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MANAGING FALL FLOODS IN THE LOWER SKEENA REGION, BRITISH COLUMBIA

by

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ABSTRACT

This study investigates flood characteristics and management strategies in the Lower Skeena River Region. Rivers in the region exhibit two annual flood seasons in which different types of floods occur. Typically, rivers tend to flood during spring freshet in May and June as a result of snowmelt runoff within the Skeena basin. However, intense and sustained rainstorms contribute to another type of flood in the fall months in the Lower Skeena Region. Although the most extensive and largest flood of record occurred as a result of regional snowmelt runoff in the spring of 1936, the flood inflicting the greatest damage occurred in the fall of 1978 as a result of three days of continuous heavy rain.

In contrast with the remainder of the Skeena basin where spring freshet floods are critical, fall floods in the Lower Skeena occur more frequently than spring floods and for the same return period are greater in magnitude. Despite the implementation of flood damage prevention measures in the Lower Skeena Region, flood damage continues to increase and this is largely the result of fall floods.

Analysis of the meteorologic and hydrologic features of fall floods indicates important differences in the duration and pattern of flooding throughout the Lower Skeena as compared to spring freshet floods. The interval between the time when the possibility of a flood is known and when it actually occurs is shorter for fall floods, different properties are subject to flooding and the frequency of flooding of most flood prone areas is greater. This indicates the need for a different strategy to manage the flood problem.

The current program of flood damage prevention measures in the Lower Skeena is based on the physical characteristics associated with spring

freshet flooding. The existing approach in the region is part of a blanket strategy toward managing floods province-wide. The strategy relies almost entirely on nonstructural measures of flood forecasting, floodplain regulation and floodproofing. The design flood, with a 1 in 200 year return period adopted as a basis for the current strategy is derived from the features of the 1936 spring freshet flood. These measures provided no assistance in reducing damages during the fall flood of 1978.

A framework for developing a comprehensive flood management strategy to handle fall floods is applied to New Remo, a Lower Skeena flood prone community. The strategy entails the following five steps:

- I Define the Spatial Distribution of Flood Damages
- II Design a Flood Forecasting Service
- III Design an Emergency Plan for Action During Floods
- IV Assess Remaining Practicable Alternatives for Reducing Flood Damage
- V Develop a Financing Policy for the Program

Potentially feasible adjustments to the flood hazard in New Remo include; (1) flood forecasting, (2) emergency action, (3) floodproofing and (4) permanent evacuation of some homes. However, to develop an optimum combination of alternative adjustments will require site specific information on flood damage risk, which currently is not available for properties in New Remo.

The flood management strategy developed for New Remo would be applicable to other communities in the Lower Skeena, prone to fall flooding. However, regional application of the approach requires tailoring the strategy according to the physical, social and economic features within each community affected by fall floods.

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CHAPTER 1

INTRODUCTION

I The Flood Problem in the Skeena

This thesis focusses on the problem of fall floods in the Lower Skeena River Region of British Columbia with a view toward developing a strategy to reduce flood damage. The study deals with the physical features of the flood hazard in demonstrating the importance of fall floods in contributing to annual flood damage. The current flood management approach is assessed in light of the fall flood problem to point out important limits in its ability to prevent flood damage. A strategy geared toward the physical features of fall floods is developed to achieve comprehensive flood damage reduction for communities of the Lower Skeena Region incurring this type of flood problem.

The Lower Skeena River Region, from Hazelton to the coast has a history of flooding. Minor floods are regular events, occurring almost annually in some localities, while in a few communities, floods have occurred twice in a single year.

At least six major floods have inflicted costly damage and severe disruption within the region during this century. The earliest, devastating flood occurred in 1936, when excessive and sustained snowmelt produced extensive damage during spring along the lower course of the Skeena. This flood was severe enough to stall floodplain encroachment in some localities and redirect other townsites toward building on less hazardous sites. To date, the 1936 flood is the largest recorded event of its type on the Skeena River but not the most damaging. In 1948 another spring flood inflicted devastating losses and disruption as renewed floodplain encroachment had prevailed in the intervening period, free from severe floods. Damaging snowmelt floods occurred once again in 1964 and 1972 and it was evident after the latter event, second only in magnitude to the flood of 1936 that recurrent and increasing flood damage was impeding optimal use of floodplains and threatening the social well-being of the regional population. Something had to be done to deal with the flood problem.

In recognition of the vital nature of floodplain resources in the settlement and development pattern of British Columbia, and the problem of mounting flood losses, the Province initiated a program of flood damage prevention for provincewide application in 1973. The program designated nonstructural measures to cope with flood problems. Flood forecasting, emergency action plans, floodplain regulations controlling development in flood zones and floodproofing requirements for new construction were developed for communities and districts facing flood problems. The emergent approach is geared solely toward the physical features associated with snowmelt floods generally occurring in spring, as these are regarded as a pervading common problem throughout the province. For example, in the Fraser, Columbia and Okanagan River Systems, as well as the Skeena, spring freshet floods continue to be a primary focus for concern in managing flood losses (Province of British Columbia, 1980).

In the Skeena River system, an apparently unrecognized flood problem emerged during the past ten years. In 1974, heavy sustained rainfall generated severe floods along many of the tributaries of the Lower Skeena and on parts of the Skeena floodplain during autumn. Not only was the timing different but the floodwaters affected different localities from those having had experience with spring, snowmelt floods. Flood damage, although localized in small communities in the Lower Skeena Region, totalled slightly in excess of $1 million. In 1978 another flood occurred in response to heavy fall rainfall, but this time the damages were more extensive and expensive, exceeding $50 million. Despite the prevailing flood damage prevention program, flood damages within the Lower Skeena Region exhibit an increasing trend, and raise critical questions about the scope of the current flood management approach.

The prevailing flood damage prevention program appears to fail in incompassing the fall flood problem. The current strategy focusses on the characteristics of the spring flood hazard in the Lower Skeena Region and the measures designated toward managing it do not assist in reducing fall flood damages in the region. This study focusses on the fall flood problem evident in the Skeena and suggests an approach toward its management. The strategy proposed here is not new, but emerges from a synthesis of the literature on flood management, in light of the nature of the flood hazard in the Lower Skeena, and the backdrop of the prevailing program operating in the region.

II Flood Management Strategies

A. Flood Control to Flood Damage Reduction

Flood management literature abounds with studies describing and evaluating policies and programs in numerous American floodplain settings. In the United States, population, development and floods interact to generate flood hazards of a more extensive nature and greater severity than in Canada. Furthermore, constitutional differences have contributed toward different institutional arrangements and organizational features applied in the management of floods in each country. Despite these and other differences, conceptual strategies have evolved along similar lines in seeking a socially optimum use of floodplain resources. Flood management strategies have shifted gradually from single purpose flood control projects, through the incorporation of multiple objectives in planning water resource programs, to the contemporary approach involving multiple means management described by White (1975, 1979).

Until 1936, the problem of floods in the United States was regarded primarily as a local or at most a state concern. The Flood Control Act of 1936, devised in the wake of devastating floods of national concern, acknowledged the federal responsibility to manage flood problems. More than this, the legislation encouraged the development of multiple purpose water resource planning and provided the criteria of economic efficiency as a basis for assessing proposed projects (James, 1972). Despite its limitations and criticisms made of it the conceptual framework of maximizing net economic benefits as a criterion provided the foundation for the evolution of current procedures for considering the social and environmental tradeoffs in resource evaluations.

For almost 30 years, the strategy for managing floods embraced a narrow range of structural adjustments. Flood control, achieved by dams, levees, floodways were distinct technical solutions within the mandate and competance of the government agencies responsible for managing floods. Consideration and implementation of alternative nonstructural adjustments, such as floodproofing and floodplain regulations were frustrated by the ease of implementation of physical solutions and its apparent success. Nonstructural adjustments appeared too intricate, and were viewed as requiring extensive administrative overhaul to achieve feasibility. Flood management programs tended to follow in the wake of disasters, and result in highly visible structural panaceas which in turn were dramatic testaments to the competance of the design agency and the power of the community.

Critics of the flood control strategy pointed to the large expenditures on flood control and protection works and the prevailing increase in annual flood damages. According to White (1975) over $7 billion in 30 years had been spent on flood control works in the United States and yet annual flood damages demonstrate an increasing trend. Platt (1979) conservatively estimates the bill for American flood damage to exceed $50 billion during the 1980's based on the prevailing trend.

Gilbert White in 1945 was first to allude to the cause of the problem and others (Kates, 1962; Kates and White, 1961; Sewell, 1965 and James, 1973) have confirmed that encroachment into floodplains was a major factor in contributing to an increase in flood damage potential. The need for supplementary, and in some cases alternative measures of flood damage mitigation became increasingly apparent.

Efforts by White (1960), Kates and White (1961) and Kates (1962) assisted in widening the choice among alternative flood management adjustments by pointing to the apparent advantages of floodproofing, landuse regulation and flood warning systems. Kates (1962) was instrumental in demonstrating the factors involved in constraining the choice of adjustments to floods made by private and public floodplain managers. Individual perception emerged as a critical factor in conditioning response to flood hazards. Adjustments made to a flood problem are conditioned by the managers'perception of the physical characteristics of the hazard and the perceived technical and economic feasibility of various adjustments available to cope with it.

The studies of White and his co-workers assisted in shifting the emphasis from structural flood management toward a behavioral approach emphasizing integrated choice from among a broad range of flood management tools (Table 1). According to White (1979) the trend is currently away from reliance on manipulating floods to a comprehensive consideration of various measures to distribute losses, alter floodplain use as well as possible flood control. Nonstructural flood management strategies have only recently been given the encouragement required to achieve comprehensive flood damage reduction (Platt, 1979).

Perhaps more significant in directing the emphasis away from flood control has been the application of economic evaluation to demonstrate the economic efficiency of nonstructural flood management strategies relative to flood control.

Debate over optimum floodplain investment and use relied on economic analysis to resolve issues (Lind, 1967; Whipple, 1968). James (1967) described a systematic procedure for determining the optimum combination of structural and nonstructural measures for flood control according to the criterion of economic efficiency. James and Lee (1971) demonstrate the design framework for evaluating technically feasible flood management alternatives in combination for particular flood hazard types. Advocating the use of an economic approach for floodplain planning, James (1972) demonstrates that benefit-cost criteria is essential in determining the elements in a unified program for managing flood losses. Economic criteria are applied to determine whether development should be permitted in a given floodplain as well as to determine whether structural measures should be built to protect the floodplain.

Rising costs of structural measures and continued increases in annual flood damage as well as environmental and other social concerns have given further encouragement toward nonstructural strategies through the 1970's. These are viewed to offer flexibility, and adaptive capabilities over traditional flood control and more importantly, seek to treat the root of the

TABLE 1

STRATEGIES AND TOOLS FOR ACHIEVING FLOOD HAZARD REDUCTION

NONSTRUCTURAL

A. Modify Susceptibility to Flood Damage and Disruption

1. Floodplain Regulations
   a. state regulations for flood hazard areas
   b. local regulations for flood hazard areas
      (1) zoning
      (2) subdivision regulations
      (3) building codes
      (4) housing codes
      (5) sanitary and well codes
      (6) other regulatory tools

2. Development and Redevelopment Policies
   a. design and location of services and utilities
   b. land rights acquisition and open space use
   c. redevelopment and renewal
   d. permanent evacuation

3. Disaster Preparedness and Response Planning

4. Floodproofing

5. Flood Forecasting and Warning Systems and Emergency Plans

B. Modify the Impact of Flooding on Individuals and the Community

1. Information and Education

2. Flood Insurance

3. Tax Adjustments

4. Flood Emergency Measures

5. Postflood Recovery

STRUCTURAL

C. Modify Flooding

1. Dams and Reservoirs

2. Dykes, Levees and Floodwalls

3. Channel Alterations

4. High Flow Diversions and Spillways

5. Land Treatment Measures

6. On-Site Detention Measures

SOURCE: A Unified National Program for Floodplain Management, January 1979
U.S. Water Resources Council, Washington, D.C.

problem rather than the symptoms. Local factors have become increasingly important, and consequently, the information requirements for evaluating floodplain plans have changed. Site specific information is required for the flood hazard but, in addition social features of the target population must also be incorporated into the investigation (James, 1973). Public involvement is viewed as prime requisite to developing successful flood management plans.

The trend, evident in the strategies evolved to manage floods highlights at least five important features: (1) Program design can draw from a wide conceptual range of flood damage reduction measures, and these can be implemented in various combinations, and at various times within the planning frame of reference. (2) The designation of program elements depends upon some systematic means of evaluating social benefits relative to costs. (3) Although the structural approach is not regarded with the same esteem it once held, it is not ruled out from consideration. More often it is used in combination with other measures. (4) Long term planning tends to favour the nonstructural approach predominantly because of its potential for flexibility, adaptability, reversibility and effectiveness demonstrated in varied settings. (5) Emphasis on nonstructural flood management strategies have intensified the information requirements for planning, necessitating more localized refinements in formulating policy elements. Flood management policies appear to have evolved to a point where they seek optimal social adjustments to various flood hazards, not by structural control alone but through such measures in combination with nonstructural approaches.

B. A Framework for Flood Damage Reduction Policy

In light of the foregoing review, it is advantageous at this point to set out the conceptual framework for this study. Flood management policies seek to designate a strategy which endeavors to provide for an appropriate level and pattern of adjustments to a flood hazard. These include practicable nonstructural and structural elements, designated in light of the flood hazard.

The appropriate combination and degrees of the practicable alternatives are derived by weighing the benefits and costs in both quantitative and qualitative terms, and comparing them with a view toward maximizing human welfare. In so doing, relevant information is set forth for choice in the political process for the design of a socially optimal flood management policy. The policy may not seek to minimize or reduce flood damages but at least the benefit-cost framework will provide an objective way to indicate the trade-offs to be made in the process.

Flood damage reduction policies seek to develop the best rather than the least use of the floodplain. Comprehensive flood damage reduction programs incorporate:

> .....all measures for planning and action that are needed to determine, implement and revise plans for the wise use of floodplain lands and their related water resources for the welfare of society (Goddard, in Dougall, 1969).

III Study, Objectives and Scope

This study has four sequential objectives in investigating fall floods in the Lower Skeena River Region. These are:

(1) to describe the physical characteristics of the fall flood hazard in the Lower Skeena Region,

(2) to describe and assess the current approach for managing floods in the region of the Lower Skeena,

(3) to exemplify the current situation in the Lower Skeena Region using New Remo as a case study,

(4) to devise and describe a strategic approach to manage fall floods at New Remo.

Hydrologic analysis of the flood problems in the Lower Skeena comprises the essence of Chapter 2. Hydrologic data is derived from Water Survey of Canada records of streamflow for British Columbia to 1979. Meteorologic characteristics of the 1978 flood on the Skeena are obtained from a report by Schaefer (1979) while hydrologic features of the same flood are taken from a congruent Water Survey of Canada (1979) report. Flood frequency analysis is applied to streamflow data for the Skeena and its tributaries in assessing the relative magnitudes of spring and fall floods in the Lower Skeena Region.

Annual reports of the Water Investigations Branch have been instrumental in describing the features of the Province's flood damage prevention program. Synthesis of the current management approach in the Lower Skeena Region was also facilitated by information provided personally by staff involved with Floodplain Planning and Management in the Waters Investigation Branch. Chapter 3 deals with the current flood damage prevention program in the Lower Skeena Region.

Information on the human dimension of the flood problem is based on unpublished data and documents provided by the staff of the Regional District of Kitimat-Stikine in Terrace. Personal interviews with staff planners of the Regional District and Municipality contributed significant information on the flood hazard and its management in local communities of the Skeena

Region, especially New Remo. Personal observations were made in the New Remo community and Lower Skeena Region during summer fieldwork of the previous year. Interviews conducted among residents in the community have been helpful in supporting the conceptualization of the flood problem in New Remo for this study and in framing the limits of current flood management approach in Chapter 4.

In light of the fall flood features in New Remo, a new strategy for selecting the appropriate pattern and degree of adjustments to reduce flood damage from fall floods is set forth in the latter half of Chapter 4. The flood damage framework synthesized in Section II of this chapter is used as a guide in designating suitable measures to manage the problem. Evaluation of alternative adjustments for New Remo is based on qualitative technical-economic criteria reflecting the primary objective of flood damage reduction.

CHAPTER 2

THE FLOOD HAZARD IN THE LOWER SKEENA RIVER REGION

I Environmental Characteristics

A. Setting

The Skeena, a major coastal river, 510 kilometres long, draining approximately 52,000 square kilometres, yields a mean monthly discharge of $900m^3/sec$. Headwaters rising in the Skeena Mountains of northern British Columbia, flow south to merge with the flow of the Satsut River from the Omineca Mountains (Figure 1). The Kispiox, draining the eastern flank of the Coast Mountains meets the Skeena while just downstream the Babine, rising from lakes on the Nechako Plateau, provides drainage from the east. The Bulkley, the southern major tributary of the Skeena, meets it at Hazelton completing drainage of the Nechako Plateau Lakes. The Skeena turns west at Terrace and is joined by a number of tributaries including the Zymoetz, Kitsumkalum, Zymagotitz and Exchamsiks Rivers which rise with short steep courses in the Coast Mountains. From Terrace to Chatham Sound, the Skeena meanders ribbon-like for 100 kilometres across a broad alluvial floodplain, 2 to 10 kilometres wide inset within a fjord, rimmed by 2000 metre high peaks of the Coast Mountains.

