Lifetime limit on successive floods: toward a new social covenant?

Mathieu Boudreault (1), Michaël Bourdeau-Brien (2)

(1) Professor (Actuarial Science), Department of Mathematics, Université du Québec à Montréal and Researcher, Intersectorial Flood Network of Quebec (*Réseau inondations intersectoriel du Québec,* RIISQ)

(2) Professor (Finance), Department of Finance, Insurance and Real Estate, Université Laval, and Researcher, RIISQ

Abstract

In April 2019, in light of the numerous spring floods that had affected southern Quebec since 2011, the Government of Quebec announced a major overhaul of its financial assistance program for disaster victims. That program was recently modified to include a $100,000 lifetime limit on coverage for successive floods, a first in Canada. The objective of this article is to assess the cost of successive floods and the financial impacts that this coverage limit will have on households.

Keywords: Flood; Risk management; Household finance.

1. Introduction

Flooding is the most frequent and costly type of disaster in Canada. According to the Insurance Bureau of Canada (2015), flooding alone accounts for 75% of the funds paid out under Public Safety Canada's Disaster Financial Assistance Arrangements (DFAA). While the economic consequences of flooding are difficult to estimate, we know that the cost of insurance claims related to extreme weather events is rising rapidly, having jumped from $400 million to $1 billion a year on average over the past three decades, due in part to climate change (Insurance Bureau of Canada, 2018). In fact, climate change is likely to increase the frequency and intensity of extreme precipitation events (IPCC, 2019), which could in turn increase the risk of overland flooding in many parts of the country (Government of Canada, 2019).

It is important to note that in Quebec, many neighbourhoods were built on floodplains. The Protection Policy for Lakeshores, Riverbanks, Littoral Zones and Floodplains, released in 2005 and updated a few times since[1] then, prescribes that no building may be built on a 20-year floodplain and that no building opening (window or door) may be located below the high-water mark associated with the 100-year floodplain. However, all buildings constructed before the policy came into effect are grandfathered. In addition, following the major floods of 2017 and 2019, the Government of Quebec instituted a moratorium affecting 776 municipalities on the reconstruction of damaged buildings located on a 0–20-year floodplain. However, the moratorium has been challenged, resulting in changes to the area affected by the moratorium so that a large proportion of the 170,000 homes initially affected are eligible for rebuilding.[2] In all cases in Quebec, the implementation, financing and maintenance of risk mitigation

[1] See http://legisquebec.gouv.qc.ca/en/ShowDoc/cr/Q-2,%20r.%2035

[2] Parts of the territory were excluded from the Special Intervention Zone (ZIS) four times in 2019 when ministerial orders came into force. At the time of writing, the special intervention area is not expected to be modified in the future. Current information on the subject is available (in French only) at: https://www.mamh.gouv.qc.ca/ministere/inondations-printanieres-2019-zone-dintervention-speciale/

measures, such as dams, reservoirs and dikes, are essentially the responsibility of municipal, provincial and federal governments. Moreover, since affordable flood insurance coverage is difficult if not impossible to obtain (Jung, 2019), in the event of a disaster, victims must turn to government programs for financial assistance.

With respect to these findings, the *Ministère de la Sécurité publique du Québec*, the province's public safety department, decreed changes to the *Programme général d'aide financière lors de sinistres réels ou imminents*, or the general financial assistance program for actual or imminent disasters, on April 15, 2019, via order-in-council 403-2019. The new iteration of this program includes, for the first time, funding for the relocation/buy-back of damaged properties. The introduction of relocation/buy-back compensation represents a paradigm shift in line with the principles of sustainable development, in which homeowners have to learn to live with floods rather than fight them (Verkerk & van Buuren, 2012). Among other things, these so-called "new" flood management mechanisms are part of a global trend toward a diversification of risk management strategies (Wiering et al., 2017).

However, the offer of compensation for relocating disaster victims and buying back, repairing or rebuilding properties does include a major condition: the decree sets a ceiling on cumulative compensation for recurrent flooding. Whereas the previous assistance program treated each flood as independent and allowed an owner to be compensated again after each flood, the new program treats the first and subsequent claims differently.

- First claim: compensation of up to 90% of rebuilding costs incurred, up to $200,000 or 100% of the replacement cost of the property, whichever is lower.

- Subsequent claims: compensation of up to 90% of rebuilding costs incurred, up to a cumulative lifetime maximum of $100,000 (or 50% of the property's replacement value, whichever is lower).

By this new provision, the decree signals a change in the social covenant, whereby it becomes unacceptable for society to assume repetitive damages which result from households' (often involuntary) decision to settle in flood-prone areas. The new program also means that households in flood-prone areas will have to bear a greater proportion of the costs of flooding in the future.

The main objective of this article is therefore to analyze the financial impacts on households of the introduction of a lifetime limit for successive floods in the Government of Quebec's financial assistance program. We start by calculating the probability of experiencing one or more floods within a 25-year horizon based on the property's being located in a flood-prone area. This horizon corresponds to the typical amortization period for a mortgage on a single-family home. Using simulations, we then estimate the distribution of direct damages resulting from these events. This allows us to identify when the lifetime limit becomes burdensome, and to comment on the potential impacts this limit could have on the financial health of households. Lastly, we address the topic of climate change by briefly analyzing our results' sensitivity to changes in flooding frequency and severity.

The Quebec government's new financial assistance program offers several options with significant, non-trivial financial implications. One of this article's key goals is also to explain the results in layman's terms in order to better equip households to make informed decisions. Both in Canada and abroad, research clearly shows that homeowners in flood-prone areas tend to underestimate the risk they face (Kellens et al., 2013; Thistlethwaite et al., 2018). In Quebec, despite major efforts being made to update floodplain maps, households are still unable to easily obtain accurate information on this source of risk.[3] Moreover, this information, when available, is traditionally presented in the form of a 20- or 100-year return period, which can be difficult to translate into concrete impacts on a property. It therefore seems desirable, even necessary, to communicate what these return periods imply in terms of expected damages in order to raise awareness among households and other societal stakeholders about the financial implications of a lifetime limit on flood compensation. For homeowners directly affected by this provision of the April 2019 decree, the simulations contained in this article provide a body of knowledge that we hope will facilitate informed decision-making.

