Introduction

A review of current disaster literature reveals a paradox. Despite increased predictive capabilities and advanced engineering expertise, losses due to natural hazards continue to rise (Sewell and Foster, 1976; White and Haas, 1975). Several reasons exist for this, including an inadequate hazard perception by decision-makers; their concentration on a narrow range of adjustment; and a tendency to allow development in areas of risk (Sewell, 1965).

Typically in the Western World, attempts towards hazards management have been stimulated by disaster. A general absence of long-term planning has led politicians and managers to deal with extreme events as crisis situations. Such a crisis management approach to hazards has been identified for example by Burton, Kates and White (1978) with respect to flooding:

> "Major legislation in the twentieth century was preceded by great floods, and in only one instance was important action taken without the press of an antecedent crisis."

As a result of this tendency to wait until crisis occurs, there is frequently a correlation between disasters and subsequent legislation. As a result, the legislation itself tends to be less than comprehensive, embodying limited alternatives. That is, it is typical of statutes formulated under time constraints resulting from crisis.

This unwillingness of decision-makers to legislate adequately to prevent future loss, appears likely to continue. Dacy and Kunreuther in 1969 estimated that damage in the United States from hurricanes, floods, tornadoes and earthquakes rose at a rate of 2.5 percent annually between 1925-1965. Wiggins in 1976, indicated that unless management strategies are altered for building construction in the United States, yearly losses will increase by more than 85 percent between 1970 and the year 2000. Damage caused by earthquakes,

landslides, expansive soils, hurricane wind/storm surges, tornadoes, floods and tsunamis, could reach approximately 19.5 billion dollars annually by the year 2000. It should also be noted that these estimates are conservative, since damage to infrastructure, such as highways and bridges, is not included. Comparable figures are not available for Canada, however, it is reasonable to expect that losses will increase proportionately.

The great increases in disaster losses in the Western World does not imply there has been a neglect of hazard research. In fact, there has been increasing emphasis given throughout North America to such studies in the last ten years. This interest has been mirrored in British Columbia, but the rate of development has been slower than in the United States (Buchanan, 1980). Topics which have been neglected in British Columbia include the management of risk areas, and the planning for damage reduction. Governments have tended to deal with natural hazards in an ad hoc manner, an approach which is no longer viable, and will lead to increased losses. Planning is required in order that alternative means of damage loss reduction may be instituted without the time constraints typical of crisis situations. The definition of planning here being the establishment of an organized program with guidelines and procedures for the management system, rather than the formal establishment of more rigid "plans".

This study for the most part will assess major components of the existing hazards management system in British Columbia. First, however, we must consider the reasons why decision-makers react to crisis in the manner which they do. Short-comings in past decisions may therefore be better understood and means of avoiding similar mistakes in future decisions investigated. Chapter one illustrates some of the faults with decision-making under crisis and explores the reasons for a planned, or organized natural hazards management program.

Decision-Making, Planning and Policies in Natural Hazard Management

Since decision-makers often exhibit short-term crisis oriented approaches to natural hazards, changes in management strategies typically take place only when government has been subjected to major

public pressure (Burton, et al 1978). This usually is forthcoming only when the hazardous event is of a magnitude spectacular enough to generate wide-spread concern. Responding to such stress does not lead to optimum decision-making. Public demands for action are articulated through the media or by concerned action groups. These increase the stresses on decision-makers and inhibit their ability to formulate long-term planning goals through proper assessment of alternatives. This in turn leads them to apply counterproductive measures, such as engineering works and relief. Although both of these responses may be viable under certain conditions a far wider range of alternative solutions should be considered.

A significantly better approach in responding to natures hazardous events is to incorporate the minimization of losses into the planning process. Planning provides a means for evaluating adjustments to cope with natural hazards and for establishing a degree of preparedness. Hewitt and Burton (1971) state that:

> A natural hazard of any sort is a function both of the physical event itself and of the state of human society; including specifically the adjustments adopted to cope with the hazard and the state of preparedness."

Planning is also a function of the management process, whereby hazard loss reduction may be entrenched into a formalized institutional arrangement.

Lang and Armour (1980) note that there are four fundamental functions within the management process and that the planning function should formulate objectives, achieve goals in accordance with available resources, and devise and select from among alternative courses of action. Control, another function of the management process, evaulates the performance of actions taken against the desired state of preparedness. The two remaining elements include organization and direction, which supply the administrative roles of the management process.

Planning will also be most effective when it is an integral part of the normal decision-making process. This viewpoint is reflected in a statement by Boulding (1971):

> "The world moves into the future as a result of decisions, not as a result of plans. Plans are significant only insofar as they affect decisions. Planning may be defined in such a way that it is part of the total decision-making process; but if it is not part of a decision-making process, it is a bag of wind, a piece of paper, and worthless diagrams."

Natural hazards planning has not yet made any significant impact on the "normal" decision-making role in British Columbia and as a result has led to decisions being made which endanger members of the public. This leads to eventual disaster and decision-making under crisis which introduces uncommonly high levels of stress into the decision-making process. A fundamental goal then for planning, in addition to reducing losses through participation in the decision-making process, is to overcome adverse aspects of decisions made under stress.

Decision-Making Under Stress

Kasperson's (1971) model for stress management in the municipal political system can be readily adapted to the analysis of past management decisions for natural hazards. In addition, using Holsti's (1978) model for cognitive performance in crisis, the behaviour of the decision-makers themselves can be better understood. Investigation shows that previous decisions relating to the management of natural hazards have been made under abnormal levels of stress. It becomes likely therefore, that unless change occurs, future decisions will also be stress generated.

Kasperson's model can be applied in this context because it provides for interaction of both the physical and human systems which is intrinsic to any hazards research. Individual elements of this stress model, as diagrammatically represented in Figure 1.1, include the event in an environmental context, the articulation of stresses to the decision-maker, the perception-evaluation process, the decision-making task and the resolution of stress through the choice of adjustments.

In responding to crisis situations, the individual's ability to make rational decisions is reduced (Holsti, 1978) since their capacity

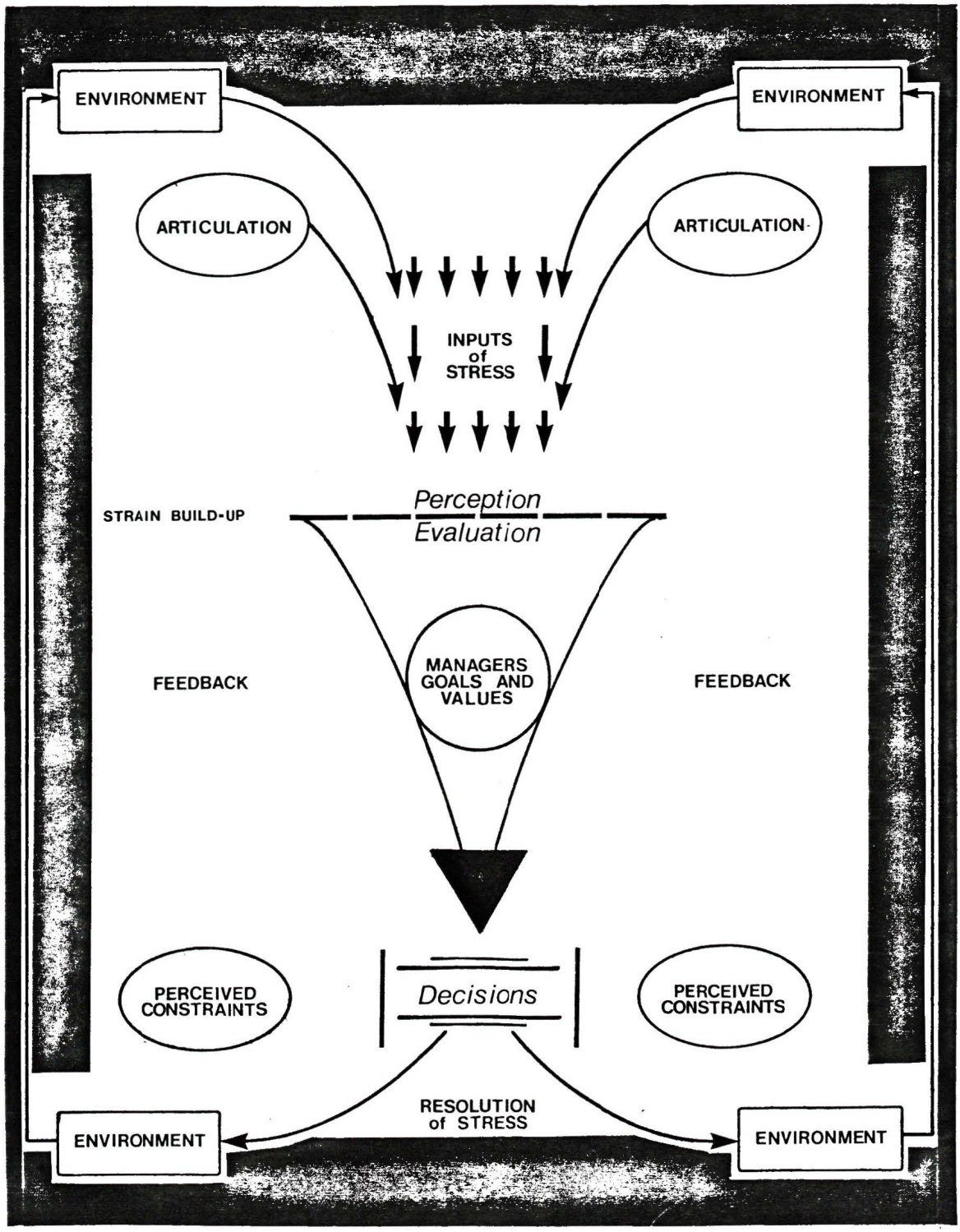

Figure 1.1: Model for municipal management under stress (from Kasperson, 1971)

to process pertinent information is limited by past experience and by the time constraints imposed by the crisis itself. The latter reduce the ability to recognize the entire range of policy alternatives. Additionally, individuals are limited in their ability to anticipate the outcomes of each alternative and an inability to priorize possible consequences on a single utility scale (Holsti, 1978).

Holsti, in explaining cognitive performance during crisis, diagrammatically represents the relationship between it and crisis, stress, and decision-making (Figure 1.2). Individual performance by decision-makers during stress is determined by several cognitive tasks which must be addressed in order to effectively make objective decisions in crisis. By satisfying these cognitive tasks, the individual's ability to make rational decisions would be enhanced. Those tasks which must be accomplished include resistance to both premature closure and action. Overcoming these two tasks extends the time limits available for the decision-maker to identify alternative courses of action and to consider ambiguities which arise in crisis events. Tasks which also benefit from extension of the decision-making process include benefit-cost analysis of various options and the ability to discriminate between possible and probable outcomes.

Logically, there is no reason why these tasks must all be addressed immediately after a disaster. Pre-event evaluation of alternatives, unencumbered by time constraints can minimize the adverse effects normally associated with crisis and stress. Overcoming the cognitive limitations of decision-makers through planning is seen therefore, as a preferred alternative to decision-making under stress.

Planning and Policy Roles

Society is generally inadequately prepared for extreme events in nature. As a result, crisis situations usually find administrative and legislative bodies unprepared to meet the problems (White and Haas, 1975). Without proper planning or defined options, while in the face of public pressure for immediate, positive action, the decision-

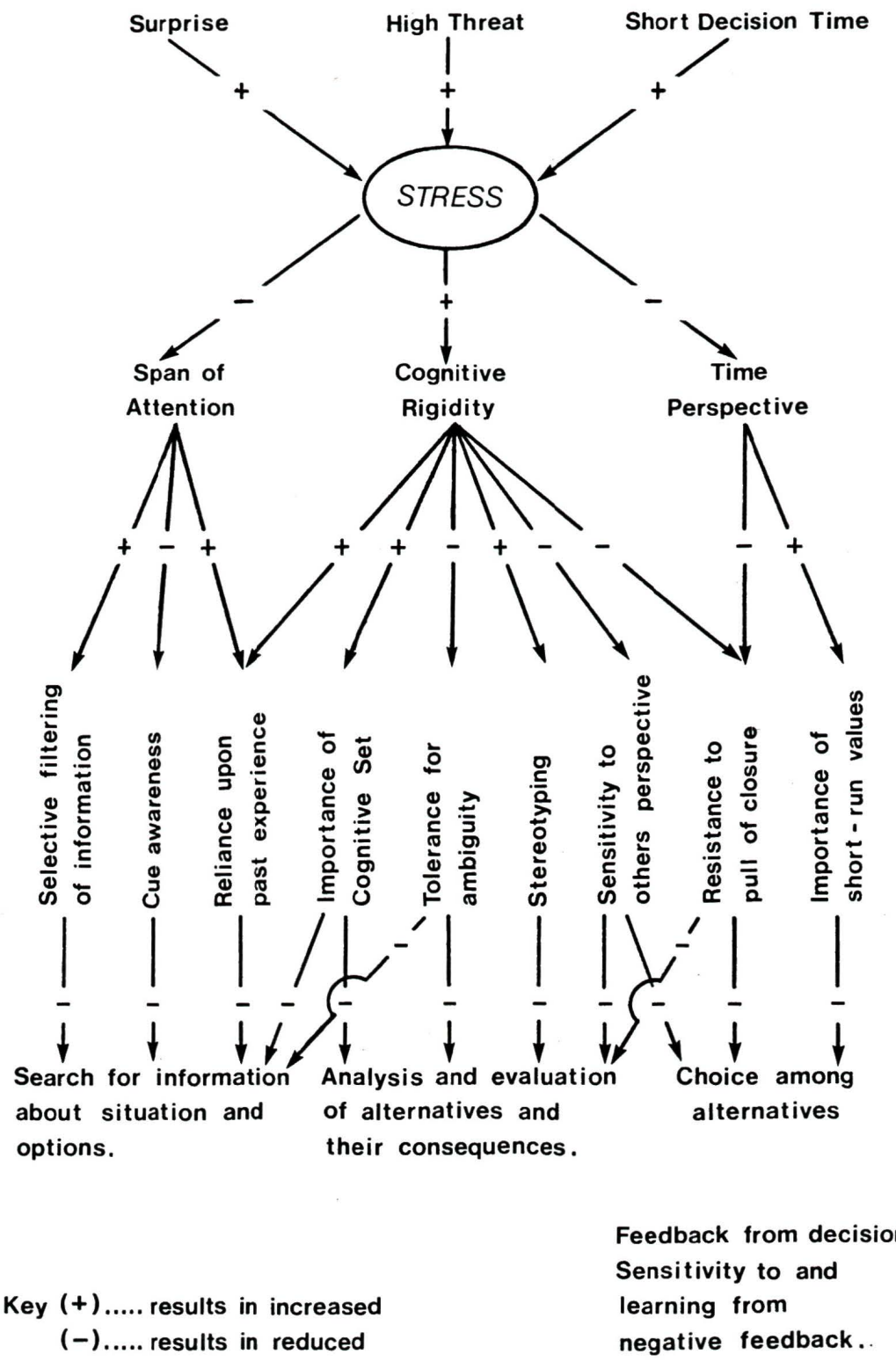

Figure 1.2: Cognitive performance in crisis: Some hypothesis (After Holsti; 1978)

makers are reduced to making choices based on their own previous experience (White and Haas, 1975; Kasperson, 1971). Policies and planning to deal with naturally hazardous events are therefore seen as viable alternatives to current ad hoc management techniques employed during periods of crisis.

Sewell and Foster (1976) stated that a sophisticated approach to hazard management would include:

> ".....(a) comprehensive planning, linking hazard loss management to resources management as a whole, and the latter to overall economic and social planning, and (b) the adoption of control measures accompanied by land use regulations and insurance, together with the development of sophisticated monitoring systems and high-speed communication devices.

Major facets of their approach being 'planning' and 'control', which constitute major facets of a policy. Policy is therefore viewed as the guideline for a planning structure to make natural hazard management decisions which are comprehensive and consistent. Natural hazard policies must be clearly defined by Federal, provincial or municipal governments because decisions by individual members of any society are normally made within the constraints placed upon them by these bodies.

The process of policy formulation, as illustrated in Figure 1.3 is a logical approach to the development of a selected policy with clearly defined monitoring systems. Policies have direct input into the management process through the planning and controlling functions. Implementation of a natural hazard policy must follow this evolutionary pattern with each crisis situation considered as part of the environmental issues package. Effectiveness of the policy will be determined by the diversity of the planning that implements the policy, its public and political acceptability, and its ability to integrate with other resource management policies.

Policies constitute a political decision, and as noted by Kates and White (1961):

> "As we see it, there are two sets of requirements for a viable political decision. The first is that

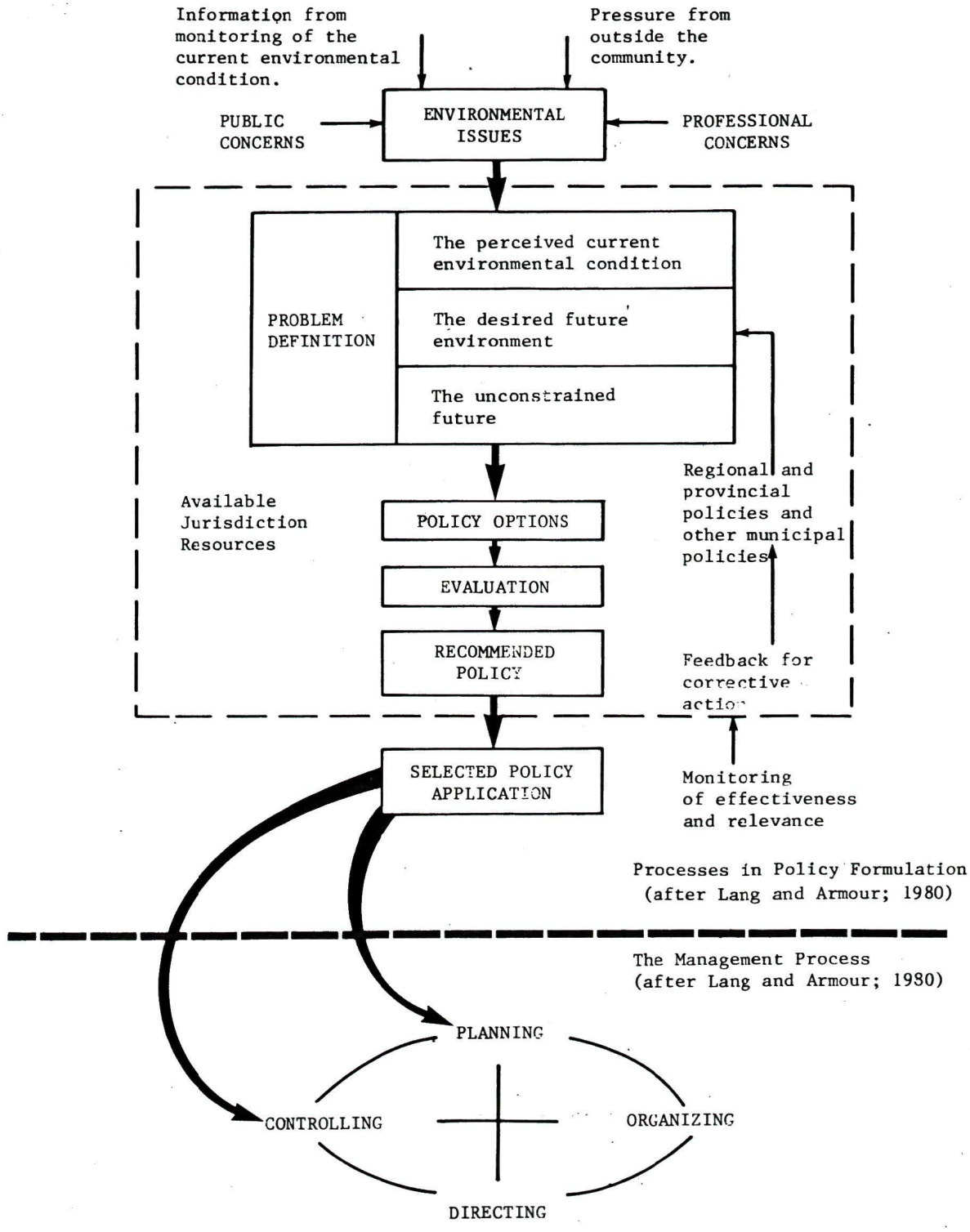

Figure 1.3: This figure indicates steps in policy formulation and the relationship of policy to planning and controlling in the management process

> the regulation be workable, explainable, and enforceable. The second is that it should fall into the broad area of action that the political scientists pertinently label as 'the possible'.

Policies become possible when they satisfy societal needs. Planning for loss-reduction from hazards and control of land-use in areas of hazard are seen as needs for society, therefore satisfying the concept of a viable political decision. Integration of a hazards policy into a broader resource management package constitutes a rational approach to meeting the needs of society and adds to its political acceptance.

Policy formulation can effectively establish the framework within which natural hazards will be dealt, while comprehensive, integrated planning formalizes the approaches taken in the management of hazardous areas. A well-defined policy also provides guidelines for the decision-maker during crisis situations. Planning assists the decision-maker by providing a range of alternatives, thereby reducing his or her reliance on their own perceptions and cognitive abilities. Comprehensive planning and policy formulation can effectively solve those problems which are intrinsic to decision-making under stress, and in turn can lead to effective management of natural hazards. A qualification, however, is that plans and policies cannot hope to cover <u>all</u> the ambiguities which may exist during a given event. Plans and policies can, however, satisfy <u>most</u> cognitive tasks faced by the decision-maker during crisis situations. As a result, the possibility of effective hazard management is increased.

In summary, evidence indicates that there is a need for greater planning and better policies for the management of natural hazards. These processes aid in satisfying cognitive requirements pressed upon the decision-makers during crisis. Management and planning can lead to loss reduction if effectively implemented. It must be recognized however, that even with comprehensive policies and planning, ambiguous situations may still arise and require ad hoc responses.

The Need for Natural Hazards Management in British Columbia

There is currently an absence of a natural hazards policy in British Columbia. Integrated natural hazard management must occur as part of a larger land-use planning system if loss-reduction is to take place. Research indicates that to date, naturally hazardous events in the province have been dealt with through ad hoc measures in nearly all cases. Each event has been treated in isolation. Decisions have been generally based upon previous experience and the political expediency of the chosen solution.

The need for a natural hazards policy was recognized within the Government as early as 1974, when a report by the Avalanche Task Force formed by the Honorable Graham Lea (then Minister of Public Works and Highways in B.C.) noted that:

> "The necessity for a policy on natural hazards is thought to be acute due to the future increase in the public's exposure to destructible geological processes."

This report highlighted problems arising from natural hazards in the province. This document also introduced several facets of a proposed policy and made recommendations for its enactment. Unfortunately, neither the policy proposals nor the recommendations have as yet been implemented in whole, or in part.

Notably, natural hazards as part of a larger resource planning package have not been totally ignored in British Columbia. For example, land-use plans for areas of the Lower Fraser-Mainland and Howe Sound have incorporated natural hazard evaluations into their development plans. The integration of natural hazards planning and management on a provincial scale however, has not as yet taken place. Though the province has a well-designed planning and management base for current land-use, it appears to lack suitable planning for future land-uses or for integrated resource planning (including natural hazards) (Times-Colonist newspaper, 1981).

Recognition of the need for a natural hazard policy and management process has not been confined solely within the public sector. The British Columbia Association of Professional Engineers,

devoted the bulk of their January, 1976 newsletter to proclaiming the need for a provincial natural hazards policy. The series of articles described benefits likely to result from the adoption of a hazards policy. The primary goal of the presentation was to illustrate how a policy could assure maximum safety for life and property (such as cities, towns, transportation corridors and industrial developments). Ancillary benefits from the adoption of a policy would include the reduction of claims against the Crown for compensation from damages by natural hazards, and a savings in development and construction costs through better recognition of the hazards involved, and a more accurate definition of risk. A pre-requisite, and a result of the policy would be the provision of an adequate data base for implementing decision-making and land-use planning.

Awareness of the need for a management program was also recognized as early as 1965, when in considering solutions for flood damage reduction in the Lower Fraser Valley, Sewell noted four important requirements:

1. increased public awareness of the problem;
2. co-ordinated efforts by various levels of government;
3. integrated water management planning with other planning activities; and
4. planning goals linked with the decision-making process.

Similar solutions may be readily applied to the natural hazards problem as a whole.

Before a management and planning program can be recommended, a general assessment must first be made of the existing data base and the infrastructure for study and administering natural hazards in the province of British Columbia. The spatial and temporal distribution, current legislation and the administrative structure may be used as indicators of the risks involved from natural hazards, and of the actions or priorities normally applied in the decision-making hierarchy. Adjustments to past crises are often reflected in the existent legislation, while the current emphasis applied in the decision-making process may be the administrative roles played by various groups in government, private enterprise and institutions.

If policies constitute political decisions, then a firm understanding of the current status and needs is required to properly educate the politician so that he or she may reach a practical and viable political decision. Once reached, the political decision and policy statement must be transformed into enabling legislation so that regulation and enforcement of guidelines, by-laws, zoning ordinances and other measures can take place. Evaluation of a structural administrative framework to apply the policy and enforce the legislation would constitute the next step in the planning process. Success of the policy may be determined by how effectively the planning program is administered in the field.

This study represents an attempt to assess facets of natural hazards programs in British Columbia and to develop what may possibly be a more comprehensive methodology for managing such hazards. Hopefully, such an assessment may stimulate decision-makers to adopt alternatives in addition to those currently employed, and to coordinate their efforts in the reduction of losses from natural hazards. Several examples of programs already in place in other countries will be used to reinforce suggested alternatives, which may be introduced to provide British Columbia with an appropriate natural hazards program.

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Chapter 2
NATURAL HAZARDS IN BRITISH COLUMBIA

British Columbia is a large, geologically active land area, influenced by frequent geomorphological and hydrological processes, the extremes of which are termed natural hazards.[1] Natural hazards occurring in British Columbia are similar to those in other countries or states in that the processes observe the same physical principles, and are considered hazardous only when they interact with human activities. One means therefore to avoid natural hazards would be to develop settlements only in areas which are not susceptible to such processes. Unfortunately, avoidance is not a viable alternative in British Columbia as all regions of the province are susceptible to some degree of risk from natural hazards. The coastal region of British Columbia is one of the most active seismic zones in Canada (Milne, 1981; Wuorinen, 1974), in addition to being subject to tsunamigenic events (Wigen, 1981) and ongoing marine erosion (Foster, 1976). Coastal and interior settlements are often influenced by high-intensity rainstorms or snowstorms which, when combined with adverse topography, lead to debris-flows, flooding, landsliding or snow avalanches, especially during the fall and winter seasons. Interior and coastal communities are particularly prone to high magnitude over-bank floods. These take place during the spring-runoff resulting from snowmelt, which lasts into the early summer and sometimes as late as mid-August (Doughty-Davis, 1976).

Distribution of natural hazards over space and time within the province is frequently underestimated, not only by the public, but by usually well-informed geologists, geographers, planners and engineers (Evans, 1974). A gross-scale representation of the spatial distribution of geological hazards is illustrated in Figure 2.1 which indicates high risk areas. This distribution implies a need for greater awareness of natural hazards when developing communities in

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[1] Variations in terminology occur throughout the literature on natural hazards. The terminology used here is derived from reviewing several classifications as outlined in Appendix B.

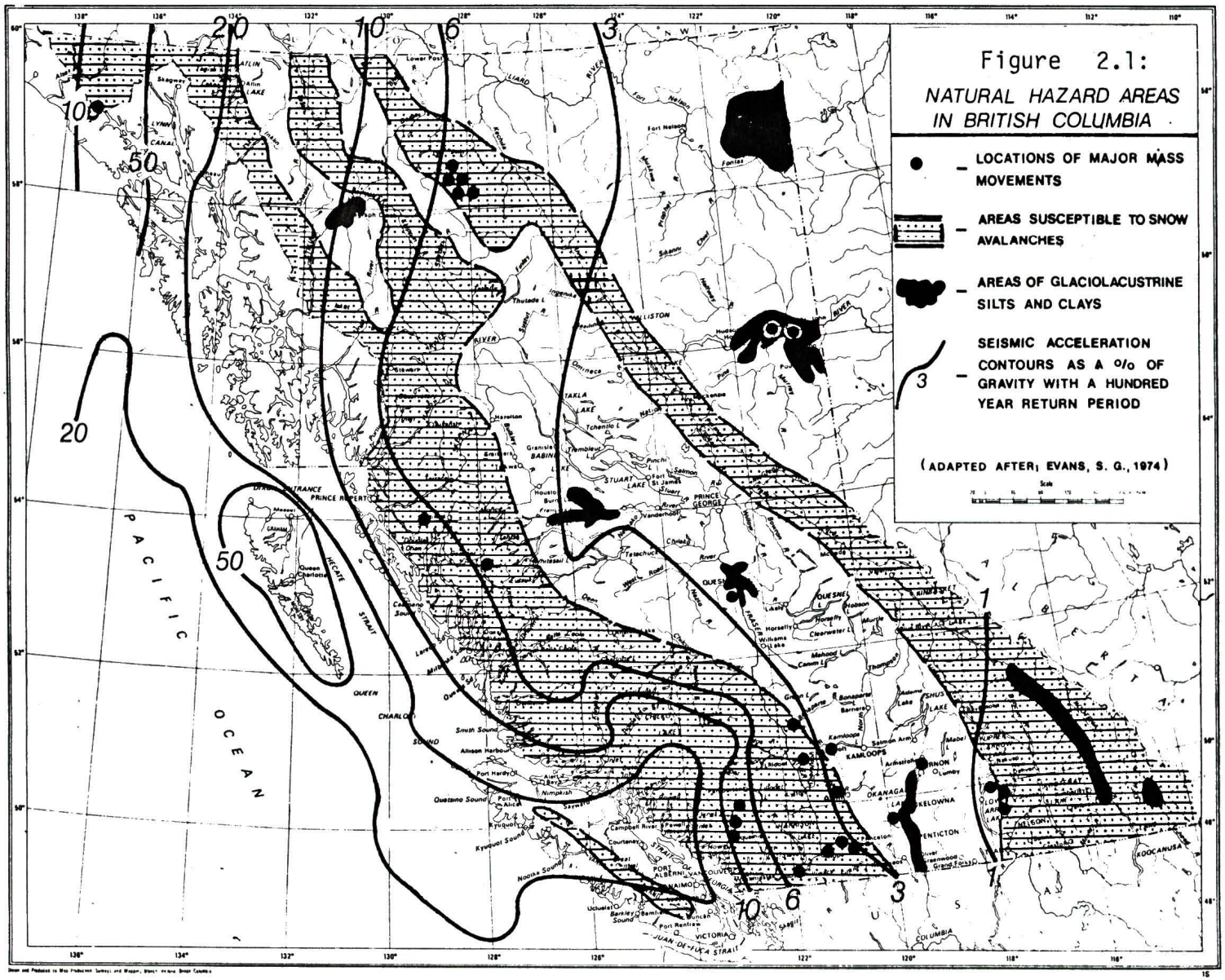
Figure 2.1:
NATURAL HAZARD AREAS IN BRITISH COLUMBIA
LOCATIONS OF MAJOR MASS MOVEMENTS
AREAS SUSCEPTIBLE TO SNOW AVALANCHES
AREAS OF GLACIOLACUSTRINE SILTS AND CLAYS
SEISMIC ACCELERATION CONTOURS AS A % OF GRAVITY WITH A HUNDRED YEAR RETURN PERIOD
(ADAPTED AFTER; EVANS, S. G., 1974)
PACIFIC OCEAN
20
10
6
3
1
50
100

British Columbia. There is a growing tendency, however, for development to take place without sufficient knowledge of the risks involved and without the adoption of protective measures.

Natural Hazard Types in British Columbia

There is a diversity of natural hazards in British Columbia with each disaster agent having unique physical properties and distinctive impacts on human activities. A classification of hazards with the highest frequencies and the greatest economic impact is provided in Table 2.1 Each is described in greater detail in the following subsections.

Table 2.1: Classifications of Natural Hazards in British Columbia

Frequency Classification	Economic Classification[+]
1. Snow Avalanches	1. Floods
2. Landslides	2. Landslides
3. Earthquakes[A]	3. Snow Avalanches
4. Floods	4. Shore Erosion
5. Tsunami's[B]	5. Subsidence
6. Subsidence (Continuous and Ongoing)	6. Earthquakes*
7. Shore Erosion (Continuous and Ongoing)	7. Tsunami's *
8. Volcanic Eruption	8. Volcanic Eruption*

A - This includes events of magnitude Richter 3 or greater; should a lower magnitude event be considered, a much higher frequency could be assumed.

B - Tsunami's of a damaging nature are infrequent on the coast of B.C.

\+ - NOTE: Forest fires in British Columbia likely cause the highest annual dollar loss, however, their origin may be natural or man-induced, are an annual event, and are considered in a context outside of this study.

* - Any one of these hazards could exceed the dollar outlay of those listed above it, should an extreme event occur.

Floods

Despite the fact that floods are predictable, recurring hazards, they still inflict the greatest property damage within British

Columbia. Most major cities are built wholly or partly on floodplains because these areas are the most desirable for development. Sewell in 1965, for example, noted that approximately one-tenth of the population in the Fraser Valley, some 190,000 people in 1980, occupied areas susceptible to inundation by a major flood.

Major damaging floods have occurred in British Columbia in several years, these being: 1894, 1948, 1961, 1972, 1974, 1978, 1980 and 1981. The 1894 flood is the "flood of record" reaching a height of 7.92 m on the Fraser River at Mission as compared with 7.62 m during the 1948 flood which caused the greatest damage. In 1948, almost 10 percent of the Fraser Valley, some 55,000 acres was flooded, causing 10 deaths, leaving some 200 families homeless, washing out 82 bridges and involving some 30,000 volunteers in flood fighting (Pethick, 1978). Approximately $5 million was provided for relief and rehabilitation to flood victims by the federal government in addition to an offer of 75 percent of the cost of repairing and strengthening the dyking system, estimated at a further $10 million. Between provincial and federal involvement, approximately $20 million was spent in offsetting losses and developing protective works in the Lower Fraser Valley, Kamloops, Prince George and Quesnel areas.

Development of an extensive dyking system in British Columbia subsequently took place in those areas inundated during the 1948 flood. By 1982 some 499 km (316 miles) of dykes have been constructed, with about 350 km of Fraser River dykes having been reconstructed in the past 10 years, while the remainder are older-style dykes that were repaired following the 1948 flood (Vancouver Province, May 25, 1982). Many areas, however, remain susceptible to flooding, as illustrated in Kamloops in 1972 (see Figures 2.2 and 2.3), and Squamish-Brackendale during 1980 and 1981. Flooding in July of 1972 in Kamloops resulted in 200 homes being inundated and approximately $8 million in damage. Floods in the Vancouver-Squamish-Brackendale areas caused damage losses of $13 million and $2 million respectively (Victoria Times-Colonist, December 31, 1980; Vancouver Province, November 2, 1981). Though dyking systems were in place at Kamloops and Squamish, they proved to be inadequate for successful protection.

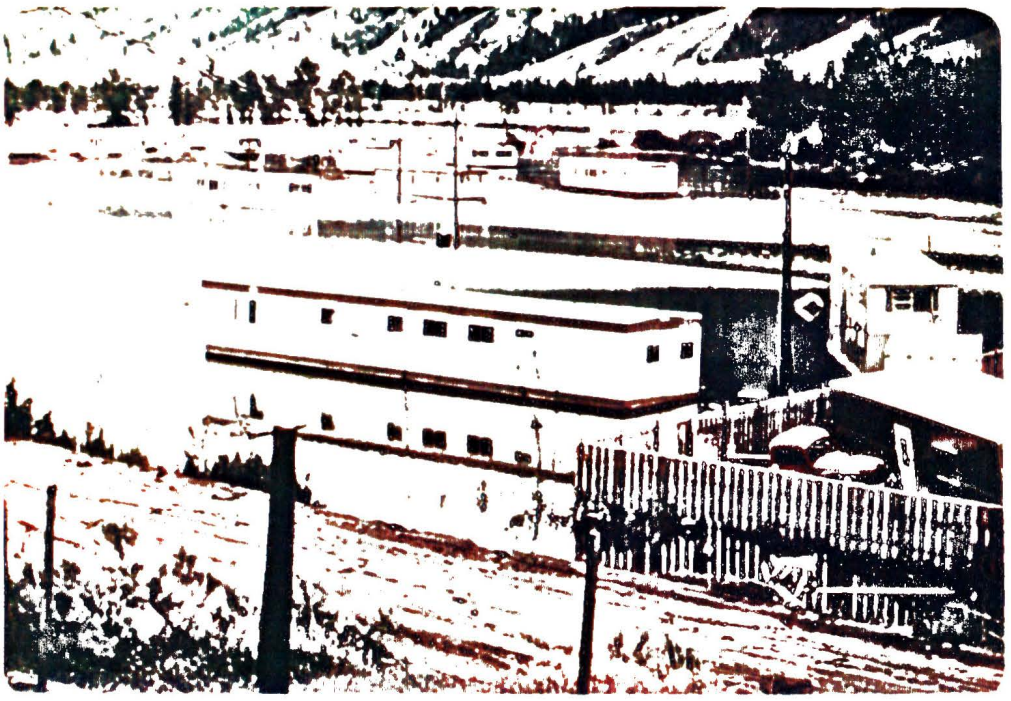

Figure 2.2: Flooding on North Thompson River at Kamloops during the spring freshet of 1972

Figure 2.3: Damage to dykes during same flood at Kamloops, 1972

Potential losses from flooding in British Columbia are very high. This loss potential was reflected in the conclusions reached by the Canada-British Columbia, Fraser River Joint Advisory Board in December, 1976:

> (a) "The Lower Fraser Valley faces a continuing and serious flood threat. Greater floods than that of 1894 can and will occur, but the specific year or years of their occurrence cannot be predicted. There is a 1-in-3 probability that the 1894 flood will be equalled or exceeded during the 60-year period from 1973 to 2032."
>
> (b) "Floods greater than that of 1894 will result in damages in the Lower Fraser Valley in the order of $500 million, always with the attendant risk to human life. Residential damage involving thousands of homes would constitute the major part of this loss. In addition, tens of thousands of people would have to be evacuated from affected Valley areas."
>
> (c) "The current Lower Fraser Valley dyking program, which does not encompass all of the developed areas, will only increase the reliability of protection against floods up to the 1894 level. Raising dykes above this level is essentially impractical, and in some cases not considered to be engineeringly sound. In addition, such raising would generate a false feeling of security."
>
> (d) "Additional flood protection is essential and could only be achieved through development of upstream storage reservoirs or diversion of major tributary rivers."
>
> (e) Substantial benefits can be achieved through operation of existing reservoirs for flood control purposes whenever necessary.
>
> (f) Non-structural measures, including flood forecasting and flood plain management practices can contribute significantly to the reduction of potential flood damage.

Although conclusions (e) and (f) are somewhat in opposition to (d), it is conclusion (f) which the author believes to be a management alternative that may create most long-term benefits. Dykes and dams

are short-term alternatives which may promote an increased potential for loss, rather than a maximization of long-term protection.

Mass Movement

Mass movement occurs as the result of natural processes or because of mans activity, which can adversely affect sheer strength and sheer stress in natural slopes. The number of lives-at-risk in British Columbia from mass movement is fairly high, at least 34 lives have been lost in the past 20 years, as a direct result of variable forms of mass movement, and damage is estimated in the tens of millions of dollars (Files: Ministry of Transportation and Highways, B.C.). The largest recent movement was the Hope landslide, which occurred on January 9, 1965, resulting in the death of 4 people and the burying of a provincial highway to depths of between 30 and 100 m (Mathews and McTaggart, 1969) (see Figure 2.4).

The threat-to-life from rapid, mass movements was made abundantly clear during the winter of 1981-82 in the Vancouver to Squamish area. Between October 28, 1981 and January 16, 1982, eleven people died as a result of debris torrents and falling rocks (10 as a result of debris torrents at "M" Creek and Strachan Creek, and one as the result of a rockfall on highway 99). Several regions within British Columbia have similar climatic, topographic and social conditions, creating high risk situations.

Additionally, many of British Columbia's major valleys are partially or wholly inundated as a result of hydro projects which create large pondages upstream of dams. Mass movement has always posed a threat to such enterprises for if a dam should be overtopped, then considerable loss of lives and property could take place downstream. Pondages which initiate or re-activate landslides have recently become key issues in dam development and operation as illustrated by the Attachie Slide in the proposed Site C flood areas; the Downie Slide in the Revelstoke Dam pondage and the slope creep failures along the Pend'Oreille valley upstream of the existing Seven Mile Dam. Millions of dollars have been spent on each project to study, monitor, model and engineer against these types of mass

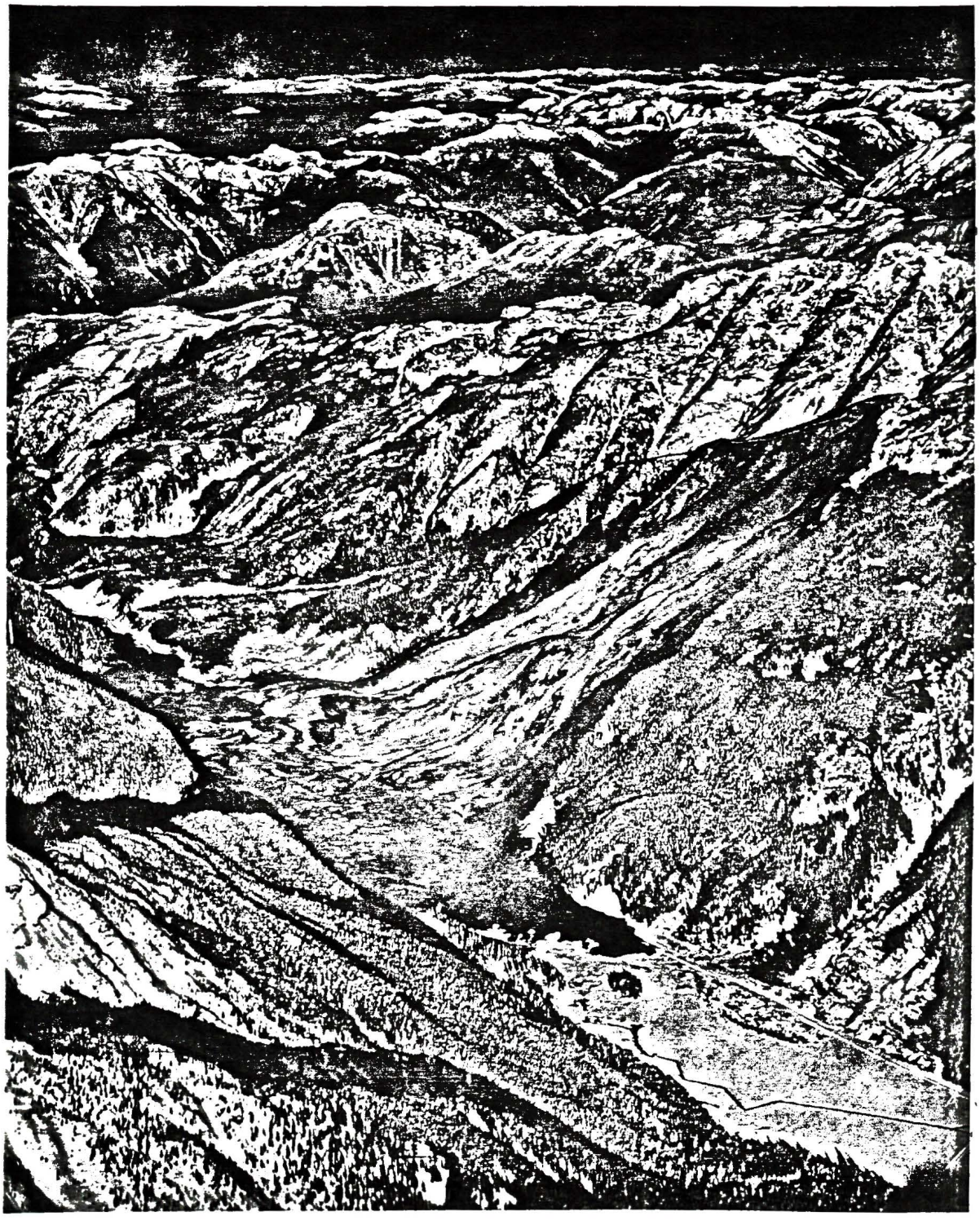

Figure 2.4: Hope Slide, shortly after it occurred on January 9, 1965 (photo supplied by B.C. Ministry of Environment)

movements (B.C. Hydro - Engineering Division).

Historically massive rock and earth movements have been recorded throughout British Columbia. A major rockslide in the Cheakamus Valley in 1855, as recorded by Major William Downie, is the focus of a case study described in Chapter 4. Deaths associated with landslides indirectly were recorded as early as 1905 when a landslide on the Thompson River blocked it and led to the inundation of a nearby Indian Village, drowning 13 people. Pethick (1978) further illustrates the economic impact of mass movements over time in describing rockslides on the Fraser River in 1913 and 1914. In these two years, rock slides blocked portions of the Fraser River in the vicinity of Hell's Gate and greatly impeded salmon runs up the river. As a result, salmon runs in 1917 and 1921 were reduced up to 75 percent with subsequent financial losses in the millions of dollars.

Some alternative means for reducing landslide losses are indicated in Figure 2.5. To date, landslide damage reduction in British Columbia has been primarily achieved through subdivision regulation and/or engineering design. Subdivision regulations for example include requirements such as; all dwellings must be setback from slopes greater than 2 horizontal: 1 vertical; no construction of habitable dwellings may take place on the property; or, a requirement that engineering studies and designs be implemented. Landslides on previously subdivided lands normally are mitigated by use of structures or possibly through re-design of the slope to a more stable configuration.

Areas of frequent mass movement in developed areas of British Columbia include Quesnel, the Peace River Valley, Sunshine Valley, the Cheakamus River Valley and the Fraser Canyon. As most of British Columbia was influenced by alpine glaciation, soils within many valleys and on many slopes are youthful, unconsolidated, and relatively unstable when disturbed. Most coastal and interior valleys have steep slopes, creating adverse conditions for development which does not fully recognize the risk existent in such areas.

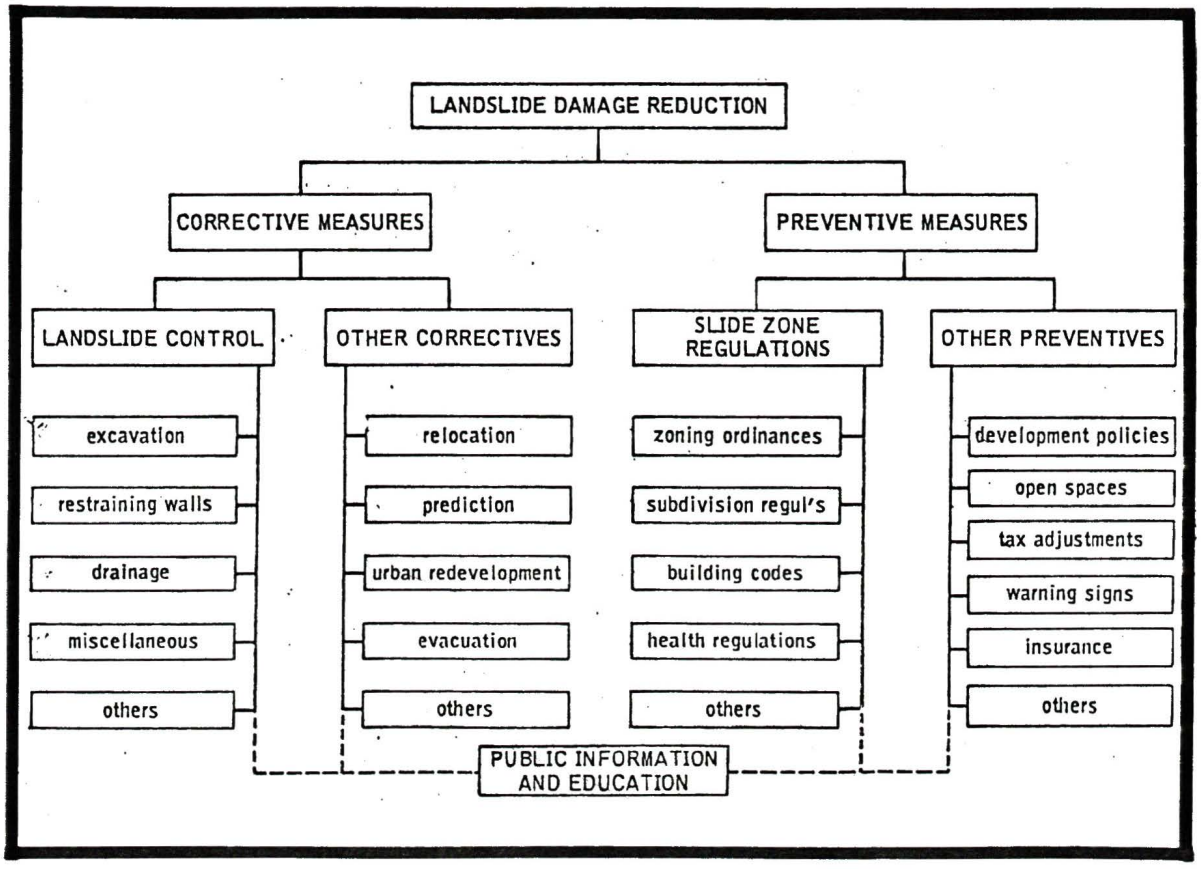

Figure 2.5: Diagram of alternative measures for reducing landslide losses (TVA, 1962)

Snow Avalanches

Avalanches are common to British Columbia and in terms of the number of deaths, are the most dangerous of natural hazards (Freer, 1980). In this century, the worst snow avalanche disaster occurred March 4, 1910, when a work train was derailed and buried in Rogers Pass resulting in 66 deaths (Office of the Senior Avalanche Coordinator, B.C.). In the same decade, a snow avalanche at the Britannia Mine in 1915, trapped 50 men and resulted in between 27 and 32 deaths (records vary as to actual number of lives lost). A similar disaster occurred during the winter of 1965 at the Granduc Mine (Leduc Camp) north of Stewart where 26 men lost their lives when the mining camp was buried by a massive snow avalanche. Since 1900, it has been estimated that 267 deaths have resulted from snow avalanches in British Columbia (see Table 2.2) (Freer and Schaerer, 1980).

Table 2.2: Deaths from Snow Avalanches in British Columbia

Year	No. of Deaths
1800-1899*	75
1900-1909	24
1910-1919	107
1920-1929	13
1930-1939	26
1940-1949	5
1950-1959	6
1960-1969	39
1970-1979	47

* Records are not complete

(Source: Freer and Schaerer (1980); Journal of Glaciology, Vol. 26, No. 94, p. 346)

In 1965, the same year as the Granduc Mine disaster, 7 more people were killed in their homes at the small forest industry town of Ocean Falls. Still, little action was taken to investigate the risk from snow avalanches in British Columbia. However, the government was finally spurred into taking action when on January 22, 1974, 7 people lost their lives from a snow avalanche which destroyed the North Route

Cafe, near Terrace. Following the event, the then Minister of Highways, the Honourable Graham Lea, instituted a Task Force to investigate the impact of snow avalanches on highways within the province. The task force was requested to report:

> "... on measures to be taken to identify and control avalanches and other hazards from snow and mud as they may endanger highways and facilities adjacent to highways in British Columbia." (British Columbia Department of Highways, 1974).

The Task Force was limited to reviewing snow avalanches along highways. However, this function was carried over into the development review process through the approving function of the Ministry of Transportation and Highways. A typical inventory of snow avalanche incidents along British Columbia highways in any one winter is provided below: (also see example Figure 2.6 and 2.7)

Avalanche Incidents: 1981-1982

Vehicles	Persons
3 completely buried	3 caught
13 partially buried	11 or more partially buried
18 trapped	0 injured
4 damaged	18 or more trapped

(Office of the Senior Avalanche Coordinator, B.C.)

Many avalanche deaths occur in recreational areas and parks within British Columbia, even though it is within these areas that snow avalanches are most carefully controlled. Our society seems often to prefer some element of danger in its recreational pastimes. As a result, several deaths occur annually which are directly attributable to skiing, climbing and hiking in areas of high risk from snow avalanches.