Drainage within the Skeena River system incorporates runoff from two broadly distinctive physiographic regions. The Interior Plateau represented by the Skeena and Omineca Mountains, Nass Basin and Nechako Plateau provide discharge to the Skeena upstream from Terrace. Rocks within this physiographic diversion are largely flatlying and gently folded metasedimentaries and volcanics of Jurassic age (Holland, S.S., 1976). Rivers

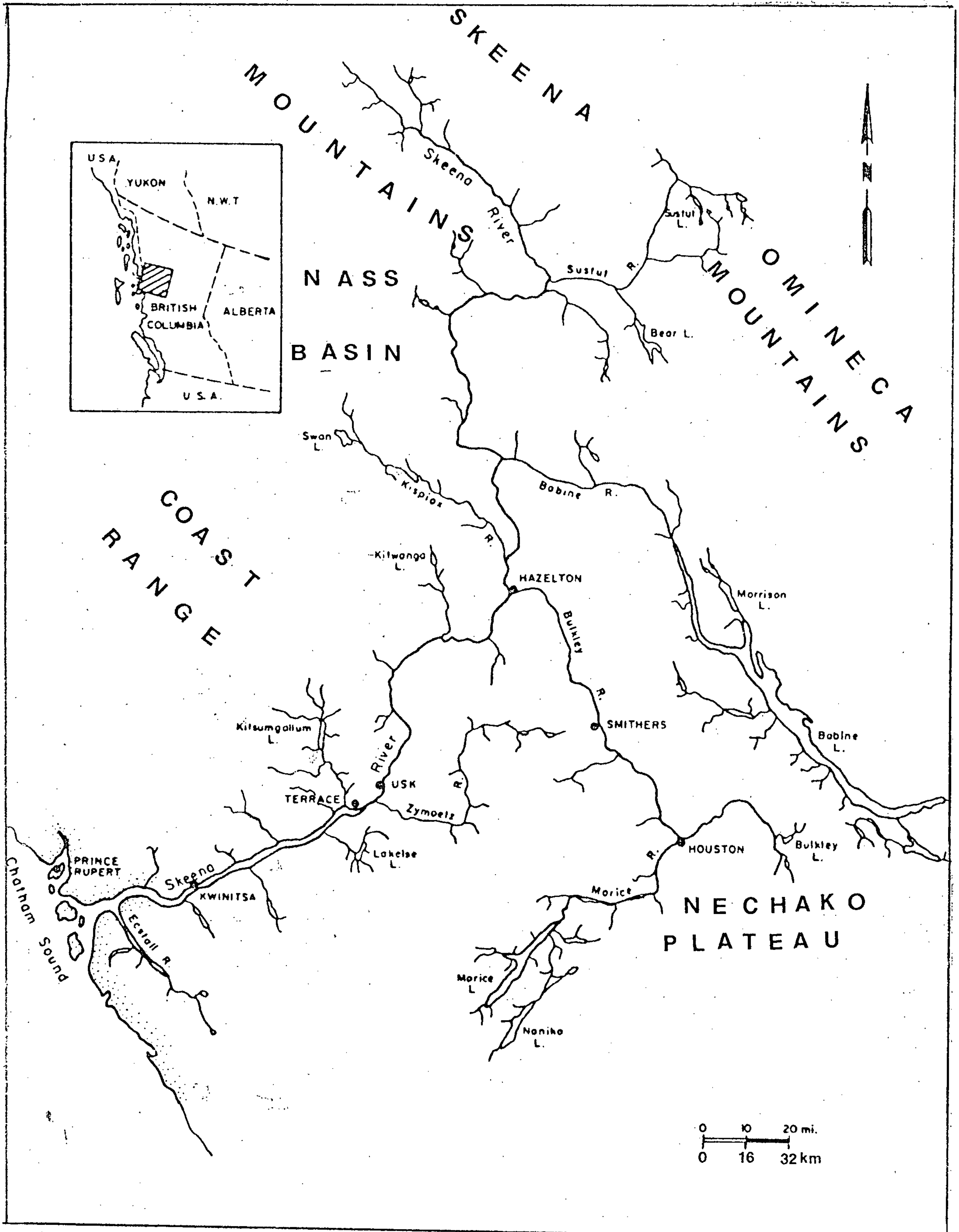


FIGURE I Skeena River Drainage Basin

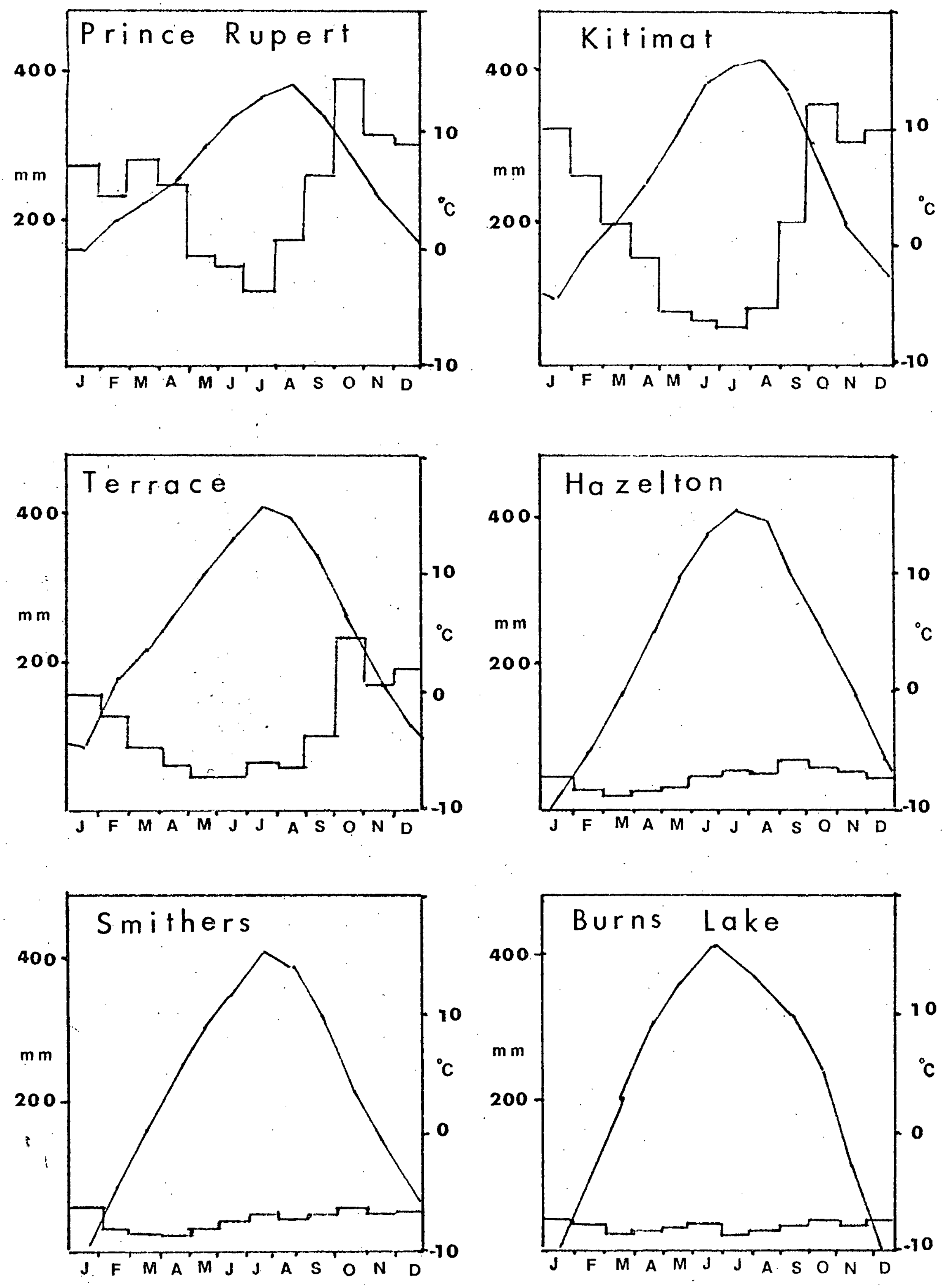
have established deeply incised, structurally controlled valleys in response to post glacial isostatic uplift and drainage. Numerous large and small lakes have been integrated within the present stream pattern through stream piracy and capture, particularly in the vicinity of Nechako Plateau in the headwaters of the Bulkley. The Coast Mountains, a distinct batholith of intruding granodiorite run northwest to southeast across the lower portion of the Skeena basin. Streams rising within this region are short, steep and relatively young in relation to the lapse of post glacial drainage.

Modified maritime conditions prevail throughout the basin all year as a result of westerly winds forcing mild, moist air masses inland from the Pacific. Orographic influences related to the mountainous terrain cause temperatures to decrease and precipitation to increase with altitude and at the same time they produce an easterly moisture gradient across the Skeena basin. A coastal climate extends over the lower region of the Skeena to near Terrace while northern and eastern parts experience a more seasonal and drier climate.

Climatic stations within the Skeena region demonstrate the variable nature of temperature and precipitation from west to east (Figure 2). At Kitimat and Prince Rupert mild wet winters are accompanied by cool slightly drier summers. Terrace, however, located 120 kilometres inland, experiences slightly colder winters (mean January temperature -6 C) and hot summers (mean July temperature 16 C) reminiscent of greater climatic extremes within the interior parts of the Skeena basin (Figure 2). Along the coast and inland through the Coast Mountains, precipitation reaches a maximum in late autumn and early winter, with snow becoming the predominant form as winter sets in. Inland, precipitation is lower and more evenly distributed through the year. However, due to subfreezing temperatures throughout November to March, snow accumulates potential runoff until late spring.

FIGURE 2

Mean Monthly Temperatures and Precipitation in the Skeena



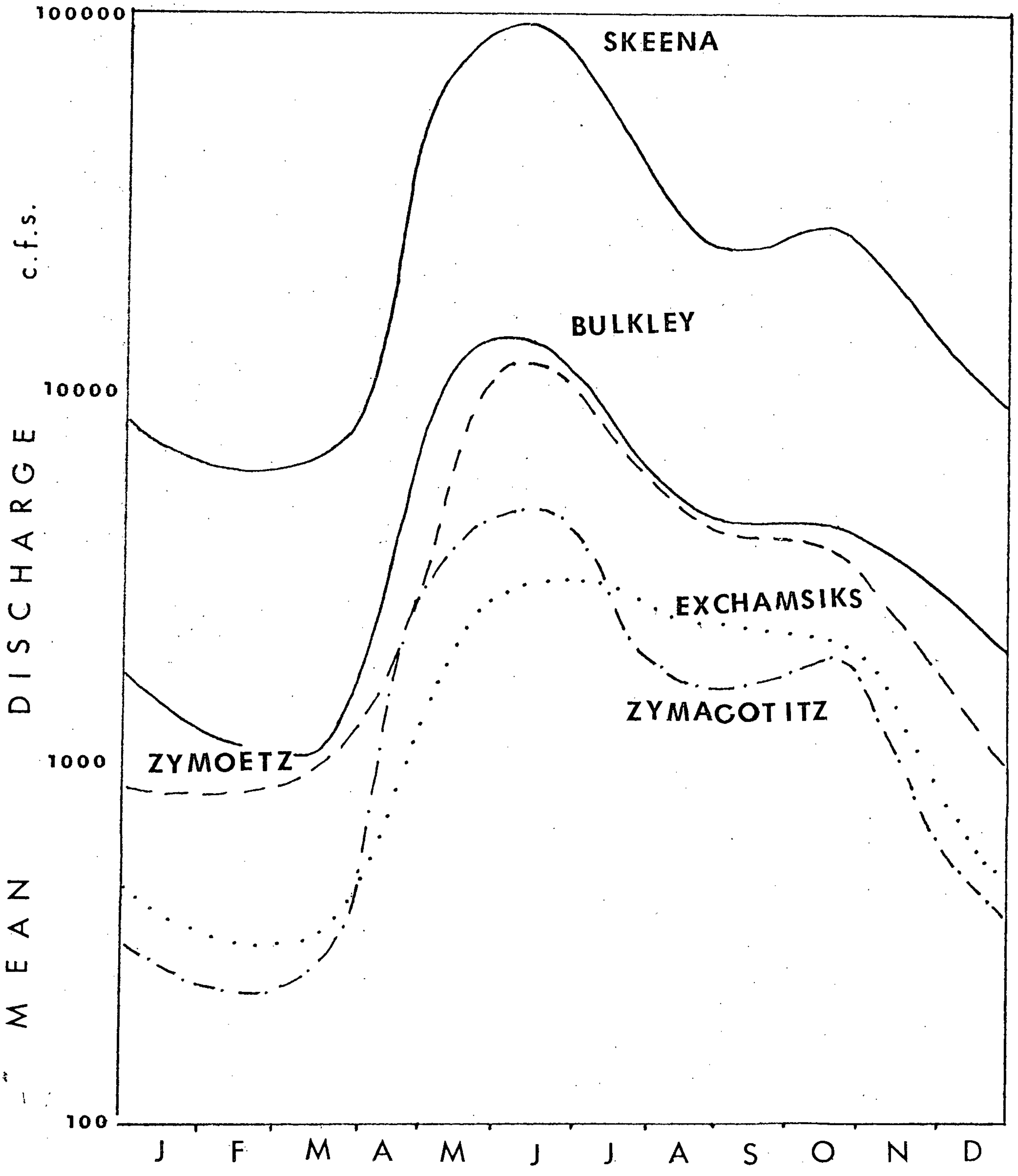
B. Hydrology and Flood Conditions

Seasonal climatic conditions together with the physiographic nature of the Skeena River basin combine to produce two peak runoff situations. The 'spring freshet', an annual high flow condition, usually occurs in the months from May to July. During this time of year streams within the headwaters of the Skeena swell with snowmelt runoff. The volumes carried depend largely on antecedent snow pack accumulation over the previous winter and the rates at which melting occurs during the months of April and May under the influence of sustained maritime polar air masses. These bring unseasonably warm and moist weather to the region which often results in rapid melting of the snowpack. Severe floods, as a result of these conditions, are regional in extent and have occurred in 1936, 1948 and 1972. These spring freshet floods appear to correlate with high flow conditions throughout the Pacific Northwest in these years and in particular with those in the Fraser System (Sewell, 1965).

Annual hydrographs for the Skeena and its tributaries demonstrate the predominance of the spring freshet, peak flow season (Figure 3). However, on most of these rivers there is a second high runoff season in autumn, when rivers swell in response to intense rainfall, particularly in the Coast Mountain region of the Skeena basin. These storms are characteristic of the coastal climate of British Columbia and the orographic effects generated by the Coast Mountains (Hare and Thomas, 1974). An upper atmospheric shift in circulation to a southwesterly flow brings unseasonably mild and moist weather toward the coast. Weakening of the arctic front and orographic lifting pushes freezing levels above 3000 metres which facilitates the onshore movement of disturbances. As a result these take the form of deep cyclonic depressions, edging slowly eastward across the Coast Mountains and the Skeena basin. Rainfall is intense and sustained for a

FIGURE 3

Hydrographs for the Skeena and Tributaries



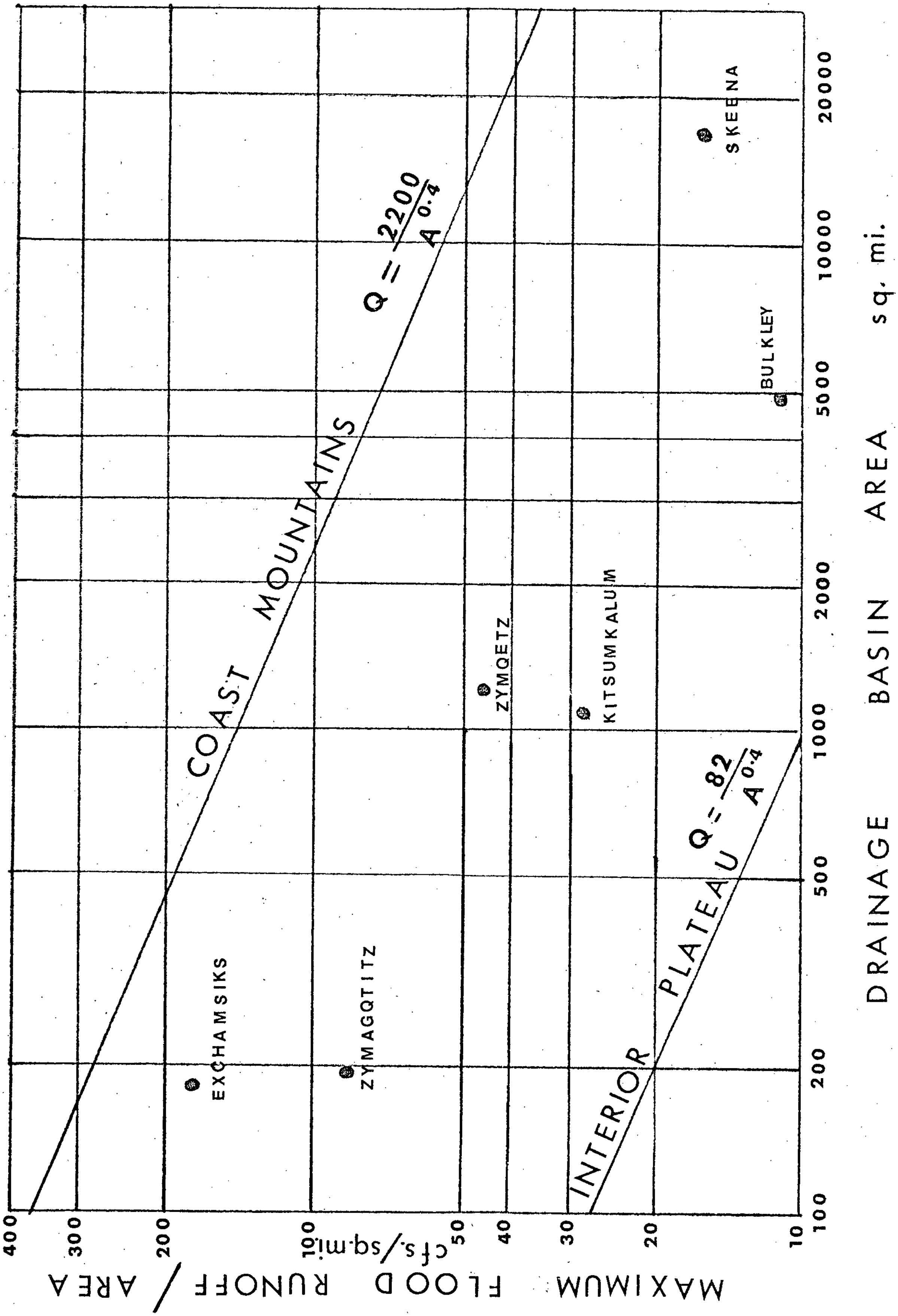
number of days as a number of such storms are drawn into the circulation pattern. Storms of this type have been responsible for rainfalls in excess of 10 centimetres within a 24 hour period (Schaefer, 1979). Such intense rain and its consequent effects within small steep catchments of coastal streams produces flash floods; some of these have been devastating in other parts of the Pacific Northwest.

