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Understanding Flood Risk Perception: A Case Study from Canada

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Abstract: In recent years, understanding and improving the perception of flood risk has become an important aspect of flood risk management and flood risk reduction policies. The aim of this study was to explore perceptions of flood risk in the Petite Nation River watershed, located in southern Quebec, Canada. A survey was conducted with 130 residents living on a floodplain in this river watershed, which had been affected by floods in the spring of 2017. Participants were asked about different aspects related to flood risk, such as the flood hazard experience, the physical changes occurring in the environment, climate change, information accessibility, flood risk governance, adaptation measures, and finally the perception of losses. An analysis of these factors provided perspectives for improving flood risk communication and increasing the public awareness of flood risk. The results indicated that the analyzed aspects are potentially important in terms of risk perception and showed that the flood risk perceptions varied for each aspect analyzed. In general, the information regarding flood risk management is available and generally understandable, and the level of confidence was good towards most authorities. However, the experiences of flood risk and the consequences of climate change on floods were not clear among the respondents. Regarding the adaptation measures, the majority of participants tended to consider non-structural adaptation measures as being more relevant than structural ones. Moreover, the long-term consequences of flooding on property values are of highest concern. These results provide a snapshot of citizens' risk perceptions and their opinions on topics that are directly related to such risks.

Keywords: perception of flood risk; flood risk management; survey; floodplain; information accessibility; governance; climate change; adaptation measures; flood risk communication

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1. Introduction

Historically, floods are the most costly and frequent natural disasters in Canada, causing over $1B in damage to homes, the economy, the environment, and infrastructures each year [1]. In addition to economic losses, floods are responsible for a range of social impacts and mental health issues such as post-traumatic stress disorder, anxiety, and depression [2,3]. Floods can occur via a range of processes, including fluvial floods (river floods), pluvial floods (surface water flowing towards rivers), coastal floods (storm surge and coastal tidal flooding), as well as floods induced by human activity. In Canada, the increasing concentrations of people and assets in areas of high flood risk coupled with climate change impacts will likely contribute to an increase in flooding episodes in coastal and urban areas [4,5]. Almost 80% of Canadian cities are located on riverine floodplains due to historical settlement around waterways that provided access to commerce and resources [6]. However, the increasing flood risk is not only due to changing climate conditions or human

development in flood-prone areas, but also to a lack of flood preparedness and effective flood risk management [7].

Flood risk is driven by a mix of meteorological processes and geographical characteristics. Riverine flooding is often generated by heavy snowpack that melts during spring, overwhelming flood defenses in downstream communities [6]. Canada has experienced several flooding events in the last few decades. The flood risk in Canada is highly variable across different provinces and territories. In 1996, the Saguenay flood was the first natural disaster in Canadian history with damages over $1B, which hit the Saguenay-Lac-Saint-Jean region in Quebec [8]. The following year, in 1997, the Red River in Manitoba flooded with a return interval ranging 500 years, and caused an estimated $500 million in damage [9]. In 2013, Alberta experienced the worst rainstorm in its history, resulting in flash floods and widespread inundation and damage in both urban and rural areas. In recent years, the most severe floods occurred in eastern Ontario (2017) and southwestern Quebec (2019), causing more than $200 million in insurable damages and impacting many people who had to be evacuated from their homes [10]. In addition to the economic damages, the consequences of floods on human health are not to be underestimated, including the risk of injuries, gastrointestinal diseases, or respiratory problems, as well as impacts on psychological health [11]. However, little is known in the Canadian context about how individuals who reside in disaster-affected communities understand the interactions between human activity and the environment. The 2017 flood events drew attention to the frequency and severity of flooding in Quebec and Ontario. These floods have helped shape the flood risk perceptions of emergency and risk managers, as well as the general population.

Generally, flood risk involves three fundamental elements: hazard (the physical characteristics of the flood events and the return period associated with it), vulnerability (the potential consequences of the event), and perception of the risk (i.e., how a potential risk is viewed by impacted stakeholders in terms of its effect on their needs [12]). The flood hazard is described by the physical characteristics of the flood events with a probability of exceedance or the associated return period [13]. Flood hazard maps are created based on the results of hydraulic modelling and provide essential hydraulic parameters for informed flood risk management, such as water depths, velocities, and timing of inundation. On the other hand, vulnerability is composed of two elements: exposure and susceptibility to damage. The exposure encompasses the local population and the built environment within the community; the susceptibility is usually described by depth–damage curve [14]. While the methods of risk analysis (hazard and vulnerability) are usually based on objective measures, subjective risk assessment, such as risk perception, is currently considered a crucial aspect in the context of flood risk management [15]. Flood risk perception is the assessment of the probability of a hazard and the perceived probability of the results [16]. Raaijmakers et al. [17] specify the definition of flood risk perception as a combination of three specific factors of risk: awareness, worry, and preparedness. It is conceptualized as a complex process that encompasses cognitive and affective aspects. The knowledge of risk perception is promoted as a prerequisite for achieving effective risk communication [18]. The necessity to take flood risk perception into account while conducting flood risk management is commonly emphasized as part of the social context [19]. It determines the attitude and the possible behavior of the residents of floodplains when facing floods. Knowledge of public risk perception is meant to ensure an improvement in the effectiveness of flood risk management [15].

Public perception has been analyzed over the years under many factors [15,20,21], with some of these factors being: the experiences of the population with the natural hazard [20,21]; the nature of the communicated message around the risks; the individual's physical location and proximity to a hazard [22–24]; the residence characteristics [23,25–28]; length of time at the residence [25]; flood consequences [25–30]; the socio-economic and demographic profiles (age, gender, education, income, number of children) [23,24,31,32]; the mitigation measures [26,27], the individual's knowledge of the hazard [28,29]; the socio-cultural context [30]; the attitudes and values towards the environment and climate

change [31]; ethnicity [32]; and the political environment [33]. Negative emotions associated with flooding and feelings of attachment to the home are other factors that can affect the interpretation of risk and the behaviors adopted. In the majority of the studies, the greatest factor affecting the perception of risk is the experience of the affected individuals with hazard events, followed by social, economic, and demographic factors. With regards to the perceptions of distance to a flood risk area, O'Neill et al. [34] found that living close to a flood zone increased flood risk perceptions. In their study on the perceptions of inhabitants and tourists of flood risk on Belgian coast, Kellens et al. [15] determined that the perception of flood risk is mainly influenced by expert-estimated risk, age, gender, and past flooding experience. Past research indicates that in post-disaster settings, it is often advantageous to use a qualitative rather than quantitative research methodology to assess risk perception [35]. A qualitative research approach allows researchers to better focus on participant's lived experiences, subjective perceptions, and individual voices. This approach has been used in different ways, including telephone surveys [36], telephone interviews [37], questionnaire surveys [30], "door-to-door" interviews [38], and online surveys [39]. In addition to questionnaires, several studies have also quantified individuals' perceptions of the spatial extent of risk or hazard using methodologies from cognitive mapping research, such as mental maps or sketch maps [40]. For example, Coquet et al. [41] stated that the individual perception of the spatial extent of coastal flooding appeared to be more influenced by the perceived distance of the home to exposed areas than the objective distance.

In Canada, studying the perception of flood risk is, however, in its early stages. While it has been established that people are more susceptible to flooding than they might be in other parts of the world, we do not yet know how these perceptions vary from place to place, or if there are consistent differences across different types of flood events. Kreutzwiser et al. [42] evaluated residents' perceptions of the floodplain development regulations in Glen Williams in the province of Ontario by using various variables, including attitudes towards attitudes toward regulation, flooding experience, length of residence, proximity to the river, age, education, and income. They found that only 28% of respondents perceived any risk of future flooding, and that previous flood experience, proximity to the river, and length of time residence were significantly related to the perception of flood risk. Similarly, Haney and McDonald-Harker [43] conducted focus group interviews with 46 residents of High River hit by the 2013 southern Alberta flood to examine the ways in which recent and dramatic flood experience changed people's thoughts on, and relationship with, the natural environment. Their findings indicated that residents felt that their environment was less stable since the flood, and they worried more about toxicity and associated environmental health risks. Shrubsole et al. [44] surveyed the floodplain residents to assess their perceptions of flood hazards, along with the perceptions of individuals working the real estate sector in Brantford and Cambridge, Ontario, Canada. The results indicated that the residents did not perceive a significant risk of future flooding, and that there was a poor understanding of floodplain regulations. They said that the characteristics location (e.g., neighborhood) and home (e.g., age of the house) are more important than the flood risk in determining property values. Enarson and Scanlon [45] studied the impacts of flooding on couples and assessed the differences between women and men in Canada's Red River Valley using various factors, such as flood experience, emergency communications, actions and emotions during preparedness, impact, relief, recovery, perceived changes in family, and life work. Their results showed that the experiences before, during, and after evacuation are more similar than different between men and women. In contrast, the functions associated with protection, evacuation control evacuation, and the recovery period are primarily assumed by the men. In addition, Thistlethwaite et al. [21] presented research on the extent to which Canadians' flood experience, perceptions of flood risks, and socio-demographics shape their intentions and adoption of property-level flood protection. They argued that property owners are not willing to accept greater responsibility for flood risk as envisioned by recent policy changes. Finally, the findings of Ziolecki et al. [46]

indicate that only 6% of respondents know they live in a designated flood risk area, and 81% of respondents have not reviewed flood maps for their community.