British Columbia to date, has few residential developments located in high risk snow avalanche areas and therefore has the opportunity to successfully institute a firm policy for land-use zoning as a means of reducing potential losses. Freer and Schaerer (1980) in their discussion of snow avalanche hazard zoning in British Columbia concluded that, "successful land-use zoning in avalanche

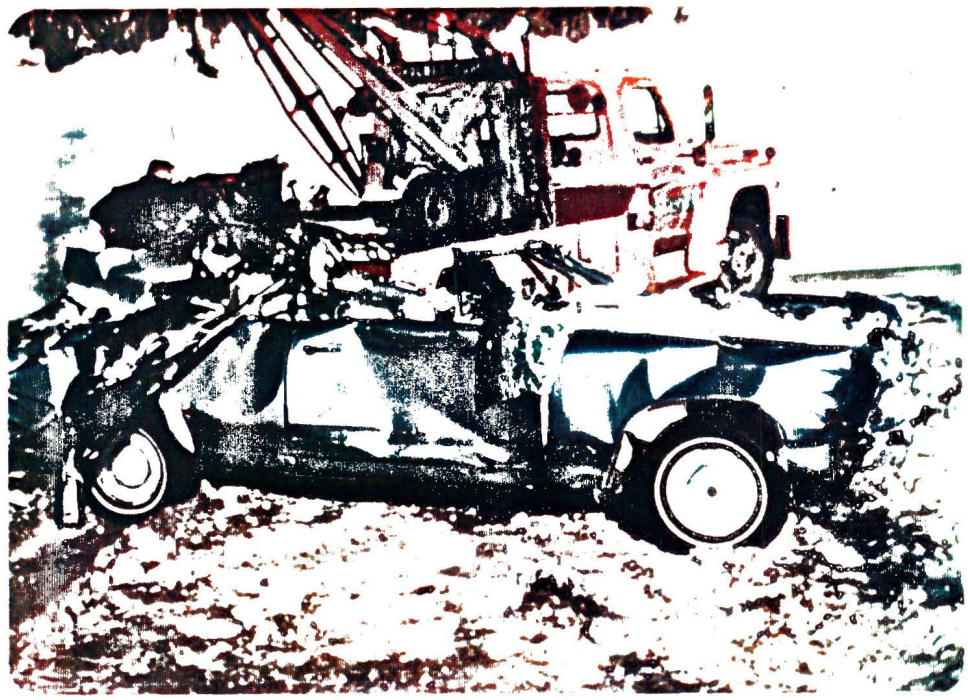

Figure 2.6: Snow avalanche buried car in Kootenay Pass during winter 1975-76 (photo supplied by Office of the Senior Avalanche Coordinator)

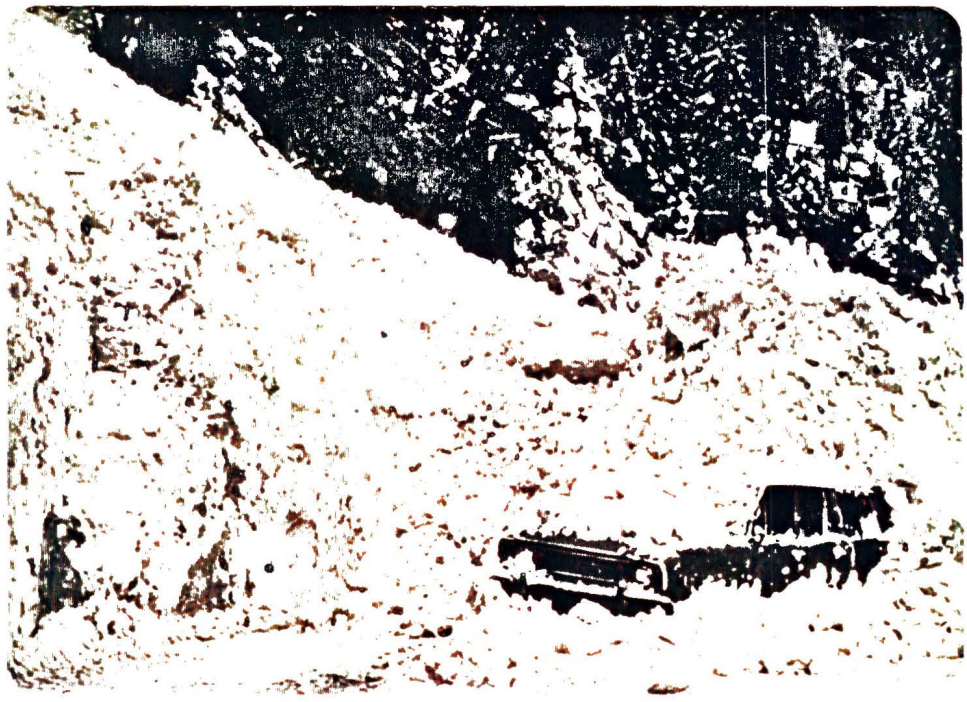

Figure 2.7: Snow avalanche buried car near Lardeau in winter 81-82 (photo supplied by Office of the Senior Avalanche Coordinator)

areas is keyed to one concept, a firm policy of hazard zoning prior to land-use zoning." In addition, they outlined the primary components of a snow avalanche hazard zoning programme, which would include:

(a) specific legislation preventing development in hazard areas;
(b) education of land-use planning and development approval personnel;
(c) development of guidelines for identifying avalanches in land-use and development planning;
(d) development and maintenance of avalanche-hazard mapping;
(e) avalanche-occurrence recording in conjunction with mapping;
(f) a technical advisory service readily available to assist in evaluating avalanche hazards.

Shore Erosion

Shore or coastal erosion in British Columbia often results in conflicts between human activity and natural processes (Terich, 1979· Capital Regional District, 1977). There are natural changes (risks) inherent with coastal and shoreline processes, and man's encroachment into these zones only compounds the dangers. Figure 2.4 provides a diagrammatic indication of some of the natural and human factors which interact in the coastal erosion process. Because development has occurred in a unique way in the coastal areas of British Columbia, only localized erosion has had any real economic impact. Development has occurred primarily along east, south eastern, or protected waterfronts, resulting in a minimum impact on dwellings and lives.

Areas of particular hazard to human occupation occur along the Saanich Peninsula, the Queen Charlotte Islands and in the University of British Columbia cliff area. Although a coastal management scheme for the Saanich Peninsula was established by the Planning Department of Capital Regional District in early 1977, it has been relatively ineffectual to date, as noted by ongoing erosion at Cowichan Head, dredging at Tsehum Harbour (Victoria Times, January 9, 1977) and the use of outmoded riprap construction in the Mount Douglas Park area (Victoria Times, August, 1977).

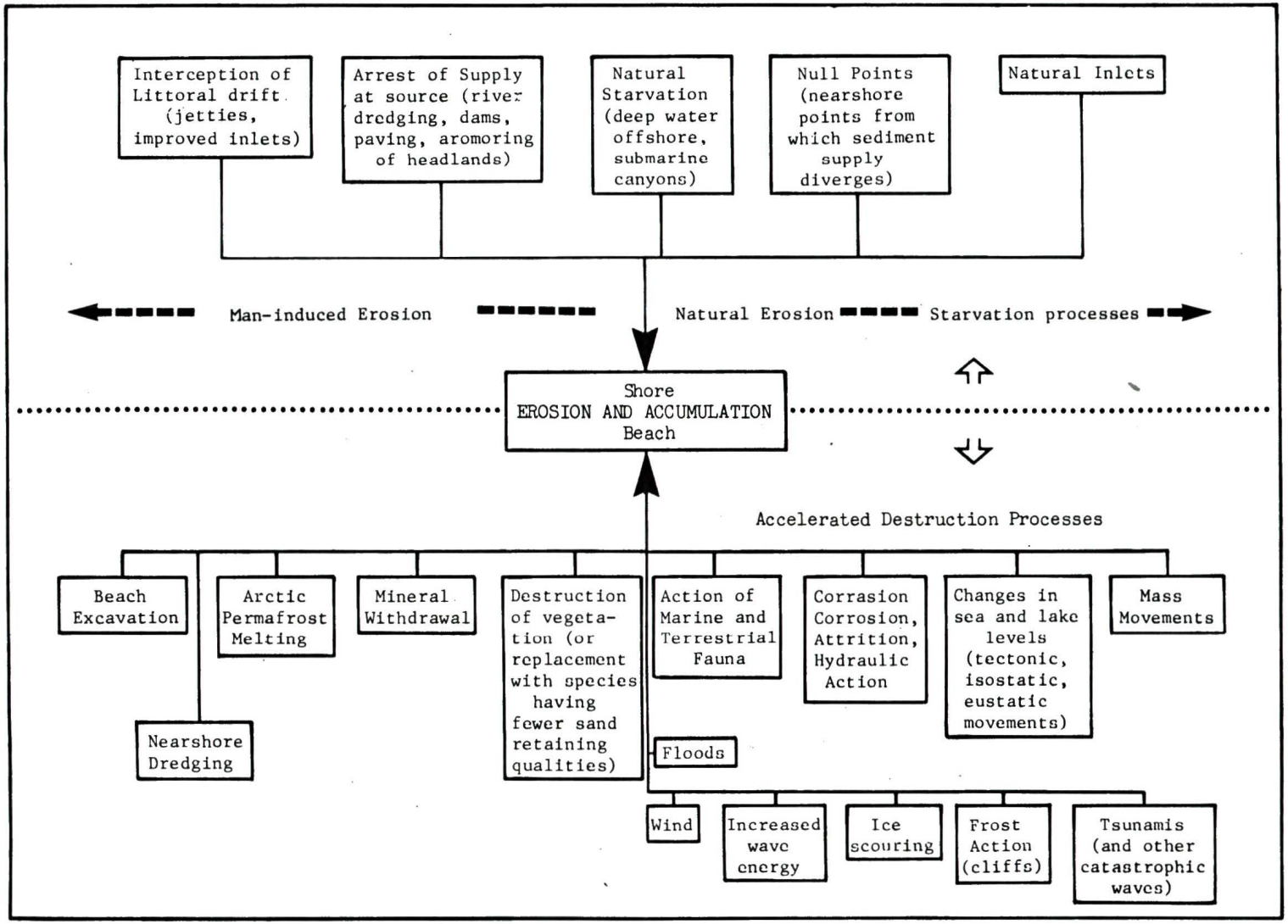

Figure 2.8: Natural and human factors in coastal erosion processes (from Sorensen and Mitchell, 1975)

Adjustments to mitigate against erosional processes are varied. Table 2.3 illustrates many of those techniques available for reducing losses due to erosion. Where localized erosional processes have been recognized during the development review process in British Columbia, restrictive covenants have been applied to restrict development from building too close to the shoreline. These covenants may be in the form of slope setbacks (2 horizontal:1 vertical) or as distance limitations (no construction of habitable dwellings within 50 m of the high water mark).

Subsidence

Within British Columbia, subsidence and directly related processes are annually responsible for considerable property damage. Subsidence features are often associated with glacial lake (glaciolacustrine) deposits of silt and clay, but may occur in areas of sands and gravels underlain by silts or clays. The location of major glaciolacustrine deposits in British Columbia are illustrated in Figure 2.1.

Subsidence features are commonly divided into two groups as a result of varying processes, these being:

(a) Caving Features

Commonly referred to as 'sinkholes', they occur when the roof of a subsurface, natural pipe or cavern fails due to loss of support from undermining of the walls (see Figures 2.9 and 2.10).

(b) Collapse Features:

These features are also referred to as sinkholes, however they result from a rapid loss of strength in the soil mass which causes consolidation of the material and subsequent settlement of the ground surface (Buchanan, 1980).

The impact on development has been dramatic in certain interior locales such as the South Columbia River Valley (Haughton, 1978), the South Thompson River Valley (Buchanan, 1977) and the Penticton area of

Adjustments to Loss	Modifications of Loss Potential	Modifications of Erosion Hazards	Adjustments Affecting Hazard Cause
Major	Major	Major	Major
Loss Bearing	Coastal zoning	Dune stabilization	Prohibition of beach excavation and harbor dredging
Insurance	Building Codes	Groynes	Sand bypassing
	Public purchase of eroding land	Bulkheads, seawalls and revetments	
	Land fill	Beach nourishment and "perched" beaches	
		Breakwaters	
Minor	Minor	Minor	Minor
Emergency public assistance	Moving endangered structures	Regulation against destruction of dune vegetation	Removal of river dams
	Installing deep pilings	Phraetophyte removal fauna	Biological control of marine
	Storm warning and forecasting systems	Artificial seaweed, bubble breakwaters	Reduction in soil conservation activities
		Emergency filling and grading	Storm track modification
		Grading slopes	

Table 2.3:
Adjustments to the Hazard of Coastal Erosion

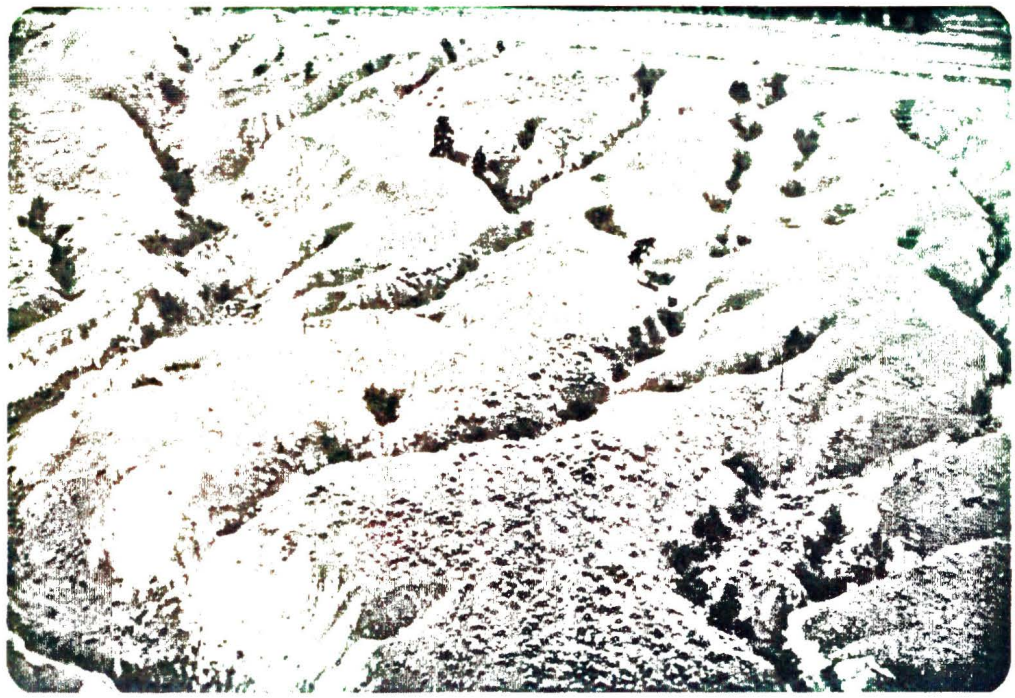

Figure 2.9: Sinkhole features: West Bench, Penticton, B.C

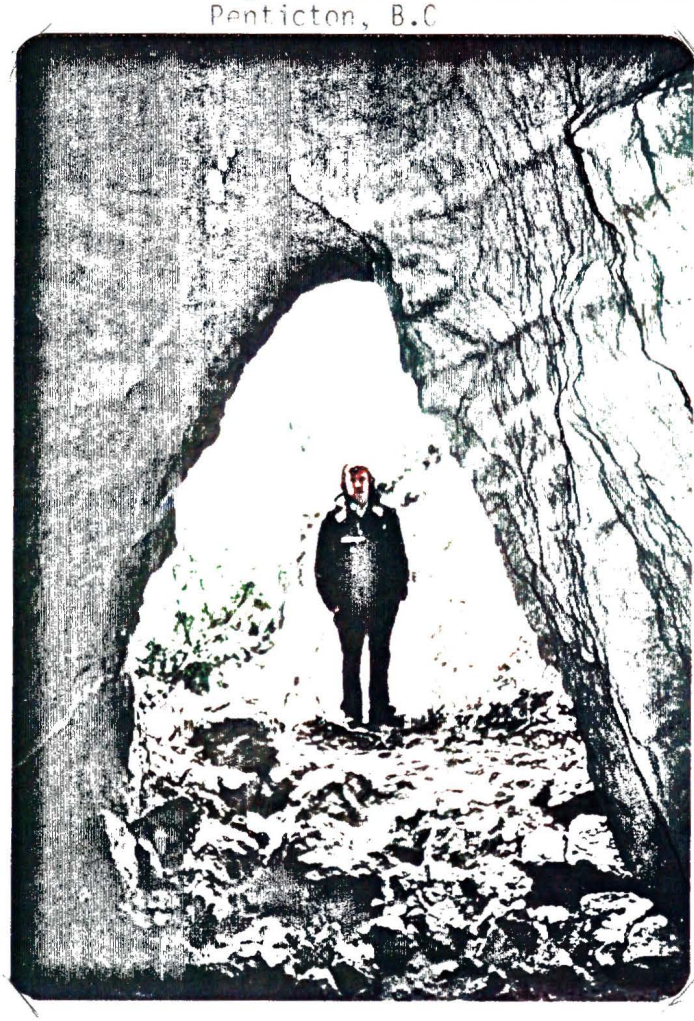

Figure 2.10: Illustrates size of pipes in South Thompson River Valley

the Okanagan Valley (Miller and Nyland, 1977), where damage losses from such hazards have approached several hundred thousands of dollars.

An example of the potential damage from subsidence was illustrated in the 1976 demise of a three-year-old public swimming pool in the Valleyview area of Kamloops. Cracks in the pool, due to subsurface soil collapse, resulted in damages estimated at between $280,000 and $300,000 (Kamloops Daily Sentinal, February 11, 1976). Today, the swimming pool has been removed and paved over as a tennis court. Many similar problems associated with subsidence processes go unrecorded. During the author's 1975-77 investigations of the South Thompson Valley, numerous stories were recounted by long-term residents of holes formed in driveways, excessive settlements and depressions in lawns, and cracking of foundations, indicating that thousands of dollars of damage has taken place in the past. Properly engineered foundations cognizant of subsidence and related processes are seen as an alternative which could effectively reduce these losses.

Earthquakes

Earthquakes are frequently felt in British Columbia, causing considerable concern to the public (Milne, 1976). Recording of seismic events in the province started in January, 1899 by the Dominion Government Meteorological Service in a location near the inner harbour of Victoria (Milne, 1976; Wuorinen, 1974). From 1899 to the present, hundreds of tremors have been measured. Several large earthquakes of magnitude 6 or greater on the Richter scale have occurred off the British Columbia coast line. The significance of seismic activity in the province can be seen from Figure 2.11, the "Seismic Zoning Map of Canada", 1970. This figure is included in the National Building Code and indicates the probability of seismic occurrence in the province. It illustrates that most of British Columbia lies within the three highest risk zones (1, 2 and 3).

To further illustrate seismic activity in the province, a record of such events occurring between 1969 and 1978, with a magnitude 4 or greater on the Richter Scale, was compiled and plotted (see Appendix C). Magnitude 4 being that seismic level on the Rossi-Forel

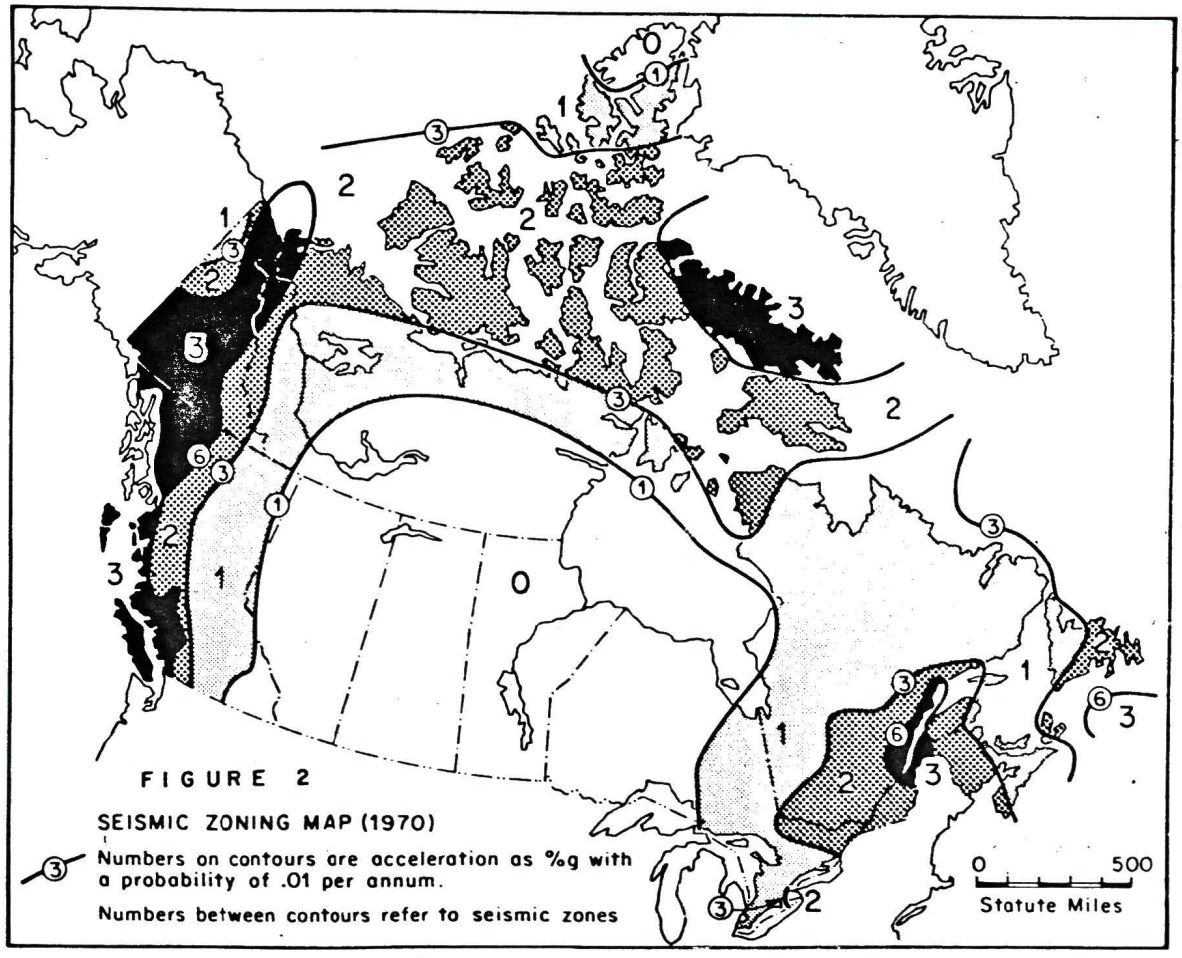

Figure 2.11: Seismic zoning map of Canada (1970)

scale which can be felt generally by everyone and can cause disturbance of furniture, beds, and ringing of bells (Richter, 1953). Some 347 tremors of this magnitude or greater occurred in the ten year period studied, with the majority centred off the west coast of Vancouver Island, as illustrated in Figure 2.12.

Damage from earthquakes in British Columbia has not been extensive to date. In studying earthquake damage in the city of Victoria, Wuorinen (1974) notes that even during Victoria's most severe tremor, caused by an earthquake of Richter magnitude 7.3 on June 23, 1946, breakage was confined mostly to chimneys and cracked walls. Other hazards such as landslides, flooding, and rockfalls, which are induced by earthquake shaking, may pose as great a risk to development as the earthquake itself. The only recorded fatality caused by the 1946 earthquake resulted when a man drowned after a slump caused wave overturned his small boat (Rogers, 1980). Probably the most costly damage of the 1946 earthquake took place at B.C. Packers at Kildonan, on the west coast of Vancouver Island, where pilings settled, resulting in repairs costing $100,000 (Rogers, 1980; Vancouver Sun, July 23, 1946). Further examples of damage on Vancouver Island from the 1943 earthquake are provided in Table 2.4.

Damage potential from a major earthquake (magnitude 7.0 or greater) is, however, growing. Widespread development has taken place on alluvial and marine deposits in the Fraser River delta which may be susceptible to liquefaction such as that which occurred in Niigata, Japan in 1964. An optimistic outlook for British Columbia in the event of a major earthquake has been presented by Dr. G. Rogers (1977) of the Pacific Geoscience Centre, Energy, Mines and Resources- Canada, who in discussing potential earthquake damages stated, "there may be some deaths and buildings may be damaged, with chimneys, signs and facades falling down, but building construction around here (British Columbia) is more resistant than in many other countries." Such an outlook is not universal, however, as Foster and Carey (1976), in their analysis of Victoria's susceptibility to earthquake damage, indicate that several areas would be susceptible to heavy (20-65% of replacement value) or moderate (7.5-20% of replacement value) damage.

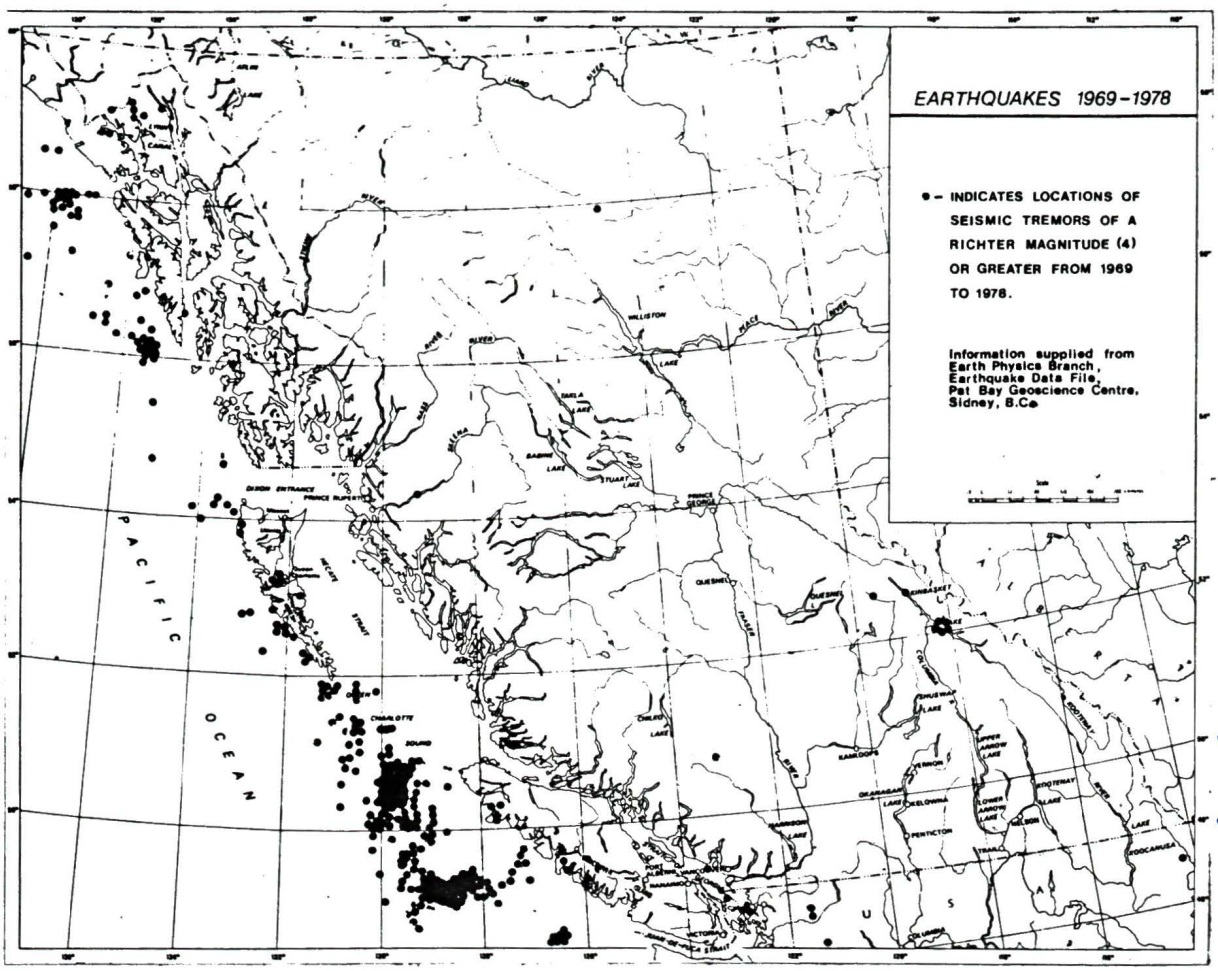

Figure 2.12: Earthquakes 1969-1978

TABLE 1. Liquefaction

No.	Location	Description*
1	Reid Island	Ground sinking up to 30 ft (9.1 m), trees and stumps splattered with blue clay (Fig. 5). N, C, H
2	Rebecca Spit	Sand boils, downdrops. C, H
3	Duncan Bay	Boiling up of black mud making bulges the size of an automobile. H
4	Campbell River	Portions of spit raised and lowered. N
5	Campbell River	Water spouts near shoreline. H
6	Campbell River	Fissure opened up, water boiled out, later filled up and covered with grey clay. N
7	Campbell River	Provincial police dock shifted 4 ft (1.2 m). N
8	Oyster Bay	Well filled almost to the top with mud. N
9	Oyster Bay	Geysers of black mud in the water near the shoreline. N
10	Oyster River	Water came over fields but soon subsided. N
11	Little River	Geysers of black mud shot out of water near shoreline to a height of 10 ft (3.0 m). N
12	Courteney	Water gushing out of earth, flooding field and leaving sand deposits. N
13	Goose Spit	Sand boils, pilings changed positions. N, H
14	Elk River valley	Piles thrown around. C
15	Comox Lake	Pilings popped out like corks. N, H
16	Mapleguard Spit	Sand boils, downdrops, pilings changed position. C, H
17	Denman Island	30 ft (9.1 m) water spout between Denman Island and Deep Bay. N
18	Powell River	Clay welt on beach. H
19	Savary Island	Wharf had appearance of roller coaster. N
20	Franklin River	Loosened pilings. N
21	Kilodonan	Sinking piles. C, H
22	Tofino	Prawns and shrimps still alive shaken out of sand. C
23	Estevan Point	Sea muddy; sea grass and unusual amount of fish eggs washed ashore. C
24	Matsqui (?)	Clay and quicksand piled to a height of 3 ft (0.9 m) on stream bank and fissures 50 ft (15.2 m) long parallel to stream. (This may be due solely to slumping.) N, H

TABLE 2. Slumps in fill or excavated areas

No.	Location	Description*
1	Kelsey Bay Highway	Severe slumping of road (Fig. 3). C, H
2	Salmon River valley	Fills on railroad grades cracked badly and in some cases flattened out. C
3	Campbell River	Clay embankment failed pushing house off foundations and filling rooms with dirt. N, H
4	Campbell River – Oyster River Road	Cracks in road. N
5	Oyster River	Highway sank 6 in. (0.2 m) at each end of bridge. N
6	Courtenay – Comox Road	Cracks in road. N, H
7	Union Bay – Comox Road	Cracks in road. N
8	Cameron Lake	Small slides across railroad. C
9	Ladysmith	Railway bed dropped 18 in. (0.5 m). N
10	Westview	Road slump. H

TABLE 3. Beach changes and underwater slumping

No.	Location	Description*
1	Jackson Bay	Beach disappeared. C, H
2	Port Neville	Water deepened. C, H
3	Williams Beach	Heave in sandy beach. N
4	Buttle Lake	Beach about 250 ft (76.2 m) long disappeared. C, H
5	Comox Lake	Beach disappeared. N, H
6	Goose Spit	Several beaches disappeared. N
7	Great Central Lake	Slump of alluvial fan. H
8	Deep Bay	End of spit disappeared causing large wave. N, C, H
9	Sproat Lake	Slump of alluvial fan. H
10	Cameron Lake	Beach disappeared. C, H
11	Alberni Canal	Underwater cables broken and buried between China Creek and Franklin River, wave observed. C, N, H
12	Cowichan Lake	Slump of alluvial fan. H
13	Nitinat Lake	Slump of alluvial fan. H
14	Kilodonan	Slump of alluvial fan. H
15	Tofino	Cracks on beach 3–4 in. (0.1 m) wide parallel to beach. C
16	Megan River	Beach heave of 20–30 ft (6.1–9.1 m). C
17	Malispina Channel	Underwater telephone cable to mainland severed. N, H

*The information is a quote or paraphrase of the original source and thus original units are retained (SI units in brackets) to aid the reader in estimating the precision of the values. The letters following the description indicate the source of the information: H = Hodgson (1946); C = correspondence to Hodgson; N = newspaper articles.

Table 2.4
Examples of damage on Vancouver Island from the 1943 Earthquake (Rogers, 1980)

Additionally, though residential structures and some reinforced buildings may survive relatively undamaged, one must also consider the threat of damage from earthquakes to such structures as bridges, railways, highways and other related infrastructure necessary for transportation and communication.

Tsunamis

Tsunamigenic occurrences in the coastal communities of British Columbia are infrequent, but potentially costly, as illustrated by the 1964 tsunami which caused severe damage in Port Alberni. Tidal records over the past 71 years at Tofino on the west coast of Vancouver Island indicate that at least 33 tsunami's have reached these shores, although most waves were only a few centimetres in height (Wigen, 1981). The 1964 tsunami which was generated from sea wave action caused during a major Alaskan earthquake centred in Prince William Sound has been British Columbia's most devastating (Hansen and Echal, 1966). Damage to the pulp mill alone in Port Alberni was some $5 million, while total damage estimates for the mill and townsite vary from $7-10 million (files: Ministry of Transportation and Highways, B.C.). Additionally, 600 men were laid off for 1 week while repairs and damage assessments were completed. Land-use plans prepared for the Port Alberni community now include tsunami inundation zones based on the extent of the 1964 flooding.

British Columbia presently has a tsunami warning system which is part of a larger international network with headquarters at the International Tsunami Information Centre in Honolulu (Foster and Wuorinen, 1976). The warning system is part of the B.C. Provincial Emergency Program, and the flow of information in the event of a tsunami warning is indicated in Figure 2.13. Evacuation of residents in a tsunami hazard zone and a subsequent reduction in loss of life is possible through employment of the warning system.

Volcanic Eruption

Particular interest in volcanic hazards has occurred since the May, 1980 eruption of Mount St. Helen's in the Cascade Mountains of

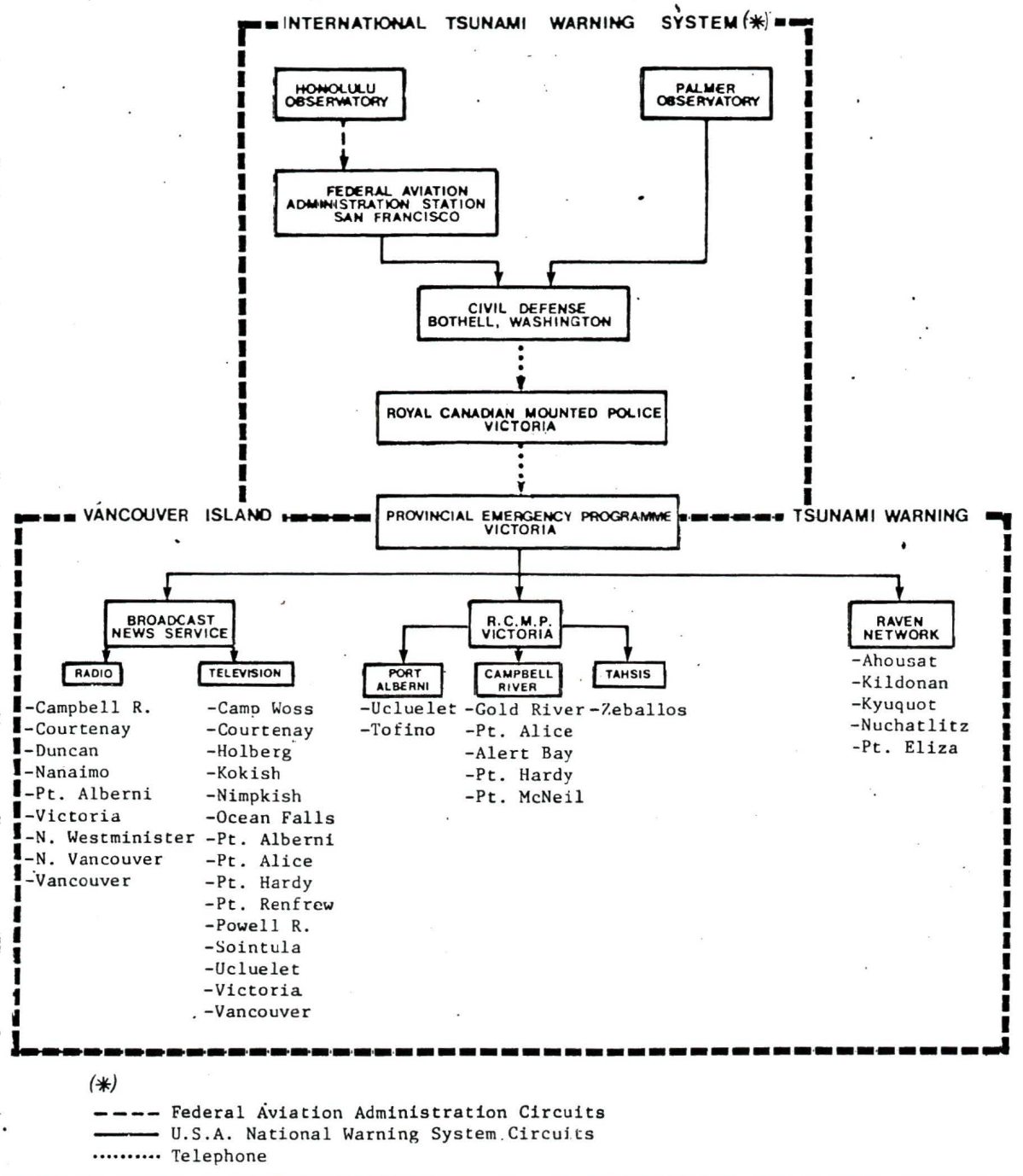

Figure 2.13: Tsunami warning system and coordination

Oregon. Several similar volcanic assemblages exist in the coastal mountain ranges of British Columbia. For example, explosive eruptions have occurred in the Bridge River area within the past 2500 years (Naismith et al, 1971). Ash deposits from previous eruptions at Mount St. Helen's, and Mount Mazama (Glacier Peak) in the Cascade Range of the northwestern United States can be found in several locations in the southern part of the province.

Currently, interest is concentrating on the effects of potential eruptions from Mount Baker in northwestern Washington State and Mount Edziza in the Stikine Region of northwestern British Columbia. Ash falls from Mount Baker could affect the Lower Fraser-Mainland area while an eruption of Mount Edziza could adversely affect proposed hydro developments on the Stikine and Iskut Rivers (Souther, 1980).

Volcanic activity is not felt to pose a high risk in British Columbia. However, because of tectonic forces existent along the coast, consideration of volcanic eruption and the impact on developments is advisable.

Effects on Areas of Human Occupance

> "As the affluence of the industrial nations rises and as standards of social security are improved there is increasing concern to cushion all members of society against unexpected loss that can result from extreme events in nature." (Hewitt and Burton, 1971).
>
> "Man is responding to the risks and uncertainties of natural events such as floods, hurricanes, and earthquakes in a way which leads to increasing property losses. (White, 1974)

The growth of development in areas of risk has continued to increase over time. Conceivably, this growth has not taken place with the knowledge that a risk is involved. Differences in the perception of risk lead individuals to develop in areas that they do not perceive as being hazardous. It is this apparent ignorance of the risks involved in developing a hazardous area which has compounded the problem of managing 'high risk' areas. (Foster, 1978; U.S. Office of Emergency Preparedness, 1969).

The effects of natural hazards on development are therefore, dependent upon three important factors of which one is the degree of risk, the second is the perception of risk, and the third is the anticipation by those who knowingly develop in high risk areas that they will be compensated should a damaging event occur. Kates, 1978, defines the 'estimation of risk' or 'degree of risk' as being based on the potential losses which could occur from event-generating mechanisms within the environment. The degree of risk therefore is dependent upon the action of an extreme natural event and the coping actions taken as a reflection of societal values at that time (Sewell and Foster, 1976). Though individuals living within areas of hazard may have as accurate a perception of risk as the experts, and possibly more so from a social aspect (Burton; et al, 1978); their intuitive estimates of magnitude will tend to be conservative and the adjustments taken, will allow for too small a margin of safety (Slovic; et al, 1978). An example of this is the often used one-in-two-hundred flood interval. Individuals are likely willing to accept a risk of one flood in two hundred years based on their past perceptions, however, they are less likely to accept the risk if it is indicated that this is a catastrophic flood level, not minor inundation. In addition, the perception of risk is reduced dramatically as a result of the anticipation that compensation will be supplied even if a predicted event should occur; and more explicitly when the compensation is considered as a right and not a gift (Foster, 1976; Sewell, 1965).

Because extreme events do not imperil lives as much as property in North America, the prevailing philosophy has tended towards property protection. Such protection has been accomplished predominantly through technological advancements. A paradox of this adjustment for damage loss reduction is that 'damage potential' is increased dramatically, yet the perceived risk is lowered because of the ubiquitous desire to believe in the protection provided by a technological device. An example of this is provided by the residents of Squamish, B.C. Having undergone flooding in the autumn of both

1980 and 1981, inundees were seen picketing highway routes[2] demanding dykes and dams for protection. They apparently did not realize that the long-term effects may be to invite further development and make the area susceptible to increased damage losses should an extreme event (greater than that predicted) occur.

A review of the period 1971 to 1980 in British Columbia indicates that there were at least 75 events which involved damage or loss of life directly from natural hazards (see Appendix D). These events caused at least 56 deaths and in excess of 60 million dollars in damages. This figure does not include snow clearance on highways as a result of avalanches, nor does it include additional costs attributed to building earthquake resistant structures or structures for erosion and other hazard control.

As illustrated in Figure 2.1, the spatial distribution of natural hazards is such that few sites in the province of British Columbia are relatively free of risk. While no increase in damaging events has been quantified, most experts in the field note a rise in the number of damaging events over the past 10-15 years. British Columbia has an excellent opportunity to institute a natural hazards program before a major disaster occurs. Post-event relief is not viewed as a suitable approach to hazards mitigation. Policy, legislation and administration are required, if losses to natural hazards are to be reduced to acceptable levels.

Enforcement of land-use restrictions as part of the planning concept are also required if developments in these areas presently known to be at risk are to be carried out in the safest manner possible. In this chapter, the severity and spatial distribution of damaging events has been presented and illustrates the need for controls which can protect against even greater disasters in the future. Because there is such a wide distribution of risk within

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2 British Columbia Television carried this news report on November 21, 1981, showing people from the Brackendale area of Squamish picketing Highway 99 to indicate their displeasure with the Government for not constructing protective dykes.

British Columbia, the need for a well-organized, planned approach to hazards mitigation seems mandatory. This planned approach will require a legislative base and it is in the next chapter where existing legislation in British Columbia is reviewed and compared with examples from other jurisdictions.

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Chapter 3
NATURAL HAZARDS LEGISLATION IN BRITISH COLUMBIA

Typically natural hazard legislation in British Columbia has been passed in response to crisis. As indicated in Chapter 2, there has been a diversity of such crises in the past and the potential for catastrophe is increasing. Power to enact legislation to deal with natural hazards lies with the provincial government, yet to date, the response has been towards making minor amendments to existing legislation or developing hazard-specific, site-specific statutes. Lessons learned in the past are not reflected in improved legislation today; conversely, there is an apparent tendency to repeat those mistakes made earlier.

In coming to grips with this widespread distribution of high risk hazard areas in British Columbia, some form of all-hazards legislation will be required to reinforce existing statutes. In order to assess the existing status of natural hazards legislation in British Columbia, a historical review of related legislation, committee development and formation of boards will follow. In addition, a comparison with legislation from several American states will be made in order to determine the level of British Columbia's legislation in relationship to other areas subject to similar risks from natural hazards.

The Development of Legislative Powers in British Columbia

The British North America (B.N.A.) Act, divided legislative power in Canada between the federal government and the provinces. Under the B.N.A. Act, British Columbia was given almost complete control of land use within the province. The provincial legislature under section (92) (13) of the B.N.A. Act, has the power to regulate "property and civil rights in the province" and "generally all matters of a merely local or private nature." In addition, British Columbia was given control over "municipal institutions in the province," much of which authority the legislature has since delegated to municipal governments (Ince, 1977).

Major powers over land-use were, therefore, designated to the provinces under the B.N.A. Act. Development of provincial legislation however, is further complicated by certain parliamentary forms. For example, prior to a provincial statute becoming law, it must be passed by the legislature and given Royal Assent by the Lieutenant Governor in Council. Statutes may not however, become law until such time as they are proclaimed. Proclamation may be decreed only by the Lieutenant Governor in Council, subject to consent of the provincial cabinet. In examining legislation, it is essential to determine whether or not a particular act or section of an act has been proclaimed, for often, statutes may apparently exist but, if left unproclaimed they have no legal standing. Another common aspect of provincial legislation is that it delegates law-making authority to a particular government body such as the Cabinet, a Minister, or a government agency (Ince, 1976). An example is the Emergency Program Act, 1960, which stipulates in section (2) "The Minister of Environment is responsible for administration of this Act."

To facilitate legislative action on technical subjects such as natural hazards, a statute may deal with a matter in generalized terms, while giving the Cabinet power to stipulate, by Orders in Council, specific technical provisions. This allows for legislative action in crisis situations where the legislature neither has the time, nor the experience to deal with the problem. Expert input on a subject, for example, may be derived from within government ministries, through private consultants or from academic sources. Unfortunately, abuses may arise as a result of this process because it tends to delegate powers to make laws without discussion or debate. Furthermore, certain problems may also arise from the almost unlimited powers delegated to authorities by the legislature without accurately defining the range of the problem to be addressed (Ince, 1976). Aspects and examples of such delegated powers will follow later in the historical review of natural hazards legislation in British Columbia.

A Historical Review of Natural Hazard Legislation in British Columbia

Most natural hazards legislation in British Columbia may be directly related to a previous disaster, often in the form of a flood as illustrated in Table 3.1. In British Columbia, the first legislative response to the hazard of flooding occurred in 1894. That year a major spring-freshet flood occurred, causing widespread inundation of floodplains along the Thompson and Fraser Rivers. Damage was confined to washed out bridges, roads and agricultural crops and minimized by the absence of major development. Nevertheless, this event stimulated legislative action and resulted in the Drainage, Dyking and Irrigation Act of 1898. This was the first piece of provincial legislation which provided assistance for dyking as a means of reducing flood impacts. Due to inadequate administration and inspection, dykes constructed under this act were disorganized and un-coordinated, the impacts of which were to be realized later.

Introduction of the Land Registry Act in 1906 was not to have any immediate impact on lands affected by hazards, however within the act certain clauses would eventually gain importance in the control of hazards in subdivisions. An example of such a clause was section (93) (c) (below) which introduced the term "against the public interest" and provided an approving officer[1] with the power to refuse a subdivision if he decided it was hazardous and against the public interest. Refusal is a subjective decision of the approving officer. This clause would not be readily used for restricting land use in areas of risk until the early 1970's.

Land Registry Act

Section (93)
In case the lands subdivided are not within a municipality, the approving officer may, at the cost of the owner of the lands, personnally examine or have an examination and report made on the subdivision, and may refuse to approve the plan if he considers that
(c) the deposit of the plan is against the public interest.

Table 3.1: The relationship of Provincial Acts and the hazard for which they were developed, including the Ministry currently administrating the appropriate sections

Act (date)	Hazard	Important Sections	Current Administrating Ministry
Drainage, Dyking and Irrigation Act (1894)	Flood	Complete Act	Ministry of Environment
Land Registry Act (1906)	All Hazards	Section (93)(c)	Ministry of Lands, Parks and Housing; Ministry of Transportation & Highways
Flood Relief Act (1948)	Flood	Section (2)(b) Section (9)	Ministry of Environment
Fraser Valley Dyking Board Act (1948)	Flood	Complete Act	Ministry of Environment
Moratorium Act (1948)	Flood	Section (3)	Ministry of Environment
Okanagan Flood Control Act (1949)	Flood	Complete Act	Ministry of Environment
Riverbank Protection Act (1960)	Flood	Section (2)	Ministry of Environment
Emergency Program Act (1960)	All Hazards	Section (3)(1)	Ministry of Environment
Local Services Act (1960)	Erosion Landslip Flood	B.C. Reg. 262/70 Section (4.06)	Ministry of Lands, Parks and Housing; Ministry of Transportation & Highways
Amendments Land Registry Act (1974)	Flood Erosion Landslip	Section (93) (1)(d)	Ministry of Environment; Ministry of Transportation & Highways
Land Titles Act (1979)	Flood Erosion Landslip Avalanche	Section (82)(1) Section (85)(3) Section (86)(1)	Ministry of Environment; Ministry of Transportation & Highways
Environment Management Act (1982)	All Hazards	Section (5)(1) Section (6)(1)	Ministry of Environment

Following this, a hiatus of approximately 40 years occurred during which no hazard related legislation was passed. It took another major flood in 1948 to stimulate concern. The 1948 flood itself caused extensive damage and spurred both the provincial and federal governments into producing preventative legislation. A special session of the provincial legislature was called in July of 1948 to cope with the disastrous flooding. As a result, three new acts were introduced; the Flood Relief Act, the Fraser Valley Dyking Board Act and the Moratorium Act.

The Flood Relief Act provided for a funding program between the provincial and federal governments for providing aid, relief and rehabilitation for flood damage and dyking in the Fraser Valley.

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1 Definition of an Approving Officer is taken from Section 90 of proposed Bill 9, "The Land Use Act". "Approving Officer" means a person appointed as an approving officer under section 90 and includes his deputy.

Appointment of Approving Officers

Section 90.

(1) The council of every municipality shall appoint as an approving officer,
   (a) a person who is employed by a municipality, or
   (b) with the minister's (Minister of Municipal Affairs) consent, a person who has been appointed under subsection (3) (a) or (b), as the approving officer for an area outside the municipality.

(2) A person who is appointed as an approving officer under subsection (1) (a) is an officer of the municipality.

(3) The Lieutenant Governor in Council may, for an area outside a municipality he specifies, appoint as an approving officer,
   (a) a person employed in the ministry pursuant to the Public Service Act, (Ministry of Transportation and Highways)

   (b) with the consent of the board, an appointed officer of a regional district, or

   (c) with the consent of the council, an approving officer of a municipality.

Provision was also made for a cost-sharing format between the federal and provincial governments. Under the format, the federal government agreed to pay 75 percent of the costs for repairs and construction of dykes, including new construction of dykes to protect against future floods (see section (2) below). In addition, the act created the basis upon which 'boards' were to be formed to carry out the provisions of the act (section 9). Shortly after proclamation, several local dyking districts and boards were established in such areas as Chilliwack, Sardis, Richmond and Mission to oversee local problems and address local priorities. Under the provisions of the act the Fraser Valley area board was to be referred to as the "Fraser Valley Rehabilitation Authority" and was to consist of two or more members appointed by the province. The Authority was responsible for provincial interests during the immediate post-event recovery period.

Flood Relief Act (1948)

> Section (2) The Lieutenant-Governor in Council may from time to time:
> (b) Enter into any agreement with the government of the Dominion with respect to provision for payment of a portion of the costs incurred on or after the fifteenth day of May 1948, by the Government of British Columbia, by the municipal authorities in the Fraser Valley, and by the departments and agencies of the Government of Canada in repairing, strengthening, constructing, and reconstructing dykes in the Fraser Valley and removing water and debris from the flooded lands in the valley in accordance with an agreement that the Government of British Columbia is hereby authorized to enter into with the Government of Canada for the purpose of establishing a division of such costs on the basis of the Government of Canada bearing seventy-five per centum thereof.

Urgent need for major reconstruction and rehabilitation followed the 1948 flood. To coordinate flood relief activities and to account for funds spent under the federal-provincial agreement for dyke construction, the province formed the Fraser Valley Dyking Board. Mandate and standing of the board was declared in the Fraser Valley Dyking Board Act (1948) with members of the board being appointed by

the Lieutenant Governor in Council and given wide powers to repair, strengthen, construct and reconstruct dykes in the Fraser Valley, and remove water and debris from flooded lands. Acting quickly, and without the aid of engineering or economic studies, the Fraser Valley Dyking Board developed dyke design standards and flood crest elevations for new or reconstructed dykes. Dykes were to be constructed to two feet above the flood level of 1894. Rehabilitation of the dyking system by the Board, was completed just prior to the 1950 spring freshet which was the third highest water level on record at Mission, exceeded only by the flood levels in 1894 and 1948 (Fraser River Joint Advisory Board, 1976). The dykes successfully held against the 1950 freshet and no flood damage resulted.

The third piece of legislation stimulated by the 1948 flood was the Moratorium Act (1948). Under the act, a moratorium was placed on any claims by individuals or groups for compensation of damages incurred from floods in the spring of 1948. Essentially the Act was passed in order to provide government agencies with time to assess damage, evaluate claims and prepare a method of payment to victims. In addition, the Act stopped any actions of foreclosure or debt assessment until such time as flood damage could be repaired or compensated for.

Under section (3) (below) of the Moratorium Act, powers were given to the Lieutenant Governor in Council to decide which areas were affected by the flood. As a result, some disparities arose in designating flood areas, especially where marginal flooding had occurred. Some of those living in marginally flooded areas received relief while others were left to absorb the losses themselves. As the Act was primarily established to provide adequate time to review claims, it was terminated on the opening of the first Legislative Assembly in 1949.

Moratorium Act (1948)

> Section (3) The Lieutenant-Governor in Council shall have power from time to time, for the purposes of this Act, to make regulations defining flood areas in the Province that have suffered

> damage by flood during the spring of 1948. Such legislation would likely be required again should a major disaster occur.

Damage caused by the 1948 flood, emphasized the need for a comprehensive evaluation of the Lower Fraser Valley. The Fraser Valley Dyking Board's rehabilitation program was considered to be inadequate to fully consider the need for a greater measure of flood protection beyond dyke construction. Need for greater protection with the growing demand for electrical power, led to the formation of the Dominion-Provincial Board, Fraser River Basin. The Board was requested to study and report on "the water resources and requirements of the area comprising the Fraser River watershed," with primary attention to power, fisheries, floods, water supply and recreation. Unfortunately, as this was the first attempt at integrated water management on the Fraser River system, the Board was hampered by an essential lack of data. Much of their study time was therefore taken up in the systematic accumulation of the required data (Fraser River Joint Advisory Board, 1976). Consequences of this study will be discussed later in relationship to further investigations carried out on the Fraser River flooding problem.

Flooding in 1948 was not solely confined to the Fraser River Valley. Considerable damage was also incurred in the Okanagan Valley and in response, the provincial legislature later passed the Okanagan Floods Control Act in March, 1949. Unlike the Fraser Valley where boards were established to administer flood related programs, administration of this act was to be carried out under the provincial Ministry of Public Works. In addition, the act did not provide for the 1948 flood damage, but provided for dyking and relief necessary after April 1, 1949. These variations arise between the Okanagan and Fraser River case because in the Okanagan, the damage was not severe enough in 1948 to declare it a disaster area and because most of the land affected by the flooding was unincorporated, therefore administrative responsibility lay with the province rather than with a particular municipality or group of municipalities such as in the Fraser River Valley.

As noted earlier, the Dominion-Provincial Board, Fraser River Basin, spent much of its time in data research which continued up until 1955. This board was then replaced under new terms of reference by the Fraser River Board which was instructed to submit an interim report on flood control by June, 1956. Further to this, the board was requested to provide a preliminary report by June, 1958 on the effective regulation of the Fraser River system for flood control and power and the resultant effects on navigation, fisheries, silting, erosion and irrigation (Fraser River Joint Advisory Board, 1976).

In June, 1956, the Fraser River Board produced their report entitled "Interim Report into Measures for Flood Control in the Fraser River Basin." In this document, the Board examined various flood-control techniques and investigated the existing defenses. It noted that the Lower Fraser Valley dykes had deteriorated and recommended they be improved, restored and maintained in accordance with the Fraser Valley Dyking Board design standards and criterion. The report also recommended that no other programs for permanent flood protection be initiated pending completion of further studies to determine the impacts of storage systems that could be provided by a multiple purpose project.

In its June, 1958, "Preliminary Report on Flood Control and Hydro Eletric Power in the Fraser River Basin", the board recommended a modified development proposal which would: (a) provide a substantial degree of flood control; (b) interfere as little as possible with fish migration and reproduction, and (c) be economically viable from its production of electrical energy (Fraser River Joint Advisory Board, 1976). The Board also reiterated its observation that the existing dyking system was deteriorating and that improvements were required. After presenting their report, however, the Board was requested by both the provincial and federal governments to revise the recommendations, a process which would not be concluded for four more years.

