Institute for Catastrophic Loss Reduction
Institut de Prévention des Sinistres Catastrophiques

Earthquake Hazard Zones: The relative risk of damage to Canadian buildings

by

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1. INTRODUCTION

In 2003, this study was launched to assess the new information about the relative risk of earthquake damage across Canada. As an outcome of this research, Canadian earthquake hazard maps (Hazard Zones) were developed to support the determination of insurance coverage terms and conditions in Canada. Created principally for insurers, Hazard Zones are new in Canada and are based on an analysis of the probability of expected loss from all possible earthquake sources and magnitudes. Postal codes are grouped into Hazard Zones with similar relative levels of expected loss.

This paper presents new information about the relative risk of earthquake damage across Canada. It brings together the most recent information about earthquakes experienced in Canada, soil studies and other data needed to better estimate the risk of future seismic damage. The objective of this research paper is to summarize this information in a format that can be applied readily to insurance practices. This includes a mapping of Hazard Zones which detail the relative risk of seismic damage by postal code. The research covers all regions in Canada and is presented with a special focus on areas of high to moderate risk in British Columbia, Quebec, and Eastern Ontario. Detailed maps are provided for Victoria, Vancouver, Ottawa, Montreal, and Quebec City.

In this research paper, we:

- discuss the background to this study
- examine the nature of earthquake risk and the role of insurance in Canada
- explain the methodology behind, and approach to, developing Hazard Zones
- review issues of implementation and timing
- present the new Canadian earthquake Hazard Zones.

2. EARTHQUAKES AND THE ROLE OF INSURANCE

In less than 30 seconds an earthquake can cause considerable loss of life, injuries, and property damage. For example, an earthquake in 1556 killed 830,000 people in Shansi, China. In 1995, more than C$150 billion in earthquake damage occurred in Kobe, Japan. An earthquake in 1700 was more powerful than the Shansi or Kobe events, and it was centred just west of Vancouver Island. Earthquakes have the potential to be very destructive.

Canadians are vulnerable to earthquakes. The risk of earthquake damage is underestimated by most Canadians. Each year more than 1,500 earthquakes are recorded in Canada – an average of about 4 events each day. Sensitive equipment is required to identify most earthquakes, nevertheless a few dozen can be felt each year, and several times each century earthquakes are strong enough to cause widespread damage. There have been large Canadian earthquakes in the past, and there will be large events in the future. It is inevitable that a major earthquake will occur near an urban centre in Canada.

Earthquake risk

We do not know when the next major earthquake will strike, but we do know where damage is most likely to occur. Three of Canada's four largest cities are located in regions of high to moderate risk of earthquake damage – Vancouver, Montreal, and Ottawa. Some other vulnerable communities include Victoria and Quebec City. It is likely that severe loss of life and property damage will be experienced eventually in or around one or more of these centres.

British Columbia is highly vulnerable to earthquake damage. The so-called Ring of Fire which circles the Pacific Ocean and includes Canada's west coast, is the most active area in the world for major earthquakes. Approximately one thousand earthquakes are recorded each year on Canada's west coast. Most are too small to be felt and do not threaten to cause damage. Also, several larger events occur deep in the earth, so there is less damaging energy released at the surface where we live.

Nevertheless, there will be earthquakes that cause significant damage on Canada's west coast. The greatest damage will be caused by a large earthquake near the surface. These events are rare but cause considerable loss. In addition to earthquakes near the surface, we are overdue for a major subduction earthquake, like the event that occurred in 1700, west of Vancouver Island. These powerful earthquakes centred west of Vancouver Island will cause shaking damage to the buildings where Canadians live, work and study, and will also trigger tsunamis that will flood coastal areas.

The risk of earthquake damage is moderate in Eastern Canada. Small earthquakes are recorded regularly, indeed almost daily, in the region that includes Ottawa, Montreal, and Quebec City. Our vulnerability to damage is elevated because of the large number of people and buildings located in this area. Furthermore, many buildings and infrastructure investments are older and were put in place before modern seismic safety codes were developed.

Earthquakes are less common in other parts of the country. Nevertheless there have been events from coastal Newfoundland to Cornwall, Ontario that have caused loss of life or property damage. The threat of seismic damage is low in the Prairie Provinces, south-western and northern Ontario, but some risk is evident. There are regions in northern Canada where seismic risk is moderate-to-high, although fewer people and buildings are located in these areas.

Hazard Zones show areas of equal risk of damage to a particular structure. This reflects the likelihood of strong seismic activity, soil conditions and other factors that affect the risk of damage. Variations in soil is the primary reason why there are different hazard zones within a city or region.

Role of insurance

Insurance is available to property owners concerned about seismic damage to their homes and businesses. The price of coverage, deductibles, and other insurance terms and conditions should reflect the best knowledge about the risk of damage. Owners, for example, seeking to insure property that is more vulnerable to earthquake damage should expect pay more for coverage and perhaps face higher deductibles and other restrictions in coverage. Those with less risk, in turn, should experience more favourable terms. Everyone concerned – including property owners and insurers – should strive to ensure that differences reflect current knowledge and understanding about the risk of loss, which is the objective of the research presented in this paper.

Included in our work is the identification of regions of comparable expected earthquake damage. Similar homes or buildings located in a particular Hazard Zone are equally likely, in our analysis, to experience damage due to an earthquake, so insurance companies might be expected to offer similar insurance coverage terms and conditions. However, the potential impact of a future earthquake should not be the only factor involved in the appropriate determination of insurance coverage terms and conditions. It is important for property owners and insurers to assess each specific property to determine its resilience and capacity to survive an earthquake – property-specific information that is not included in the assessment presented here.

