The Impacts of Flooding Events on Mental Health in New Brunswick

Sandra Magalhaes, PhD
Haylie Simmons, BSc
Jillian Cameron, MSc

Adele Lundy, MPH
Simon Youssef, MB BCh, MPH
Ali Beykzadeh, MSc

Project Title

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Principal Investigator

Sandra Magalhaes, Research Associate, NB-IRDT

Research Team

Adele Lundy, Senior Environmental Epidemiologist, GNB
Simon Youssef, Data Analyst, NB-IRDT
Haylie Simmons, Research Assistant, NB-IRDT
Jillian Cameron, Data Analyst, NB-IRDT
Ali Beykzadeh, Data Analyst, NB-IRDT

Publication Date

September 2023

Acknowledgements

This study was prepared by the New Brunswick Institute for Research, Data and Training for the New Brunswick Department of Environment and Local Government (DELG), Government of New Brunswick.

This project was supported with funding from New Brunswick's Climate Change Fund. The Climate Change Fund supports climate change initiatives related to greenhouse gas reductions, adaptation to current and future climate conditions, or climate change education opportunities, in accordance with the Climate Change Act. This work was also supported by the Maritime SPOR Support Unit (MSSU), which receives financial support from the Canadian Institutes of Health Research (CIHR), the Nova Scotia Department of Health and Wellness, the New Brunswick Department of Health, the Nova Scotia Health Research Foundation (NSHRF), and the New Brunswick Health Research Foundation (NBHRF). The opinions, results and conclusions reported in this paper are those of the authors and are independent from the funding sources. No endorsement by the MSSU or the Climate Change Fund is intended or should be inferred.

Project Data

Research analytic outputs were produced using platform data accessed through the New Brunswick Institute for Research, Data and Training, as well as project-specific data from the New Brunswick Department of Justice and Public Safety provided by the Department of Environment and Local Government, and several open-source data sets available for public use.

How to Cite This Product

Magalhaes, S., Lundy, A., Youssef, S., Simmons, H., Cameron, J., & Beykzadeh, A. (2023). The impacts of flooding on mental health in New Brunswick. Fredericton, NB: New Brunswick Institute for Research, Data and Training.

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Executive Summary

Flooding events are among the most devastating natural disasters – and as a result of climate change, natural disasters such as flooding are expected to occur more frequently and be more severe.

The effects caused by flooding can create a lot of stress and uncertainty. Previous research studies consistently demonstrate negative mental health impacts associated with flooding, such as anxiety, depression, and post-traumatic stress disorder (PTSD) and increases in need for health services. However, the research in this area is limited by lower quality research methodology, including self-selected samples and uncontrolled statistical analyses.

The research study presented in this report describes mental health impacts of flooding. In doing so, it fills an important knowledge gap, as it is among the few studies to use population-based sampling and multivariable regression models in estimating the impacts of flooding and to identify high-risk population sub-groups that are more vulnerable to the impacts of flooding.

The specific objectives of this research are to:

(1) Characterize populations affected by flooding in the province of New Brunswick.

(2) Determine which mental health outcomes are negatively affected by flooding.

(3) Identify high-risk population sub-groups that may be more vulnerable to the mental health impacts of flooding.

A population-based longitudinal cohort study design was established using linked, pseudonymized person-level administrative data available for access through the New Brunswick Institute for Research, Data and Training (NB-IRDT). Seven significant flooding events in New Brunswick were examined: 2005, 2008, 2012, 2014, 2015, 2018, and 2019. Cohort members were defined as **exposed** if they lived in a geographic area identified to have any flooding based on a combination of flood-related data from the Government of Canada and the Government of New Brunswick.

Six mental health outcomes and six alternate outcomes were compared between exposed and unexposed populations. Mental health outcomes include health service use for mental illness and more specifically for mood and/or anxiety disorders, hospitalization for mental illness-related reasons and for post-traumatic stress disorder (PTSD), and physician services for counselling/psychotherapy, as well as death by suicide.

Several alternate outcomes were also examined to provide a fuller understanding of the experiences of the exposed population, including Emergency Department use, hospital service use, school attendance in children, and withdrawal from post-secondary education in youth. Risk factors for mental health and alternate outcomes were also considered in exposed populations, including flood-related, sociodemographic, and health-related characteristics.

Advanced regression modeling techniques were used to compare outcomes during the same time period in an exposed population relative to an unexposed population that was similar with respect to age, sex, socioeconomic status, and pre-flooding mental health.

Highlight of Findings

Health service use for mental illness was the most prevalent (14.2%) mental health outcome and was primarily comprised of health service use for mood and/or anxiety disorder (9.8%). Health service use for mental illness primarily consisted of physician service use, as hospitalization for mental illness was rare (0.8%; 0.07% for PTSD-related hospitalization). Death by suicide was the rarest mental health outcome (1.0 per 10,000 population). About one-third had an Emergency Department visit, and 16.2% of youth withdrew from post-secondary education in the year following the flooding event.

Overall results suggest that flooding is associated with an approximately 10% increased risk of health service use for mental illness, for mood and/anxiety disorders, as well Emergency Department (ED) use and withdrawal from post-secondary education.

Flood-related and sociodemographic characteristics were found to be associated with higher risk of mental health burden following flooding.