C. Flood Types

In the Skeena River system, headwater tributaries predictably produce freshet snowmelt peak flows in late spring while lower tributaries in the vicinity of Terrace add another dimension to flooding by contributing peak runoff during late autumn. Both effects are apparent in the hydrographs compiled from mean monthly discharges for the Skeena and its tributaries (Figure 3). In these graphs most of the variability in peak flows is concealed by averaging. The variability through the range of discharges for many of the lower tributaries amounts to a factor of 10 times. Consequently flood peaks in autumn periods can and often do exceed those associated with the spring freshet (Figure 3). However this is not the case for the Skeena and its tributaries upstream from Terrace.

Significant differences are also apparent in the duration and inundation patterns of spring compared to autumn floods. Spring freshet runoff requires a longer period to build toward peak flow conditions as discharge is gathered by the Skeena from its upper basin over many days or even weeks of snowmelt. When in flood, the rivers spread excessive discharge from the main channel by spillover onto the adjacent floodplain. Low lying swales and sloughs fill as both spillover and rising water table conditions extend floodwaters toward the floodplain margins on both sides of the river. The hydraulic

FIGURE 4
Flood Runoff vs Drainage Area in the Skeena



characteristics of river channels, upon which its discharge capacity depends, often become modified through erosion of saturated and weakened bank materials along the main stem of the flooding current. Thus during sustained, high discharge, flooding and erosive damage emanates from the permanent river channels and is largely confined within a narrow floodplain zone. Moreover, flood potential during the spring freshed period can be anticipated with considerable certainty by monitering river flows upstream and assessing the impact of prevailing weather conditions on snowpacks within contributing catchments.

Fall floods are a different matter. Severe and often localized rainstorm runoff requires significantly less time for its peak flows to appear in mountainous streams whose catchments are in the Coast Mountains. Thin soil cover, steep slope gradients, outcrops of impervious rock and at high altitudes antecedent snow accumulation combine with the intense rainfall rate to produce a flashy runoff response. Often accompanying the high runoff are slope failures and mudflows clogging and diverting stream courses with debris. Although smaller in area, these catchments are capable of producing instantaneous peak flows in the autumn that exceed those occurring during the spring freshet. Flooding occurs in association with impeded surface runoff and streamflow debris accumulation. The pattern although not necessarily random, is highly disorganized occurring on tributary floodplains, stream confluences and in gullies which were essentially dry before the storm. Much of the flooding lies outside the common areas flooded by the Skeena River and is not readily disclosed by monitering its flow. Furthermore, anticipation of these flash floods is hampered by their short flood to peak rise of a matter of hours and the complex influence of washouts and debris damming their downstream conveyance of flow.

Thus, in the Skeena River system, two distinct types of flooding takes place at different times of the year. Each type arises from a different set of contributing conditions and produces a distinctive type of flood. The spring freshet floods involve extensive runoff and yield a low rate of flood discharge per unit drainage area (Figure 4). Such streams in the Skeena River system reflect drainage from the Interior mountains and plateaus. Higher rates of runoff to drainage area occur on Coast Mountain tributaries of the Skeena primarily associated with flashy autumn floods.

II The Human Dimension

A. Flood Prone Lands and Communities

Approximately 16,000 people reside in the Lower Skeena region in the vicinity of Terrace, which in 1976, had a population of just over 10,000 (Province of British Columbia, 1977b). The remainder of the population reside on small farms, Indian Reserves and towns along the banks of the Skeena and its tributaries (Figure 5).

The majority of residents, including those living in Terrace, inhabit floodplain lands. Virtually every type and size of settlement within the region is affected by flooding. Some, however, are extremely flood prone, having experienced numerous severe floods in their history. Despite flood experience and the incursion of damages, these communities continue to persist and thrive. Historically, settlement was attracted to the floodplains of the region and the enhancement and expansion of landbased transportation has reinforced floodplain settlement.

The Skeena and Bulkley valleys have served the region as a natural transportation corridor and have even given added emphasis in this regard

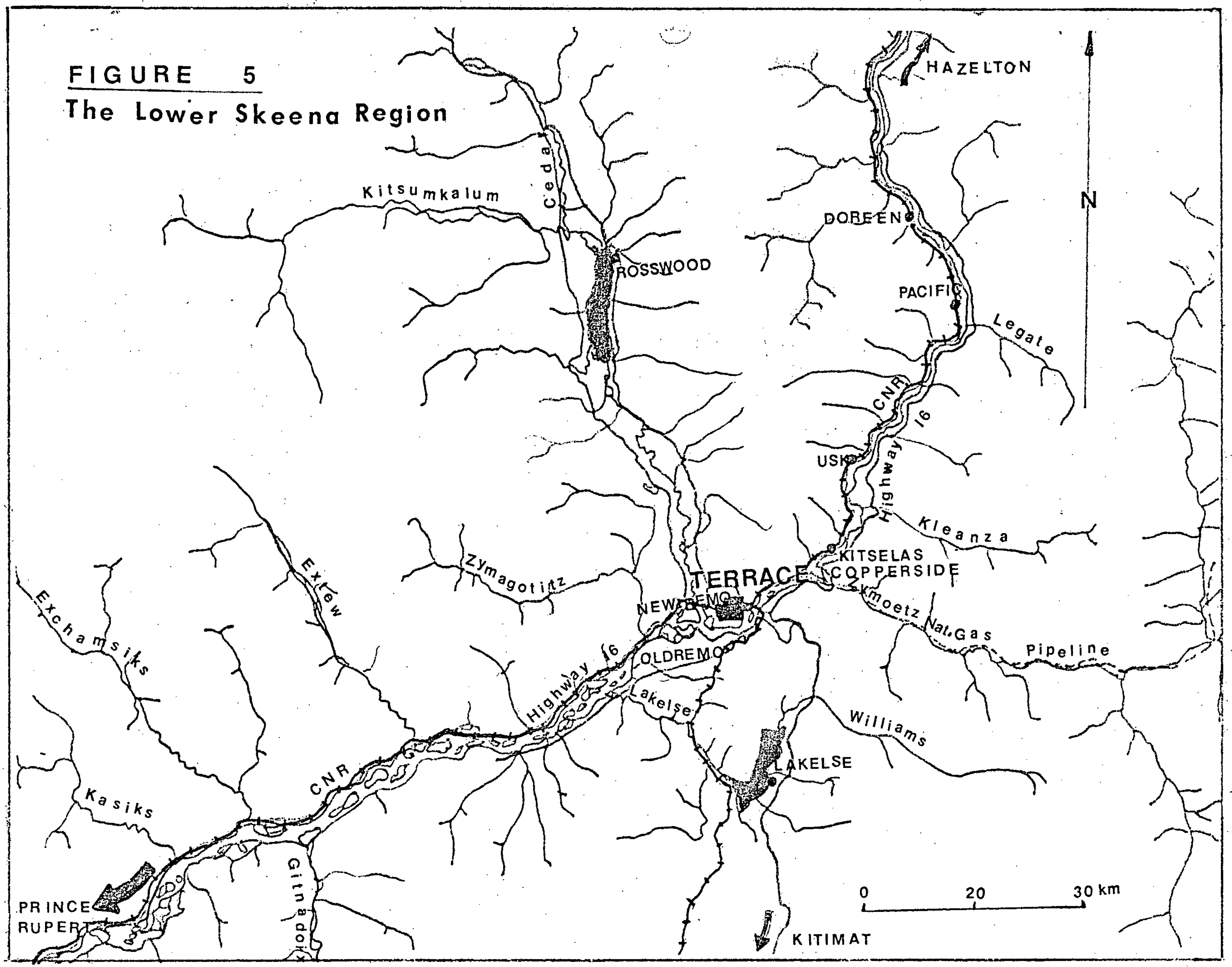


FIGURE 5
The Lower Skeena Region
HAZELTON
N
Kitsumkalum
Cedar
DOREEN
ROSSWOOD
PACIFIC
Legate
CNR
Highway 16
USK
Kleanza
KITSELAS
COPPERSIDE
TERRACE
Zymagotitz
Extew
Exchamsiks
NEW REMO
Skmoetz
Nat. Gas
Pipeline
OLDREMO
Highway 16
Lakelse
Williams
LAKELSE
CNR
Kasiks
Gitnadoix
PRINCE
RUPERT
KITIMAT
0
20
30 km

by developments during the last 30 years. Both highway and rail line follow the course of the rivers from Prince Rupert on the coast to Prince George in the interior of the province. These frequently are situated on floodplains and often cross the major rivers and their tributaries in transecting the region. Recent developments in the forest, mining and marine resource industries in the region have placed added value on the connective linkages (Province of British Columbia, 1977b). Accessibility afforded by transportation developments and opportunities associated therewith have assisted in spreading settlement along floodplains of the Skeena and its tributaries. Many of the smaller communities in the vicinity of Terrace offer lower cost land and amenity values not accessible in the municipality. Rapid population growth, although concentrated largely in Terrace (Province of British Columbia, 1977b), produces spillover effects in many of these communities. Floodplain occupance not only persists but has been increasing through the past decade.

Approximately 17,000 hectares of potentially arable land occur on the alluvial soils in the vicinity of Terrace; less than one third of this area occurs in Class III or better (Province of British Columbia, 1977b). The residual area remains forested. Approximately 200 residents in the region are classed as farmers and 30 farms utilize on 500 hectares. Much of the farming is carried out to supplement seasonal income in resource industries. Many of these farms are located on the floodplains of the Skeena and its tributaries and hence are prone to flooding.

Within the vicinity of Terrace there are nine communities in which flooding poses a problem (Table 2 and Figure 5). Floods occur either in spring or fall and affect significant parts of each of these communities situated on the floodplains. Major, regional floods, occurred in spring

TABLE 2

FLOOD PRONE COMMUNITIES IN THE LOWER SKEENA REGION

COMMUNITY	RIVERS RESPONSIBLE	FLOOD SEASON(S)	MAJOR FLOOD YEARS	COMMUNITY POPULATION	% OCCUPYING FLOODPLAIN *
Hazelton	Bulkley Skeena	April-June	1936,48,64,72	1000	50
Cedarvale-Kitwanga	Skeena	April-June	1936,48,64,72	500	20
Usk	Skeena	April-June	1936,48,72	500	75
Lakelse Lake	Lakelse Lake & Tributaries	Oct-Dec	1935,58 65,74,78	500	10
Terrace	Skeena	April-June	1936,48,72	11,000	20
Dutch Valley	Kitsumkalum & Tributaries	April-June Oct-Dec	1964,72 1923,74,78	50	100
New Remo	Skeena Zymagotitz	April-June Oct-Dec	1936,48,72 1961,74,78	150	100
Copperside-Kitselas	Zymoetz & Tributaries	April-June Oct-Dec	1974,78,79	500	50
Old Remo	Skeena	April-June	1936,48,72	100	100

*Estimates based on identification and delineation of approximate geomorphic floodplain limits without regard to flood frequency. These have been taken from maps of the floodplains in the region and data from the Kitimat-Stikine Regional District.

during 1936, 1948 and 1972 when the Skeena was responsible for flooding communities such as Hazelton, Cedarvale, Usk and Old and New Remo. Significant fall floods occurred in 1974 and 1978 inflicting damage on communities situated on the tributary floodplains of the Skeena, Copperside, Dutch Valley, Remo and Lakelse Lake communities are affected by the Zymoetz, Kitsumkalum, Zymagotitz Rivers and Lakelse Lake tributaries respectively. New Remo, situated at the junction of the Zymagotitz and Skeena Rivers, displays a unique susceptibility to flooding on two counts within a given year.

Population growth and associated development pressures have tended to aggravate flood problems in many of these communities. Economic advantages have encouraged the further conversion of floodplain land to agriculture, residential and other land uses which have a greater potential for flood damage. Collective action was taken by the provincial government to control and manage the development of floodplains in the early 1970's. Their mandate is to assist in achieving flood damage reduction. The current policy is directed toward this end but has critical shortcomings based on events and actions occurring since the 1978 floods.

B. History of Floods and Damages

At least ten damaging floods have occurred during the past 50 years, recurring on average every four to five years. Some communities have experienced damage from floods twice within the same year (Table 2). The largest magnitude flood on the Skeena River, near Terrace, occurred in 1936 while the most damaging flood occurred in the same area during 1978. Floods in some years such as 1948 and 1972 correlate with floods which occurred simultaneously on other rivers in British Columbia, especially the Columbia and Fraser. Snowmelt runoff generated these floods in response to delayed and rapid melting of extensive mountain snowpacks within the Pacific Northwest Region. Other floods in 1961, 1974 and 1978 were limited to the Lower Skeena Region and these occurred in response to sustained, heavy fall rains, accompanying above normal seasonal temperatures.

Although the gaging station of Usk has the longest record of Skeena River discharge, extending from 1928 to the present, no observation is recorded for the flood conditions during 1936 as the gage was removed by floodwaters (Water Survey of Canada, 1979b; Asante, 1972). Correlations with Fraser and Columbia River flood conditions and flood routing simulation have been used to estimate the flow magnitude involved in the 1936 flood is believed to have a 200 year recurrence interval (Marcellin and Beg, 1974) and relics of its impact derived from interviews and surveys have been employed to compile information necessary for the construction of floodplain maps for the Lower Skeena Region. However the exact magnitude of the flood is unknown as the gage was destroyed during the 1936 flood (Asante, 1972).

During the 1936 flood, water depths exceeded 2 metres on the lower terrace in Hazelton causing minor damage while major damage was incurred downstream and west of town where floodwaters eroded soil and removed almost one dozen homes (Marcellin and Beg, 1974). Near Cedarvale floodwaters extended to depths of 1 to 2 metres with erosion localized on the north bank of the Skeena River. Farther downstream at Usk, the 1936 flood breached the railway embankment separating the town from the river and reached depths of 4 to 5 metres throughout the main streets of town. At Terrace, only the lowerest most parts of the floodplain were flooded. Floodwaters covered Braun's Island, Ferry Island and Little Island and most of the land south of Graham Avenue to depths of 2 to 3 metres while downstream the entire community of Remo was inundated by the combined floodwaters of the Skeena and backwater effects on the Zymagotitz River to depths exceeding 2 metres. Recession of the floodwaters took almost two weeks at some of the sites in 1936. Damages were severe and extensive throughout the Lower Skeena Region (Asante, 1972). Communities were isolated by a severed rail line and the only bridge across the Skeena, at Terrace took almost one year to restore. Probable impacts within the region would have been even more severe, were it not for the small number of inhabitants at the time.

Floods in 1948 and 1972 similar in nature were not as severe but correlated with widespread flood conditions in the Fraser and Columbia River basins. In 1948 floodwaters inundated only two small communities at Hazelton and Remo while in 1972, the second largest flood of record on the Skeena, inundation was more extensive but damages remained relatively minor (Marcellin and Beg, 1974).