The rest of this article is structured as follows: Section 2 briefly presents the theoretical risk management framework and positions this article's contribution within that framework. Section 3 describes the simulation modelling approach while substantiating some key assumptions and identifying the main limitations inherent in this approach. Section 4 presents the results obtained, along with a discussion of their implications. Section 5 examines the results' sensitivity to variations in flood frequency and severity, thus providing information on the potential impacts of climate change. Section 6 is the conclusion.

2. Brief overview of the theoretical background of risk management

The last resort financial assistance analyzed in this article is part of the general flood risk management process. Whereas this process is expressed differently across disciplines, it is usually segmented into four main interrelated steps: risk identification, risk analysis (quantification), selection of risk treatment strategies, and implementation of the strategies. Figure 1 below maps the risk management process by drawing on the ISO 31000 standard.

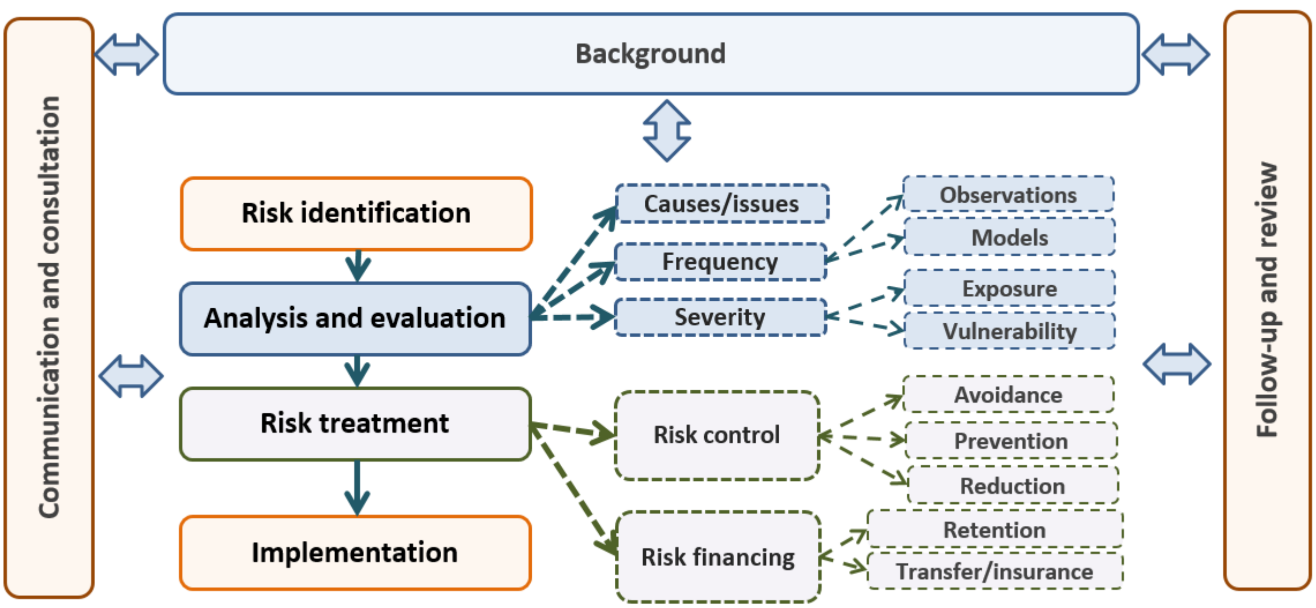

Figure 1: Risk management process
(based on ISO 31000, https://www.iso.org/obp/ui/#iso:std:iso:31000:ed-2:v1:en)

Risk management strategies are usually classified into two categories: risk control measures and risk financing measures. Risk control is defined as a deliberate action taken to reduce the frequency or

[3] The https://geoinondations.gouv.qc.ca/ portal has recently begun providing information on this topic.

severity of an accidental loss. Control measures include prevention, reduction (of severity), diversification and avoidance.

Risk financing consists in ensuring the availability of funds that will be needed to compensate victims for financial losses. Financing measures consist in transferring the risk, purchasing a hedging instrument or retaining (assuming) the risk. The financial assistance of last resort analyzed in this article is a risk transfer measure, in the same way as flood insurance.

Any risk management strategy entails costs that must be weighed against anticipated gains. The choice of a risk management strategy depends not only on the frequency and severity of the risk, but also on several factors specific to the decision-maker. For instance, a person with high risk aversion may be satisfied with paying more to minimize risk or to be assured of compensation in the event of a claim, while another person with low risk aversion may prefer to reduce the costs of managing uncertainty by personally taking on more risk. An optimal risk management strategy typically combines control measures and financing measures.

In the rest of this article, we will analyze the effect of last-resort financial assistance in isolation. In other words, we will not comment on the optimal nature of this government compensation for a typical investor and will disregard the synergies that may exist between this type of financing measure and other existing flood risk management strategies. Rather, our analysis is intended to describe the long-term effects of a cap on last-resort compensation for floodplain residents.

3. Simulation modelling

We will now analyze the direct monetary consequences of flood risk over a 25-year horizon using simulations. The approach used breaks down flood *risk* into these components:

1. Hazard: frequency and intensity;
2. Vulnerability and exposure;
3. Direct damages.

Frequency. Flooding frequency is measured using what is referred to as a *return period*. For example, a flood with a return period of 20 years means that over a very long expanse of time (say, 10,000 years), a flood of this type will occur on average once every 20 years. Therefore, in any given year, there are one-in-20 odds, or a 5% probability, of a flood occurring. A flood with a return period of 100 years therefore has a 1% probability of occurring in any given year.