Those at higher risk of negative mental health outcomes are those who have less experience with flooding (1 or 2 floods, rather than 3 or more) or have a property damage claim in their area, those in the most and least socioeconomically deprived areas, and children and youth.

Differential impacts on ED use and withdrawal from post-secondary education were also found.

ED use was greater in those who experienced fewer floods or who had a property damage claim in their area, those with a chronic condition, and those who lived in the least socioeconomically deprived areas. For older adults, those who lived alone were also at higher risk of ED use.

Withdrawal from post-secondary education was greatest in youth who experienced more flooding events (3+ floods), who lived with others, or in areas with less ethnocultural diversity.

This study provides a first look into the population-level impacts of major flooding events and identifies population sub-groups who are at greater risk of negative mental health outcomes following flooding. The results support the findings of survey-based studies in this area, which consistently suggest that flooding has negative impacts on mental health. Though, similar to the results of this study, the small number of population-based studies also find smaller impacts on mental health than survey-based studies.

This research study adds to the limited literature on the impact of flooding on health service utilization, including Emergency Department and hospital service use, and on children and youth, with a focus on both health and educational outcomes. Research on older adults is also scarce in the literature.

1. Introduction

1.1 Background

Floods are the most frequent and expensive natural disaster in Canada.[1] Flooding occurs when an overflow of water submerges land that is usually dry, and floods are increasing in frequency and intensity due to climate change.[2] While floods are often primarily associated with the destruction of physical property, they can impact individuals' lives in other ways as well.

Several studies demonstrate negative effects on the mental health of individuals who have been exposed to floods.[3–5] Mental health is a state of mental well-being that enables people to cope with the stresses of life, realize their abilities, learn well and work well, and contribute to their community.[6] Post-traumatic stress disorder (PTSD), anxiety, and depression are suggested to increase during flooding and have been suggested to be elevated up to six years after flooding.[4,7] After natural disasters such as flooding, use of health care services is found to be higher, especially for people with pre-existing mental illness.[8]

Generally, studies on this topic are survey-based and capture the lived experiences of flood-exposed individuals. A pre-post flooding study found that the number of disasters and pre-flooding mental illness are associated with deteriorating quality of life.[9] An Australian study on women's health, which linked health data with national climate data, did not identify negative impacts on general health or on mental health but did find significantly higher perceived stress among those exposed to flooding.[10]

Research using population-based data sources, with control for confounding, is limited to a small number of studies. These studies suggest smaller impacts of flooding on mental health than studies using primary data collection.[5,11] A UK study using administrative data to describe mental health impacts at the population level reports a 1% increase in prescriptions for antidepressant drugs after flood events,[11] while a Canadian study finds no difference in postpartum mental health after flooding.[5,12]

Several aspects of flood events can negatively impact mental health, including evacuation, displacement, damage to property, and isolation. During these events, residents can be evacuated and displaced, and properties and belongings may be damaged. The more severe a flood is, the longer symptoms can be expected to persist after the event.[13,14] While being present during a flood is the number one contributor to elevated levels of PTSD and anxiety,[15] property damage is another key contributor,[16] as well as being a significant stressor. The period of rebuilding after a flood can often be more stressful than the flood itself.[17] Attachment to place and isolation are found to be important factors in the severity of mental health impacts.[18,19] Additionally, stress is found to increase annually during the freshet (i.e., snowmelt) and flood watch period, in anticipation of potential flooding.[7,18]

The focus of flooding and mental health studies has primarily been on adult populations, with a need for more research on children, youth, and older adults.[20] Children and older adults are sub-populations that are suggested to be more negatively affected by climate change.[21] For

example, an increase in suicide or suicidal ideation in children has been observed after floods,[7] and seniors have been shown to have higher rates PTSD after flooding.[22] Therefore, they are a target group of interest as the risk of floods continues to increase. Certain sub-groups of the population may be impacted by floods differently, with more affordable housing often available in flood risk areas causing those with lower income to be more greatly impacted and older individuals less able to respond to floods.[18]

To adapt to the increasing frequency of floods, many governments are actively updating their flood management policies. Evidence on the mental health impacts of previous flooding events can help inform their decision-making and support development of targeted policies aiming to reduce the negative impacts of flooding most effectively within the population. The research evidence presented in this report provides among the most robust evidence on the mental health impact of flooding in the scientific literature and can be used to support these efforts.

1.2 Flooding Events in New Brunswick

This research study focuses on flooding events in the Canadian province of New Brunswick, which has experienced a number of significant flooding events over the last 15 years. Spring floods occur almost every year in New Brunswick, though they fluctuate in severity. During spring thaws, flood water has risen over two meters beyond flood levels in certain areas.[23]

For this study, data for seven spring floods were combined. There were three recent historic floods in the years 2008, 2018, and 2019, and smaller flooding events in the years 2005, 2012, 2014, and 2015. Table 1 provides details about each flooding event, which are described briefly in this section.