By 1972, population in Terrace and communities along the Skeena had grown beyond 10,000, heightening the impacts of floods and aggravating the hazard condition through floodplain encroachment. A flood of similar magnitude to that of 1936 would have been devastating (Marcellin and Beg, 1974).

1974 brought the onset of a different set of flood conditions throughout the region. Heavy, sustained rainfall during an unseasonably mild spell in October generated widespread flood conditions on many of the tributaries of the Skeena near Terrace. The Kitsumkalum, Zymagotitz and Zymoetz Rivers reached the highest stages experienced during their short record of hydrologic observation (Water Survey of Canada, 1979b). Flooding along these rivers affected communities which had grown up aware of the Skeena River flood hazard and apparently enjoyed a relatively safe, flood free location prior to 1974. Although the floodwaters were not as deep as those encountered in earlier spring floods, it travelled with greater velocities causing extensive erosion and building numerous debris dams which aggravated the extent of floodwater inundation. Claims for flood damage compensation were lodged from numerous communities within the region, however the majority were submitted from Remo where flooding was severe as the Skeena and Zymogotitz combined to inundate almost the same area flooded in 1978.

The 1978 flood occurring only four years later and similar in nature to that of 1974, caused the most extensive flood related damages to date. Despite previous flood experience, floodwaters caught residents and public officials by surprise. As in 1974, the Skeena River was not involved directly in flooding and the meteorologic circumstances were reminiscent of those prevailing in 1974 (Shaefer, 1979). The actions taken in the wake of the 1978 flood, like those following 1974, tended to maintain and restore community momentum in the region. Pervading attitudes regarded the flood as a 'freak', circumstance and community spirit sought to maintain the status quo (Scanlon, et al, 1979). Provincial programs of restoration and compensation along with federal funding reacted to community concerns and harriedly buttressed the status quo. It is highly likely that if a flood of similar magnitude were to occur in the near future, flood damage would exceed the figure for 1978.

The scope of the prevailing flood management strategy may require extensive alteration to facilitate its achieving a more comprehensive reduction in flood damage. A first step in this regard is an assessment of flood risks (Linsley, Kohler and Paulhus, 1978). In regard to the Lower Skeena Region, this implies a distinction between the hydrologic characteristics of fall and spring floods involved within the dual nature of the flood problem. Although the seasonal nature of flooding in the region seems to be a common understanding, flood frequency assessments, designating flood risks have often not acknowledged the differences between rain floods and snowmelt floods in the annual flood series (Water Survey of Canada, 1979b; Water Survey of Canada, 1972). Consequently, significant uncertainty is associated with probabilities assigned to floods experienced within the historical record.

C. Recent Flood Experience

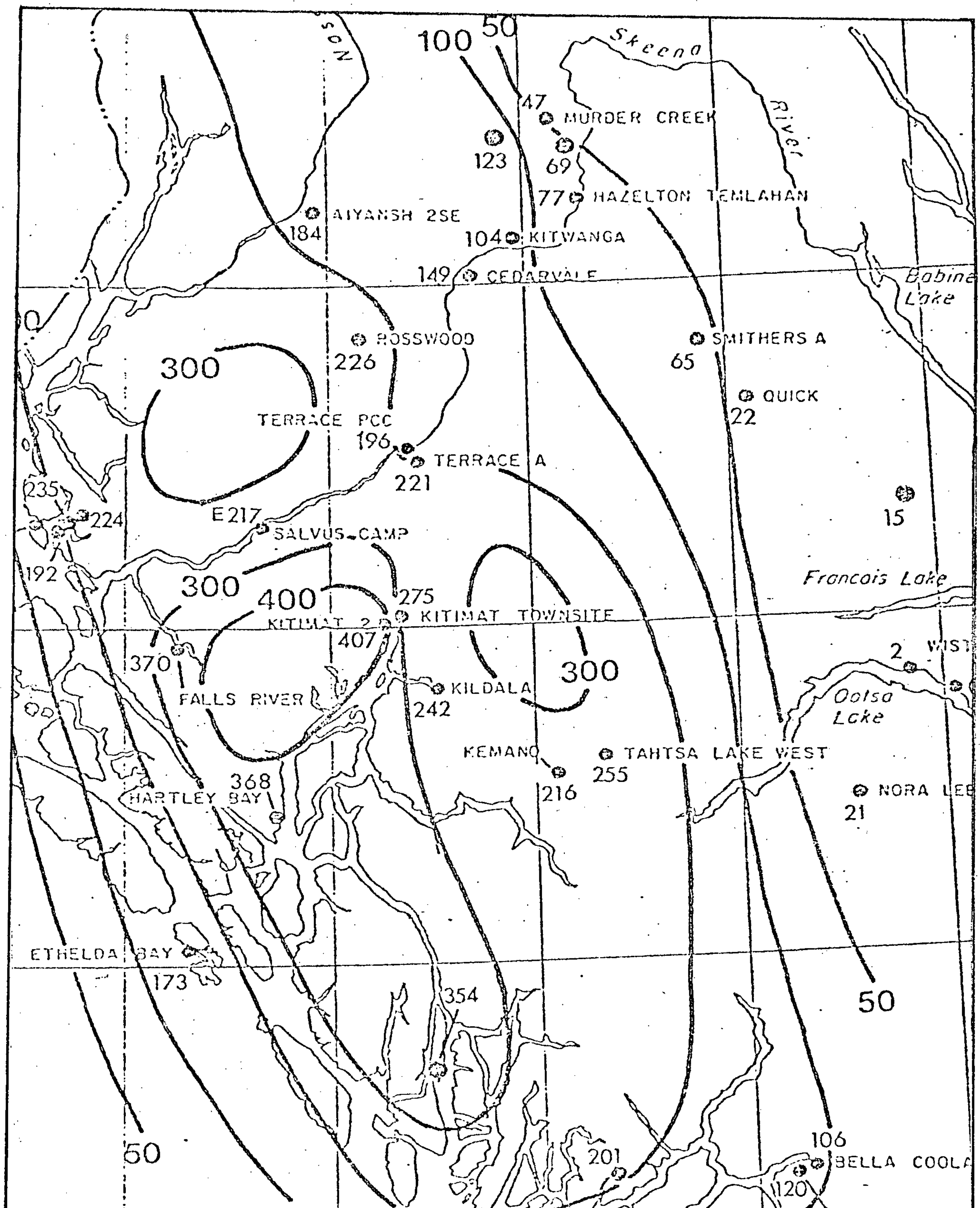
(a) Characteristics of the 1978 Flood

Serious flooding on the lower tributaries of the Skeena River near Terrace during late October, 1978 occurred in response to a multi-day rainfall event (Shaefer, 1979). The storm dropped 221.1 mm of rain at the Terrace Airport while up to 407 mm fell near its centre around Kitimat to the south. An area of almost 52,000 square kilometres received over 220 mm through the storm's two day duration. The return period was estimated to be in the 80 to 100 year range (probability .013 to .010). The anticedent weather conditions through the month of October played a major role in the development of the storm characteristics (Schaefer, 1979). However these conditions are not unusual for this time of year in this region of the Coast Mountains (Hare and Thomas, 1974). The antecedent meteorologic conditions contributed to intensifying orographic effects by slowing the storm's passage and concentrating its track south of Terrace (Figure 6).

Through October freezing levels had averaged near 1500 metres, rising to 3000 metres during two short mild spells, while prior to the storm of October 29, they had fallen to 1000 metres. During the month little snow had fallen. At the beginning of the storm, the freezing level was lying

FIGURE 6

Isohyetal Map of the October, 1978 Storm



(after Schaefer, 1979)

above 3000 metres. On October 29, a high pressure ridge lay across the north coast forcing a strong frontal zone southward ahead of a deep low over Alaska.

On October 30, the front was situated over the Queen Charlotte Islands and aligned from northeast to southwest, beneath a warm flow of moist air aloft. The front remained quasi stationary as at least three distinct frontal waves moved inland across the Coast Mountains. Finally on November 2, the front shifted and cold air invaded the region with freezing levels returning to 1000 metres and surface air temperatures cooling to near freezing. Instability associated with the cold front produced moderate showers in the days that followed. However, the amounts were small compared to that which fell during October 29 to November 2.

Near Terrace, rainfall was measured on October 30 to be falling at an average rate of 1 mm per hour (Shaefer, 1979). By the next morning the rate had increased steadily to 9.6 mm per hour. Over the 24 hour period (10 p.m. October 30 to 10 p.m. October 31) 114.8 mm fell, exceeding previous record falls. Added to this total a further 89.1 mm fell on November 1 producing a second record 24 hour fall. The recurrent probabilities for the one day falls ranged from .025 to .014 while the two day fall had a return probability of .01 to .008 (Shaefer, 1979). On the basis of the magnitude of rainfalls, this storm has a long recurrence indeed. However, these recurrence probabilities are well within expectancy based on floodplain zoning criteria aimed toward the 1 in 200 year flood on the Skeena and other rivers (Sloan, 1974). By this standard, the fall storm of 1978 cannot be regarded in itself as extraordinarily severe and certainly not unique.

The stalled low pressure system, responsible for the intense rainfall generated immediate hydrologic response within the catchments of the lower tributaries of the Skeena and in the adjacent Kitimat watershed. All of the streams carried peak flows on November 1 which exceeded those previously recorded during their relatively short gaged history. The Skeena at Usk peaked later and did not reach mean annual floodstage. Instantaneous peak discharges are tested for some of the streams near Terrace in Table 3.

TABLE 3

Instantaneous Peak Discharges, 1978 Flood

	November 1*	Mean Annual Flood**
Zymoetz River above Ok Creek	111,000 cfs	22,000 cfs
Zymagotitz River near Terrace	18,700 cfs	5,900 cfs
Exchamsiks River near Terrace	30,500 cfs	9,500 cfs
Skeena River at Usk	150,000 cfs	159,000 cfs

Estimates of return periods for the Zymoetz flood discharge range from 25 to 100 years (p = .04 to .01) while for the Exchamsiks, between 25 and 40 years (p = .04 to .03) and the Zymagotitz only 20 years (p = .05). The

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*Obtained from Water Survey of Canada, 1979, Preliminary Report on Terrace-Kitimat Flood of November, 1978 Environment Canada, Vancouver

**Mean annual flood is the discharge exceeded every 2 to 3 years and represents the bankfull discharge. If peak discharge exceeds mean annual flood magnitude, river flow will spill onto the floodplain signifying a flood. Estimates here are graphically determined from flood frequency curves presented in Figure 7 (Section III).

Skeena as mentioned above was not in flood during the storm but did receive higher volumes of flow than normally occur in late October (Water Survey of Canada, 1979a).

Although the peak flows experienced in the region were extreme, they do not represent discharges beyond the 1 in 100 year return period, let alone the 1 in 200 year recurrence interval. Using correlation methods to extend short gaging records over earlier years within the region, floods of greater magnitude can be inferred. These have return periods between 100 and 200 years (see Section III). Despite this difficulty, the flood of 1978 was responsible for substanial and serious damage, unequalled during previous flooding.

(b) Patterns of Flooding and Damages

Strong, gusty winds associated with the rainstorm on October 30 and again on November 1 were responsible for numerous power outages, downed telephone lines and windfelled trees. These developments preceded the flooding and contributed to a disruption of communications which may have further aggravated the impact of the storm (Scanlon et al, 1979). Storm runoff damage began early on October 31 and intensified over the next three days in direct response to the falling rain.

Early on the morning of October 31 a mudslide occured on Highway 16, approximately 40 kilometres east of Terrace. By mid-day a 60 metre segment of the road from Terrace to Lakelse had been washed out by floodwaters. In the afternoon, rains had washed rock onto the CN mainline between Terrace and Prince Rupert, derailing a passenger train. Later in the day, problems had spread as small bridges were continuously washed out by floodwater and logging roads and power transmission lines undermined. By the next day, Highway 16 had been affected by washouts and slides making it impassible and small slides and washouts were common along the rail lines. On the evening of November 1, a natural gas pipeline through the Telkwa Pass had been broken in several places by floodwaters and slides. Flood effects and damages were culminating on Thursday as two men were killed when floodwaters washed two cars of a train into the Skeena River on the line to Hazelton. At this time road and rail transportation had been cut in all directions from Terrace along with the supply of natural gas. Floodwaters joining the Skeena had isolated communities on tributary rivers and flooding along Highway 16 had stranded travellers. The floodplain lands resembled a collection of islands (Scanlon et al, 1979).

Most of the damages inflicted by the floodwaters and associated erosion and mudslides occurred within approximately 35 kilometres of Terrace along the Skeena, Kitsumkalum, Zymoetz, Zymagotitz Rivers and other small stream floodplains and valleys.* Communities at Lakelse, New and Old Remo, Cedarvale, Rosswood and Greenville were severely flooded. Local residents sustained minor damages to residences and establishments. The bulk of the damage was incurred, by the infra structure of the regional economy and components of the business and industrial sectors which relied on communication and transportation. Approximately $38 million of the total compensation expenditure by the British Columbia government was directed to restore transportation and communication facilities and services.

Although this paper is not intended to evaluate the economic impact of the flood on the Terrace community and regional economy, some measure of the degree of disruption is suggested by the length of time, restoration of flood damages required. Complete normalization of power services took

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*Damages occurred in the Kitimat Region, however, they are not investigated in this study.

almost two weeks. Telephone communications were not as severely affected and were restored within a few days of the flood crests. Natural gas however, required six days to be restored. The C.N. mainline was out of service for over a month. The roads and highways were plagued with over 25 bridges lost or damaged beyond repair. Restoration and repair efforts were hampered by inaccessibility and further adverse weather conditions and in many cases necessitated the costly use of helicopters in place of conventional equipment.

Although local labour was employed along with available equipment in the repair efforts, the floods had a severe disruptive effect on employment and business in the region. Forestry operations were curtailed and layoffs followed. Natural gas shortages limited milling operations. Stranded trucks and supplies on the highway and roads halted other businesses as well (Scanlon et al, 1979). Some businesses, previously stocked, such as hardware and liquor stores received a lift in trade during the aftermath. As is the case with many community adversities, some individuals, in particular repair workers, gained while others lost. Some of the losses could not be adequately compensated in financial terms.

(c) Implications

The pattern of flooding and associated damages generated by the storm and flood of 1978 were severe, particularly along the Skeena and its tributaries. The heaviest flood damages were incurred in the vicinity of the tributaries of the Skeena; the Zymoetz, Zymagotitz, Kitsumkalum and Exchamsiks. On the valley slopes and on the floodplains of these rivers much of the damage was caused by slides and debris clogging channels and resulting in washouts and inundation of flood prone land. Flood peaks rose very rapidly while rain was continuing to fall in the area and produced floodstages and discharges which exceeded previously recorded maxima on most of the tributaries downstream from Terrace.

The flooding, although severe and damaging, cannot be regarded as resulting from an extraordinary set of meteorologic conditions. Storms of this type are common throughout the region of the Pacific Northwest from Alaska to Northern California. They generally occur in the autumn and early winter months as moist, mild air intrudes the Coastal Mountain ranges producing intense, sustained orographic rainfall or snow (Hare and Thomas, 1979). Their magnitude varies temporally and spatially in a random manner. The 1978 storm has a probable recurrence of 80 to 100 years while the flood discharges experienced on the rivers of the Lower Skeena region have a return period of between 25 to 100 years. The magnitudes associated with these floods appear to be large enough to warrant attention and on the basis of their probabilities floods of this type should not be regarded as exceptionally rare events.

In the fall of 1974, flooding occurred in the Lower Skeena region under similar meteorologic conditions and involved many of the same tributaries. Flood magnitudes were very near the discharges experienced in 1978 (Water Survey of Canada, 1979a).* The Skeena carried a larger discharge during this flood and spilled onto the floodplain at Terrace inflicting only minor damage as most of the floodwaters inundated lands to within the limits of the 1 in 200 year flood. Downstream, minor flooding occurred, mainly at the confluences of the tributaries with the Skeena. Landslides and washouts were not as widespread in 1974 as they were four years later,

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*October 15, 1974	Zymoetz River	104,000 cfs
October 15, 1974	Zymagotitz River	19,400 cfs
October 15, 1974	Exchamsiks River	25,800 cfs
October 10, 1974	Skeena River at Usk	209,000 cfs

probably due to the rainfall accumulating within the mountain catchments of streams over a two week period, rather than 2 to 3 days as in 1978.

The pattern of flooding in 1974 resembled that which is often associated with 'spring freshet' floods. The flood, therefore, may have reinforced ingrained perceptions concerning the timing and manner in which rivers in the region flood their banks. Furthermore, since its impact was relatively minor it may have led to a false sense of confidence in existing flood damage reduction measures, allaying floodplain managers' concerns for added flood control. Yet there is reason to suspect that in the recent history of the Skeena basin, rivers have risen in autumn at other times.