In the interim, provincial legislators introduced two new acts, the Riverbank Protection Act and the Emergency Program Act, both in 1960. The Riverbank Protection Act was conceived to provide the

provincial government with the right to study and evaluate needs for dyking in areas not directly administered by dyking boards. It also provided for private individuals or groups to apply for studies to be undertaken (see section (2) below) in areas of developed, yet unprotected lands. Creation of the act was spurred by findings of the Fraser River Board and by the realization that many areas in the province not administered by a dyking board were still subject to potential flooding. Considerable development had taken place in the province since 1948, therefore, dyking was required in areas not previously protected nor possibly evaluated in subsequent studies.

Riverbank Protection Act (1960)

> Section (2) The Lieutenant-Governor in Council on application by the owners, supported by a majority in interest of the owners, where it appears to him necessary in the public interest that protection work be executed to prevent the encroachment of a river on its banks, may direct the engineer[2] to prepare a report under this act.

Introduction of the Emergency Program Act resulted from the "Cold War", a time when nuclear warfare was considered likely. It reflected a psychological crisis period unlike the physical disasters (crises) which spawned much of the previous legislation. The act was constructed to conform with national civil defense plans, therefore the emphasis of the act was oriented toward "civil defense" with "civil disasters" incorporated in a secondary role. Unlike most legislation, the Emergency Program Act calls for the complete integration of provincial and federal civil defense plans. This coordination has been applied to civil defense but has not extended to natural disaster planning. The only exceptions are those where a large magnitude event such as an earthquake could disrupt civil defense planning. With the waning of the cold war period however, that portion of the act concerning civil disaster became more prominent.

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2 "The Engineer" - refers to a member of the Water Management Branch, Ministry of Environment (often the Inspector of Dykes).

An important facet of this act was its appointment of a director and a staff to administer a "Provincial Emergency Program" (P.E.P.) (see Section (3) (1) below). It was not until 1965 however, that staffing for the program as part of the Regional Operations Division, Ministry of Environment took place. Powers within the act also provide the Lieutenant-Governor in Council, the Minister of Environment and the Director of the Provincial Emergency Program with extensive emergency powers, including the right to purchase land for public safety. An application of this power in the Mount Garibaldi flood and rock slide hazard area is described in Chapter 5.

Emergency Program Act

> Section (3) (1) A director, Provincial Emergency Program and other officers, technicians, clerks and employees as are required for the proper carrying out of this Act may be appointed under the Public Service Act.

While new legislation was being brought forth to cope with disasters, the flooding studies on the Fraser River continued. As noted earlier, the Fraser River Board was to take almost four years before it presented its revised report in 1963 entitled, "Final Report on Flood Control and Hydro Electric Power in the Fraser River Basin". A Canada-British Columbia Committee was then formed in 1966 to review the recommendations of this report and to determine the requirements for sea dykes, improved drainage and pumping capacity, and erosion protection. In its 1967 report, the Committee outlined a potential plan for flood protection at a projected cost of $33 million (Fraser River Joint Advisory Board, 1976).

Based on the recommendations of the Committee, Canada and the Province of British Columbia signed an agreement on May 24, 1968, covering a plan for flood control in the Fraser Valley. In this agreement the two governments made provisions for construction of flood control works and for a review of previous studies of potential reservoir developments in the upper reaches of the Fraser River and

funded to a limit of $18 million each (total $36 million)[3]. Such expenditures under this agreement having a built-in termination date of March 31, 1978.

Originally the concept was to protect land in the Lower Fraser Valley from inundation by the spring freshet of the Fraser River. However, over subsequent years the scope was broadened to provide a comprehensive flood control program for the area, including rehabilitation of existing dykes, construction of new dykes, increased river bank protection and improvement of internal drainage facilities (Fraser River Flood Control Program, 1968). To operate the program, the two governments formed the Fraser River Joint Advisory Board (3 federal appointees and 3 provincial appointees) and a Joint Program Committee (3 federal appointees and 3 provincial appointees).

Regressing slightly, in 1960, the Local Services Act was passed to assist in assuring the safe, healthful, efficient, economical, and attractive subdivision of land." No reference is made to natural hazards in the 1960 text, but within this act, provisions were made for the design of subdivision regulations which in 1970 formally became "British Columbia Regulation 262/70:Subdivision Regulations." Authority of these regulations, like the act is restricted to lands not within a municipality, not regulated by a regional district, nor those lands within Community Planning Area 24 (the Lower Mainland). The Local Services Act does not appear to have been initiated by any previous crisis, however the subsequent subdivision regulations make the most direct reference to natural hazards of any legislation reviewed. Section (4.04) of the "Subdivision Regulations" notes that approval of any subdivision may be refused if it:

> (a) (i) contains land which is subject to erosion; or
>
> (ii) contains a parcel which is divided by land subject to erosion into areas not suited to the use to which it is intended; or

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3 Inflationary costs resulted in an amendment to the agreement April 29, 1974, increasing the funding from $18 million to $30.5 million and to cover costs for dyking at Kamloops, which were needed after the 1972 flood.

(b) (i) contains land which may slip when developed, used or occupied; or
(ii) contains land which when developed, used or occupied may cause land on an adjacent parcel to slip; or
(iii) contains land which may be inundated by a land slip if land above on another parcel slips; or

(c) contains land which is subject to flooding so as to render as unsuitable for the use to which it is intended; ...

In addition, it is possible under section (4.06) of the regulations to request from the subdivider "a professional engineer's report on the effect on soil stability of disturbing natural grades or natural growth or changing the moisture content of the soil by developing, using or occupying the land." This clause is rarely invoked, although exceptions may arise where problems are extremely obvious or there is some expediency in having the proposal reviewed.

Like the Fraser River flood program and the Provincial Emergency Progam, other acts changed their emphasis, or were amended to more accurately describe and deal with natural hazards. For example, the Land Registry Act made amendments in 1974 which introduced hazard specific clauses (see section (93) (1) (d) below) to aid in defining processes which were "against the public interest."

Land Registry Act

Section (93) (1) In case the lands subdivided are not within a municipality, the approving officer may, at the cost of the owner of the lands, personally examine or have an examination and report made on the subdivision, and may refuse to approve the plan if he considers that

(c) the deposit of the plan is against the public interest;
(d) the land is subject to, or could reasonably be expected to be subject to, flooding, erosion or land slips;

(3) Where land within a plan of subdivision is subject to, or could reasonably be expected to be subject to, flooding, no approving officer shall approve the subdivision without the prior consent of the Deputy Minister of Water Resources who may

> require, as a condition of his consent, that the subdivider enter into a covenant, registrable under section 24A, that the subdivided lands will not be built upon, or will not be used in such manner, having regard to the nature of the flooding, as may be specified in the covenant.

Several disasters or potential disasters led to the 1974 amendments, including the 1972 flood which devastated areas of Kamloops and the Fraser Valley. Extensive erosion of riverbanks along the Thompson and Fraser Rivers prior to and during the flood caused considerable property loss and endangered many residences and facilities along the rivers. In addition, a court case in 1973 dealing with the British Columbia Department of Highways refusal to allow subdivision of the flood/landslide susceptible Rubble Creek fan near Mount Garibaldi (see chapter 5) based on its being "against the public interest" accentuated the ambiguity of the term. Definition of those hazards most common to British Columbia was felt to be required and led to the amendments in the act.

Subsection (3) of the act was included because, the Department of Water Resources was responsible for all facets of water management including flood control. Notably, subsection (3) was further amended in 1976 to become section (93A) wherein, consent of the Minister of Environment was substituted for the Deputy Minister of Water Resources (the Department of Water Resources having been incorporated into the Ministry of Environment in 1975). The act was to be expanded and subjected to radical change in 1979.

Before discussing changes to the Land Registry Act, however, further alterations in the joint agreement on flood control on the Fraser River should be highlighted. In the interim between 1974 and 1976, escalation of costs for flood control works had resulted in the realization that insufficient funds had been allocated by the two governments. As a result, Amending Agreement No. 3 was signed October 5, 1976, allocating expenditure of $60 million from each government, and extending the termination date from March 31, 1978 to March 31, 1984. Though the costs appear high ($120 million), the potential damage when calculated even crudely, could amount to over $1.0 billion in 1982 dollars.

The Land Registry Act was repealed in 1979 and replaced by the Land Titles Act, which altered those sections pertaining to natural hazards. Under the Land Title Act, the right to refuse subdivision in areas of high risk was retained, however flooding was given greater emphasis under its own section (82) (Subdivided Land Subject to Flooding) and additions were made to section (86) (previously section (93) of the Land Registry Act) as indicated below.

Land Titles Act

> Section (82) (1) Where land within a plan of subdivision is subject or could reasonably be expected to be subject, to flooding, no approving officer shall approve the subdivision without the prior consent of the Deputy Minister of Environment who may require, as a condition of his consent, that the subdivider enter into such covenants registrable under Section 215 as the Deputy Minister considers adviseable.
>
> Section (86) (a) Without affecting the generality of section (85) (1), in considering an application before him for subdivision approval in respect of land not within a municipality, the approving officer may
> (c) refuse to approve the subdivision plan, if he considers that
>
> (5) the land is subject, or could reasonably be expected to be subject to, flooding, erosion, land slip, or avalanche, or
>
> (6) after due consideration of all available environmental impact and planning studies, the anticipated development of the subdivision would adversely affect the natural environment to an acceptable level, or ...

Addition of avalanche to subclause (5) was made to separate landslides (slips) from snow avalanches. The change being made in recognition of the differences between earth and snow processes and to emphasize work carried out by the Maintenance Operations Division, Snow Avalanche Section of the Ministry of Transportation and Highways. Right to refusal, based on the proposal being against the public interest had been retained within section (85) (3), however, subclause (6) of section (86) (1) (c) could be applied in a similar manner.

Disaster struck again in the spring of 1980, when floods hit the Brackendale Subdivision north of Squamish. Acquisition of relief funds became difficult, however, for the Minister of Environment found that expenditures for disaster relief first had to be approved by the provincial cabinet. Even though funds were required quickly after a disaster, considerable periods of time could elapse before members of the legislature might be gathered and relief funds subsequently released. As a solution, the Environment Management Act was proposed in the fall of 1980, and was proclaimed in full in January, 1982. Under section (5) (1) of this act, the Minister of Environment is empowered to declare the existence of an environmental emergency (crisis) and may expend funds under section (6) (1), without cabinet or legislative approval (see below). Funds needed immediately for compensating victims can now be acquired without the time delays incurred previously.

Environment Management Act

> Section (5) (1) Where the minister considers that
> (a) an environmental emergency exists, and
> (b) immediate action is necessary to prevent, lessen or control any hazard that the emergency presents,
> he may declare, in writing, that an environmental emergency under this section exists.
>
> Section (6) (1) Where the minister certifies that money is required for immediate response to an environmental emergency, the amount he certifies to be required may be paid out of the consolidated revenue fund without an appropriation other than this section.

Municipal Legislation

Provincial legislation and agreements reviewed to this point have primarily concerned themselves with aspects of senior government authority. In British Columbia however, the provincial legislature has delegated considerable authority over land use to local, municipal governments through the Municipal Act (1957). Municipal legislation which can be applied to hazards regulation if required, is contained within local bylaws which are subject to local interpretation, but whose powers are defined by the generalities of the Municipal Act.

The Municipal Act under sections (710), (716) and (729) provides controls for development at the local level, in areas of hazards. These controls may be accomplished through the preparation of plans, zoning and regulation of subdivisions respectively. In section (710) of the act it states:

Municipal Act

> Section (710) The council may have community plans prepared or revised, and they may be expressed in maps, plans, reports or any combination of them.

This allows municipal councils to plan for and examine areas of high risk. Where areas are found to be hazardous subsequent to preparation of the community plan, then a revision may be legally instituted. Zoning regulations, as presented below, under section (716) give municipal governments express powers to designate specific uses or prohibit uses in designated areas.

Municipal Act

> Section (716) (1) The Council may by a zoning bylaw
>
> (a) divide all or part of the area of the municipality into zones and define each zone either by map, plan or description, or any combination of them;
> (b) regulate the use of land, buildings and structures, including the surface of water, within the zones, and the regulations may be different for different zones and for different uses within a zone, and for the purpose of this paragraph the power to regulate includes the power to prohibit particular uses in specified zones;
> (c) regulate the size, shape and siting of buildings and structures within the zones, and the regulations may be different for different zones and with respect to different uses within a zone; ...
>
> (2) In making regulations under this section, the council shall have due regard to
> (a) the promotion of health, safety, convenience and welfare of the public;
> (e) the character of each zone, the character of the buildings already erected and the peculiar suitability of the zone for particular uses;
> ...

In many respects, zoning powers available to municipal councils for natural hazard regulation are more comprehensive than those applicable to crown lands. Regulation and management of hazardous areas is possible at the planning stage under sections (710) and (716), and enforcement is possible under section (716) clauses (b) and (c). Additionally, where prior decisions or zoning through circumstance may have excluded a hazardous area, regulation of development is still possible under section (729) Regulations and Procedure for Subdivisions). Section (729) states that:

Municipal Act

> Section (729) (1) The council may regulate the subdivision of land, and for that purpose may by bylaw
> (a) regulate the area, shape and dimensions of parcels of land and the dimensions, locations, alignment and gradient of highways in connection with the subdivision of land, and may make different regulations for different uses for different zones of the municipality;
> (b) prescribe minimum standards for matters in paragraphs (a) and (d); ...

Unfortunately, it appears that it is at the municipal level where hazards receive their lowest priority in management decision-making. Exceptions do exist however, as provided by examples from the townsites of Tumbler Ridge and Elkford. Under section 8.4 (Development Considerations Policies) of the Tumbler Ridge, Official Community Plan, provisions are made for development in areas of risk (see below). Similar provisions are made under section 4.5 of the Official Community Plan for Elkford (to follow Tumbler Ridge provisos).

Tumbler Ridge - Official Community Plan Regulations

8.4 DEVELOPMENT CONSIDERATIONS POLICIES

Several factors will influence the location of various land uses in the townsite and environs. Development will only be permitted in areas free from hazards, both natural and man-made, and will be directed away from areas known to have important resource values. The following policies will ensure a safe environment

for the townsite and will protect important resources from alienation.

8.4.4 Slope

Development on slopes in excess of 15% will not be permitted, unless an engineering study shows the proposed development to be both safe and feasible.

8.4.5 Floodplain

The District will direct development away from lands subject to flooding along the Murray River and Flatbed Creek. Where there is no alternative land available, and where mobile homes or buildings to be used for habitation, business, or the storage of goods damageable by flood waters are to be located or constructed in any area liable to flooding, such buildings or mobile homes shall be flood-proofed, that is, conform to setback and elevation restrictions, in accordance with the floodproofing requirements of the Ministry of Environment.

8.4.6 Setback from Stream Bank

Development will be restricted to the area behind the setback line indicated on Figure 5 due to the instability of the stream banks. In addition, the District will designate a restricted zone extending 300 metres beyond the setback line where no development permitting the concentrated infiltration of storm or sewage water will be allowed; development in this area will require storm water management and connection to a community sewer system.

8.4.7 Avalanche

The District will encourage the Ministry of Forests to maintain the natural forest cover on the face and immediate ridge top of Tumbler Ridge in order to minimize avalanche hazards. No development will be permitted on the face of Tumbler Ridge.

4.5 Policies to avoid and mitigate the risk of natural hazards.

4.5.1 A detailed study of the snow avalanche hazard shall be completed prior to any development or clearing of trees in the potential avalanche terrain area identified in Schedule E.

4.5.2 The Village shall comply with floodplain management policies and regulations established by the Provincial Government.

4.5.3 The Village of Elkford shall request assistance from the Provincial Goverment to carry out the necessary studies and provide the necessary mitigative works to reduce the potential of the slide hazard on the eastern side of the Elk Valley.

4.5.4 The Village of Elkford shall request assistance from the Provincial Government to monitor slopes on the east side of the Elk River.

4.5.5 The Village shall encourage the relocation of existing residential, commercial and industrial uses in the area designated as Protected Open Space. Uses such as agriculture, playing fields and passive recreation activities shall be encouraged in this area.

4.5.6 No new residential, commercial or industrial use or expansion of existing residential, commercial or industrial uses shall be permitted in the area designated as Protected Open Space, unless such development is compatible with the floodplain management policies of the Provincial Government and/or any conclusions that may be reached with respect to the slide area.

4.5.7 Council shall encourage the cancellation of existing vacant lots in the area designated as Protected Open Space.

4.5.8 Site specific engineering investigations shall be undertaken to determine appropriate construction techniques in the glaciolacustrine clay and silt deposits indicated on Schedule E.

4.5.9 Setbacks along the top of the benches to lot lines shall be established at 8 m (26.2 feet) unless geotechnical soil conditions require greater setbacks.

In other cases, some recognition has been given to flood hazard, but other hazards with similar event probabilities are largely ignored. Areas which must receive notice are: (a) effects of wind and wind gusts; (b) stress loads due to earthquakes motion; (c) loads due to accumulations of snow on roofs; and (d) rain loads on roofs. These hazards are considered because they are required to be designed for, by the "National Building Code", which was adopted in British Columbia as the building bylaw for municipalities and regional districts through an amendment to the Municipal Act in 1973. Though the purpose of the National Building Code is to "safeguard life or limb, health, property and public welfare with respect to the design, construction and alteration of buildings by the provision of appropriate minimum standards," it makes no provisions for landslides, snow avalanches, flooding, tsunami's, subsidence, shore erosion or volcanic eruption.

Proposed Legislation - The Land Use Act

New legislation entitled the "Land Use Act" has been presented to the Legislative Assembly of British Columbia, which is likely to have an impact on land use planning for natural hazards. Originally, this act was put forward by the Ministry of Municipal Affairs, as the "Planning Act" in the spring of 1981. A discussion paper describing the Planning Act was circulated to the public and distributed to

affected government agencies to garner responses to contentious clauses.

Within the discussion paper the minister had proposed sweeping changes to the planning process in the province. These included setting up two levels of planning; one at the "provincial regional" level; and another at the "urban regional" level. Under Part 3 (Policy Plans), Division 2, section (58), and Division 3, section (74), provisions for hazardous lands designation were made clear (see following page). Due to the sensitivity involved in designating hazardous areas, many bureaucrats and politicians pressed for a reduction in the scope of these early statements. It appears that where areas have previously been developed, the government felt it would subject itself to a degree of liability if these were to be designated hazardous as a result of the new legislation. This pressure resulted in several changes in the subsequent Land Use Act, especially in those sections dealing with hazardous lands. This careful rewording of the original discussion paper is reflected in Part 3 (Official Plans), section (13) (Content of official plans) in the Land Use Act (see below), where there is a change of emphasis from designating risk areas to applying restrictions on the uses of such lands. In addition, provision is made for identifying areas of "special problems or conditions", however, these areas are not mandatory requirements for official plans. The result of these changes has therefore been to reduce the designation of high risk areas from being mandatory to being dealt with through ad hoc restrictions and subjective interpretation of problems or conditions.

Planning Act (Discussion Paper)

> Part 3, Division 2, Section (58) (Content)
> Subject to guidelines established by the Environment and Land Use Committee, a provincial regional plan shall include:
> (6) a description of emergency programmes that may have application in the region;
> (7) a designation of identified land areas subject to hazardous conditions; ...

Part 3, Division 3, Section (74) (Content)
Subject to guidelines established by the Environment and Land Use Committee, an urban regional plan shall include:
(6) a description of emergency programmes that may have application in the urban region;
(7) designation of identified land areas subject to hazardous conditions; ...*

(* The contents of Urban Regional Plans are essentially the same as for a Provincial Regional Plan.)

The Land Use Act (Bill 9, as presented to the Fourth Session, Thirty-second Parliament, 1981-82)

Section (13) (1) An official plan is a statement of the objectives and policies of the local government respecting the form and character of the future land use pattern within the area covered by the official plan.

(2) An official plan shall be in writing, and may include plans, maps, tables or other graphic material and shall include statements respecting the following:
(e) restrictions on the use of land in areas that are subject to hazardous conditions; ...

(5) The official plan may, for the purpose of Section (55)(4), identify areas that are subject to special problems or conditions that exist by reason of a need
(a) to restrict development because of the natural environment,
(b) to preserve or safeguard the natural environment,
(c) for special attention to siting of buildings and structures by reason of existing or proposed development or amenities, ...
and where an area is so identified, the plan shall describe the special problems or conditions that justify the identification.

Few opportunities present themselves for making dramatic changes in policy. The proposed Land Use Act is a case where considerable advances could be made in recognizing and planning for natural hazards, however, government inertia is likely to effectively reduce the potential impact of the proposed legislation to a minimum. With the changes discussed, new legislation may in fact be placing greater

responsibility with local governments for the designation of hazards where previously hazard planning and management have received the lowest priorities. Should the proposed Land Use Act be passed in its present state, it is possible that comprehensive planning and management of natural hazards may be further impaired.

A Comparison With Legislation in the United States

A review of hazards literature indicates that many of the states in the United States are well advanced in the implementation of hazards legislation. For this reason, a comparison is made with several states which have similar types of natural hazard legislation or hazard specific legislation. In particular, a comparison will be made with the state of California which has some of the most advanced natural hazards legislation in North America.

In 1974-75 the British Columbia Department of Highways conducted a survey of hazards legislation in all 50 states in the United States, and much of the succeeding discussion is based on the information derived. Replies were received from all but eleven states and the following are excerpts from a cross-section of the letters and legislation received.

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4 The Land Use Act (Bill 9)
(Development Control Areas)
Section (55) (1) Where an official plan identifies areas that are subject to special problems or conditions that exist by reason of a need

(a) to restrict development because of the natural environment,
(b) to preserve or safeguard the natural environment,
(c) for special attention to the siting of buildings and structures, related to existing or proposed development and amenities.

the local government may, in its land use bylaw, designate those areas or parts of them as development control areas, and show the boundaries of the areas by map.

Examples of those states with general hazard legislation include Vermont, Illinois, Nebraska, Florida and Hawaii. Because Vermont is afflicted with several areas which have a high risk of landslides, the Land Use and Development Law was passed in 1973, its purpose being to "provide general and uniform policies on land use and development." In its section on the Preservation of Resources (see below), a basis is provided whereby review of subdivision applications on "excessively steep or unstable slopes" may take place (Vermont Attorney General's Department). Similar provisions exist within the Land Titles Act and the Municipal Act in British Columbia. Although the Vermont legislation for referral of an application for review of slope stability is mandatory, in British Columbia the individual approving officers at the provincial or municipal levels make the decision.

Vermont - Land Use and Development Law

> "Before granting a permit the board of district commission shall find that the development or subdivision will not cause unreasonable soil erosion in the capacity of the land to hold water so that a dangerous or unhealthy condition may result."

Illinois and Nebraska are influenced by frequent floods; and in response, both have developed legislation to mitigate the hazard. The state of Illinois' "An Act in Relation to the Regulation of Rivers, Lakes and Streams of Illinois (1973)" analyzes the problems of floodplain development and recommends a process for floodplain management be established. In Nebraska the "Nebraska Soil and Water Conservation Flood Control Act (1943)" has a similar intent, but proceeds further to limiting development in those areas subject to "a flood of one hundred year frequency". British Columbia has comparable legislation in its Flood Relief Act and has attained a similar standard for flood frequency evaluation (1 in 200 year flood frequency in B.C.) as that applied in Nebraska. Variance exists in that in British Columbia the Flood Relief Act is primarily oriented towards post-event relief, while most advances in floodplain management and control may be attributed to the reports and recommendations of the various joint provincial-federal boards established since the 1948

Fraser River floods.

Subsidence in underlying limestone, poses a particular hazard in the state of Florida, as does soil erosion in the state of Hawaii. Recent events in Florida, where buildings and highways have been swallowed up by massive cave-ins, gives evidence to the hazards from subsidence. In the 1960's, Florida passed legislation "directing the Department of Transportation to evaluate existing road structures periodically to ascertain whether or not such subsurface indications might be documented as to the incipient development of such land features (Florida Department of Transportation). The influence from this legislation is that it is confined to the highway system, but not to developments. A similar relationship exists in British Columbia in respect to snow avalanches, where the Senior Avalanche Coordinator, Ministry of Transportation and Highways has a mandate to review and identify snow avalanche hazards along all highways in the province. Through the subdivision approving function of the same ministry, under the Land Titles Act, this mandate carries over into development review of unincorporated lands (lands outside of municipalities). Identification and protection against development in areas of subsidence hazard however, must be considered as being "against the public interest."

Amongst the responses to the 1974-75 survey by the British Columbia Ministry of Transportation and Highways, were several pieces of legislation which had been specifically designed to control development in hazardous areas. Examples are taken from four states, Washington, Montana, Colorado and Nevada. Each has similar natural hazards and topography as found in British Columbia. Notably, in each piece of legislation examined, there is an emphasis towards controlling development through subdivision controls rather than through alternatives such as zoning, land-use restrictions or building codes.

Washington state, bordering British Columbia to the south, passed its "Land Development Act (1973)" partially in response to a situation where "land had been developed with recreational ski cabins in an avalanche area, and the state had no power to regulate or prohibit the

development" (Deputy Attorney General-Washington State). The state's intent was not to limit development of areas, but to protect prospective buyers. Buyer protection is therefore an important part of the act as it requires that when selling a piece of land, the seller must enclose "pertinent information concerning land development ... including the physical characteristics of the land" in order that the buyer may "be provided with full, complete, and accurate information of all pertinent circumstances affecting their purchase." Sections of the act pertaining to the registration of a potential development (section 58.19.060) and to the advertising of the development for sale or lease (section 59.19.070) guarantee buyer awareness. Both sections require that "a statement of any hazard on or around the development" must be made. These statements are verified by the Washington State Department of Motor Vehicles before approval is given.

A similar condition to Washington State exists in Colorado. Under the Colorado State "Act Concerning the Division of Land into Sites, Tracts, or Lots and Providing for the Regulation Thereof (1972)" protection of the public peace, health and safety requires that a subdivider provide "evidence to show that all areas of the proposed subdivision which may involve soil or topographical conditions presenting hazards or requiring special precautions have been identified by the subdivider and that the proposed uses of these areas is compatible with such uses." Evidence supplied by the subdivider is subject to review by the Colorado Geological Survey "for an evaluation of those geological factors which would have a significant impact on the proposed use of the land."

In comparison, considerable differences exist between British Columbia, Colorado State and Washington State. British Columbia does have legislation to require a developer to disclose adverse aspects of a proposed subdivision under British Columbia Regulation 262/70, except in those areas specified in the Local Services Act. Through the subdivision approving function under the Land Titles Act, review of a subdivision proposal for natural hazards is possible through referral to the appropriate government agency, and buyer protection

may be accomplished by attaching a restrictive covenant to the land title. Unlike Washington State or Colorado State however, the emphasis is on the government to denote hazards and guarantee safety of the development rather than on the developer. Costs for investigations are therefore derived from the public purse rather than from the individual subdivider.

Montana and Nevada have taken similar tacts in preparing their legislation to deal with natural hazards. Both states have legislation which stipulates protection for hazardous lands. These states vary in that the delineation of high risk areas is included as part of the planning process as well as within the subdivision approval process. Montana's "Subdivision and Planning Act (1973)" provides that:

> "The governing body of every county, city and town shall ... adopt subdivision regulations reasonably providing for the orderly development of their jurisdictional areas; and the avoidance of danger or injury to health, safety, or welfare by reason of natural hazard."

Augmenting and pursuant to the act are the "Minimum Subdivision Regulations", determined by the Montana Department of Intergovernmental Regulations as part of the "Montana Administrative Code." Within these regulations the section on "lands unsuitable for development" makes provision for denial of a proposed subdivision in any area where natural conditions present a potential hazard to public safety or health. This section also denotes that:

> "The specified hazards shall at least include flooding, avalanches, rockfalls or slides, land or mud slides, high water tables and excessive slopes. The regulation shall provide that where the hazards are eliminated or will be overcome by approved design and construction of plans, the proposed subdivision shall be considered for approval."

Correspondingly, Nevada "for the purpose of promoting health, safety, morals, or the general welfare of the community" enacted a set of Planning and Zoning Statutes in 1973. One of the goals in the physical planning process established is to "protect life and property

in areas subject to floods, landslides, and other natural hazards."

The inference in both cases is that natural hazards will be considered in planning for development and shall be regulated through subdivision approval or denial. As previously indicated, the approving officers in British Columbia under the Land Titles Act, Local Services Act and the Municipal Act, are provided with the same powers as their american counterparts. Inclusion of the designation of high risk areas in the planning process though, is not a requirement in British Columbia statutes. Hazard specific clauses as part of subdivision regulations are found within British Columbia Regulation 262/70 and are as definitive as those in statutes from Montana and Nevada.

Two variations between British Columbia and these two states are apparent. One variation is that the province does not include the requirement for disclosure or delineation of hazardous lands within the planning process. This was proposed in the British Columbia Planning Act discussion paper, but subsequently altered when presented as the Land Use Bill; reducing the control aspects of the proposed act to development regulation. As a result, development would not be determined by the existence of hazards. Another variation is that British Columbia legislation does not make provision for mitigating risk through engineered means such as possible under Nevada's Minimum Subdivision Regulations. Such provisions may be made at the administrative level in British Columbia, but are subject to internal ministry policies.

An area of potential improvement for British Columbia and possibly Montana and Nevada would be the designation within the legislation of a review agency for cases involving natural hazards. Like Washington's Department of Motor Vehicles and Colorado's Geological Survey, a defined agency for hazards review would likely provide the public with a contact agency and a means of dispersing information to government departments and the public alike. Such an agency would also likely provide a more consistent approach to the management and planning for natural hazards.

California - A Model to Examine

California has some of the most well-advanced natural hazards legislation. As with most hazards legislation, its inception has been normally the result of a previous crises. Such crises are constantly arising as the state of California has one of, if not the highest, incidence of natural hazards in the counterminous United States. In response, the state has enacted very detailed statutes, codes and regulations. Such legislation may be grouped into the following:

(a) Earthquake Hazard Zoning - concerns limitations on developments in the vicinity of active fault lines;
(b) Health and Safety Codes - relate to conditions of subdivisions;
(c) General Planning Requirements - relates to the requirements of all general plans for counties, cities and towns;
(d) Disaster Compensation - concerns constitutional amendments and the Natural Disaster Assistant Act; and
(e) Earthquake Safety of Buildings - concerns changes to existing building codes.

(a) Earthquake Hazard Zoning

The Alquist-Priolo Act (1972)[5] initiated programs in California to study and delineate areas of risk in and around active fault lines. Spurred by earthquake damage in 1972, the act defined the initial role of the State Geologist (see below) in preparing special study zone maps and then stipulated that "the site of every proposed new real estate development or structure for human occupancy (within the Special Studies Zone) shall be approved ... in accordance with policies and criteria established by the State Mining and Geology Board." Developments or structures "will not be approved if an undue hazard would be created, and approval may be withheld pending geologic and engineering studies to more adequately define the zone of hazard."

---

5 The Alquist-Priolo Act comprises sections (2621) and (2624) of the California Public Resources Code and refers specifically to hazards resulting from surface faulting or fault creep due to earthquakes.

Role of the California State Geologist

(1) "designate appropriately wide spread special study zones to encompass all potentially and recently active traces of ... faults;"
(2) "compile maps delineating the special studies zones ...;"
(3) "continually review new ... data ... and shall require the special studies zones to be updated."

Examples of the "policies and criteria" prepared by the State Mining and Geology Board include the following:

(1) No structure shall be permitted to be placed across the trace of a fault (or within 50 feet of it).
(2) Application for all real estate developments and structures within the Special Studies Zones shall be accompanied by a geologists report concerning possible ground displacements.

(b) Health and Safety Codes

In 1974, amendments were made to the California Health and Safety Codes which were specifically related to the risks from natural hazards, particularly in areas of new subdivisions. The codes require that a soils (foundation) report and a geologic (hazards) report be prepared for "every such subdivision likely to be affected by hazardous geologic conditions ... or containing slopes whose dimensions are five horizontal:one vertical, or steeper." Should a report on hazards indicate a problem, sufficient enough to cause structural defects, then "corrective procedures shall be designed to prevent damage at an unstable or geologically hazardous site ..." Objectives of the codes being therefore, to:

" extend in the interest of public safety, the present requirement for soils investigations of proposed subdivision sites ... to include where warranted investigations of all geological conditions for the possible presence of other geological hazards such as, but not limited to; active faults ... mudflows, landslides, debris flows or rock falls, alluvial slope wash, or rock materials subject to settlement or subsidence, rapid erosion, volcanic activity or slopes whose

dimensions are five horizontal to one vertical or steeper."

Generally, the codes are oriented towards "new" development, but, also within the regulations are definitions of what are termed "blighted areas". Purpose for the classification is so that under the Community Redevelopment Law of California, there is forewarning of potential hazards in areas where reconstruction may be considered. Definition of such a blighted area is based upon:

> "... the existence of a seismic hazardous area susceptible to surface ruptures from faulting, to ground shaking, to ground failure, or to the effects of seismically induced waves such as tsunami and seiche."
>
> "... the existence of a geological hazardous area susceptible to mudslide, landslides or slope instability."
>
> "... the existence of substantial damage from seismic disturbances or other natural disasters."

(c) General Planning Requirements

General plan requirements were passed into law in California in 1972 with the express purpose of developing and adopting guidelines for the preparation and content of mandatory elements to be included in city and county "general plans". Mandatory elements of the plans include Land Use, Housing, Conservation, Open Space, Noise, Scenic Highways, Seismic Safety and Safety, of which the latter two contain aspects of hazards control. Government Code Section 65302 (f) requires that all "general plans" contain a statement of seismic safety which is defined as follows:

> "A seismic safety element consists of an identification and appraisal of seismic hazards such as susceptibility to surface ruptures from faulting, to ground shaking, to ground failures, or to the effects of seismically induced waves such as tsunami's and seiches. The seismic safety shall also include an appraisal of mudslides, landslides, and slope stability as necessary geologic hazards that must be considered simultaneously with other hazards such as possible surface ruptures from faulting, ground shaking, ground failure and seismically induced waves."

Interestingly enough, by 1978, 90 percent of California's cities and 93 percent of the counties had completed a seismic safety element for their general plan, and virtually all have since adopted either the 1976 or the succeeding 1979 Uniform Building requirement, with lateral force requirements covering all new construction (Olson and Scott, 1980). A general safety element of city or county plans also requires that "protection of the community from fires and geologic hazards" be considered. The safety element in the plans is designed to protect the infrastructure, for example highway routes (necessary for evacuation), water supplies, bridges and other structures. During the preparation of the safety element in a general plan, recognition of geologic hazard mapping in areas of known geologic hazards must be made.

(d) Disaster Compensation

California has prepared for disaster through changes in its constitution and by enacting legislation specifically designed for compensating victims. In 1973, California passed Amendment No. 26, An Amendment to the Constitution, which authorized the state legislature to create a "system of catastrophe compensation against loss of or damage to improvements to real property or to personal property by reason of earthquake, flood, landslide or tidal wave." A year later, The Natural Disaster Assistance Act (1974), empowered the California Department of Finance with powers to allocate funds to local agencies for the repair or restoration of "real property and public works, that are damaged or destroyed by a natural disaster, which means, a fire, flood, storm, tidal wave, earthquake or other similar public calamity resulting from natural causes." This act provided significant improvements over past compensation procedures for victims, as it specifies the agency responsible and provides it with a clear mandate.

(e) Earthquake Safety of Buildings

As part of the Health and Safety Code (1974), there was a requirement that Seismic Design and Construction Standards be prepared for the state, in addition to those outlined in the 1973, Uniform

Building Code. Particular emphasis was placed on the seismic safety of hospitals and schools. However, the Imperial County Services Building in El Centro, California which was built to the code standards, was subjected to considerable damage during a moderate (Richter 6.6) magnitude earthquake in 1979. Compliance with seismic building codes is therefore not an assurance of complete safety.

A California - British Columbia Comparison

Perhaps because of far greater disaster losses California's natural hazards legislation is far more advanced than British Columbia's. In preparing their legislation, California has provided for the comprehensive assessment, delineation and preparation for, natural hazards. A great proportion of this legislation is oriented towards new construction, although provisions are made for upgrading of existing buildings and sites, and reconstruction subsequent to disaster. Subdivision regulation, as in Washington, Montana and Colorado states is a primary facet in California's control of new development, but like Washington and Colorado, a central agency (the State Geologist) has been designated to identify and discern whether lands are hazardous or not.

Avoidance of hazardous areas, or at least the reduction of damage, is mandatory under California hazards legislation. Correspondingly, the bulk of British Columbia's legislation is oriented towards subjective decision-making by approving officers, not necessarily enforcing the reduction of risk and potential damage. Unlike California, British Columbia has not undertaken programs to delineate risk and therefore provide the developers and public with appropriate notice of hazard. Division of responsibilities for study and determination of risk is divided amongst several agencies and ministries in British Columbia without a defined coordinator such as the California State Geologist. This division of responsibilities results in hazard specific studies being implemented, for example the Ministry of Environment studies and maps floods and flood prone areas while the Pacific Geoscience Centre (a federal agency) studies

earthquakes and tsunami's. There is not a designated agency however, to gather the hazards information and assemble it into a comprehensive evaluation of risk.

It would be inaccurate to say that British Columbia should mirror California's example. What is indicated is that British Columbia requires legislation which will establish programs necessary to coordinate existing agencies and studies in the province in an effort to improve its current status. At this time, sections of the Land Title Act and the Municipal Act may be implemented to control subdivision development in areas of hazard, while the Emergency Program Act and Emergency Management Act provides for compensation and relief in the event of disaster. Additionally, all communities in British Columbia have adopted the National Building Code of Canada wherein building regulations for earthquake resistance may be found, similar to the United States Uniform Building Code. These pieces of legislation or groups of regulations are comparable to California legislation although they lack the definitiveness apparent in their statutes. A further avenue to follow, would be for British Columbia's hazard legislation to be applicable to all lands including municipalities, crown lands, indian reserves and parks. This would reflect the implications of California's general planning requirements.

Conclusions

Clearly there is a need for coordinated hazards legislation in British Columbia. Historical assessment of the evaluation of natural hazards legislation indicates the high correlation between disasters and enactment of statutes. This relationship between crisis and legislation may account for the lack of consistency between programs which have resulted from such legislation.

Improving the existing legislation by clearly defining authority and by establishing procedures for pre-event land-uses and post-event recovery are seen as necessary. At present, the rights of the governing bodies to take action in times of crisis are far more clearly defined than are the rights of the individual to be forewarned of, or protected from, disasters. To many statutes contain clauses

which are initiated with phrases such as "Where the minister considers that ... " This provides for a paternalistic system wherein the government may, or may not act and as a result, the long term protection from natural hazards may not necessarily be forthcoming.

Comparison with American counterparts illustrates avenues which may be pursued to improve the situation in British Columbia. In addition, the examples chosen indicate the status of existing provincial programs which can be expanded if appropriately mandated through introduction of new legislation or the expansion of existing laws in an effort to create an increased trend in loss reduction. Construction of enabling legislation to identify the contents of hazard programs, and to obligate officials to recognize risk in their planning systems appears justified. In addition, the bulk of existing statutes lack the clear definition of hazards (other than the Land Titles Act and Subdivision Regulation 262/70) necessary to clarify what should or shouldn't be reviewed. By clearly defining those hazards covered by each legislative act, the less arbitrary is the statute and the greater the definition of duties for the programs established to administrate them. Duties of programs now in force are discussed in the following chapter.

The Emergency Program Act in British Columbia clearly defines the responsible agency (the Provincial Emergency Program). Similar definition in other acts is not apparent, therefore a provincial agency for hazards regulation and systems coordination embodied by appropriate legislation would also appear to be necessary. This seems necessary under the existing set of statutes, however, as noted earlier, should responsible agencies be defined for particular hazards or programs then a central agency may not be required, although preferential for acting as a contact group for public inquiries.

British Columbia also needs to extend the sphere of its hazards legislation. Obvious risks from natural processes could, through legislation, be mitigated. Damage loss reduction and an increase in public safety are potentially feasible by extending the basis for hazards planning and the delineation of risk through comprehensive and coordinated legislation.

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Flood Relief Act, 1948
Fraser Valley Dyking Board Act, 1948
Moratorium Act, 1948
Okanagan Floods Control Act, 1949
Municipal Act, 1957
Riverbank Protection Act, 1960
Emergency Program Act, 1960
Land Titles Act, 1979
Environment Management Act, 1980
Land Use Act (Bill 9), 1981

Legislation - United States
- Vermont - Land Use and Development Law, 1973
- Nebraska - Soil and Water Conservation Flood Control Act, 1943
- Illinois - An Act in Relation to the Regulation of Rivers, Lakes and Streams, 1973
- Washington - Land Development Act, 1973
- California - Alquist-Priolo Act, 1973
- California - Natural Disaster Assistance Act, 1974

Chapter 4
ADMINISTERING NATURAL HAZARDS IN BRITISH COLUMBIA

The complexity of the administrative framework in British Columbia for natural hazards is illustrated by the fact that there are at least 10 agencies involved in their review, delineation, control and mitigation. Of these, six agencies are provincially administered while the remaining four are under federal jurisdiction. They can be generally classified into three categories; those who are administering preventative, pre-event programs; those who administer programs for post-event relief compensation and recovery; and those agencies involved in the scientific investigation of hazards and risk. A further breakdown of the pre-event administrative units indicates that their programs evolve around more specific areas including subdivision control, hazard mapping and development of building regulations or codes.

Administrative programs designed to prevent development in areas of natural hazards will significantly reduce the damage potential from such processes. Unfortunately in British Columbia, the majority of the administrative programs center on subdivision control which is one of the latter stages in land development or land zoning. An absence also exists in the development of programs for preventative planning.

Like many of its American counterparts, British Columbia has established a subdivision approval (land development) system of administration wherein each application may be reviewed for its susceptibility to natural hazards. The aim of the approving process is to determine whether or not the proposed use of the land is compatible in terms of public health, public safety (natural hazards), public services, resource management and effects on local amenities. Four phases are evident in the approval process as indicated in Figure 4.1, shown on the following page.

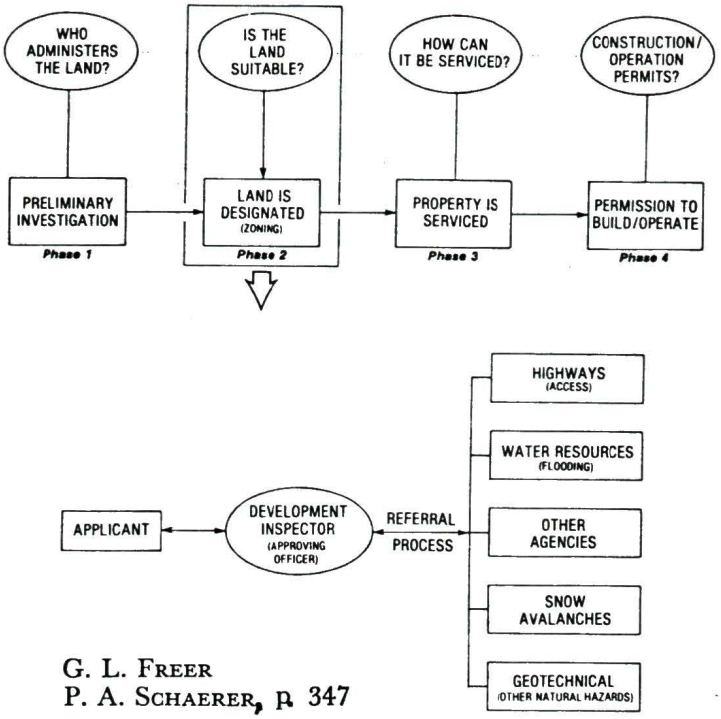

Figure 4.1: The subdivision approval process in British Columbia

a) Phase 1: Preliminary administrative investigation: Who administers the land?
b) Phase 2: Designation (zoning): Is it suitable for the proposed development?
c) Phase 3: Servicing: How can it be serviced?
d) Phase 4: Development: Are the construction and operation compatible with local regulations?

Though this system of subdivision approval provides adequate protection for proposed new development, it does not provide for alternative land uses in areas designated as high risk. Land use planning could effectively delineate hazard zones, stipulate alternative uses and provide developers with a compatible program of development. In addition, developers would not have to face the initial costs and delays which result during the approvals referral process.

A central figure in the approving process is the Approving Officer who reviews the applications for subdivision and submits them to a referral system (see Figure 4.2). This system provides each agency with an opportunity to evaluate and determine the risks involved should development take place. In British Columbia the subdivision approving function is a responsibility of the Ministry of Transportation and Highways which has six regional approving officers and a Headquarters Research Officer (Victoria). Figure 4.3 indicates the boundaries of the six regions which have regional centers in Burnaby, Kamloops, Nelson, Prince George, Terrace and Nanaimo. Approving officers in each of these regions are independently responsible for subdivision approval in their region, except for those lands within municipal boundaries where the municipal approving officer has jurisdiction.

Referral agencies to whom the Approving Officer may submit applications for evaluation for natural hazards begin with three primary provincial agencies, these being; Water Management Branch, Ministry of Environment; Geotechnical and Materials Branch, and Snow Avalanche Section, Ministry of Transportation and Highways. In turn, these agencies may refer to other units whose specialties lie in mapping or analysis of particular hazard types. For example, the Geotechnical and Materials group may refer to the federal Pacific Geoscience Centre for information on the risks from earthquakes or tsunamis'. Each group therefore plays an important role in the direct or indirect administration of lands susceptible to natural hazards. The individual agencies involved are discussed in the following sections where their administrative responsibilities, areas of study and accomplishments are indicated.

Preventative Pre-Event Programs

Water Management Branch - Ministry of Environment

This Branch is responsible for several programs involving flooding, dyking, floodplain development, river protection, inventory and mapping. Some of those programs which the Branch administers are

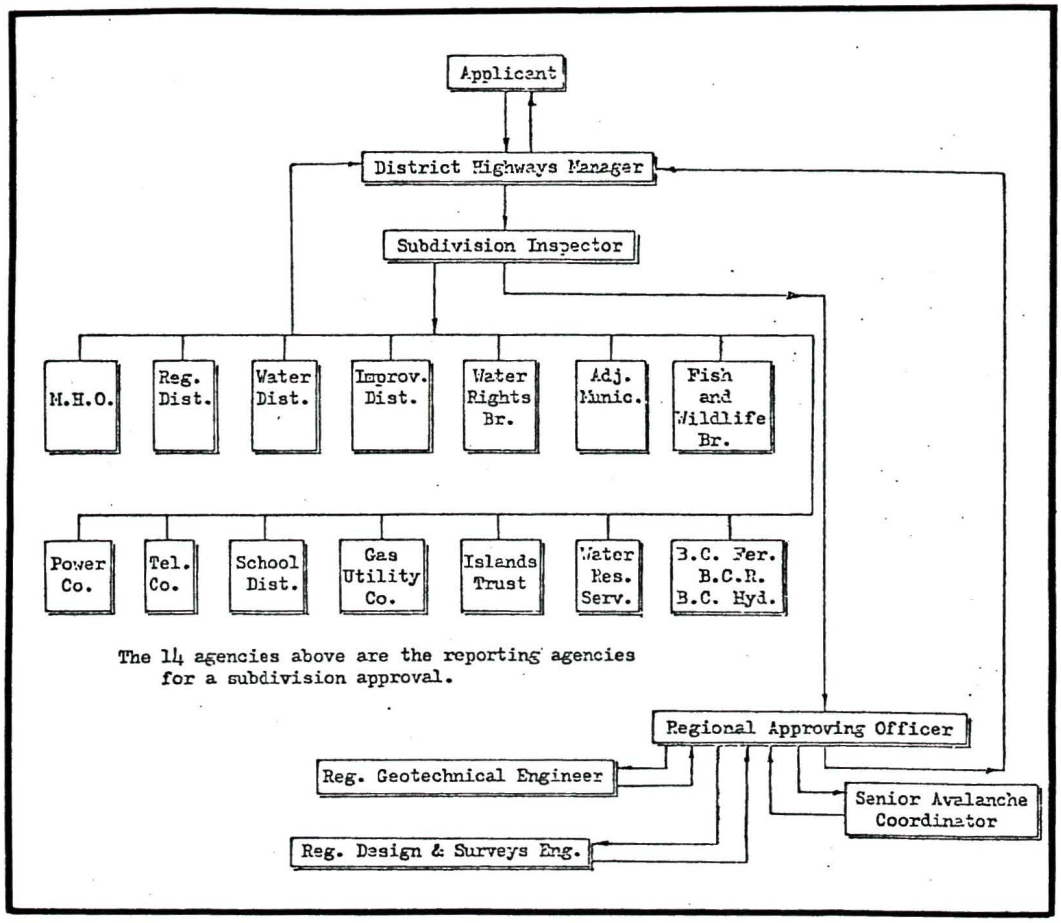

Figure 4.2: Referral agencies in the subdivision approval process in British Columbia

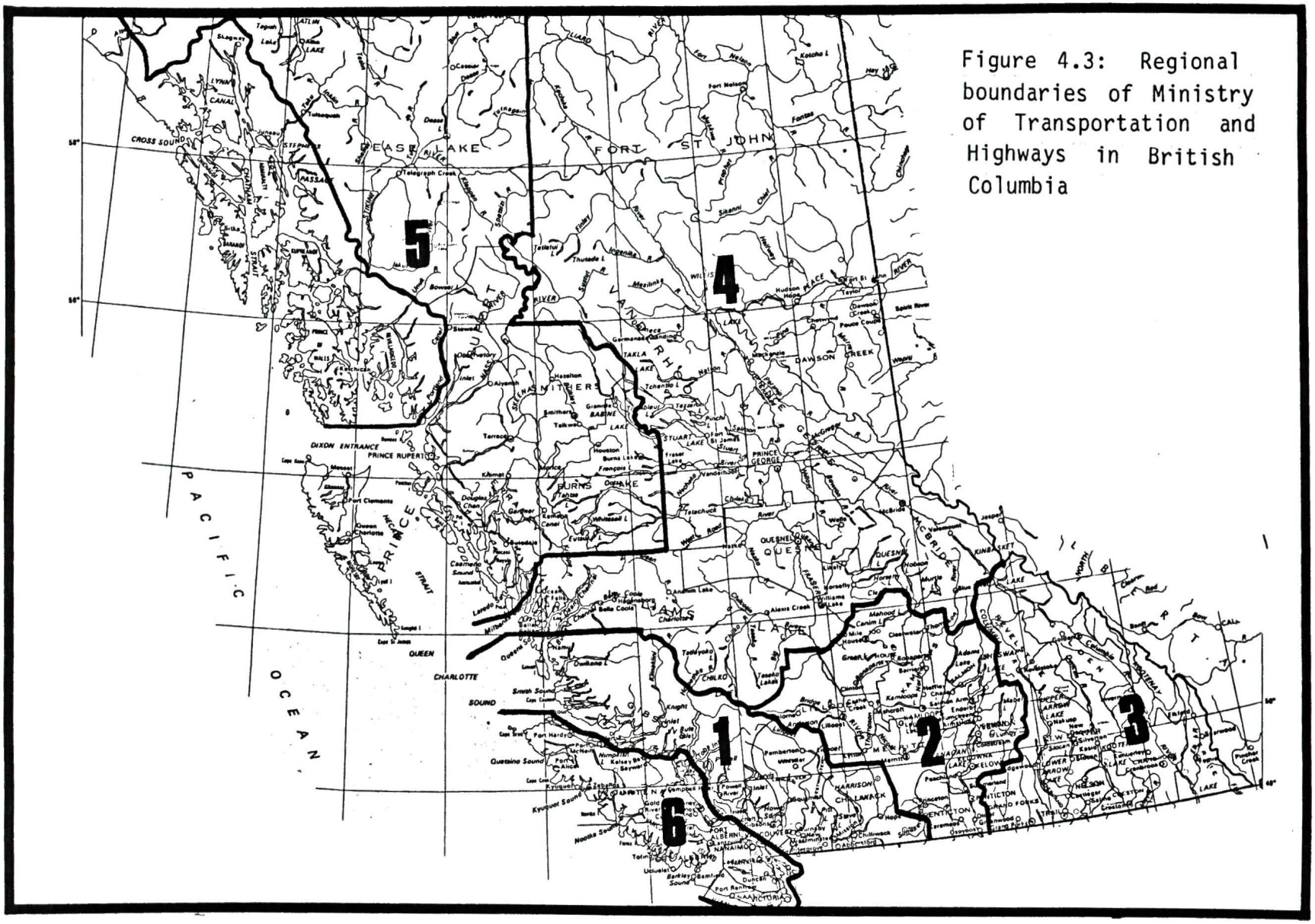

Figure 4.3: Regional boundaries of Ministry of Transportation and Highways in British Columbia

listed below and its position in the Ministry organization indicated in Figure 4.4:

a) Flood Damage Prevention Program,
b) Floodplain Development Control,
c) Channel Clearing and River Protection,
d) Fraser River Flood Control, and
e) Dyke Inspection Program

The Flood Damage Prevention Program is essentially a warning system which analyzes snowpack data from the Fraser and Thompson River basins as a means of predicting potential floods in the Fraser Valley. The program has also been expanded to develop a flood-warning system for the Squamish River Valley during the fall period when expectations of flooding are at their highest (Ministry of Environment, 1981).

Subdivision development along with other land use applications are administered under the Floodplain Development Control Program which has been in operation since 1974. This program was implemented as part of the Canadian Flood Damage Reduction Program instituted by the federal government also in 1974. Aims of the program include the following:

a) identification of Flood Risk Areas,
b) recommendations on the Management of Floodplain Lands,
c) review of subdivisions, Official Regional, Settlement and Community Plans and Zoning bylaws,
d) encouragement of Public Awareness, and
e) establishment of Flood Warning Systems and Emergency Preparedness.