In light of these studies, this research aims to provide a better understanding of the flood perceptions that the residents of the Petite Nation River watershed (Quebec, Canada) have regarding floods, particularly the perception of flood risk and its associated determinants. The method is based on a survey questionnaire covering six main themes: knowledge and flood hazard experience, information accessibility, trust in different public authorities and government, perception of climate change drivers and physical changes in the environment, perception about the consequences of floods, and the adaptation and compensation measures.

2. The Petite Nation River 2017 Flood

In 2017, spring snowfall and heavy rainfall caused floods in southern Quebec. Approximately 4500 residences were flooded, 4066 people were evacuated from their homes, and 261 municipalities were affected, largely in the Outaouais region, the greater Montreal area, and the Montérégie region [10]. Floods were estimated to have caused more than 376 million $CAD in damages to municipalities located in southern Quebec [10]. Those inundations essentially resulted from river level increases due to a combination of heavy rain and melting of the ice sheet.

In the Outaouais region, exceptional flooding impacted several municipalities in the Petite Nation River watershed. The municipalities of Papineauville, Plaisance, Ripon, and Saint-André-Avellin were the most affected by the flooding, leading to the activation of emergency measures and evacuation orders. Many citizens of these municipalities left their homes, while others stayed behind to protect their homes. Water rose over the tops of vehicles and halfway up the sides of some homes, and streets were no longer accessible other than by boat. The municipality of Saint-André-Avellin (population of 3749) was the hardest hit by the flood (Figure 1). The municipality declared a state of emergency on 20 April 2017 after several hours of flooding, and the Canadian Armed Forces were deployed to help evacuate hundreds of residents. To this day, many families continue to be displaced after losing their homes and most of their belongings in the flood. Many residents also faced continuing social, emotional, and psychological difficulties in the aftermath of the flood.

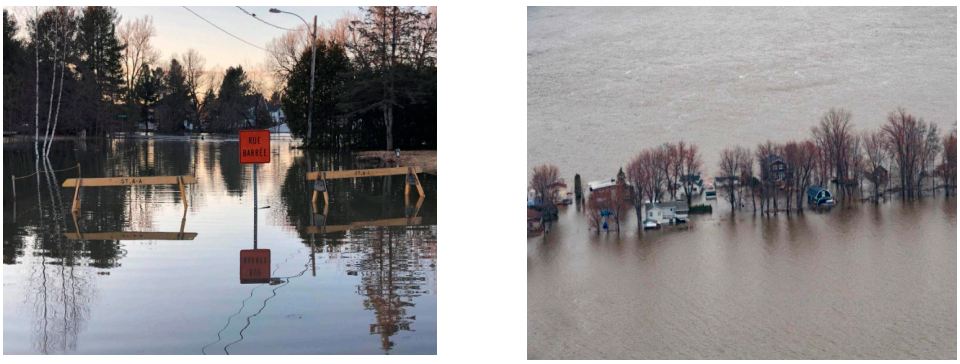

Figure 1. Flooded areas in Saint-André-Avellin-2017 (https://infopetitenation.ca/) (accessed on 20 April 2017).

With the growing influence of climate change on river processes combined with factors such as land use and urban development, it is essential to understand how the public perceives the risk of flooding and their flood risk management preferences.

3. Methods

3.1. Study Area

The study area was located in the Petite Nation River watershed (Figure 2), where the population is estimated to be at 17,509. Furthermore, 29% of this population lives in urban

areas, in the municipalities of Papineauville and Saint-André-Avellin, which are the main urban centers of the Petite Nation watershed, although the municipalities of the watershed are largely characterized by their rural character. The northern part of the watershed is characterized by important forest cover, as well as important water bodies and streams, such as Lac-Simon, which is not heavily occupied by human activity, notwithstanding the presence of holidaymakers. The southern part of the watershed is characterized by a dense agricultural landscape with major agricultural activities.

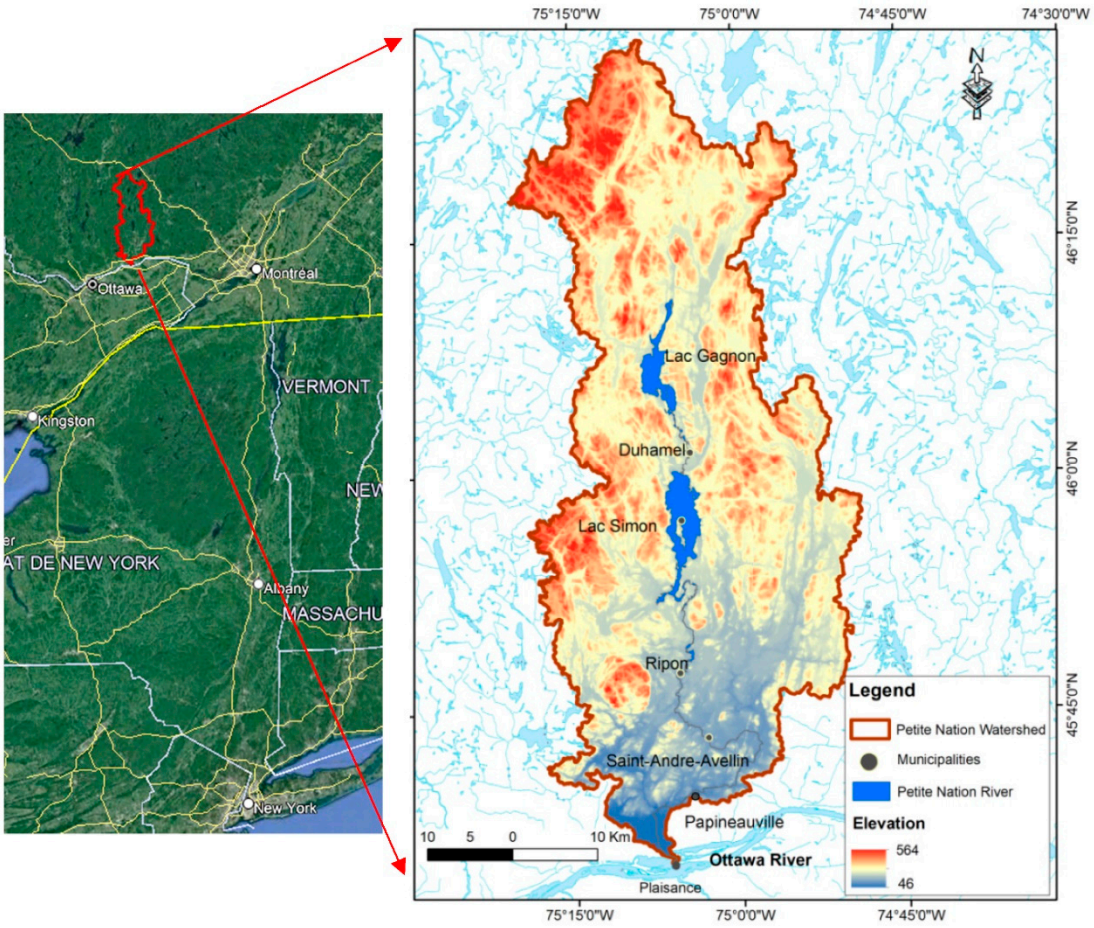

Figure 2. Location map of the study area.

The climate in the Petite Nation watershed is mainly controlled by meteorological conditions in the Great Lakes and Atlantic Ocean. However, water body temperatures vary according to the weather conditions over the Canadian Shield and the Laurentian Mountains. The mean annual precipitation varies between 250 and 500 mm (from April to October). Overall, the population concentration of this watershed shows a decreasing gradient from south to the north. The municipalities in the northern part see their population increase drastically during the summer period due to vacationing and tourist attractions. The Petite Nation River flows southward for a total of approximately 129 km and crosses the municipalities of Duhamel, Lac-Simon, Ripon, Saint-André-Avellin, Papineauville, and Plaisance, where it flows into the Ottawa River.