In Quebec, the Protection Policy for Lakeshores, Littoral Zones and Floodplains (PPRLPI) defines what is called a flood zone or floodplain, i.e. an area where properties could be flooded. Return periods of two years, 20 years and 100 years are used to define three floodplain categories often used in decision-making activities such as land use planning. In order to calculate return periods and identify floodplains, experts use historical river flows and hydrological and hydraulic models; these are known as floodplain maps or mapping. In our modelling exercise, return periods are used to determine both the properties' ex-ante risk level, that is, the risk level before the event (by providing information on the anticipated flood frequency), and whether or not flooding occurs in a given year and for a specified floodplain (this is done by generating numbers at random).

However, note that the previous formulation of frequency based on return periods may suggest that floods are cyclical (e.g. once every 20 years) and that if such a flood occurs, then there will be no comparable floods for the next 19 years. Nevertheless, it is quite conceivable that several floods could occur within a short period, even though these floods are supposedly rare. To illustrate this point, we calculated in Table 1 the distribution of the number of floods over a period of 25 years[4], which generally corresponds to the amortization period of a mortgage.

For example, a property located on a 20-year floodplain has "only" a 28% chance of not experiencing any flooding during a 25-year period, leaving a 72% chance of at least one flood occurring during the same period. A property that has 1-in-100 odds of being flooded within the space of one year (a 100-year floodplain) has a 22% chance (100% – 78%) of being flooded at least once over a 25-year period. As a result, the risk of flooding is far from negligible over 25 years, supporting the idea that medium- and long-term projections of flood-related costs is needed to analyze the effects of a lifetime limit for successive floods.

Risk associated with location and topography		**Number of floods over 25 years**					
Risk level	Floodplain	0	1	2	3	4	5+
Extreme	2 years	0.00%	0.00%	0.00%	0.01%	0.04%	99.95%
Very high	10 years	7.18%	19.94%	26.59%	22.65%	13.84%	9.80%
High	20 years	27.74%	36.50%	23.05%	9.30%	2.69%	0.72%
Non-negligible	100 years	77.78%	19.64%	2.38%	0.18%	0.01%	0.00%
Low	1,000 years	97.53%	2.44%	0.03%	0.00%	0.00%	0.00%

Table 1 Distribution of the number of floods over a 25-year period

Intensity. The intensity of a flood is often characterized by the flood depth, i.e. the water level in relation to the ground. For a given recurrence, the flood depth will differ so that, for example, a flood recurring every 100 years will result in a greater flood depth (and more substantial damages) than a flood recurring every 20 years. Therefore, the intensity of a flood depends on the recurrence observed in our modelling.

Vulnerability and exposure. Several physical features are used in the scientific literature to define the vulnerability of buildings. For example, Leclerc et al. (2003) combine property values, number of storeys, construction type and elevation of the first floor above the flood depth to estimate direct damages resulting from flooding. However, among all of a building's physical features, it has been recognized since Grigg & Helweg (1975) that the elevation of the ground floor is the most critical variable in the analysis. Consequently, and in order to simplify the presentation of the analysis, we describe two types of buildings according to the speed at which water reaches and rises above the ground floor.

1. Low exposure: A building situated and built in such a way that, depending on the flood depth, water floods the basement before reaching the ground floor. Damages are therefore relatively limited at shallow flood depths and increase significantly as the water reaches and surpasses the ground floor, until the total loss of the building occurs at substantial flood depths.
2. High exposure: A building whose construction and geographical situation are such that the water directly and quickly reaches the ground floor and immediately causes relatively extensive damages, the value of which increases with the building's flood depth, to the point of total loss.

[4] We obtain our first results by assuming that return periods are constant over time and that floods are independent and identically distributed from year to year. Note that we then conduct robustness tests to analyze the effect of an increase in flood frequency (which may be due to changes in settlement patterns or the effect of climate change).

To simplify the presentation, we will assume that flood damage only affects buildings and that the building in question is a bungalow (single-storey building) valued at $250,000[5]. As an indication, the *Institut de la statistique du Québec* counted nearly 1,800,000 single-family homes in the province in 2019 with an average taxable value of $275,000[6] (including building and land).

Direct damages. Flooding causes a wide range of damages to a building and its contents (furniture, appliances, etc.). As water enters the basement, it seeps into walls, basement flooring, electrical outlets, the HVAC system, the ground floor structure and more. In the end, direct damage includes not only the obvious reconstruction costs, but also the costs of cleaning, replacing furniture and appliances, landscaping and temporarily relocating the home's residents. In the literature, this direct damage is modelled by a damage curve or a flood-depth/damage curve. However, floods also cause other types of indirect damages not examined in this study. While these indirect damages are often difficult to estimate, they do have a cost to society that sometimes surpasses the cost of direct damages (Green & Penning-Rowsell, 1989; Lekuthai & Vongvisessomjai, 2001).[7]

In our simulations, damages are expressed as a percentage of the building value, which is then associated with each return period and property type. These percentages are based on the damage curves presented in Appendix B of the *Canadian Guidelines and Database of Flood Vulnerability Functions* (Natural Resources Canada & Public Safety Canada, 2017). We take a slightly simpler approach by associating each "floodplain/recurrence of an extreme event" pair with a damage percentage, without explicitly modelling actual flood depths. Table 2 describes the damage assumptions used in our subsequent modelling.

Property type	**Risk associated with location and topography**		**Severity of flooding (by return period)**				
	Risk level	Floodplain	2 years	10 years	20 years	100 years	1,000 years
Low exposure	Extreme	2 years	10%	15%	20%	80%	100%
	Very high	10 years	0%	10%	15%	25%	90%
	High	20 years	0%	0%	10%	20%	80%
	Non-negligible	100 years	0%	0%	0%	10%	25%
	Low	1,000 years	0%	0%	0%	0%	10%
High exposure	Extreme	2 years	50%	70%	80%	90%	100%
	Very high	10 years	0%	50%	60%	80%	90%
	High	20 years	0%	0%	50%	70%	90%
	Non-negligible	100 years	0%	0%	0%	50%	80%
	Low	1,000 years	0%	0%	0%	0%	50%

Table 2 Damage assumptions expressed as a percentage of a building's value by risk level and property type.