By June, 1982, floodplain mapping under the program had identified 41 different flood areas as illustrated in Table 4.1, involving some 873 kilometres of river systems. This has been accomplished at an approximate cost of $3,125/kilometre of river, or an approximate total cost of $2,728,125 (Personal Communication - Planning Section, Water Management Branch, Ministry of Environment). An example of a typical floodplain map is provided in Figure 4.5. In association with the University of British Columbia, School of Architecture, the program

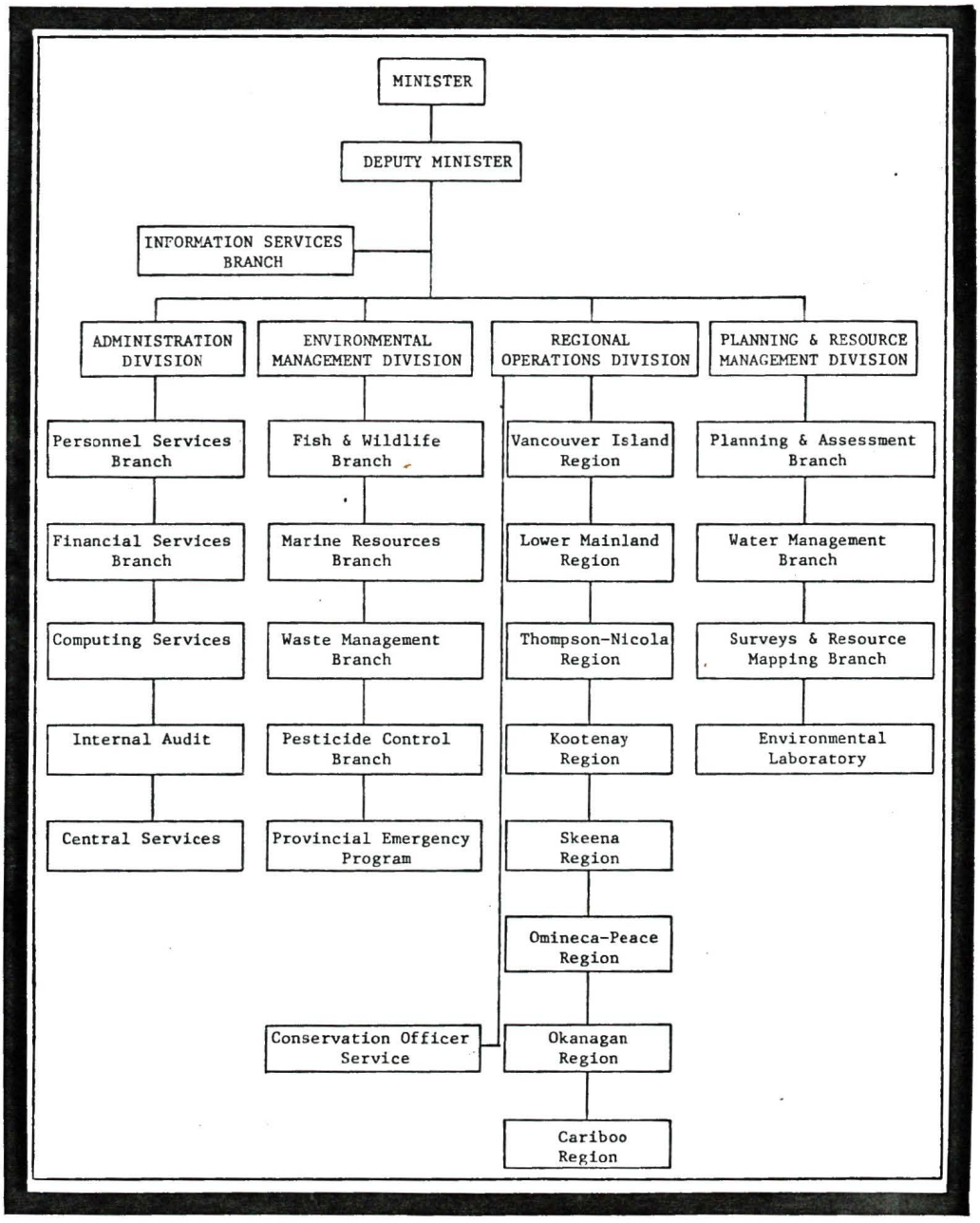

Figure 4.4: Organization of Ministry of Environment

Table 4.1
Floodplain Mapping Status - June 1982

ITEM NUMBER	PROJECT LOCATION	NUMBER OF MAPPING SHEETS	APPROXIMATE RIVER LENGTH (Kilometer)
1.	Bella Coola River - Hagensburg	2	11
2.	Bulkley River - Smithers, Telkwa, Houston	-	-
3.	Chilliwack River - Vedder Crossing to Slesse Creek	6	20
4.	Columbia River - Golden	4	17
5.	Columbia River - Windermere Lake to Radium	9	27
6.	Columbia River - Columbia Lake to Windermere Lake	6	34
7.	Coquihalla River - Hope	2	4
8.	Coquitlam River	7	16
9.	Courtenay River	3	5
10.	Cowichan Lake	4	-
11.	Cowichan and Koksilah Rivers - Duncan	5	19
12.	Deep Creek - Okanagan	4	-
13.	Eagle River	7	25
14.	Elk River - Fernie	7	28
15.	Elk River - Sparwood	2	16
16.	Fitzsimmons Creek - Whistler	3	3
17.	Fraser and Nechako Rivers - Prince George	1	16
18.	Fraser River - Quesnel	1	6
19	Illecillewaet River at Revelstoke	-	-
20.	Kaslo River	-	2
21.	Kettle and Granby Rivers - Grand Forks	7	28
22.	Kitimat River	11	24
23.	Kootenay River - U.S. Border to Kootenay Lake	6	31
24.	Lillooet River - upstream of Lillooet Lake	10	37
25.	Mission Creek - Okanagan	-	-
26.	Nechako River at Vanderhoof	-	-
27.	Nicola and Coldwater Rivers - Merritt	5	-
28.	Okanagan River - Vaseux Lake	-	-
29.	Powers Creek	-	-
30.	Salmon and White Rivers - Sayward	6	27
31.	Shawnigan Lake	3	-
32.	Shuswap River - Mara to Mabel Lakes	17	60
33.	Similkameen River - Border to Princeton	17	96
34.	Skeena River - Terrace	1	6
35.	Skeena River - Hazelton	-	-
36.	Somass River - Port Alberni	3	8
37.	Squamish River	2	27
38.	Tulameen River - Coalmont to Tulameen	4	16
39.	Thompson River - Kamloops Area	19	32
40.	Thompson River (North) - Kamloops to Vavenby	28	160
41.	Thompson River (South) - Kamloops to Chase	15	72

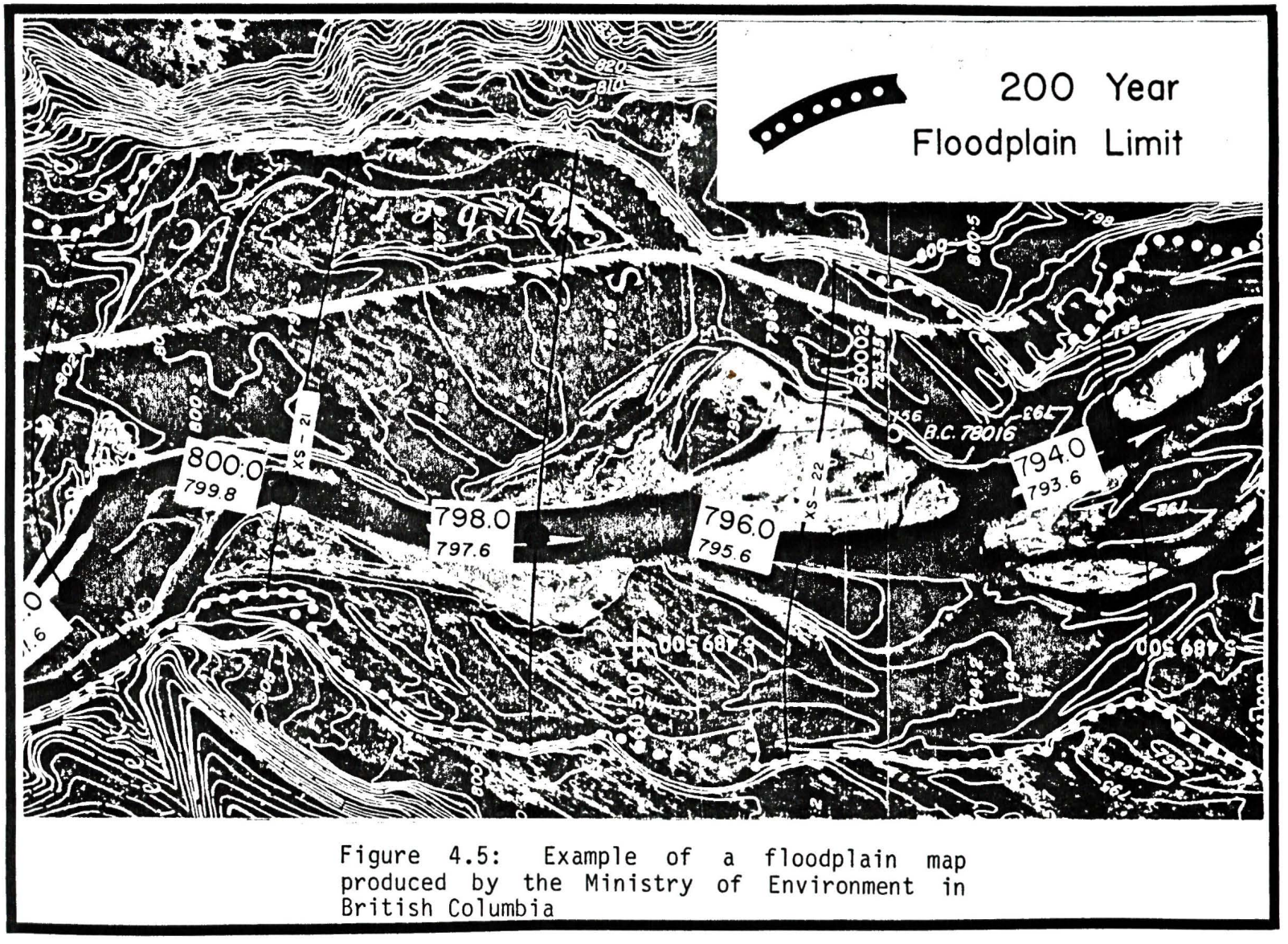

Figure 4.5: Example of a floodplain map produced by the Ministry of Environment in British Columbia

has also aided in the preparation of a brochure entitled "Flood-Proofing New Residential Buildings in British Columbia". The savings from floodproofing being indicated by MacLaren (1978) where he estimates that the additional expenditure to protect a single family home of 149 square metres would only be between 2 and 12% of the total construction cost, dependent upon flood depth, floodproofing technique, and site conditions.

The Channel Clearing and River Protection Program provides for such projects as rehabilitation and extension of the Pemberton Valley Dyking District's flood and erosion protection works, and clearing of ice jams on Mission Creek in Kelowna. Erosion and flooding studies have also been done for areas of the Similkameen River, Nicola River Corridor, Nusatsum River Fan, Salmo River, Slocan River, Kitimat Dykes and Bellevue Creek. Areas susceptible to landslides and floods have also been studied in the municipalities of Port Moody, Port Coquitlam and Haney. These projects are part of the preventative programs to reduce flood potential and erosion of valuable lands during peak flow periods (Ministry of Environment, 1981).

The Fraser River Flood Control Program was developed to provide adequate protection against floods in the Lower Fraser Valley. As noted in Chapter 3, several boards and commissions were formed to study the flood problems on the Fraser River after the 1948 floods. Under the federal-provincial agreement signed between British Columbia and Ottawa expenditures of $120 million have been allocated to construction, rehabilitation and upgrading of dyking systems. Expenditures under this program by fiscal year to March 1981, are listed in Table 4.2.

Inspection of dyking systems in the province is administered under the Dyke Inspection Program. Purpose of the program is to "ensure the safety, proper maintenance and operation of all dykes in the Province". During the fiscal period of 1980/81, spot inspections of all dyking districts in the Lower Fraser Valley were carried out under the program. During peak flood periods such as during the December-January period 1980/81, on-site inspections were carried out

Fiscal Year	Expenditures			
	Design	Construction	Upstream Storage	Total
1968-69	$ 5,165	$ 120,396	---	$ 125,561
1969-70	658,871	105,464	---	764,335
1970-71	769,659	1,164,383	$ 3,410	1,937,452
1971-72	592,110	1,214,645	492,531	2,299,286
1972-73	650,875	1,456,465	295,618	2,402,958
1973-74	867,542	4,370,870	64,994	5,303,406
1974-75	1,173,697	8,849,305	92,602	10,115,064
1975-76	1,280,582	10,368,685	75,732	11,724,999
1976-77	919,987	9,020,330	32,066	9,972,383
1977-78	1,101,902	8,606,174	600	9,708,676
1978-79	882,251	11,053,066	---	11,935,317
1979-80	734,857	6,618,397	---	7,353,254
1980-81*	217,054	8,945,047	---	9,162,101
Total Expenditures	9,854,552	71,893,227	1,057,013	82,804,792

* 1980-1981 figures are estimated

Table 4.2
Fraser River Flood Control Program
Expenditures by Fiscal Year

on a 24 hour basis, and even then, failures resulted. Such failures occurred on the Nicomekl dyke, McElroy Road dyke and in the Surrey Dyking District systems, however, damage was minimized through the close observation given during the flood period (Ministry of Environment, 1981).

Geotechnical and Materials Branch - Ministry of Transportation and Highways

This agency may be referred to by an Approving Officer for an evaluation of risk on areas of proposed subdivision or development outside of a municipality. Annually, this branch may review between 200-300 subdivision applications per year for a diversity of hazards such as landslides, shore erosion, subsidence, earthquakes, tsunami's and volcanic eruption. In addition to such site-specific studies of individual subdivision proposals, the Branch has also carried out several large-scale analyses in the areas indicated in Figure 4.6.

Such investigations and studies are accomplished with a minimum of manpower as approximately 10 individuals spend an average of 15-20% of their working time dealing with the assessment of hazards on proposed subdivisions or development areas. It has been estimated that approximately 25 hours are spent reviewing each application at a total cost of approximately $129,000 per year (258 subdivision applications x 25 hours x $20/hour). A minimal cost in comparison with any of the processes reviewed.

Though the Branch carries out detailed investigations where requested by the Approving Officers, most subdivision applications go without review. In the Ministry of Transportation and Highways 1980-1981 Annual Report, it recorded that 3,179 subdivision applications had been processed while noting that the Geotechnical and Materials Branch only reviewed 258. Part of this situation may be explained by analyzing the administrative framework for subdivision review which exists in the Ministry (see Figure 4.7).

This is a detailed organizational arrangement which unfortunately requires that the least trained members of the administration, the District Technicians, are the ones who must decide if a hazards

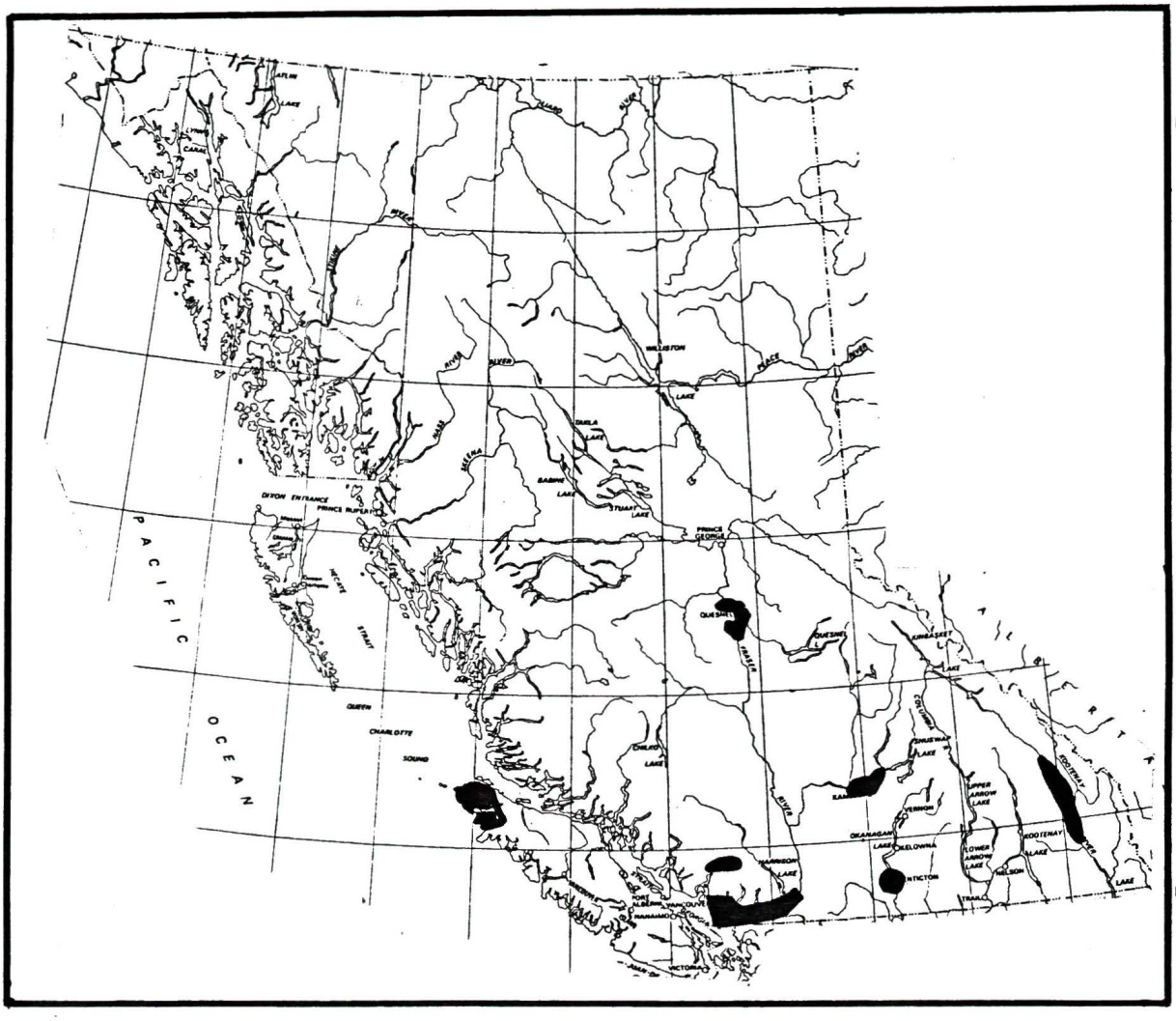

Figure 4.6: Map of British Columbia indicating areas where large scale hazard studies have been undertaken

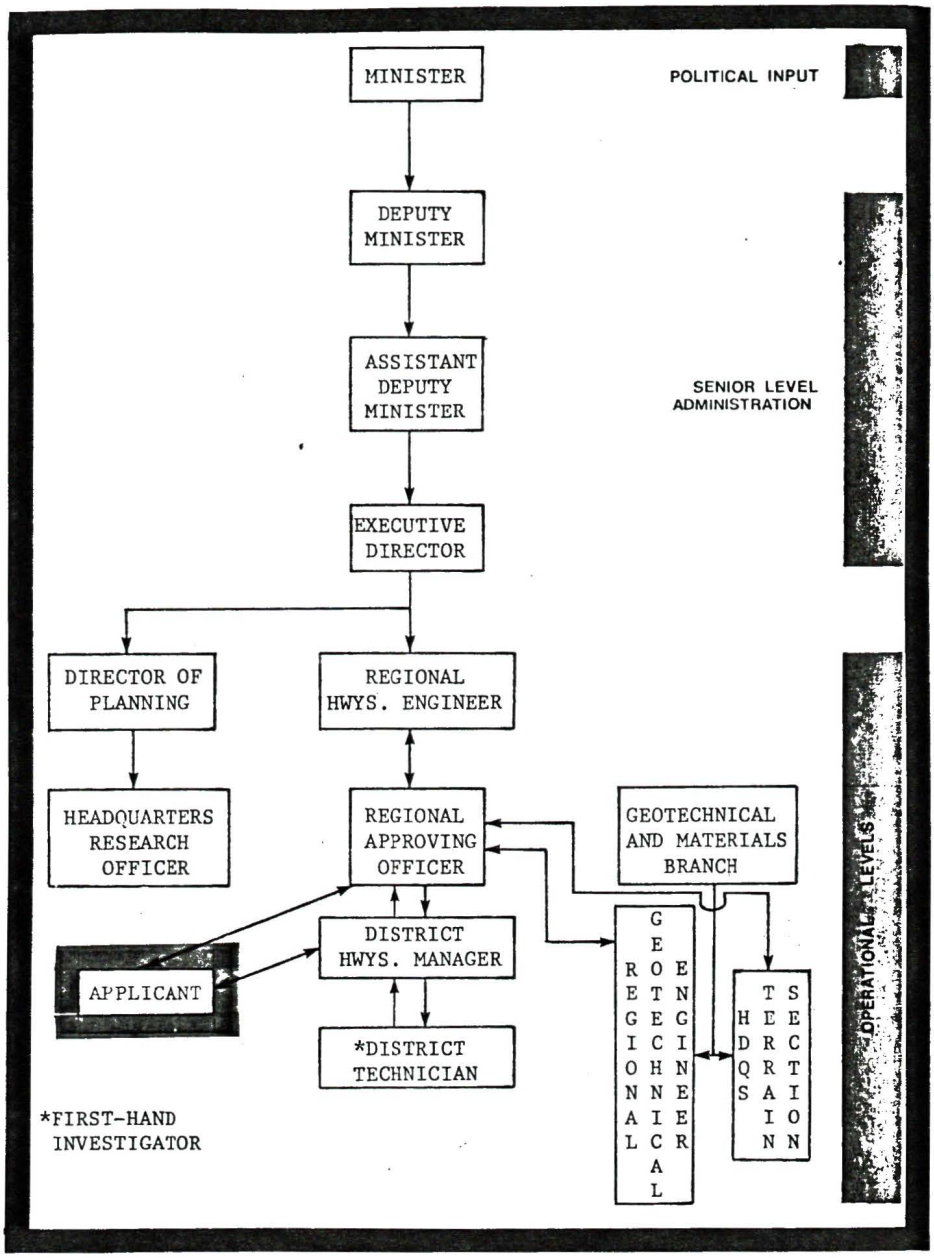

Figure 4.7: Administrative framework in Ministry of Transportation and Highways for subdivision review

investigation is warranted. In most cases this is done without the use of a risk map or prior knowledge of local conditions concerning potential hazards. In an effort to increase the technicians awareness of natural processes and hazards, the Geotechnical and Materials Branch, annually provides lectures on the identification of natural hazards as a means of reducing potential damage, but this often has only a limited impact.

On those subdivisions where the Branch personnel recognize that a seismic hazard exists, they will most likely contact the Pacific Geoscience Centre for information on the risk from an earthquake or tsunami. This is a federal scientific agency specifically designed to administer study programs for such hazards (for organization see discussion in section - Pacific Geoscience Centre - Energy, Mines and Resources Canada). Where a potential volcanic eruption is possible, another federal agency, the Geological Survey of Canada will be approached for information. The Geotechnical and Materials Branch therefore acts as a liaison between the scientific community and the Approving Officer.

Jurisdiction for reviewing proposed subdivisions for natural hazards comes from the Land Titles and Local Services Acts. Though providing the jurisdiction for administering sections of the acts dealing with subdivision for hazards, the acts do not provide the Geotechnical and Materials Branch or any other branch with the powers to plan for variable land uses in areas of risk. Risk is therefore assessed after the application for land development is received, rather than prior to the development planning. If areas of high risk could be indicated, then land use planning compatible with conditions could be implemented prior to the development planning with a resultant savings to both the developer and government alike.

Snow Avalanche Section - Ministry of Transportation and Highways

Like the Geotechnical and Materials Branch, the Snow Avalanche Section is one of the referral agencies for the Approving Officer. Where indications are that a subdivision proposal may be susceptible to snow avalanches, then the Section will be requested to evaluate the

site. However, this is only one of three programs which this section administers. The other two programs include the evaluation of all British Columbia highways for risks from snow avalanches, and the review of all ski area developments for similar risks. Review of the highway system for avalanche hazard is the primary responsibility.

As noted in Chapter 2, the formation of this section took place as a result of the catastrophe which occurred January 22, 1974, at the North Route Cafe, west of Terrace, where 7 people were killed. Formation of the Avalanche Task Force preceded the Snow Avalanche Section, which was formed after the task force completed its report in October, 1974. Primarily, the section has since been involved in preparing an avalanche-management program for the Ministry's operations, as well as conducting avalanche studies along all major highway systems. To accomplish these goals, the Snow Avalanche Section has been educating those individuals involved. Several levels of courses are available with the initial short seminars designed for Senior management in the Ministry of Transportation and Highways whose awareness is necessary, for their advice is directed to senior government officials involved in the approval process (Freer and Schaerer, 1980).

Other courses are designed for the education of those at the initial level of the approval process (the District Technician) and for land-use planners, approval officers and other interested parties, such as engineers responsible for highways and electric transmission line locations or forest management personnel. One-day seminars are sponsored by the British Columbia Ministry of Transportation and Highways, and four-day courses have been jointly developed by the National Research Council of Canada, the British Columbia Institute of Technology and the Highways ministry. Through these courses, ministry personnel and others can become familiar with the avalanche phenomena, recognition of avalanche terrain and hazards, and available technical assistance (Freer and Schaerer, 1980).

The Snow Avalanche Section is a small group, comprised of some 13 staff with 6 part time staff. Nine of the members are stationed in Victoria while 4 other staff are employed in regional trouble spots at

Lillooet, Hope, Creston (Kootenay Pass) and Terrace. An annual operating budget of between $1 and $2 Million is equally split between staff costs and expenses. As part of their surveillance program the section has constructed and monitors 94 separate weather stations throughout the province. Additionally, the section must supply emergency rescue equipment for staff and emergency volunteers. To date, this unit has investigated 1 187 km of highway for snow avalanche hazard and has identified 190.5 km where a risk of avalanche exists (number of individual paths totalling 1,017). By August 1982, 13 atlases had been prepared showing snow avalanche hazard areas along all major highway corridors, (see Figure 4.8) enabling Highway Managers to develop loss-reducing programs within their individual jurisdications.

Only 10-15 subdivision applications per year are normally investigated by the section and a similar number of proposed ski developments are reviewed. Proposals for new ski areas are referred by the Ski Coordinator, Ministry of Lands, Parks and Housing - Housing Division. In addition, the Ski Coordinator may also refer cases for safety assessment to the Snow Avalanche Section. This function was previously the responsibility of the Coordinator, Outdoor Recreation Safety Programs, Parks and Outdoor Recreation Division, Interagency Programs, Ministry of Lands, Parks and Housing, but is now the responsibility of the Ski Coordinator.

Parks Canada, as a federal agency, administers programs within the national parks system. However, the Rogers Pass section of the Trans Canada Highway, which runs through Yoho National Park is the responsibility of the Snow Avalanche Section. Although responsible for the investigation of weather conditions and avalanche activities, the Section often carries out joint studies with members of the National Research Council of Canada, Division of Building Research.

Terrestrial Studies Branch - Ministry of Environment

The Terrestrial Studies Branch is responsible for the Terrestrial Environmental Management Program and the Coastal and Estuary Management Program. Under the Terrestrial Environmental Management Program,

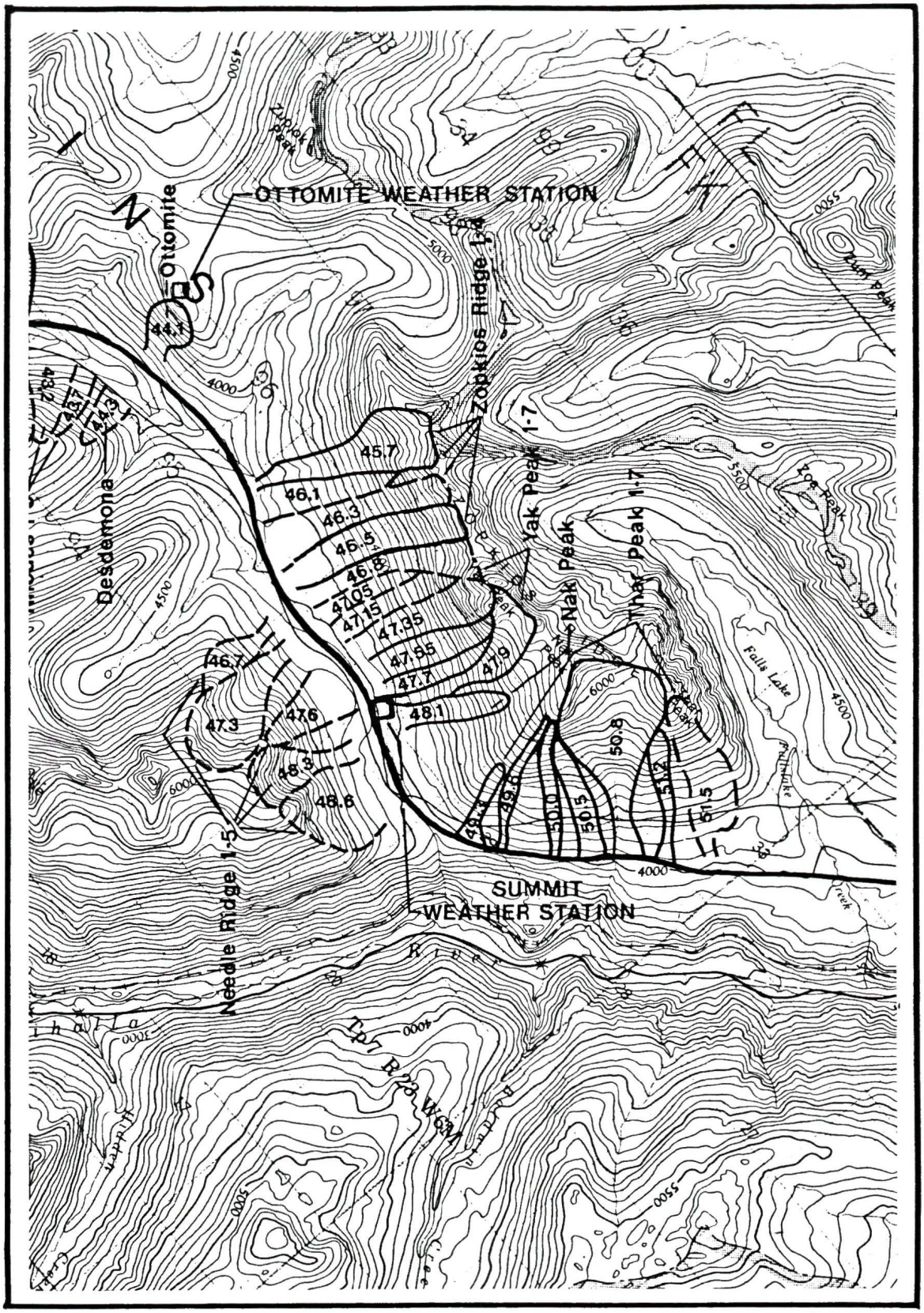

Figure 4.8: Typical snow avalance map prepared by the Snow Avalanche Section, Ministry of Transportation and Highways in British Columbia

the branch provides information on the soils, surficial geology (including natural hazards), vegetation, and wildlife biophysical habitat for land use planning. Mapping of natural hazards has basically been undertaken by the Surficial Geology Unit of the Terrain Section-Terrestrial Studies Branch (see Figure 4.4) as part of their terrain inventory studies. In May, 1980, a working report entitled "Guide to the Preparation of a Geological Hazards Map" was prepared specifically for use by "planners, resource managers, foresters, engineers and other people concerned with allocation of the land resource" (Ryder and MacLean, 1980). The purpose of the report was to explain how other administrators could use available surficial geology maps to interpret areas of hazard so that they could be avoided during the planning process. Unfortunately, this program was greatly curtailed in 1981 due to staff and funding shortages. As illustrated in Figure 4.9, by 1981, approximately 35% of the province has been mapped for surficial geology at a scale of 1:50,000. Use of surficial geology maps for hazards assessment is illustrated in Figure 4.10.

Currently the Surficial Geology Unit is composed of 3 members with an annual budget of approximately $125,000. Unfortunately, their mapping priorities are established through requests by other agencies and are not carried out as part of a systematic mapping program. Natural hazards are only part of their total program and may account for less than 10% of total expenditures, or $12,500 per year. This is a minimal amount in comparison to savings possible by recognizing risk areas in land use plans.

Division of Building Research - National Research Council of Canada

The National Research Council-Division of Building Research, develops, evaluates and amends building codes for the Canadian construction industry and has consolidated them in the "National Building Code". These codes have been adopted in British Columbia since 1973 when they became the building bylaw for municipalities and Regional Districts through amendment to the British Columbia Municipal Act. Administration and enforcement of these codes on an operational level (building inspection) is therefore the responsibility of

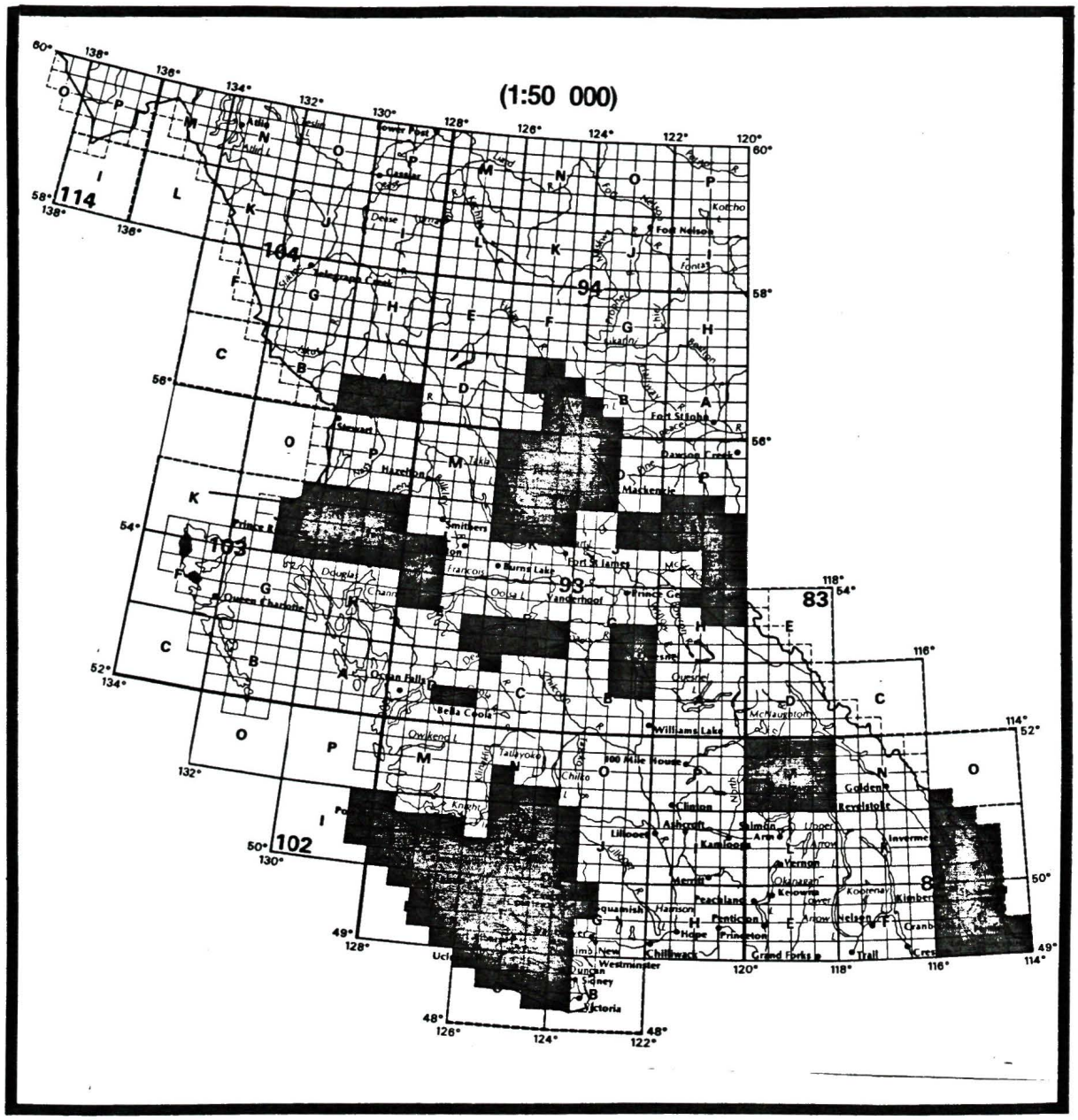

Figure 4.9: Index indicating areas of British Columbia where surficial geology mapping has been completed by the Terrestrial Studies Branch, Ministry of Environment (1981)

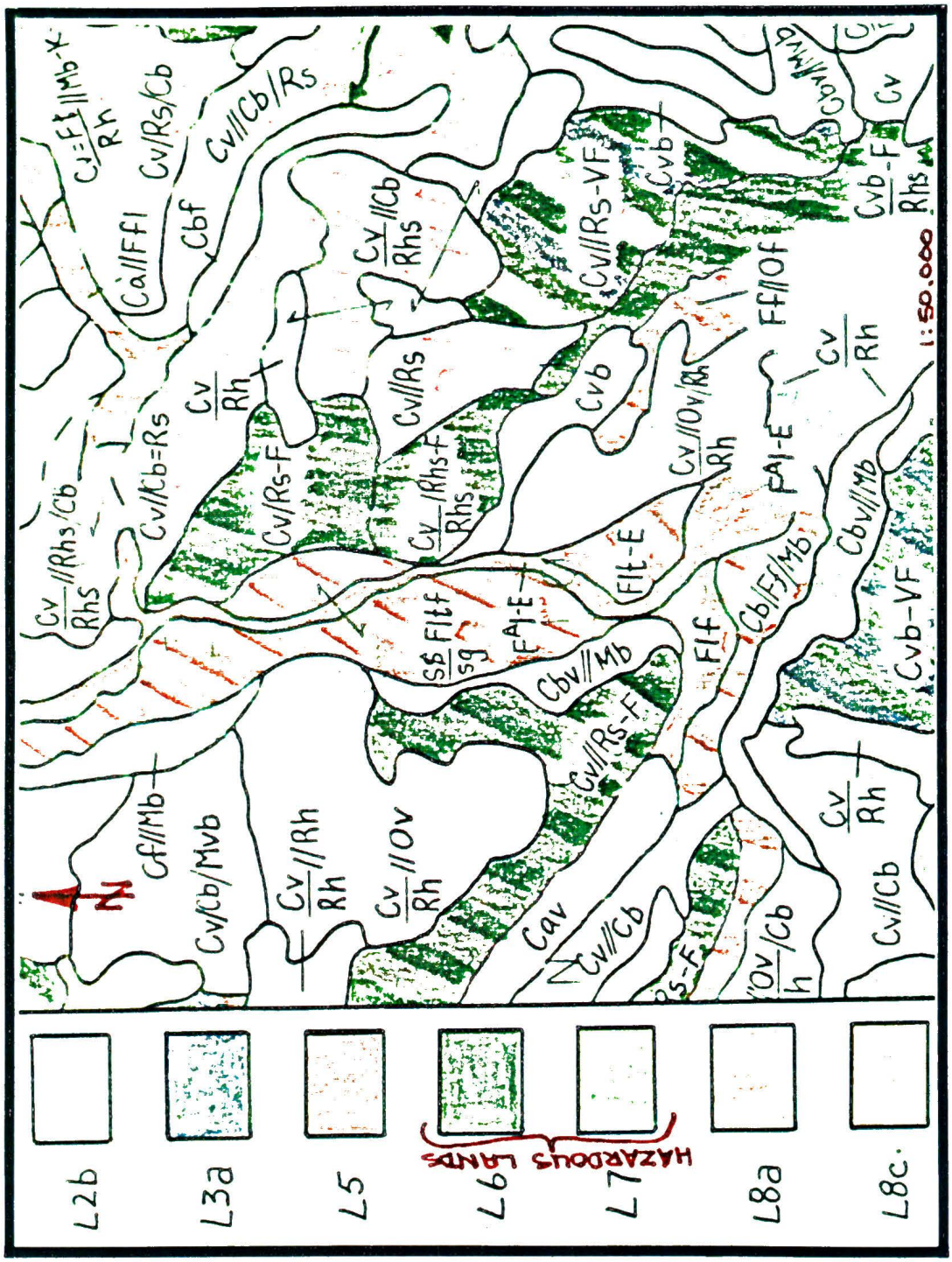

Figure 4.10: How to prepare a geological hazards map, by Ryder and Maclean, Terrestrial Studies Branch, Ministry of Environment (1981)

individual municipalities and regional districts within the province of which there are 141 municipalities and 28 regional districts.

Within the National Building Code there are requirements for structural design to protect against the following natural hazards:

a) effects of wind and gusts;
b) effects of earthquakes - lateral loads due to earthquake motion;
c) effects of loads due to snow accumulation on roofs; and
d) effects of rain loads on roofs.

Of those hazards which most frequently occur in British Columbia, only earthquakes require specific building regulations. As British Columbia has not recently been shaken by a major quake, it is difficult to determine if these codes are sufficient. Changes in the earthquake loading codes are likely in the next 2-3 years based on revised data collected by the Earth Physics Branch, Energy, Mines and Resources Canada (Personal communication-Pacific Geoscience Centre, Earth Physics Branch).

Only a vague reference is made to problems associated with sloping ground susceptible to landslides or snow avalanches. In section 4.2.3.3 the National Buiding Code requires that "existing stresses within the soil or rock shall be considered in the design," however, enforcement of this section by building inspectors in British Columbia is seldom ever employed. By contrast, the Uniform Building Code in the United States which is administered in a similar manner, contains a section specifically dealing with slope and slope related problems, which can be expanded to cover all forms of natural hazards. Chapter 70 of the Uniform Building Code, entitled "Excavation and Grading" states that:

> "If in the opinion of the Building Official, the land area for which grading is proposed is subject to geological or flood hazard to the extent that no reasonable amount of corrective work can eliminate or sufficiently reduce the hazard to human life or property, the grading permit and building permits for habitable structures shall be denied."

As a result, unlike their american counterparts, administrative programs that deal with the enforcement of building codes in British Columbia spend only a fraction of their time studying the impacts of natural hazards on structures. Greater emphasis will likely have to be placed on the impacts from natural hazards before Canadian building codes will be altered to more accurately reflect the risks involved.

Post-Event, Relief, Compensation and Recovery Programs

Provincial Emergency Program - Ministry of Environment

Program development under the Provincial Emergency Program (P.E.P.) has taken place since 1965 and has undergone considerable changes in emphasis. Instituted as a civil defense agency, the Program has since trended more to emergency response in cases of disaster and to search and rescue exercises. With the decrease in emphasis on civil defense, the P.E.P. has also become progressively more active in disaster relief and rehabilitation coordination. For example, members of the program aided in the post-event rehabilitation of Port Alice after the November 13, 1975 debris-flow, and in the evacuation of residents along Howe Sound during the October-December storms of 1981 when debris-torrents threatened communities at the mouths of several creeks.

In 1980, the Provincial Emergency Program Plan was revised to give greater emphasis to emergency planning at the municipal level (Ministry of Environment, 1981). Prior to this, the emphasis lay in developing a provincial network for emergency response and preparedness. Much of the work done under the program has not centered on preparation for natural hazards but on hazards from man's own activities. This is emphasized by those courses available through the Provincial Course Program in emergency planning as administered by the Training Section of the Provincial Emergency Program. Courses provided through the Provincial College in Victoria include; community emergency planning, transportation of dangerous goods, marine rescue, management of land searches, casualty simulation, oil spill control, techniques of instruction, cliff rescue and tracking.

Working in cooperation with other provincial ministries, the P.E.P. has been working toward establishing a province-wide emergency communications network. As part of this network was the establishment in 1980 of a radio base station at the Provincial Emergency Program headquarters in Victoria (call letters V37 PEP). Over the next two years, it is hoped that volunteers under the Program will be equipped with new communications equipment whereby quicker response and greater coordination may be facilitated. Additionally, the Program has also sponsored an exercise to update the province's Tsunami Warning System and is developing a new signal for radio and television broadcasts to more effectively warn potential tsunami victims (Ministry of Environment, 1981).

Effectiveness of the program has been indicated by the rapid response which has occurred in times of emergency. Records indicate that during the 1980-81 fiscal period, the Program aided in the rescue of some 1,716 lives and the saving of $3.5 million in property damage. Operating budgets have been estimated at near $500,000 at a benefit:cost ratio of 7:1 on property damage alone. However, only a fraction of this amount (5% approximately) is employed in programs oriented towards planning for the impacts of natural hazards in excess of the rescue of victims ($25,000). A notable exception being the Tsunami Warning System. It becomes apparent that if the agency were to offset the increase in losses from natural as well as man-made hazards, then it would have to deviate from its present response orientation to one of planning, protection and loss reduction.

Emergency Planning Canada

Responsibility of this organization is to coordinate the emergency planning of federal departments, agencies and Crown corporations, and to liaise between them and the provincial government. Emergency Planning Canada coordinates federal emergency planning for disaster and defense, and encourages other levels of government to plan for emergencies by; providing funds to the provinces for certain approved emergency planning projects; sponsoring approximately 50 courses and conferences a year at the Federal Study

Centre, Arnprior, Ontario; sponsoring research projects on various aspects of emergencies; and by presenting written and visual aids for emergency planning. Brochures for "Self-Help Advice" are available for such hazards as floods, earthquakes and severe storms. A generalized history of the formation and changes since inception of Emergency Planning Canada is outlined in Table 4.3.

In 1980-81, this agency had a national operating budget of $4.66 million of which $2.7 million was for operating costs (including salaries), while $1.96 million was allocated for aid to provincial emergency programs. In the past, the federal government has annually contributed amounts to provincial governments which were added to the provinces general revenues. Recent changes in the federal program now require that the province's indicate specific projects they want funding for, and monies will only be allocated for those specific projects (Personal communication-Office of Emergency Planning Canada-Victoria). Sixty-eight staff members comprise this agency, however, 43 of these are based in Ottawa while only 2 are permanently located in British Columbia, at Victoria. As a result, these 2 members actions are generally confined to the coordination of activities between Emergency Planning Canada and the Provincial Emergency Program (Emergency Planning Canada, 1981).

One of the organizations more important administrative functions is to administer the federal Disaster Assistance Program on behalf of the Department of Finance. Under this program, when a disaster occurs of such a magnitude that relief and rehabilitation place an undue burden on the provincial economy, then the province may apply for assistance. Such assistance for example has been recently applied for during the winter floods at Terrace (1980) and Squamish (1980-81). Financial assistance may be requested when relief costs are likely to exceed $2.5 million.

Scientific Agency Programs

Pacific Geoscience Centre - Earth Physics Branch, Energy, Mines and Resources, Canada

The Pacific Geoscience Centre was established in 1978, consoli-

Table 4.3
The History of Civil Emergency Planning in
Canada up to the Formation of Emergency Planning Canada

Date	Organization and Department	Director/Coordinator
1948	Civil Defence Organization in Dept. of National Defence	Gen. F.F. Worthington
1951	Civil Defence Organization to Dept. of National Health and Welfare	Gen. F.F. Worthington
1957	Emergency Measures Organization created in Privy Council Office	Mr. R.B. Curry
	Civil Defence Organization remains in Dept. of National Health and Welfare	Gen. F.F. Worthington
1959	Graham Report:	
	-EMO assumes planning and coordinating role.	
	-Civil Defence Organization abolished.	
	-Government departments (National Health and Welfare, Justice and Defence) assume some functional responsibilities	Mr. R.B. Curry
1963	EMO moved to Ministry of Defence Production	Mr. R.B. Curry
1964	---	Mr. P.A. Faguy
1965	EMO moved to Ministry of Industry	Mr. C.R. Patterson
1968	EMO moved to Department of National Defence	
1974	Dare Report:	W.B. Snarr (PCO)
	-EMO becomes National Emergency Planning Establishment, operating under the Emergency Planning Secretariat in the Privy Council Office. Under the Federal Identity Program the organization is known as "Emergency Planning Canada."	C.R. Patterson (EPC)

Table 4.3 (cont'd)

Date	Organization and Department	Director/Coordinator
1976	---	Mr. V.J. Walton (EPC)
1980 July	Prime Minister Trudeau appoints Hon. Yvon Pinard, President of the Privy Council, to be responsible for providing ministerial guidance for policy development, inter-departmental coordination and liaison with provincial governments in the area of emergency planning. Mr. Pinard is to be supported by the Assistant Secretary to the Cabinet for Emergency Planning, and the staff of Emergency Planning Canada.	W.B. Snarr
	Emergency Planning Canada will now become, under the guidance of Mr. Pinard, an integrated organization comprising the Office of the Assistant Secretary to the Cabinet and the planning staff, with the latter to continue to be administered by the Dept. of National Defence.	W.B. Snarr

dating sections of the Earth Physics Branch and Geological Survey of Canada employed in the study of earth science along the Pacific margin. On the west coast, the Centre is associated with the Institute of Ocean Sciences. Earth Physics Branch scientists are subdivided into three divisions; Seismology and Geothermal Studies, Geomagnetism and, Gravity and Geodynamics. These groups administer programs involved in the study of broad-ranging geophysical processes, including the monitoring of earthquakes and study of the tectonic setting as it affects the environment through earthquakes, tsunamis and coastal phenomena (wave action, erosion, tides).

Research into earthquakes at the Centre is directed towards the study of conditions that lead to both large and small tremors. Patterns and frequency of events that could affect populated areas of southwestern British Columbia and Vancouver Island are continuously monitored. Monitoring is accomplished by a network of seismic observation stations spread over British Columbia which is part of the

National Seismograph Network. The Pacific Geoscience Centre is the control for those stations operating in the province. Seismic information is also gathered through a network of permanent stations around the Strait of Georgia, called the Western Canadian Telemetred Network. This network continuously feeds information to a computer at the Centre, which stores the data and can almost instantly ascertain the size, position and depth of any event that affects the critical, populated, southwestern region of British Columbia (Energy, Mines and Resources, 1980). From data gathered since the turn of the century the Centre has been able to plot the location and magnitude of all major earthquakes as indicated in Figure 4.11.

Geological Survey of Canada - Energy, Mines and Resources Canada

Primarily, this mapping agency provides geological information in all areas of Canada. Its surficial geology and geotechnical sections also map and study landform features such as areas of large mass movements. As a scientific agency, the Geological Survey of Canada is not directly involved in the planning process or the administration of natural hazards. The indirect usage of its information for delineating areas of risk by other agencies such as the provincial Geotechnical and Materials Branch or the Terrestrial Studies Branch makes it important. The close association of the Geological Survey with the National Research Council of Canada aids in developing a greater understanding of earth and hazard processes. Provincial agencies may therefore use this information where planning may be required or the need foreseen.

Justifying Administrative Costs

Costs for protection from natural hazards increase annually. The price for such protection should not exceed the potential for damage losses. Benefit-cost ratios of expenditure versus losses (or potential losses) should not exceed 1:1 if the system is to be viable. This, however, implies placing a value on human life. It is sometimes difficult, to effectively determine the protection provided

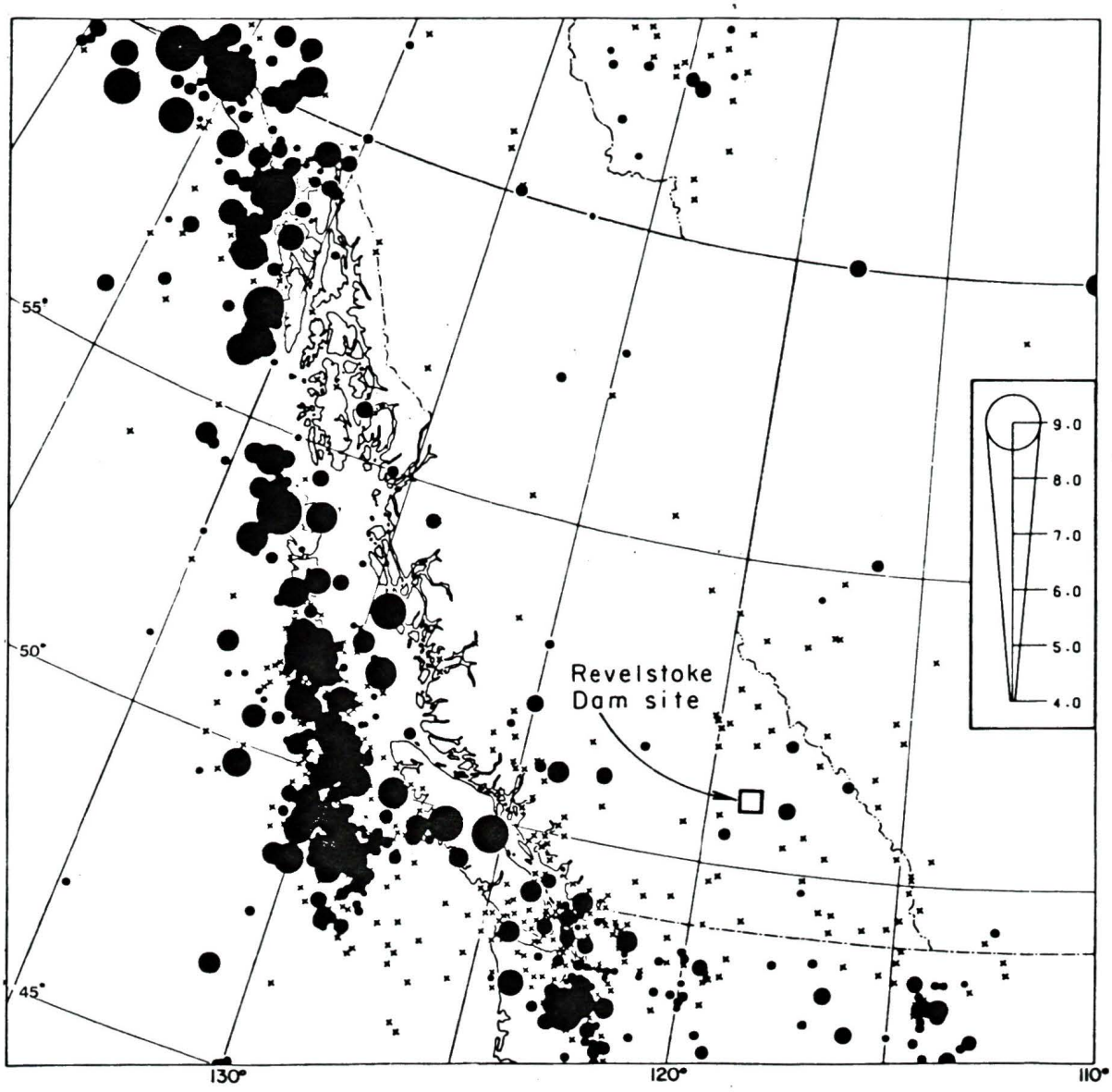

Figure 4.11: Map of location of earthquakes in and around British Columbia from 1899 to 1975 (from Rogers, 1980)

by an administrative program, particularly if the program does not involve construction of some manner which is an obvious, observable expenditure. An example of such a construction program in British Columbia versus potential estimated losses may be taken from the Fraser Valley flood protection works. The Canada-British Columbia, Fraser River Joint Advisory Board stated in 1976 that, "Floods greater than that of 1894 will result in damages in the order of $500 million". This figure was based on 1974 property values which can easily be doubled today, resulting in a potential $1 billion estimated loss. To protect against this loss, federal and provincial governments have allocated $120 million for dykes and dams. If effective (?) the benefit-cost ratio indicates a significant benefit (8.33:1) could be derived by the flood protection program. Such figures as proposed here are possibly somewhat optimistic as benefit-cost figures prepared for California are considerably lower (see Table 4.4). Still, a definite benefit is enjoyed by employing loss-reduction measures over an uncontrolled, build anywhere system.