The impact of the 1978 flood suggests critical limitations prevail within the scope of the current flood management approach in the Lower Skeena region in coping with the dual nature of the flood problem. The prevailing strategy is geared predominantly toward preventing damage from spring freshet floods and seems to ignore the features and impacts of fall rain floods. The extent and expense of damages incurred in 1978 further suggests that floods of this type might be of increasing regional importance, if potential flood damage is allowed to mount through floodplain encroachment.

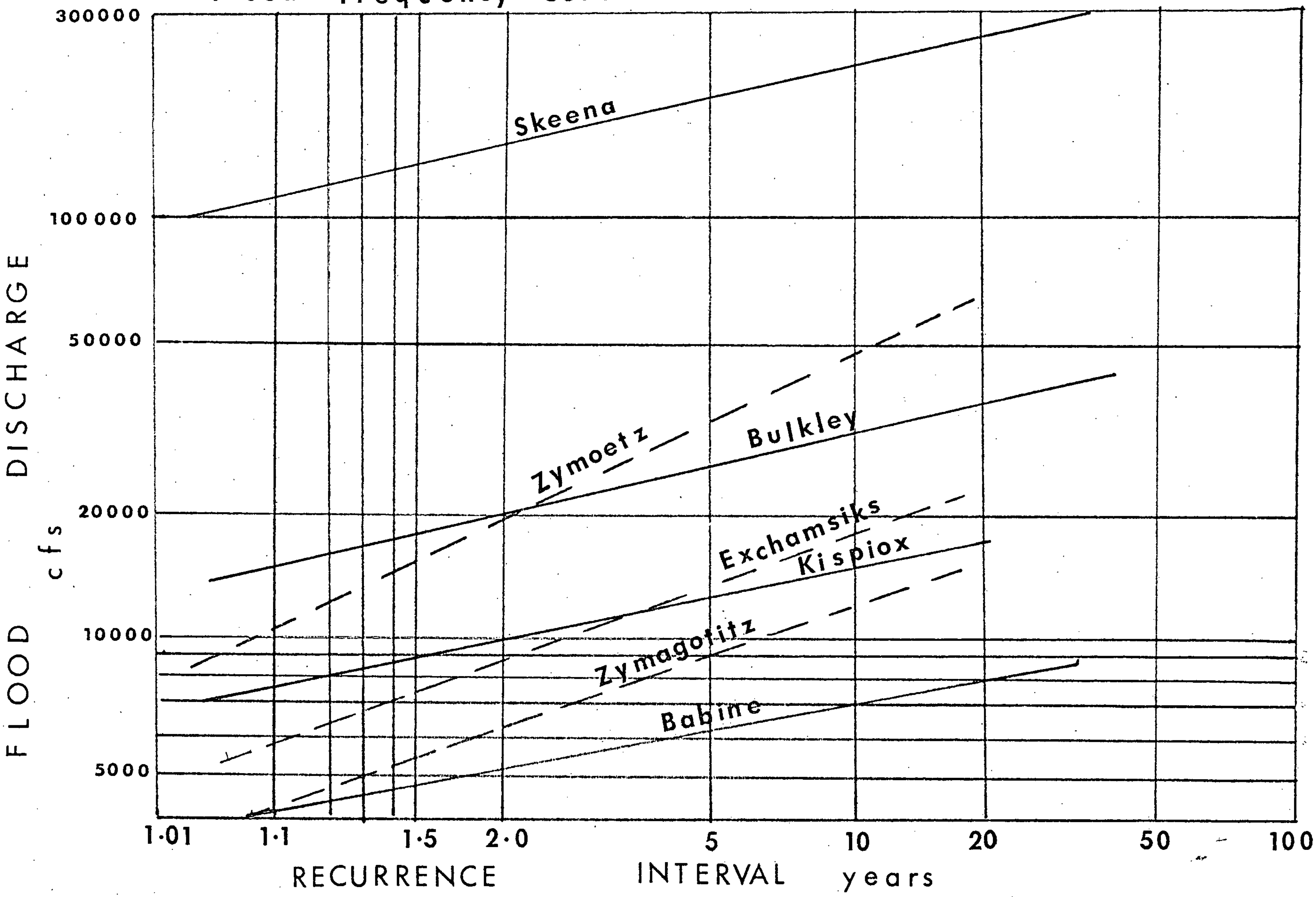
III Assessment of Flood Risk

A. Flood Frequency Analysis

Flood frequency curves derived from streamflow data in Water Survey of Canada (1979b) are illustrated on Gumbel probability paper in Figure 7. The pattern among the Skeena and its tributaries is most striking. Headwater tributaries (ie. those rising in the Interior Plateau) consistently have gentler sloping frequency curves that those flowing to meet the Skeena from the Coast Mountains, implying associations with two distinct probability

FIGURE 7

Flood Frequency Curves for the Skeena and Tributaries



distributions. In fact, there is no logical reason to lump spring freshet and fall rain floods into a single, annual series of instantaneous discharges. Resolution remains limited by the short hydrologic records despite inclusion of both flood types in a single series and most importantly, a smoothing effect is introduced which suggests unfounded certainty in the frequency distribution. Despite the apparent clarity in fitting a linearized distribution to the annual flood data, considerable uncertainty resides in the specification of recurrent flood magnitudes, especially those large floods.

Furthermore, there is a sound argument, based on meteorologic factors, seasonality and hydrologic behaviour for retaining the distinction between spring freshet and fall rain floods in assessing flood risk. Since these floods have been shown to be different in these respects, there is good reason to deal with them in two different annual flood series, compiled by ranking the largest floods in each seasonal series and subsequently computing recurrence intervals for plotting positions on extreme value graph paper. In this way the risks of both spring and fall flooding can be assessed more realistically.

B. Spring Freshet Floods vs Fall Rain Floods

Spring freshet floods are consistently greater than fall floods on the Skeena River. Tributaries such as the Zymoetz, Zymagotitz and Kitsumkalum experience larger floods in fall during some of the years of record. Figure 8 illustrates composite flood frequency curves for these rivers derived by separation of recorded floods into seasonal, annual series for fall and spring floods.

Fall flood frequency demonstrates a different distribution to that derived for spring floods. Furthermore, for a given recurrence interval

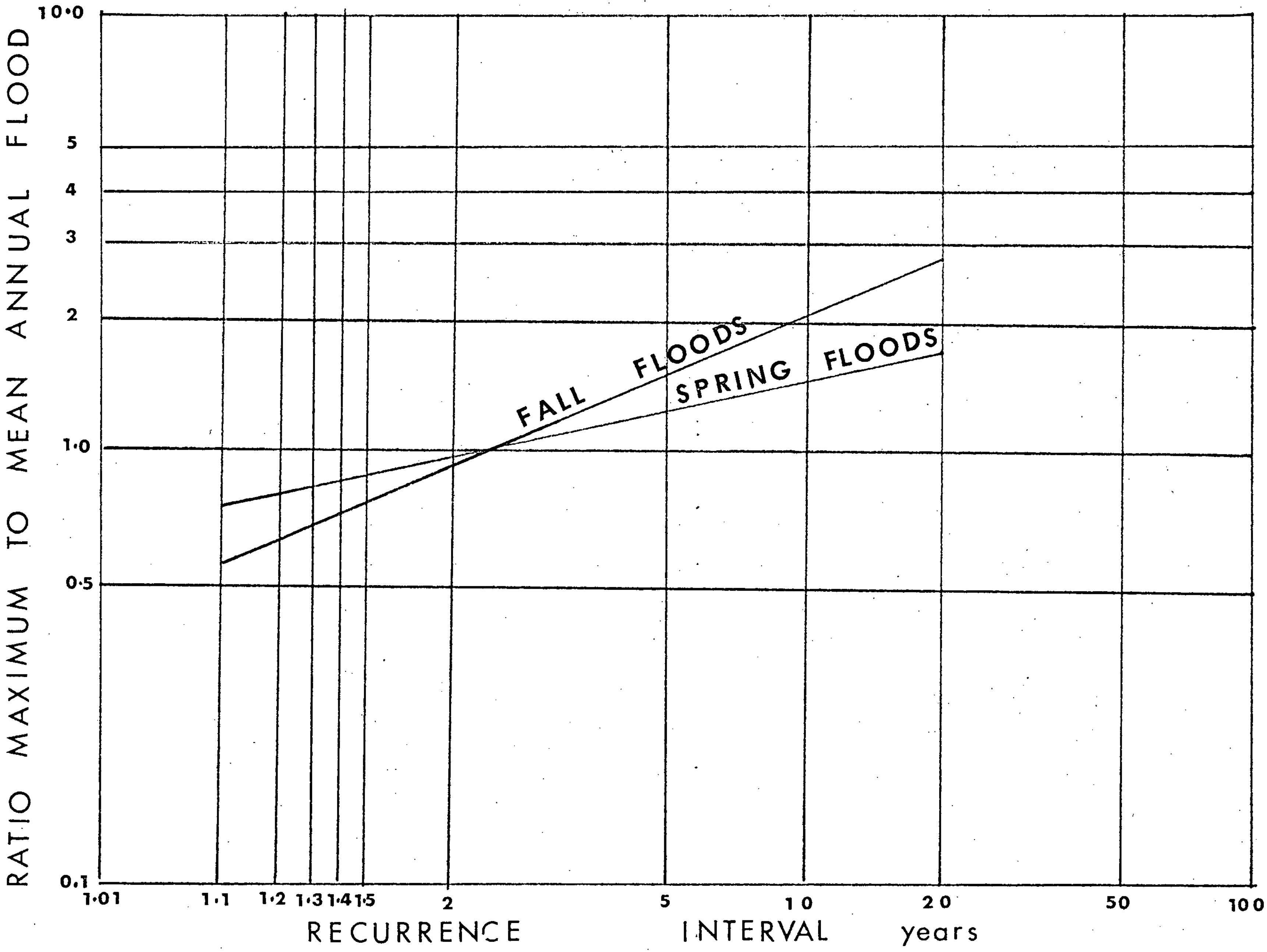


FIGURE 8
Relationship Between Fall and Spring Floods

or frequency, the magnitude expected for fall floods is consistently greater than spring floods above the mean annual flood probability of 0.50. Beyond a recurrence interval of 20 years, the curves may intersect, however, the short lengths of gaging records and the statistical uncertainty associated with curvelinear extrapolation, limit the definition of these relationships to the observed flood record. Figure 8 demonstrates that the Lower Skeena tributaries experience fall floods of greater magnitude than spring floods. For the same frequency, rain generated floods are greater than those resulting from snowmelt.

Although the availability of the hydrologic data limits some of the statistical reliability within these relationships, the pattern illustrated in Figure 8 confirms the importance of fall floods within the region. This is particularly important for floods recurring relatively frequently, especially those with frequencies of 5 to 20 years.

IV Implications for Flood Management

Floods occurring in fall are physically different to those associated with regional snowmelt conditions in spring through the Lower Skeena. These differences are important in developing a practicable and ultimately an efficient strategy to manage flood problems in the region. The physical nature of the flood hazard places a primary constraint on the feasible range of flood adjustments that can be made to reduce flood damages. From a management standpoint, it is critical to recognize the dual nature of the flood problem in the Skeena Region and as well to appreciate the spatial and temporal variations in the degree of the flood hazard. A strategy designed to reduce flood damages should consider not only the total intensity of the flood problem but also the relative intensities of its seasonal facets while facing variations in the degree of the problem in different localities.

Strategic flood management is based on an accurate and effective flood forecasting and warning system (White, 1975). Recognition of diagnostic meteorologic and hydrologic conditions is fundamental in regard to providing sufficient lead time to allow managers in the flood prone areas to take emergency action against the likely flood conditions and thereby reduce some of the damage that might otherwise occur.

The characteristics exhibited by fall floods in the Skeena demonstrate that diagnostic conditions are clearly different to those associated with snowmelt floods. Spring floods can be forecast up to a few days in advance of the freshet crest moving down the Skeena. Extensive evacuation and emergency action can be effectively organized and employed to mitigate some of the damaging effects of the pending flood. In contrast, fall floods generated by rapidly moving rainstorms, are not as readily diagnosed nor is there the same amount of lead time for emergency activities once pending flood conditions are recognized.

These differences imply that a new flood forecasting and warning system would be required to handle fall floods. A much tighter and efficient communication network would be needed to relay information on flood conditions throughout the Lower Skeena Region. Moreover, different instrumentation facilities would be needed to monitor rainfall and storm conditions as opposed to headwater snowpack and daily weather conditions in relation to snowmelt flooding.

Structural flood control measures to control spring floods will probably not work very well against fall floods. Dyking along the Skeena does not prevent flooding from its lower tributaries during high runoff conditions in fall. Fall floods affect different areas than those affected by spring floods. In some communities which experience both types of floods, like New Remo, dyking of the entire community might be necessary to reduce flood damage. Where fall floods are of greater magnitude and socio-economic significance, the design and installation of structural measures should be based on their physical characteristics.

Nonstructural measures such as floodproofing, floodplain regulation and flood insurance designed in accord with spring freshet flooding will necessitate some changes for communities where fall flooding is a greater problem. If fall flooding damage potential is taken into account in the determination of flood insurance premiums, the premiums will be more expensive than if they were based on spring flood features alone. In view of the more frequent fall floods of similar magnitude, more costly flood-proofing measures would be justified. For similar reasons, evacuation measures, may prove more economically efficient in reducing flood damage, especially in those communities where there is a dual, seasonal flood problem. Since fall floods have a greater magnitude for a given frequency than spring floods, measures taken to reduce associated damages can be more expensive than those aimed at spring floods. Benefits for communities derived by averting fall flood damage should exceed those for spring floods, making costlier measures, economically efficient. In communities where there is a dual flood problem it may be necessary to design appropriate flood adjustments in light of both fall and spring flood characteristics. Taking both types of floods into account could suggest a different mix of adjustments than treating each flood problem separately.

From the foregoing, three important points emerge:

(1) Communities affected by fall flooding require different treatment to those affected by spring floods. Localities where there is a dual flood problem comprise a third category.

(a) Flood warning systems for fall floods need to be different than the spring freshet warning system and specifically designed to take into account the short interval available.

(b) Since potential damages from fall flooding are large, these damages combined with spring flood damage potentials justify much larger investments in flood damage reduction measures than could be justified on the basis of spring flooding alone. This would be particularly significant for the design of structural controls and evacuation.

(2) The mix of adjustments appropriate in coping with spring floods will be different to that suited for flood damage reduction associated with fall floods.

(3) The design of strategies to deal with these different flood problems within the Lower Skeena Region will require site specific information on both types of hazard for the design of efficient flood damage reduction.

CHAPTER 3

CRITIQUE OF THE CURRENT FLOOD MANAGEMENT APPROACH IN THE LOWER SKEENA REGION

I Scope of Provincial Management of Floods

A. Flood Damage Prevention Objectives

Although the flood problem in the Lower Skeena is regarded by some (Scanlon et al, 1979) as a national concern, management of the problem remains in provincial hands. To date, federal involvement has been ad hoc, particularly following the 1978 flood event within the region. Federal funds provided much of the resources used in restoration and assisted flood victims in compensating their flood losses. However, the provincial government, by constitutional jurisdiction, assumes the responsibility of managing flood problems in the region of the Skeena. Since 1976, the provincial government has implemented a program of flood damage prevention within the Lower Skeena Region.

The purpose of this chapter is to review the elements of the program, and to assess their effectiveness in dealing with the fall flood problem within the Skeena Region. The program currently applied in the region is nonstructural, relying on flood forecasting and warnings, floodplain regulation and floodproofing. Outside of minor dykes around part of the old townsite of Hazelton, long since fallen into disrepair, non of the flood prone communities are protected from floods by dykes. In New Remo, recent construction has been completed on a training berm for the Zymagotitz River. However, this structure is not designed to provide flood control (Province of British Columbia, 1980).

The program of flood damage prevention is designated and implemented province-wide to achieve the following objectives:

(1) To reduce the public danger due to flooding.

(2) To reduce public costs associated with flood damages.

(3) To achieve a policy within the legal framework and implement it province-wide.

(4) To control development on flood susceptible lands (Province of British Columbia, 1974).

Although some may find fault with the stated objectives in relation to their limited scope, and even, perhaps in terms of their constraining effects on policy, these are not assessed explicitly in this study. They are presented here as a basis for framing the features of the flood damage prevention program elements. The focus, in light of these objectives, will be with the designation and implementation of the program elements in the Lower Skeena Region.

B. Program Elements and Implementation Mechanisms

Current flood forecasting in the Lower Skeena involves extensive monitoring of snowpack, weather and streamflow conditions to determine the magnitude of the spring freshet. Meteorologic and streamflow stations on the Skeena River System together with snow course stations throughout British Columbia are integrated by telecommunication facilities to provide data for the Water Investigation Branch in Victoria, on the potential and prevailing river and watershed conditions over the province (Province of British Columbia, 1976). During spring freshet, continuous daily forecasts are made for rivers and streams. Warnings are issued via regional water managers within the various districts of the province when rivers near critical floodstages.