To illustrate how our research can be applied, we may consider two homes with similar resale values. If they are in the same Hazard Zone with similar resilience to earthquakes damage – perhaps because they were built at the same time by the same homebuilder, with similar maintenance – then our research suggests that they should also expect to be offered similar insurance coverage terms and conditions. However, if one home is located in a region where the hazard risk is higher, then the owner should anticipate higher cost to purchase insurance, perhaps increased deductibles and some restrictions in coverage relative to the home in the region of lower risk. Moreover, the homes may be in the same region but one may be less vulnerable to damage because of newer construction or seismic safety improvements, and this would lead in turn to more favourable insurance terms. Differences in buildings and methods of construction are critical for the determination of vulnerability and appropriate insurance terms and conditions beyond the earthquake hazard zone analysis presented here.

3. METHOD FOR IDENTIFYING HAZARD ZONES

This is the first time earthquake Hazard Zones have been produced to support the determination of insurance coverage terms and conditions in Canada. This is a new tool seeking to enhance the traditional efforts of insurers to determine insurance coverage. Our research brings together the latest information about the risk of earthquakes in Canada, soil research, and other data that are important to determine the risk of seismic damage to property. This research was conducted by EQECAT using the CANADAQUAKE® model (EQECAT is a division of ABS Consulting, an international leader in comprehensive risk management). Funding and direction for the research was provided by the Insurance Bureau of Canada and the Reinsurance Research Council of Canada. The Institute for Catastrophic Loss Reduction provided support for the preparation of this research paper to summarize and share our assessment of the Hazard Zones project.

For many years, Canadian insurers have had access to CRESTA (Catastrophic Risk Evaluation and Standardizing Target Accumulations) Zone maps to help manage seismic exposure. CRESTA was established in 1977 by the international insurance and reinsurance community to develop a uniform system to assess and control liabilities arising from natural hazards. CRESTA Zones were first established for Canada in 1986 with a focus on seismic exposure. This tool helps insurers and reinsurers measure and manage their accumulated exposure. It has been important for the determination of catastrophic reinsurance coverage terms and conditions. CRESTA Zones, however, do not provide any direct information that is helpful in the determination of insurance terms for particular homes or businesses, which is the object of our new Hazard Zones.

In 2002, the Insurance Bureau of Canada and the Reinsurance Research Council of Canada decided to fund and direct a research project that led to the development of the earthquake Hazard Zones presented here as well as an update in the Canadian CRESTA Zones that was released earlier by the Bureau and Council. This research takes into account important information that was not available for inclusion in the original CRESTA Zones and had never previously been developed into Hazard Zones. The new Canadian CRESTA Zone information is available from the Insurance Bureau of Canada (*CRESTA Earthquake Accumulation Zones, Canada, October 2003*), while this paper provides information on the new Canadian earthquake Hazard Zones.

The updated CRESTA Zones and the new earthquake Hazard Zones were developed using a sophisticated analytical tool for assessing and managing insured earthquake risk – EQECAT's CANADAQUAKE® model. EQECAT developed the CANADAQUAKE® model as an analytical tool for individual insurers to manage their earthquake risk. The model provides the foundation for the research presented in this study. The model is based on the 1995 Geological Survey of Canada hazard model. It uses three-dimensional planar fault modeling to simulate all potential major earthquake types including strike-slip, thrust, blind-thrust, and subduction events. The database simulates more than 100,000 potential earthquake events for 34 defined Canadian seismic sources. Uncertainty regarding the epicentre location, depth of the event, directionality and exact magnitude requires many combinations of these variables to be modeled.

The Hazard Zone modelling process

EQECAT used the following step-by-step process to develop Hazard Zones:

- **Determine what is subject to a loss (that is, the asset at risk)**. Various insurance companies provide this information. All risk location information is computed using the latest (November 2001) dataset of 6-digit postal codes and 3-digit forward sortation areas (FSAs). The use of postal codes (rather than a uniform grid) diminishes the possibility of the assets at risk not properly reflecting the population density.

- **Model the hazard**. The potential shaking intensity is performed following a review of the history (that is, earthquake frequency, location, and magnitude) experienced in each zone. The database simulates over 100,000 earthquake events for the 34 defined Canadian seismic sources. The hazard is estimated using a full probabilistic definition of the disaster event. A probabilistic analysis of all major sources and magnitudes of the hazard is carried out, leading to a description of occurrence of the hazard intensity through "hazard curves". A hazard curve typically defines the probability of exceeding a hazard intensity level in a given time period, usually one year.

- **Extend the shaking to nearby locations**. The effect of an event of a given magnitude, and its attenuation or amplification as it extends from the source to a particular site, is estimated as a function of the distance between the site and the event location. In other words, the further away the zone is from the epicentre, the less the shaking will be. These calculations are based on the physical characteristics of the geology and terrain (for example, local soil types and depth) between the epicentre and nearby sites. In the case of earthquake hazards, the shaking intensity at the various sites depends on the earthquake source variables (for example, magnitude, depth, epicentre, location, geological conditions of the travel path of the seismic waves, and the local soil conditions). Accordingly, it can be expected that the variability of shaking intensity at sites close together is more highly correlated than the ground motions at sites some distance apart (which may differ geologically).

- **Estimate the damage to insured properties and infrastructure**. This phase of the analysis makes use of a database of input information to estimate the damage induced by the hazard at each site. The database includes the attributes of insured sites, as well as location, values at risk, structure type, occupancy and use. For the creation of Hazard Zones, it is assumed that all properties are of the same type and construction. For a particular value of hazard intensity and structural system type, a damage factor is derived for each individual property and this factor expresses the relative cost of repair that the structure is likely to need (with respect to its insured value) if the property experiences an earthquake of a given intensity.