Direct expenditures on hazard reduction programs is not easily subdivided from the annual operating costs for most agencies. As shown in Table 4.5, an approximation of annual expenditures for hazards reduction has been made for provincial and federal agencies involved.

Assuming that radical changes in expenditures by these agencies are unlikely to occur if a coordinated program were instituted, the cost effectiveness of a program is likely to prove positive. It is difficult to accurately project benefit-cost ratios, but assuming that one third of annual losses to natural hazards could be achieved, then a ratio of 1:1 would be possible. This figure would exclude benefits where potental disaster was avoided. We can conclude from this then that a well-organized, mandated hazards program, could be cost effective in reducing risk and loss potential.

Table 4.4: Ranking of Hazards on the Basis of the Benefit:Cost Ratio of Performing Loss Reduction Measures in California

	Geologic problem	Benefit:cost ratio
1.	Loss of mineral resources	170:1
2.	Expansive soils	20:1
3.	Landsliding	9:1
4.	Earthquake shaking	5:1
5.	Volcanic hazards	5:1
6.	Fault displacement	1.7:1
7.	Subsidence	1.5:1
8.	Tsunami hazards	1.5:1
9.	Erosion activity	1.5:1
10.	Flooding	1.3:1

Source: California Division of Mines and Geology (1973).

Table 4.5: Estimation of Program Costs by Agency for Loss Reduction From Natural Hazards in British Columbia

1.	Ministry of Environment, Water Management Branch	$303,000
2.	Min. of Environment, Terrestrial Studies Branch	$ 12,500
3.	Ministry of Env., Provincial Emergency Program	$100,000
4.	Ministry of Transportation and Highways, Geotechnical and Materials Branch	$129,000
5.	Min. of Trans. & Hwys., Snow Avalanche Section	$1-2,000,000
6.	Emergency Planning Canada	$ 60,000
7.	Energy, Mines and Resources Canada, Pacific Geoscience Centre	$300,000
	TOTAL	$1,904,500/year to $2,904,500/year

Difficulty in accurately predicting the savings achieved from hazards administration arises from the fact that benefits are normally seen only over the long term. Administrative expenditures are currently minimized in most agencies. However, benefits would appear to be high, as losses could easily exceed present limits without the minimum of protection already provided. From the analysis made here, it would be beneficial to the administrative process to establish a central agency to gather data on the spatial arrangement of hazards in the province, to create a data base for the accurate determination of risk and to coordinate programs to study or reduce risk. Without such

an agency, the benefits of natural hazards programs will likely be significantly less effective.

Priorities applied to hazards programs will also need to be upgraded if a significant increase in loss-reduction is expected. Agencies like the Geotechnical and Materials Branch, Ministry of Transportation and Highways are involved in hazards investigation programs on a request basis rather than as an integral part of the planning and subdivision approvals process. Greater emphasis placed on the delineation of hazard areas for risk assessment could possibly lead to developments which recognize the risks involved and take appropriate steps to reduce the potential losses. Priority however must first be given to risk assessment if loss-reduction is going to be possible. Decision-makers must decide whether protection of the public is more important than rights to build wherever they wish. Established administrative programs must be coordinated to develop in a comprehensive and consistent manner rather than in the current isolated and ad hoc manner.

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Chapter 5
MOUNT GARIBALDI - A CASE EXAMPLE

One of the major arguments presented in this thesis has been that in British Columbia decision-making with regards to natural hazards is ad hoc. As a consequence, both planning and management are inadequate. These weaknesses can be illustrated by a case study of the Mount Garibaldi flood-rockslide event. Previous chapters have assessed the individual components of hazards management in the province. This chapter illustrates a working example of the system as well as the social impacts of ad hoc decision-making.

The Physical Setting

Mount Garibaldi is located approximately 30 kilometres northeast of the town of Squamish, or 70 kilometres north of Vancouver as indicated in Figure 5.1. The area of high risk lies on the east side of the Cheakamus River Valley, extending up Rubble Creek to a geological formation known as the "Barrier" (see Figure 5.2). The creek is the main access to the alpine area of Garibaldi Lake which is part of Garibaldi Provincial Park. Rock debris may be found throughout the length of the Rubble Creek valley and constitutes the bulk of the large fan at the mouth of the creek (see Figure 5.3). This rock debris has been attributed to a major rockslide which originated at the Barrier in 1855 (The Garibaldi Advisory Panel, 1978). The slide involved upwards of 30×10^6 cubic metres of material, making it comparable in volume to the 1965 Hope landslide which has been estimated to contain about 45×10^6 cubic metres of rock and soil (Mathews and McTaggart, 1969).

Existence of natural hazards was recognized in the Mount Garibaldi area long before modern development took place. Native indians reported to Major William Downie, who was exploring in the area in 1858, that a major flood had occurred three years prior to his visit. After examining the site Downie reported that tremendous devastation had taken place along the Cheakamus River and surmised that the debris and flood had resulted from the sudden release of

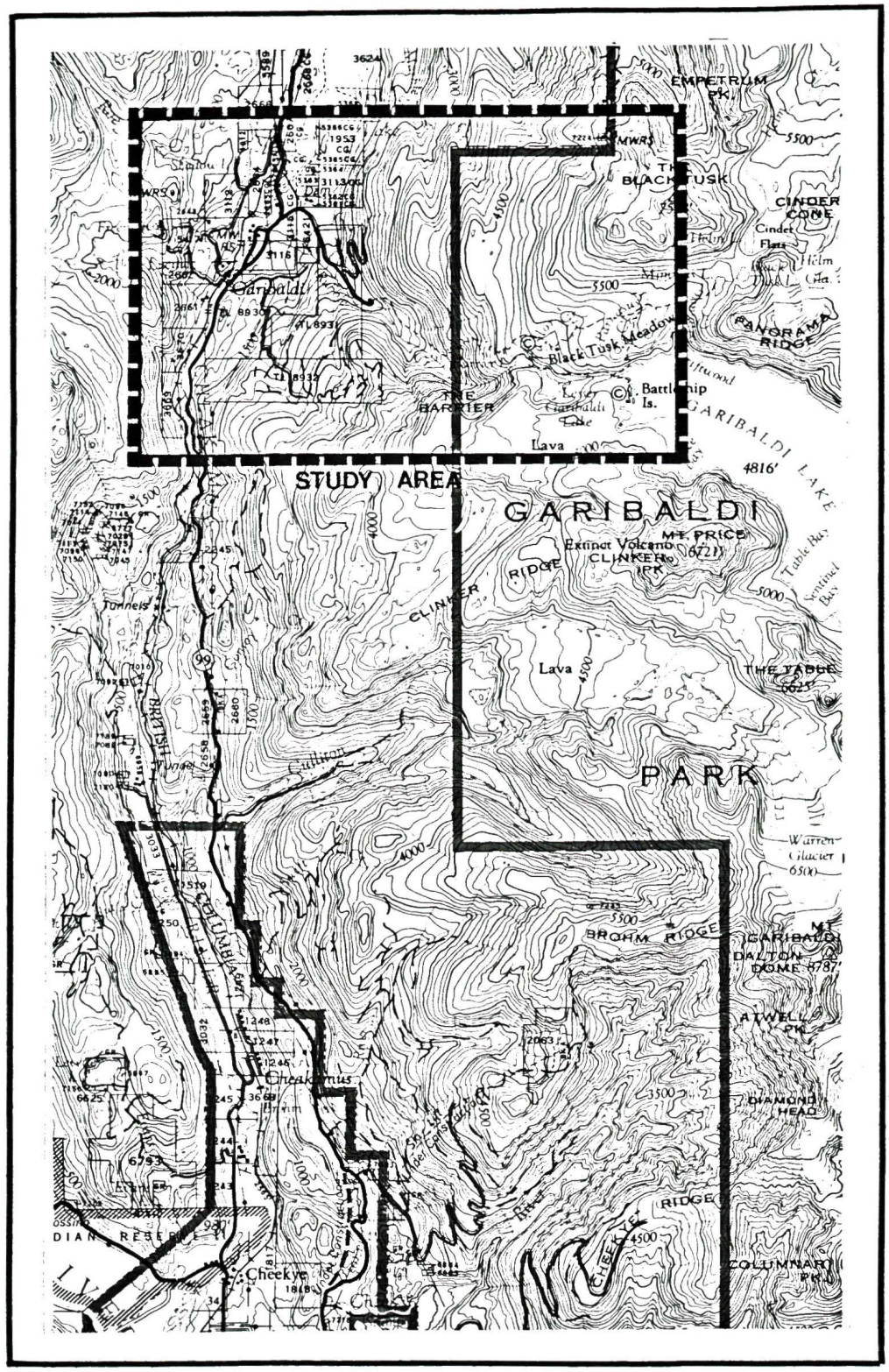


Figure 5.1: Location plan of the Mount Garibaldi Study area (scale 1:250,000)

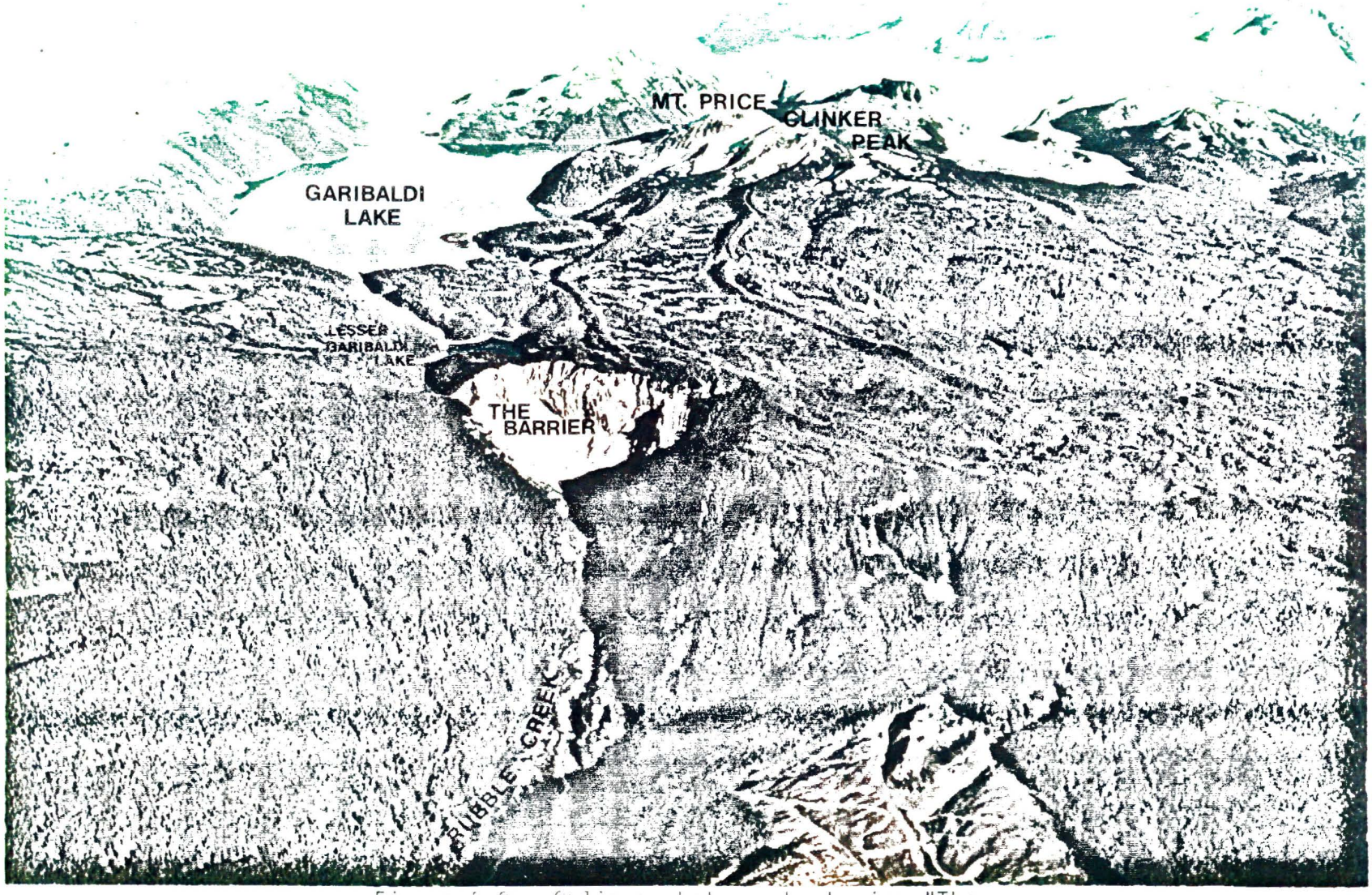


Figure 5.2: Oblique photograph showing "The Barrier" and surrounding features as indicated (Photo supplied by B.C. Ministry of Environment)

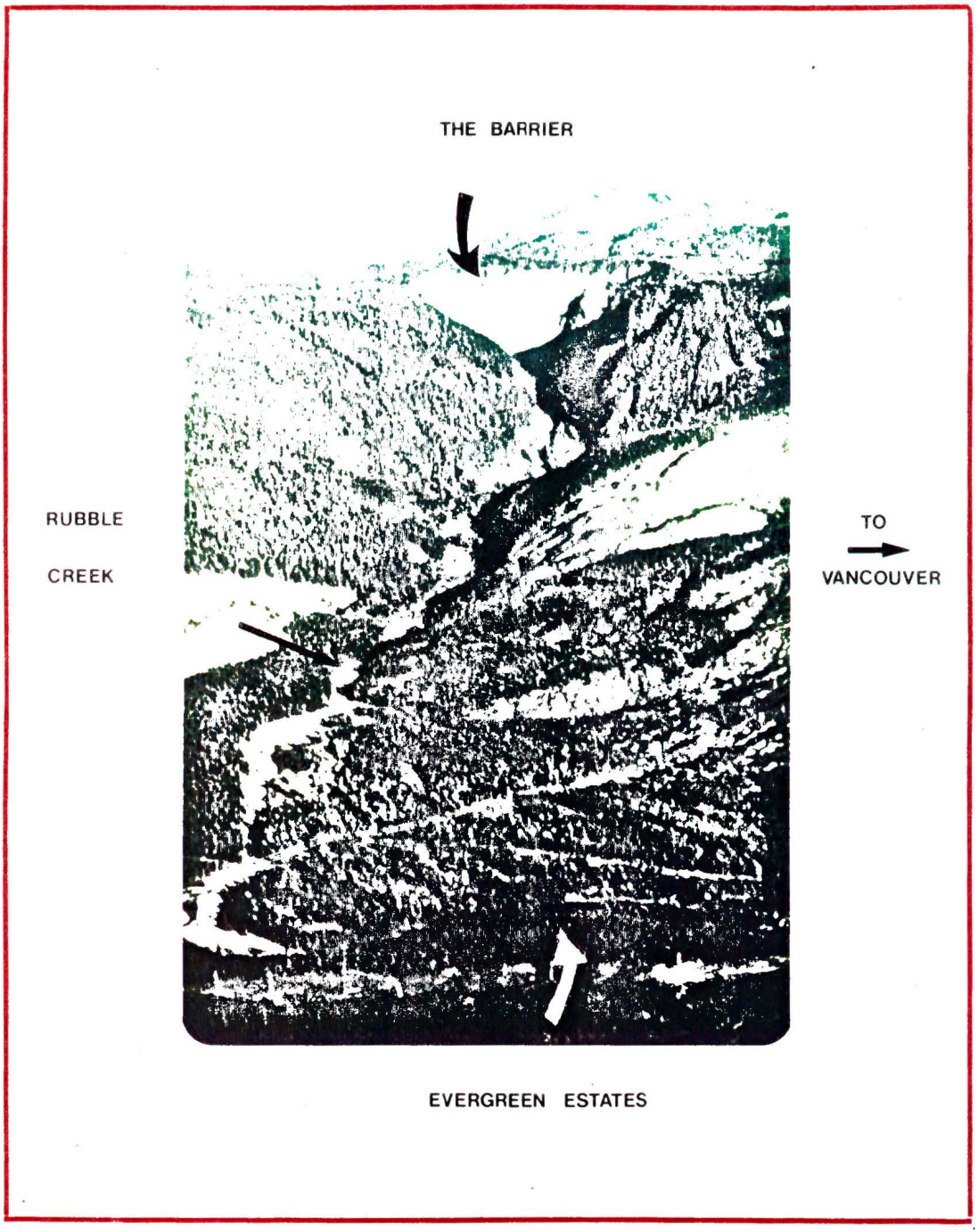


Figure 5.3: Photograph showing the relationship of the Barrier to the Rubble Creek fan and the Evergreen Estates subdivision

mountain lake waters. The cause of the slide and characteristics of the resulting flood-debris flow are still subject to speculation, however field evidence substantiates the fact that at least one major slide and flood had occurred in, or around, 1855.

Geology and Geomorphology of the Barrier and Adjacent Area

The Barrier consists of a nearly vertical rock face 160 metres in height which is composed primarily of layered lava flows. These are predominantly dacite flows which in turn overlie granitic intrusives at depth. It is known that these lava flows originated from Clinker Mountain (see Figure 5.2). In the case of the Barrier, lava flows poured down the northwestern slope of the mountain then flowed into the neighbouring valley of Rubble Creek, filling the head of the valley to a depth of over 250 metres, forming a dam and eventually impounding several lakes. The latest lava flow formed four lobes, with the second and third lobes crossing to the north side of the Rubble Creek Valley and acting as dams for Lesser Garibaldi Lake, Barrier Lake and in part Garibaldi Lake (Horcoff, 1972). The 1855 rockslide occurred within the lava from the third lobe.

Volcanic eruption of Clinker Peak occurred at the same time as glacial ice filled the valleys and covered many mountain tops in British Columbia. As a result, some unique features were formed. Lava which flowed northwest out of Clinker Peak into Culliton and Rubble creeks, uncharacteristically ended in high faces, a feature rarely found elsewhere in the world. Mathews (1952) attempts to explain this phenomenon by saying that the glaciers which filled these creek valleys were of sufficient size and elevation to dam the down slope movement of the lava. As a result, when the ice retreated and downwasted, high, vertical faces were left along the contact zone. Subsequent failures along the faces of the lava have accentuated the ruggedness and uniqueness of the features.

Continuous failures and long term weathering of the lava face at the Barrier has resulted in the accumulation of large talus deposits at the base. Causes for failure result from the columnar and tabular jointing of the lavas, excess pore water pressures, extensive

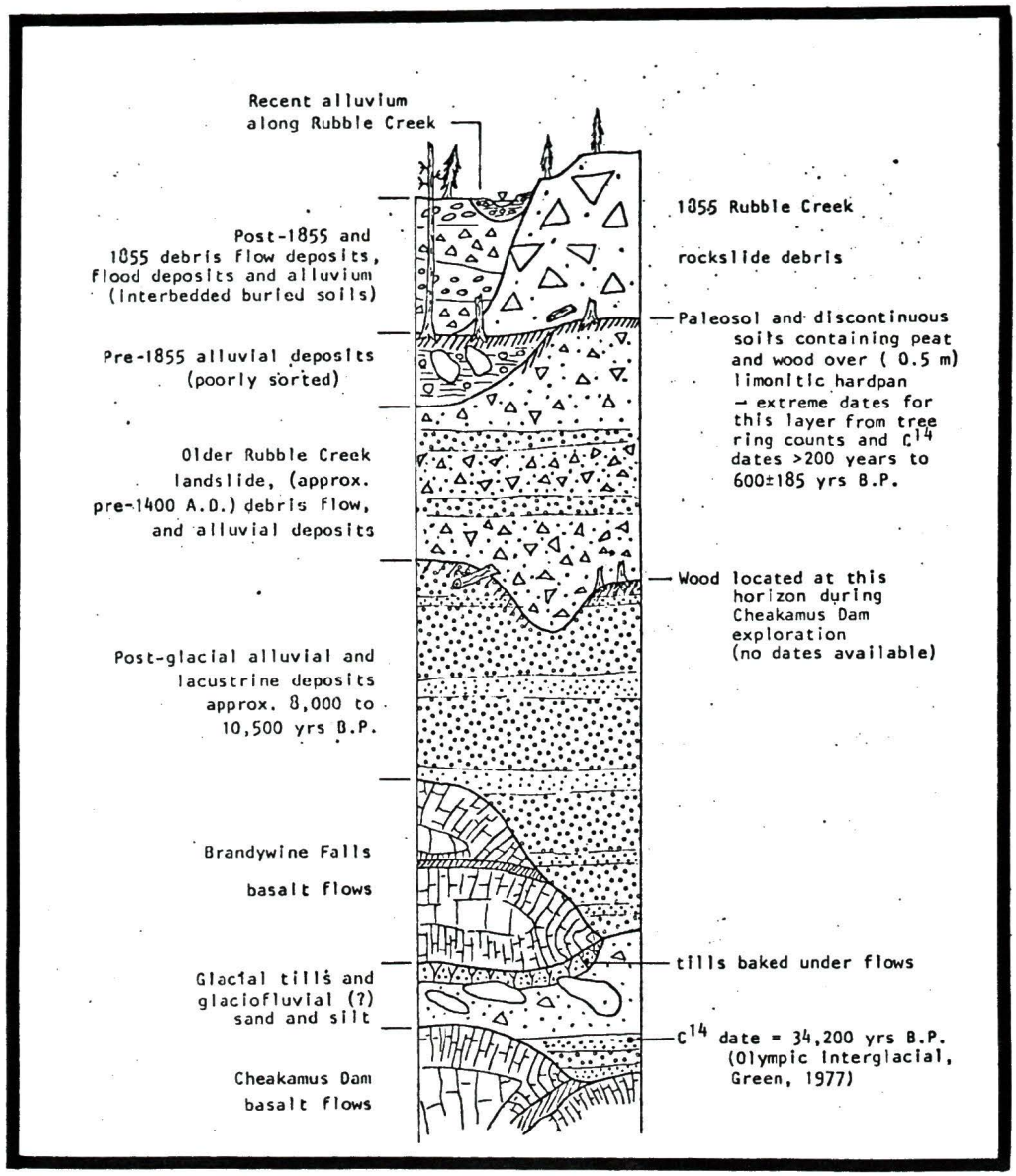
fracturing of the rock material, and high stresses along the vertical face. It has been postulated, that should another major slide occur at the Barrier, it is probable that this talus would be incorporated, forming between 15 and 40% of the total new slide material (The Garibaldi Advisory Panel, 1978).

Deposition which resulted from glaciation in the Mount Garibaldi area took place throughout the period of volcanic activity. As a result, glacially deposited materials may be found under and over the lava flows resulting in a complex stratigraphy (see Figure 5.4). This situation has further been complicated by mass-wasting and continuous erosional processes. In the river valleys, a distinctive difference does exist however, between the glacial and erosional deposition and the rock debris resulting from massive rockslides such as the one in 1855. Glacial and erosional deposits consist of rounded rocks in a matrix of silt and clay which often exhibit a well defined bedding structure. Rock debris is recognized by the angularity of the rocks and boulders, the inclusion of organic material such as logs and bushes, and exhibits no structure.

Broken rock debris is found in both the Rubble Creek and Cheakamus River Valley. Much of this material in the Cheakamus River Valley has been reworked by glaciofluvial and fluvial action, whereas this is not the case in the Rubble Creek Valley. Debris from slides off the Barrier, litter the floor of Rubble Creek Valley to considerable depth. These slides may also have dammed the Cheakamus River Valley, causing waters to back-up and flood areas north of Rubble Creek and possibly inundating sites downstream as the dams were overtopped or eroded (The Garibaldi Advisory Panel, 1978).

Major Interest Groups in the Mount Garibaldi Area

Human as well as physical processes must be present before a hazard can exist. The evaluation of risk may, however, be dependent even further on the actions of the participants. In the Mount Garibaldi area, several diverse groups participated in the determination and evaluation of risk. Primary factors having thereforebeen placed into three different categories. The first



(From the Garibaldi Advisory Panel; (1978); Report of the Garibaldi Advisory Panel - Part 1; for the B.C. Department of Highways)

Figure 5.4: Stratigraphy of slide and glacial deposits in the Rubble Creek and Cheakamus Valleys

consisting of those residents, owners and developers in the hazard area who were directly impacted by the outcomes of investigations and decisions reached. Secondly, the group of provincial government ministries responsible for initiating studies and for making decisions regarding risk and its mitigation. Lastly, the group of scientists, engineers and judiciary who objectively evaluated the physical and legal aspects of the Mount Garibaldi data and whose conclusions molded those decisions which resulted in far-reaching impacts for the local inhabitants.

Public groups with particular interests included the owners of lots in Garibaldi Village, the Garibaldi Ratepayers Association, the Squamish-Lillooet Regional District and Cleveland Holdings Ltd. whose subdivision proposal "Evergreen Estates" initiated the hazards review of the Rubble Creek area by the Ministry of Transportation and Highways. Provincial agencies directly involved include; the Ministry of Transportation and Highways; the Ministry of Environment; the Provincial Emergency Program Office; and, the Ombudsman of British Columbia. The sequence of these agencies corresponds to the order in which they became involved during the evolution of the case history.

Over the ten year period of hazard assessment of Mount Garibaldi, a number of engineers, academics, geologists and other experts were referred to for their comments and experience in regards to the flood and rockslide hazards in the area. Their involvement being triggered by a court case between Cleveland Holdings Ltd. and the Highways Ministry. Justice Berger was chief magistrate of this case and it was his summary of proceedings, based on expert witnesses' testimony, which highlighted the hazards involved and acted as the basis upon which subsequent decisions were made.

In fact, Berger concluded in 1973, that both flooding and rockslides could occur in the Mount Garibaldi area, and more particularly, throughout the length of Rubble Creek and over the existing fan. Later, a consulting group of engineering geologists called the Garibaldi Advisory Panel, would reinforce Berger's conclusions. Results of their investigation indicated that should an event of the same magnitude as the 1855 flood-slide, or a maximum

flood occur, total devastation of the Rubble Creek fan would be possible.

The roles of these participants varies considerably as indicated by some of the examples above. What follows is an evaluation of the risk by those members of the owners-resident group, and a review of events since the conflict between Cleveland Holdings Ltd. and the Highways Ministry.

Evaluation of Residents Perceptions-In the Mount Garibaldi Case Example

Often, residents and developers do not perceive the risk from natural hazards in the same manner as do supposed experts. This leads to disagreement in many cases on the existence of risk and the methods of hazards mitigation that may be employed. Such becomes evident in the Mount Garibaldi case and more particularly in the Rubble Creek Valley and fan areas. In order to assess the social implications of those decisions made regarding development in these areas over time, a general questionnaire was prepared to assist in evaluating perceptions and attitudes during the course of events. Results were obtained by phone or letter contact with 41 out of the 102 owners of property in the hazard area sent an information questionnaire (see O.I.C. 1185 which follows), and were intended to assess residents perceptions of risk at various stages in the proceedings. Where applicable, the responses derived have been interspersed throughout the text.

That a degree of risk exists, was established by Downie in 1858. The physical setting has indicated that the area is very rugged and the determination of risk made more difficult because of the complicated geology and geomorphology in the area. It is against this background that the following questions were posed by the author.

Questions Asked of Residents in the Mount Garibaldi Hazard Area

1. Were you aware of any hazards before you moved into or purchased property in the Mount Garibaldi area?

2. What was your perception of the hazard after the Cleveland Holdings Subdivision development was halted by the Ministry of Transportation and Highways?

3. Did your perception of the hazard change after the findings of the court case and the report by the Garibaldi Advisory Panel were presented?

4. Do you believe your lives would be in danger if you still lived on the site?

5. What were your major objections to the format devised by the government for compensation?

6. What was your reaction to the governments relocation program?

7. Would you move back?

8. If you had been allowed to stay in the hazard area, would you have requested compensation if a slide or flood occurred?

The purpose of questions one through four was to evaluate the perception of risk at four distinctive phases during the Mount Garibaldi hazard evaluation program. Those four phases considered included; the initial period of development prior to public disclosure of the hazard; after the non-approval of Cleveland Holdings subdivision; subsequent to the results of the ensuing court case and engineering study; and, the current assessment of risk based on previous events. Prior to the refusal of Cleveland Holdings subdivision application for reasons of potential rockslide and/or flooding and subsequent coverage in the local media, few residents were aware of the degree of risk they faced. Of the 41 responses received, 27 were from those who had been permanent residents. From this group, 11 were aware that some risk of a flood on the Rubble Creek fan was possible, however none indicated any awareness of a potential massive rockslide. One respondent replied "no one knew that a slide would occur, and no one cared." As each phase of the Mount Garibaldi case proceeded, an increasing number of residents became aware that a risk existed, although very few realized the impact that an event could have on the local community. A resident of Phase 1 of

Cleveland Holdings subdivision remarked "we all were told or heard that there was a hazard, but I don't think anyone realized how severe it was until the government (provincial) wanted to buy us out."

Questions five and six were designed to test the reaction of residents to the government compensation and relocation programs. Responses were very vocal in condemning both the compensation and relocation programs proposed by the government. Both programs were described by all respondents as being either, "inadequate", "unfair", "repressive", "inconvenient" or "communist". All 41 of those surveyed were opposed to the means by which the government programs were applied. Some responses were almost violently opposed to the programs as evidenced by one owner who stated "those lousy ... government guys stole our property, for no reason whatsoever." Further illustration of owner complaints with the proposed government schemes will be presented by the Ombudsman of British Columbia in following sections.

The remaining two questions (seven and eight) were posed in order to determine whether after ten years of debate, investigation, and conflict, those individuals affected fully realized the risk of residing in the declared hazard zone. Responses received to question seven varied but could easily be grouped as follows:

Yes - 12 responses
No - 13 responses
"It wouldn't bother me to move back, but I don't think I'd live there forever now." - 16 responses

The latter group indicating a willingness to accept the risk for a short amount of time, but not for the long term. This indicates that people have a difficult time realizing that the risk of an event today, is as great as it is tommorrow. Risk is not cumulative over time, it does not increase as the days and years go by. Awareness of the real "risk-at-place" appears confined to the investigators and decision-makers.

It has been established, that the perception of risk is often dramatically reduced when compensation is anticipated (Foster, 1976; Sewell, 1965). This is illustrated by those responses received to question eight. From the 41 responses received, 29 firmly declared that they would have requested compensation. The remaining 12

respondents indicated they would not have expected relief, but couched their responses by stating that this would be dependent upon their being able to retain property rights and the right to re-sale of their land. Positive responses for compensation often provided examples of where relief had been supplied previously, as illustrated by this respondents statement, "Why shouldn't we get relief, the people at Squamish got paid last year for their flood" (referring to spring 1980 flood). Though willing to accept the risk of devastation, the respondents are not ready to accept the financial responsibility of such a decision. Liability for damage is perceived to lie, at least in part, with the provincial and federal governments.

Events Leading to Order in Council 1185

Where ad hoc management exists without well-defined policy or legislation, decisions made are subject to dispute, often resulting in litigation. At Mount Garibaldi, dispute arose between Cleveland Holdings Ltd. and the British Columbia Ministry of Transportation and Highways, over the right to subdivide part of the Rubble Creek fan, below Mount Garibaldi and the geological feature known as the Barrier. Conflict arose as a result of inconsistent decisions made by the Highways Ministry as to the viability of the proposed Cleveland Holdings Ltd. subdivision development, Evergreen Estates.

In May, 1971, Cleveland Holdings initiated a potential 288 lot residential subdivision on the Rubble Creek fan. Three phases were proposed for the subdivision; and in February, 1972, Phase I of the proposal was approved by the Highways Ministry. In August of the same year, the Senior Approving Officer for the Ministry, refused approval of Phase II of the development, because of new information he now considered it to be, "against the public interest." Two weeks prior to the refusal by the Senior Approving Officer, the Squamish-Lillooet Regional District had rezoned the area of Phase II for residential development. Conflict between policies of the two levels of government was evident, resulting in the Regional District following a policy which promoted development in a hazardous area, while the provincial government was instituting a policy restricting development

in areas of high risk. Notably, the provincial policy was internal and as such, the regional district or other agencies (such as the developer, Cleveland Holdings Ltd.) would not necessarily be made aware of the policy, or changes in the policy. This emphasizes the need for a public, natural hazards policy which would dictate policy for all levels of government.

The policy re-assessment by the Highways Ministry concerning land affected by floods or slides had in fact taken place between February and August, 1972. As a result of this change, particular interest in Cleveland Holdings development was raised, when a letter by Mr. K. Farquharson, then president of the B.C. Sierra Club was received by the Ministry. In his letter, Mr. Farquharson noted that Mr. Karl Terzaghi, a respected soils engineer, had indicated that the settlement of Garibaldi, including the area of the proposed Evergreen Estates, was located on old slide debris from an event in 1855. Mr. Farquharson went on to say:

> "The critical question is whether the Barrier Cliff at the head of Rubble Creek, which was the source of the previous slide, is now stable or not. I have not heard of any engineering analysis being made of its stability. Until expert opinion is prepared to state that the cliff is stable, it is very unwise, in my opinion, to allow settlement in the path that any future slide will follow."

Mr. Farquharson's comments on the proposed subdivision were accepted by the Senior Approving Officer because under Section (96) of the Land Registry Act, "interested persons" may submit objections to development where applicable. To validate Mr. Farquharson's statements, the Senior Approving Officer proceeded to obtain a second opinion on the slide hazard from Dr. M. Mathews, head of the Department of Geology at the University of British Columbia. Dr. Mathews agreed that another major slide off the Barrier could occur and possibly would destroy the subdivision site (Berger, 1973). Non-approval for Phase II of Evergreen Estates therefore seemed justified.

Of interest, however, is that prior to Mr. Farquharson's letter and the investigation by Dr. Mathews, another renowned geologist,

Mr. V. Dolmage, had publicly declared that he did not think that there was a risk for another massive slide at the Barrier. Conflicting opinions by experts in the field, emphasizes the problems in assessing the risk from natural hazards and of portraying those risks to the public. An uninformed public, such as in the case of the Garibaldi residents and developers, were faced with diametrically opposed expert opinion, which forced them to rely on their own assessments of the risk. Such perceptions were based on personal experience and limited information. This was basically reinforced by responses received during the informal questioning of some residents. Amongst the answers given, one resident noted that "if the experts couldn't agree on whether or not there's going to be a slide, I don't known how I'm supposed to."

As a consequence of being notified that further development of their subdivision would not be approved, Cleveland Holdings appealed to the Supreme Court of British Columbia, under section (98) of the Land Registry Act, for a decision on whether or not the Ministry of Transportation and Highways were legally correct in their refusal. Hearings took place from March 21-29, 1973, with the Honorable Mr. Justice Berger presiding over the case. Cleveland Holdings held dispute with both the potential for flooding and the potential for a massive rockslide. Evidence was presented by both sides initially on whether flooding was a potential hazard, and whether it would have an impact on the subdivision area. At the time, the Senior Approving Officer was personally aware of previous floods in the area, particularly those in 1967 and was concerned that should development occur and a flood take place, victims would seek compensation from the provincial government (Berger, 1973). Apparently, the initial phase of Evergreen Estates was approved even though the Senior Approving Officer was cognizant of a flood hazard. The risk from this hazard however, was not deemed significant until the Ministry's internal policy was altered and Mr. Farquharson indicated an even greater hazard existed in the form of a potential rockslide.

Liability is a common concern amongst decision-makers although, in British Columbia there is no legal responsibility assumed by any

agency of the government at any time to supply compensation for hazard losses. What does exist, is a moral obligation by the government to aid members of its society in times of need. Compensation may be viewed as politically expedient by elected members in a damaged area who look upon it as a means of rapidly satisfying public outcry. Numerous cases of compensation have occurred after floods and landslides such as at Squamish, Terrace, Port Moody, Kamloops and in the Lower Fraser Valley.

In respect to flooding, Mr. Berger considered both parties' evidence and made the following judgements:

> "On the evidence adduced there is no suggestion that any personally dangerous condition is liable to arise by reason of the flooding. It is purely a matter of possible damage to private property that may occur and that is an issue which is now before me."
>
> "If flooding were the only issue here I would approve the subdivision on condition that training works be established. If there were any dispute about the approximate design of the training works, I would order a reference to a special referee with suitable qualifications in engineering to inquire and report: section (63), Supreme Court Act, R.S.B.C. 1960, C. 384. I think this Courts power, under section (98)(4) of the Land Registry Act, to make "such order ... as the circumstances of the case require, goes far enough to allow such a practical disposition of the appeal."

Consideration of these judgments highlights several problems in dealing with natural hazards. Firstly, Justice Berger decided that, because it was only "possible" that damage could occur and that personal liability was not at question, therefore development could not be refused. Based on this decision it would appear that areas of "potential hazard" where loss of life cannot be guaranteed, can be developed. If this policy were to be followed, it raises the question of "who will pay for the damage?", if an event occurs. Referring to the results of previous disasters, and to the results of question eight of the questionnaire, it would certainly appear that the government would be morally obligated to provide compensation and would be duly requested by victims to do so.

A consequence of this type of decision-making is that planners and decision-makers would be unable to adequately protect against future events, through land-use regulation, as subdivision refusal would no longer be legal. There is therefore, a tendancy to use alternatives such as compensation (relief) or protection (technological approaches) in lieu of other avenues. Berger notes that approval in this case, based on the single hazard of flooding, would be dependent upon the establishment of training works designed by a suitable engineer. Alternative approaches such as land-use regulation or flood-proofing, among others, were not presented as alternatives. Traditional means of flood hazard mitigation such as dyking and relief were evidently regarded by Mr. Berger as the only alternatives readily available to resolve the conflict.

Conversely, in the question of a catastrophic rockslide, Mr. Berger showed a unique interpretation of "risk", as it applied to the Evergreen Estates development. Basic arguments from experts on both the apellants (Cleveland Holdings Ltd.) and the respondents (B.C. Ministry of Transportation and Highways) sides were presented. Experts on the apellants side included Dr. Dolmage, Dr. Stimpson and Mr. C. Brawner (the initial two being consulting geologists and the latter a consulting engineer) while the respondents relied upon Dr. Mathews and Mr. H. Naismith (another consulting geologist). The risk of a future slide was assessed by each side. It was the decision of Mr. Berger's that the theories on the 1855 slide and the risk of future slides were best presented by Dr. Mathews and Mr. Naismith. Both of these gentlemen agreed that there is a probability of a slide at the Barrier within the next 10,000 years. Mr. Berger based his judgment on a return period of 1 in 10,000 years, therefore establishing a precedent never before used in a judicial decision regarding natural hazards in British Columbia. Use of such a time frame was clarified by Mr. Berger in his summation when he stated that:

> "On a human time scale, there is a risk here. It is a risk that can be understood. It is a substantial risk. It may not be an immediate risk, yet it is there. Who is to say that the life of the subdivision would be merely one generation? Who is to say that any community established there

> would not last. The presumption must be that there is every likelihood that the structures built there will be replaced by new structures and that those will, in turn, be replaced. The life of the community may be one of hundreds of years. Ours is a new country. But in Europe, Asia and Africa communities have existed for hundreds, in some cases, thousands of years. Even on this continent we know of native indian communities with a continuous history going back to pre-Columbia time. If we adopt such a time scale, Dr. Mathews' warnings do not appear at all unreasonable. I am not saying that any community built at Phase II is going to last for a long time. I don't know. But the life of the community will likely be at least a generation. The evidence shows there is a risk - a risk that reasonable men can not exclude - that a disaster will occur within the life of the community."

A return period of this magnitude, if applied to other areas, would allow the decision-maker greater latitude in determining whether or not a "real risk" existed. Based on Mr. Berger's earlier statements on flooding however, decision-makers when considering other sites, may only refuse development if "life" as well as "property" is endangered. Property loss may still not be a suitable basis to refuse development in a potentially hazardous area.

As a result of his judgement that a risk exists for a catastrophic rockslide, Mr. Berger dismissed the appeal by Cleveland Holdings Ltd. and sided with the Highways Ministry in refusing further development of Evergreen Estates. Subsequently, the provincial legislature passed amendments to the Land Registry Act which allowed for Approving Officers to refuse subdivisions if they were "subject to, or could reasonably be expected to be subject to, flood, erosion or landslips ..."

Statements made in Mr. Berger's decision regarding flood damage have clouded the issue of development on floodplains in British Columbia. Past refusal for developing on floodplains has been based on mapping and site studies carried out by the Water Management Branch, Environmental Management Division, Ministry of Environment. Even though the Land Registry Act was amended and these amendments further clarified in the Land Titles Act, arguments raised by

potential developers may still be based on the ground that if there is no potential for loss of life from a flood on their developments, then approval should be given. The author is unaware if there has been any test cases where Berger's judgment was used as a precedent, however, it is conceivable that future uses may arise. The government's only alternative appears that if a judgment goes in favor of the developer, it may still request that protective works (e.g. dykes or diversions) be constructed.

A further consequence of the court case was that public attention was drawn to those conditions which existed at the site and to the governments role in the approving process. Media coverage of events illustrated to a wide audience, the general discontent of local residents and developers to the findings of the court case. Impacts on such things as house and land prices in the Garibaldi area were emphasized. In June of 1974, following the court case, the Vancouver Sun followed then Premier, Mr. Dave Barrett on a train trip from Vancouver to Prince George. During the trip, the train stopped at Garibaldi where approximately 20 local demonstrators approached Mr. Barrett to complain about the Highways Ministry and the Supreme Courts decision not to allow further subdivision by Cleveland Holdings. In responding, Mr. Barrett made two important comments which were carried by the Vancouver Sun newspaper on June 21, 1974. Those comments were:

1. "Before a final decision is reached, he said, a team of geological experts will be sent to the area and a public meeting for local residents will be held."

2. "Barrett told the demonstrators he would look into the matter but cautioned them that if the geological evidence showed the area was unstable he would not interfere with the earlier decisions."

The Highways Ministry was presented with the particularly difficult task of meeting these promises. In order to avoid any further appeals subsequent to a report by the team of experts, the Ministry carefully considered that members of the study team would require such high stature that their findings would be beyond argument. After eliminating several potential candidates, the department requested that

Dr. R.M. Hardy (Chairman), Dr. N.R. Morgenstern and Dr. F.D. Patton form a panel to investigate the risks of recurrence of the 1855 slide in the Rubble Creek Valley in the Mount Garibaldi area. They were also requested to present means to alleviate these risks. All three members were highly respected Canadian, geotechnical and geological engineers. The panel was formed in the spring of 1975 and was officially named "The Garibaldi Advisory Panel".

During the formation of the Garibaldi Advisory Panel, the Highways Ministry organized a public meeting for all interested parties at Garibaldi on December 10, 1974. The meeting was conducted to procure ideas as to what were the main issues seen by the registered land owners and what could be done to solve them. Generally, the meeting took issue with statements made during the court proceedings and with the resulting decisions. However, during the discussions which took place, mention of relocation and compensation was brought forward by the residents, as indicated by the following statements taken from the minutes:

> "... I would just like to have the Highways Department trade my house, the value of my house, for other property up the valley or somewhere where its safe."

> "I would say that the government buy my property at the price, the asking price, which they were willing to pay for it, and get out of it (the Rubble Creek problem)."

These statements gained importance later as decision-makers weighed alternative solutions to mitigate risks. Investigation of the Barrier and the Rubble Creek debris, however, was required before any of the solutions could be properly considered.

The sheer magnitude of the investigation resulted in the Panel taking nearly three years before preparing their findings. Cost of the study conservatively exceeded $200,000 while providing a very detailed description of the Barrier and the hazards to the Rubble Creek fan. Results of the investigation, fully vindicated the refusal for subdivision by the Highways Ministry and illustrated the risks which exist in developing in an area where previous floods or

landslides have occurred.

Original terms of reference for the "Panel" were established by the Deputy Minister of Highways, on April 14, 1975 and required them to:

(a) "Ascertain whether a hazard of a landslide exists in the Valley of Rubble Creek and, if so, the degree of frequency of risk that may exist;"

(b) "Determine the possible mechanism of a second catastrophic slide similar to that which occurred in 1855 in Rubble Creek, its extent, and impact on the present and future land use of Garibaldi Park, Rubble Creek Valley and the Cheakamus River Valley;" and

(c) "Recommend measures and costs to prevent or minimize risk to human life and property arising from a slide in Rubble Creek Valley (Files - Ministry of Transportation and Highways)."

Upon receipt of the terms of reference, the Panel was further requested, by the Department of Highways to propose a study program. Accordingly, the Panel developed a four stage proposal which was fairly closely followed during the investigation. The four stages included:

Stage I - Initial orientation, including review of documents by the individual Panel members; field tour of Rubble Creek area (made with Mr. J. Horcoff as representative of Ministry of Transportation and Highways, June 23, 24 and 25, 1975); and discussions with Department of Highways officials.

Stage II - Carry out detailed field investigations.

Stage III - Compile and review the data derived.

Stage IV - Institute further studies, if required.

Field work and analysis under Stage 2 was subdivided into sections IIa and IIb, after a meeting on August 15, 1975 between the panel and Highway's officials. This resulted in a revised submission entitled "Revised Proposal for Phase II Studies", dated August 20, 1975. Phase IIa being subdivided into ten components, these being;

geology, geotechnical studies, hydrology, topography and aerial photography, climate, seismology, botany, local experience, analysis of debris transport, and study of the Devastation Glacier Slide (which occurred on July 22, 1975 and assumed flow characteristics similar to those believed to have developed at Rubble Creek). Phase IIb work included items which were contingent upon the results of work completed under Phase IIa (e.g. a relatively expensive deep drilling program at the 4th Lobe) (The Garibaldi Advisory Panel, 1978).

Seismic, climatic, hydrologic and botanical components of Phase IIa appeared to require specialist professional evaluation. Mr. G.A. McMechan of the Victoria Geophysical Observatory of the Division of Seismology and Geothermal Studies of the Federal Department of Energy, Mines and Resources, was commissioned to study the seismicity of the area and he prepared a report entitled "Seismic Risk Evaluation". Preliminary assessment of the hydrological setting in Rubble Creek Valley was undertaken by Dr. Rolf Kellerhals, (a consulting engineering hydrologist) while an initial analysis and definition of the usefulness of botanical studies in determining the depositional history was commissioned from Mr. D.L. Dobbs, (a member of an environmental-engineering consulting company) (The Garibaldi Advisory Panel, 1978). It was later decided that in-depth studies for hydrology and botany were not required as they overlapped with aspects of the geological and geotechnical components being studied by panel members.

Detailed climatic detail was obtained through the Geotechnical and Materials Branch, Department of Highways, who obtained the information from Mr. R.G. Wilson, Head Climatology Section, Resource Inventory Division, Environment and Land Use Committee - Secretariat (Files - Ministry of Transportation and Highways).

Primary investigation of geological, geotechnical and specific hydrological components of Phase IIa was commissioned to F.D. Patton Consultants Ltd. who employed Mr. H.R. Smith, as a professional engineering assistant, and Ms. Leslie Strike, who compiled data on the "local experience" component as well as aiding in other areas of study. Slide mechanics, plate tectonics, laboratory analyses of

samples and carbon dating were commissioned to technical experts at the University of British Columbia and the University of Alberta (The Garibaldi Advisory Panel, 1978).

During the course of their investigation, the Panel often consulted with Dr. W.H. Mathews, Professor of Geology at the University of British Columbia. Dr. Mathews was one of the expert witnesses employed by the Highways Ministry during the Garibaldi Court Case and upon whose experience and opinion, Justice Berger relied heavily in making his judgement. Coincident with the Panel's investigation, Dr. Mathews supervised a graduate study (M.A.Sc.) by Mr. D.P. Moore who investigated in-depth, aspects of the Rubble Creek slide and who subsequently provided views and interpretations to Dr. F.D. Patton on new data collected which related to the historical sequence of events in the valley.

Additional fieldwork such as drilling, sampling, seismic survey and surface control surveys, was normally undertaken on behalf of the Panel by crews from the Ministry of Transportation and Highways. Drilling, sampling and seismic surveys were conducted by the Operations Section, Geotechnical and Materials Branch, Burnaby and by a private drilling company. Surface control surveys were undertaken by the Design and Surveys Branch, Vancouver. Costs resulting from these studies were not included in the costs accrued by the Panel and were in addition to proposed costs.

Projections made by the Panel in 1976, indicated that a report on conditions could be available in the spring or summer of 1977. Considerable concern on the length of time taken for the investigation was voiced by the Garibaldi Ratepayers Association, and the Squamish - Lillooet Regional District. A particular concern of local residents was that a "freeze" or moratorium had been placed on all land transactions in the area, subject to completion and reporting of the Garibaldi Advisory Panel. As completion of the study was delayed beyond January, 1978, the Garibaldi Ratepayers Association wrote to their elected MLA the Honourable Allan Williams and expressed their concern as follows:

> "Again we are writing about this Barrier. We have written two letters since we talked with you eight months ago and each time another drilling crew has arrived in the area costing the taxpayers several thousands of dollars and the local residents in the area more heartache and unanswered questions of the whys, wherefores and whens of this report that we are promised." (Letter from Mr. G.D. Wellard, President G.R.A., to the Honourable Allan Williams, Feb. 3, 1978).

Officials in the Highways Ministry in response to Mr. Williams subsequent queries as transmitted through the Minister of Highways, pressed the panel for completion of their report. In response, members of the Panel sent a summary letter on February 20, 1978 to the Senior Geotechnical and Materials Engineer, Ministry of Transportation and Highways, Victoria, who was acting as liaison between the Panel and the Ministry. The letter responded to the terms of reference as earlier stated and went on to say:

> "In the opinion of the Panel, a significant hazard does exist in the Rubble Creek Valley for a recurrence of a landslide of the same order of magnitude as occurred in 1855. Each of the components, such as character, volume and distribution of rock, and availability of surface and sub-surface water, which contributed to the rockslide in 1855, still exists. A triggering mechanism for a rockslide of comparable dimensions to the 1855 event could act within the current environment of the Barrier. There are insufficient data available to permit a meaningful analysis of the frequency of risk."

> "In general, the Panel is of the view that future land use in the region under consideration should recognize that the impact of a new slide on life and/or developed property in the Cheakamus Valley and near the centre of the present fan to relatively minor towards the perimeter of the fan. No practical measures exist to prevent a major slide, but a variety of measures are possible to alleviate risk and damage from minor slides, debris flows, and floods emitting from Rubble Creek Valley."

Though this information was presented to the government, it was not passed on to the Garibaldi Ratepayers Association (although they

were informed that it was being made available by Mr. Allan Williams) and it is unclear as to whether or not the Squamish-Lillooet Regional District was notified at this time. Members of the Highways Ministry commented, that external agencies were not informed of Panel statements outside of the context of the total report, and they recognized that some degree of liability for corrective measures in existing developed areas may be perceived by local residents.

Finalization of part I of a three part report by the Panel did not occur until July, 1978. Initial distribution of the report being confined to senior officials of the Ministry of Transportation and Highways and B.C. Hydro. During this period, applications for rezoning of sections of Rubble Creek fan continued to be presented to the Squamish-Lillooet Regional District. Through their involvement in the local Technical Planning Committee, the Highways Ministry continued to recommend to the Regional District that the applications be rejected due to the "Rubble Creek geological hazard". As of March, 1979, however, the Regional District was still inquiring as to when a copy of the Panel Report would be made available to them (Files - Ministry of Transportation and Highways).

Distribution of report information was being delayed within government so that political and technical components of the finalized reports could be considered. Technical considerations centred around the potential for establishing a monitoring or surveillance system on the Barrier. Political considerations were concerned with aspects of risk assessment and risk reduction in an attempt to decide upon the best method of mitigating the problem. A Committee of Cabinet was struck to review the matter.

Consideration of a surveillance system evolved from recommendation 8.5.4 in the 1978 Panel report which stated that;

> "The panel recommends that a minimal surveillance program of the Barrier be undertaken. The purpose of this would be to provide a basis for evaluation of any future concerns for deterioration of the stability conditions at the Barrier."

Costing and development of this program was undertaken by the Geotechnical and Materials Branch, Ministry of Transportation and

Highways. By February, 1980, the surveillance program had not been implemented, nor, as it turns out, is it likely that it will ever be developed. The surveillance system could not be used as a warning system, only as a means of determining movement, therefore, the usefulness of the system was considered to have limited value.

By April, 1980, the Director of the Regional District for Garibaldi was still attempting to obtain a copy of the Panel's report. After being continually frustrated by various government ministries the Director contacted Dr. Karl Friedmann, the Ombudsman for British Columbia. Dr. Friedmann in turn, approached the Assistant Deputy Minister of Transportation and Highways, Administration, on May 23, 1980 and was informed that "this matter is presently before a Committee of Cabinet. ... It is expected that some statement may be made shortly." (Friedmann, 1981).

During the same period, a decision was reached within the Cabinet Committee to purchase those properties subject to risk from floods or slides in the Mount Garibaldi Hazard area. However, as there was no appropriate statute under which the Highways Ministry could purchase lands subject to a natural hazard, the Ministry of Environment assumed responsibility for the mitigation program which could be instituted under the Emergency Program Act. Under Sections (4) and (17) of the Emergency Program Act;

> Section (4)
> "The Lieutenant Governor in Council has power to do and to authorize acts and things and to make regulations he considers necessary, and without limiting the generality of the foregoing may
> (c) acquire property;
>
> (d) take any measures which he thinks proper to carry out a request of Canada, or the Director General of Civil Defence for Canada, or any civil defence or disaster organization, for any action concerning civil defence or disaster."
>
> Section (17)
> "When it appears to the Lieutenant Governor in Council that an emergency exists by reason of enemy attack, anticipated enemy attack, sabotage, other hostile action or disaster, he may by proclamation

> declare a state of emergency in the Province as a whole or in any area of it."

The Act provided that the ministry could purchase land in cases of civil defence or civil disaster. As no disaster had occurred, the area of potential hazard from catastrophic rockslide was declared a civil defence zone.

Upon making these decisions, the government in the form of the Executive Council and the Lieutenant Governor, instituted Order in Council 1185, on May 30, 1980, declaring the area of the Rubble Creek fan as a "civil defence zone, that is to say, an area requiring inter alia precautionary or safety measures for the prevention, limitation or amelioration of civil disaster." Within paragraph (3) of Order in Council 1185:

> "The Minister of Environment is authorized to acquire property within such parts of the designated area (see Figure 5.5 for designated area) as he considers necessary to eliminate or reduce the danger of continued occupation of it, and for the purposes of this paragraph
> (a) a sum not exceeding $7,000,000 may be expended under section (16) of the Act (Emergency Program Act), and
>
> (b) section (4) (c) of the Act (Emergency Program Act) is proclaimed in force during the period this Order is in effect."