The drainage basin of the Petite Nation River has an area of 2248 km^2 at its mouth. The only hydrometric station in the basin is located in the city of Ripon (St 040406). The river has an average daily flow of 29.8 m^3/s ([47]). According to historical data from the Quebec Water Expertise Direction [41], peak flows of the Petite Nation River are observed during spring freshet (April–May) and are followed by low water levels towards the end of summer (June–July). In addition, a frequency analysis was carried out for the historical flow data of the hydrometric station for the 1970–2002 periods (Table 1). The results

of this frequency analysis express the flows associated with different return periods. For information purposes, in the spring of 2017, the maximum flow recorded at the hydrological station of Ripon exceeded historical maximums by reaching more then 150 m^3/s [47].

Table 1. Frequency analysis results at station 040406. Flow rate values are in m^3/s and return periods are in years.

Return Periods (Years)	Flow Rate (m^3/s)
2 years	96.5
5 years	115.5
10 years	124.7
20 years	131.9
50 years	139.5
100 years	144.5

3.2. Flood Risk Assessments Tools

Faced with recurring floods (2008, 2017, and 2019), and in order to help the vulnerable communities of the Petite Nation watershed to be better equipped to deal with climate-related flooding, INRS (Quebec's National Institute of Scientific Research) developed a series of flood risk assessment tools in partnership with the Organization of Watersheds of the Rouge, Petite Nation, and Saumon Rivers (OBVRPNS); the Canadian Federation of Municipalities; and six partner municipalities of the Petite Nation watershed (Duhamel, Ripon, Saint-Andre-Avellin, Papineauville, Lac-Simon, Plaisance). The tools were designed to help communities to better respond to flooding, to understand the impacts of climate change, and to promote upstream–downstream solidarity among municipalities. Two main tools were developed in this project:

- GARI (Gestion et Analyse du Risque d'Inondation /Flood Risk Management and Analysis): This geospatial application [48] allows the estimation, analysis, and visualization of flood-related risks for individuals, residential buildings, and in some cases for critical infrastructure. GARI contains three main modules:
  - ➢ Flood mapping: Shows the extent of the flooded area and the submersion heights at each point of the flooded area using a Lidar DEM. The module is based on a simple regression model based on the water level discharge function at each point of the domain;
  - ➢ Vulnerability assessment: Indicates the vulnerability of the affected population based on their socioeconomic characteristics;
  - ➢ Damage to buildings and infrastructure: This module generates a map of the estimated damage to each building during a given flood event.

Figure 3 represents the flood risk map (combining hazard and vulnerability) simulated by the GARI tool for the municipality of Saint-André-Avellin, for a maximal record discharge of 215 m^3/s;

- A Story Map for flood risk communication [42]: this tool provides interactive maps of flooded areas and affected streets and buildings for current and projected flows.

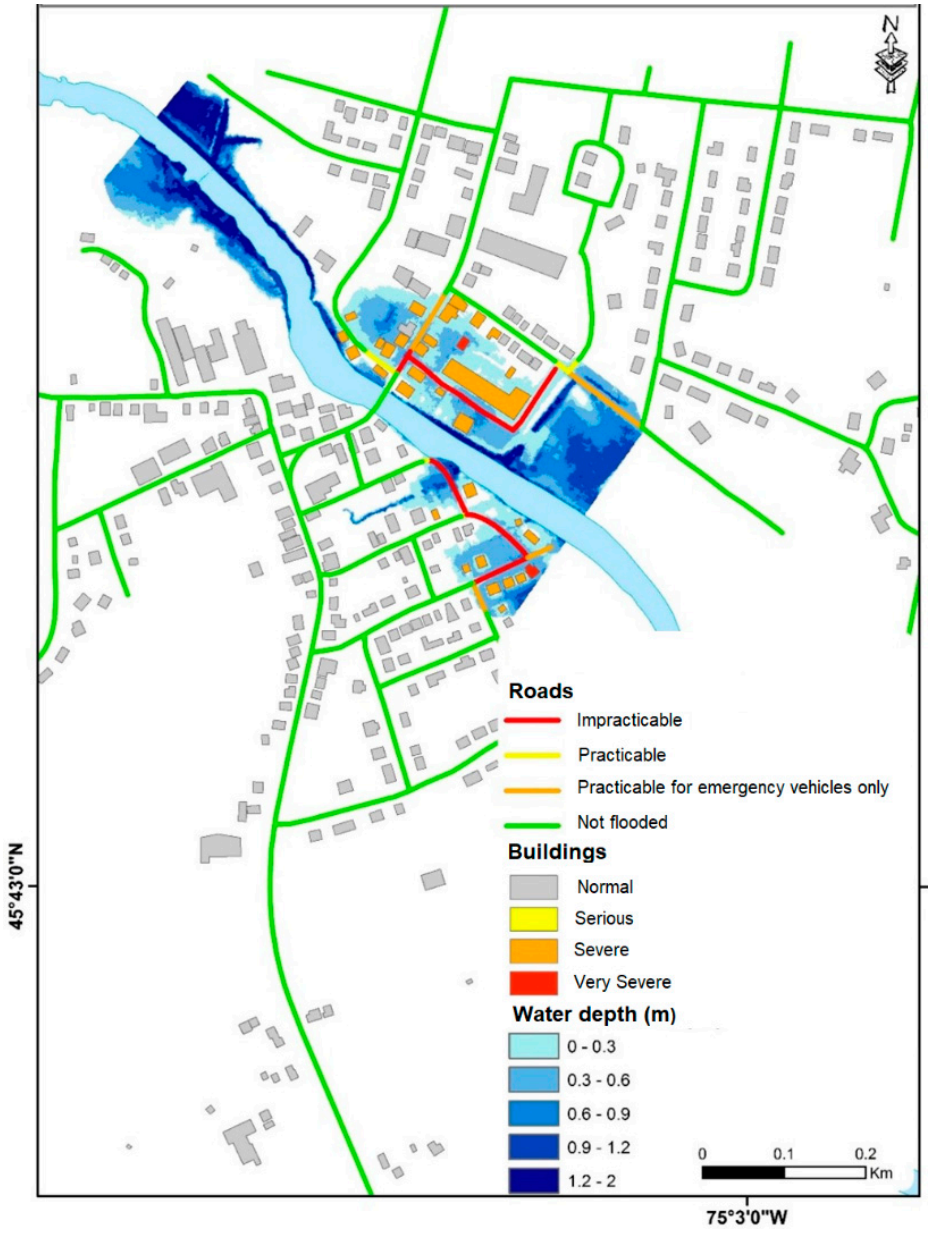

Figure 3. Flood risk map for Saint-Andre-Avellin municipality with discharge: 215 m^3/s.

3.3. Questionnaire Development

As part of this study on the Petite Nation River flood risk, a survey questionnaire was deployed online over a three week period from 2 to 25 October 2019 for 130 residents living within five kilometers of the Petite Nation River watershed. The respondents were distributed across the six main municipalities of the watershed (Figure 4). The municipalities with a higher level of respondents were Saint-André-Avellin and Ripon. A resident located five kilometers from the river does not face the same concerns as someone living 100 m from the river; the information collected provides a better understanding of the problems faced by residents living near the river.

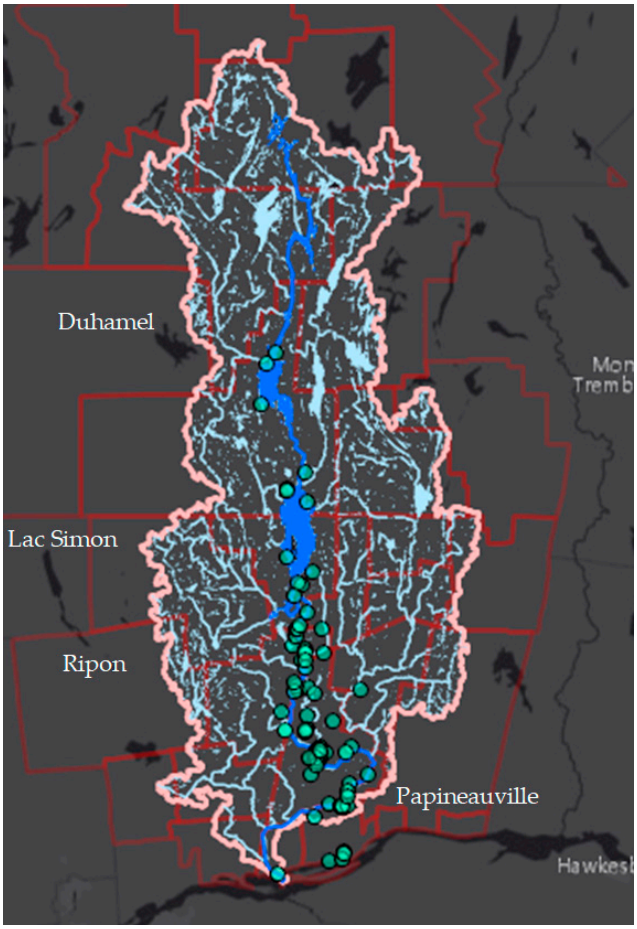

Figure 4. Location of the survey participants.