- **Compute the loss estimates**. This last step involves the estimation of insured losses. Estimated losses are based on information provided by the insurance industry (damage, deductibles, coverage limits, and total insured value). Net loss to primary insurers and losses to reinsurers are further calculated based on the appropriate insurance information. To create Hazard Zones, annual damage by postal code is calculated as the average of all risks in the area. Zones with roughly the same estimated damage are grouped into one of six “equal range” zones ranging from West 1 (Extreme) to West 6 (Very Low) for British Columbia, or from East 1 (Extreme) to East 6 (Very Low) for Ontario and Quebec. These equal range Hazard Zones are presented in the last section of this research paper.

4. IMPLEMENTATION AND TIMING

It is expected that reinsurers will begin using the revised CRESTA Zones in time for submissions for the January 2005 renewal season. It may be possible to use the newly developed Hazard Zones in conjunction with Default Loss Estimate factors in future regulatory filings.

5. CANADIAN EARTHQUAKE HAZARD ZONES

Canadian earthquake Hazard Zones have been developed for the following geographic locations:

- British Columbia
- Vancouver and Victoria
- Eastern Canada
- Ottawa
- Montreal
- Quebec City.

The new Canadian earthquake Hazard Zones are presented as both maps and tables in the pages that follow.

Appendix I

Earthquake Hazard Zones -- Quebec

Hazard Zone	Description	Postal Codes
East 1	Extreme	H1A, H1B, H1G, H1J, H1V, H2Z, H3N, H3R, H3X, H4B, H4S, H4V, H4Y, H7A, H7B, H9A, H9P, J0P, J0S, J2W, J2X, J2Y, J3A, J3B, J3E, J3G, J3H, J3L, J3M, J3N, J3V, J3X, J3Y, J3Z, J4B, J4G, J4H, J4J, J4K, J4L, J4M, J4N, J4P,J4R, J4S, J4T, J4V, J4W, J4X, J4Y, J4Z, J5A, J5J, J5R, J5W, J5X, J5Y, J5Z, J6A, J6J, J6K, J6N, J6R, J6S, J6T, J6V, J6W, J6X, J6Y, J6Z, J7B, J7C, J7J, J7K, J7L, J7M, J7N, J7P, J7R, J7T, J7X, J8H, J8L, J8M, J8P, J8R, J8T, J8V, J8Y, J9E, J9L
East 2	Very High	G3Z, G5L, G5M, G5N, G5R, G8T, G8V, G8W, G8Y, G8Z, G9A, G9B, G9C, G9H, G9N, G9P, G9T, H0A, H0M, H1H, H1L, H1W, H2A, H2B, H2C, H2E, H2G, H2H, H2J, H2K, H2L, H2S, H2V, H2X, H2Y, H3A, H3B, H3G, H3P, H3S, H3T, H3W H3Z, H4A, H4C, H4G, H4H, H4P, H4R, H4T, H4W, H4X, H5B, H7H, H7R, H8R, H9C, H9E, H9G, H9H, H9J, H9K, H9R, H9S, H9W, H9X, J0G, J0H, J0J, J0K, J0L, J0N, J0V, J0X, J2B, J2C, J2E, J2N, J2R, J2S, J2T, J3P, J3R, J3T, J5V, J6E, J7A, J7E, J7V, J7Z, J8G, J8Z, J9A
East 3	High	G0S, G0X, G0Z, G1B, G1C, G1G, G2A, G2B, G2C, G2E, G2J, G2K, G2L, G2M, G2N, G3A, G3E, G3G, G3H, G3J, G3K, G3L, G4A, G4W, G5C, G5H, G5V, G6C, G6J, G6K, G6P, G6T, G6X, G6Z, G7A, G7G, G7H, G7J, G7K, G7P, G7S, G7T, G7X, G7Y, G7Z, G8A, G9R, H1C, H1E, H1K, H1M, H1N, H1P, H1R, H1S, H1T, H1X, H1Y, H1Z, H2M, H2N, H2P, H2R, H2T, H2W, H3C, H3E, H3H, H3J, H3K, H3L, H3M, H3V, H3Y, H4E, H4J, H4K, H4L, H4M, H4N, H4Z, H5A, H7C, H7E, H7G, H7J, H7K, H7L, H7M, H7N, H7P, H7S, H7T, H7V, H7W, H7X, H7Y, H8N, H8P, H8S, H8T, H8Y, H8Z, H9B, J0C, J0R, J0T, J0W, J1M, J1Z, J2A, J2K, J5K, J5L, J7G, J7H, J7Y, J8A, J8B, J8C, J8E, J8N, J8X
East 4	Moderate	G0A, G0H, G0L, G0P, G0R, G0V, G1E, G1H, G1J, G1K, G1L, G1M, G1N, G1P, G1Y, G2G, G4X, G6L, G6R, G6S, G6V, G6W, G7B, G7N, G8B, G8C, G8E, G8G, G8L, G8N, J0A, J0B, J0E, J1A, J1G, J2G, J2H, J2J, J2L, J9J
East 5	Low	G0J, G0K, G0M, G0N, G0T, G0W, G0Y, G1A, G1R, G1S, G1T, G1V, G1W, G1X, G4R, G4S, G5A, G5B, G5J, G5T, G5X, G5Y, G5Z, G6A, G6B, G6E, G6G, G6H, G8H, G8K, G9X, J1E, J1H, J1J, J1K, J1L, J1N, J1S, J1T, J1X, J9H, J9P
East 6	Very Low	G0B, G0C, G0E, G0G, G4V, G4Z, G8J, G8M, G8P, J0M, J0Y, J0Z, J9T, J9V, J9X, J9Y, J9Z