In 2012, 2014, and 2015, spring flooding resulted in the declaration of a state of emergency, which caused thousands of people to evacuate and leave their homes.[24] [25,26] In 2018, an evacuation notice affected over 1,900[27] individuals, which resulted in over 1,100 households consisting of 2,458 people registering with the Red Cross.[28] Firefighters made several emergency evacuations, and in 2012 even helicopters were needed to rescue citizens due to meter-high flood levels.[29]

In all the floods examined, there were significant reports of property damage. The highest costs for damages in New Brunswick were incurred in 2018, costing an estimated $75 million.[30] In more recent years, reports of power outages have been documented, and NB Power was required to shut off utilities for extended periods of time to over 200 households due to safety concern with the rising water.[31]

In one year in particular, the flood water was contaminated with sewage, causing the water to be toxic. In two separate years, the flooding became so hazardous that patients had to be evacuated from a local hospital and transported to another nearby hospital.[26,32,33]

Generally, every spring, roads are closed due to flooding. This is especially problematic for the capital city of Fredericton, where the closure of roads and businesses due to rising water levels drastically impacts the economy in the downtown core.[34]

1.3 Study Objectives

Many frightening and traumatizing events are caused by the spring floods in New Brunswick, and, as a result of climate change, such extreme flooding events are predicted to become more frequent. A qualitative study on mental health of New Brunswickers after the 2018 historic flood describes the negative impacts on mental health the people experienced after the floods.[18,35] However, more research is needed to better understand the impact of flooding and to identify populations that may be more vulnerable to negative outcomes and in need of support to help mitigate harms associated with flooding.

The goal of this study is to describe mental health impacts after flooding. The specific objectives are to:

(1) Characterize populations affected by flooding in New Brunswick.

(2) Determine which mental health outcomes are negatively affected by flooding.

(3) Identify high-risk population sub-groups that may be more vulnerable to the mental health impacts of flooding.

2. Methods

2.1 Study Design

This is a population-based longitudinal cohort study in New Brunswick, Canada. The study cohort was established using linked, pseudonymized person-level administrative data available for access through the New Brunswick Institute for Research, Data and Training (NB-IRDT), as well as project-specific data from the Department of Justice and Public Safety (DJPS) obtained directly from the Department of Environment and Local Government (DELG) and several open-source data sets available for public use.

Administrative data were used to define and describe the populations residing in areas impacted by flooding, to quantify selected mental health outcomes, to identify a comparison group not residing in areas impacted by flooding, and to quantify the mental health impacts associated with major flooding events in the average population and in specific population sub-groups.

The cohort study was developed to examine the association between living in a residential area affected by flooding and mental health in the one year following a flooding event. A longitudinal cohort of individuals living in New Brunswick was identified using the Citizen Data obtained from the NB Department of Health.

The Citizen Data includes demographics and residential postal codes for all residents in the province who have a valid provincial health care card. Health care is publicly provided, and thus the Citizen Data has nearly total population coverage. Individuals with active status in the Citizen Data for the entire year prior to and following flooding were included in the cohort. The following groups were excluded because the administrative data in custody do not cover them: individuals in the armed forces, Royal Canadian Mounted Police (RCMP) personnel, individuals incarcerated in federal prisons, and First Nations populations.

Residents are required to update the residential address associated with their provincial health care card when they move to a new residence. Address data at the time of each flood year was used to define flood exposure status. Study cohort members were categorized as exposed or unexposed to flooding, based on residential address.

Mental heath outcomes were defined in the one year following flooding for each cohort member. Rates for each mental health outcome in the exposed populations were compared to rates in the unexposed population while adjusting for important confounding factors.

The study cohort was also categorized according to several flooding, sociodemographic, and health-related characteristics, which were used to profile the exposed population and to explore the differential impacts of flooding on mental health. In comparing differential impacts of exposed and unexposed populations, the independent impacts of flooding and of specific population characteristics can be uniquely estimated.

2.2 Study Variables

2.2.1 Flood Exposure Variables

Two data sets were used to identify geographic areas where flooding occurred:

(1) Open-source data available for download from the Government of Canada (GoC) provided map files for flood years 2005, 2008, 2015, 2018, and 2019.[36]

(2) Government of New Brunswick data from the Department of Environment and Local Government (DELG) provided information on provincial property damage claims for years 2008, 2012, 2014, 2018, and 2019.

The GoC flood maps are created by Natural Resources Canada (NRCan) with satellite images to classify flooded areas using machine learning techniques. ArcGIS Pro was used to layer maps of flood-affected areas on maps with Statistics Canada geography to identify dissemination areas (DAs) located in geographic areas with flooding.

DAs are relatively small geographic units (generally composed of several city blocks in urban areas) and have populations of approximately 400 to 700 people. For each flood year, DAs were defined as flood-affected if they were included in geographic areas with flooding. They were defined as not affected if they were not in geographic areas in New Brunswick affected by flooding. These data were available for five of the seven floods included in this study.

A measure of the amount of the DA flooded was estimated (percentage area flooded). DAs that were completely overlayed with GoC flooded areas were defined as 100% flooded, whereas those not completely flooded were assigned a percentage depending on how much of the DAs' total surface area overlapped with GoC flood maps.

In addition to geographic flooding data, flood-related property damage claims data were obtained directly from the Department of Environment and Local Government (DELG). These data include records indicating reports to the Department of Justice and Public Safety (DJPS) for property damage claims resulting from damages of flooding. These data were available for five of the seven floods and were used to define an exposed population in the flood years that GoC flood map data were not available (2005, 2012, and 2014). These data were also used to derive a variable to define DAs that had a property damage claim due to flooding (residential and other property (business, cottage)). The number of claims per DA was also described.

These area-level variables derived from the GoC and DJPS data were linked to data for each individual cohort member. Residential information from the Citizen Data was used to identified individuals with addresses within flood-affected DAs. Address information from the Citizen Data was recorded using six-digit postal codes. Postal codes for individual addresses at the time of flooding were assigned to a DA using the Statistics Canada PCCF+ program.