Regarding the simulation procedure, we start by exogenously establishing the property's type and ex-ante risk level. We then generate 100,000 scenarios. In each scenario, we draw one random number

[5] Unless otherwise specified, we will not distinguish between building and property, as damage to the property itself is generally minimal and the Financial Assistance Program covers damage to the building exclusively.

[6] See http://www.stat.gouv.qc.ca/statistiques/profils/comp_interreg/tableaux/valeur_moyenne.htm (page in French only; page consulted on December 11, 2019).

[7] Indirect damages include various economic costs (a health network overloaded due to stress, anxiety and other deleterious flood-related health conditions; destruction of public infrastructure; loss of income due to business closures; and a temporary economic slowdown), as well as the consequences of environmental damage resulting from the destruction of ecosystems and so on.

per year for 25 consecutive years in order to express the flooding in terms of a return period. We then transform this return period into a percentage of damage using the data in Table 2.

Note that we work on the assumption that flooding has no long-term effect on property values. In other words, we assume that properties are rebuilt or repaired after each flood so that the value of the building the following year remains unchanged at $250,000. On the one hand, this assumption may lead to an underestimation of cumulative losses if the housing market is growing. On the other hand, this assumption may lead to an overestimation of cumulative losses if the floods result in a long-term loss of value for affected properties.[8]

Figure 2 illustrates the relationship between the return period and the percentage of flood damage for a low-exposure property located on a 20-year floodplain.

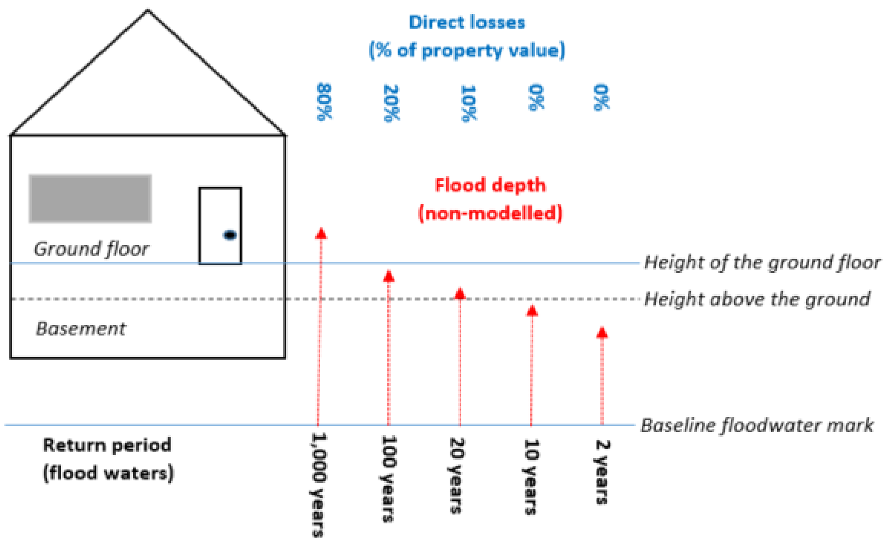

Figure 2 Return period and direct damages for a low-exposure property on a 20-year floodplain.

Given that this property is situated on a 20-year floodplain, spring floods or other climate events of low relative severity (those with a 2- or 10-year return) do not cause any damages to the property. However, a flood occurring on average once every 100 years (100-year return period) causes direct damage equivalent to 20% of the value of the building. With the typical building valued at $250,000, this translates into $50,000 in damages.

[8] It is important to distinguish between the effect of being located on a floodplain and the effect of an extreme event. Luechinger & Raschky (2009) report that properties in the United States are worth between 0% and 12% less when located on a 100-year floodplain. Bélanger et al (2018) report a loss in value in Quebec of approximately 4%. However, there is no consensus in the scientific literature on the effect of flooding on property values—estimates of value loss vary between 0% and 40%. However, several international empirical studies show that the loss in value is temporary and that it is reabsorbed over a period of three to five years (Bélanger & Bourdeau-Brien, 2018; Beltrán et al., 2019; Jessica Lamond & David Proverbs, 2006). To our knowledge, although a few research projects are underway in Quebec, no published studies have emerged from the province.

4. Results

4.1 Total expected losses over 25 years

The first result of the simulation exercise is a set of 100,000 damage trajectories over 25 years for each property, categorized by risk type and level. These trajectories provide important information on the predictable monetary consequences of flood risk. Unsurprisingly, a ranking of these trajectories according to the total cumulative losses over 25 years shows that the first trajectories are those where no or few floods occur over the 25-year period, while the last ones are the most critical cases where several extreme floods have occurred over the same period. We use this ranking of trajectories in Table 3 to illustrate the losses that a property could suffer according to the median trajectory (50th percentile) and a few trajectories affected more significantly by flooding (75th to 99th percentiles). Remember that the higher the percentile, the more the specified trajectory involves serious and damaging floods. The same table shows average annual losses, which we interpret a little lower down in this article.

Property type	**Risk associated with location and topography**		**Total expected losses over 25 years (in $) based on various scenarios**					**Average annual losses (in $)**
	Risk level	Floodplain	50th percentile	75th percentile	90th percentile	95th percentile	99th percentile	
Low exposure	Extreme	2 years	462,500	575,000	675,000	750,000	900,000	19,264
	Very high	10 years	87,500	125,000	200,000	262,500	350,000	3,968
	High	20 years	37,500	62,500	100,000	150,000	250,000	1,892
	Non-negligible	100 years	0	0	37,500	50,000	75,000	332
	Low	1,000 years	0	0	0	0	25,000	24
High exposure	Extreme	2 years	1,800,000	2,050,000	2,275,000	2,412,500	2,675,000	71,872
	Very high	10 years	325,000	500,000	675,000	775,000	975,000	14,612
	High	20 years	150,000	275,000	400,000	475,000	625,000	7,128
	Non-negligible	100 years	0	0	150,000	175,000	300,000	1,408
	Low	1,000 years	0	0	0	0	125,000	120

Table 3 Distribution of total flooding costs over a 25-year period for a Type 1 building worth $250,000

To read Table 3, first choose a risk level, which results from the combination of the type of property and its presence on a floodplain. For example, for a low-exposure property located on a 20-year floodplain (5% annual probability of flooding), the median scenario implies total 25-year losses of $37,500. If more than the median number of extreme floods occur over the next 25 years, then the total costs will also be higher. In the 99,000th "worst" scenario (99th percentile), the cumulative losses are $250,000. It goes without saying that a household owning such a property has a non-negligible probability of incurring losses that will exceed last resort assistance with a lifetime limit of $100,000.