Earthquake Hazard Zones -- Ontario

Hazard Zone	Description	Postal Codes
East 1	Extreme	J9B, K0B, K1C, K1E, K1T, K1W, K2P, K4A, K4B, K4C, K4K, K4M, K4P, K4R, K6A, K8H
East 2	Very High	K0A, K0C, K1B, K1G, K1H, K1J, K1K, K1N, K1P, K1S, K1V, K1X, K2C, K2E, K2G, K2H, K2M, K2S, K2V, K6H, K7S, K7V, K8A, K8B
East 3	High	K1A, K1L, K1M, K1Z, K2A, K2B, K2J, K2K, K2L, K2R, K6J, K6K, K6V
East 4	Moderate	K0E, K0G, K0J, K1R, K1Y, K2W, K6T
East 5	Low	K0H, K2T, K7A, K7C, K7G, K7H, K7K, K7L, K7M, K7N, K7P, K7R, K8R, K8V, L2N, P0J, P1A, P1B
East 6	Very Low	K0K, K0L, K0M, K8N, K8P, K9A, K9H, K9J, K9K, K9L, K9V, L0A, L0B, L0C, L0E, L0G, L0H, L0J, L0K, L0L, L0M, L0N, L0P, L0R , L0S, L1A, L1B, L1C, L1E, L1G, L1H, L1J, L1K, L1L, L1M, L1N, L1P, L1R, L1S, L1T, L1V, L1W, L1X, L1Y, L1Z, L2A, L2E, L2G, L2H, L2J, L2M, L2P, L2R, L2S, L2T, L2V, L2W, L3B, L3C, L3K, L3M, L3P, L3R, L3S, L3T, L3V, L3X, L3Y, L3Z, L4A, L4B, L4C, L4E, L4G, L4H, L4J, L4K, L4L, L4M, L4N, L4P, L4R, L4S, L4T, L4V, L4W, L4X, L4Y, L4Z, L5A, L5B, L5C, L5E, L5G, L5H, L5J, L5K, L5L, L5M, L5N, L5P, L5R, L5S, L5T, L5V, L5W, L6A, L6B, L6C, L6E, L6G, L6H, L6J, L6K, L6L, L6M, L6P, L6R, L6S, L6T, L6V, L6W, L6X, L6Y, L6Z, L7A, L7B, L7C, L7E, L7G, L7J,L7L, L7M, L7N, L7P, L7R, L7S, L7T, L7V, L8E, L8G, L8H, L8J, L8K, L8L, L8M, L8N, L8P, L8R, L8S, L8T, L8V, L8W, L9A, L9B, L9C, L9G, L9H, L9J, L9K, L9L, L9M, L9N, L9P, L9R, L9S, L9T, L9V, L9W, L9X, L9Y, M1B, M1C, M1E, M1G, M1H, M1J, M1K, M1L, M1M, M1N, M1P, M1R, M1S, M1T, M1V, M1W, M1X, M2H, M2J, M2K, M2L, M2M, M2N, M2P, M2R, M3A, M3B, M3C, M3H, M3J, M3K, M3L, M3M, M3N, M4A, M4B, M4C, M4E, M4G, M4H, M4J, M4K, M4L, M4M, M4N, M4P, M4R, M4S, M4T, M4V, M4W, M4X, M4Y, M5A, M5B, M5C, M5E, M5G, M5H, M5J, M5K, M5L, M5M, M5N, M5P, M5R, M5S, M5T, M5V, M5W, M5X, M6A, M6B, M6C, M6E, M6G, M6H, M6J, M6K, M6L, M6M, M6N, M6P, M6R, M6S, M7A, M7X, M7Y, M7Z, M8V, M8W, M8X, M8Y, M8Z, M9A, M9B, M9C, M9L, M9M, M9N, M9P, M9R, M9V, M9W, N0A, N0B, N0C, N0E, N0G, N0H, N0J, N0K, N0L, N0M, N0N, N0P, N0R, N1A, N1C, N1E, N1G, N1H, N1K, N1L, N1M, N1P, N1R, N1S, N1T, N2A, N2B, N2C, N2E, N2G, N2H, N2J, N2K, N2L, N2M, N2N, N2P, N2R, N2S, N2T, N2V, N2Z, N3A, N3B, N3C, N3E, N3H, N3L, N3P, N3R, N3S, N3T, N3V, N3W, N3Y, N4B, N4G, N4K, N4L, N4N, N4S, N4T, N4V, N4W, N4X, N4Z, N5A, N5B, N5C, N5H, N5L, N5P, N5R, N5V, N5W, N5X, N5Y, N5Z, N6A, N6B, N6C, N6E, N6G, N6H, N6J, N6K, N6L, N6M, N6N, N6P, N7A, N7G, N7L, N7M, N7S, N7T, N7V, N7W, N7X, N8A, N8H, N8M, N8N, N8P, N8R, N8S, N8T, N8V, N8W, N8X, N8Y, N9A, N9B, N9C, N9E, N9G, N9H, N9J, N9K, N9V, N9Y, P0A, P0B, P0C, P0E, P0G, P0H, P0K, P0L, P0M, P0N, P0P, P0R, P0S, P0T, P0V, P0W, P0X, P0Y, P1C, P1H, P1L, P1P, P2A, P2B, P2N, P3A, P3B, P3C, P3E, P3G, P3L, P3N, P3P, P3Y, P4N, P4P, P4R, P5A, P5E, P5N, P6A, P6B, P6C, P7A, P7B, P7C, P7E, P7G, P7J, P7K, P8N, P8T, P9A, P9N