Exposed populations were those with addresses geocoded to DAs defined as flood affected. Individuals who were defined as exposed to more than one flood event were identified (one

flood, two floods and three or more floods). A variable was also derived to identify individuals defined as exposed to the 2018 and 2019 floods, as there was severe back-to-back flooding in the same geographic areas in these two flood years.

Unexposed populations were those living in DAs in New Brunswick that were not affected by flooding at the time of flooding.

2.2.2 Mental Health Outcome Variables

Department of Health data sets were used to define selected mental health outcomes in the one year prior to and one year following each flooding event. Six mental health outcomes were defined, including the following:

(1) Health service use for mental illness, generally (defined using Canadian Chronic Disease Surveillance System [CCDSS] data – 1995-2019).

(2) Health service use for mental illness, more specifically for mood and/or anxiety disorders (defined using CCDSS data – 1995-2019).

(3) Hospitalization for mental illness-related reasons (defined using Discharge Abstract Data [DAD] – 1999-2021).

(4) Hospitalization for mental illness-related reasons for post-traumatic stress disorder (PTSD) (defined using DAD – 1999-2021).

(5) Physician service claim for counselling/psychotherapy (defined using NB Physician Billing claims data – 2000-2020).

(6) Suicide (defined using NB Suicide Data – 2012-2019).

Those having records for any of these outcomes were identified, and where possible, the total number of records of each outcome was described. Due to the timing of data transfer from the Department of Health to NB-IRDT, outcome data for 2019 flooding were only available for certain outcomes. Suicide data are only available from 2012 onward and do not include earlier floods.

In addition to these main mental health outcomes, six alternate outcomes were also defined, as they may serve as indicators for poorer mental health. While these outcomes are not specific to mental health, they provide an opportunity, where possible, to get a better sense of the overall health service use experience of the exposed population. Alternate outcomes that were defined include the following:

(1) Emergency Department (ED) use (defined using data from Horizon Health Network using the population in the Fredericton and Saint John health regions only – 2017-2021).

(2) ED use in older adults (defined using data from Horizon Health Network using the population in the Fredericton and Saint John health regions only – 2017-2021).

(3) Hospital service use for physical illness, overall (defined using DAD – 1999-2021).

(4) Hospital service use for physical illness in older adults (defined using DAD – 1999-2021).

(5) School attendance in children (age <16 years; defined using Department of Education and Early Childhood Development (EECD) data – 2018-2021).

(6) Withdrawal of youth from post-secondary education (age 16-24 years; defined using student enrollment data from NB universities – 2004-2020).

Data for alternate outcomes were also limited by time. Both ED and education-related data have only been available more recently and thus only cover more recent floods. Impact on ED use is only for the 2018 and 2019 floods, and school attendance is only for the 2019 flood.

2.2.3 Variables Profiling the Exposed Population and Stratifying Outcomes

This study examines how levels of mental health outcomes differ in relation to selected characteristics to better understand which population sub-groups are at greatest risk of mental health outcomes following flooding. The variables used for these purposes are described in this section, and how they are used in the statistical analysis is described in Section 2.4.

The exposed population was profiled, including a description of flood-related, sociodemographic, and health-related characteristics. Flood-related characteristics were described previously (Section 2.2.1) but include flood year, number of floods, back-to-back flooding in 2018/19, residing in a DA for which a property damage claim was submitted to DJPS, and percent DA flooded.

Sociodemographic characteristics include age (children: 0-15; youth: 16-24; adults: 25-64; older adults: 65+), sex (male, female), marital status (married, single, other), household composition (lives alone or with others), time lived at address (0-5, 5-10, and 10+ years), and recipient of Department of Social Development income assistance.

Area-level socioeconomic measures include community size (<1,000, 1,000 and 29,999, and >30,000 population), the Canadian Index of Multiple Deprivation (CIMD quintiles) and Census variables for median income quintile, precent completed high school, and employment rate. CIMD and Census variables were taken from the census year closest in time to the corresponding flood year. CIMD is a socioeconomic index with four sub-scores that each range from 1 (least deprived) to 5 (most deprived) to quantify area-level social vulnerability, residential instability, economic dependency, and ethnocultural composition using a composite of Census variables.[37]

The health-related characteristics focused on both mental and physical health. The same mental health outcomes that were defined in the year following flowing were also defined in the

year prior to flooding to understand and account for changes over time. Department of Health CCDSS data (1995-2019) and New Brunswick Cancer Registry data (1992-2020) were used to characterize the chronic disease burden, including cancer, diabetes, and a variety of cardiovascular, respiratory, neurological, and musculoskeletal conditions. Two physical health variables were derived using these data: presence of a chronic condition (yes/no) and multimorbidity (none, 1, 2+ chronic conditions). Department of Social Development Long-Term Care program clients are older adults with high functional limitations receiving in-home care or care in community-based housing for activities of daily living.

2.3 Bias

This study addresses bias common in observational research through several methodological approaches. Population-based sampling was used to identify a study cohort. Routinely collected population-based data were used to define exposure based on residential address for all residents of New Brunswick and to define outcomes based on objective data from clinical interactions. A large number of key flood-related, sociodemographic, and health-related variables were used to describe and understand how the exposed population differs from an unexposed population during the same time period. The statistical analyses utilize adjustment for population difference but also for pre-flooding mental health in both exposed and unexposed populations.