This action occurred in close association with the initiation of an investigation by the Office of the Ombudsman into the management of the Mount Garibaldi investigation and mitigation program. Possibly, stresses were instituted by the threat of the Ombudsman's investigation, prompting the Cabinet Committee to act. The Squamish-Lillooet Regional District finally received a copy of the Panel's report on May 30, 1980, the same day as Order in Council 1185 was made public. Even though the Squamish-Lillooet Regional District was directly involved in the planning and land-use administration of the Rubble Creek fan, it was not fully informed of results of the Panel's report, nor was it informed of the development of Order in Council 1185 until such time as both were made public. The assessment of risk

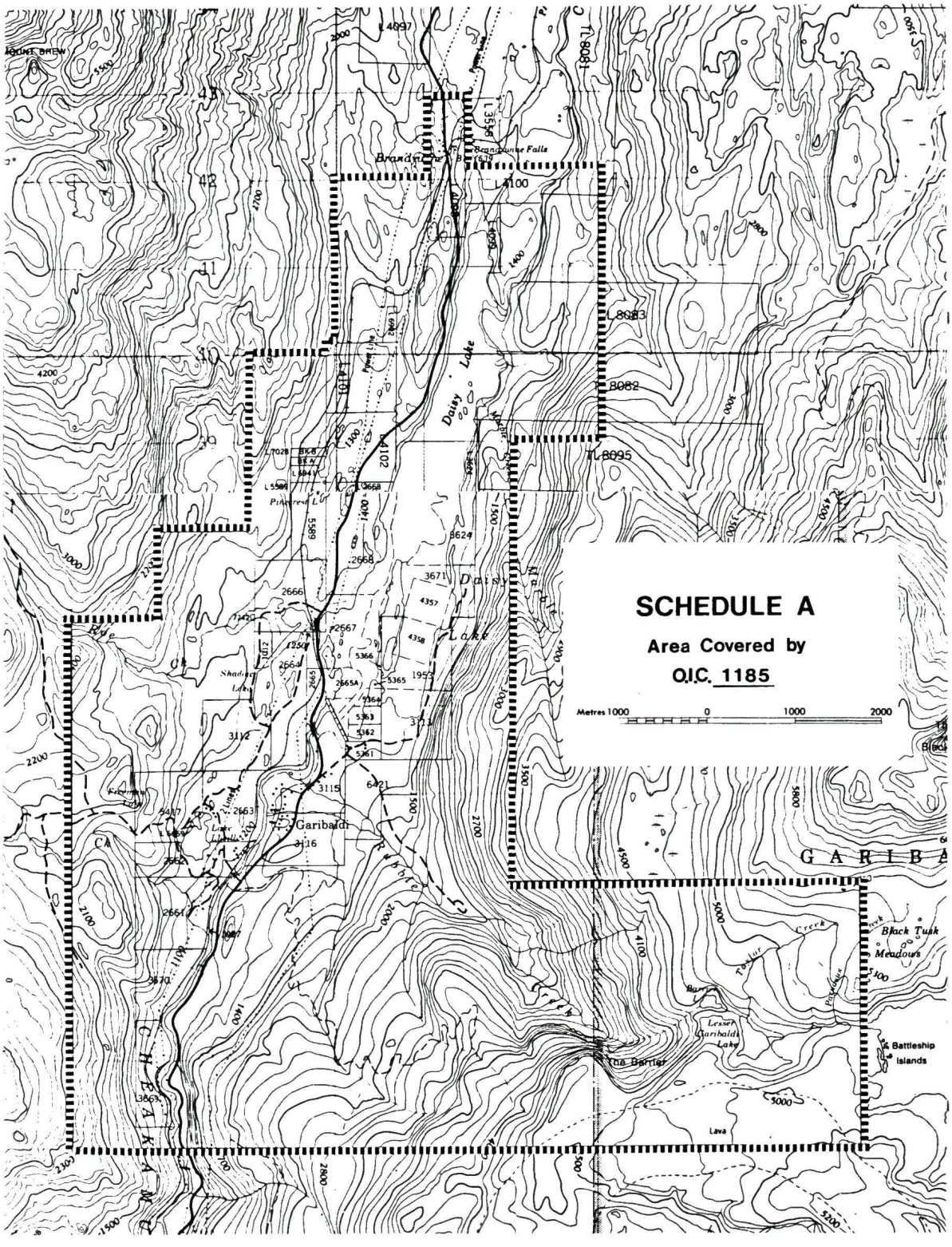


Figure 5.5: Hazardous land areas as specified by Order In Council 1185

by both the regional managers and the residents was hindered in this manner by the provincial governments reluctance to make public the results of the Panel's investigations.

Implications of Order in Council 1185

The introduction of Order in Council 1185 was to have severe impacts on owners of lands covered by the order. Economic, social and emotional stresses were suffered by affected property owners. These stresses resulted from the programs which Order in Council 1185 introduced, dealing with purchase of properties, relocation, and loss of common property rights. Results of questions five and six in the questionnaire, clearly indicate the adverse reaction of local residents to the methods of mitigation proposed by the government. This reflected a lack of planning and administration which could have effectively assessed the impacts of Order in Council 1185, and reduced the stresses incurred by the Mount Garibaldi land owners. This view is similarly reflected by Dr. Karl Friedmann in his 1981, "Summary Report to the Legislative Assembly of British Columbia - the Garibaldi Case", where he discusses the programs developed under Order in Council 1185 and states that, "I can only convey my impression and my conclusion that a lot of anxiety, frustration, and disturbance could and should have been avoided had the program been better planned and more fairly administered.

Order in Council 1185 directly impacted 102 different landowners in the Mount Garibaldi "civil defence zone". Though initially the landowners recognized the governments wish to reduce the risk to residents, they became increasingly distressed over the bureaucratic proliferation of procedures and conditions established for the acquisition of lands and homes.

The Garibaldi Ratepayers Association convened a public meeting on June 1, 1980 to discuss the impacts of Order in Council 1185 and to form an ad hoc committee to investigate the proposed compensation programs. To further clarify the impacts of the Order in Council, the Garibaldi Ratepayers Assocation requested their local member of the Legislative Assembly, the Honourable Allan Williams to attend a public

meeting on June 7, 1980. In the interim the Deputy Minister of Environment had already convened with the Canadian Independent Adjusters Conference (C.I.A.C.) to negotiate the acquisition of properties for the Ministry. At the same time, he delegated administrative responsibility for the acquisition program to the Director of the Provincial Emergency Program (Friedmann, 1981). As a result, the Chief Assessor of the Canadian Independent Adjusters Conference then attended the public meeting on June 7, 1980 with Mr. Williams and reported back to the Director of the Provincial Emergency Program.

Questions raised during the public meeting prompted the Garibaldi Ratepayers Association to request the Deputy Minister of Environment to meet with the ad hoc committee on June 28, 1980. Information derived from this meeting was circulated to members of the Garibaldi Ratepayers Association and has been paraphrased by Friedmann (1981) as follows:

> 1. The Ministry of Environment and the Ministry of Transportation and Highways believe there is no practical solution to stabilizing the Barrier and there are no further studies being done for this purpose.
>
> 2. The boundaries of the area designated by the O.I.C. were originally drawn wide as it is easier to release an area from the zone rather than attempt to include it after the O.I.C. was approved. The Ministry is now finalizing the boundaries to be included in a revised O.I.C. and are using the 400 metre elevation level.
>
> 3. The Ministry of Lands, Parks and Housing and B.C. Hydro are looking at the possibility of Crown land in the area that could be used for relocation. The Deputy Minister stated that they should attempt to get a fair settlement for the people here and then given people the opportunity of first option on a new Crown subdivision. He noted that there was no option included in the O.I.C. for relocation. He said that all the Ministry was prepared to do at this time is to buy the land and improvements being offered for sale by the owners. Relocation can be arranged at a future date.

4. With respect to the future use of the Garibaldi area, he indicated that he did not know at the moment what may or may not be allowed. He suggested that campsites and trails might be permitted.

5. The Deputy Minister said that the O.I.C. clearly stated that developed land will be compensated but not unoccupied land. Serviced lots which have no buildings on them would not be compensated. He pointed out that the matter of compensation for unimproved lands is to be reconsidered. He said that businesses could be purchased by the Ministry and that people holding a legal lease on land would be compensated to some degree.

6. The Deputy Minister noted that the O.I.C. curtails the use of land in the area because of the provisions of section 4. The Government must act in order to protect the people who live in the area. What the Government has decided to do seems fair and reasonable to everyone in the government. It has never paid compensation prior to a disaster. In this case, a precedent is being set.

7. The date for evaluating fair market value is May 28, 1980. September 30 is the deadline for requesting appraisals. The Government hopes to consummate the deals as quickly as possible. The Chief Assessor stated that December 31, 1980 is the date set for completion of all sales. The Deputy Minister said that it was up to the owner whether or not to sell his property to the Government. However, after January 1, 1981, he is on his own. After that an owner will retain legal title to the property but will be unable to sell it to anyone else. Also, such an owner will be unable to perform any work on the land without the express permission of the Ministers (as provided by section 4 of the O.I.C. - see Appendix B).

8. The Chief Assessor said that an independent appraisal firm would be appraising each property individually. The Property Negotiator for CIAC would then negotiate with each individual owner. The appraisals will not be given to the owners. This is a standard procedure. The Deputy Minister suggested that if no agreement could be reached the dispute could be resolved by a third party. There would have to be a written agreement between the parties that they would abide by the decision of

the third party.

9. The Deputy Minister indicated that the Ministry would not agree to purchase property and then lease it back to the vendor for an indefinite period. However he did indicate that he would consider the possibility of purchasing properties and then leasing back to the vendors until such time as a relocation subdivision was developed. He stated that it could be a term of the agreements of sale that the vendor purchase the buildings from the Government. If no such term was included the Government would auction the improvements for salvage.

10. The Government does not intend to remove or modify section 4 of the O.I.C. at a later date. Although the O.I.C. is open ended, it is not open ended with respect to valuation and purchase. December 31, 1980, is the cut off date. His Ministry would not agree to permit people to stay and allow them to sell their properties on the open market, even if the owners agreed to accept an endorsement on their titles warning prospective purchasers of the dangers referred to in the Report of the Garibaldi Advisory Panel.

Terms of acquisition and lack of any relocation site were pressing concerns of those affected by the order in council. A lack of information on the acquisition program, and the impact on owners of undeveloped lands brought many complaints. These complaints against the government were further compounded when on August 28, 1980, the Director of the Provincial Emergency Program requested the Registrar of Land Titles in Vancouver, to add a notation to the land titles of all affected properties that they were restricted by the conditions of Order in Council 1185. Land owners were not notified prior to, nor after the notation was attached (Friedmann, 1981).

Criticism of the proposed mitigation plan as being "underhanded" and "unfair" comes largely from the governments lack of consultation prior to action. Amongst responses from those owners contacted, one owner noted that "the government didn't tell us anything until they told us we had to move." No public information system seems to have been established for what could be referred to as the victims of Order in Council 1185.

An apparent reason for this is that the Director of the Provincial Emergency Program had relied upon the Garibaldi Ratepayers Association, "the local grapevine" and the local media for distribution of information. Unfortunately, the Garibaldi Ratepayers Association represented less than 50% of the owners. In addition, many of the landowners did not live in the area, particularly those with undeveloped lots. As a result, written notice of the conditions established by the order in council were not sent to all affected properties until March, 1981, almost 10 months after being introduced.

As options were limited and the consequences undesirable, many owners were faced with a stressing dilemma; sell their properties at a value fixed on May 28, 1980; or stay and face the loss of all common property rights. By September 9, 1980, fourteen of the eighty-four improved properties had been sold to the government, seventy-seven of the improved properties had requested appraisals of their property through the Canadian Independent Adjusters Conference, while the other seven land owners had been sent appraisal application forms by double registered letter. Up to this time eighteen owners of unimproved properties had also applied for appraisals, however, these were rejected by the Ministry of Environment under the provision of section (4) of Order in Council 1185.

On September 22, 1980, the Premier and several Cabinet members met with a committee of representatives of the community on board a special Cabinet train travelling through Garibaldi. The meeting was precipitated by a resident who threatened to place his bulldozer on the railway tracks to stop the train should the Premier decide not to discuss matters. Minutes of the meeting, as provided by the residents, stated that "the Premier instructed the Attorney General to coordinate and meet with all the Ministries affected by the problems submitted by this committee and attempt to get some answers back to the Chairman (of the G.R.A.) as soon as possible." Public pressures as articulated in this manner proved successful as on September 30, 1980, the Deputy Minister of Environment wrote to the Ad Hoc Committee of the Garibaldi Ratepayers Association and advised them that the sale

date for properties had been extended from December 31, 1980 to June 30, 1981 (Friedmann, 1981).

In a further attempt to continue residence in the area, 20 of the owners formed the Garibaldi Heritage Committee with the purpose being to negotiate terms with the government by which they could continue residency and retain their property rights. The response by the government was to continue their policy of total evacuation, however, on the invitation of the Garibaldi Ratepayers Association, the Director of the Provincial Emergency Program, the Chief Assessor for the Canadian Independent Adjusters Conference and the property negotiator dealing with the owners, agreed to attend a public meeting on October 19, 1980 to discuss these and other issues. Within the minutes of the meeting taken by the association, the Director of the Provincial Emergency Program provided the following considerations:

> 1. The Government is anxious to establish a relocation site, and a proposed subdivision at Brandywine (north of Garibaldi is under active consideration. The Government may have some difficulty in obtaining mineral rights to the area, now held by a third party.
>
> 2. The values that were used in determining the appraisals for Garibaldi (i.e. fair market value, May 28, 1980) will apply for the purpose of establishing the value of lots in the relocation subdivision.
>
> 3. Improvements in Garibaldi which are sold to the Ministry, if repurchased by the owner, may be left on their present site until such time as a relocation subdivision is available. Third parties purchasing such improvements will still be required to move them within twenty-one days.

Owners who had already sold their properties to the Ministry of Environment were unable to take advantage of this last option because their homes had either been sold and moved, or demolished.

Formation of the Garibaldi Heritage Committee illustrates the property owners reluctance to recognize the risk which they would face, should they remain in the area. In responding positively to question seven of the questionnaire, the owners have indicated their disagreement with the assessment of risk by investigators and

decision-makers. The implication is that these owners believe the risk has been exaggerated by the investigators and that their own perception of the risk is more accurate. Those respondents who indicated that they could accept the risk for a short period of time appear to recognize that a hazard exists, but in lieu of personal considerations are willing to accept the risk over the short term.

It is at this juncture that the Ombudsman of British Columbia began to take an active role in the "Garibaldi Case". By November of 1980 the Ombudsman had received complaints from seven property owners in the Garibaldi area. In response, the Ombudsman wrote to all owners affected by the order in council and arranged an open meeting on November 26 and 27, 1980, during which time he, or his staff, met with fifty-four more individuals and groups. This brought the total number of complaints to sixty-one. Staff members in the Office of the Ombudsman paraphrased the complaints as follows: (Friedmann, 1981)

> 1. The O.I.C. was not justified and ought not to have been approved and/or that there were improper motives behind the approval of the O.I.C. (twelve complaints).
>
> 2. I received no direct notice of the effects of the O.I.C. on my property and/or was not adequately informed about the Ministry of Environment's acquisition program and/or was not given a copy of the written appraisal of my property done for the Ministry and/or was not adequately informed about the terms of the Ministry's salvage and disposal program (thirty-three complaints).
>
> 3. The criteria upon which compensation for improved properties is being determined are unfair (twenty-eight complaints).
>
> 4. Unfair pressure has been exerted upon owners of improved properties in order to compel them to sell their properties to the Ministry of Environment (sixteen complaints).
>
> 5. No compensation is being paid for unimproved properties (fourteen complaints).
>
> 6. The Ministry of Environment has refused to vary or add additional terms to the agreements of sale (nine complaints).

7. My property has not been excluded from the designated area (five complaints).

8. The Ministry of Environment has not committed itself to providing a relocation site and/or has not provided adequate information about the relocation program (twenty-eight complaints).

9. B.C. Hydro and other government authorities have been allowed to maintain and/or improve their facilities in the O.I.C. designated area (nineteen complaints).

10. The amount of compensation offered and/or paid for my improved property does not fairly represent its value (thirteen complaints).

11. The Ministry will not pay compensation for other costs and/or inconvenience directly caused by the provisions of the O.I.C. (seventeen complaints).

The complaints received by the Ombudsman, accentuate those responses received to questions five and six of the questionnaire, dealing with proposed government compensation-relocation programs. Dissatisfaction with the programs concentrates on the arbitrary, and unequal compensation decisions being made. In addition, an inadequate public information system further reduced the ability of owners to adequately evaluate the consequences of the proposed government programs.

Notification of these complaints was transmitted to the Minister of Environment. During the following 6 months, a continuous stream of correspondence was to be exchanged between the Ombudsman and the Deputy Minister of Environment, and eventually the Lieutenant Governor in Council. Feeling that the Deputy Minister was not giving sufficient emphasis and consideration to his questions, the Ombudsman filed a report on April 22, 1981 with the Legislative Assembly, pursuant to section (30) (2) of the Ombudsman Act, R.S.B.C. 1979, Chapter 306[1].

Media coverage of the report applied considerable pressure to the politicians involved as the report was highly critical of government procedures and actions. A result of the stresses applied by Mr. Friedmann and the media was to lead to an expansion of the government offer to all affected parties, including owners of undeveloped land.

As reported in the Vancouver Province newspaper on June 15, 1981, the Environment Minister, told a news conference that a new government policy had been developed to deal with the Garibaldi situation. Under the new policy:

1. Owners of undeveloped property could receive a cash buy-out from the government.

2. Owners of developed property would have the option of buying alternative lots in a new subdivision. Price of lots in the new subdivision being based on the value on May 28, 1980.

3. Owners of undeveloped lots would not be permitted to buy lots in the new subdivision at the 1980 market value.

4. The new policy also shrinks the boundaries of the affected area.

5. The deadline for the buy-out offer was extended to September 30, 1981.

Such alternatives had been proposed in the March, 1981 letter sent to all land owners by the Deputy Minister of Environment, however, initial confirmation was delayed until disclosure took place through the above noted news release.

Summary and Conclusions

The Mount Garibaldi Case continues even now, as negotiations between land owners and the government are still taking place. Continuation of ad hoc decision-making seemingly still plagues the mitigation process. The lack of a hazards policy during the initial

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1 Ombudsman Act - Section (30) (2)

"The Ombudsman, where he considers it to be in the public interest or in the interest of a person or authority, may make a special report to the Legislative Assembly or comment publicly respecting a matter relating generally to the exercise of his duties under this Act or to a particular case investigated by him."

stages of this problem may very well have led to the management techniques employed. No formalized approach or format was in place upon which programs could be constructed, therefore decisions were made on an event-to-event, or crisis-to-crisis basis, and as indicated in the initial chapter, crisis decision-making tends to limit the evaluation of alternatives and outcomes. The weighing of outcomes from actions taken could not be properly evaluated in the short time frames imposed as a result of the stresses from media exposure and public demands for action. Planning was required to offset such mistakes as not informing residents of the conditions of Order in Council 1185, attaching of covenants to land titles, or not providing a relocation site for victims.

From the use of an obscure section of the Provincial Emergency Act, to the introduction of site-specific legislation in the form of Order in Council 1185, we can conclude that the need for a piece of comprehensive legislation is more than necessary. Jurisdictional boundaries were unclear during the initial stages of this case example and as a result both the public and government were unsure as to agency responsibility during the course of events. Designation of the Provincial Emergency Program as the coordinating agency did not take place until the decision to purchase properties had already been made. It may be concluded from this then, that a designated agency is necessary in the initial stages of a program if actions are to be coordinated throughout the course of a disaster. Such an agency would be better prepared to deal with disaster. It would be cognizant of the impacts of alternative actions possible after disaster and could recommend actions to be taken prior to disaster.

This hindsight review of the Mount Garibaldi problem provides an experience upon which new methodologies may be built to the benefit of all British Columbians. In this case, the provincial government made what must be considered a morally correct decision in trying to protect the residents of Garibaldi from a disaster. In the absence of a planned reaction, however, the decision-makers were reduced to making ad hoc decisions. The following chapter explores various

conditions and methodologies which may be employed in preparing a hazards plan for British Columbia, in an attempt to prevent the re-occurrence of the Mount Garibaldi situation.

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Chapter 6
PLANNING FOR NATURAL HAZARDS IN BRITISH COLUMBIA

Effective planning for natural hazards is possible in British Columbia. The efficiency of such plans will depend on their comprehensiveness and their ability to overcome the inertia existent within existing government and private organizations. Planning for geomorphological disasters will also be dependent upon the level of support which it receives from the provincial and municipal governments, and to what degree it is able to satisfy those questions (requiring decisions) likely to arise before, during and after a disastrous event. It is worthwhile noting that without such effective planning, decisions made under crisis tend to lead to inferior performance and a preventable increase in losses (Foster, 1980).

Constraints in Initiating a Plan

Any attempt to implement a hazard reduction plan in British Columbia must take into consideration three important factors: (1) the current level of adjustments versus ability to reduce losses; (2) what are the requirements of a comprehensive natural hazards plan; and (3) what constraints of the existing system will likely have an impact on any plan proposal.

A heuristic model based on a risk-growth sophistication matrix has been described by Sewell and Foster (1976) as a means of relating risk to the level of adjustments applied in order to establish a management strategy to deal with environmental hazards in developing countries.

Degree of risk being described as the potential losses which are likely to occur from hazard processes, however, it is conditioned by both physical processes such as geology, climate, terrain vegetation, and human factors, including the nature of society, its economy and its infrastructure. Stages of economic growth vary from subsistence societies to industrialized and urbanized social structures and may be classed accordingly. This factor is important in that as Sewell and Foster point out, "As economic growth proceeds, it tends to accelerate

the pace of high-risk location." The levels of sophistication of adjustments are widely varied, however they seem to fall into four major categories: (1) bearing the loss, (2) modifying the loss burden, (3) modifying the physical process, and (4) modifying damage susceptibility. Scaling this factor may proceed from the lowest level of total inaction to the upper level where a highly integrated comprehensive response to the threat from natural hazards is taken. The model can be used as a means of diagrammatically representing the apparent sophistication of adjustments for natural hazards as employed in British Columbia, though it is far from the status of a developing country. As indicated in chapter 2, varying degrees of risk from a natural hazard exist throughout the province, with several areas susceptible to a high risk from a variety of such events. Degree of risk will of course rise as human use of risk locations increases, especially when physical and social adjustments for loss reduction are not employed. Figure 6.1 indicates where the author perceives the management strategy to currently exist in B.C., and secondly, where the strategy should lie. Two factors, 'degree of risk' and 'stage of economic growth' are perceived as constants. However the third factor, 'sophistication of adjustment' is perceived to require shifting from the existing lower level to a higher, more appropriate level. The model indicates that the current level for sophistication of adjustments is inconsistent with the provinces high standard of economic development and the extensive spatial distribution of risk areas.

A comprehensive natural hazards plan will require an integrated system which involves the coordination of vital agencies and resources into a program for hazard mitigation, preparedness, response and recovery from natural and man-made situations. Comprehensive natural hazards planning should be all-risk and all-phase: 'all-risk' in that it addresses all types of hazards in any area; 'all-phase' in that it addresses all aspects of hazards managment inclusive of policy formulation, enabling legislation, administration, risk mapping, mitigation, warning, response and reconstruction (U.S. Conference of Mayors, 1980). Reduction of decision-making under crisis and

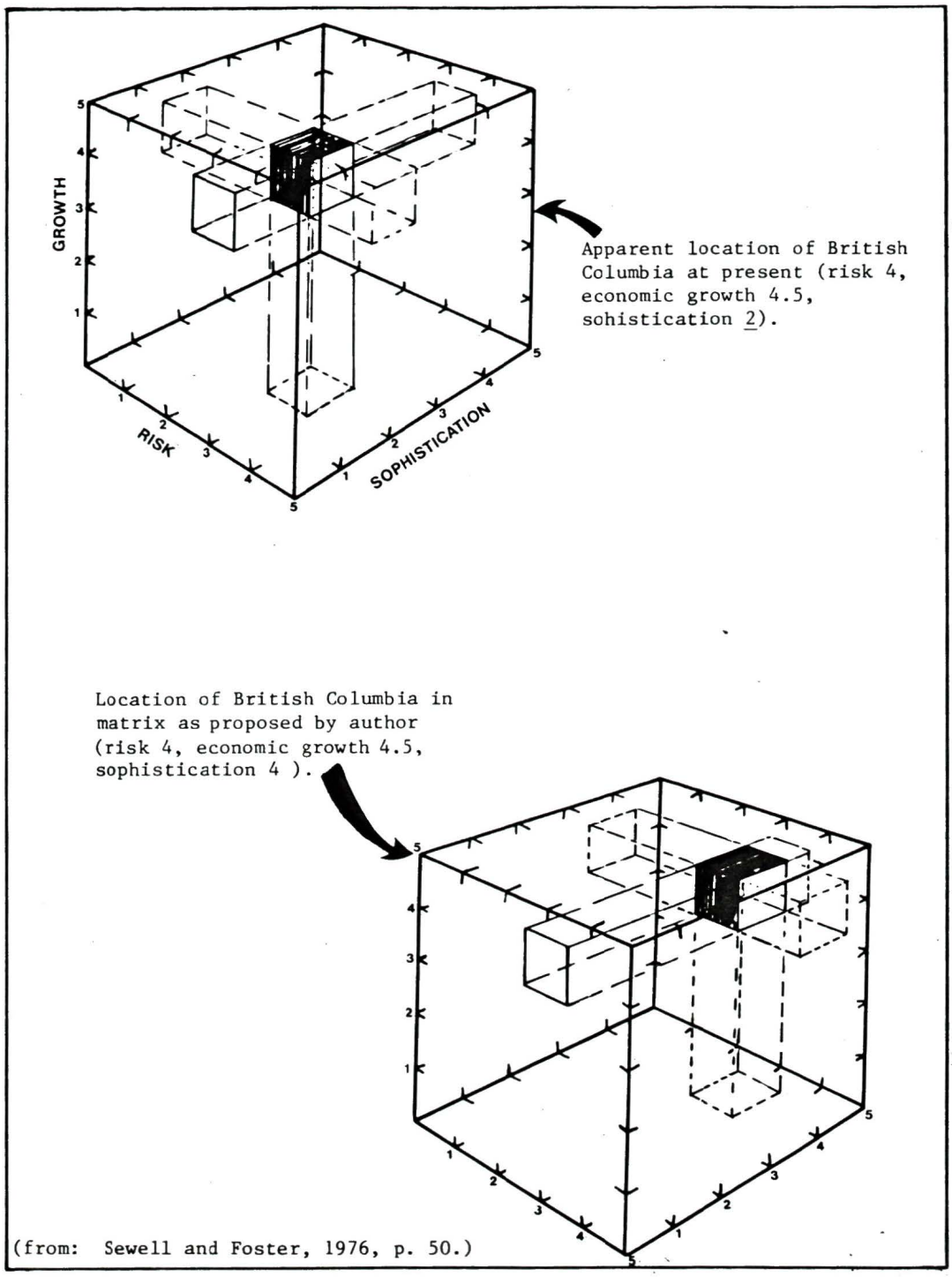


Figure 6.1: The position of British Columbia in relationship to a Risk - Growth - Sophistication matrix

optimization of physical, economic and social impacts acting as goals for the planning program.

Contents of such a disaster plan for local communities has been prepared by (Foster, 1980) and is provided in Figure 6.2. By expanding the context and orientation of the individual sections of this format, it can be adapted for use as a basis for a provincial hazards plan. Practicality requires however, that application of the plan take place over a period of time sufficiently long enough to analyze the variables of each component, yet, short enough to circumvent extensive development of high risk areas prior to plan implementation. A proposed timetable for instituting a hazards planning program is indicated in Figure 6.3. This is an adaptation of a safety program timetable also prepared by Foster (1980) and includes those initial elements of a plan which give credence to the planning program itself.

Priority is given in both the plan and the timetable to the development of a policy statement and enabling legislation. The policy should describe broad objectives of the plan, while legislation must be established to indicate obligations and powers of each level of government in respect to hazard planning. Both should be clear and decisive so as to eliminate any misinterpretation in objectives or implementation. Individual characteristics of each element in the hazard plan will be discussed in greater detail in following sections.

It becomes obvious that a natural hazards plan will only be realized if it constitutes a viable political decision at the senior level of government (in this case the provincial government). Such a plan must therefore be cognizant of the constraints which exist that can reduce a planning program (and a political decision) from the 'practical' to the 'impractical'. In evaluating the conditions which exist in British Columbia, the natural hazards plan will have to recognize at least some of the following constraints:

1. In British Columbia there are two major political parties (at this time), the objectives of each which must be addressed. The governing Social Credit party must be considered as being development oriented and a promoter of

Table 6.1
Content of a Comprehensive Disaster Plan, Adaptable for Construction of a Provincial Geological Hazards Plan

1. Policy statement on value of disaster planning by chief executive officer

2. Legislative authority for the design of the disaster plan and for the steps it contains

3. Aims of the plan and conditions under which it comes into force

4. Assessment of community disaster probabilities

5. Disaster scenarios

6. Relationships with other levels of government, particularly emergency-related agencies

7. Authority organization chart

8. List of names, addresses, and telephone numbers of all relevant agencies, their heads and deputies

9. Operation of warning systems:
   (1) types of warning
   (2) distribution
   (3) obligations on receiving warnings.

10. Preimpact preparations:
    (1) relationships between type of disaster agent and necessary preparation
    (2) responsibilities of different agencies
    (3) location of greatest risk sites

11. Emergency evacuation procedures:
    (1) conditions under which evacuation is authorized
    (2) routes to be followed and destinations
    (3) accommodating the special needs of the elderly, ill, or institutionalized

12. Shelters:
    (1) locations
    (2) facilities

13. Disaster control centre and subcentres:
    (1) location(s)
    (2) equipment
    (3) operation
    (4) staffing

Figure 6.2 (continued)

14. Communications

15. Public information

16. Seach and rescue:
    (1) responsibilites
    (2) equipment
    (3) areas most likely to require servicing

17. Community order

18. Medical facilities and morgues:
    (1) location
    (2) transportation
    (3) capacity
    (4) facilities

19. Restoration of community services
    (1) order or priorities
    (2) responsiblities

20. Protection against continuing threat:
    (1) the search for secondary threats
    (2) actions to be taken if discovered

21. Continuing assessment of total situation:
    (1) responsibilites
    (2) distribution

22. Reciprocal agreements and links with other municipalities

23. Testing the plan:
    (1) disaster simulations
    (2) simulation evaluations

24. Revision and updating of the plan

25. Plan distribution

'caveat emptor' (buyer beware) philosophy. It is recognized, however, that extreme geomorphic events are costly to compensate for and create disgruntled voters if not correctly handled. The opposition New Democratic party are considered to be oriented more towards social programs and environmental protection. Therefore, two constraints must be satisfied, one requiring that land development take place at a minimum cost and with a minimum of restrictions;

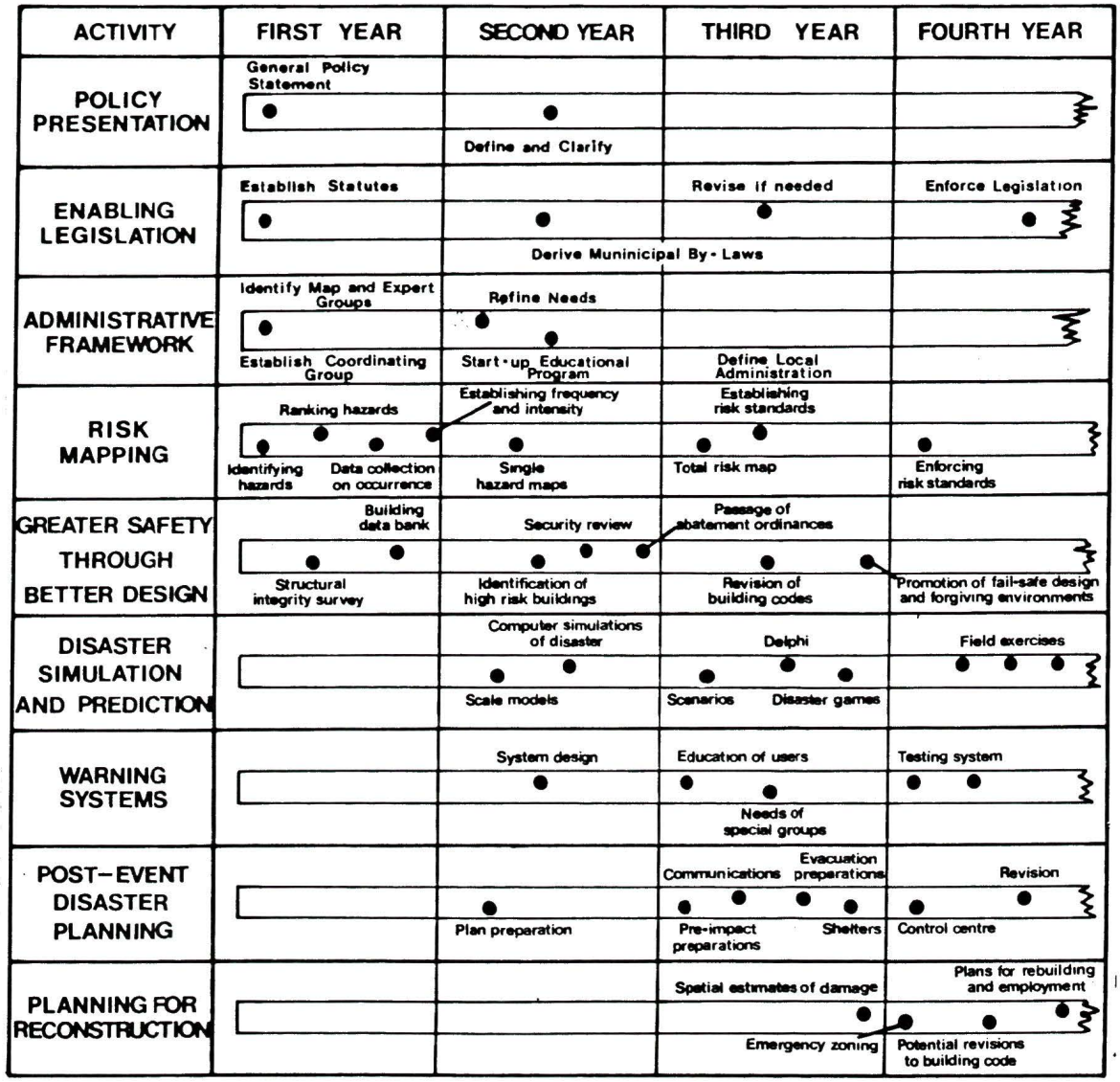


Figure 6.2: A proposed timetable for instituting a hazards planning program in British Columbia (adapted from: Foster, 1980; p. 36)

the second requires that the land development be beneficial to the environment and socially sound.

2. It has been established that policy statements will be made at the political level but, legislation and administration will generally be established at the bureaucratic level. Notably, legislation will likely be drafted by both politicians and upper level administrators. One problem foreseen in the province of B.C. is that generally legislation is promoted through a singular ministry mode rather than an integrated ministry mode. An agency such as the Environment and Land Use Committee-Secretariat previously supplied this form of coordination, but the agency was disbanded in 1980 without replacement. The constraint here then is that either two approaches must be estabished or an alternative presented; either one ministry must be established or an integrated system must be formulated under which several ministry's provide input. At present, the responsibility is fragmented.
3. As a condition of constraint no. 2, ministries in general, work in isolation; communication is comparatively poor, plans are husbanded within each separate ministry. Therefore, a coordinating body may have great difficulty in integrating a program because ministries consider them an infringement upon their own powers.
4. Changes within government will be slow and methodical except in cases of crisis. When a crisis arises, government ministries will generally make rapid assessments of the problem and consider a limited number of alternatives (usually short-term in nature). Rapid changes are possible through new legislation. However, in B.C. legislation dealing with natural hazards is at least partially in place. Therefore new legislation must be aware of the existing programs already established.

5. Perceptions of natural hazard planning at public and private levels must be considered in order to make any approach feasible. If the approach taken is inflexible or unwieldy, then the public will be antagonized and the plan will fail, especially if this should create political disfavor. The plan therefore must not create financial hardships. It must have feasible development features and the creation of adequate protection.

6. An important problem which also must be overcome is the question of risk or more appropriately the degree of risk which the government is willing to assume. Generally, the government is not willing to assume any risk, except in cases of auto accidents or house fires such as undertaken through the Insurance Corporation of British Columbia. However, in making land use decisions, government agencies are unconsciously evaluating the risk of development and assuming a moral liability for the safety of the property. Any plan must therefore attempt to reduce the risk factor and in turn the liability before it will gain full political and administrative support.

7. In British Columbia it is also noted that communication and cooperation between levels of government is generally poor. Relationships exist between the senior provincial government, the regional districts and the individual municipalities, with each having a variety of planning and regulatory controls. Conflict is common, and therefore designation of powers must be clear and precise if a hazards policy and plans are to overcome the discrepancy in viewponts which are often apparent.

8. It must also be considered that the personality of the actors will play a large part in the ability of government to enact such a plan, and this must be considered throughout the duration of the plan implementation.

9. The plan must have flexibility in order that appeals and variations in concepts, attitudes and design can be given sufficient consideration and that alterations and amendments can be made in a suitable manner.

The methodology designed to overcome these constraints must firstly identify the proper procedure to be used, and then identify the alternative actions available to the politician, the administrator and the public. Proper procedure will be dependent on optimizing situations in British Columbia while integrating into current working relationships.

Policy Formulation

A well-defined policy statement is the first step in the formulation of a natural hazards plan. In British Columbia, the policy statement will have to be cognizant of the constraints described previously, yet accurately and forcefully to establish the desired objectives. Such a policy statement will have to show that the senior government strongly supports the strategies and program proposed. Strategic objectives for natural hazards management can be established for the province as part of the policy statement and can therefore establish the guidelines for further levels of planning.

Policies established at this level will consider long-term goals, be broad in scope and flexible to changes over time. Recognition of internal, operational policies such as existed in the Ministry of Transportation and Highways during the Mount Garibaldi evaluation, can be made within the 'provincial policy statement'. However, it is preferable that strategic objectives be established and then let operational policies be developed by individual ministries and agencies in order to satisfy those objectives. By so doing, the

politically oriented provincial policy can remain broader and more flexible without being burdened with the specifics required of an operational or administrative level policy.

A point which must also be contained within the policy is that of integration with existing policies in a manner which will reduce conflicts and result in overall benefits. For example, policies for flood damage reduction must recognize housing and industrial development policies and attempt to provide guidance so that an optimal level of development takes place with suitable protective measures implemented. As noted by Sewell and Foster (1976), "the challenge is to find a set of management strategies which permit the more intensive use of higher-risk locations but minimize the associated losses. Bearing this in mind, a potential, public policy statement for British Columbia is outlined below.

A Policy On Natural Hazards In British Columbia

A natural hazards policy for British Columbia might contain a statement such as the one which follows. This is partially derived from the 1974 United States federal Disaster Relief Act:

> Because disasters often cause loss of life, human suffering, loss of income, property loss, damage, and because they often disrupt normal functioning of governments and communities, and adversely affect individuals and families; then a policy to plan for, mitigate against and render assistance from, natural hazards is deemed necessary. Natural hazards to be defined as those natural processes normally referred to as; snow avalanches, landslides (slips), earthquakes, floods, tsunami's, subsidence, shore erosion and volcanic eruption.
>
> Development of programs to recognize, to delineate and to mitigate against the impacts of natural hazards will be developed within the resource planning framework in place in the province. Programs will be established to provide:
>
> 1. the development of comprehensive plans and practicable programs for preparing against disasters, including hazard reduction, avoidance and mitigation;

2. disaster preparedness plans for mitigation, warning, emergency operations, rehabilitation and recovery;
3. training in evaluation and response;
4. coordination; and
5. research.

Legislation will be prepared to provide the legal base for the government framework to be used, and to establish the regulatory powers of those agencies which will be responsible for enforcing the conditions of this act or acts. This legislation will authorize the provincial, regional and local governments to begin to plan against, and prepare for, natural disasters.

Objectives of this policy are to reduce the risk of damage and life loss with a minimum of restrictions; and, to provide mitigative programs for individuals or businesses currently within areas of higher risk.

The policy as presented here is only a proposal, however it is felt that it provides those conditions necessary to establishing a natural hazards program. In making the policy public, it shows that there is strong support by the government. Program development is seen as a requisite, yet the statement makes note that in-situ programs will not be displaced by the new provisions. 'Provincial guidelines will establish strategies which must be followed by the regional districts and municipalities, therefore providing that a consistent approach to natural hazard assessment and management will take place. A statement that legislation will be developed is required in order to insure that objectives of the programs have legal standing and to make sure that the next step in the planning process is guaranteed. Noting the objectives is a means of indicating the value of the plan to the people of British Columbia, and acts as an assurance that this will not be restrictive legislation. An objective is also to provide protection for those individuals who are currently in higher-risk areas and will be impacted by the new program.

Enabling Legislation

Construction of enabling legislation subsequent to the policy statement, will identify the particulars of the hazards plan and obligate provincial and local officials to incorporate hazardous land considerations into their land planning. Such legislation would be justified in British Columbia as long as it met the following conditions; as provided by Yanggen (1981) in his discussion on erosion hazard regulations:

1. the legislation would serve public objectives in the promotion of public health, safety and welfare;
2. the legislative provisions are a reasonable means to achieve objectives; and
3. there is a reasonable basis for the classification of uses and lands subject to the legislation.

As noted in chapter 3, legislation in several states in the U.S. have developed clauses in their legislation which promote the investigation and delineation of hazardous areas for purposes of public safety. It is reasonable to assume that these clauses were considered reasonable and required.

Clearly, there is a need for similar natural hazards legislation in British Columbia. The legislation must pertain to the province as a whole, inclusive of municipalities and regional districts, which are not currently required to include hazardous lands designation in their plans. Therefore, the province must introduce legislation which will override the two principal planning and control acts; The Land Titles Act (1979) and The Municipal Act (1957); or amend sections within these acts to be hazard specific so that there will be no misinterpretations. As a means of accomplishing this, use of sections of the proposed Planning Act (1981) and clauses from various legislation from California will be introduced later.

New legislation should also require that a coordinating unit, with specific powers, be designated. The inter-action and power to supersede or make requests upon other ministries or agencies should be

clear in order that the coordinating body will be guaranteed a degree of cooperation and aid in meeting its goals.

The exercise of preparing this proposal will indicate that such hazard legislation will not be difficult to attain, nor may it necessarily interfere with current working relationships. Consistency and fairness are to be sought, however, there must be some insistence that plans designate areas of risk and consider post-event reactions, both immediate and long-term. Bearing this in mind, the following legislative clauses are proposed for use in British Columbia.

New Legislation

Note* This piece of test legislation will not include the preambles normal to most legislation such as 'Definition of Terms' and 'Statement of Purpose'. Individual components of the proposed legislation will be annotated at the left of each section to indicate reasoning.

Provincial Legislation For Lands Subject to Natural Hazards -

	Section 1
Establish policy statement and guidelines	The province shall prepare a provincial plan or plans, based on policy statements designating special studies zones to encompass areas susceptible to natural hazards.
	Section 2
Establish risk and risk levels	Guidelines will be established within this legislation establishing the variable levels of risk and determining use restrictions which will apply to each special study zone determined by the level of risk.
	Section 3
Sets up timetable and Coordinator	Special study zones and Coordinator will be established within 3 years of this legislation being proclaimed. Compilation and distribution of the plan(s) and guidelines will be managed through the Provincial Emergency Program who will also act as the coordinating unit between ministries involved in management and delineation of lands affected by natural hazards.

	Section 4
Provides for support	Members of the Provincial Emergency Program under this Act are ensured of the cooperation from provincial, municipal and private agencies in the preparation of plans showing special study zones and the outlining of provincial land use guidelines in risk areas.
	Section 5
Covers all Lands in Province	Use restrictions as determined under the guidelines will apply to all lands in the province inclusive of crown lands, municipal lands and parks administrated by the province.
	Section 6
Allows municipalities to plan within current format	Municipalities within the province will incorporate within their community plans and bylaws, all land areas classified to be subject to natural hazards use re-use restrictions, as established under the provincial guidelines. These changes shall be determined within 3 years of enactment of this legislation.
	Section 7
Provides for disaster situations	In a state of emergency as the result of a natural disaster, Lieutenant Governor of the province may declare a state of emergency in the Province as a whole or in any part of it. The Provincial Emergency Program will then be responsible for coordination of emergency services during the immediate post-event period.
	Section 8
Retroactivity and relief clause	The province will establish mitigation and compensation guidelines for properties which may fall within high risk areas, or which are affected during a natural disaster. Again, the program will be administered under the Provincial Emergency Program.
	Section 9
Covers Post-event Reconstruction	Within the provincial guidelines, the province will designate a format for reconstruction planning which will be required in areas devastated should a natural hazard event occur. Such guidelines shall apply to all lands in the province. Guidelines for reducing the impact of social dislocation as a result of disaster will also be prepared.
	Section 10
Gives act powers over other acts	This legislation supersedes sections of the Land Titles Act and the Municipal Act previously used for controlling lands susceptible to natural hazards.

	Section 11
Review Clause	Guidelines established by the province will be subject to review as new data is brought forward and as technological or social attitudes change over time. Special study zone plan(s) will also be subject to revision as new information is developed.

Proposed legislation as prepared here is only the framework for a completed statute. However in determining the context of the legislation, one aspect is always promoted and that is positiveness. Legislation for natural hazards (as well as any other legislation) must be forceful and positive if it is to have any impact on existing decision-making and administrative processes.

Components of the legislation as shown here, also guarantees that the steps which follow will be undertaken. Special Study Zone maps are to be prepared and coordination or central administration for the hazards program will be through the Provincial Emergency Program unit. Guidelines and plan(s) preparation are assured, as are mitigative techniques for the reduction of losses. For those victimized during a disaster, it is proposed that compensation guidelines be developed which, as a matter of pragmatism would be directly linked to the reconstruction planning guidelines. Cases are likely to result where full compensation for property losses is required because reconstruction will be refused due to probable reoccurrence of the hazard and relocation therefore recommended.

Risk Mapping For Special Study Zones

Once legislation is in place, risk mapping becomes the next priority so that delineation of hazard zones can take place and be integrated into land use planning. A methodology for preparing such maps or plans can be chosen or adapted from several examples currently in use. Initially however, a decision must be made as to whether or not the maps will show multiple hazards or singular hazards as a means of assessing the risk. Example of a single hazard map has been taken from the Urban Geology Master Plan prepared for the state of California in 1973, see Figure 6.3. A major problem with single hazard maps is that they do not adequately illustrate the actual risk

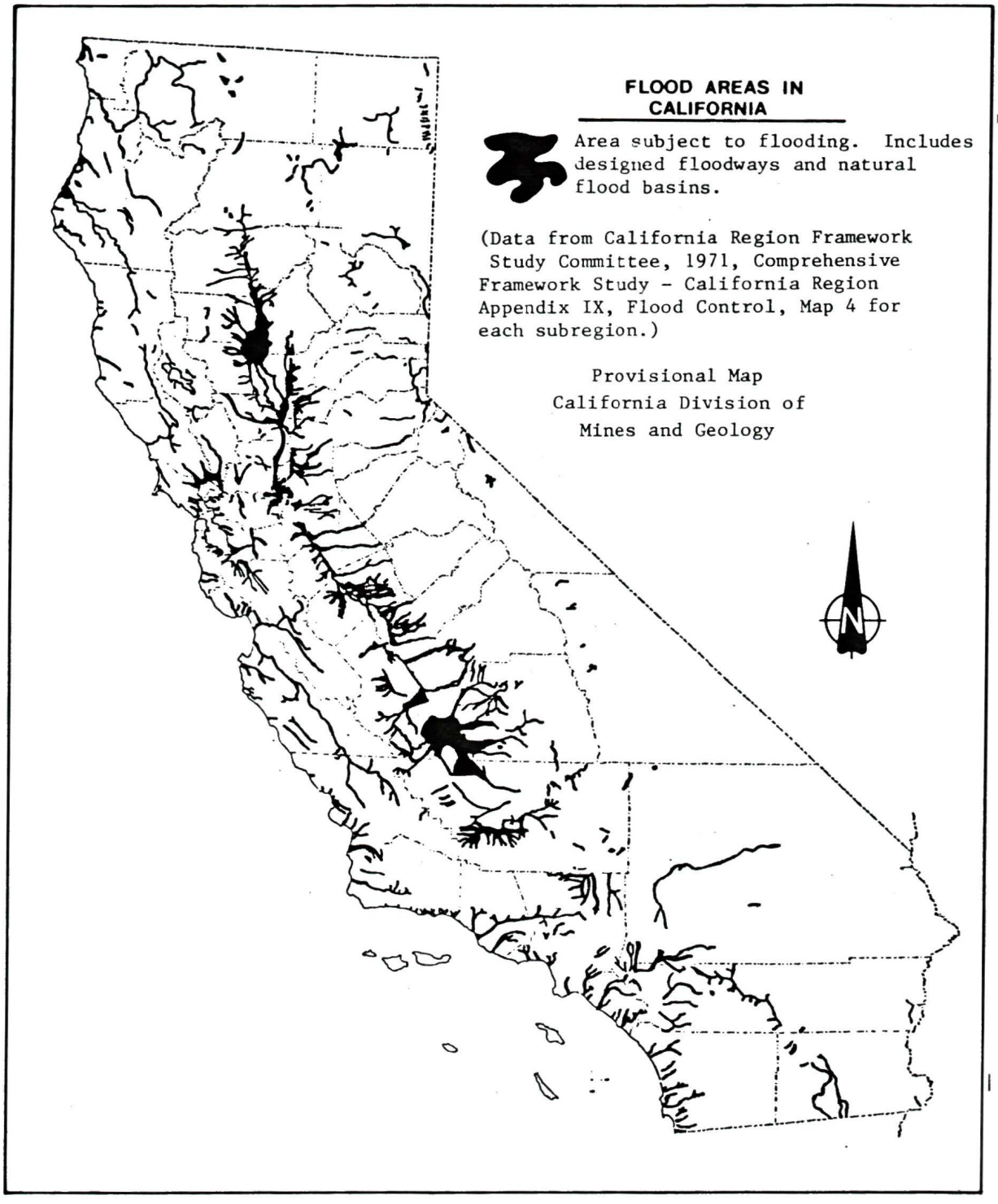


Figure 6.3: Single hazard mapping: An example from the (1973) California - Urban Geology Master Plan (p. 30)

in an area, as for example the Mount Garibaldi Case where flooding and rock slides both are independently possible. A map showing only flood hazard would not accurately convey the degree of risk at the site.

Multiple hazards maps are therefore deemed to be more practical for application to the planning program proposed for British Columbia. The concept of multiple hazards, or 'total risk' mapping has been promoted by Hewitt and Burton (1971) and more recently by Wuorinen (1979). Preparation of "all-hazards-at-a place" maps provide the planner with a truer concept of risk and eliminates the review of a number of hazard maps, thereby reducing the possibility of misinterpretation or oversight. Development of this concept is probably best exemplified in the preparation of the Urban Geology Master Plan for California, which has its basis in the evaluation of a number of hazards for determination of risk, designation of special study zones being dependent upon the severity of the hazard and the cumulative risk involved. Figure 6.4 provides an example of the cumulative hazard map prepared and the methodology used in its derivation. Scale of this map should be noted for it is only useful for indicating areas of hazard. Accurate definition of risk must be done at a much larger, more localized scale of mapping.

A similar, multi-hazard approach to mapping has been applied in Switzerland, a country subject to many of the hazards prominent in British Columbia. Criteria used for forming zones of varying risk differ from those used in California and provide another example upon which British Columbia can base its own methodology (see Figure 6.5). The Swiss have developed their mapping on a destructive force basis. Zones are determined by the amount of damage a structure will likely incur should a designed event occur. A multiple hazard risk factor is involved in each zone and is determined over a time frame of 100 to 150 years. Building location and structural design restrictions are applied to each zone as means of reducing potential losses.