We can easily see from the above results that the losses caused by successive floods can be anything from zero to very high, sometimes high enough to jeopardize personal finances. The next subsection examines how flood insurance is being used to meet this need for risk transfer.

4.2 Flood insurance

In Canada, overland flooding is not covered by basic home insurance policies. Overland flood insurance coverage was introduced as an endorsement (optional layer of added protection) by a few insurers in 2015/2016 and is now common. However, this endorsement's availability, coverage and premium can differ from one insurer to another for the same property, and obviously, even more so for properties located in different neighbourhoods. When available, flood insurance is often combined with the sewer backup endorsement. According to the Insurance Bureau of Canada, approximately 30% of policyholders (April 2019) have purchased flood insurance coverage.

The largest component of the insurance premium is linked to the anticipated costs of flooding. Since home insurance contracts generally have a term of one year, the premium depends primarily on the expected annual loss. Before going any further, it is important to note that insurance premiums do not exactly correspond to the expected annual losses. To obtain a more accurate picture of the premium, we must consider the list of items covered (movable property, living expenses, etc.) and any coverage limits. To this, we must add contract issuance costs and other expenses incurred by the company. A margin of safety must also be factored in to reflect the unpredictability and difficulty of diversifying flood risk. Consequently, the actual insurance premium could be two to three times higher than the average annual losses, as shown in Table 3. The fact remains that although each insurer has its own flood risk assessment models, the last column of Table 3 provides excellent information on the amount a household may have to pay for flood insurance coverage.

As we can see, average annual losses can result in prohibitive insurance premiums, quickly exceeding $1,000 a year for high-exposure properties and those whose flood risk is high. As a result, flood insurance is often simply not available for properties located on 2- to 20-year floodplains and is very expensive for buildings on 20- to 100-year floodplains (https://bac-quebec.qc.ca/en/insurance-issues/flooding/). To limit premiums, flood insurance coverage is capped at $50,000 or $100,000, but such caps are often not enough to cover the cost of cleaning, repairing and refurnishing a flooded property.

When the overland flood insurance endorsement is not available, as is the case for many Quebec properties located on 2- to 20-year floodplains, citizens must rely on last resort financial assistance available through the *Programme général d'aide financière lors de sinistres réels ou imminents,* the province's general compensation and financial assistance program for actual or imminent disasters, which is administered by Quebec's department of public safety. In short, despite the recent development of new flood insurance products, a high proportion of properties at high risk of flooding will not be insurable against this risk, leaving homeowners to rely on last resort financial assistance when flooding occurs. In future, these households will therefore have to absorb losses above and beyond the maximum lifetime indemnity of $100,000 or take advantage of the immunization or relocation options provided for in the program.

4.3 (In)sufficiency of a lifetime limit

For households without access to flood insurance, it is important that they understand the financial implications of a $100,000 lifetime limit on last resort assistance before choosing between repairing the property and staying, immunizing it or relocating it. The above calculations provide information on flooding probability (Table 1) and the losses resulting from this flooding (Table 3). In this subsection, we combine these two sets of results to estimate the probability that a property will suffer cumulative losses of more than $100,000 over 25 years, as well as the financial burden that will be borne exclusively by homeowners.

Property type	Risk associated with location and topography		Probability of exceeding the $100,000 limit	Average loss over $100,000 (in $)
	Risk level	Floodplain		
Low exposure	Extreme	2 years	100.0%	381,700
	Very high	10 years	35.9%	79,000
	High	20 years	9.9%	72,000
	Non-negligible	100 years	0.1%	19,300
	Low	1,000 years	0.0%	0
High exposure	Extreme	2 years	100.0%	1,696,800
	Very high	10 years	92.7%	293,900
	High	20 years	72.2%	147,000
	Non-negligible	100 years	22.0%	59,800
	Low	1,000 years	2.4%	26,100

Table 4 Probability of accumulating losses over $100,000 and conditional losses over $100,000

In light of the results shown in Table 4, we note that it is common for a property located on a non-insurable floodplain to suffer damages in excess of $100,000 over a 25-year period. For example, a $250,000 low-exposure building located on a 20-year floodplain has 1-in-10 odds of accumulating over $100,000 over that period. This probability is 72% for a property with a high exposure to flooding. When losses exceed $100,000 for these properties, owners must therefore expect to pay an average of $72,000 or nearly $150,000 depending on the property type (over and above the $100,000 provided by the financial assistance program). However, as this is an average for scenarios where losses exceed $100,000, it is quite possible to pay more than the amounts shown in Table 4.

Considering that the typical property in our analysis is worth $250,000, these are very significant disbursements that can easily exceed 50% of the value of the building and must be borne by the households. It should be remembered here that our simulations are based on the assumption of a building worth $250,000. However, the $100,000 lifetime limit also applies to more luxurious properties. As a result, flood victims with more valuable properties must invariably bear more losses. By keeping the other simulation assumptions constant, a $500,000 low-exposure building located on a 20-year floodplain will have a 30% chance of incurring losses exceeding $100,000 over 25 years. The average loss in excess of $100,000 will then be $116,000.

To assume such costs, the claimant must dip into personal savings and/or borrow (for example, by re-mortgaging his or her property), which significantly increases the risk of insolvency. A claimant with no personal savings and limited borrowing capacity may have to declare bankruptcy.

4.4 Risk of insolvency of flood victims

In this subsection, we analyze the insolvency[9] risk of a claimant whose property was acquired at time 0 and who suffers one or more successive floods over a 25-year period in a situation where flood insurance is not available.