2.4 Statistical Analyses

Descriptive statistics are presented as counts, percentages, mean and standard deviation (sd), and median and interquartile range (IQR). Advanced regression modelling techniques were used to estimate the risk of having a mental health outcome in the exposed population relative to a comparison group of a similar population not living in flood-affected areas during flooding events. Mixed effects logistic regression models with adjustment for age, sex, CIMD subscale scores, and pre-flooding mental health, and random effects for DA and for individual were used to derive adjusted relative risk estimates and corresponding 95% confidence intervals.

Interaction terms were used in this regression framework to derive relative estimates comparing mental health outcomes within the exposed population across different levels of the selected flood-related, sociodemographic, and health-related characteristics, and in comparison to the expected risk in a similar unexposed population. These analyses provided important insights into which are the high-risk population sub-groups among the entire exposed population. Interaction terms that were deemed to be significant using $p \leq 0.05$. Adjusted (age, sex, CIMD sub-scores, and pre-flooding mental health) relative risk estimates were calculated for models with significant interaction terms that indicated higher risk due to flooding.

3. Results

Section 3.1 provides a profile of the population defined as exposed to flooding, with a focus on flooding-related, sociodemographic, and health-related characteristics. Section 3.2 presents results on the impacts of flooding on mental health. Section 3.3 follows with results on the impacts of flooding for several alternate outcomes, including Emergency Department use and hospital service use for physical illness, as well as withdrawal from post-secondary education among youth.

3.1 Characteristics of Exposed Population

Table 2 describes the characteristics of the exposed population. For comparison purposes, the same characteristics are provided for the unexposed population. The characteristics profiled include flooding-related, sociodemographic, and physical and mental health-related characteristics.

3.1.1 Flooding-Related Characteristics

There were 353,960 individuals in the exposed population, half of which experienced more than one flood (51.7%), with nearly one-third (30.1%) experiencing three or more floods (maximum seven floods). The 2018 flood included the most individuals (192,186; 26.6%) and the 2012 flood the least (9,242; 1.3%), with the four most recent floods representing 83.2% of the exposed population. The two most recent floods (2018 and 2019) impacted the same areas, and 93.3% of those exposed in 2019 were also exposed in 2018.

Property damage claims data were available for five flood years. More than half of the exposed populations (51.1%) were living in a DA that had a residential property damage claim, and nearly one-third (28.7%) were living in a DA with other types of property damage claims (e.g., business, cottage). The total number of property damage claims varied greatly. Half of the DAs had one claim or no claim, but some areas had very high numbers of property damage claims.

As DAs were used to define the flood-exposed population (i.e., exposed is defined as residing in a DA that had any flooding), the percentage of a DA that was flooded was estimated to assess flooding impact in the exposed population. There were 20,205 individuals (3.6%) who were residing in a DA that had over 75% of its surface area flooded; however, most were residing in areas with less than 25% flooding (82.3%).

3.1.2 Sociodemographic Characteristics

Of those exposed, half were female (50.86%). Adults (25-64 years) represented the highest proportion (55.8%) of the exposed population, with older adults (65+ years; 17.6%), children (<16 years; 16.1%), and youth (16-24 years; 10.5%) comprising smaller proportions. The majority exposed population were married (42.9%) and lived with others (72.7%).

The majority floods occurred in rural communities (62.4%); however, a quarter were in a larger population centre (>30,000 population). Most of the exposed population had address durations of less than five years (48.0%), though more than a quarter were living at the same address for more than ten years.

The areas exposed to flooding were predominantly represented by those with the highest incomes, in the 4th and 5th quintiles (46.5%). The average percentage of the exposed population that had completed high school was 82.5%; and the population also had a 69.0% employment rate. A small proportion was receiving Social Development income assistance (5.3%).

For the Canadian Index for Multiple Deprivation (CIMD) subscales, the exposed population was most represented in the 1st and 2nd quintiles for situational vulnerability, economic dependency, and residential instability, whereas ethnocultural composition was most represented in the higher quintiles.

3.1.3 Physical Health-Related Characteristics

Of the exposed population, 39.5% had a chronic condition (i.e., diabetes, heart failure, COPD, acute myocardial infarction, hypertension, ischemic heart disease, stroke, dementia, asthma, epilepsy, Parkinson's disease, multiple sclerosis, or cancer), with 17.3% having more than one of these conditions.

About 8% of the exposed population had been hospitalized for a physical illness in the year prior to flooding. Among those who were hospitalized, half were hospitalized once, and 25% had two or more hospitalizations. Over 7,500 older adults in the exposed population were clients in the Social Development Long-Term Care program.

3.1.4 Mental Health-Related Characteristics (Prior to Flooding)

Table 3 describes mental health in the one year prior to flooding in both the exposed and unexposed populations. In those exposed, 13.6% had health service use for mental illness (physician or hospital service use), with a large proportion of this health service use (9.5%) for mood and/or anxiety disorders specifically.

Acute hospitalization for mental illness was rare. In the year prior to flooding, 0.7% of those exposed to flooding were acutely hospitalized for mental illness, and a much smaller proportion (0.07%) was acutely hospitalized for PTSD. When hospitalized, the exposed population was hospitalized once, on average, in the year prior to flooding.