Respondents were somehow evenly distributed across the study area. The detailed distribution in the municipalities of the Petite Nation watershed was as follows (Table 2): 1% in Cheneville, 8% in Duhamel, 5% in Lac-Simon, 2% in Lochaber, 1% in Notre dame de la Paix, 8% in Papineauville, 17% in Ripon, 58% in Saint-André-Avellin. The majority of respondents are located in the largest cities of the Petite Nation watershed (Saint-André-Avellin and Ripon), the most affected cites most during the 2017 and 2019 floods. Among the 130 respondents, 46% were males and 54% were females. The age of respondents was as follows: 2% were under 17 years of age, 73% between 17 and 60 years of age, and 25% were over 60 years of age, indicating that our sample covers more people between the ages of 18 and 60 years of age. The level of education is as follows: 8% of respondents have no high school diploma, 48% have a collegial diploma, 28% have a university diploma, and 16% have secondary school diploma, which means that the participants have an intermediate to superior level of education.

Table 2. This descriptive analysis of socio-demographic characteristics.

Variables	Percentage (%)
Male	46
Female	54
Age (years)	
<17	2
17–60	73
>60	25

Table 2. *Cont.*

Variables	Percentage (%)
Education	
Without diploma	8
Secondary	16
Collegial	48
University	28
Municipalities	
Chénéville	1
Duhamel	8
Lac-Simon	5
Lochaber	2
Notre-Dame-de-la-Paix	1
Papineauville	8
Ripon	17
St-André-Avellin	58

The survey was advertised on the Facebook page of OBVRPNS, as well as on the participating municipalities' websites. In addition, three local newspapers ("La Petite-Nation", "Journal les 2 Vallées", and "Le Droit") participated in the campaign by publishing an article highlighting the project and inviting citizens to participate in the survey (Figure 5).

Figure 5. Survey advertisement in the newspaper journal "Les 2 Vallées" published on 16 October 2019.

According to the executive director of OBVRPNS, "If the population responds in sufficient numbers, this citizen perception survey will be an excellent tool to guide the next necessary actions and make the Petite Nation community more resilient to extreme weather events related to climate change".

The survey questionnaire was designed based on the dimensions and factors of disaster risk perception, as well as the concepts related to community resilience. Public perception of flood risk was structured around six different components (Figure 6):

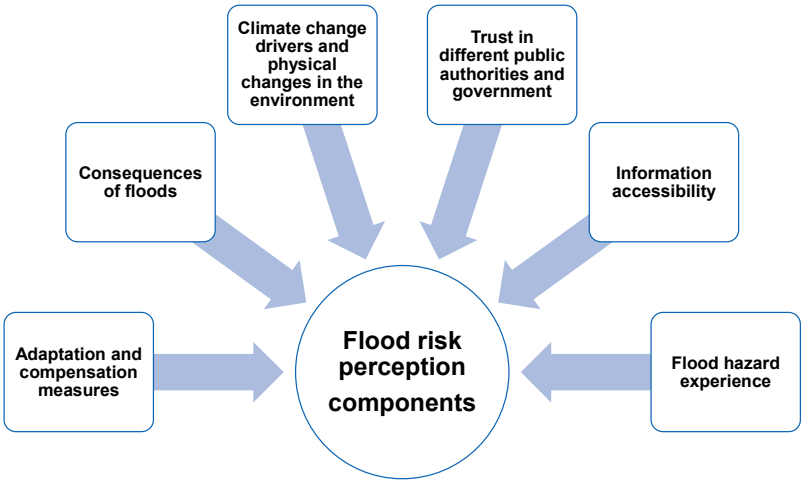

Figure 6. Diagram of flood risk perception components.

Project description and general information: The first part of this survey included the description and objective of the questionnaire, the profile of each respondent (e.g., address, age, gender), and the location of the house in relation to the area affected by floods.

1. Knowledge and flood hazard experience: This item aimed to determine the location of residence in flood zone and the number of times that the residence had been flooded. It also delt with the experience and number of floods experienced by the respondent.
2. Perceived information accessibility: This aspect was defined as a combination of the type and quantity of information, as well as how that information was organized to be accessible to participants. Information organization can be represented through several categories established by the government of Quebec: (1) flood emergency plans; (2) disaster assistance programs; (3) Quebec floodplain maps; (4) good practices to be adopted during flooding events (Red Cross). The respondents were asked to indicate whether this information was accessible, understandable, and relevant for their own situation. These questions were answered using a scale covering:
   - Understanding: "difficult to understand", "understandable", "easy to understand";
   - Accessibility: "not accessible", "accessible", "very accessible".

   This approach made it possible to assess whether the participants' perceptions in terms of access and clarity of this information were favorable or not.
3. Trust in different public authorities and government: Flood risk management is a shared responsibility across different levels of government, depending on the service required. Therefore, trust in public governance was first assessed through different public authorities, given that they each has specific responsibilities related to flood risk management for different public authorities: (1) provincial government; (2) Provincial Ministry of Public Safety; (3) Provincial Ministry of Transport; (4) municipalities, (5) MRC (Regional County Municipality); (6) fire department; (7) Quebec's Provincial Police (Quebec Surete); (8) Canadian Armed Forces (CAF). Each public authority plays a specific role in flood risk management. Complementarily, we checked the respondents' perceptions of the special intervention zone (ZIS), instituted by decree

in June 2019 by the Provincial Government of Quebec, to promote better management of flood-prone areas. This decree resulted in a moratorium on the construction and reconstruction of buildings located in all 0–20-year flood recurrence zones, as well as in the flooded areas from 2017 and 2019. In total, 813 municipalities were covered by the ZIS. Of these, 312 were affected by the major floods in 2017 and 2019.

4. Perception of climate change drivers and physical changes in the environment: Climate change has become a major issue for many communities in Quebec. In this study area, climate change projections are supported by the study presented in [49] and by the Hydroclimatic Atlas of Southern Quebec [50]. The main climate change projections are summarized in Table 3. To better assess the level of participants' perceptions of climate change, the respondents were asked to rank the following events according to their level of concern. Six climate hazards were selected in this survey: more frequent heat waves, ice storms, tornadoes, floods, heavy rain, and fires. Each event was rated on a scale from 1 to 7, where "7" meant "no concern at all" and "1" indicated the highest level of concern. In addition, the respondents were asked if they observed any physical changes in their environment since they have lived there.
5. Perception about the consequences of floods: Floods have large consequences for the economy, society, and the environment. In this survey, the respondents were asked about five consequences: (1) loss of physical assets; (2) decrease in the value of real estate (property); (3) problems selling their property; (4) health risk and mental problems (the latter can be caused by stress, depression, and anxiety); (5) insurance.
6. Adaptation and compensation measures: Risk perception plays a critical role in how individual choose to mitigate the risk [51]. In order to measure the perception of respondents for adaptation measures, different options were selected: (1) installation of dams and dikes; (2) works in watercourses; (3) land use changes and regulatory policies; (4) government buyout of flood-prone lands; (5) wetland protection; (6) sandbags.

Table 3. Projected climate hazards in southern Quebec.

Climate Hazard	Projections
Precipitation	Significant increases in "heavy and extreme" precipitation throughout Quebec. Projected precipitation changes vary according to seasons and regions. However, climate models throughout Quebec show increases in total precipitation during winter and spring, as well as summer and fall increases in the northern and central regions. The range of values for the expected changes for southern Quebec and the Gulf of St. Lawrence in summer and fall varies between slight decreases and increases.
River flow	In southern Quebec, we expect a decrease in average flows for most rivers in summer, spring and fall (moderate consensus).
Droughts	For southern Quebec, observations show a slight downward trend of meteorological drought indicators (events of consecutive days without precipitation). Longer periods without rainfall in summer.
Storms	It is not yet possible to make projections for lightning and freezing rain with the current state of knowledge on these phenomena. With regards to thunderstorms, a few preliminary studies indicate that an increase in the frequency and intensity of thunderstorm is to be expected the closer we get to the year 2100 (without being able to establish a significant level of certainty for these projections)
Winds	Reduction in winds in summer and weak increase in winds in winter, but this remains to be validated.
Fires	Increasing in the coming decades due to warmer temperatures and longer fire periods.

