An Appeal for Flood Risk Assessments in Canada

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Floods: A Global Curse

Floods are the most widespread and most significant geohazard on Earth in terms of economic cost and loss of life. Red Cross data for the period 1971-1995 indicate that river and coastal floods, in an average year, kill more than 12,700 humans, affect 60 million people, and render 3.2 million homeless. The number of extreme flood disasters requiring international assistance has grown: in the years 1990-1998 it was higher than in the previous 35 years (1950-1985) combined. In Canada, flood events have claimed the lives of at least 200 people during the 20th century, with over $2 billion in damage, a statistic that emphasizes that floods in industrialized nations typically result in low human losses (a notable exception is the 1,200 fatalities due to Hurricane Katrina) but very high economic losses (similar to landslides). Additional major flood events may be expected in the coming decades partially due to predicted increase in the frequency of extreme weather events, but most importantly because of densification of urban development and infrastructure on flood-prone terrain.

Hazard versus Risk

In Canada as in many other developed nations, flood hazard management is predicated largely on an arbitrary return period flood. This "design flood" forms the basis for the design of bridges, dikes and other flood protection measures. Economic or life loss potential is not explicitly considered, irrespective of increased development in flood-prone areas. Thus, even in the absence of any long-term increase in flood hazard, flood risk must increase. This paradigm is exemplified in Figure 1.

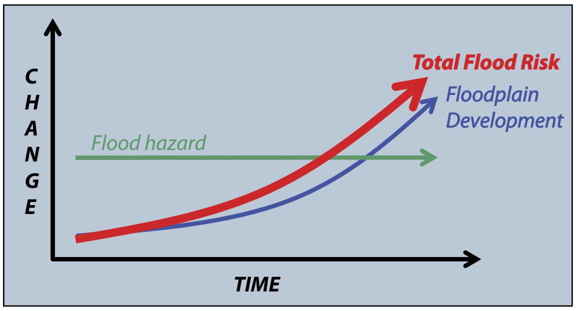

Figure 1

Figure 1 would need to be adjusted if, for example, flood hazard is expected to increase as a consequence of net sediment deposition that decreases the conveyance capacity of the channel, long-term changes of flood-producing hydroclimatic events, sea-level changes, long-term and widespread environmental changes caused by land use, reduction of glacial cover and beetle infestations that may alter the long-term flood hazard. Flood mitigation upgrades (dike improvements, floodways, river diversions) may partially neutralize any increased flood hazard. But protective measures almost never keep up with the increase of development. For the vast majority of developed Canadian floodplains, total flood risk has increased in proportion to development density, local business activity, and additional economic activity associated with railways, pipelines, transmission lines, telecommunication lines and highways.

Major recent river flood events in Europe as well as the 2005 New Orleans sea-borne flood disaster have forcefully reminded society and decision makers that engineered protective works cannot guarantee paramount safety, and that the residual risks are higher than previously thought. These and earlier flood disasters have increased worldwide interest in flood warning systems and quantitative flood risk assessments and have led to a paradigm shift in Europe from a rule-based approach (flood hazard assessments) to a risk-based process. On November 26, 2007, the European Directive on the assessment and management of flood risks was enacted. It outlines a set of actions on preliminary flood risk assessment, flood risk mapping and the preparation of flood management plans to be completed by the end of 2015. The directive covers coastal floods, urban and groundwater floods, mandates basin-scale planning and requires consideration of the potential impacts of climate change on flood conditions. The use of the phrase "Management of Flood Risk" in the directive's title emphasizes that European flood philosophy has evolved from attempts at flood control to the management of flood risks.

Quantitative Flood Risk Assessments

A hazard is an existing or potential future event with an adverse effect. In contrast, risk is defined as the product of the likelihood of a hazard occurring and its anticipated consequence. Vulnerable assets may include residential developments and infrastructure, business developments and activities on the floodplain, business activities associated with transport of goods and services, as well as social, ecological and historical values. Estimation of consequence includes a comprehensive inventory of values, followed by analysis of potential damage or loss for various event scenarios.

Procedures for natural hazard identification and risk assessment guide decision makers and the public to minimize risks from these hazards; however, it is rarely possible to completely eliminate them, and residual risks are a fact of life. Where the consequences of a particular natural hazard are largely economic in nature, the risk management process is suited to risk cost benefit analysis and economic optimization techniques. A limitation is that these techniques fail to address ecological, archaeological and social issues because they are difficult to quantify. These are increasingly included in holistic semi-quantitative approaches.

Quantitative Flood Risk Assessments (QFRA) evaluate the likelihood *and* consequences of flooding, and reflect possible combined contributions to flood risk of various operational, hydrologic, hydraulic, and geotechnical factors. By taking into account both flood likelihood, (including the likelihood of dike breaches) and consequence, risk-based approaches offer a systematic way to identify locations of high risk that occur not necessarily from changes in flood hazard, but rather due to increases in the vulnerabilities and consequences of a flood. They also allow a transparent and repeatable evaluation of potential flood mitigation alternatives, permit comparison of flood risk to other risks faced by society, and help define thresholds for the tolerance of flood risk. This method is thus well suited to allocate public resources directed toward flood risk reduction.