Because it is difficult to conduct an exhaustive analysis of all possible financial situations, we make some simplifying assumptions:

[9] In the remainder of this article, insolvency and bankruptcy will be used interchangeably.

- Households' borrowing capacity and the amount borrowed is $250,000, i.e. 100% of the building's value. Considering the value of the land, it is therefore possible that the maximum borrowing capacity is approximately 70–80% of the total value of the property (land and building).
- The only source of savings available to households therefore comes from the difference between their borrowing capacity and the outstanding mortgage balance.
- The property value remains constant over time. In a manner considered equivalent for our purposes, the rise in property value over time perfectly matches buildings' loss in value following a flood (once repairs are completed).

In our simulations, insolvency occurs when flood damage is not covered by last resort financial assistance and exceeds households' available savings and borrowing capacity. Bankruptcy therefore occurs when the value of the assets is lower than the value of the debts.

Our definition of bankruptcy likely underestimates the probability of actual household bankruptcy. Many personal bankruptcies result from liquidity problems following a default when the household fails to make periodic mortgage payments, even if the value of the household's assets exceeds that of its debts. However, the simplifying assumptions we make enable us to compare the costs of one or more floods, while taking into account their timing in comparison with the household net worth, which increases over time.

Given that floods causing relatively little damage over $100,000 have the potential to lead to bankruptcy, particularly in the first few years after the property is acquired (a high mortgage balance means low net worth), it makes sense to establish the point at which the $100,000 lifetime limit is surpassed before formally examining the probability of bankruptcy. Table 5 shows the result of this analysis.

All things being equal, losses in excess of $100,000 occur earlier when the ex-ante risk is higher. Nevertheless, in 1% of trajectories, low-exposure properties on a 20-year floodplain use all available last resort assistance within five years. This jumps to 22.6% for high-exposure properties on the same floodplain. This provides a first indication that the risk of bankruptcy arising from the lifetime limit on last resort assistance is non-negligible.

Property type	**Risk associated with location and topography**		**Point at which the $100,000 limit is exceeded**				
	Risk level	Floodplain	0–5 years	6–10 years	11–15 years	16–20 years	21–25 years
Low exposure	Extreme	2 years	32.5%	52.6%	13.2%	1.6%	0.2%
	Very high	10 years	2.4%	4.7%	7.7%	10.1%	11.1%
	High	20 years	1.0%	1.4%	1.9%	2.5%	3.1%
	Non-negligible	100 years	0.0%	0.0%	0.0%	0.0%	0.1%
	Low	1,000 years	0.0%	0.0%	0.0%	0.0%	0.0%
High exposure	Extreme	2 years	96.8%	3.0%	0.1%	0.0%	0.0%
	Very high	10 years	41.1%	24.2%	14.1%	8.4%	4.9%
	High	20 years	22.6%	17.5%	13.5%	10.5%	8.1%
	Non-negligible	100 years	4.9%	4.6%	4.5%	4.1%	4.0%
	Low	1,000 years	0.5%	0.5%	0.5%	0.5%	0.5%

Table 5 Time at which the $100,000 lifetime limit is exceeded for a $250,000 loan

We continue our modelling exercise to more accurately quantify the risk of bankruptcy. This time, we compare the net value to the cost of flood losses in excess of $100,000. Figure 3 shows the bankruptcy risk for a low-exposure property on a 20-year floodplain.

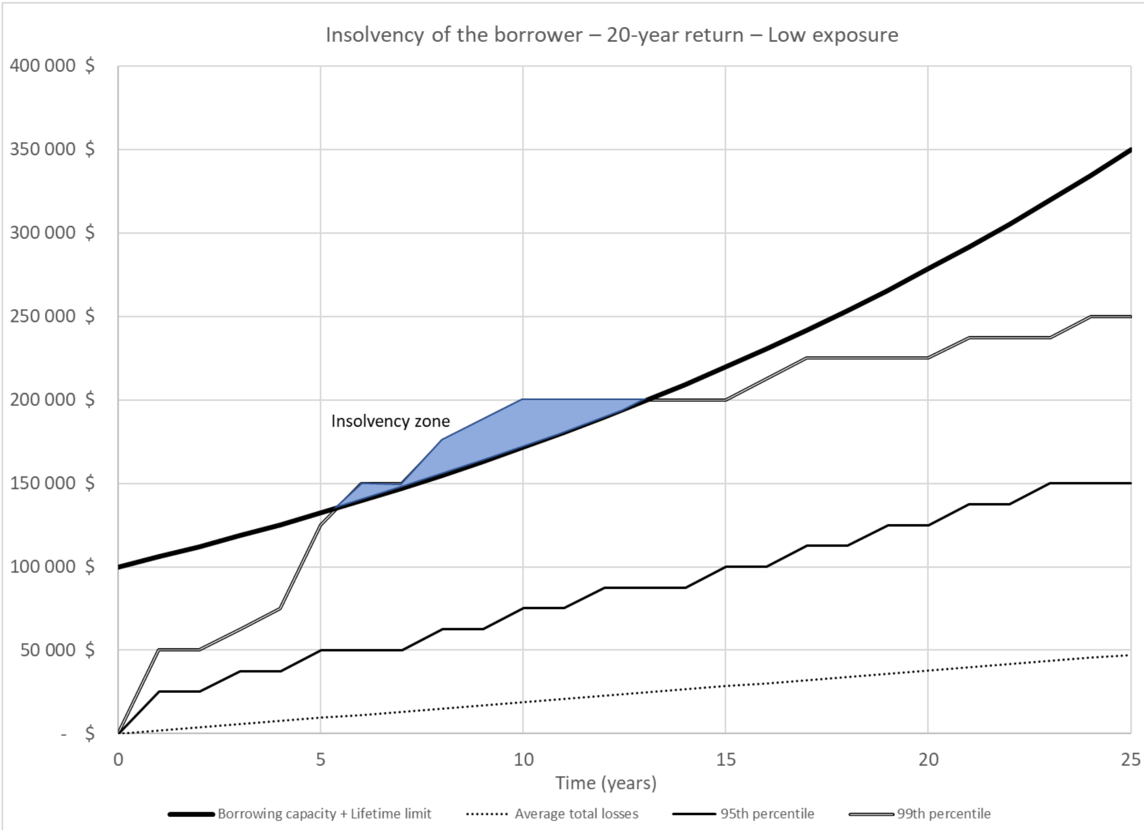

Figure 3 Insolvency risk for a low-exposure property on a 20-year floodplain.