Earthquake Hazard Zones – British Columbia

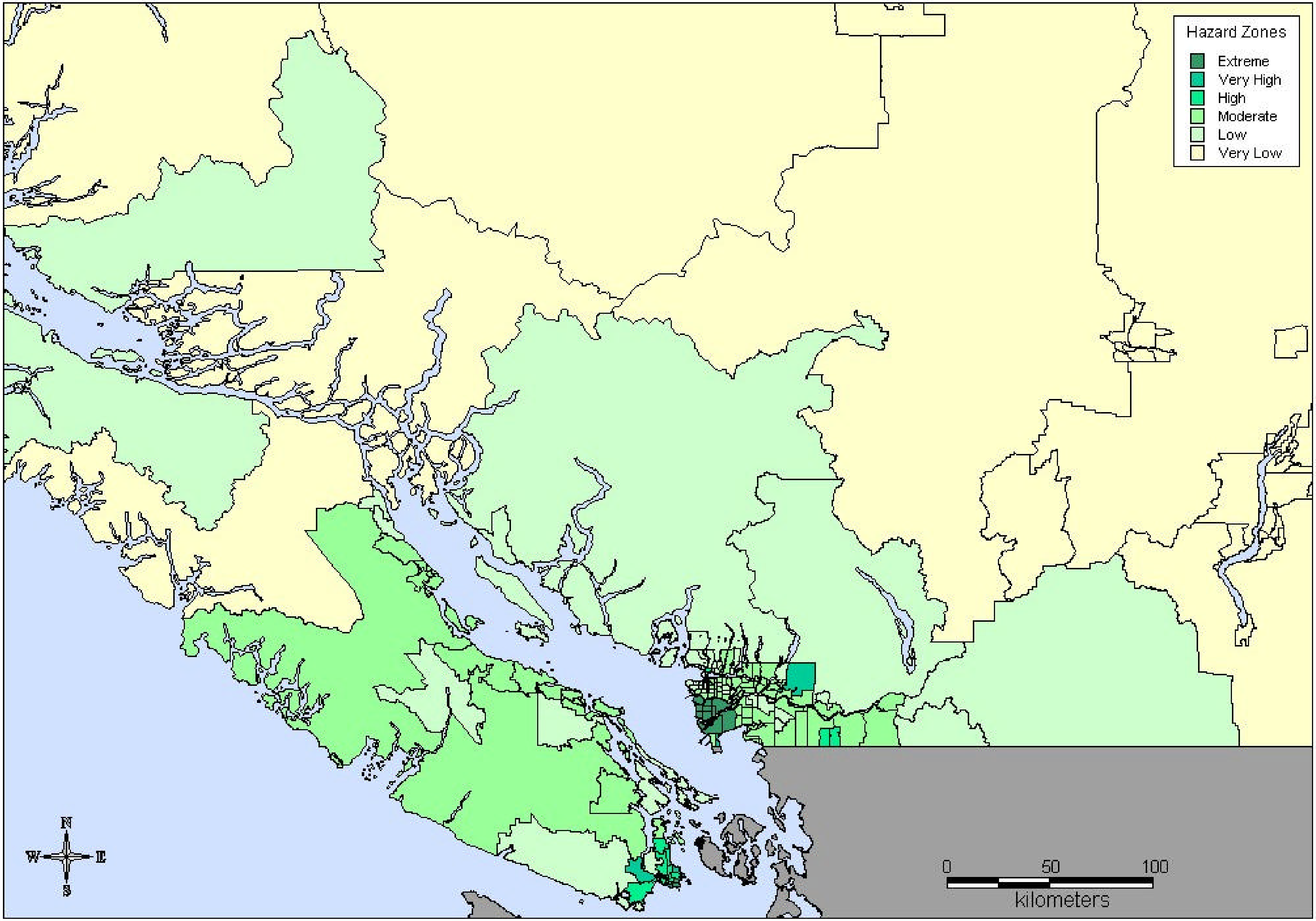
Hazard Zones	Description	Postal Codes
West 1	Extreme	V4G, V4K, V6V, V6W, V6X, V6Y, V7A, V7B, V7C, V7E, V8R, V8S, V8V
West 2	Very High	V4L, V4R, V8N, V9B
West 3	High	V2S, V2T, V7P, V8M, V8P, V8T, V8W, V8X, V8Y, V8Z, V9A,V9C
West 4	Moderate	V0R, V1M, V2P, V2R, V2V, V2W, V2X, V2Z, V3B, V3C, V3E, V3G, V3H, V3J, V3K, V3L, V3M, V3N, V3S, V3V, V3W, V3X, V3Y, V4A, V4B, V4C, V4E, V4M, V4P, V4W, V4X, V5A, V5B, V5C, V5J, V5K, V5N, V5P, V5R, V5S, V5T, V5V, V5X, V6A, V6N, V6P, V7H, V7J, V8L, V9G, V9J, V9K, V9L, V9M, V9N, V9P, V9R, V9S, V9T, V9V
West 5	Low	V0M, V0N, V0S, V0X, V2Y, V3A, V3R, V3T, V4N, V4S, V4Z, V5E, V5G, V5H, V5L, V5M, V5W, V5Y, V5Z, V6B, V6C, V6E, V6G, V6H, V6J, V6K, V6L, V6M, V6R, V6S, V6T, V6Z, V7G, V7K, V7L, V7M, V7N, V7R, V7S, V7T, V7V, V7W, V7X, V7Y, V8A, V8K, V9E, V9H, V9W, V9X, V9Y
West 6	Very Low	V0A, V0B, V0C, V0E, V0G, V0H, V0J, V0K, V0L, V0P, V0T, V0V, V0W, V1A, V1B, V1C, V1E, V1G, V1H, V1J, V1K, V1L, V1N, V1P, V1R, V1S, V1T, V1V, V1W, V1X, V1Y, V1Z, V2A, V2B, V2C, V2E, V2G, V2H, V2J, V2K, V2L, V2M, V2N, V4T, V4V V8C, V8G, V8J