In contrast to QFRA, flood management in British Columbia has traditionally been based on flood hazard (likelihood), as measured by the expected height of a design flood augmented by a standard increment of dike height ("freeboard"). Consequence is included only implicitly in that it forms the motivation for a particular assessment (eg, assessments would occur only in locations with potential consequence). For example, for the Fraser River, the design flood is the largest flood on record (1894), the return period of which has not been defined with great certainty, though flood frequency analysis estimates a probability of approximately 500 years. Recent consulting reports have shown that existing dikes fail to contain design flood levels or even a 200-year return period flood (roughly equivalent to the 1948 flood). This fact and the extremely high consequences of an extreme flood suggest that a purely hazard-based approach may no longer provide a rational decision tool for effective flood management.

Where to go from here?

BGC Engineering in collaboration with the City of Chilliwack, Terasen Gas, Kinder Morgan Pipelines, Indian and Northern Affairs Canada, the Ministry of Transportation and Ministry of Environment recently completed a pilot flood risk assessment for the City of Chilliwack that addressed economic risks to the area and pointed toward vulnerabilities of populations living on the Fraser River and other floodplains. The study demonstrated that a flood due to dike breaches or overtopping could result in overall direct damages approaching $1 billion for the City of Chilliwack alone. Furthermore, associated losses to the BC economy have been estimated to approximately $20 million per day. These numbers demonstrate the extreme flood loss potential along the lower Fraser River and, by extrapolation, highlight that an extreme Fraser River flood would likely turn into Canada's most expensive natural disaster, vastly exceeding the losses caused by the Quebec Ice Storm of January 1998.

Similar, though in no way standardized, studies are now underway for a handful of other jurisdictions in BC following the Chilliwack example. These studies, however, are not mandated by the provincial or federal governments but arise from due consideration by local government officials who recognise the compelling information revealed by QFRAs. While this development is laudable, isolated flood risk assessments that are not based on established provincial guidelines fail to provide a province- or nation-wide rational decision-making framework. For example, the BC flood protection fund that was inaugurated in 2007 explicitly excludes scientific studies, but aims to provide funds for engineered flood protection. Clearly from a public perspective, a systematic quantification of flood risk ought to form the basis for where these limited funds should be expended.

Where the anticipated consequences include the potential for loss of life, the decision-making process requires that risks be compared against risk tolerance criteria as a way to prioritize flood hazard risk management activities. Quantitative tolerable risk or risk acceptance criteria for natural hazards, including floods, have never been defined by any British Columbia public governmental agency. Notwithstanding, quantitative thresholds for tolerable risk have been cited as a useful approach for the evaluation of British Columbia offshore oil and gas development and for residential developments.

A risk-based decision-making framework for assessment of flood hazards in Canada would be compatible with Canadian and international guidelines for quantitative risk assessment in that it would involve a systematic, transparent, and reproducible method for assessing risk based on both the likelihood of occurrence and the consequences of an event. Floodplains of major Canadian rivers are increasingly being used as principal infrastructure arteries and undergo replacement of agricultural land by urban development. Even though there are regulatory barriers to converting farmland into urban land, these barriers tend to be thwarted in the long run whenever economic incentives to overcome them become sufficiently powerful. Furthermore, agriculture itself is increasingly highly capitalised. These inescapable political and social realities emphasize the need for systematic and standardized flood risk assessments for rational decision making in areas exposed to flooding. This need is further emphasized not only by the non-linearity of the development process, but by fluvial and hydroclimatic regime shifts that may result in changing flood frequencies.

A future extreme flood on a major Canadian river is a statistical certainty as will be the consequent economic costs and perhaps loss of life. In the post-flood period, government decision makers will be questioned by the public as to the reasons for the extreme losses and why those affected were not sufficiently protected. A standardized and systematically applied flood risk approach based in legislation cannot avoid losses; however, it can provide the much-needed rational basis for the optimal allocation of funds to those areas that are likely to suffer the greatest losses. This optimization of public resources ought ultimately to be the responsibility of elected government officials. Political realities sometimes discourage science-based decision making, which is partially because of the failure of the professional community to communicate their findings effectively to the wider public. Rather than succumbing to this perceived dichotomy, it should motivate engineering and geoscience professionals, the general public and local decision makers to urge their elected officials for a shift towards a risk-based flood-management system.

Under the auspices of APEGBC, senior consultants, provincial government engineers and academics have proposed the developement of a provincial flood hazard professional practice guideline that will explicitly address risk and climate change factors. While not replacing current directives and regulations, the new guideline would serve to promote a transition from hazard to risk-based flood management, at least in British Columbia. Ultimately, we hope, this evolution will provide an improved decision-making framework in the face of continuing social and economic development and ongoing climate change. ⊠

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