The adaptation measures were selected based on their technical relevance to flood risk management in the catchment area. Each measure is defined by its characteristics and its effectiveness and varies by way of the inputs required, such as the effort and materials needed, the investment required, and the potential efficacy in dealing with the risk of flood damage. In addition, these measures can be classified as structural (hard) or not structural (soft). Structural measures include any physical construction undertake to reduce or avoid possible impacts of hazards, while non-structural measures (such as monitoring and early warning systems) are measures not involving physical construction, which use knowledge, practices, or agreements to reduce disaster risk.

"Land use changes and regulatory policies" are increasingly used to adapt to flood hazards by provincial governments in Canada. Land use planning involves rules attached to building permits that impose construction requirements meant to minimize flood risk, and also legal restrictions on the location, type, scale, and density of development in flood risk areas. "Government buyout" is considered as another beneficial measure to alleviate the damages caused by floods. Most states and governments use the terms ''buyout" and ''acquisition" to describe a set of actions whereby a government purchases a property from a willing seller, demolishes existing structures on the property, prohibits future development, and allows the property to naturally revert to open space. Finally, "sandbagging" is a flood prevention technique that has been around for centuries. This measure consists of building a barrier with sandbags to help divert and stop water from getting inside vulnerable doors and around foundations.

4. Results

In this section, we examine how respondents perceive and interpret flood risks. This includes respondents' understandings of flood hazard experience, climate change, and the perceived accessibility information. It also includes respondents' trust in public authorities, as well as their opinions about flood adaptation measures and consequences.

4.1. Knowledge and Flood Hazard Experience

In order to understand the knowledge and flood hazard experience, each resident was were asked to indicate whether their residence was located in the flood zone or if they had been flooded in the last 10 years. They could also indicate if they did not know whether their area was a flood zone or if they had been flooded. The results are shown in Figure 7.

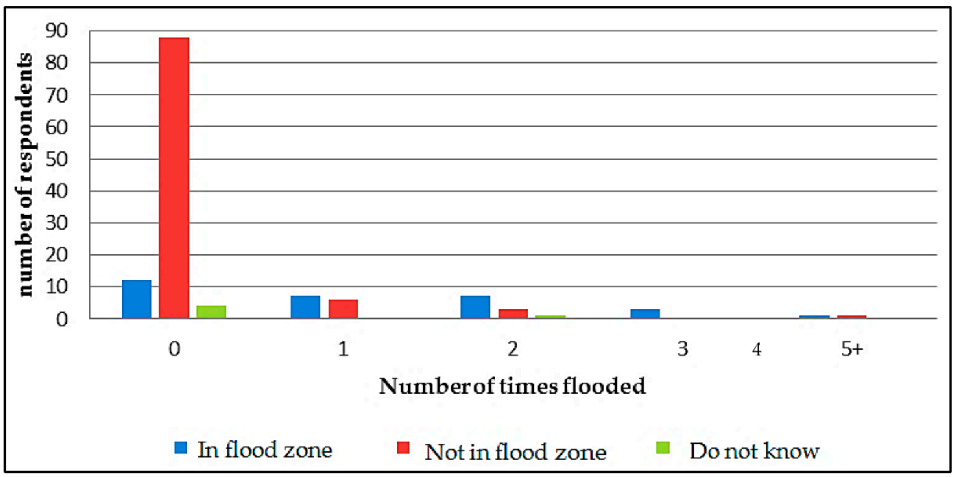

Figure 7. Respondents' perceptions of whether their community is located in a flood zone.

Amongst 130 responses received, only 31 of residents believed that they lived in a flood zone, while 20 of those indicated that they had experienced at least one flood on their property in their lifetime. Although the majority of respondents (97 participants) declared that they were not in a flood zone and had never been flooded, 10 of them had experienced

one or more floods since acquiring their home. In contrast, 11 respondents who considered their residence to be in a flood zone said that they had never been flooded (never or rarely experienced any flooding).

4.2. Perceived Information Accessibility

To assess the perceived accessibility and understanding of information sources (see Section 3.3), respondents were asked to indicate whether the specific information about the flood-related item was understandable and accessible to them.

The results indicate that most respondents (70%) considered that the information they obtain from "flood emergency plans", "disaster assistance programs", "flood maps", and "good practice guides" is understandable, ranging from "understandable" to "easy to understand". However, some respondents (20%) consider the information incomprehensible and difficult to understand. Overall, it is important for policy makers to consider these factors in order to improve the quality of emergency planning in flood-prone areas.

Regarding the perceived accessibility of the flood information, more than half of the respondents (>50%) consider that it is readily available. Overall, the survey found that all flooding-related information is readily accessible. Information from "flood maps" was considered the most accessible by respondents, especially for those who have experienced flooding in these specific areas, while the "good practices guides" were considered the least accessible.

Through the analysis of the survey responses, the perception of the accessibility of information was correlated with the reality of whether or not they had experienced flooding. This made it possible to assess whether the information is accessible to the most targeted audience, as it is difficult to assess the relevance of the information for those who never had to consult it.

The majority of those who had been flooded or knew someone whose home was flooded considered it useful to help them understand what had happened to their home and to support them in deciding how to proceed.

The respondents also indicated that they rely on other important sources of information during flood assistance, e.g., media, newspapers, TV, and social networks (Facebook, Twitter). Media plays an important role in shaping public risk perception by providing quick and easy access to information on the impacts and risk management priorities, amplifying the perceived vulnerability to future events, while mutual aid among neighbors was also frequently mentioned.

4.3. Trust in Different Public Authorities and Government

Trusting public authorities and government can be an important component of people's perception and use of information about risks. In this survey, respondents were asked about their trust in different public authorities, as detailed in Section 3.3. The results are shown in Table 4 and Figure 8.

The results suggest that the level of trust in different institutions is linked to the type of flood management service provided. Authorities that act in the field and directly interact with the population (fire department, police, army) clearly attracted the highest confidence level (>50% of high to very high confidence) from the survey participants. Municipalities were close behind however (44%), as they are the familiar faces and local leaders. Furthermore, their role in flood management extends to both before and after the flood event. The government authorities for public safety and transport both play important roles in coordination, support, and intervention during a flood event. However, as they interact more with the municipalities than with the general population, they are perceived with a more moderate confidence level (>60% or moderate to high confidence level). The regional planning authority and the "global" provincial government are probably more associated with laws, land planning regulations, and financial reclamations, which are not necessarily popular subjects, resulting in their lower confidence level (>60% or moderate to low confidence level).

Table 4. Trust levels for public authorities.

Public Authorities	Very High Confidence Level	High Confidence Level	Medium Confidence Level	Low Confidence Level	Very Low Confidence Level
Provincial government	2%	17%	39%	23%	10%
Ministry of Public Safety	4%	31%	39%	14%	6%
Ministry of Transport	3%	16%	44%	17%	12%
Municipality	15%	29%	33%	14%	5%
MRC	6%	15%	41%	20%	7%
Fire Department	25%	37%	18%	10%	1%
Quebec Surete (Police)	19%	34%	27%	10%	2%
Canadian Armed Forces	16%	34%	23%	12%	5%