By 1976, floodplain regulations and floodproofing requirements were established by the Floodplain Planning Division of the Water Investigation Branch for communities within the Lower Skeena (Province of British Columbia, 1980b). These measures consist of a flood damage prevention clause included in zoning bylaws pertaining to floodplain development. Bylaw #37, Section 1.10.0 for Greater Terrace typifies the format of these restrictions:

> Not withstanding any other provisions of this Bylaw, no building shall be constructed, nor mobile home located:
>
> (a) With the underside of the floor system of any area used for habitation, business or storage of goods damageable by floodwaters, the ground level on which it is located, lower than:
>   i) Two (2) feet above the one in 200 year flood where this level can be determined,
>   ii) Twenty (20) feet above the natural boundary of the Skeena River where the one in 200 year floodplain has not been determined by the Water Investigation Branch,
>   iii) Five (5) feet above the natural boundary of a lake,
>   iv) Ten (10) feet above the natural boundary of any other water course.
>
> (b) Within:
>   i) Two hundred (200) feet of the natural boundary of the Skeena River,
>   ii) Twenty-five (25) feet of the natural boundary of a lake,
>   iii) One hundred (100) feet of the natural boundary of any other water course.
>
> If landfill is used to achieve the required elevation, the toe of the fill slope shall be no closer than the above distance(s) from the natural boundary, and the face of the fill slope must be adequately protected against erosion from flood flows and/or wave action.
>
> Provided that, with the approval of the Deputy Minister of Environment, these requirements may be reduced.

Similar Bylaws are applied in the flood prone communities of Lakelse, Dutch Valley, Remo, Usk, Cedarvale and Hazelton. Moreover, the Regional District of Kitimat-Stikine has adopted ordinances for floodplain lands outside of municipalities and existing towns in the Skeena Region.

These regulations generally apply to new development on floodplains in the Skeena Region. Although there is no specified penality for contravention, enforcement of the regulations is achieved through the denial of building permits or service connections unless codes in the zoning bylaw are adhered to. Developers, within rights under the Land Act, appealing to the Ministry of Environment for a relaxation or change in subdivision requirements, now face a covenant attached to the Land Registry Title, releasing the Province from responsibility toward flood problems associated with the site. The covenant applied to flood prone lands in the Municipality of Terrace reads as follows:

> The owner agrees to save harmless, the Province of British Columbia and District of Terrace in the event of any damage being caused by flooding to any building, improvement or other structure built, constructed or placed upon said lands and to any contents thereof (District of Terrace, Land Registry Office, 1980).

Although the purpose of the covenant seems clear, it is not certain whether in the event of widespread flood damage throughout the Lower Skeena Region, the Province will not provide compensation or restoration assistance to property owners. At present, the Provincial Emergency Program, administers a substantial disaster fund, which no doubt would be drawn against in the event of extensive flood damage in the region (Province of British Columbia, 1980).

Finally, communities have the opportunity under the Water Act to form Water Management Districts for administration and funding of special projects in relation to water development and problems. These districts provide cohesive management units to define the framework and scope for dealing with localized problems and issues concerned with water (Province of British Columbia, 1980b). The Water Management Branch of the Ministry of Environment uses these as a basis for administering Agricultural Redevelopment Act projects within the province. Such an application assisted in financing the construction of erosion protection works in New Remo during 1980 (see Chapter 4, Section IC).

A number of such projects have been implemented in the Lower Skeena Region, developing flood control structures, notably dykes and berms to protect and enhance agricultural land productivity. However, this avenue of flood damage prevention is not easily utilized unless there is significant agricultural land of Class 4 or better threatened by floodwaters. Moreover the degree of protection deemed feasible is usually much lower than that which might seem so in the residential and commercial section of floodplain communities. Yet, in few of the floodplain communities is there an awareness of this adjustment. Even where it has been brought to the attention of residents, a major difficulty has been the achievement of consensus among participants in the project (Marcellin, 1980, pers.comm.). The issues involved are examined in Chapter 4 in relation to controlling floods in the Community of New Remo.

II Effectiveness of Current Measures in Dealing with Fall Floods

A. Flood Forecasting

The current flood forecasting system within the Skeena Region is part of the province-wide network established to deal with spring freshet, snowmelt floods. In the past these floods have at times resulted in devastating effects on other rivers as well as the Skeena. From past records, these floods have been coincident events on the Skeena, Fraser and Columbia Rivers as well as in the Okanagan Valley. Considerable experience in forecasting spring freshet conditions has contributed to the current, highly effective monitoring of runoff and streamflow throughout the province in relation to these floods (Province of British Columbia, 1973, 1976, 1980). The threat of severe, province-wide flooding has assisted in encouraging technically efficient refinements in the network and predictive models, such that antecedent freshet conditions can be noted and streamflow forecast at least two days in advance of peak runoff for most large rivers (Province of British Columbia, 1980b).

The flood forecasting system is only effective and efficient where it can be linked to action toward reducing flood damage (White, 1975). The warning system contingent on forecasts of spring freshet flows seems to work effectively. During high runoff and flooding in 1972, the warning system assisted in reducing some flood damage (Province of British Columbia, 1973). However, these floods were noticeably smaller in magnitude and less extensive than those in 1948 (Water Survey of Canada, 1979). Flood forecasting and warnings to generate emergency action works best where flooding occurs regularly. Spring freshets occur each spring during May and June on almost all rivers of British Columbia. Despite the lack of flooding, communities are given annual reminders of the persistent threat of flood damage, in the seasonal rise of river levels during late spring.

The existing forecast and warning system has no relevance to the fall flood problem. A different meteorologic prognosis is required in forecasting the rise of rivers in response to fall rainstorms. The spatial and temporal features of these rainstorm floods bears little relationship to the behaviour and pattern of spring freshet floods (Chapter 2). In forecasting these floods, time is of the essence as storms move with speeds ranging between 30 and 50 kilometres per hour from west to east across the tributary watersheds of the Lower Skeena. Flooding begins in many of these catchments before the Skeena River begins to show any sign of rising to floodstage.

During the fall of 1978, forecasts and flow measurement of the Skeena near Terrace provided contradictory indications of developing flood conditions in the region downstream. At Terrace, the Skeena remained well below floodstage, yet at Remo, a few kilometres downstream, half of the community was under 2 metres of water. Not until near the end of the flood were warnings issued from Terrace for the surrounding flood prone communities. By this time most of the damage had been inflicted (Scanlon et al, 1979).

The forecasting network employed to deal with spring floods is not operational in relation to fall floods. In its current form and distribution it provides too broad coverage within the province to provide comprehensive detail relevant to fall rainstorms and flooding. Moreover, the instrumentation, data and analytical approaches would have to be modified in forecasting fall floods (Linsley, Kohler and Paulhus, 1978). Under present arrangements, the flood forecasting system in the Skeena Region could not be expected to accurately and efficiently forecast pending fall floods.

B. Design Flood Frequency and Floodplain Mapping

The design flood frequency selected for managing floods in the Skeena River system is the 1 in 200 year flood. The magnitude and associated depth and area of flooding associated with this frequency is highly uncertain, especially when estimated from short hydrologic records, such as those available for the Skeena and its tributaries (Chapter 2).

The reasons for selecting a 1 in 200 year flood frequency for the Skeena are not clearly evident in the rationale set forth in Water Investigation Annual Reports (Province of British Columbia, 1973 to 1980). However, this flood frequency seems to be one that has been designated for other rivers in the province and may reflect the Province's objectives in developing a uniform policy of flood damage prevention (Sloan, 1974).

The 1 in 200 year flood in the Skeena River System essentially coincides with the magnitude of the historic flood of 1936. The procedure used by the Hydrologic Section of the Water Investigation Branch is briefly described as a modelling process incorporating correlation, simulation and a strong judgemental component in deriving the design flood magnitude by Sloan (1974). Despite assigning the 1 in 200 year frequency to the 1936 flood, the precise magnitude of Skeena River flow during the historic event remain uncertain. The flood swept away gages when the bridge at Terrace was washed away (Asante, 1972). In addition, in attempting to map the area affected by these floodwaters, Marcellin and Beg (1974) illustrated examples of the uncertainty and contradictory evidence associated with using markings on the floodplain and resident accounts of the flood effects of the past. Most of the flood effects from the 1936 flood have been erased by time and by more recent flooding in 1972.

Setting these concerns aside, the design flood for management bears no relationship to the frequency distribution derived for fall floods (Chapter 2). On the Zymoetz and Zymagotitz Rivers, fall floods appear to be of consistently larger magnitudes than those of spring. Clearly the 1 in 200 year flood for these rivers and their floodplains should be derived from the fall flood series, not the overall annual flood series as is done for the Skeena where spring floods predominate. This distinction is important when considering the design flood magnitude and subsequently becomes critical in directing the focus of floodplain mapping programs. The complex, terraced and sloughed alluvial floodplain of the Skeena, especially in the vicinity of lower tributaries make it critical to accurately determine design flood limits in relation to topography. Maps of the flood hazard zone within a community are essential bases for effective planning implementation (Kates and White, 1961).

In the Lower Skeena, floodplain maps reflect only the inundation pattern of the 1 in 200 year flood of the Skeena River. Tributary rivers have not been analysed nor mapped to date (Province of British Columbia, 1980b). The short length of gaging records, watershed land use changes and the general lack of gage sites has impeded the designation of the 1 in 200 year flood for these rivers. However, it appears from evaluations conducted in this study for tributaries in the Lower Skeena Region that primary focus should be towards fall rain floods rather than spring floods despite the inability to precisely define a 1 in 200 year flood magnitude.

The floodplain mapping program in the Lower Skeena, spurred by flooding in 1972, has only recently been completed, taking well over four years to provide maps of the flood hazard in communities from Hazelton to New Remo (Province of British Columbia, 1980a). The completed maps present the flood hazard in a limited way. Although 2 foot (0.8 metres) contours have been used throughout, only the 1 in 200 year flood limit is shown on these. More frequent floods, presumably occur within this limit but this assumption may not be the case, especially where tributaries like the Zymoetz and Zymagotitz or Kitsumkalum join the Skeena. In these localities, tributaries generate larger magnitude fall floods, which when combined with high stages on the Skeena produce flooding beyond the 1 in 200 year limit on these parts of the floodplain.

Thus, the design flood frequency and the nature of the Skeena and its tributary floodplains contribute toward an apparent uncertainty in delineating experienced and potential flood limits. Furthermore the exclusion of fall flood effects seems to compound the degree of uncertainty within the current flood management approach.

C. Floodplain Regulation and Floodproofing

The flood damage prevention clause, added to the zoning regulation for the Regional District of Kitimat-Stikine in 1976, was designated prior to the floodplain mapping in the region being completed. Without maps, it is often difficult for local area planners to convince floodplain developers of their value in preventing flood damage (White, 1975). Moreover, since the regulations instituted prior to 1978 did nothing to minimize flood damage for floodplain residents during the recent flood, there seems to be little confidence in their ability to do so in the future. Local residents in New Remo frequently express a view that current regulations are unfair and ineffective in dealing with floods in their locality and regard them as an impediment to community development (Chapter 4).

Floodplain regulation and floodproofing requirements could prove to be the most effective measures in coping with fall as well as spring flood damage. Once regulations have been implemented and enforced they can readily be supplemented with site specific information on the fall hazard and enforced in the same way as they are now for spring flood risks. Floodproofing measures taken toward spring floods are not as effective in mitigating fall flood damage. Although these adjustments either prevent floodwaters from entering buildings or provide protection to the contents of buildings against the one type of flood in spring, they could provide partial protection against the fall type of flood. However, despite the prevalence of floodproofing requirements in zoning bylaws for subdivision development, measures of this type have not been implemented in the Lower Skeena Region particularly with respect to existing buildings within the 1 in 200 year flood limit. They only apply where a building permit is requested. Little technical advice accompanies floodplain regulations, other than the implied means of raising the first floor of the building above the specified elevation on the floodplain. Alternative means of floodproofing could be implemented if encouragement and advice were provided (Shaeffer, 1960). Consequently there are few available means of reconciling residual flood damages in currently developed communities through the Skeena Region other than to have floodplain residents bear the loss or seek compensation by the government. Floodproofing for existing development is relegated to individual initiatives in the Lower Skeena Region.

Taken in this light, together with some of the preceding problems evident in the current approach, it is not surprising that many residents in communities like New Remo, Dutch Valley and Lakelse Lake avoid taking floodproofing action. In such communities, where there is a perception of the high flood risk and no faith in the effectiveness of the current management approach, residents press public officials for flood control measures. Such has been the case in New Remo, where the residents sought to have the community dyked. When structural measures of this type are increasingly used to fill voids in the current program, serious shortcomings are suggested in the strategy.

III Implications

Structural flood protection measures have not been implemented in the Lower Skeena Region. Despite the reliance within the current flood management approach on nonstructural flood damage prevention measures, fall floods are not encompassed by this strategy.

Flood forecasting, fundamental to any strategy of flood management, is aimed only at spring freshet floods. The current approach is not designed to deal with fall floods. Fall flood forecasting requires a different network of meteorologic and hydrologic stations as well as designing instrumentation and predictive models aimed at recording, processing and forecasting developing flood conditions within a relatively short lead time. Forecasts will have to be issued more frequently, rather than daily, as they currently are developed for spring floods. Data on rainstorm, precipitation potential together with temperature profile of approaching air masses and ground surface conditions will be required to predict likely rainfall totals and intensities. Runoff models will be required for the rivers draining into the Skeena through the flood prone communities. Initially, the program will have to address itself to identifying the information needs and evaluate the relative costs of enhancing the data base within the region compared to the benefits derived in dealing with the fall flood problem. Evidence presented earlier in the study indicates that the problem is likely to increase if it continues to elude management.

Some measures applied to spring floods have the capacity to be effective, if only in part against fall floods. This is apparently true for floodplain regulation and floodproofing. However, these are not currently implemented as efficiently as they might be. To work effectively these measures require community understanding, approval and action (James, 1973). Under the current approach, these measures are not explicitly encouraged within the frame of reference set out in the designated program.

Inherent uncertainties in designating the design flood and identifying its limits on the floodplain are not acknowledged. The 1 in 200 year flood boundary is implied on maps of the Lower Skeena to signify certain flooding within its limits. Studies of floodplain occupants in other settings (Kates, 1962; Shanks, 1972; James, 1973; Mitchell et al, 1978) have shown that many of these do not perceive the nature of probabilities and hence the significance of the design flood boundary. Furthermore, with the limited range of alternative adjustments perceived available to deal with the flood problem and with first hand experience with flood damages, many residents may develop a sense of frustration in trying to do anything about the flood problem (White, 1960).

The current strategy applied to flood damage prevention is too limited in scope to deal with fall floods. Moreover, the existing implementation mechanisms are not as efficient as they may have been presumed in designating the program. The prevailing approach appears to have shortcomings in dealing with spring freshet floods. The current approach cannot be simply extended to cover the fall flood problem. A new strategy will have to be developed for the region based on assessment of the entire range of flood hazards and the varied alternative adjustments possible within the setting of the Lower Skeena. New Remo offers an illustrative case for the development of such a strategy.

CHAPTER 4

TOWARD A STRATEGY FOR MANAGING FALL FLOODS IN NEW REMO

I Community Features and Flood Hazard

A. Flood Experience

New Remo is situated approximately 8 kilometres west of Terrace on the north side of the Skeena River (Figure 5). The community is spread over floodplain land shared by the Zymagotitz and Skeena Rivers (Figure 9). The flood hazard within the community is regarded as chronic as both rivers inflict flood damage (Marcellin and Beg, 1974).

The community dates back to the early 1930's when completion of the CNR line to Prince Rupert offered the opportunity for settlement (Asante, 1972). However, most of the current population located within the area since the early 1950's following the completion of Highway 16 to Prince Rupert. Approximately 150 people live in New Remo, occupying approximately 50 land-holdings (Figure 9).

The Zymagotitz River, known locally as the Zymacord, drains approximately 377 square kilometres, flowing out of a deep, glacier-fed valley on the eastern flank of the Kitimat Range of the Coast Mountains. The floodplain of the Zymagotitz at Remo is extensive, resembling a delta or fan deposit where the valley in which it flows widens to meet the Skeena. Its surface is gently undulating to flat with scattered oxbows and sloughs throughout. A large slough, a relic from an earlier course of the Skeena, runs through the community. Most of the homesites in New Remo are built on past islands of the Skeena or Zymagotitz Rivers, divided by these old water-filled back channels.

Disastrous floods occurred in 1936, 1948 and 1972 when the Skeena River breached the CNR embankment separating the town from the river. In 1936, floodwaters inundated the entire townsite of New Remo and other parts of the floodplain around it to depths of 2.5 metres (Marcellin and Beg, 1974). Although not as deep, floodwaters in 1948, caused even more extensive damage as more people had located and built homes in the community by this time.

Minor floods, referred to as indirect by Marcellin and Beg (1974) in their study, occur almost annually in either spring or fall as a result of combined high runoff on both the Skeena and Zymagotitz Rivers. This hazard occurs when the Skeena River backs the Zymagotitz flow onto its floodplain. This type of flood occurred in 1972 (Marcellin and Beg, 1974) and may have been associated with part of the flood impact in 1974 and again in 1978 (Province of British Columbia, 1980a). Fall floods, generated by heavy warm rains, however, usually send the Zymagotitz on the rampage. Floodwaters enter the floodplain north of the community and flow into the large, abandoned slough, attempting to join the Skeena east of town (Marcellin and Beg, 1974). The combined highway and railway embankments block this natural floodway from merging with the Skeena, backing floodwaters onto adjacent properties (Figure 9). In 1961, floodwaters up to 1 metre in depth inundated properties in New Remo. These were situated nearest the Zymagotitz River on the west side of town and near the southern bank of the slough (Marcellin and Beg, 1974).