A non-specific physician service claim for counselling/psychotherapy from a family doctor or psychiatrist was found in 5.2% of the exposed population. There was substantial overlap between the individuals that had this service claim in the year prior to flooding and those that had health service use more specifically for a mental illness. Among those with a psychotherapy/counselling service claim, half had one claim in the year prior to flooding.

3.1.5 Comparison with the Unexposed Population

The unexposed population represents the general New Brunswick population. Overall, the exposed and unexposed populations were similar in regard to demographic and area-level characteristics, with a comparable distribution for age, sex, marital status, household composition, address duration, community size, completion of high school education, and employment rate. However, there were important differences in socioeconomic characteristics.

Important differences were observed in the distribution of income and the subscales of the CIMD when comparing between the exposed population and the unexposed populations. In general, area-level measures were evenly distributed across quintiles in the unexposed population. However, as described above, the exposed population was better represented by higher income; lower economic dependency, situational vulnerability, and residential instability; and more ethnocultural diversity.

While mental health in the one year before flooding was similar between the exposed and the unexposed populations, in all instances the exposed population had lower rates of mental health records than the unexposed population. This suggests that the exposed population had better mental health, on average, than the unexposed population at the time of flooding.

These are important characteristics to consider when examining impacts of flooding on mental health in the one year post-flooding. Socioeconomic characteristics and pre-flooding mental health were adjusted for in regression analyses, the results of which are described in the next sections.

3.2 Impacts of Flooding on Mental Health

Six mental health outcomes are considered in this section:

(1) Health service use for mental illness, generally.
(2) Health service use, more specifically, for mood and/or anxiety disorders.
(3) Hospitalization for mental illness.
(4) Hospitalization for post-traumatic stress disorder (PTSD).
(5) Family doctor or psychiatrist service claims for counselling/psychotherapy.
(6) Death by suicide.

Overall results suggest that flooding can have a negative impact on mental health.

Based on unadjusted statistical estimates, the exposed populations were found to have lower rates of mental health outcomes in the year following flooding than the general New Brunswick population. However, this difference is due to confounding, as the exposed population was found to have a higher socioeconomic status than the general population.

Adjusted regression model estimates provided the ability to statistically compare the exposed population with a selection of the general population that is more similar with respect to

socioeconomic status. Adjusted statistical estimates suggest that those exposed had higher rates of mental health outcomes, than a similar unexposed population.

Effect sizes for the impact of flooding on mental health were low and suggest that flooding increases the likelihood of health service use for mental illness by 10%. The impact was primarily driven by service use at the physician level, as no significant impacts of flooding were found for acute hospitalization for mental illness.

3.2.1 Unadjusted Estimates

Unadjusted statistical estimates are helpful to understand how mental health outcomes in the exposed population differ from the unexposed population. However, to quantify the specific impacts of flooding on mental health, statistical adjustment is needed (see Section 3.2.2).

Table 4 presents the unadjusted estimates for the percentages of exposed and unexposed populations that experienced mental health outcomes in the one year following flooding. No major differences in the percentage were found for any of the six mental health outcomes. Overall, the unexposed population had slightly higher rates, but this is likely due to differences in socioeconomic characteristics between the exposed and unexposed populations.

3.2.2 Adjusted Estimates

Table 4 presents the results of adjusted regression model estimates for each of the six mental health outcomes examined. The first set of regression model estimates is adjusted for place (e.g., DA), and the second set of regression model estimates is additionally adjusted for age, sex, pre-flooding, and the four subscales of the CIMD.

Following adjustment, those exposed were found to have a 10% higher risk of health service use for mental illness generally, and a 7% higher risk of health service use specifically, for a mood and/or anxiety disorder. They were 8% less likely to be hospitalized for mental illness. While the average estimate suggested the exposed population was also less likely to be hospitalized for PTSD, the 95% confidence interval suggests there may be no impact. There was no increase in likelihood of a service claim for counselling/psychotherapy among the exposed population.

3.3 Impacts of Flooding on Alternate Outcomes

As mental health outcomes may be difficult to capture in administrative data, six alternate outcomes were also examined to better inform on the experience of the exposed population. Emergency Department (ED) use and hospital service use for physical illness (excluding mental illness defined in the previous section) in the one year following flooding were examined in the entire population, and specifically in older adults (65+ years). School absences were described in children (<16 years). Withdrawal from post-secondary education was examined in youth (16-24 years).

Overall results suggest that flooding has a negative impact on ED use overall and specifically in older adults, as well as on withdrawal from post-secondary education in youth.

Based on unadjusted statistical estimates, the exposed populations were found to have lower rates of ED use and of hospital service use, overall and in older adults, than the unexposed population. Meanwhile, in youth, the rate of withdrawal from post-secondary education was higher in the exposed population than the unexposed population.

Adjusted statistical estimates provided evidence that those exposed had higher rates of ED use in the year following flooding; however, they remained less likely to have any hospital service use for physical illness. Effect sizes for the impact of flooding on alternate outcomes were small and suggested that flooding increases the likelihood of ED use by 10% and youth withdrawal from post-secondary education by 8%.

3.3.1 Unadjusted Estimates

Unadjusted statistical estimates are helpful to understand how alternate outcomes in the exposed population differ from the rest of the population that was not exposed. However, to quantify the specific impacts of flooding on alternate outcomes, statistical adjustment is needed (see Section 3.3.2).