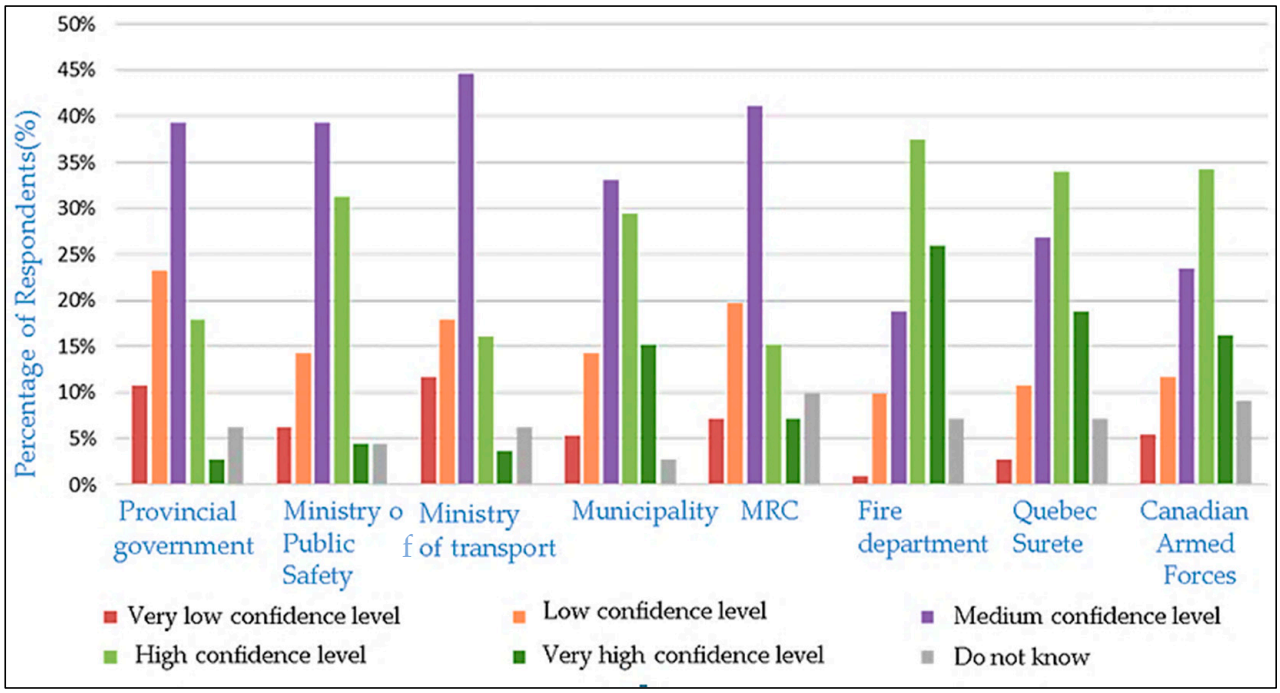

Figure 8. Trust respondents for public authorities.

The CAF are involved in flood-related emergencies on an ongoing basis. They provide flood assistance when required by the federal government such filling sandbags, transporting affected citizens, maritime patrols, and building dikes. In addition, the armed forces can provide the installation of shelters for civilians, the distribution of provisions, then repair of broken pumps, and the use of search and rescue equipment. During the 2017 floods in southern Quebec, a total of approximately 1650 CAF members were deployed to support citizens in the four affected regions and to help with coordination efforts.

In addition, fire departments have always rescued people during floods and will continue to do so; however, such services need to be properly resourced, with sufficient staff to deal with more frequent flooding and the best equipment to deal with the hazards. The Quebec's Police are also involved in coordinating emergency services in the event of flooding. They will help people to evacuate buildings and take full control of the situation. The respondents were also asked about their knowledge on the measures taken by the government of Quebec during the 2019 floods. As shown in Figure 9, most respondents (55%) agreed with the measures and 20% disagreed. The others did not know. The main

concern stemmed from the fact that these measures applied only to the main residences, so that many respondents whose secondary residence was flooded were left out, which induced a certain amount of distress among these residents. Many also wanted their situation to be evaluated on a case-by-case basis rather than through a systematic method proposed by the government, as this excluded from the process many residents living in special situations. Others felt that this measure was going to be detrimental to them, as it impacted on potential changes to their property.

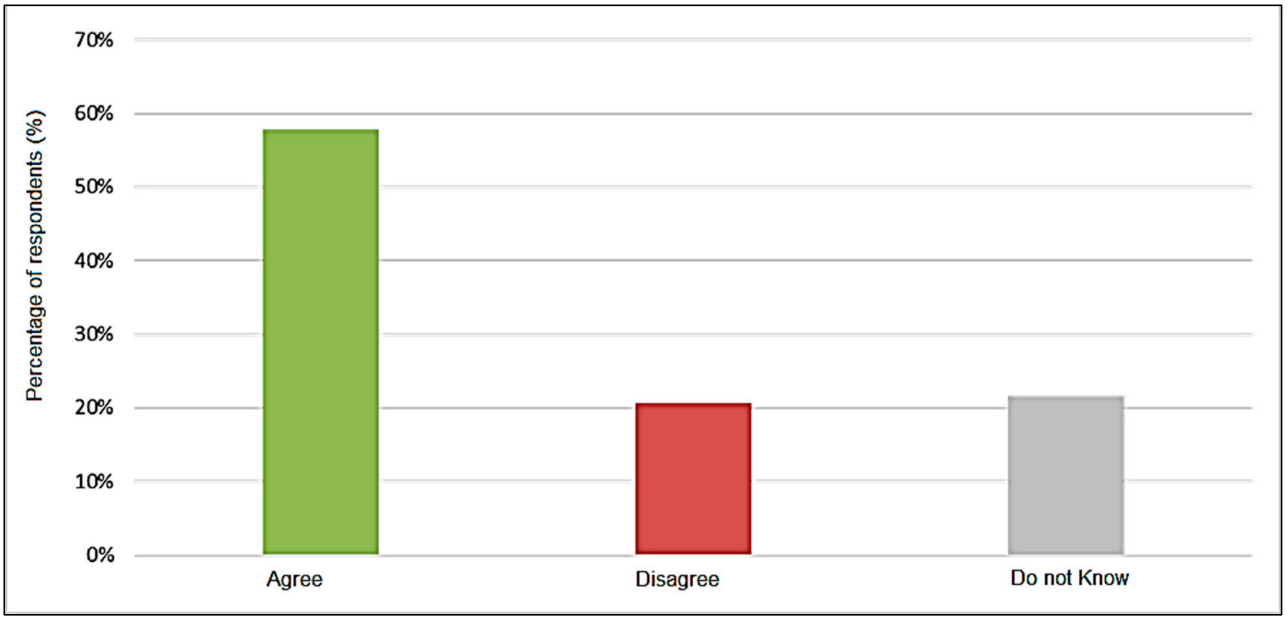

Figure 9. Opinions about the measures taken by the provincial government in 2019.

4.4. Perception of Climate Change Drivers and Physical Changes in the Environment

In this analysis, the majority of respondents (60%) ranked the impacts of weather conditions such as intense winds, stronger winds, more frequent ice storms, less snow, warmer winters, and drier and wetter summers as the most important adverse effects of climate change (drivers of climate change), while they were less worried by heavy precipitation. This may be due to increased exposure to media coverage of floods during the recent floods of 2017 (e.g., TV networks, radio news). The lowest levels of concern were reported for the fires that resulted from warmer summer temperatures and drought conditions. The low perception of respondents towards fires can be explained by the fact that fire represents a low risk for most Quebec residents compared to others frequents natural hazards such as floods. In addition, most respondents perceived that these physical changes are associated with climate change, indicating that there is a certain public perception about physical changes that could be attributed to climate change.

Other respondents particularly highlighted that changes occurred on their property in recent years, such as shoreline erosion. Many respondents are nowadays aware of this problem or of the effects it could have on their property. Shoreline erosion is associated with higher levels of sedimentation due to increased stormwater runoff generated by urbanization, which in turn contributes to frequent flooding, as well as to lower water levels in summer and higher water levels in spring.

In addition, several respondents raised concerns related to the management of the Barrière Lake dam located in the upstream municipality of Lac-Simon. Some residents believe that the current management of the dam is different from previous years, leading to problems during spring floods and low summer flows.

4.5. Perceptions of Adaptation and Compensation Measures

In this survey, a series of six adaptation measures were presented to respondents to assess whether these measures were perceived as relevant or not. The main results are illustrated in Figure 10 and Table 5.