The most severe flooding occurred in 1978 when rain-flood conditions prevailed throughout the Lower Skeena Region. New Remo was one of the communities hardest hit and given the most attention by media and public officials (Scanlon et al, 1979). Although a similar flood occurred in 1974, few people were prepared in 1978. The floodwaters appeared to rise so suddenly that emergency mitigative action seemed futile and even evacuation was impeded. Observers, who witnessed the rise of floodwaters in the community were astounded by the speed at which it travelled and the heights to which it rose. The floodwaters, carrying extensive debris and silt, reached a height of over 3 metres on the western part of town. One resident escaped his home by cutting through the roof and travelling by boat to the highway (Scanlon et al, 1979).

Direct flood damage in the community exceeded $200,000. However, long term effects have been even more destructive. Property values in New Remo have shown a rapid decline since 1978 (Marcellin, 1980, pers.comm.).

B. Landuse and Flood Patterns

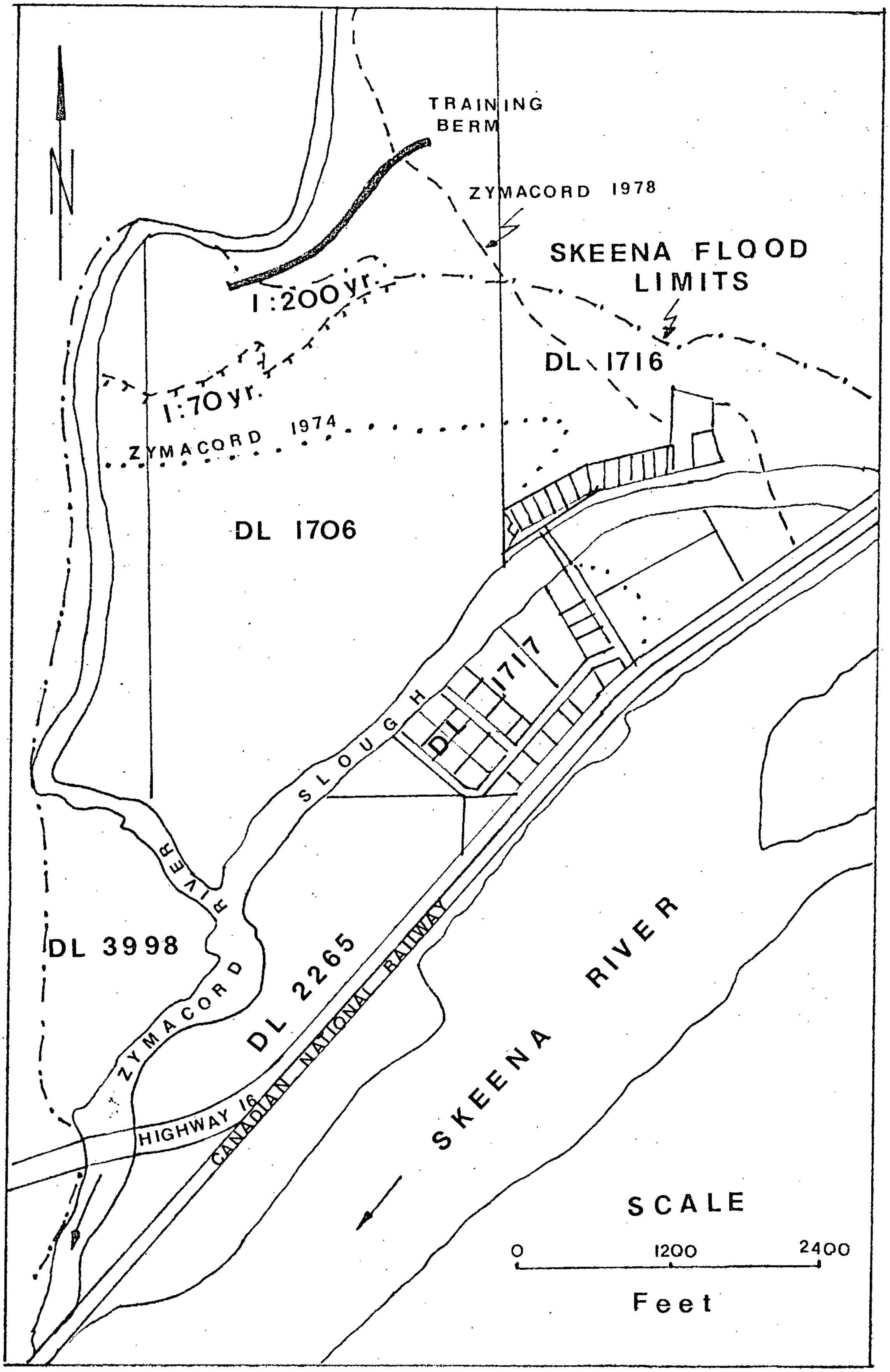
Land on the floodplain at New Remo is generally devoted to residential use. Approximately 45 homes have been built on properties ranging in size from about 0.5 hectares to 10 hectares and these sites comprise the major portion of the townsite (Figure 9).

On the northern and western periphery, farming is practiced on the fertile alluvial silts deposited by the Zymagotitz River. Mixed agricultural production predominates in these areas with vegetable crops destined for local marketing in Terrace and small amounts of milk provided for dairy production. Most residents maintain domestic poultry and cultivate small gardens and orchards for some degree of self-sufficiency. No commercial establishments are situated in the community other than a carpentry shop and autobody repair firm.

The flood hazard within the community varies in accord with the type of flooding and season. Distinction is evident in the pattern of flooding associated with the Skeena and that inflicted by the Zymagotitz. Skeena

FIGURE 9

Flood Hazard in New Remo



(after Province of B.C., 1980a)

floods occur when the rail line embankment is breached south of the townsite. Floodwaters spread evenly northward through the community, covering properties up to the 1 in 200 year flood limit (Figure 9). Skeena River floods, however, have not inundated the New Remo community since 1948.

Flooding, associated with the Zymagotitz River, affects the community in different ways. Floodwaters cover those properties west and south of the slough (Figure 9). Flood depths are greatest in the west nearest the river during these events and in those areas nearest the river such as on DL2265 and DL1717, flooding due to backwater effects of the Skeena occur almost annually to varied depths. The distinction between these flood patterns in New Remo provides the basis for different measures to cope with the flood hazard. However, maps available which delineate probability limits for various magnitude floods depict the entire community within a 1 in 70 year flood limit. This flood type is a Skeena River Flood (Province of British Columbia, 1980a).

C. Developments Affecting the Flood Hazard

Flood control in New Remo dates back to the construction of the CNR mainline to Prince Rupert. The railway embankment offers protection from Skeena River floods up to a 1 in 70 year magnitude (Province of British Columbia, 1980a, Figure 9). The Highway 16 embankment alongside reinforces the protection at the same flood frequency. A flood equal in magnitude to the 1 in 200 year flood (or 1936 flood) would rise over these apparent dykes to a height of 1 metre and flood the entire community.

Floodplain regulations were adopted by the Regional District of Kitimat-Stikine in New Remo in 1976 designating setbacks and floodproofing requirements for new construction. These, however, are based on characteristics of Skeena River floods and do not relate to the pattern of flooding associated with the Zymacord. About one half dozen new homes have been constructed since that time and most of these have been sited on land south of the slough.

During the summer of 1980, a rock-filled and earthen berm was constructed along the east bank of the Zymacord River, north of the townsite to provide erosion protection and ensure the river does not break its course during flood and occupy the old slough through the town. Although the works are designed to keep the Zymacord in its present channel and to allay local residents' fears of a breakout developing a new course through the area, no protection against backwater flooding from the Skeena River is provided by these works. Protection against flooding in general by dyking is regarded as unfeasible (Province of British Columbia, 1980). The report suggests:

> Future building in the New Remo Subdivision Area should either be discouraged, or structures must be designed, sited and built to conform to the requirements of the Kitimat-Stikine Regional District Bylaw No.73.
>
> Recognizing the limited protection that affordable dyking can provide, existing homeowners at New Remo would be wise to also consider plans for floodproofing to protect their property against future floods (Province of British Columbia, 1980).

D. Community Regard Toward Flood Management

Despite the real and diverse flood hazard, residents remain in New Remo. Yet, few have taken it upon themselves to floodproof their buildings in accord with Regional District recommendations. However, floodproofing requirements, if adhered to, would not mitigate direct flood damage from the Zymacord. They are based on Skeena flood patterns.

Few residents within the community appear to have the resources or display the initiative to do much about flooding on their property. Following the 1978 flood, property values have declined markedly in New Remo.

Yet, most residents choose to remain located in the community despite their experience with fall floods.

The majority of residents favour dyking as the best means of dealing with the flood problem. Residents who occupy land south of the slough demonstrate a continued concern over the threat of fall flooding. Although the training berm has removed the threat of the Zymacord River breaking out of its course the southwestern part of the community continues to face the annual threat of backwater flooding from the Skeena during both spring and fall seasons.

Despite the actions taken in the community toward the fall flood hazard the need remains for a comprehensive strategy to contend with the complete scope of the flood problem. Fall flooding should be its focus and it should provide the scope and means for framing a practicable and feasible range of adjustments to reduce flood losses. The strategy should provide for residents of the community to make adjustments and take action against the hazard while minimizing the application of public funds.

II Developing a Comprehensive Strategy to Manage Fall Floods in New Remo

A. The Framework for Choice

In Chapter 1 a conceptual framework was identified as a basis for selecting the appropriate level of flood damage mitigation and designating the combination of flood damage reduction measures to achieve it. This approach is followed here in dealing with the fall flood problem in New Remo. The purpose, implicit in the approach, is to provide an evaluative framework in which to facilitate the selection of a socially optimal set of management alternatives and to generate evaluative information pertinent to public choice.

The strategy is initiated by considering the full range of alternatives (Table 1, Chapter 1) and sifting out the practicable adjustments, in light of the flood hazard characteristics and the technical feasibility of these measures. The second step in the process involves a comprehensive evaluation to designate the optimum combination of alternative measures from those determined to be practicable. Evaluation at this step is to determine the social benefits relative to costs so that an optimal choice can be made to determine the level and degree of flood management. Thus the implications of choosing one alternative or set of alternatives can be expressed in values relevant to public decisionmaking.

B. Strategic Elements

The flood problem at New Remo, necessitates immediate and continued planned action to achieve flood damage reduction. As a minimum, immediate steps should be taken toward defining the specific degrees of the dual flood hazard in the community and simultaneously undertaking actions to develop a flood warning service and linked emergency activities. Beyond these actions, efforts could be directed to evaluating remaining alternatives for reducing flood damage. The strategy would comprise the following steps:

Step I Define the Spatial Distribution of Flood Damages

The analysis would commence with a distinction between spring freshet and fall rain floods in the annual flood series for the Zymacord River at New Remo. Although the streamflow record is short, a probable frequency can be established for each type of flood, defining magnitudes and return periods (Chapter 2). In light of topographic information on the floodplain, depths and flood areas for different return periods can be derived for specific sites in the community. Based on these data it is not only possible to estimate the potential damages for each designated return period for the community as a whole but individual property owners will be able to estimate their risk of flood damage (James, 1973).

This is a critical step for two reasons: First, it assists in making private and public floodplain managers aware of flood hazard and the specific flood damage potential associated with properties in the community. Some of the managers may choose to take immediate, mitigating action to minimize their risks and thereby contribute to flood damage reduction (Kates, 1962). Second, spatial data on flood damages can assist long range planning by serving as the evaluative base in comparing the costs of alternative adjustments to the flood hazard in the community.

Step II Design a Flood Forecasting Service

The need for a fall flood forecasting service extends beyond the community of New Remo, to the entire region of the Lower Skeena and is regarded as fundamental to mitigating some damage during severe floods but more importantly, information provided in advance of flooding may save lives. If anticipated storm conditions and rainfall accumulation can be provided early enough, warnings can be issued and emergency action taken to mitigate some damage.

Forecasting fall floods requires comprehensive information on both atmospheric weather conditions and ground level conditions over the Coastal Mountain catchments of the Skeena. Currently, weather observation data is assembled at Prince Rupert as a basis for developing regional weather forecasts. Observations pertaining to atmospheric freezing levels, vertical temperature profiles, storm areas, humidity and precipitable water content and prevailing wind conditions are made on advancing Pacific disturbances

(Shaefer, 1979). Such information is vital to forecasting potential rainfall pattern, duration and intensity. However, a flood forecasting system requires linking meteorologic conditions to runoff potential within the catchments of the Lower Skeena to predict anticipated river flows and ultimately flood depths in the communities of the region. This type of information is currently unavailable for New Remo.

The Ministry of Environment should assume responsibility in regard to developing the flood forecast system for the Lower Skeena Region. Forecasting flood depths for New Remo would appear to be only a part of the service as there are other communities in the region facing the fall flood problem. The Water Investigation Branch in conjunction with the Water Survey of Canada would be required to determine storm rainfall-runoff relations for the Zymacord and other rivers of the region generating a fall flood threat. The Water Investigation Branch would be called on further to establish flood stage-streamflow relationships for communities like New Remo so that they might anticipate likely flood levels based on storm conditions.

With this information at hand, it is then possible to develop an integrated forecast and flood warning system. Such a service would be envisaged as operating through the fall months, prior to the season when efforts commence on forecasting spring freshet flood potential.

The flood forecast and warning service probably should be based in Terrace where the Regional Manager of Operations in the Ministry of Environment currently has a task of co-ordinating activities on water related problems. In a co-ordinative capacity, the Regional Manager is in a strategic position to integrate the flood information and make it relevant and useful to communities of the Lower Skeena. Analytical facilities in the regional office are currently linked by telecommunication and computer to Victoria in providing the capability for flood monitoring. Inter agency linkages in disseminating forecast information will require strengthening. Although the R.C.M.P, Provincial Emergency Program and Ministry of Highways are regarded as important, the Regional District Office should be involved and equipped to provide flood warnings to critically flood prone communities like New Remo through the media as well as by citizen band radio transmission.

In this way fall flood forecasts can be made efficiently, and warnings issued that are accurate and relevant to communities of the Lower Skeena. Furthermore such a comprehensive service is fundamental to effective emergency planning with regard to the flood problem. The nature of the fall flood hazard and its relationship to localized hydrologic and settlement characteristics necessitate a regional strategy aimed at forecasting potential flood conditions in each community. Effective emergency flood damage mitigation is only possible when this type of information is available to residents of these communities.

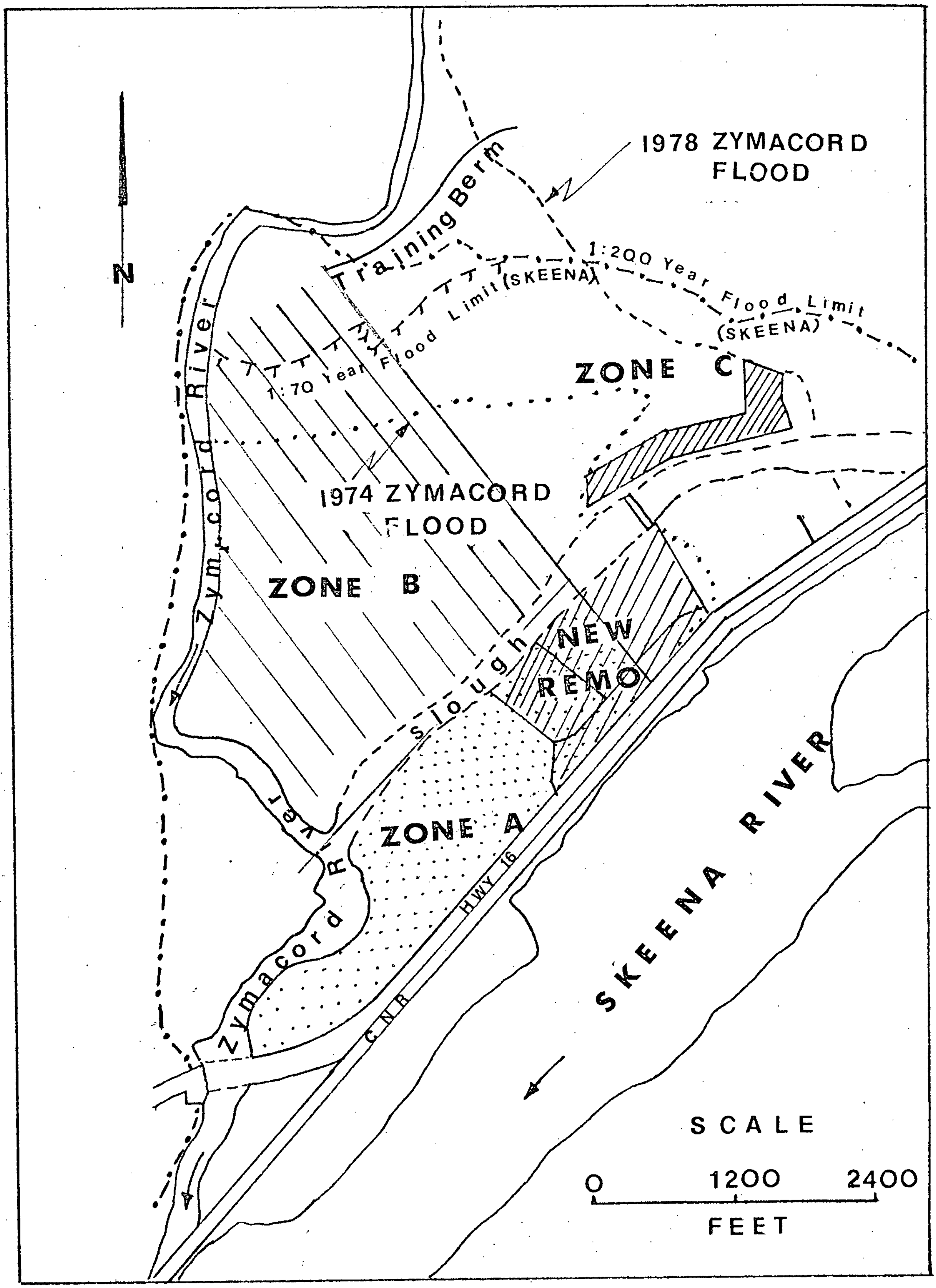
Step III Design of An Emergency Plan for Action During Floods

This step is contingent upon successful completion of the two preceding actions. Emergency action can be efficiently undertaken by residents of New Remo only if they perceive a threat of flooding and translate the flood magnitude into likely damaging effects. Residents require not only timely and accurate information on the pending flood conditions but must be able to relate these to probable flood levels on their properties. Furthermore, effective emergency action requires that residents be aware of what they should do to mitigate damage during the short time it takes the floodwaters to rise onto their land.