The $100,000 cap on last resort assistance covers a significant portion of the losses in a majority of flood trajectories over 25 years. In the 95,000th "worst" scenario (95th percentile), the cumulative losses exceed the $100,000 limit approximately 15 years after the property is acquired. However, by that time the homeowners have accumulated enough savings in the form of net worth to cover losses in excess of $100,000. In the 99,000th "worst" scenario (99th percentile), the cumulative losses cross the $100,000 threshold much faster, only four years after the property is acquired. Losses in subsequent years are therefore borne by the homeowners, who will exhaust their financial resources. In this scenario, the homeowners will face bankruptcy approximately six years after the $100,000 limit is imposed. Our analysis reveals that the vast majority of insolvencies occur within 10 years of acquisition. Incidentally, we will look specifically at bankruptcy risk during this critical period.

The insolvency zone in Figure 3 can also be expressed as a probability of bankruptcy. Taking all scenarios into account, a household with a low-exposure property located on a 20-year floodplain has an approximately 2% chance of bankruptcy within 10 years of acquisition.

Not surprisingly, the probability of bankruptcy increases with the level of ex-ante risk and is also higher for high-exposure properties. Table 6 shows the risk of bankruptcy by property type and level of ex-ante risk. We also present the results of simulations using a building value of $500,000 while keeping the other parameters unchanged.

Property type	Risk associated with location and topography		Probability of insolvency over 10 years	
	Risk level	Floodplain	$250,000 building	$500,000 building
Low exposure	Extreme	2 years	57.7%	85.9%
	Very high	10 years	4.0%	10.0%
	High	20 years	1.8%	3.3%
	Non-negligible	100 years	0.0%	0.2%
	Low	1,000 years	0.0%	0.0%
High exposure	Extreme	2 years	99.5%	99.9%
	Very high	10 years	50.1%	65.2%
	High	20 years	26.9%	40.1%
	Non-negligible	100 years	5.7%	9.5%
	Low	1,000 years	0.4%	1.0%

Table 6 Probability of insolvency over 10 years

We note in Table 6 that the probability of insolvency in the first 10 years varies between 2% and 40% depending on the type and value of the property when located on a 20-year floodplain. Therefore, unless the homeowner has put significant savings aside and/or made a substantial down payment (higher initial net worth), the first 10 years after acquiring a property can be critical for the creditworthiness of a homeowner whose property is located on a floodplain. In fact, a lifetime limit of $100,000 for successive floods combined with a high mortgage balance at the beginning of the amortization period limits the claimant's financial capacity to repair damage to the property, reducing its value and increasing the borrower's risk of insolvency.

Note that this analysis may underestimate the actual risk of insolvency because of other indirect flood-related costs not considered. For example, the assistance program covers repairs and movable property deemed essential, which reduces the compensation received for the rest of the no-less-significant damage. As a result, the lifetime limit is reached more slowly, but the claimant will have larger disbursements sooner, increasing the risk of insolvency in the short term. The analysis also excludes loss of income during and after the floods and the resulting pressure on available liquid assets, which again underestimates the risk of insolvency.

5. Sensitivity of results

Up to this point, we have assumed that annual flood probabilities are constant over time. However, several factors can affect the evolution of flood risk. Land use planning and climate change are contributing to an increase in flood risk in several parts of Quebec (the former affecting vulnerability and the latter, hazard). Since Quebec's public safety department implemented its action plan in spring 2018, the Montreal and Quebec City metropolitan communities, regional county municipalities (MRCs) and the non-profit organization Ouranos have been working to update floodplain maps to account for both changes in land use and climate change.

In Quebec, overland flooding is described as having three seasonal hydrological regimes: winter, spring and summer/fall. In winter, flooding can be caused by ice jams and breakup, whereas snowmelt is a central element of spring floods. In summer and fall, extreme precipitation is the biggest single factor affecting river flows. Higher temperatures due to climate change could increase the number and intensity of extreme precipitation events in many parts of the world (IPCC, 2019). However, given Quebec's winter climate, higher temperatures will also affect winter and spring hydrological regimes in a non-trivial way.

As part of the *2017 FORUM Inondations*, a forum on flooding organized by Quebec's environment department, the *Ministère québécois de l'environnement* (MDDELCC), Ouranos published a fact sheet[10] summarizing climate change's expected impact on flooding in southern Quebec. The organization stresses the importance of watershed size on future trends, and that in general the risk of flooding will not decline. In fact, the trend appears to be rather uncertain with respect to large watersheds and increasing for smaller ones.

That said, it is possible to analyze the results' sensitivity to flooding frequency and severity by comparing two return periods. For example, if we assume that the inherent risk of a property located on a 20-year floodplain doubles with the new mapping, whether because of updated land use maps or climate change, then we need only compare results with those for a 10-year floodplain. We therefore see that the probability of insolvency increases from 1.8% to 4% for a low-exposure property by comparing 20-year and 10-year floodplains. Similar results are obtained in several other contexts.

6. Conclusion

In April 2019, the Government of Quebec announced a major overhaul of its financial assistance program for flood victims which included the introduction of limited lifetime coverage of $100,000 for successive floods, a first in Canada. The introduction of a lifetime cap represents a real paradigm shift that reflects a lack of societal support for an approach whereby all taxpayers assume the financial risk of repeated flooding on a minority of properties. Shifting some of society's financial burden to high-risk households can potentially increase risk awareness and place more responsibility on the households themselves. However, for owners of buildings located in flood-prone areas, risk management decisions are difficult because the required information on flooding frequency and severity is incomplete, imperfect and complex. In this situation, how can a household that has just experienced a major disaster make an informed decision to relocate, immunize, move, rebuild or repair its property?