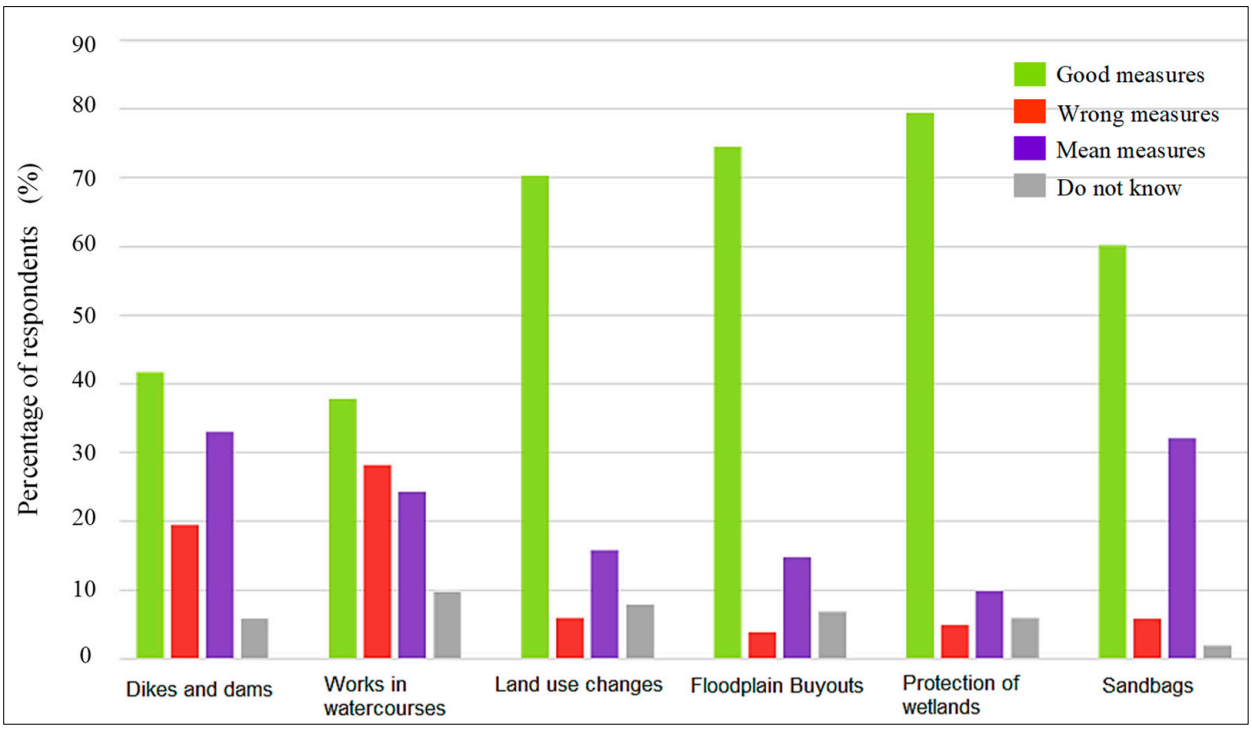

Figure 10. Respondents' perceptions of adaptation measures.

Table 5. Respondents' perceptions of adaptation measures.

Adaptation Measure	Good Measure	Wrong Measure	Mean Measure
Dikes and dams	42%	19%	32%
Work in watercourses	38%	28%	22%
Changes to land use planning and regulations	70%	5%	15%
Government buyout of floodplain land	75%	3%	13%
Protection of wetlands	80%	4%	10%
Sandbags	60%	4.5%	31%

The three measures with the highest relevance (>70%) are all non-structural measures ("land use changes and regulatory policies", "government buyout of flood-prone lands", "protection of wetlands"), which is a good indicator of the level of awareness of the population regarding flood risk. The structural measures taken to modify or control the flow are the least popular. Using sandbags is perceived as a good structural measure, although as it is a temporary measure it gets rather mixed reviews. In Quebec and during the 2017 flood event, residents used sandbags, pumps, and generators to reduce damage to their homes (Figure 11).

With respect to these findings, the Quebec Ministry of Public Safety decreed changes to the general financial assistance for actual or imminent disasters on April 2015. The new iteration of this program includes, for the first time, funding for the relocation or buyout of damaged properties.

Figure 11. Sandbags placed around homes to prevent flooding in Saint-André-Avellin in 2017.

4.6. Perceptions of the Consequences of Floods

The respondents were asked about their concern regarding six potential consequences of floods: (1) loss of physical assets; (2) decrease in the value of property; (3) problems selling their property; (4) insurance; (5) damage to the land; (6) health risk and mental problems. The results are shown in Figure 12 and Table 6.

Surprisingly, the loss of physical assets was of lower concern for the respondents, even if it is probably the more frequent and short-term consequence of a flood. However, the long-term consequences seemed to be of a greater concern, as property values, problems with selling a house, and insurance premiums rated high. A house located near a river might be attractive, but not if it is frequently flooded. The risk posed to the land itself or to the health of the respondents seemed to be of a lower concern, although the stress caused by these events was increased several times in the comments. Flooding was indicated to have had negative physical and mental health impacts on members of households. The health effects observed during and after floods include injuries, infections, mental health problems, psychological distress, and depression. Little is known about the perceptions of these vulnerable households to the flood risks and health impacts.

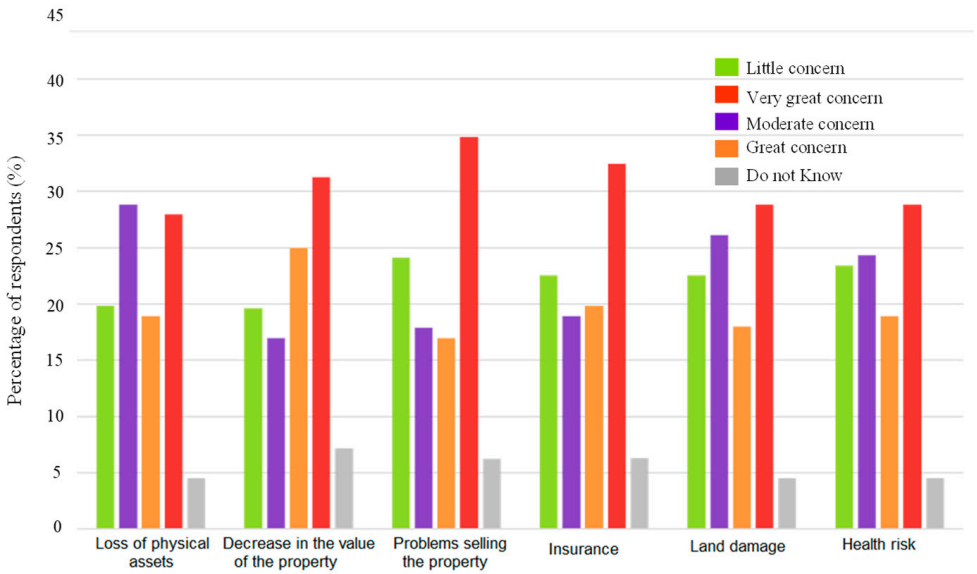

Figure 12. Respondents' perceptions of flood consequences.

Table 6. Respondents' perceptions of flood consequences.

Type of Consequences	Very Great Concern	Very Concern	Moderate Concern	Little Concern
Loss of physical assets	27%	19%	29%	20%
Decrease value of the property	31%	25%	16%	19%
Problems selling the property	35%	16%	17%	24%
Insurance	32%	20%	18%	22%
Damage to the land	29%	17%	26%	22%
Health risk	29%	18%	24%	23%

5. Discussion

The purpose of this study was to improve the understanding of citizens' perceptions with regards to flood risk and management through a survey questionnaire. Several aspects of flood risk were analyzed.

First, flood hazard experience is considered as an important determinant for flood risk perception. Flood hazard experiences were perceived differently by each group of respondents living or not living in a flood zone. Thus, flood hazard information is associated with knowledge about historical flooding, and is not only related to a single flood event, but rather to a series of events over time. Previous studies have also found that people with flood experience had more knowledge and a better understanding of historical flooding [52]. However, future studies would likely need to be conducted in order to better understand the relation between individuals' flood hazard experiences and their perceptions of risk, such as classifying different levels of floods hazard, including households who have never experienced flooding (low flood hazard household) or households who have experienced multiple floods (high flood hazard household). Furthermore, in future research it would be worth investigating the differences between rural and urban communities' perceptions of flood hazards.

Second, perceived information accessibility stood out as an important element in our survey. Information was generally considered as highly available, understandable, and relevant, and had a positive and significant effect on the perception of access. Although availability, comprehensibility, and relevancy were positively associated with access, the impact of availability and comprehension on access seems more important. This information appears to be well spread and widely available. However, there are some difficulties in understanding and finding useful information, especially during emergencies, when there is an urgent need for advice. However, the results show that citizens may require further information to make better use of the previous information provided. At the same time, there is also room for improvement in terms of providing citizens with information on flood risk reduction programs. In addition, another important element cited in the perceived accessibility section is the accessibility of flood zones or maps. In Canada, the perception of flood hazard maps is a major reason for this gap. However, no recent studies have evaluated how people perceive these maps. In Quebec, the flood hazard maps are outdated and fragmented [53]. The perception of flood hazard maps depends on various factors such as communication and understanding of the map, its contents, the way people interpret the contents of the map, and how it is presented.

Third, our results indicate that trust in public authorities is significantly associated with risk perceptions. These findings are consistent with other studies and provide evidence of the positive association between trust in public authorities and risk taking [54–56]. The belief that risk management actions by government can be trusted to reduce future risks offers people a measure of near- and long-term security, which in turn is reflected in their perceptions of risk. Flood warnings and response coordinated through emergency management plans and implemented by local authorities are recognized as an important strength of the Canadian flood risk management approach. Local emergency management responders, such as fire departments, police, and paramedics, are an integral part of emergency preparedness decisions and deployment, aiding in the effectiveness of evacuation.

Our results also show that the majority of respondents found that political entities (government of Quebec) actively sought to create a sense of security, and in doing so diminished the risk perception by presenting a set of measures. Overall, these results suggest the importance of building a good communication strategy between local government institutions that deal with flood risk management and residents in order to improve flood risk perceptions and to reduce flood vulnerability among flood victims. However, there is a need for further research to evaluate how the level of trust in public authorities impacts the level of citizen participation.