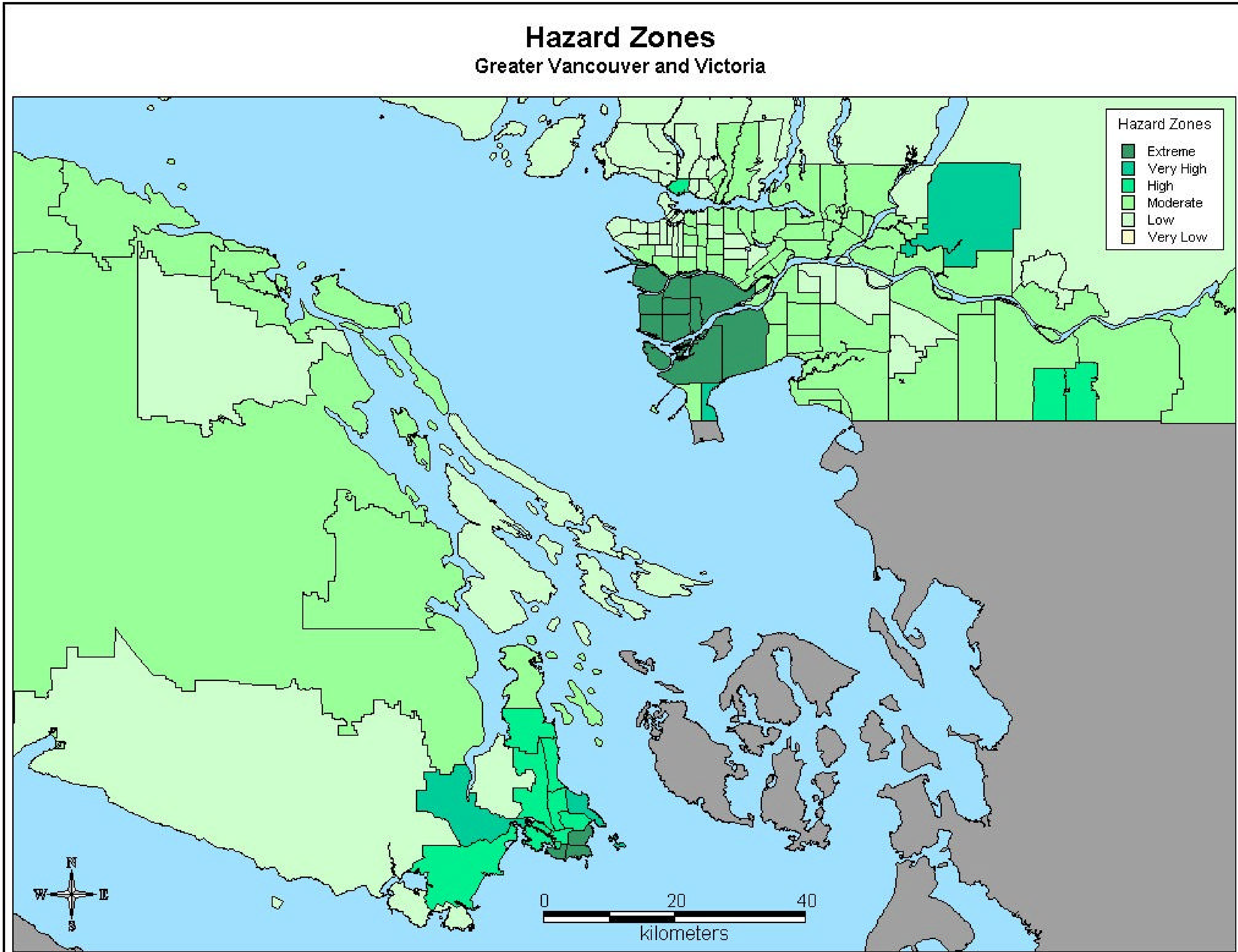
Appendix II

Earthquake Hazard Zones - Maps

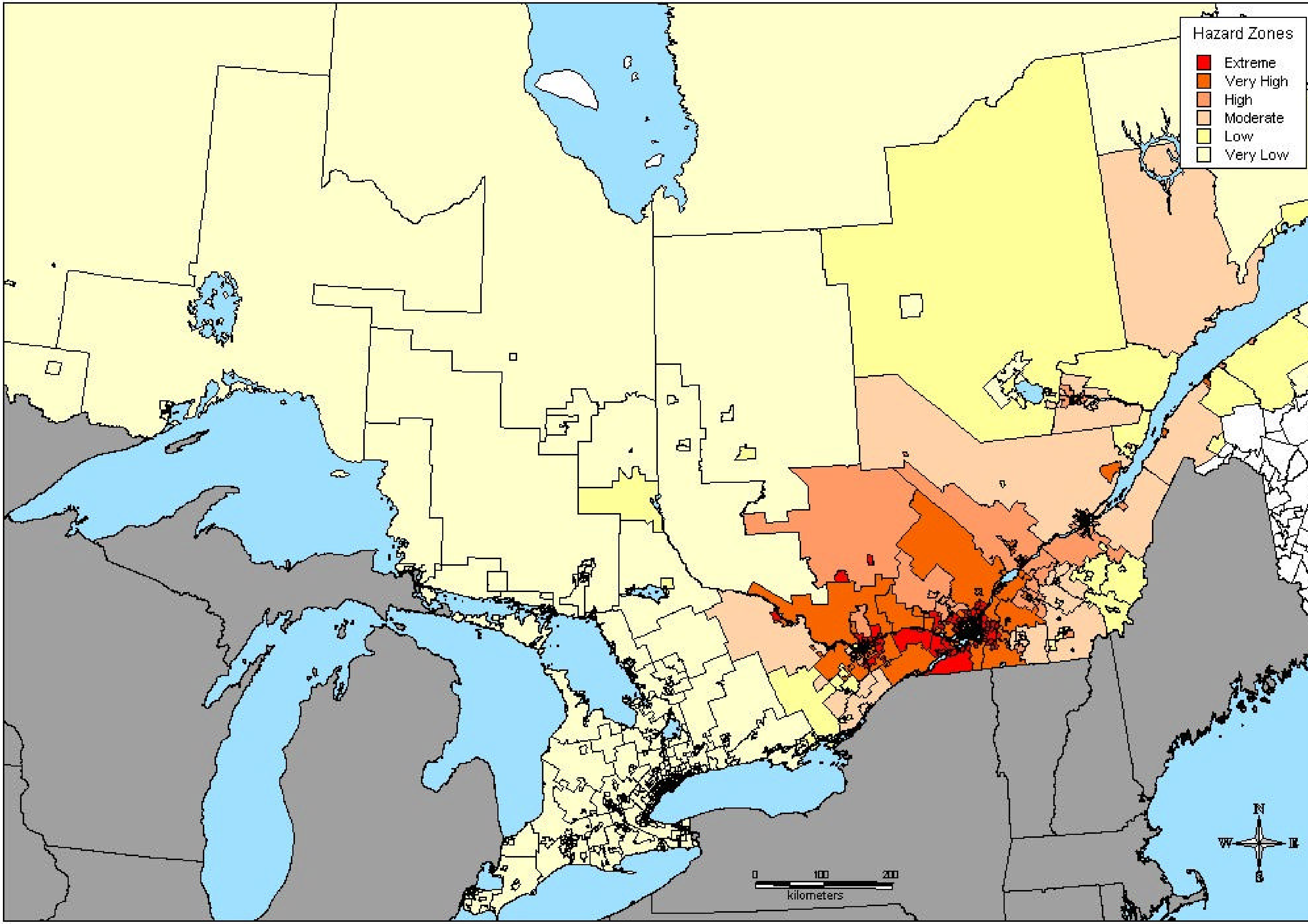
Hazard Zones

Southwestern British Columbia