Table 4 presents the unadjusted estimates for the percentages of exposed and unexposed populations that experienced the alternate outcomes in the one year following flooding. As with the main mental health outcomes, no major differences were noted between exposed and unexposed populations, though the unexposed populations had poorer outcomes, except for withdrawal from post-secondary education (16.2% in exposed and 15.6% in unexposed).

3.3.2 Adjusted Estimates

Table 4 presents the results of the adjusted regression model estimates. The first set of regression model estimates is adjusted for place (e.g., DA), and the second set of estimates is additionally adjusted for age, sex, and the four subscales of the CIMD. Models for hospital service use were also adjusted for hospital service use in the one year prior to flooding.

ED use was found to be 11% more likely in the exposed population, both overall and in older adults. However, the exposed population was 7% less likely to use hospital services for physical illness in the year following flooding. Exposed youth were found to be 8% more likely than unexposed youth to withdraw from post-secondary education.

3.4 Differential Impacts of Flooding

Sections 3.2 and 3.3 present the mental health impacts of flooding for the average population, whereas in this section impacts specific to sub-populations are explored. These analyses help to better understand the differential impacts of flooding and provide an opportunity to identify high-risk target groups in need of support to mitigate harms from flooding.

Differential impacts were examined for several factors, including:

(1) **Flood-related characteristics**: Number of floods (1, 2, or 3+), back-to-back flooding (2018/19), flood damage.

(2) **Sociodemographic characteristics**: Age, sex, household composition (lives alone or with others), address duration (<5, 5-10, 10+ years), income assistance recipient, Canadian Index of Multiple Deprivation (CIMD) subscales.

(3) **Health-related characteristics**: Pre-flooding mental health, presence of a chronic condition, multimorbidity.

Overall results suggest that flooding has differential negative impacts on mental health. In addition, differential impacts on emergency department (ED) use, hospital service use for physical illness, and withdrawal from post-secondary education were found. Several higher risk sub-populations were identified that were found to be more likely to experience negative outcomes in the one year following flooding.

3.4.1 Mental Health Outcomes

Table 5 presents results showing the differential mental health impacts of flooding in relation to several flood-related, sociodemographic, and health-related characteristics.

Mental health in the year following flooding was differentially impacted by the number of floods, back-to-back flooding exposure, property damage in DA, age, address duration, and all four CIMD subscales (social vulnerability, residential instability, economic dependency, and ethnocultural composition). Those who were most vulnerable to the mental health impacts of flooding included those who were exposed to one flood or to back-to-back flooding in 2018/19; those who lived in an area with a property damage claim; children and youth; and those with a shorter address duration. For CIMD, those in areas with the greatest economic dependency and situational vulnerability, but also those with the least economic dependency and the least ethnocultural diversity, were at higher risk due to flooding.

3.4.2 Alternate Outcomes

Tables 6 to 8 present results showing the differential impacts of flooding on alternate outcomes in relation to several flood-related, sociodemographic, and health-related characteristics.

The alternate outcomes of ED and hospital service use (overall and in older adults) and withdrawal from post-secondary education (in youth) were found to be differentially impacted by several flood-related, sociodemographic, and health-related characteristics.

ED use was differentially impacted by the number of floods, property damage in a DA, presence of a chronic condition, and the CIMD subscales of social vulnerability, residential instability, and economic dependency. Those exposed to one or two floods (but not three or more), who had a property damage claim in their DA, and who had a chronic condition were at higher risk of ED

use. Examining CIMD subscales, those living in areas with the least residential instability, economic dependency and situation vulnerability were at higher risk.

In older adults (65+), ED use following flooding was found to be modified by the number of floods, property damage in a DA, and household composition. When exposed, older adults who were exposed to one or to two floods, who lived in a DA with a property damage claim, and who lived alone were at higher risk of ED use due to flooding.

While hospital service use for physical illness was found to be less likely in the exposed population, specific sub-groups had greater vulnerability due to flooding. This includes age, chronic condition or multimorbidity, and the CIMD subscale for situational vulnerability. Specifically, hospital service use for physical illness was higher in adults (25-64 years) and older adults who were exposed to flooding, and in areas with highest levels of situational vulnerability. Individuals with a chronic condition were at higher risk of hospital service use for physical illness when exposed to flooding, but this was found to be primarily driven by greater risk in those with multimorbidity.

The variables found to differentially impact withdrawal from post-secondary education in youth were the number of floods, household composition, and ethnocultural composition. A higher number of floods (three or more) was associated with a higher risk of withdrawal from post-secondary training following flooding, as was living with others (but not living alone) and living in areas with lower ethnocultural diversity.

3.5 Changes in Mental Health Pre- and Post-Flooding

Table 3 also compares mental health in the one year pre- and post-flooding in the exposed and unexposed populations.

When examining changes over time, increases were noted in health service use for mental illness to a similar extent in both the exposed and unexposed populations. Though, the exposed population had lower rates than the unexposed population for all mental health outcomes in both the pre- and post-flooding periods.

In the one year prior to flooding, 13.6% of the exposed population had a record for health service use for mental illness, which increased to 14.2% in the one year following flooding. The increase was likely due to other types of mental illnesses, as the rate for mood and/or anxiety disorders changed from 9.5% to 9.8% over time. Data on physician health service use for other types of mental illnesses are not available.