Fourth, our results suggest that perception of climate change makes a contribution to the need to understand the local community's knowledge of the future. Most respondents indicated perceptions of increased drivers of climate change, such as wind and storms. In addition, they indicated that these changes are linked to climate change. As shown in the Hydroclimatic Atlas of Southern Quebec, the communities in the Petite Nation watershed and in southern Quebec are becoming increasingly vulnerable to hazards posed by a changing climate. Moreover, the effects of climate change in the Petite Nation are expected to increase the frequency of heavy snowpack, more rapid warming during the transition from winter to spring, and heavier rain during this same time period, as well as decreased in average waterflows in summer, spring, and fall [57].

Fifth, adaptation measures are of important significance when it comes to explaining flood risk perceptions. In this study, we observed significant responses across a set of structural and non-structural measures. Strategies are evolving towards the use of more non-structural measures compared to structural measures, such as "land use changes and regulatory policies" and "government buyout". Due in part to the enormous cost of building and maintaining flood control works, Canada's provincial governments are increasingly embracing non-structural measures such as land use regulation. Moreover, the experience with riverine flooding, particularly in the United States, has demonstrated that structural adjustments such as dams and dykes have not reduced the total annual flood damages [58]. However, non-structural adjustments, such as sandbagging, are considered less attractive for low-lying and vulnerable polders, as these measures are less secure and the consequences of failure are very severe. In Quebec, reflection is needed in terms of taking proper and proactive adaptation measures in order to reduce the flood risk, such as strengthening green infrastructure. Green infrastructure can be defined as a type of land use consisting of a network of natural areas and open spaces that optimizes biodiversity and the protection of natural spaces, which will then generate other environmental and social benefits (such as reducing heat islands, improving air quality, enhancing recreational activities). For example, in urban areas such as the Greater Montreal Area, "green infrastructure" projects are being put in place to reduce the impacts of flash flood events and to keep water in place rather than evacuating it as quickly as possible [59].

Sixth, when respondents were asked to elaborate on flood consequences, health risks related to mental problems came up repeatedly. Previous studies have shown that risk characteristics such as the perception of loss from floods were important attributes for laypeople's judgments of risks [60]. In the Petite Nation watershed, the residents experienced immediate stress during the 2017 flood event, but after several months this stress was still present in their lives. Several factors can explain this stress reaction, including a negative perception of events perceived as traumatic, a history of similar disasters, the fact that they live close to a river or lake, a lack of preparedness for extreme events, and fear of not receiving adequate compensation for losses. In addition, the 2017 flood event was perceived as having a severe impact on people's daily activities. This is especially true in the Petite Nation basin, where the majority of individuals work outside their municipality and have no way of accessing their property during the day. The anticipation of future floods and fear of not being compensated for their loss were among the key elements that stood out. Some residents were still caught in a precarious living situation several months after the spring floods, which can greatly impact the resilience of the community and affect the psychological state of residents. Another important element to mention is the decrease

in leisure activities of the disaster victims. Leisure time is an important factor for health and well-being, and it has been shown that a lack of leisure time leads to depression and other negative psychological consequences. Reductions in such activities could weaken the mental health of disaster victims. Valois et al. [61] indicated an increase in self-reported physical and mental health issues related to past flooding events, as well as a larger proportion of people having consulted a health professional because of these problems. Another point that was raised by respondents regarding perceptions of the floods consequences was insurance. Flood insurance in Canada was introduced for the first time in 2016 to reduce the pressure on government programs. This new policy is intended to provide a better framework for managing and financing the risks of flooding. Since flood insurance is voluntary and not regulated and companies can choose their own policy design, most offer an optional endorsement limited to overland flooding or a bundled product that includes sewer backup. This marked a significant shift in Canada's approach to flood risk management (FRM) by introducing a risk-based flood recovery mechanism. Canada's insurance industry has been proactively engaging with the government to address gaps in coverage and affordability, but more work is necessary to ensure that flood policies and services are effective, affordable, and appropriate across all regions and communities in Canada.

The results of this research were obtained from a small group in the Petite Nation watershed (n = 130), despite the efforts and publicity campaigns made to communicate and publish the survey on social networks (such as Facebook), as well as in local newspapers in the study area. In addition, the survey was limited to a few municipalities in the study area. Therefore, the responses to this survey are not representative and clearly cannot be generalized to the entire study area. This confirms the need for in-depth surveys with a much larger sample size in order to conduct in-depth statistical analyses using a more effective flood communication approach and effective information campaigns involving authorities, the media, local communities, and other agencies, so as to raise awareness of flood risks and climate change.

Big data technologies can be used to assess the perception of risk in the population and stimulate preparedness measures such as the purchase of insurance policies to compensate for losses [62]. This could be achieved by analyzing data coming from various sources, such as social media (Facebook, Twitter), machine learning, crowdsourcing, sensors, and disaster organizations within a country, using big data technologies. By analyzing these sources, one could identify communities where individuals have been affected by a natural catastrophe, as well as information on where they live and their age, sex, income, education level, and health status. The use of these data could also allow an understanding of the different behaviors of individuals. By collecting information from different types of sensors, one could also find out where people are located, for instance by using GPS. In addition, social networks can be used to detect social movements before an event occurs. They can help detect whether an individual is living or working in a disaster area and to initiate appropriate actions, such as alerting, evacuating, or sheltering. Finally, these types of technologies could also be used to analyze and predict how disasters could affect people. A great example is that of FEMA (Federal Emergency Management Agency), which uses data analytics to anticipate disasters and adapt their responses. However, this approach requires high data volumes, which are not always available from the public or private sector.

The Petite Nation flood in 2017 was followed by another major flood in the city, which occurred in 2019. Much of the discussion in the news and popular media in the weeks and months following the 2019 floods emphasized that because of climatic change, the probability of future floods of a similar scale was very high; add to this the magnitude of the resulting damages—over $6 billion in damages as we note above—and it becomes difficult to imagine that these factors would supersede demographic characteristics that might otherwise lead to relatively small differences in perceived risk. For the 2019 spring flood, $127 million was paid out in compensation in Quebec according to the Insurance Bureau of Canada, and more than 10,000 people had to leave their homes. Considering the

significant but necessary investments following the events, it is necessary to reflect on the measures to be taken before these disasters occur. Some countries, such as the Netherlands, have rethought their approach to rivers. Their "room for river" programs aim to redevelop a part of the territory in order to give back space to the rivers and to reduce the flooding of infrastructure. In Quebec, various measures have already been proposed and implemented.

6. Conclusions

Community perceptions and understandings of flood risk in the Petite Nation watershed were investigated through a survey of the flood zone inhabitants (130 respondents). The survey contained questions on six aspects related to flood risk management: flood hazard experience, environmental and climate changes, information accessibility, flood risk governance, adaptation measures, and flood consequences. The results of the survey show the following principal observations and perceptions:

- The knowledge of being (or not) in the flood zone is unclear;
- Consequences of climate change on floods are unclear;
- Information about flood risk management is available and generally understandable;
- The level of trust is good towards most authorities involved in flood risk management but higher for field respondents;
- Non-structural adaptation measures are more relevant;
- Long-term consequences of flood on property values are of highest concern;
- Health consequences are starting to be more of a concern.

This study can serve to improve decision making during risk management and enhance community resilience to floods. To better understand how flood risk is perceived in different contexts, further research should take into account more than just significant indicators—it should also take into account multiple dimensions of flood risk perception (e.g., perceived likelihood of occurrence, response knowledge, education, perceived insurance coverage, social environment, perceived probability, perceived damage).

Based on the results of this study, policy makers could implement certain actions in order to increase the flood risk awareness of the population of the Petite Nation watershed. Ideally, each inhabitant should know whether they live in a flood zone or not and what the probability is of being flooded. Small municipalities rarely have the technical resources to develop such an application. However, some work could be done jointly with the regional government or the watershed authority. Otherwise, certain commercial applications, often with insurance companies, are also available to provide this kind of information for each household. A municipality could inform its population of this possibility.

Although the majority of respondents considered the information relating to emergency planning in flood-prone areas to be generally available and accessible, there was still a significant percentage for whom this was not accessible. Policy makers should work on improving these aspects. It has also been noted that people often get their information through traditional and social media during a flood event. A municipality could organize public workshops each winter to improve their preparedness by communicating and explaining the different resources available for individual risk management approaches. These types of sessions could also cover climate change impacts and different kinds of climate risks, as well as information on the impact of floods on property values. To increase the number of people that are better prepared to face flood workshops, should be held yearly and backed up by a communication strategy. A survey like the one used in this study could also be done every year to monitor the evolution of the level of awareness and preparedness of the population and to constantly adapt the policy maker's strategy.

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