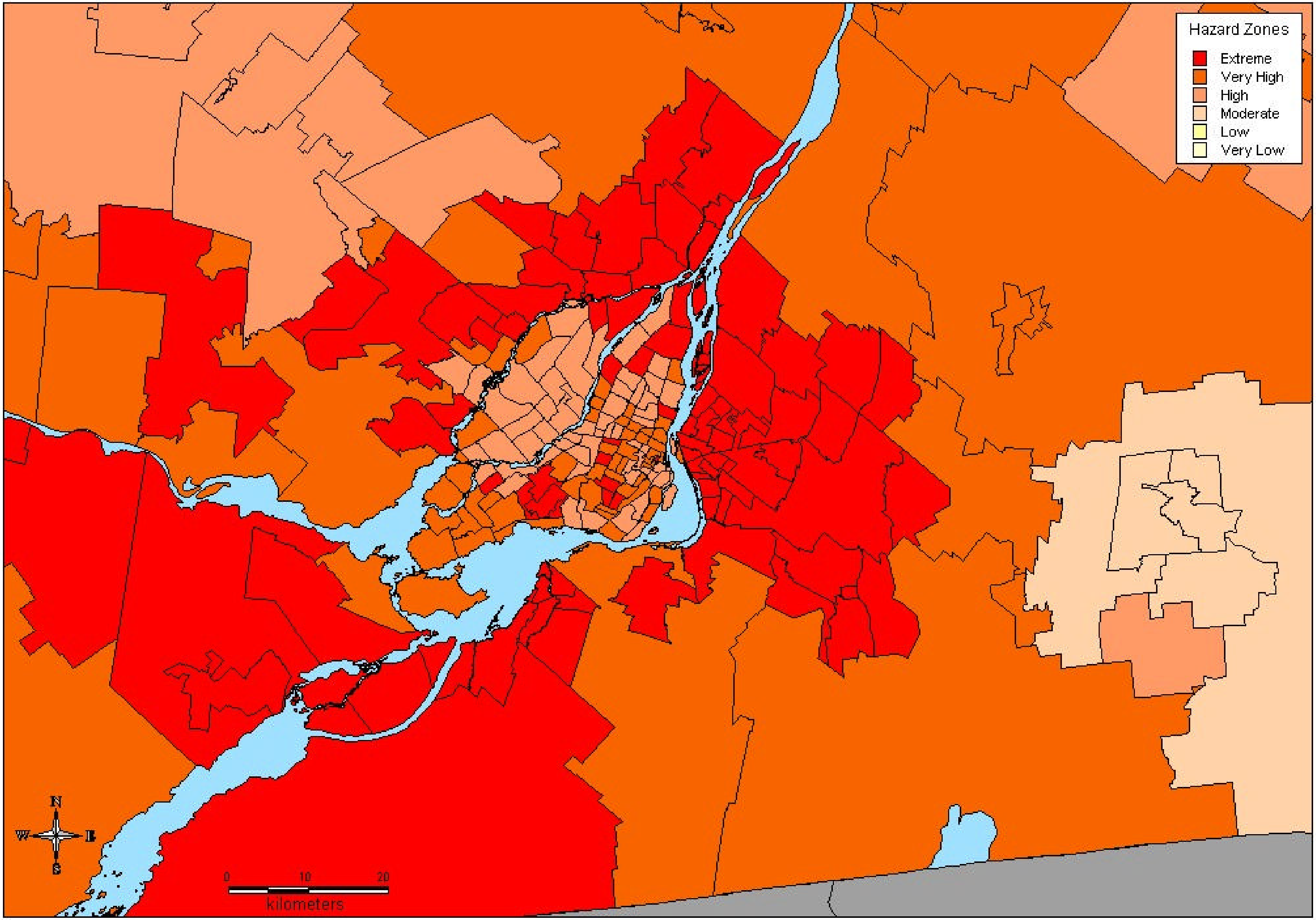



Hazard Zones
Greater Vancouver and Victoria
Hazard Zones
Extreme
Very High
High
Moderate
Low
Very Low
N
W
E
S
0
20
40
kilometers

Hazard Zones