Currently, the Provincial Emergency Program (Ministry of Environment) co-ordinates emergency planning for spring freshet floods within the region through a ministerial representative in Terrace. It seems reasonable to

FIGURE 10

Flood Zones in New Remo



extend the duties of this position to fall flood emergency planning in the Lower Skeena. However, this type of flood problem is clearly more localized and requires different actions to mitigate damage than those appropriate for spring floods.

The non-uniform pattern evidently associated with the flood hazard in New Remo suggests that varied actions among residents will be necessary to provide for appropriate mitigative efforts during fall floods (Figure 10). Under a particular set of flood conditions, the risk of flood damage varies in three distinct zones within the community. Flood zone A has the largest risk of flooding and properties in this flood zone experience the greatest depth of flooding. Flood zone B, currently unoccupied, has a moderate flood risk while zone C experiences the lowest flood depths of all three areas. Flood conditions similar to those of 1978 would probably allow residents in zone C to remain on their property during flooding and take mitigative action to reduce damage by moving valuables and furniture from ground level to higher locations in their homes and buildings. Residents in Zone A would be advised to evacuate homes immediately. The plan for action within the community would need to be co-ordinated but at the same time provide for the diversity evident in the hazard and the potential mitigative actions to reduce flood damage.

Developing a community based emergency plan for New Remo and other communities of the Lower Skeena facing fall flood problems requires that residents be involved in the planning process and the plan ultimately be tailored to the particular community. Residents of New Remo will have to be informed as to the particular flood hazards they face on their homesite and instructed as to what they should and can do to prevent flood damage on their properties. Some type of public forum may be necessary, perhaps in workshop format to facilitate the flow of information, education and ultimately the organization of the community toward the fall flood problem. As individual residents clearly perceive their personal risks from flooding they are more likely to want to do something about it and adhere to designated actions to minimize impacts (White, 1975). Planning toward probable fall flood emergency is but one step in the strategy to manage floods however, consultation with community residents at this stage can influence perceptions of the hazard and strategic actions which may serve to increase awareness and strengthen willingness to follow long term planning measures toward the flood problem.

Step IV Assessing Remaining Alternatives for Reducing Damages

Having taken these steps, the investigation is open to evaluation of remaining adjustments to reduce flood damage in New Remo. Although these comprise a wide range of theoretically applicable structural and nonstructural measures, some are not practicable to the situation in New Remo.

Flood insurance is ruled out at this time, since it is not generally available from private insurance companies, nor is there a government flood insurance program available to residents in the region of the Lower Skeena. Any of the remaining nonstructural measures could be applied in New Remo (Table 1, Chapter 1). Structural control of fall floods at New Remo is practicably limited to dyking. Dams on the Zymacord are ruled out because indirect flooding by the Skeena would continue to affect the community, even if the flow of the Zymacord is effectively regulated. Yet even with dykes protecting New Remo, since they offer only partial flood protection and frequently encourage encroachment, nonstructural measures, such as floodplain regulation and floodproofing, may be necessary to contend with the residual flood damage potential.

The practicable range of alternative adjustments for New Remo would appear to entail:

(1) Dyking the Entire Community

(2) Prohibiting Further Building in the Floodplain

(3) Floodproofing Existing Buildings

(4) Permanent Evacuation of Some Homesites

A comprehensive evaluation of these alternatives is beyond the scope of this study and must await site-specific data on flood damage potential derived in Step I. However, in light of the flood hazard and community features in New Remo it is advantageous to investigate these alternatives further toward suggesting better adjustments to the flood problem than those currently being made. Ultimately the selection of an optimum set of flood damage reduction measures would be made on the basis of providing an acceptable degree of flood protection at least cost.

The current management standard within the Lower Skeena Region is the 1 in 200 year flood. The approximate costs of each of these measures determined to achieve this level of flood protection are compared to indicate the least cost alternative combination.

(1) Dyking the Entire Community

The existing berm provides partial protection against fall floods (Province of British Columbia, 1980a). It is designed to prevent direct inundation up to the 1 in 200 year flood height. However, it offers no protection against indirect flooding when the Skeena backs the Zymacord flow onto the floodplain in New Remo. Dyking the entire community along the Zymacord is estimated to cost $500,000 (Province of British Columbia, 1980a). The protection provided, however, is only up to the 1 in 70 year Skeena spring freshet flood height as the highway and rail embankment along the southern side would be breached above this height (Figure 9). To achieve protection up to the 1 in 200 year flood, not only the dyke would require modification but the highway embankment would have to be raised and buttressed as well as modifications carried out on the bridge across the Zymacord (Province of British Columbia, 1980). The costs of such a scheme would probably exceed the total value of property in the floodplain at New Remo, estimated at $2 million at most (Marcellin, pers. comm., 1980).

(2) Prohibiting Further Building in the Floodplain

Currently this measure is applied by the Regional District of Kitimat-Stikine through Zoning Bylaw 73. New buildings are required to have the living space sited at least 2.6 metres (8.6 feet) above ground level. However, this regulation is based on Skeena flood heights and not those associated with the Zymacord. The 1 in 200 year flood height, related to the Zymacord requires siting the first floor of some buildings above 3.2 metres (10.6 feet), while others might require less elevation as floodproofing. However, the precise degree of floodproofing must await site specific evaluation of buildings in New Remo.

Prohibition of new construction would serve to halt the growth of future flood damages. However, on its own, this measure does nothing to reduce existing flood damage potential. Its effect might not be felt for some time and then it may depend on the effective implementation of other adjustments to the flood problem.

(3) Floodproofing Existing Buildings

Floodproofing would entail raising some homes at least 3.2 metres (10.6 feet) while other buildings would require less floodproofing to provide protection up to the 1 in 200 year flood limit. Some of the buildings, particularly older homes located in flood zone A, may not be structurally fit to be raised. These have incurred extensive flood damage and the costs of retrofitting them would probably exceed their current market value (Figure 10). However, for the northern part of the community in flood zone C, some homes would not have to be floodproofed to the same degree and raising these buildings would probably be feasible. However, accurate cost estimates for each property would be needed in either case to assess the suitability of floodproofing buildings. Assuming it costs approximately $10,000 per home to raise the first floor, the aggregate cost should not exceed $500,000 for the community but this figure would not include floodproofing older homes in zone A.

(4) Permanent Evacuation of Some Homesites

Although it may be the most economically efficient measure for some of the properties south of the slough in Zone A, complete evacuation of the community is probably out of the question. Obviously a property by property appraisal will be required to assess the need to permanently evacuate or floodproof each site. Information in this regard is contingent on data derived in Step I above. However, permanent evacuation should be considered as potentially applicable, particularly for those homesites which cannot be efficiently floodproofed.

In flood zone A there may be as many as fifteen such homes involved. Residents of these could be relocated with equivalent size and valued properties in zone C. Compensation could amount to as much as $50,000 per household. Aggregate cost of evacuation would probably exceed $500,000 but would eliminate significant flood damage.

(5) Comparing and Combining Adjustments

If dyking the entire community is taken as the standard for comparison, this measure will achieve protection from Zymacord River floods up to the 1 in 200 year return period at a cost of about $500,000. However, to eliminate all flooding in New Remo, including backwater flooding related to the Skeena, the costs would exceed $2 million to achieve 1 in 200 year flood protection (Province of British Columbia, 1980a).

For this level of flood protection, floodproofing and permanent evacuation of some homes in an appropriate combination would probably be more economically feasible. Assuming the costs of floodproofing averages $10,000 per homesite and approximately 25 homes would be floodproofed in zone C totalling $250,000. Evacuation of the remaining properties in zone A might average $50,000 per household, totalling just over $750,000. Floodproofing and permanent evacuation would cost approximately $1 million to achieve the same degree of protection as dyking the community.

Both floodproofing and permanent evacuation offer other advantages to dyking the community. Dyking would encourage further encroachment and development in the floodplain increasing community size and property values. Nonstructural measures, such as floodproofing, permanent evacuation and floodplain regulation, encourage more efficient use of floodplain land. These measures would tend to curb over-development. Measures taken to floodproof dwellings not only minimize flood damage but can also serve as reminders within the community of potential flood severity and subtly keep residents and newcomers aware of the problems they must face in building on flood prone land. Permanent evacuation removes the problem completely, provided floodplain regulations are implemented preventing subsequent occupation of evacuated land. The nonstructural approach also encourages individuals within the community to assume responsibility for taking action toward the flood problem while structural measures appear to work in the opposite direction.

Step V Development of a Financing Policy

Policies to accommodate Steps I, II and III are available within the current set of institutional arrangements to manage floods within the Lower Skeena Region. Although these are geared toward spring freshet floods, resources might be supplemented to provide services toward the fall flood problem. Moreover since fall flooding is regional in extent, the costs of a program to carry out steps I through III should be undertaken on a region-wide basis for the Lower Skeena with due consideration to the specific features of the flood problem associated with individual communities.

Currently, the Ministry of Environment handles flood problems and the complete scope of the strategy proposed here would fit within its mandate. Step I could be added to the present tasks of the Water Investigation Branch in mapping and assessing floodplains. A fall flood forecasting and warning service could be handled efficiently by the Hydrologic Section while Step III could be developed by the Provincial Emergency Program within the Lower Skeena Region. The costs involved with these steps in the strategy should be borne by the Province since the benefits would extend beyond the Lower Skeena Region and these measures are fundamental to achieving flood damage prevention.

Financing floodproofing and permanent evacuation of parts of the New Remo community could be accommodated under the River Protection Assistance Program. A 25 per cent local contribution is required in sharing the costs of river protection works with the Province. Although this formula has only been applied to flood control projects such as dyking, there is little preventing its use to encourage other types of adjustments to flood hazards. In New Remo, a potentially better adjustment to the flood hazard could be achieved through floodproofing and permanent evacuation.

If the funds required to dyke New Remo against the 1 in 200 year Zymacord flood were available to residents to floodproof their homes instead, they might achieve a greater degree of protection against the complete flood hazard. The cost of such a dyking project amounts to $500,000 (Province of British Columbia, 1980a). However, it only achieves protection up to a 1 in 70 year Skeena River flood. If the 75 per cent provincial share of the project's cost ($375,000) was made available to the property owners of New Remo to carry out floodproofing measures, they would have approximately $9,000 per household. Adding their 25 per cent contribution to the figure should provide adequate funds to floodproof up to the Regional District standard for New Remo in regard to the 1 in 200 year Skeena River flood height. In this way, the funds which would have paid for partial protection with the dyke, provides for comprehensive flood protection to a higher standard in the community and in line with flood damage prevention in other parts of the Lower Skeena.

III Discussion and Implications

The application of a comprehensive strategy to determine an appropriate set of adjustments to the flood problem in New Remo, systematically demonstrated the steps to be followed in dealing with the fall flood problem. The procedure illustrated the simple logic required to designate measures to reduce flood damage in the community. Evaluation of practicable alternatives for New Remo indicated that floodproofing and permanent evacuation are potentially better measures to achieve flood damage reduction than dyking the community, especially if standard flood protection up to the 1 in 200 year regional flood limit is applied to the consideration of costs.

The strategy recognizes the non-uniform features of the flood hazard in New Remo. The steps proposed for management suggests a localized, community-based approach. Residents of New Remo would have to fully participate in the implementations of the strategy. They should be informed and educated regarding the risks of flooding and instructed as to practicable short and long term adjustments to the hazards in the community. Such an approach requires a change in the perspective toward managing floods in the Region of the Lower Skeena which can facilitate the development of diverse efficient adjustments to flood problems like those in New Remo.

The primary step identified in the strategy is fundamental to those which follow it. However, it involves a different type of hydrologic investigation than that which is typically involved to design structural flood control measures. To provide relevant information for the consideration of both structural and nonstructural measures requires information on the hazard as a function of frequency and on the average annual damages at every location in the floodplain (James, 1973). In dealing with individual property owners, the only relevant information is the flood hazard for that particular property and the damages that hazard can be expected to cause.

Making such information available to residents of New Remo should assist in generating successful response to subsequent steps in the strategy and encourage committment toward reducing flood damage in the community.

At the same time, the strategy calls for a different approach to managing floods on the part of the Ministry of Environment. In dealing with New Remo residents, agency staff charged with developing a flood management plan would be required not only to communicate data on the flood hazard but to instruct residents in techniques to reduce damage. Moreover, in evaluating the potential long term measures to be taken against the flood hazard, a broad range of structural and nonstructural alternatives would have to be set forth, in understandable terms for local consideration, with all of the financial implications on the table and decision criteria evident from analyses of the flood problem setting, it will then be possible for the community of New Remo to approach a socially optimal adjustment to the flood hazard.

IV Study Conclusions

A. The Flood Hazard

Persistent fall floods in the Lower Skeena have contributed to increasing flood damages despite the prevailing program of flood damage prevention in the region. Fall floods arising from heavy rainfall are more hydrologically significant than spring freshet floods on some of the Lower Skeena tributaries. They pose a severe hazard in communities like New Remo. Although these floods are not as extensive as the spring problem they are locally severe, and as pressures for floodplain development continue in the region, ensuing encroachment will contribute to a continued rise in damage potential from fall floods. The fall flood hazard requires a different strategy for management than spring floods.

B. The Current Management Approach

Existing nonstructural flood damage prevention measures applied in the Lower Skeena Region do not incompass the fall flood problem. Floodplain regulation and floodproofing requirements for communities in the region are too uniform to take into account the diverse problem settings within the region and apply only to new development in floodplains. Flood forecasting and warning systems along with emergency plans are geared toward flooding in spring as a result of coincident high runoff from snowmelt. The current situation in Lower Skeena communities, illustrated by New Remo, suggests the need for a comprehensive strategy to manage fall floods.

C. Flood Management Strategy for New Remo

A systematic, step by step procedure is applied to the complex flood problem in New Remo, based on a framework for considering a broad range of potential adjustments to the flood hazard. Floodproofing and evacuation are suggested as more feasible and efficient alternatives to dyking the community. Moreover, the strategy points out the information required in the development of a comprehensive flood management program for New Remo. Procedural steps in the strategy include:

I Defining the spatial and temporal characteristics of the flood problem in New Remo.

II Developing a flood forecasting service.

III Designing an emergency plan.

IV Evaluation of practicable adjustments to the flood hazard.

V Developing financial arrangements for feasible adjustments.

Such an approach can be accommodated within the scope of current policy and institutional arrangements in the Lower Skeena Region. However, a prime requisite would be the involvement of New Remo residents in the management process.

Although floodproofing is suggested as a potentially efficient adjustment to the flood hazard in New Remo, elsewhere in the region, it may prove unfeasible. To effectively evaluate floodproofing along with other alternatives requires accurate site specific data on flood levels and potential damages. Even though fall flooding emerges as a critical problem in other communities of the Lower Skeena, such as Lakelse, Dutch Valley, Copperside, Rosewood and Greenvale, the specific formula developed for New Remo may not necessarily apply. This is especially so in regard to structural and nonstructural flood damage adjustment combinations. For each flood problem setting, it will be necessary to generate a strategy to provide site specific information on the degree of the flood hazard as a basis for determining the appropriate combination of adjustments.

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