This article provides a first body of knowledge on the direct effects of including a lifetime limit on financial assistance programs for flood victims. Using a simulation approach, we model the expected cumulative losses over a 25-year period for a property defined by its risk and exposure levels. We determine the size and timing of the losses that will from this point forward be borne by households.

Our results indicate that introducing a lifetime limit could significantly increase the risk of household insolvency, especially when the property is located on a high-risk floodplain and/or when its property type and location quickly expose it to damage. We found that the risk of insolvency is significant in the first 10 years of a (25-year) mortgage because when the first, second or even third flood occurs, the mortgage balance is still high compared to the original loan amount. Consequently, the introduction of a lifetime limit in the Government of Quebec's financial assistance program could have significant financial impacts on households and financial institutions.

Moreover, all the evidence suggests that we also underestimate the actual risk of insolvency for a majority of Quebec households because (1) the Government of Quebec's financial assistance program covers only damages and so-called essential or last resort items, whose total value is less than the actual direct damages and (2) indirect damages such as lost wages and health problems during the recovery process increase pressure on these households' finances.

[10] Fact Sheet available at https://www.ouranos.ca/publication-scientifique/FicheAvisInondation2018-Fr.pdf

Before the full effects of this lifetime limit emerge in the next few years, it is more urgent than ever to debate the role of citizens, insurers and municipal, provincial and federal governments in sharing the financial risks of flooding in Quebec and the rest of Canada in order to find a fair and sustainable solution in the face of climate change.

References

Bélanger, P., & Bourdeau-Brien, M. (2018). The impact of flood risk on the price of residential properties: the case of England. *Housing Studies*, *33*(6), 876–901. https://doi.org/10.1080/02673037.2017.1408781

Bélanger, P., Bourdeau-Brien, M., & Dumestre, M. (2018). The Impact of Flood Zones on Residential Property Prices: The Case of Canada. *Journal of Sustainable Real Estate*, *10*(1), 135–162. https://doi.org/10.5555/1949-8276.10.1.135

Beltrán, A., Maddison, D., & Elliott, R. (2019). The impact of flooding on property prices: A repeat-sales approach. *Journal of Environmental Economics and Management*, *95*, 62–86. https://doi.org/10.1016/j.jeem.2019.02.006

Insurance Bureau of Canada (2015). *The Financial Management of Flood Risk*. http://assets.ibc.ca/Documents/Natural%20Disasters/The_Financial_Management_of_Flood_Risk.pdf

Insurance Bureau of Canada (2018). *Property and Casualty Insurance in Canada*. http://assets.ibc.ca/Documents/Facts%20Book/Facts_Book/2018/IBC-Fact-Book-2018.pdf

Government of Canada (2019). Canada's Changing Climate Report (p. 446). Bush, E., & Lemmen, D.S. (eds). https://changingclimate.ca/CCCR2019/

Green, C.H., & Penning-Rowsell, E.C. (1989). Flooding and the Quantification of 'Intangibles.' *Water and Environment Journal*, *3*(1), 27–30. https://doi.org/10.1111/j.1747-6593.1989.tb01363.x

Grigg, N.S., & Helweg, O.J. (1975). State-of-the-Art of Estimating Flood Damage in Urban Areas. *JAWRA Journal of the American Water Resources Association*, *11*(2), 379–390. https://doi.org/10.1111/j.1752-1688.1975.tb00689.x

IPCC (2019). *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M., & Waterfield, T. (Eds.). https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_Low_Res.pdf

Lamond, J. & Proverbs, D. 2006. Does the price impact of flooding fade away? *Structural Survey*, *24*(5), 363–377. https://doi.org/10.1108/02630800610711960

Jung, D. (April 18, 2019). Difficile de s'assurer contre les inondations | Crue printanière 2019. *Radio-Canada.ca*. https://ici.radio-canada.ca/nouvelle/1165169/catastrophe-assurance-crues-inondations-indemnisations

Kellens, W., Terpstra, T., & Maeyer, P.D. (2013). Perception and Communication of Flood Risks: A Systematic Review of Empirical Research. *Risk Analysis*, *33*(1), 24–49. https://doi.org/10.1111/j.1539-6924.2012.01844.x

Leclerc, M., Secretan, Y., Heniche, M., Ouarda, T.B.M.J., & Marion, J. (2003). Une méthode prédictive non biaisée et géoréférencée d'estimation des dommages résidentiels d'inondation. *Canadian Journal of Civil Engineering*, *30*(5), 914–922. https://doi.org/10.1139/l03-065

Lekuthai, A., & Vongvisessomjai, S. (2001). Intangible Flood Damage Quantification. *Water Resources Management*, *15*(5), 343–362. https://doi.org/10.1023/A:1014489329348

Luechinger, S., & Raschky, P. (2009). Valuing flood disasters using the life satisfaction approach. *Journal of Public Economics*, *93*(3), 620–633. https://doi.org/10.1016/j.jpubeco.2008.10.003

Natural Resources Canada & Public Safety Canada. (2017). *Canadian Guidelines and Database of Flood Vulnerability Functions* (Canadian Floodplain Mapping Guidelines Series, p. 228). Government of Canada.

Thistlethwaite, J., Henstra, D., Brown, C., & Scott, D. (2018). How Flood Experience and Risk Perception Influences Protective Actions and Behaviours among Canadian Homeowners. *Environmental Management*, *61*(2), 197–208. https://doi.org/10.1007/s00267-017-0969-2

Verkerk, J. & van Buuren, A. (2012). Space for the river: A condensed state of the art. In J. Edelenbos, A. van Buuren, & J.F. Warner (Eds.), *Making Space for the River*. IWA Publishing.

Wiering, M., Kaufmann, M., Mees, H., Schellenberger, T., Ganzevoort, W., Hegger, D.L.T., Larrue, C., & Matczak, P. (2017). Varieties of flood risk governance in Europe: How do countries respond to driving forces and what explains institutional change? *Global Environmental Change*, *44*, 15–26. https://doi.org/10.1016/j.gloenvcha.2017.02.006