Eastern Canada

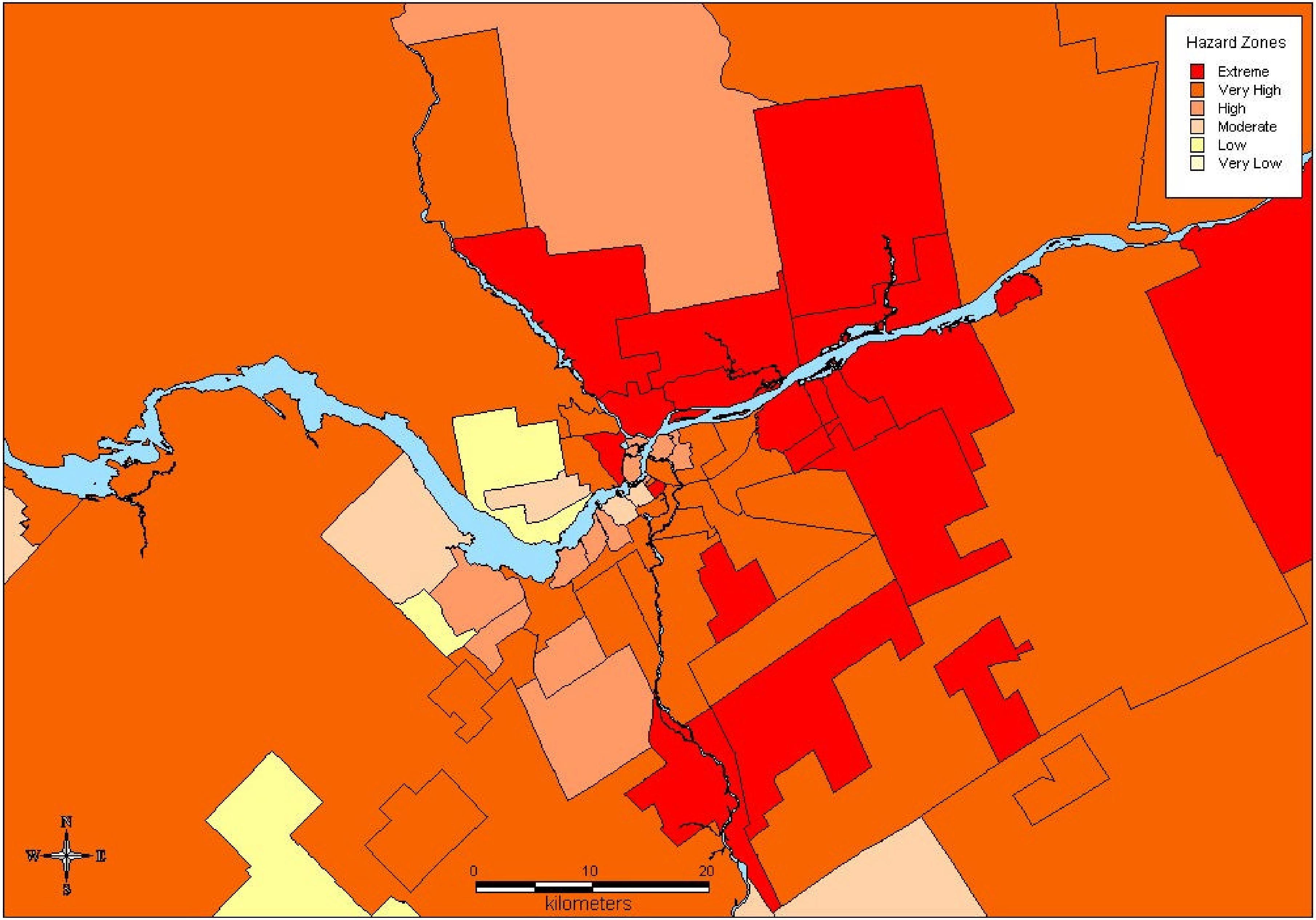


Hazard Zones
Greater Montreal Area



Hazard Zones

Ottawa and Surrounding Area



Hazard Zones

Quebec City and Surrounding Area