During review of British Columbia's natural hazards administration in chapter 3, it became apparent that particular agencies were restricted to consideration of isolated hazards, or at best to jurisdiction over a minimal number of hazard types. It is

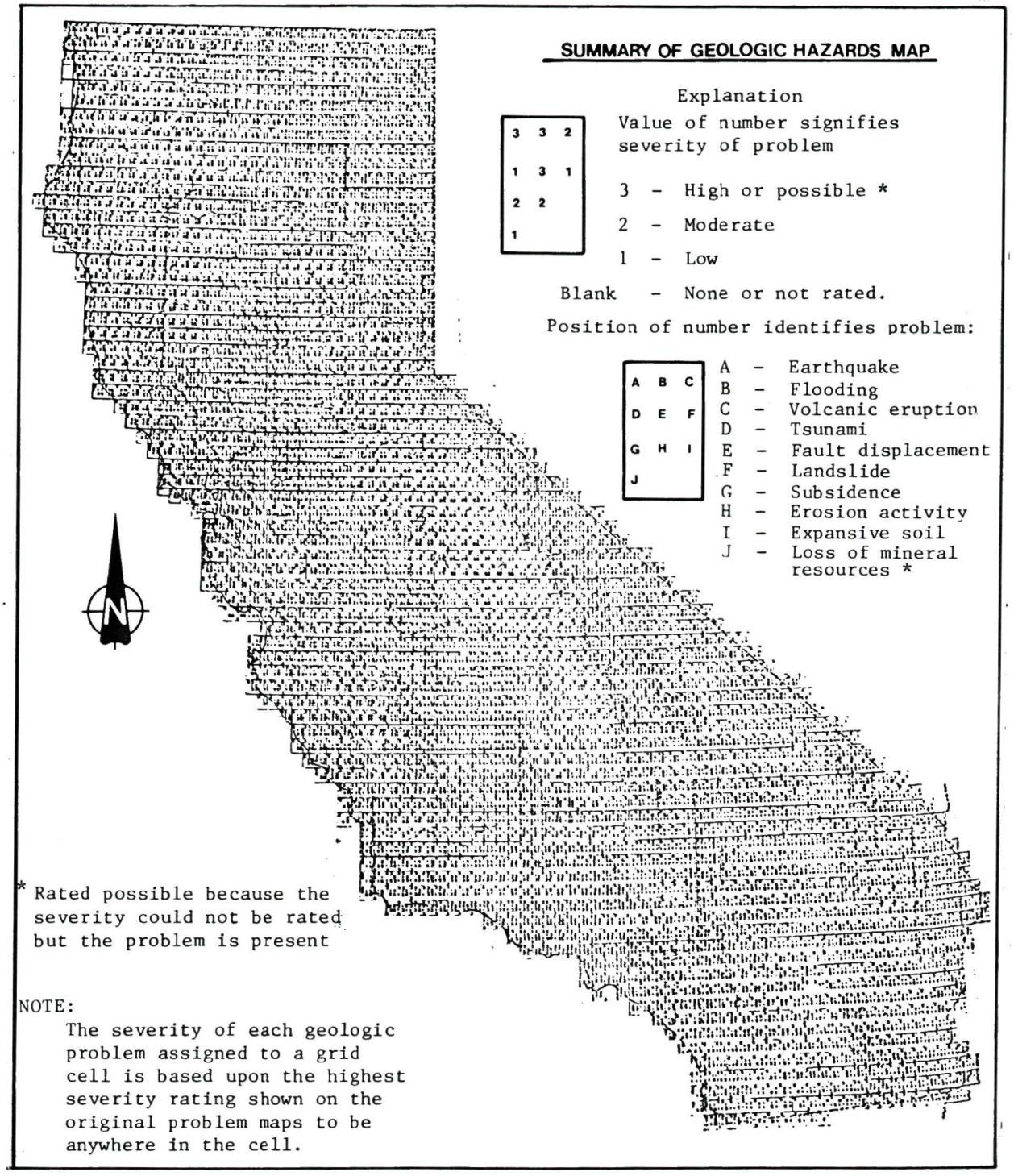


Figure 6.4: Example of computerized - multiple hazard mapping taken from the (1973) California - Urban Geology Master Plan (p. 72)

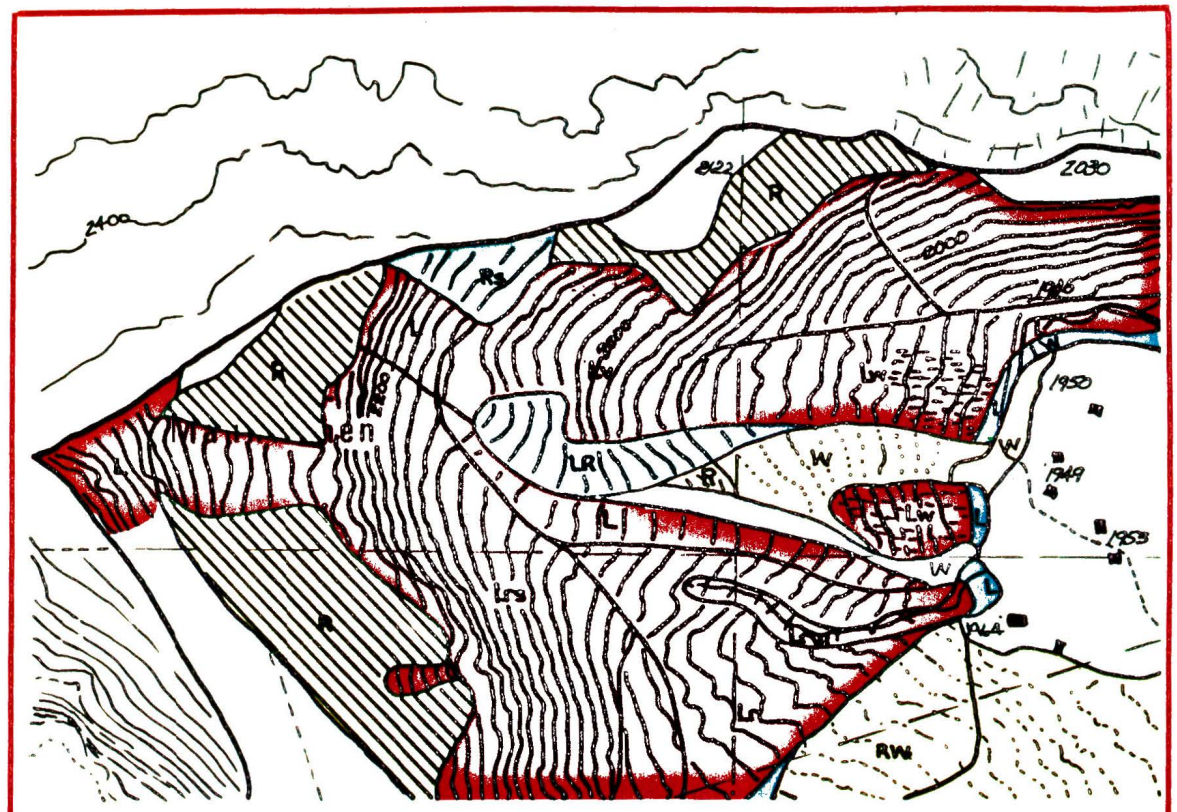


Figure 6.5: An example of multiple hazard mapping taken from Switzerland (Bern University, 1977)

probably advantageous to retain such a format for mapping individual hazards in the province. Upon completion of a map area by all the individual agencies, then a hazard mosaic may be developed by standard mapping procedures or through a computerized system as promoted by Wuorinen (1979) at the University of Victoria. Agency responsiblity for mapping has been tentatively proposed in Figure 6.6, however this may be changed considerably if required.

Those experienced with large scale mapping projects have pointed out that these types of projects take considerable time to prepare and must be sufficiently detailed to satisfy the needs of the users. In British Columbia a very small percentage of the province is subject to human occupance. Therefore it is conceivable that hazards mapping could initially concentrate on urban areas and the surrounding hinterland which would be determined by the level of activity and demands for development. In this manner, the program could be reduced to manageable levels and yet achieve the goals of providing suitable risk maps in those areas required. Over a longer period of time, the program could be developed to a point where it would closely compare with the level achieved in California or Switzerland.

Administrating The Program - A Proposal

As stipulated in the legislation, the Provincial Emergency Program has been designated as the coordinating unit that is responsible for making sure the program meets schedules and achieves set goals. In the administrative review undertaken in chapter 4 it was noted that the existing system in the province is disorganized and quite complex. The Provincial Emergency Program would, therefore be faced with establishing a new administrative arrangement, or work within the current arrangement with powers as provided by the proposed legislation (see Section 4 of proposed legislation).

An entirely new administrative framework for natural hazards management was proposed by the British Columbia Professional Engineers Association in 1976, and can be used as an example for noting the inherent problems of a new framework versus an established one. The proposed new organization chart is shown in Figure 6.7. Under the

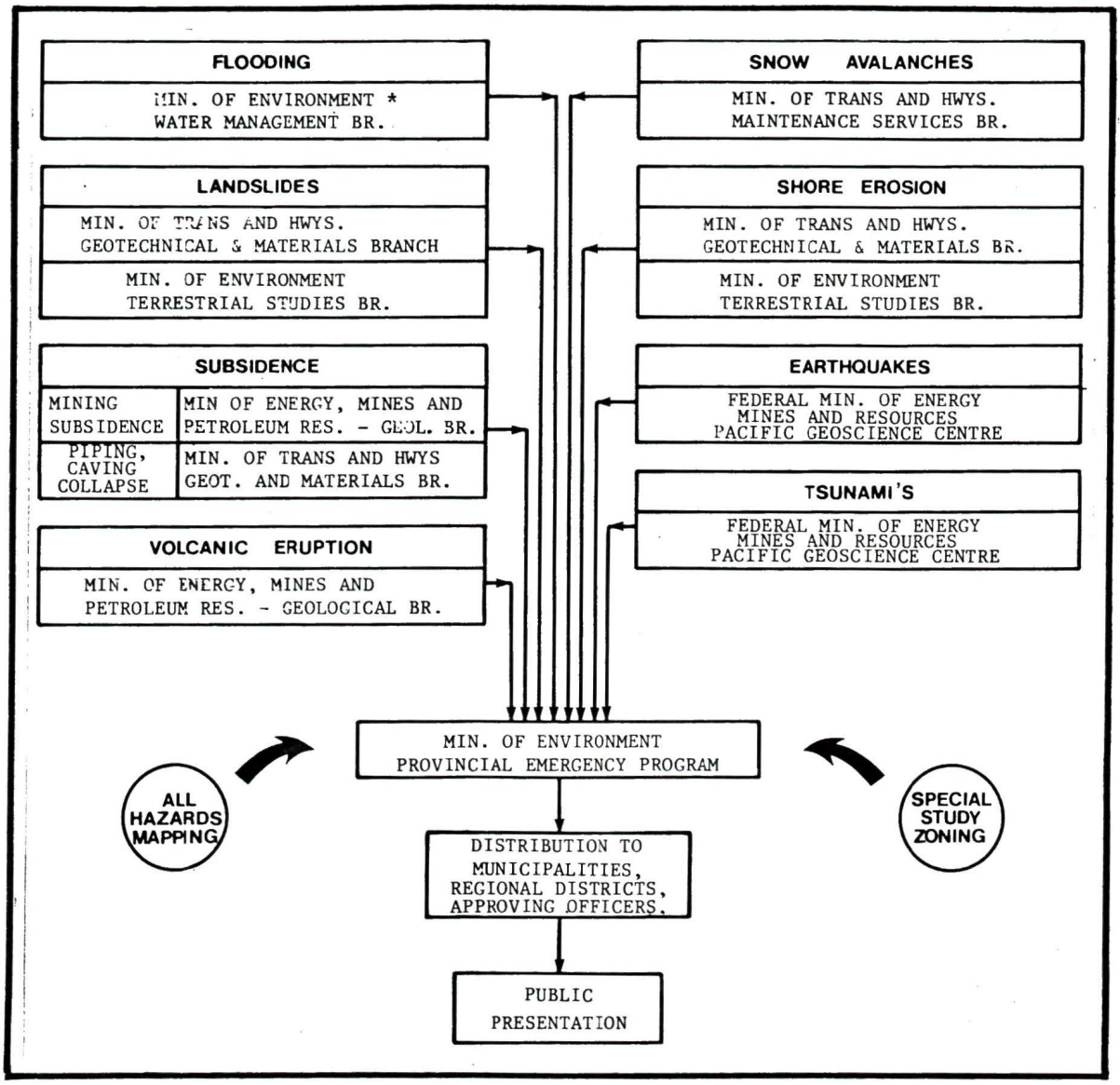


Figure 6.6: Diagrammatic representation of agency responsibility for hazard mapping in British Columbia

proposal, two significant additions would be made to the existing system; one would be the gathering of a technical staff for data compilation and assessment; and the second would be the provision of a 'Natural Hazards Board' which would be responsible for operational planning and policy, in addition to acting as an appeal board for individuals who would be disputing technical staff decisions. In both cases, these additions would involve staff increases and further steps in the reporting process.

Traditionally, governments have been pressured to retain as few public service employees as possible, and as recently observed in newspaper articles, in British Columbia there is definite pressure to reduce the number of public sector workers. As a result, proposals involving additional staffing and development of new administrative bodies are generally not well accepted. In addition, unless the proposed legislation designates specific powers to the new staff and board, then they will be faced with the inertia which exists when requesting information from competing agencies. Formation of a 'Natural Hazards Board' would introduce another level of bureaucracy, which under the proposed format could easily become subject to political maneuvering, particularly where technical staff are over-ruled or decisions are revised by the board.

This is not a condemnation of the proposal, however it is felt that a more practical approach would be to coordinate existing agencies and fully apply their built-in expertise. A diagrammatic representation of the administrative system proposed here (see Figure 6.8) makes use of existing ministries and branches within provincial government and projects the responsibilities each could assume. Within this proposal each ministry would concentrate on specified hazards e.g. the Senior Avalanche Coordinator, Ministry of Transportation and Highways, would be responsible only for the mapping of snow avalanche hazards and the review of disputed boundaries where required. This system would also recognize the jurisdictional arrangements which currently exist between lands controlled by the provincial government and those under municipal control.

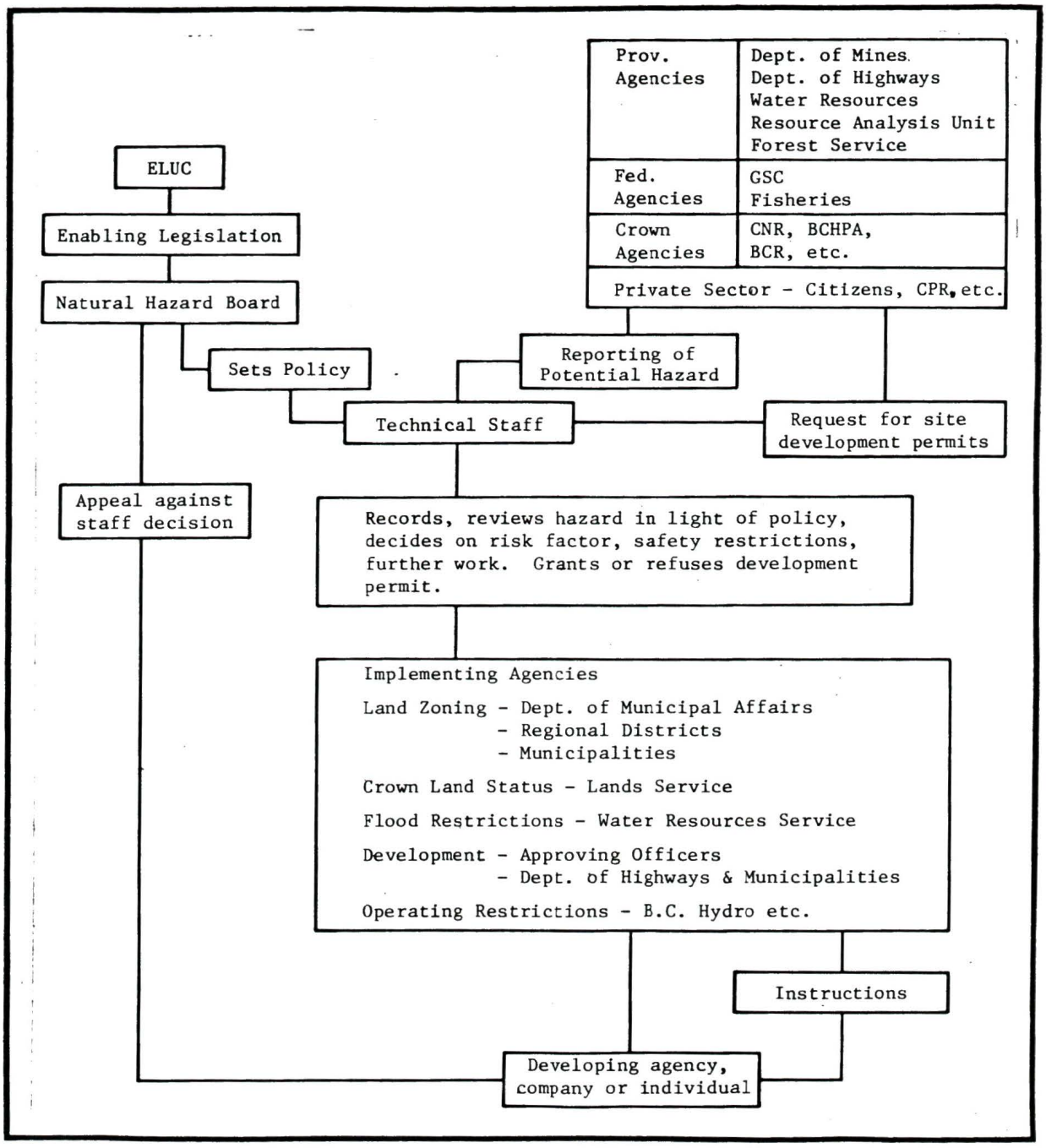


Figure 6.7: An administrative framework for natural hazards management as proposed by the B.C. Professional Engineers Association (1976)

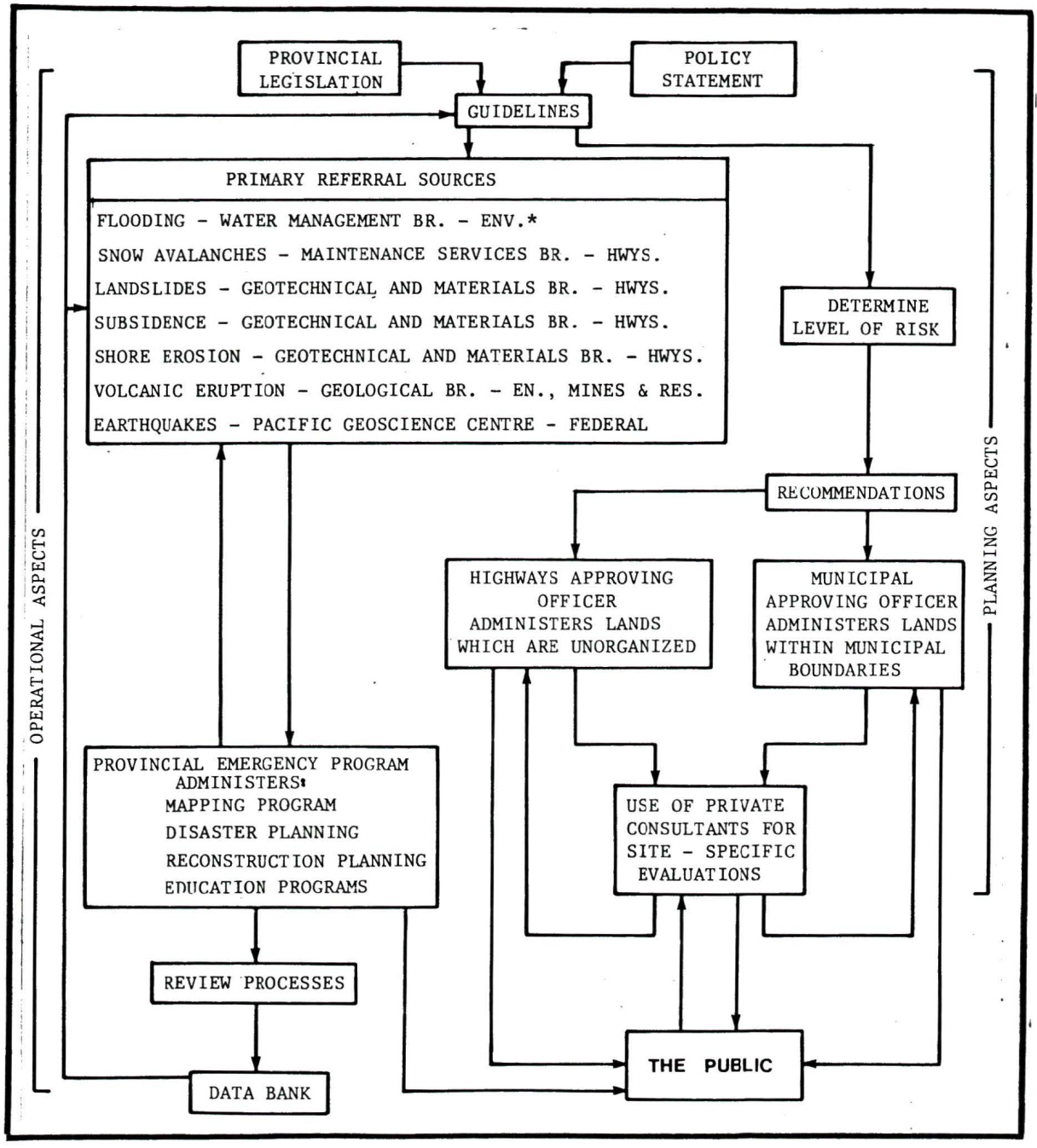


Figure 6.8: A proposed administrative framework using existing agencies in British Columbia

Appointment of the Provincial Emergency Program (P.E.P.) unit as a control coordinator with a well defined mandate as declared in the proposed legislation is viewed as the strength of retaining the existing system. The role of the P.E.P. under the proposed program would be to satisfy needs, particularly in the areas of pre-event planning and mapping, development of public information programs and planning for post-event reconstruction. Under the existing system, immediate-post-event administrative responsibilities are relatively well-defined, therefore that area of administration in the hazards program may be altered the least.

The subtle approach prescribed here is in recognition that government agencies are able to respond to changing goals and policies only with small incremental steps (Crook, 1975). In her evaluation of land use policies in British Columbia, Crook recognized that;

> "Drastic re-orientations are difficult to implement because of the enormous cognitive exertion, which is required. This point undoubtedly has some applicability to the activities of the Provincial Government bureaucracy."

Further recognition of the difficulties in introducing a new program, rather than altering existing ones has been considered by Mayne (1960) where in discussing the administering of regional economic plans in Puerto Rico he noted:

> "The practical planner must realize that decision-making with respect to the allocation of resources, by both government and private enterprise, is a continuing process. While the planner may feel that the current method of decision-making is not adequate, he must recognize that there is already a decision-making apparatus in being. Part of the task of the practical planner is to develop the strategic and tactical measures whereby the decision-making techniques called for by the development plan can gradually replace existing decision-making operations. A head-on collision between the existing and proposed decision-making apparatus will generally spell failure for the newer techniques. The strategy of the take-over must be subtle and virtually unnoticed."

The statement is designed for planners. However it applies to administrators as well and lends credence to retaining the current administrative arrangement, while providing it with greater direction.

Adjustments to Natural Hazards in British Columbia

With the implementation of the first four phases in the natural hazards plan a definite attempt to reduce losses could take place in British Columbia. Operational aspects of the program however require consideration of the techniques of mitigation which may be implemented to reduce damage losses from natural hazards. A wide-range of adjustments to natural hazards have been considered, most falling within the following six classes (Hewitt and Burton, 1971; Burton, Kates and White, 1968) which further refines those categories used by Sewell and Foster in their risk-growth-sophistication matrix:

In the realm of reducing or changing the hazard condition, three procedures are recognized:

1. Affect the cause or natural agent directly,
2. Modify the hazard, and
3. Modify loss potential.

Where damage has occurred, three ways to deal with losses are recognized:

1. Spread the losses,
2. Plan for losses, and
3. Bear the losses.

As seen to date, British Columbia has basically followed a "bear the losses" type of policy except in cases of flooding where dams and dykes have been constructed in an attempt to modify damage susceptibility. In the Urban Geology Master Plan for California (1973), four objectives for hazard loss-reduction are presented which could be used for molding programs for hazards mitigation in British Columbia whereby all six classes of adjustments could be assessed within the timetable established in Figure 6.2 The objectives are

arranged in a time sequence relative to the expected occurrence of particular natural hazard events:

1. Avoid or prevent damage from future events by assessing the nature and location of probable events, taking steps to control those events, and guiding human activities away from hazardous areas in which it is not feasible to correct the hazards.
2. Minimize unavoidable or unpreventable losses by requiring thorough analysis of the physical environment prior to design, then provide safe design, construction and maintenance practices by adequate codes and ordinances.
3. Take emergency action to save lives and property during or immediately following any particular disastrous event.
4. Take long-range recovery action following a particular event, to study its lessons, re-establish normal life, and rebuild.

At the same time, seven main functions for reducing losses from natural hazards have also been presented as shown in Table 6.2. Those functions must be considered within the planning process as a method for the accurate assessment of the parameters of any particular hazard. Several of the functions in B.C. have already been clarified (such as the enabling, enforcement, overall cognizance and coordination functions), at least at the provincial level, although functions at the local level must still be studied and developed. Functions such as data preparation and engineering design and construction can best be satisfied in British Columbia by retaining the current structure and using the individual expertise of each agency to develop data and design bases.

In considering various mitigative techniques which may be applied to situations applicable to British Columbia, a wide-range of adjustments must be considered as needs will change over time as well as with applicability to varying hazard types (Hewitt and Burton, 1971). As new forms of adjustments develop and technology advances, adjustments will accordingly change (if necessary). Certain

adjustments for loss reduction for one hazard may not be applicable for another hazard. For example, construction of floodways may be suitable for reducing flood impact. However they would not be economical for containment of snow avalanches or debris flows. As a result, potential alternative adjustments for those hazards most common to British Columbia are varied.. An example of the wide variety of potential adjustments to flooding alone has been indicated by Sewell and Foster (1976) and is shown in Figure 6.9.

Table 6.2: Loss-Reduction Functions

A. DATA FUNCTIONS
   1. Research programs to gather, prepare and interpret data.
   2. Information dissemination.

B. PLANNING FUNCTIONS
   1. Land-use planning.
   2. Recovery planning.

C. ENGINEERING FUNCTIONS
   1. Planning and design.
   2. Construction.

D. ENABLING FUNCTIONS
   1. Political and administrative action.
      a. Authority, policy guidance, action dates.
      b. Resources (funds, manpower) to conduct action programs.
   2. Coordination and operational guidance (e.g. criteria, model language).

E. ENFORCEMENT FUNCTIONS
   1. Governing body and administrative review and management.
   2. Operational inspection and enforcement.

F. EMERGENCY-ACTION FUNCTIONS
   1. Overall coordination, definition and guidance.
   2. Contingency planning, preparation and testing.
   3. Response.
   4. Post-disaster review.

G. OVERALL COGNIZANCE AND COORDINATION FUNCTIONS
   1. Monitor progress of loss-reduction measures and techniques.
   2. Provide overall coordination mechanism.

(From: Urban Geology Master Plan for California, 1973, p. 52)

Table 6.2 (cont'd)

Several forms of mitigation have been studied and their uses in British Columbia are considered. Mitigative techniques evaluated include the following:

A. Insurance,
B. Land-Use Regulation,
C. Building Regulations and Codes,
D. Warning Systems,
E. Public Information Programs, and
F. Reconstruction.

A. Insurance

Disaster insurance for homeowners and businesses in British Columbia is not readily available, nor is it inexpensive when it is available. Earthquake and sometimes flood insurance may be obtained with large deductibles and annual payments. However, all-hazard or all-risk policies are not apparently provided by private or public insurance agencies. Lack of a comprehensive insurance package does not make B.C. unique, however, several countries have contemplated or implemented such programs, for example Australia (Rept. by Tech. Com., 1978), the United States, New Zealand and some Communist countries. For example in their 1974 report to the Washington State Legislature, the Ad Hoc Committee on Geologic Hazards urged the legislature to direct its efforts towards developing a concept of "all-risk" insurance with respect to geologic hazards in the state of Washington. They also went on to say "existing insurance programs dealing with such hazards are deficient in present coverage, due to unavailability, fragmentation, or high cost."

In his recommendations for a natural hazards policy for the United States, Wiggins (1974) prescribes that disaster insurance, if coordinated with other government programs, could significantly reduce hazard losses. He concludes that:

> "Nationwide natural hazards and disaster insurance, providing appropriately coordinated roles for our government and the insurance industry, encouraging responsible actions by individuals who purchase insurance, would contribute significantly to true reduction of natural hazards losses. The mechanism of insurance, if fully developed, might help

MODIFY THE FLOOD	MODIFY THE DAMAGE SUSCEPTIBILITY	MODIFY THE LOSS BURDEN	BEARING THE LOSS
Flood Protection	Flood Plain Management	Emergency Measures	Bear the loss
Dykes	Land-use regulation	Flood warning	
Floodwalls	Statutes	Flood fighting	
Channel improvements	Zoning ordinances	Evacuation	
Floodways	Building codes		
River diversions	Urban renewal	Redistribute Losses	
Reservoirs	Subdivision regulations	Disaster relief	
	Government purchase of land or property	Financial aids	
Watershed Management	Subsidized relocation	Tax write-offs	
Terracing		Flood insurance	
Gully control	Structural Change		
Bank stabilization	Use of Impervious material for basements and walls		
Forest fire control	Land elevation		
Revegetation	Construction of high floor houses		
Weather Modification			
Seeding of major storms	Flood Proofing		
	Permanent closure of low level windows & other openings		
	Waterproofing interiors		
	Store counters on wheels		
	Underpinning buildings		
	Installation of removable covers		
	Closing of sewer valves		
	Anchoring machinery		
	Plastic sheets covering machines		
	Seepage control		
	Sewer adjustment		

(from: Sewell and Foster, 1976, p. 53)

Figure 6.9: Examples of adjustments to flooding

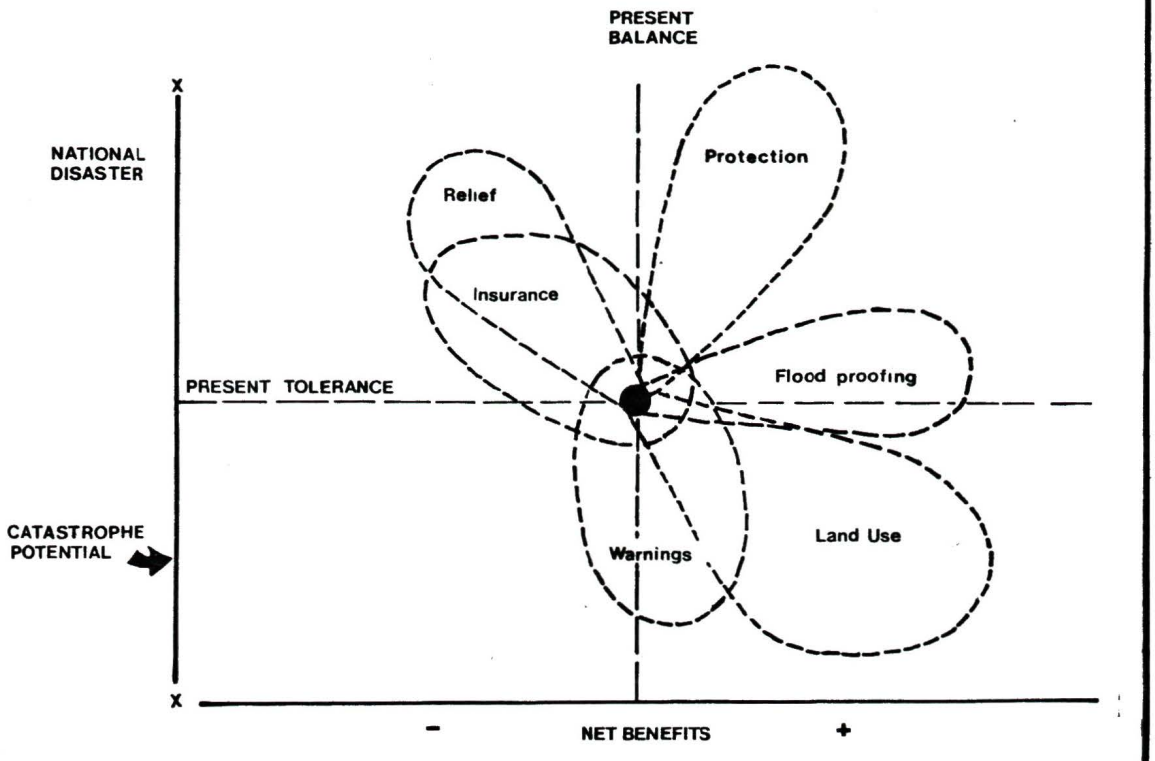
> minimize the federal role. It is essential however that it be tied in with other hazard reduction practices spanning all areas of human involvement."

To illustrate this statement he goes on to say that:

> "With such insurance and inter-government coordination, governments can encourage more prudent practices in construction and land use planning. For example, if insurance rates were higher for owners building in areas of high flooding risk, they might think twice about locating their structures in that zone - or if they did so because of over-riding business considerations, they might construct the building utilizing design and building practices reducing the expected flood loss, and accordingly justifying reduced insurance rates. In other words, the owner needs to be encouraged to make better decisions, based on sound economics, as to where to locate and how to build. Such wiser decisions can be stimulated by insurance coverage stemming from lending requirements and coordinated with governmental land use and construction standards."

To be successful, an insurance program must be linked with other types of adjustments. In British Columbia, the detrimental aspects of insurance, promote development in flood prone areas because relief is available, and reduce the perception of risk because damaged materials will be replaced through insurance. Negative benefits of insurance as a means of reducing flood losses is indicated in Figure 6.10, wherein White and Haas (1975) illustrate the tendency for insurance to promote potential disaster.

If an insurance scheme is to be effective, it must also be mandatory, for if only a small percentage of potential victims have coverage then a catastrophe for non-policy holders still exists; a crisis usually met with relief from public funds. Simple availability of hazards insurance is not sufficient, as has been found in the state of California where earthquake insurance has been marketed since 1916, but has never been widely purchased (Working Group on Earthquake Hazards Reduction, 1978). Why people refuse or neglect to purchase insurance voluntarily has been attributed to the fact that, "because of the difficulties people have in collecting and processing information, they refuse to pay attention to, or worry about events



(from: White and Haas, 1975, p. 268.)

Figure 6.10: Trends and limits of adjustments to floods

whose probability they feel is below some threshold level," and as a result then, "a person is likely to be uninsured because he has limited information on the hazard and available insurance rather than because he makes a thorough cost-benefit analysis based on his estimate of the probability of the occurrence of an earthquake in his area, the losses associated with such disaster, and insurance premiums" (Working Group on Earthquake Hazard Reduction, 1978).

In reviewing the situation in British Columbia, it is surmised that insurance may be particularly useful in situations where, after the hazard plan(s) is prepared, an area may be found to be in a high risk zone. Here, insurance could be used to protect the public purse from having to meet the full cost of a disaster and to guarantee the victims that funds will be received for damage, where in some cases relief funds may not be sufficient to fully cover all losses.

All dwellings and businesses in designated high risk zones should be forced to buy hazard insurance much like all new, mortgaged properties must obtain fire insurance. In the same instance, those residents or businessmen who undertake protective measures (e.g. flood-proofing, avalanche deflectors, rolling rock traps) should be rewarded with lower rates than those who refrain from alternative forms of protection. By requiring all potential victims to purchase insurance, it is also possible that premiums could be effectively reduced to manageable levels.

For British Columbia a three-level liability package is proposed, involving the individuals liability, the private insurance companies liability, and provincial (and provincial-federal) liability. First level liability would propose that individual policy-holders would assume damage costs of amounts sufficiently high enough to dissuade developments in high-frequency, high-risk areas, yet low enough to still be affordable for most potential victims. A suggested limit might be in the range of $2,000 and be considered under the deductible portion of an insurance policy. The deductible would cover cases of minor inundation, property loss through landsliding and house repairs as a result of subsidence. Second level liability would be covered by private insurance and would cover losses up to a prescribed amount

(for example 50% of the value of the dwelling). Total coverage of property losses would be ideal, though in the event of a major disaster, most insurance companies would be unable to meet the costs involved. By only having to cover half the dwelling costs, premiums could be further reduced. The third level of liability would involve the provincial government covering the remaining damage costs. Normally, in a disaster the province is morally expected to provide relief. Under the proposed program the liability has been reduced by 50% or more, as in many cases dwellings and buildings are only partially destroyed. Should a major disaster occur however, the provincial government would, with the aid of the federal government under federal-provincial agreement, cover losses. In addition, it is proposed that an upper liability figure be attached to private insurance claims (e.g. $1,000,000) at which time the province would commence relief funding, possibly over and above the normal 50% proposed. This would be a guarantee of some sorts that the private insurance firms were not bankrupted, leaving the victims without any coverage at all.

B. Land-Use Regulations

It is stressed throughout the literature that insurance must be coordinated with other loss-reducing alternatives. Land use regulations as an alternative are one of the most effective means of minimizing damage potential, as is exemplified in Figure 6.12. Past performance indicates that in most cases, adoption of land use controls to protect life and property have been exceptionally slow to develop. It can be particularly effective as a loss-reduction measure, however its application has been retarded, partly because of the concern for possible inverse condemnation lawsuits (California Urban Geology Master Plan, 1973).

As with insurance, land use regulations must be coordinated with the adoption of other alternatives as it cannot stand alone in the attempt to reduce damages from natural hazards. In their research assessment of land use management and regulation in hazardous areas, Baker and McPhee (1975) point out that three distinct social benefits

can be expected from suitable land use management, these being:

1. a substantial reduction in the population and economic investment-at-risk;
2. a substantial reduction in the expenditures of private and public agencies for evacuation, relief and rehabilitation; and,
3. dependence upon protection works can decrease.

Conversely, they also state that "the primary problem with land use as an adjustment to natural hazards is the length of time required for the full benefits of the program to accrue .... areas that are already urbanized, the typical time span is 20-25 years."

The extended period of time required for benefits to accrue is seen to be a major stumbling block in implementing land use regulations in British Columbia. Additionally, land use controls are often restrictive and infringe upon the common law rights of property owners, making them even less attractive as a loss-reduction method. It is suggested, therefore, that land use regulations should be introduced in coordination with other alternatives and be particularly accented towards non-urbanized areas. As brought forth in the California Master Plan, "a generally higher benefit-cost ratio can be achieved by applying loss-reduction efforts to areas undergoing rapid urbanization rather than to areas already developed." Land use restraints (like other alternatives) in currently undeveloped areas are more effective and evoke less controversy for decision-makers.

Land use controls could be instituted through subdivision regulations, zoning ordinances, zoning maps and building restrictions. As was found in Chapter 3, much of the legislation necessary to establish such controls exists in British Columbia, particularly at the local level. Impetus is required to promote the use of such controls in the same way as similar controls are used to keep houses a certain distance back from the property line or where building types are restricted to particular uses through zoning. For the sake of consistency it would be recommended that the provincial guidelines, as proposed earlier, be used to define regulations and

that municipal bylaws be designed accordingly. In this manner, when transition areas at the fringes of municipalities are developed, then development will be subject to the same restrictions, and land developments will be consistent both inside the municipal boundaries and outside in areas governed by regional districts or the Province.

The special study zone plan(s) would provide sufficient indication of where land use regulations for natural hazards were most needed. New legislation or amendments to the Land Titles Act and the Municipal Act could be used to delimit the powers of government. In the case of the Municipal Act, local decision-makers already have powers to plan for, zone, and regulate development in hazardous areas. However, their perception of hazards and potential losses needs to be expanded so that natural hazards planning and land use regulations are given sufficient priority.

C. Building Regulations and Codes

Building regulations can be used to control and systematize engineering practices, building design, materials, and test standards (Davis, 1978). Reduction of risk through the adequate design and regulation of buildings has long been a goal (Foster, 1980). The mitigation of risk to life and property being divided between the development of building regulations and the design of building codes. Building regulations are an integral part of land-use regulations specifically designed to protect dwellings from the impact of natural hazards. They are generally designed to regulate uses on and around a property inclusive of the building site itself. A typical example of a building regulation is provided by Ontario Regulation 735/73 made under the Conservation Authorities Act, which restricts the placing of fill, the building of structures and the altering of a watercourse. Purpose of the regulation being to "control what happens to a watercourse and its valley and to prevent flooding and erosion problems..." (Metropolitan Toronto and Region Conservation Authority, 1974). Similarly in British Columbia, recommendations involving building regulations have been used in specific areas to control against hazards from subsidence and landslides. An example of such

recommendations are condensed from a report dealing with "Geological Hazards and Urban Development of Silt Deposits in the Penticton Area," (1977), which read:

> "Recommendations regarding future development are aimed at delineating hazardous areas and reducing the addition of water.
> Red zone on the hazard zoning (see Figure 6.11) map covers those areas where the hazard is so great that no further building should be allowed. Includes ...:-
> - areas of piping, caving or collapse plus a 50' wide setback
> - areas of past piping, caving or collapse plus a 50' wide setback
> - remnant areas, and
> - areas near steep slopes falling within the zone bounded by a 2 1/2 horizontal to 1 vertical sloping line.
> The orange zone is designated as a zone of conditional development. Hazards in this area can be reduced by instituting special water control measures in all developed areas of the West Bench. These measures should include storm and sanitary sewers systems, curb and gutter street design, sprinkling controls, dole valves on outside water services, collection of roof and driveway runoff and conveyance to storm sewer systems, plus maximum safeguards against damage due to breakage of water and sewer lines. No construction of habitable or commercial buildings should be allowed on uncompacted fills ... all fills compacted to at least 100% of Standard Density as defined in A.S.T.M. D698, Method A.
> Hazard in green zone judged sufficiently low to permit 1/2 acre minimum lot size."

These types of regulations stipulate land use as well as design criteria for site development.

Unlike regulations, building codes are specific to the building design and its foundation. The Working Group on Earthquake Hazards Reduction (1978) in the U.S. provides the following definition of a building code:

> "Building codes are designed to: establish minimum safeguards in the construction of buildings, protect occupants from fire hazards or the collapse of the structure, and prohibit unhealthy or unsanitary conditions. They deal with new as well

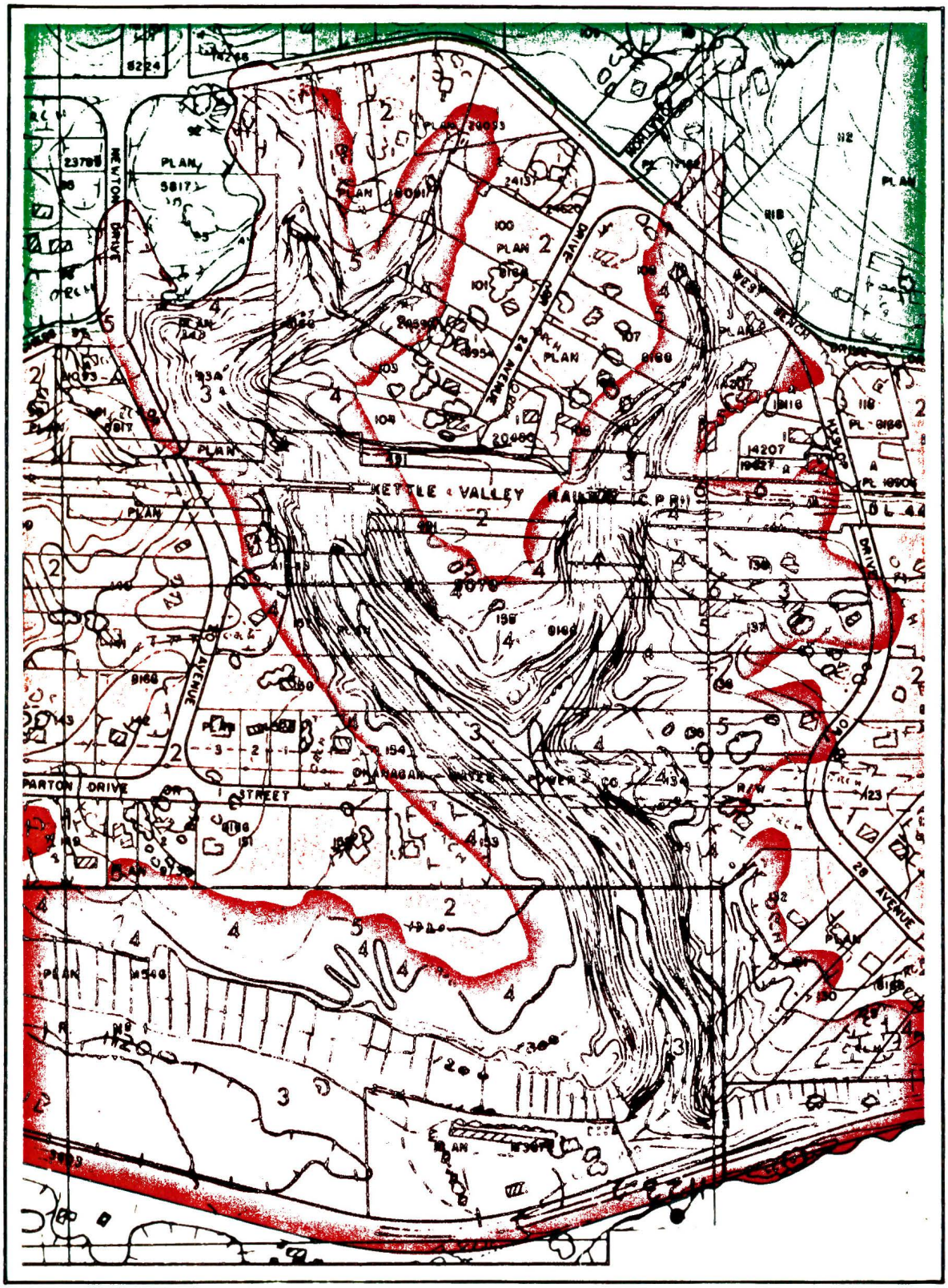


Figure 6.11: Zoning map from report on Geological Hazards and Urban Development of Silt Deposits in the Penticton Area - Indicating areas covered by building regulations

> as existing construction. These regulations are laws; they represent minimum requirements and are widely accepted as necessary for the public interest."

Minimum safeguards in Canada are established in the National Building Code and in the United States-Uniform Building Code. Within the National Building Code, emphasis is placed upon snow load capacity for roof structure and to the observation of lateral load requirements as a result of earthquakes.

A slightly different approach to the standard building code for earthquakes, which specifies lateral forces and design requirements has been applied in Long Beach, California. This municipality has instituted a balanced-risk approach to designing earthquake resistant structures and its code effectively states: "Design all buildings in a city so that probability of getting killed in any particular building during an earthquake is equal to or less than getting killed in an auto accident or while working" (Wiggins, 1972). The idea of the code is that buildings with few occupants and a short life-span need not be built to the same standards as buildings with high occupancy and long lifetime.

Good examples of building regulations and codes being interrelated with land-use regulations as a means of hazards mitigation are provided in the Santa Clara County Planning Commission Seismic Safety Plan; (U.S. Geological Survey, Professional Papers 941-A and B and Circular 690) and, the Texas Coastal and Marine Council Model of Minimum Hurricane-Resistant Building Standards for the Texas Gulf Coast.

Design of structures in British Columbia follows the National Building Code which proposes that builders design against progressive failures of individual building components, or that designs assume a maximum possible impact and design the structure to resist it. Whatever the case, it is probably best that the province integrate existing building regulations and codes with other alternatives, particularly in areas of existing development. It appears that construction of earthquake-resistant structures (through upgrading) and the application of flood-proofing techniques in established areas

might signficantly reduce damage losses. Other areas where building design and location may be effective is in the mitigation of subsidence and rockfall hazards as these tend to be lower magnitude events which can be defended against through proper engineering practices.

D. Warning Systems

Warning systems can effectively save lives if they are well-designed and the users well-educated (Foster, 1980). A proper warning system will comprise of two discrete components, one which illustrates the risk while the other defines alternative causes of action which can prevent, avoid, or minimize such risk (Williams, 1964; Foster and Wuorinen, 1976; Foster, 1980). In designing a warning system, decision-makers, researchers and technicians must recognize that if the system is to operate properly, then the general public, for whom the warnings are designed, must be made fully aware of how the system works and what actions are to be taken in the event of a warning.

A variety of problems arise in adequately protecting the public through the use of warning systems as seen in the case of the Tsunami Warning System in place in British Columbia. Initially, the decision-maker must decide if and where warning systems are necessary and what type of warning is required. For instance, a system designed to warn against landslides is probably not feasible because any steep slope or riverbank may be susceptible to failure and generally they occur so rapidly that evacuation is almost impossible. Very rapid, high or low frequency events once in motion are very difficult to warn against except through such means as land use regulations, building restrictions, maps, plans or warning signs. Even where evacuation warnings can take place for floods or tsunamis, occupants of the hazard areas are unaware of where to evacuate to, or whether the warning even applies to them.

An idealized warning system has been prepared by Foster (1980) and is illustrated in Figure 6.12. Sophistication and complexity of a

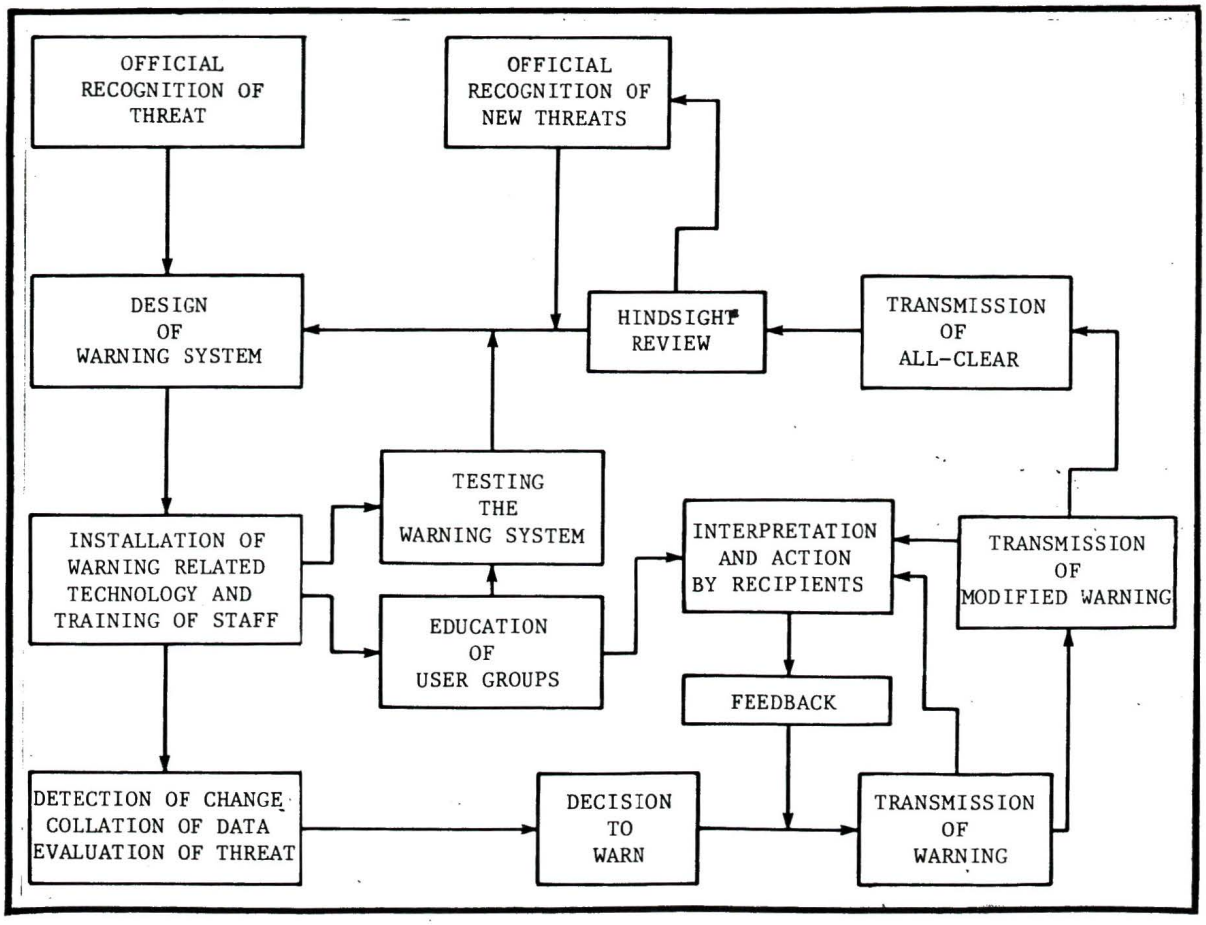


Figure 6.12: An idealized hazards warning system

valid system is indicated and under his proposal, successful operation would involve sixteen basic steps which have been briefly outlined in Table 6.3. Factors influencing responses to such a warning system, and which detract from the successful operation of the system, are outlined by Mileti (1975) in Table 6.4. Unfortunately, many individuals are unaware of the significance of warnings. Sociological and psychological research draws three important generalizations for why people respond in the manner they do, to hazard warnings. The generalizations are:

1. Even though a wide variety of people may be listening to the same warning message, everybody hears and believes different things.
2. People respond to warnings on the basis of how what they hear encourages them to behave.
3. Individuals are stimulated differently depending on who they are, who they are with, and who and what they see (Foster, 1980; Mileti, 1975).

A conclusion which may be reached from this is that although warning systems may successfully reduce loss of life in the case of a hazardous event, their overall success will often be hindered by typical human behaviour. In consideration of these and other factors it becomes obvious that the operation of a warning system in British Columbia may be difficult to develop and even more difficult to derive consistent results if a warning system is instituted.

Table 6.3: Basic Steps in Developing a Warning System

1. Recognition by decision makers that there is the possibility of danger from a particular source.
2. Design of a system to monitor changes in the hazard and issue warnings if danger increases beyond certain thresholds.
3. Installation and operation of the system.

Table 6.3 (cont'd)

4. Education of the user group, often the general public, so that should a warning be issued, responses will be appropriate. The infrastructure may also have to be modified to permit effective operation.

5. Testing the system, when there is little danger, to ensure that it is technically sound and that those involved in issuing and receiving its warnings act as required.

6. Modifying the system if test results indicate that changes are necessary.

7. Detection and measurement of changes in the hazard which could result in increases in death, injury and/or property damage.

8. Collation and evaluation of incoming information.

9. Decisions as to who should be warned, about what damage, and in what way.

10. Transmission of a warning message, or messages, to those whom it has been decided to warn.

11. Interpretation of the warning messages and action by the recipients.

12. Feedback of information about the actions of message recipients to the issuers of the warning messages.

13. Transmission of further warning messages, corrected in terms of the user groups' responses to the first and subsequent messages and noting any secondary threats.

14. Transmission of an all-clear when danger has passed.

15. Hindsight review of the operation of the warning system during potential disaster situations and the implementation of any necessary improvements.

16. Testing and operation of the revised system.

(taken from: Foster, H.D., 1980, pp. 172-173)

Table 6.4: Factors Influencing Response to Disaster Warnings

1. Any warning messages broadcast, especially the early ones, will be accepted at face value only by a minority of the recipients. Most will engage in confirmation efforts for a time.

2. The more warning messages received by an individual, the fewer the attempts at warning confirmation.

3. The closer a person is to the target area of a warning, the higher the incidence of face-to-face communication and the larger the number of sources used in confirmation attempts.

4. Warnings from official sources (police, state patrol, fire department) are more likely believed.

5. Message content per se influences belief. The more accurate and consistent the content across several messages,the greater the belief.

6. The more personal the manner in which a message is delivered, the more it will be believed.

7. Belief in eventual impact increases as the number of warnings received increases.

8. The recipient's sense of the sender's certainty about the message is important to belief.

9. Message believability is related to what happens in the confirmation process. The response of official sources to questions which call for validation, corroboration, or refutation helps determine believability.

10. A person is more likely to believe a warning of impending danger to the extend that perceived changes in his physical environment support the threat message.

11. Persons who see others behaving as if they believe a warning to be valid are themselves more likely to believe the warning.

12. Past experience may render current warnings less credible if disaster is not part of experience, or more credible if disaster is part of experience.

13. The closer a person is to the target area of warning, the more rumors he will hear and the less accurate will be his understanding of the character of the forecast events.

Table 6.4 (cont'd)

14. Persons do not readily evacuate on the basis of the first warning received, and the number of warnings received thereafter is directly related to evacuation.

15. As the warning message increases in its accuracy, and/or information about survival choices, and/or consistency with other warnings, and/or clarity about the nature of the threat, the probability of adaptive response increases.

16. Whether or not a person takes actions depends on his belief in the warning message. But even if he believes, he may fail to take adaptive action due to his misinterpretation of the meaning of the message content.

17. Evacuation tends to be a family phenomenon. The best way to accomplish evacuation appears to be repeated authoritative messages over broadcast media which stimulate discussion within the family and lead to evacuation (if it is going to happen at all).

18. Persons receiving face-to-face warnings in a family setting from authorities are more likely to evacuate.

19. Persons with recent disaster experience are more likely to take protective actions.

20. Perceived amount of time to disaster impact is also important.

21. Belief that impact could occur at the location from which a person may be about to evacuate is critical.

22. Older persons are less likely than the young to receive warnings regardless of warning source, and less likely to take protective actions.

23. Regardless of the content of a warning message, people tend to define some potential impact in terms of prior experience with that specific disaster agent.

Source: Haas (1973) and Mileti (1975)

In reviewing the existing system it was noted that British Columbia is already a member of the International Tsunami Warning System and has a snow avalanche signing program along most of its highway transportation network. As an alternative then to development of a full-scale warning system, it is proposed that programs in

existence be expanded. An area of careful consideration may be to consider the communication links intrinsic to successful operation of a warning system. Oliver (1978) states that "a good communication system is obviously essential so that the flow of information cannot be interrupted and so that it can be easily distributed to everyone concerned." He also goes on to say that it is "vital that there should be no ambiguities in the warning messages so that their meaning can be widely and correctly interpreted."

Risk map(s) or plan(s) already proposed may be used as a means of forewarning individuals of the risk in any particular area; and additionally, attachments should be made on land titles in areas of "high risk" so that potential buyers are fully aware of the hazards involved and can take appropriate measures to mitigate the risk. A lesson to be learned from the Garibaldi-Barrier study however, is that the existing owners should be notified of the attachments so that they too, are aware of the risks which exist. Such steps attempt to raise the level of cognizance of occupants of hazardous areas, although they are not event warnings such as sirens and klaxons. In British Columbia, it may be difficult to recommend that a full-scale warning program be instituted beyond such measures as mentioned due to the relatively inconsistent results of such systems, and the complexity of the required communication system.

E. Public Information and Participation

Accurate communication of risk and the alternative actions available during and after an event are very difficult to translate to the public at large (Oliver, 1978). One of the most difficult tasks being, how to get people to accurately perceive their risk when only a small proportion of hazard-related research findings ever reach the general public (White and Haas, 1975). Another problem may be that the public appraisal of extreme events, and the canvass of alternatives, are interdependent and that people have difficulty evaluating more than a very small number of alternatives at one time (Burton, Kates and White, 1978). Those individuals at-risk therefore will tend to look at available alternatives based on their personal

perceptions of the damage potential from an extreme event, and how likely is its occurrence.

In supplying public information the scientist or administrator should strive to provide simple, but accurate details on the hazard types in the particular area, the potential for an event of varying magnitudes, and the alternatives available to mitigate the hazard including an accurate description of how alternatives may be integrated to provide adequate protection. It is suggested that a multi-hazard approach should be taken when presenting the information so as to more clearly define the degree of risk. In other words, each hazard type may be detailed, but information should not be presented solely for floods or landslides in areas susceptible to multiple hazards.

The state of Texas has been formally providing natural hazards information to its coastal public since 1974 through the Hurricane Awareness Program (Tubbesing, 1979). To date, the author is unaware of any similar information systems being established in British Columbia. Public education and participation in natural hazards has been limited to media coverage of events and to personal involvements as the result of an event in post-disaster clean-up or search and rescue for example. A public information-public awareness program is prescribed as part of the proposed hazards program (see Table 6.1 and Figure 6.2) for British Columbia and institution could take place over time. Development of special study zone plans and the designation of building regulations and codes may be used as initial steps in the development of an information system.

Certainly within British Columbia, the public information system will be partly determined by the organizational/political/cultural context which does and will continue to exist. As a result, members of the Provincial Emergency Program, as coordinators, will likely have to choose which means is best for transmittal of information for public dissemination. The table illustrated in Figure 6.13 indicates the pro's and con's of varying information systems and successfully summarizes the choices available for public education on natural hazards in British Columbia.

Figure 6.13: Information - feedback techniques

TECHNIQUE	DESCRIPTION	ADVANTAGES	DISADVANTAGES
Media 1. Visualize Aids Purposes	Techniques to assist in describing the project. to aid understanding	Helps to visualize and relate to the form of the housing. Shows how the housing project fits into neighbourhood context and demonstrates its possible impact. Models put in public places help to promote program.	Models - Can be used to give a distorted view of the project. Slides - Require useful commentary and good organization to be effective.
2. Exhibits Films Tape presentations	Brief pictorial presentation of the program and specific projects. Purpose: create awareness and inform.	Very useful for generating interest and discussion. Can reach a wide number of people if used in open-house setting.	May be expensive initially
3. Information kits	Folder or binder with basic information on one agency planning concepts, methods municipal government procedures.	Provides useful background information. Can be sent out to various organizations and groups and put in libraries to reach a wide audience.	No feed-back Best used with other techniques.
4. Newspaper reports	Articles in local papers discussing the project Purpose - to inform	Inform a wider audience May interest people in becoming involved May give favourable publicity to the agency	May not give an objective view May be used to raise other issues or objections to the project May result in unfavourable publicity
5. Tours of existing projects and meetings with tenants.	Field trip to the site of existing or potential projects. Purpose - provides an opportunity to see the program in operation.	Allows people to make their own judgments about the program. Answers questions about management and operations. Gives an "insiders" view as a balance to the community's perspective.	Tenants should be able to relate well to working committee members. May raise misleading expectations about new projects. Time consuming.
6. Newsletters	Regular publications from the local association. Purpose - to keep residents informed.	Keep area residents informed and up-to-date.	May not be objective - may misinform. May be used in place of other meetings.
7. Open Letters	Correspondence from aldermen or commissioner an issue.	May fill communication gap if residents are not kept informed through other means.	May raise more questions than it answers. Allows no feedback. Occurs usually in response to a crisis. More open communication would eliminate the need for this response.

(from: Lang and Armour, 1980, p. 303.)

F. Reconstruction as an Alternative

Plans for reconstruction are useful because they are a conscious commitment to reduce risk (Foster, 1980). In the event of a disaster, therefore, reconstruction which mitigates against future reoccurrences of a similar disaster will be advantageous to both victims and decision-makers. In the case of post-disaster recovery, reconstruction plans must consider three key elements, these being:

1. the immediate stabilization of the disaster area and attention to human needs which will include the clearing of rubble, temporary housing construction, opening of aid stations and general programs to restore order from chaos;

2. the implementation of short term recovery programs whereby priority reconstruction (and possible relocation) takes place which is cognizant of larger scale plans to mitigate against future events (redevelopment of the infrastructure); and

3. the development of long-term recovery and mitigation programs which will institute several alternative adjustments to reduce the risk of future events (U.S. Conference of Mayors, 1980).

The purpose of the reconstruction program is to have a pre-designed plan for orderly redevelopment. This should accommodate the economic and social problems which are likely to occur after a disaster. Reconstruction planning as part of a natural hazards plan also allows for the pre-disaster accumulation of data, which will be important when considering where relief funds and compensation should be made to, where land acquisitions or relocation is necessary, and who is responsible for organizing the reconstruction. Kates (1977), after reviewing the reconstruction of San Francisco (earthquake, April 18, 1906), Anchorage (earthquake, March 27, 1964), Managua (earthquake December 23, 1972) and Rapid City (flood, June 9, 1972), concluded that an optimum strategy for reconstruction does the following:

> "... emphasizes reconstruction preparation before the disaster; the use of emergency acquisition, withdrawal and compensation mechanisms rather than normal ones; the reduction of uncertainty by rapid and simple areal designation; the giving of generous compensation for providing options where needed; and the pursuit of modest, phased and flexible planning with nonprofessional inputs, timed to the natural phases of the recovery cycle. Before the disaster strikes is the time to create an inventory and safe storage of routine information, to create the land acquisition and withdrawal mechanisms, to debate the value issues of compensation and public participation, and to designate reconstruction organization and responsibility."

Tremendous economic and social pressures arise after a disaster and even though there is recognition of a need to reassess and plan for reconstruction to reduce risks, the influx of relief funds and demands to get things going usually results in new construction taking place in areas of high risk from similar future events. An example of this was provided after the 1964 Alaskan earthquake where large portions of Anchorage were totally devastated, and even though city planners recognized that reconstruction should avoid certain high risk locations, redevelopment took place on previously devastated sites and in some cases at higher densities than before (Schoop, 1969).

Similarly, Port Alberni, a small community on the west coast of Vancouver Island, was damaged from a seismically generated sea wave as a result of the 1964 Alaskan earthquake. In investigating the site today, it becomes obvious that considerable reconstruction of domestic dwellings has taken place on those same sites which were inundated in 1964. Even though local planners are now fully aware of the risks, the immediate post-event reaction of land owners was to rebuild on the land which they already owned. Relocation may very well have been a superior choice of action, for the risk of serious damage still exists, even though the risk-to-life has been reduced through involvement with the International Tsunami Warning System which can provide pre-event warnings in time for evacuation.

British Columbia has lessons from which it can learn, yet

persistently, reconstruction takes place in high risk areas. Cases arise such as at Port Alice and in the Lower Fraser Mainland where protective works have been implemented to mitigate the hazards, however, these types of development often increase the potential for even greater disaster. A planned reaction to a disaster inclusive of plans for reconstruction is needed.

Summary Statement

Comprehensive natural hazards planning is an effective means of reducing risk. In implementing the plan however, the decision-makers and the planners must have legislative support, administrative organization and a firm commitment to risk reduction through all hazard phases (pre, during and post). Constraints in any system will tend to hinder new policies and administrations. However in British Columbia a loosely-organized administrative arrangement exists and has functioned for several years although often in a state of flux. Formalization of a natural hazards policy and the provision of enabling legislation is viewed as being necessary if such organizations are to define their duties and responsibilities and to integrate themselves into a proper program for risk reduction.

There is no need to rush such a program. Development of a natural hazards plan can be undertaken in an orderly manner such as proposed under the timetable in Figure 6.3. Time to develop organizations, compile data and prepare special study zoning plans are provided for, without development of new administrative groups, or large-scale expenditures. Reduction of damage losses is the priority of all goals which are set.

An evaluation of alternative mitigative techniques has also been provided, with some examples from which lessons may be learned and used in preparing a natural hazards program. The author recognizes that this is but a brief overview of natural hazards management. However, with an "increase" in direction and a firm policy to stand on, the benefits in terms of reduced losses in structural damage and lives will far outweigh the increased expenditures (if any).

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Chapter 7
SUMMARY AND RECOMMENDATIONS FOR FURTHER RESEARCH

Residents of British Columbia are constantly reminded that they live in an area of the world susceptible to frequent and varied natural hazards. It is surprising then that greater concern has not been given to plans for mitigating against such hazards. To date, decision-makers in British Columbia have been willing to accept losses and deal with each event on a crisis level. Increasing pressures to develop in areas of high risk however requires that prevailing attitudes must change and alternative forms of action are required. Human adjustments have tended to prefer technological approaches or relief to other alternatives such as land-use planning, land-use restriction or building codes. Existing attitudes assume a fundamental imbalance between true hazard potential and the prevailing risk assessment (Kates, 1978). It is hoped that the present study may portray the existing hazards and their management, and more significantly, that it serves to sensitize decision-makers to the broad context of naturally hazardous events and to the alternative solutions available for loss-reduction.

Risks and Adjustments

A movement away from crisis oriented decision making is almost certain to help reduce hazard losses and to better prepare for disaster. Aspects of decision-making under crisis and the adverse results have been analyzed in the opening chapter. Need for a coordinated and comprehensive program is indicated by the diversity of hazard types and the spatial arrangement within the province. With the presentation of alternative actions in Chapter 6, greater consideration can be given to overcoming the reluctance to innovate new ideas, and to the implementation of lessons learned by others.

With our present knowledge of hazardous events, it is possible to predict only that events will continue to occur in the future and that catastrophic events are likely to occur where human use takes place in areas of high risk. In summary then, it appears that there are

several ways in which provincial (and local) authorities may help in a more effective program to alleviate losses. Such a management program must contain:

1. The drafting of a definitive policy on natural hazards which encourages the development of comprehensive land-use plans and disaster preparedness programs.
2. Enabling legislation to establish regulatory powers to ensure that land planning and land use takes into consideration physical processes which lead to a hazardous event.
3. Innovative management techniques which are needed in an attempt to sway the current tendency of using engineering technology and relief, to the detriment of other alternatives.
4. Means of stimulating public interest and public knowledge of the risks involved are necessary to encourage their participation and acceptance of alternative solutions.
5. A core agency for collection and dissemination of data is required to provide management and public alike with information on all facets of natural hazards in the province. In addition, this agency can be used as the coordination unit between various agencies collecting hazards data and/or administrating special hazards programs.

Foremost of all however, is the need for decision-makers, both political and administrative to act in a conscientious and inciteful manner. This is typified in a statement by White (1978) where in overviewing research on natural hazards in the United States he summarized that:

> "The net gain or loss which may be enjoyed by the nation in the management of natural hazards depends upon the vision of those who draft Executive Orders (legislation) and administrative procedures to translate plans into action and the acuity and political perspicacity of the administrators who guide the new agency."

The information presented in this thesis is designed to provide an introductory base of information upon which further research may be

established. For some hazards, enough information may already be on hand to predict the behaviour of the phenomena and the human reactions in resultant disasters. For many other areas of hazard research these abilities have not been developed. However, even the small amounts of information available can be used to develop a hazards policy and indicate avenues to successfully implement it. The only caution being that "unless carefully designed, new policies can either halt the current efforts, or divert them into unproductive directions, just as a new constriction on a river can either deepen the channel or dissipate it in shallow overbank flow and backwaters" (White, 1981).

Recommendations for Further Research

An essential strategy for carrying out the findings in hazard research is to assure that the results are presented to those agencies or persons who can act at the administrative or legislative level. Their actions are more likely to be beneficial if they understand how alterations in policy could advance public aims by affecting the ways in which choices are made between the many alternatives available (White and Haas, 1975). White and Haas (1975) also have stated that, "Right now, only a small proportion of all hazard-related research findings ever reach the general public... This needs to be corrected if wise action is sought."

Findings in this research provide a preliminary analysis of existing hazards management programs in British Columbia. The method employed in developing the data may be extended to develop a more extensive evaluation of risks from hazards and the management alternatives possible. In chapter 2 and appendix C, an introductory base of disaster specific information has been compiled. This data however, provides only spatial, frequency and loss information, it does not effectively indicate the risk-at-place. A much larger data base is required on physical processes and social patterns throughout the province in an attempt to come to grips with frequencies and magnitudes of hazards risk, development patterns and social attitudes. With the considerable number of agencies involved in the analyses of individual hazards at both the provincial and federal

levels, it is not presently possible to rapidly determine if a development is, or is not, at risk.

Development of total risk mapping techniques should be pursued as recommended by Hewitt and Burton (1971) and Wuorinen (1979). Such methods of risk mapping may be employed by planners in determining land-use; by administrators of hazard protection and response agencies to determine advantageous deployment of resources in financial and personnel terms; and, to establish a base for the determination of insurance premiums and for the grading of premiums dependent upon the degree-of-risk involved. Methodologies for developing the necessary data base should be pursued in conjunction with studies considering how the information is to be accessed and dispersed. A clearing house service such as the Natural Hazards Research and Applications Information Center, University of Colorado, or the Ohio State University Disaster Research Center may provide the answer. However many other avenues are open to investigation.

Creation of new legislation to create a natural hazards program can best be formulated if it benefits the public-at-risk and if it has a large number of existing examples to draw from. Research of existing legislation on a worldwide basis and determination of legislative arrangements on a more local level are required. The present position of legislation-by-crisis can only be changed if public officials and administrators are aware of the alternatives available to them and the implications of establishing new legislation. Means of transmitting legislative changes to the public in a harmonious manner is important so as to avoid inconsistent or incorrect interpretations.

The actions of individuals operate within the limits set by their communities or governments, which in turn react to the actions of collective groups of individuals (Burton, Kates and White, 1978). Relationships between administrative units at varying levels of government in the province are currently founded on an ad hoc basis. Research into the influences, interactions, levels of responsibility and development of adequate frameworks are deemed necessary. Bureaucratic overlap or inertia in some areas of response to natural hazards

has likely led to expenditures and losses in excess of necessary levels. Relationships between local, provincial and federal agencies need to be explored in order that a well-designed administrative arrangement will be established wherein the transmission of loss-reducing benefits to the public-at-large will proceed smoothly and efficiently. All areas of administration from pre-event land-use analysis to post-disaster relief and reconstruction need further investigation if an effective long-term program is to be implemented.

A preliminary review of hazards literature indicates that there are a large number of alternatives which have been proposed or employed in attempting to reduce impacts from natural hazards. Some of these alternatives have operated over a period of years and can now be evaluated for their effectiveness. For example, many types of technological adjustments have been employed including dykes and dams for flooding, snowsheds and fences for avalanches, building designs for earthquakes, etc. Application and viability of these and other alternatives in the environment of British Columbia could benefit decision-makers greatly when solutions are required in both the short and long terms.

Public information and public response programs have been given considerable emphasis in studies in the United States. Response of the human population to some of the programs presented in chapter 6 will play a large part in the effectiveness of those proposals. The author is unaware of any public awareness studies in British Columbia which have been carried out on the scale of those in the U.S. An obvious need for some social research is apparent and could effectively evaluate individual determinations of risk as well as consider responses to hazard program implementation.

A large number of avenues still need pursuing. Compiling of knowledge on natural hazards will aid greatly in the development of policies and programs to reduce the risks faced by residents in British Columbia. Hopefully this study will add to the growth of knowledge available and spur others to pursue it further.

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APPENDIX A
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APPENDIX B
Natural Hazards Terminology

The diversity of terms existent in natural hazards studies has led to confusion in the ranks of the public and professionals alike. Variations in terminology are partially attributed to the wide variety of disciplines involved in hazards research. For example, in British Columbia many engineering and pseudo-engineering groups refer to those hazards studies here as "geological hazards", whereas, Wiggins (1974) in the U.S. refers to them as "geophysical processes". Table 1 below notes several examples of where the same geomorphic processes are referred to in varous terms.

Table 1
Examples of Hazard Terminology Used in the Literature

1. Natural hazards (White, G.F.; 1974)
2. Extreme natural events (Hewitt, K. and Burton, I.; 1971)
3. Natural disasters (Foster, H.F.; 1980)
4. Environmental hazards (Kates, R.W.; 1978)
5. Geophysical hazards (Wiggins, J.H.; 1977)
6. Geological hazards (Bolt, B.A., et al; 1975)

Terminology of a generalized nature is required in order that newly discovered hazards may be rapidly assimilated, and areal variations of processes may be discussed within the proper context. However, when such varied terminology exists within the ranks of the informed, it is only natural that the public is somewhat confused. For example, Hewitt and Burton (1971) prepared a table showing only some of the terms which are commonly applied in discussing natural hazards (see Table 2). The discussion of individual hazard types sometimes further confuse the issue, as individuals misinterpret between an individual hazard type such as landslips with the larger class termed natural hazards.

Table 2
Potentially Hazardous Natural Agencies or Processes

1. Atmospheric

Single Element	Compound Hazards
a) Rain	a) Rain and wind storms
b) Freezing rain ("Glaze")	b) "Glaze" storms
c) Hail	c) Thunderstorms
d) Snow	d) Tornadic storms & tornadoes
e) Wind	e) Hurricanes
f) Lightning	f) Blizzards
g) Temperature: "Cold Spell", Frost, "Heat Wave"	g) "Whiteout"
h) Fog	h) Drought

2. Hydrologic

a) Flooding: i) Riverine (rain, snowmelt, natural dam-burst floods)
ii) Lakeshore floods
iii) Marine floods (tidal, storm-surge, tsunami)
b) Lake and sea-shore wave action
c) Waterlogging
d) Sea-ice and icebergs
e) Run-off "drought"
f) Glacier advance

3. Geologic

a) Mass-movements: landslides, avalanches, mudflows, subsidence, etc.
b) Erosion (foundations, soils, etc.)
c) Silting (dykes, rivers, harbours, farmland)
d) Earthquakes
e) Volcanic eruptions
f) Shifting sands

4. Biologic

a) Severe epidemics in man
b) Severe epidemics in plants
c) Severe epidemics in domestic and wild animals
d) Animal and plant invasions (e.g. locusts)
e) Forest and grassland fires

Public awareness programs could aid greatly in clarifying any misinterpretation of terms, but first of all, the scientific community must either agree to universal terms or explain in greater detail their individual definitions.

APPENDIX C

Earthquake Record for British Columbia 1969-1978*

*1. The years 1969-1978 provide a ten year period of study similar to that for the content analysis in Appendix D (1971-1980). The same time frame has not been used because a computer printout of earthquake data for 1979 and 1980 is not yet available from the Earth Physics Branch, Pat Bay Geoscience Centre from whence the information found here has been derived.

2. The date clearly reflects the large number of seismic occurrences off the west coast of B.C. and the general groupings which occur.

3. The data shown is from January 1, 1969 up to December 31, 1978 and includes only seismic tremors of a Richter magnitude 4.0 or greater. Boundaries of the computer printout information are outlined below:

The north latitude boundaries are	54.00	60.00
The south latitude boundaries are	48.300	54.000
The east longitude boundaries are	-114.000	-120.000
The west longitude boundaries are	-134.000	-139.000

Date (Yr/Mo/Day)	Latitude	Longitude	Depth (km)	Magnitude
1969/03/10	50.50 N	129.60 W	0	4.1
1969/03/18	50.27 N	129.50 W	41	4.1
1969/03/18	50.10 N	129.70 W	0	4.5
1969/03/18	50.17 N	129.88 W	0	5.1
1969/03/18	50.10 N	130.00 W	0	5.0
1969/07/17	49.20 N	128.30 W	0	4.2
1969/08/13	48.46 N	126.49 W	0	4.6
1969/08/13	48.50 N	126.50 W	0	4.6

Date (Yr/Mo/Day)	Latitude	Longitude	Depth (km)	Magnitude
1969/09/04	49.40 N	129.20 W	0	4.2
1969/10/01	48.49 N	126.51 W	23	4.9
1969/10/01	48.50 N	126.50 W	0	4.7
1969/10/20	57.30 N	126.60 W	18	4.4
1969/10/23	50.40 N	129.90 W	18	4.1
1969/11/03	50.77 N	129.52 W	40	4.6
1969/11/03	50.80 N	129.50 W	0	4.5
1969/11/10	48.55 N	121.51 W	0	4.3
1969/11/10	48.50 N	121.50 W	0	4.3
1970/02/01	50.00 N	129.00 W	18	4.0
1970/02/01	50.48 N	129.30 W	0	4.0
1970/02/01	50.40 N	129.30 W	0	4.0
1970/02/18	50.30 N	129.80 W	18	4.7
1970/02/18	50.29 N	129.72 W	21	4.6
1970/02/18	50.20 N	129.80 W	28	4.7
1970/02/18	52.40 N	131.50 W	18	4.8
1970/02/18	52.29 N	131.52 W	4	4.7
1970/02/18	52.40 N	131.50 W	4	4.8
1970/02/19	53.30 N	132.30 W	18	4.0
1970/02/19	53.19 N	131.80 W	0	4.0
1970/02/19	53.30 N	132.30 W	0	4.0
1970/02/22	48.40 N	114.60 W	9	4.0
1970/05/18	48.60 N	122.70 W	18	4.0
1970/05/18	48.60 N	132.72 W	11	4.0
1970/05/18	48.60 N	122.70 W	11	4.0
1970/05/28	48.47 N	126.66 W	3	4.9
1970/05/28	48.40 N	126.70 W	3	4.9
1970/06/24	51.86 N	130.97 W	18	4.9
1970/06/24	51.82 N	130.75 W	33	5.0
1970/06/24	51.80 N	130.80 W	0	4.9
1970/06/24	51.74 N	131.00 W	18	7.0
1970/06/24	51.77 N	130.76 W	22	5.7

Date (Yr/Mo/Day)	Latitude	Longitude	Depth (km)	Magnitude
1970/06/24	51.80 N	131.00 W	12	7.0
1970/06/24	51.74 N	131.20 W	64	5.2
1970/06/24	51.90 N	131.10 W	0	5.5
1970/06/24	51.94 N	130.30 W	0	5.5
1970/07/03	51.80 N	131.00 W	18	4.0
1970/11/10	50.60 N	129.50 W	18	4.1
1970/11/10	50.58 N	129.22 W	49	4.1
1970/11/10	50.60 N	129.50 W	0	4.1
1970/11/16	49.30 N	128.10 W	18	4.5
1970/11/16	49.35 N	128.04 W	0	4.5
1970/11/16	49.30 N	128.10 W	0	4.5
1970/11/27	52.70 N	119.30 W	15	4.3
1970/12/01	52.70 N	119.30 W	15	4.2
1970/12/31	50.20 N	129.50 W	0	4.3
1971/01/20	58.90 N	137.20 W	0	4.0
1971/02/05	51.75 N	130.65 W	18	5.5
1971/02/05	51.78 N	130.78 W	20	5.1
1971/02/05	51.89 N	130.86 W	0	5.7
1971/02/11	54.70 N	135.20 W	0	4.6
1971/03/10	49.35 N	127.46 W	8	5.0
1971/03/10	49.30 N	127.40 W	0	5.0
1971/03/13	50.56 N	129.90 W	18	6.4
1971/03/13	50.61 N	129.99 W	22	5.7
1971/03/13	50.60 N	129.90 W	0	6.1
1971/03/14	50.60 N	129.90 W	18	4.3
1971/03/14	50.60 N	129.90 W	18	4.0
1971/03/14	50.60 N	129.90 W	18	4.3
1971/03/14	50.78 N	129.70 W	0	4.3
1971/03/14	50.80 N	129.60 W	0	4.2
1971/03/14	50.60 N	129.90 W	18	4.1
1971/03/14	50.70 N	129.70 W	0	4.2
1971/03/14	50.76 N	129.40 W	39	4.2

Date (Yr/Mo/Day)	Latitude	Longitude	Depth (km)	Magnitude
1971/03/15	50.60 N	129.90 W	18	4.2
1971/03/15	50.20 N	129.49 W	35	4.8
1971/03/15	50.10 N	129.60 W	35	4.8
1971/04/08	59.13 N	136.50 W	18	4.0
1971/05/28	52.40 N	132.40 W	18	4.6
1971/05/28	52.81 N	132.89 W	0	4.6
1971/05/28	52.80 N	132.90 W	0	4.6
1971/06/29	51.20 N	129.60 W	18	4.2
1971/06/29	51.30 N	130.00 W	0	4.2
1971/06/29	51.20 N	129.80 W	0	4.4
1971/07/15	54.60 N	133.60 W	18	5.3
1971/07/15	54.00 N	134.00 W	0	4.9
1971/07/15	54.20 N	133.70 W	0	5.2
1971/07/22	50.60 N	129.20 W	18	4.2
1971/07/22	50.77 N	129.40 W	0	4.2
1971/07/22	50.80 N	129.40 W	0	4.1
1971/08/21	50.60 N	129.40 W	0	4.3
1971/11/20	48.60 N	129.40 W	18	5.0
1971/11/20	48.79 N	129.46 W	28	5.5
1971/11/20	48.80 N	129.50 W	0	5.7
1971/11/23	48.32 N	121.44 W	18	4.1
1971/11/25	49.10 N	129.00 W	18	4.4
1971/11/25	49.38 N	129.37 W	8	4.4
1971/11/25	49.40 N	129.40 W	0	4.4
1971/11/25	49.00 N	129.10 W	18	5.1
1971/11/25	48.76 N	129.16 W	0	5.1
1971/11/25	48.80 N	129.40 W	0	5.1
1971/12/05	49.40 N	129.50 W	18	5.2
1971/12/05	49.53 N	129.47 W	5	5.5
1971/12/05	49.60 N	129.40 W	5	6.0
1971/12/05	49.80 N	129.20 W	18	5.0
1971/12/05	49.68 N	129.25 W	14	5.1

Date (Yr/Mo/Day)	Latitude	Longitude	Depth (km)	Magnitude
1971/12/05	49.70 N	129.10 W	16	5.1
1971/12/08	49.20 N	128.10 W	18	4.6
1971/12/08	49.23 N	128.41 W	0	4.6
1971/12/08	49.20 N	128.40 W	0	4.6
1971/12/08	49.20 N	128.10 W	18	5.0
1971/12/08	49.12 N	128.53 W	35	5.3
1971/12/08	49.10 N	128.50 W	0	5.3
1971/12/09	56.43 N	135.59 W	18	4.2
1971/12/10	49.80 N	129.00 W	18	4.0
1971/12/10	49.80 N	129.00 W	41	4.0
1971/12/10	49.70 N	129.10 W	0	4.2
1971/12/11	49.20 N	128.40 W	18	4.2
1971/12/11	49.17 N	128.39 W	26	4.2
1971/12/11	49.20 N	128.40 W	26	4.5
1971/12/25	49.30 N	128.50 W	18	4.3
1971/12/25	49.25 N	128.48 W	1	4.3
1971/12/25	49.30 N	128.40 W	0	4.5
1971/12/30	49.10 N	128.80 W	18	4.0
1971/12/30	49.09 N	128.80 W	0	4.0
1971/12/30	48.90 N	128.80 W	0	4.2
1972/01/14	50.32 N	130.79 W	18	4.4
1972/01/14	50.78 N	129.69 W	5	4.4
1972/01/15	50.80 N	129.60 W	0	4.5
1972/01/28	50.90 N	129.30 W	0	4.5
1972/01/28	50.70 N	129.60 W	0	4.2
1972/03/12	58.98 N	137.90 W	44	4.3
1972/03/12	58.90 N	136.90 W	29	4.2
1972/05/14	50.90 N	129.40 W	38	4.4
1972/05/20	49.40 N	128.40 W	28	4.7
1972/05/29	57.40 N	137.50 W	0	4.2
1972/06/05	50.80 N	129.40 W	0	4.1
1972/06/17	50.40 N	129.70 W	0	4.3

Date (Yr/Mo/Day)	Latitude	Longitude	Depth (km)	Magnitude
1972/06/18	54.27 N	133.61 W	18	4.3
1972/07/05	49.59 N	127.18 W	25	5.7
1972/07/05	49.45 N	127.19 W	26	5.6
1972/07/05	49.50 N	127.20 W	27	5.8
1972/07/18	49.00 N	128.70 W	0	4.8
1972/07/23	50.12 N	129.25 W	18	4.8
1972/07/23	50.11 N	129.09 W	0	4.8
1972/07/23	50.20 N	129.10 W	0	4.5
1972/07/23	50.10 N	129.30 W	31	5.8
1972/07/23	50.10 N	129.30 W	0	6.4
1972/07/23	50.39 N	128.88 W	18	6.4
1972/07/23	50.21 N	129.16 W	20	4.8
1972/07/23	50.10 N	129.30 W	0	4.8
1972/07/23	49.82 N	129.77 W	18	4.8
1972/07/23	50.06 N	129.30 W	0	4.8
1972/07/23	49.90 N	128.70 W	0	5.0
1972/07/30	56.77 N	135.91 W	29	6.2
1972/07/30	56.80 N	135.70 W	25	7.6
1972/07/30	56.30 N	136.10 W	0	4.5
1972/07/30	56.55 N	136.90 W	69	4.5
1972/07/31	56.63 N	135.78 W	18	4.3
1972/07/31	56.50 N	136.30 W	0	4.3
1972/07/31	56.01 N	135.53 W	18	4.2
1972/08/04	56.23 N	135.64 W	18	4.9
1972/08/04	56.20 N	135.50 W	18	5.0
1972/08/04	56.19 N	135.42 W	18	5.5
1972/08/04	56.20 N	135.30 W	20	5.8
1972/08/10	55.98 N	135.67 W	18	4.0
1972/08/15	56.31 N	135.57 W	23	5.4
1972/08/15	56.30 N	135.50 W	21	4.8
1972/08/18	57.40 N	136.10 W	0	4.1
1972/10/09	58.50 N	138.40 W	37	4.1

Date (Yr/Mo/Day)	Latitude	Longitude	Depth (km)	Magnitude
1972/10/09	58.50 N	138.20 W	0	4.0
1972/11/07	56.23 N	135.71 W	18	4.4
1972/11/07	56.70 N	134.60 W	0	4.4
1972/11/15	56.34 N	136.15 W	18	4.2
1972/11/15	56.40 N	136.32 W	0	4.2
1972/11/17	56.03 N	135.60 W	0	4.8
1972/11/17	56.00 N	135.50 W	0	5.0
1972/12/08	56.30 N	135.90 W	0	4.2
1973/01/12	56.10 N	135.51 W	18	4.3
1973/01/14	56.27 N	135.52 W	18	4.3
1973/03/04	52.06 N	118.07 W	18	4.6
1973/03/04	52.08 N	118.00 W	16	4.6
1973/03/04	52.03 N	118.04 W	18	4.3
1973/03/04	52.09 N	118.00 W	15	4.3
1973/03/11	56.91 N	136.43 W	0	4.3
1973/03/22	52.06 N	118.01 W	18	4.2
1973/03/22	52.07 N	118.00 W	15	4.2
1973/03/25	48.95 N	128.93 W	0	4.2
1973/03/28	50.54 N	129.59 W	0	4.2
1973/04/17	50.83 N	129.52 W	19	4.2
1973/06/05	50.55 N	130.31 W	18	4.2
1973/06/03	50.64 N	129.80 W	28	4.5
1973/07/01	57.84 N	137.33 W	0	6.1
1973/07/01	57.78 N	137.28 W	0	5.2
1973/07/01	57.68 N	137.50 W	0	4.2
1973/07/02	57.93 N	137.68 W	0	4.5
1973/07/03	58.05 N	137.73 W	0	4.6
1973/07/03	57.98 N	138.02 W	0	6.0
1973/07/03	57.99 N	137.88 W	0	5.1
1973/07/04	58.06 N	137.31 W	0	4.5
1973/07/04	58.01 N	137.85 W	0	4.6
1973/07/05	58.01 N	137.29 W	0	4.5

Date (Yr/Mo/Day)	Latitude	Longitude	Depth (km)	Magnitude
1973/07/05	57.90 N	137.90 W	0	4.9
1973/07/09	50.90 N	129.71 W	0	4.5
1973/07/11	57.92 N	138.06 W	10	4.6
1973/07/13	49.12 N	127.84 W	0	4.8
1973/07/13	49.02 N	128.02 W	18	4.5
1973/07/13	49.03 N	128.01 W	0	5.3
1973/07/14	58.00 N	138.00 W	0	5.0
1973/07/27	58.05 N	137.66 W	5	4.0
1973/07/28	58.00 N	137.89 W	10	4.7
1973/09/05	53.87 N	133.07 W	18	4.0
1973/09/06	51.17 N	130.40 W	18	4.3
1973/09/06	51.10 N	129.88 W	0	4.6
1973/09/16	50.32 N	129.65 W	0	4.4
1973/10/26	59.11 N	135.37 W	0	4.8
1973/11/05	54.43 N	129.06 W	10	4.9
1974/01/27	59.35 N	136.37 W	29	4.0
1974/01/29	49.31 N	129.12 W	14	4.2
1974/02/07	59.17 N	137.03 W	0	4.0
1974/03/07	50.76 N	129.77 W	0	4.2
1974/04/03	54.12 N	133.41 W	18	4.5
1974/04/08	54.25 N	133.36 W	18	4.5
1974/04/08	54.13 N	134.10 W	0	4.0
1974/04/15	59.19 N	136.43 W	7	4.2
1974/05/30	49.06 N	128.39 W	0	4.8
1974/07/06	49.59 N	129.49 W	0	4.4
1974/07/20	49.70 N	127.04 W	18	4.2
1974/07/20	49.92 N	126.52 W	0	4.0
1974/08/01	50.66 N	129.67 W	0	4.1
1974/08/17	49.11 N	128.40 W	0	4.7
1974/08/20	51.06 N	130.70 W	18	4.3
1974/08/20	51.20 N	129.94 W	0	4.3
1974/08/22	48.94 N	128.60 W	0	4.4

Date (Yr/Mo/Day)	Latitude	Longitude	Depth (km)	Magnitude
1974/11/14	49.34 N	129.23 W	0	4.4
1974/11/26	50.67 N	129.64 W	0	4.5
1974/12/07	49.26 N	128.63 W	0	4.1
1975/01/02	49.33 N	128.98 W	0	4.4
1975/01/29	50.08 N	129.35 W	0	4.5
1975/01/29	50.06 N	129.55 W	0	4.3
1975/02/06	49.33 N	129.60 W	0	4.3
1975/02/18	50.72 N	129.93 W	0	4.2
1975/02/18	50.71 N	129.77 W	0	4.0
1975/03/19	49.31 N	127.35 W	0	4.2
1975/03/20	50.72 N	129.24 W	0	4.3
1974/03/31	49.27 N	125.96 W	18	5.4
1975/03/31	49.40 N	125.60 W	33	5.3
1975/04/07	51.64 N	130.88 W	18	4.1
1975/04/07	51.80 N	130.10 W	0	4.2
1975/05/23	51.22 N	131.23 W	18	4.7
1975/05/23	51.34 N	131.24 W	0	5.1
1975/06/05	57.95 N	124.80 W	18	4.2
1975/08/01	49.27 N	128.79 W	16	4.7
1975/08/07	49.16 N	129.03 W	20	4.4
1975/08/20	51.53 N	130.62 W	0	4.5
1975/11/24	51.52 N	130.51 W	0	4.8
1975/11/28	49.61 N	126.32 W	0	4.0
1975/11/30	49.36 N	123.51 W	0	4.7
1975/12/11	50.05 N	130.19 W	18	4.1
1975/12/11	50.12 N	129.93 W	0	4.7
1975/12/11	50.09 N	130.11 W	18	4.1
1975/12/11	50.18 N	129.85 W	22	4.8
1975/12/12	49.68 N	130.16 W	18	4.1
1975/12/12	50.02 N	130.23 W	18	4.3
1975/12/12	49.98 N	130.24 W	18	4.1
1976/01/01	50.26 N	129.72 W	0	4.6

Date (Yr/Mo/Day)	Latitude	Longitude	Depth (km)	Magnitude
1976/01/01	50.19 N	130.18 W	19	4.3
1976/01/01	50.27 N	129.82 W	19	4.9
1976/01/01	50.18 N	129.56 W	0	4.3
1976/01/02	50.38 N	130.02 W	22	4.4
1976/01/02	50.39 N	129.83 W	22	4.2
1976/02/15	57.91 N	138.57 W	18	4.1
1976/02/23	51.46 N	130.76 W	18	4.1
1976/02/23	51.60 N	130.51 W	18	4.3
1976/02/23	51.47 N	130.44 W	16	6.0
1976/02/23	51.47 N	130.68 W	18	4.7
1976/02/23	51.58 N	130.07 W	0	4.6
1976/02/27	50.87 N	130.71 W	18	4.0
1976/02/28	51.00 N	130.76 W	18	4.1
1976/04/25	49.41 N	127.11 W	18	4.4
1976/04/25	49.54 N	126.57 W	0	4.3
1976/05/13	52.86 N	132.24 W	18	4.8
1976/05/13	53.11 N	132.10 W	0	4.8
1976/05/15	49.11 N	128.76 W	0	4.5
1976/05/16	48.80 N	123.34 W	18	4.6
1976/05/16	48.80 N	123.36 W	62	5.1
1976/06/06	49.04 N	127.86 W	18	5.0
1976/06/06	49.03 N	127.87 W	0	5.3
1976/06/06	49.13 N	127.74 W	0	4.5
1976/06/07	48.96 N	127.68 W	0	4.2
1976/06/18	53.92 N	133.06 W	18	4.3
1976/08/12	50.62 N	123.01 W	0	4.2
1976/08/26	50.63 N	129.43 W	0	4.4
1976/11/07	57.88 N	137.79 W	18	4.2
1976/11/07	57.72 N	138.04 W	0	4.0
1976/11/09	50.61 N	129.84 W	18	4.0
1976/11/09	50.59 N	129.76 W	0	4.6
1976/11/10	51.37 N	130.67 W	18	4.1

Date (Yr/Mo/Day)	Latitude	Longitude	Depth (km)	Magnitude
1976/11/17	49.44 N	126.15 W	18	4.3
1976/11/17	49.53 N	125.80 W	0	4.2
1976/12/20	49.09 N	128.72 W	0	4.2
1976/12/20	49.00 N	128.88 W	18	4.7
1976/12/20	49.08 N	128.96 W	0	5.1
1976/12/20	49.02 N	128.67 W	18	5.1
1976/12/20	48.80 N	129.29 W	0	6.7
1976/12/20	48.90 N	128.72 W	0	5.1
1976/12/20	49.19 N	129.17 W	18	4.1
1976/12/20	49.16 N	129.02 W	0	5.1
1976/12/20	48.92 N	128.57 W	0	4.9
1976/12/26	49.43 N	129.62 W	0	4.7
1976/12/26	49.38 N	130.03 W	18	4.1
1976/12/26	49.42 N	129.49 W	0	4.7
1977/01/20	57.86 N	137.86 W	18	4.3
1977/01/20	57.65 N	138.02 W	36	4.5
1977/03/16	50.80 N	129.56 W	33	4.5
1977/04/03	50.67 N	129.86 W	4	4.7
1977/07/09	51.05 N	130.01 W	33	4.2
1977/07/14	49.15 N	129.57 W	10	4.3
1977/08/08	55.56 N	135.26 W	18	4.6
1977/10/09	53.69 N	118.04 W	33	4.4
1978/01/13	52.65 N	132.13 W	18	4.1
1978/01/13	52.75 N	132.08 W	33	4.1
1978/05/10	59.15 N	136.14 W	18	4.2
1978/05/14	52.66 N	118.70 W	10	4.4
1978/05/15	49.26 N	129.13 W	10	4.2
1978/05/26	50.86 N	130.45 W	18	4.4
1978/05/26	51.17 N	130.43 W	17	4.5
1978/06/02	50.13 N	127.64 W	18	5.0
1978/06/02	50.26 N	127.69 W	21	5.2
1978/06/11	49.26 N	129.50 W	10	6.1

Date (Yr/Mo/Day)	Latitude	Longitude	Depth (km)	Magnitude
1978/06/30	49.12 N	129.01 W	10	4.1
1978/07/07	49.10 N	129.30 W	10	4.2
1978/07/11	52.67 N	132.03 W	18	4.8
1978/07/11	52.77 N	132.10 W	10	5.1
1978/07/11	52.62 N	131.85 W	18	4.1
1978/07/12	56.70 N	137.50 W	38	4.1
1978/07/19	50.74 N	128.69 W	18	4.0
1978/07/25	50.19 N	127.37 W	18	5.0
1978/07/25	50.30 N	127.58 W	11	5.1
1978/08/03	58.46 N	137.79 W	33	4.5
1978/08/18	56/36 N	135.19 W	18	4.2
1978/09/01	58.00 N	138.23 W	18	4.3
1978/09/01	57.99 N	138.63 W	33	4.1
1978/11/01	50.76 N	129.69 W	33	4.0
1978/11/11	50.63 N	130.40 W	18	4.0
1978/11/11	50.85 N	129.78 W	33	4.3
1978/11/24	49.55 N	129.47 W	10	4.1

APPENDIX D

Content Analysis For Geological Hazards In British Columbia From 1971-1980

1. Content Analysis of newspapers for the years 1971-1980 is presented in the following listing. Newspapers surveyed included:
   A. Victoria Times,
   B. Vancouver Province, and
   C. Vancouver Sun.

2. In addition, government agencies were able to supply partial lists (with approximate costs) of events which were not covered in those newspapers studied. These have been incorporated into the listing.

3. A large number of small magnitude events have also occurred, however these have generally gone unrecorded or have only fragmented information.

GEOLOGICAL HAZARDS IN BRITISH COLUMBIA 1971-1980

Date	Location	Hazard Type	Damage	Loss of Life	Cost	Comments
June 8/80	Garibaldi	(Rockslide) Flood	Pre-event Action	---	$9,000,000	First case of outright purchase prior to the occurrence of an event causing damage - sets a precedence for other cases in the future.
July 28/80	Pend d'Orielle River	Landslide	1 home & approx. four acres were lost	---	$150,000	Caused by rapid drawdown in B.C. Hydro Reservoir.
Dec. 12/80	Three Valley Gap	Snow Avalanche	Trans Canada Hwy. blocked	---	$5,000	Due to heavy snowfall.
Dec. 18/80	Vancouver Island	Earthquake	No damage	---	---	Magnitude 6.25 quake was centered too deep to do any surface damage.
Dec. 1980	Bella Coola	Floods	Extensive damage to homes and buildings & to spawning streams, transportation routes cut	1	$2,000,000	Caused by high intensity, near record rainfalls.

Date	Location	Hazard Type	Damage	Loss of Life	Cost	Comments
Dec. 25/ 31/80	Lower Mainland and Vancouver Island	Floods	Destruction of homes by flood water and land-slides, highways cut & numerous homes were evac-uated, railways also damaged.	---	$13,000,000	Due to record rainfalls.
Feb. 5/79	Victoria (Colwood)	Landslip	Cracked walls and foundation	---	$5,000	Poor construction tech-niques on landslip prone area
Feb. 12/79	Salmo-Creston Pine Pass	Snow Avalanche	Highways blocked	---	$5,000	Heavy snow and warm temperatures
Feb. 13/79	Mica Dam	Snow Avalanche	B.C. Hydro Power line was damaged	---	$60,000	
Feb. 13/79	Rogers Pass	Snow Avalanche	Highway bridge was shifted off abutments	---	$500,000	Approx. 3 km west of Connaught Tunnel
Feb. 14/79	Golden	Snow Avalanche	No damage	7	---	Day skiing exhibition trapped by avalanche
Feb. 20/79	Flute Creek	Snow Avalanche	---	1	---	Whistler Mountain area
Feb. 23/79	Mt. MacKenzie	Snow Avalanche	---	1	---	Approx. 5 km south of Revelstoke

Date	Location	Hazard Type	Damage	Loss of Life	Cost	Comments
Feb. 24/79	Stanley Park Glacier	Snow Avalanche	---	2	---	---
Mar. 13/79	Vancouver Island	Earthquake	No damage	---	---	3.5 magnitude quake centred in Juan de Fuca Strait
Mar. 17/79	25 km N.W. of Goldbridge	Snow Avalanche	---	1	---	---
Nov. 27/79	Rennell Sound	Landslide	Extensive damage to salmon spawning creek	---	?	Resulted from poor logging practices
Dec. 10/79	Hope	Mudslides	Buried mine buildings & closed roads	1	$125,000	Man killed while working in shed-slide due to torrential rains
Dec. 13/79	Prince Rupert	Landslide	Derailed 11 train cars and engine	---	$275,000	Caused by heavy rains and winds
Dec. 14/79	Victoria	Flood	Damage to highways, flooded basements, some small slides	---	$50,000	Caused by heavy rains
Dec. 15/79	Port Moody	(Floods) Landslide	Destroyed 1 home & damaged others and inundated several areas	---	$1,000,000	Caused by record rainfalls

Date	Location	Hazard Type	Damage	Loss of Life	Cost	Comments
Dec. 13 -21/79	Southwest BC	(Landslide)	Many homes flooded, cars trapped, roads washed out	---	$5,000,000	Caused by record rainfalls
Jan. 1978	Rogers Pass	Snow Avalanche	Closed Trans Canada Hwy. periodically	---	$10,000	Heavy snows and high winds
Mar. 9/78	Revelstoke	Landslide	No damage	---	Nil	12,000 tons nearly hit several men
Jul. 26/78	Northern Vancouver Island	Earthquake	No damage	---	---	Minor tremor of about 5 minute duration
Jul. 31/78	Kamloops (Barnhartvale)	Landslide	Endangered approx. 20 houses - led to removal of 1 home	---	$250,000	Slide occurred in "geologically very unstable" area
Aug. 24/78	Victoria	Earthquake	No damage	---	---	3.6 on Richter - 2nd in five days
Sept 27/78	Field	Mudslide	2 locomotives & 3 train cars derailed; 2 cars trapped on highway; highway closed for 48 hrs.	---	$1,000,000	Occurred during high rainfall period in area of previous slide in 1925

Date	Location	Hazard Type	Damage	Loss of Life	Cost	Comments
Nov. 2-8/ 78	Terrace - Kitimat	Flood	Extensive damage to transportation links, natural gas lines, buildings, spawning streams and resort facilities	2	$4,000,000	Record rainfalls and melting snow cause floods; Prov. Gov't. major disaster fund employed and federal aid was requested
Dec. 16/78	Denn's Creek Basin	Snow Avalanche	---	1	---	14 km north of Roseberry
Mar. 16/77	Diana Lake (Brisco)	Snow Avalanche	---	1	---	---
Mar. 17/77	Bugaboo Lodge	Snow Avalanche	---	3	---	Skiers caught in avalanche path
Mar. 21/77	Apex Alpine Snow Resort	Snow Avalanche	---	1	---	Skier caught by avalanche approximately 20 miles west of Penticton
Aug. 26/77	Nakusp	Sinkhole	Swallowed a power pole, construction equipment & a stack of tires	---	$20,000	Caused by water entering an existing hole which resulted from erosion or glacial activity
Oct. 1977	Field	Snow Avalanche	---	1	---	---

Date	Location	Hazard Type	Damage	Loss of Life	Cost	Comments
Oct. 29/77	Trans Canada Hwy-Mile 31.6	Rockfall	Blocked highway	---	$2,000	Occurred during intensive rainfall
Nov. 1/77	Kelowna	Landslide	Inundated building lot and caused reduced property values	---	$75,000	Sub-excavation in area of known instability
Nov. 3/77	McConnel Creek	Mudflow-flood	Damaged cars and inundated field	---	$25,000	High rainfall and rapid runoff
Dec. 28/77	Vancouver	Rockslide	Rubble blocked seawall	---	$2,000	Heavy rain in unstable undermined material
Jan. 16/76	East of Salmo (20 miles)	Snow Avalanche	---	3	$25,000	---
Feb. 12/76	Kamloops (Valleyview)	Land Subsidence	Extensive damage to swimming pool and rec. centre	---	$300,000	Actual shutdown of pool in May, 1975
Mar. 23/76	Paradise Base Mountain	Snow Avalanche	---	1	---	Occurred in the Bugaboo Mountain range
May 16/76	Lower Mainland and Victoria	Earthquake	Minor damage to windows and cracked walls	---	$100,000	Largest in 56 years

Date	Location	Hazard Type	Damage	Loss of Life	Cost	Comments
Jul. 29/76	Vernon	Landslide	Buried mobile home and injured women	---	$45,000	Possible result of irrigation
Aug. 25/76	Lion's Bay	Landslide	Derailed BCR train engine & cut highway	---	$1,000,000	
Sept. 2/76	Victoria	Earthquake	Minor	---	---	Localized earth tremor
Sept. 4/76	Prince Rupert	Mudslide	Cut power lines & blocked highway	---	$20,000	Resulted from high-intensity rainfalls
Sept. 5/76	Port Edward	Mudslide	Cut hydro lines, highway and CNR line	---	$125,000	Resulted from high-intensity rainfalls
Dec. 12/76	Chancellor Peak	Snow Avalanche	---	3	---	In Yoho National Park
Feb. 13/75	Allison Pass	Snow Avalanche	Residence and part of service station hit	---	$100,000	Sumallo Service
May 1/75	Chase	Landslide	Trans Canada Hwy damaged	---	$250,000	Highway was closed for 4 days
May 4/75	Mount Robson	Landslide	CNR Railway damaged plus station bldgs.	---	$250,000	People waiting for trains nearly hit

Date	Location	Hazard Type	Damage	Loss of Life	Cost	Comments
Nov. 13/75	Port Alice	Mudslide Flood	Extensive damage to town & spawning streams-	---	$1,000,000	Extensive protection works constructed against future events
Dec. 1/75	Victoria	Earthquake	Minimal damage	---	---	4.0 on Richter scale
Jan. 22/74	28.5 miles W. of Terrace	Snow Avalanche	3 buildings were totally destroyed	7	$150,000	Occupants of buildings were killed
Feb. 7/74	Mica Mountain	Snow Avalanche	---	1	---	Occurred in area 7 miles west of Valemont
June 15/74	Fort St. John	Landslide	BCR Rail line cut	---	$1,000,000	Railway service cut for 2 1/2 months
June 20/74	Fraser River	Flood	Extensive damage to agricultural areas	---	$250,000	Caused many cattle to be marooned
Nov. 20/74	Malahat	Mudslide	1 vehicle	---	$5,000	Occurred during high rain-fall period
Dec. 29/74	5 miles west of Golden	Snow	---	1	---	---
Jan. 22/73	10 Miles from Kenans	Snow Avalanche	Damage to BC Hydro Transmission Tower	---	$100,000	Occurred at 2300 foot elevation

Date	Location	Hazard Type	Damage	Loss of Life	Cost	Comments
May 17/73	Attachie	Landslide	Minimal	---	---	Blocked Peace River for 24 hours
Dec. 20/73	Port Alice	Mudslide	Destroyed 1 home and damaged others	---	$300,000	1st debris flow in town-site
Jan. 23/72	Revelstoke	Snow Avalanche	Blocked Big Bend Highway for 3 days	---	$15,000	5 people were trapped for 2 days
Mar. 5/72	Giant Mascot Mine	Snow Avalanche	Damaged vehicle; blocked access road	3	$10,000	Due to heavy snowfall
Apr. 8/72	Whistler Mountain	Snow Avalanche	---	4	---	---
Apr. 23/72	12 miles SE of Nelson	Snow Avalanche	---	1	---	Near proposed Whitewater ski development
June 1/72	Hedley	Flood	Homes destroyed	---	$200,000	Floodwaters on Similkameen River
June 20/72	Ashcroft	Flood	Considerable flood damage to homes and water supply facilities	---	$5,000,000	$2.5 million in aid promised by Ottawa

Date	Location	Hazard Type	Damage	Loss of Life	Cost	Comments
July 13/72	Kamloops	Flood	Trailer Park near totally destroyed and North Kamloops heavily damaged	---	$8,000,000	Some help from Ottawa 3-5 days before flood waters receded
Sept 12/72	Natal	Landslide	Severely damaged open pit mine	2	$2,000,000	Kaiser charged with negligence - as mine waste slid down hill and into open pit
Feb. 16/71	Boston Bar	Landslide	CNR train derailed	3	$2,500,000	Bodies were swept into Fraser River
Dec. 23/71	Granite Mountain	Snow Avalanche	Nil	1	---	Result of heavy snowfall
Dec. 24/71	Flathead (Fernie)	Snow Avalanche	1 vehicle destroyed	3	$10,000	Result of heavy snowfall

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AN ASSESSMENT OF NATURAL HAZARDS MANAGEMENT IN BRITISH COLUMBIA

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