Acute hospitalizations for mental illness increased to a lesser extent and represented 0.84% of the exposed population prior to flooding and 0.86% in the year following flooding. Acute hospitalizations for PTSD decreased slightly over time among those exposed to flooding (6.9 per 10,000 to 6.6 per 10,000 population).

Just over half (51.8%) of the exposed population that had a mental health record in the year prior to flooding had a mental health record in the year following flooding. This represents 6.8% of the 13.7% exposed population that had a mental health outcome following flooding. The other 6.9% (of the 13.7%) are individuals who did not have a mental health record in the year prior to flooding. Of the exposed population that had a mental health record in the year prior to flooding, 6.3% had no mental health record in the year following flooding. Meanwhile, 80.0% of the exposed population had no mental health record prior to or following flooding.

While those with a pre-existing mental illness were more likely to have a mental health outcome in the year following flooding, there was no evidence for an interaction between exposure and pre-flooding mental health.

Hospital service use for physical illness was similar over time, with 8.6% of the exposed population hospitalized in the year prior to flooding and 8.7% hospitalized in the year following. In older adults, there was a larger increase over time, though the change was small (19.5% pre-flooding and 20.1% post-flooding).

School absences in children increased over time, as 50.8% of children in the exposed population were absent from school at least once in the year prior to flooding, compared to 52.9% in the year following flooding. While the median days absent (6 days) remained the same pre- and post-flooding, the average days absent increased by half a day (from 8.0 to 8.6 days) in the year post-flooding.

4.0 Discussion

Section 4.1 presents a summary of the key findings of this study, and Section 4.2 follows with a discussion of these findings in the context of the existing scientific literature on impacts of flooding exposure. Section 4.3 presents some of the important strengths and limitations of the research, and Section 4.4 provides concluding remarks and opportunities for additional research to build on the study's results.

4.1 Summary of Findings

A negative impact of flooding was identified in this population-based cohort study. On average, a nearly 10% increase in risk of mental health service use, risk of Emergency Department (ED) use, and risk of withdrawal from post-secondary education were found.

4.1.1 Mental Health Outcomes

Health service use for mental illness was the most prevalent mental health outcome among the exposed population. This includes a visit to a physician or to a hospital due to a diagnosed mental illness. In those exposed, 14.2% had a health service use for mental illness in the year following flooding, which was higher than their health service use in the year prior to flooding (13.6%). However, health service use for mental illness in the general population also increased to a similar extent over time.

When considering an unexposed population that was similar to the exposed population with respect to sociodemographic characteristics and pre-existing mental health, the results show that those exposed had a 9% higher risk of health service use for mental illness in the year following flooding. Nearly 10% of the health service use for mental illness in the exposed population was for mood and/or anxiety disorders specifically. The exposed population was found to have a 7% increased risk of health service use for mood and/or anxiety disorders in the year following flooding, when compared to the unexposed population.

Health service use for mental illness primarily consisted of physician service use, as hospitalization for mental illness-related reasons was rare, representing less than 1% of the exposed population. Hospitalization rates for mental illness were similarly low in the general population and also increased slightly over time. Hospitalization specifically for PTSD was about one-tenth rarer, representing 0.07% of the exposed population. On average, the exposed population that has a hospitalization was only hospitalized once in the year following flooding.

Death by suicide was the rarest mental health outcome. There were 63 deaths by suicide in the year following flooding among the exposed population. The exposed population had a slightly lower rate of death by suicide (1.0 vs. 1.3 per 10,000 population). However, to estimate adjusted risk of death by suicide, it was not feasible to use the regression model framework that was used to estimate the risk of the other mental health outcomes. A different study design is needed.

4.1.2 Alternate Outcomes

In addition to mental health-specific outcomes, several alternate outcomes were examined to better understand the experience of those exposed. Specifically, Emergency Department (ED) use and hospital service use for physical illness were examined in the year following flooding, as were school absences in children and withdrawal from post-secondary education in youth.

Nearly one-third (29.8%) of those exposed visited the ED once in the year following flooding, which was similar to the unexposed population (30.3%). ED use in older adults was higher (32.2%) than in the overall exposed population but lower than in the unexposed population of older adults (32.8%). When comparing more similar populations, those exposed (overall and older adults) had a 10% increased risk of having an ED visit.

Interestingly, hospital service use for physical illness remained less likely in the overall exposed population than in the unexposed population, even after adjustment for key confounders. Results were similar in both the exposed population overall and among older adults. Among those exposed, 8.7% used hospital services for a physical illness, as compared to 9.3% of the unexposed population. After adjustment, the risk of hospital service use for physical illness was 7% lower in the exposed population.

Withdrawal from post-secondary education was examined in youth specifically. Youth represented the smallest proportion of the overall population; however, in examining differential impacts of flooding by age, youth were found to have the highest risk of a mental health outcome in the year following flooding.

In addition to higher rates of mental health outcomes following flooding, exposed youth were also more likely to withdraw from post-secondary education. Of the exposed youth who were registered in a post-secondary institution at the time of flooding, 16.2% withdrew from their program the following September, as compared to 15.6% of unexposed youth. Following statistical adjustment, a 7% increased risk of withdrawal from post-secondary education due to exposure was estimated.

4.1.3 Differential Impacts

Differential impacts of flooding were also expected in relation to key flooding-related, sociodemographic, and health-related characteristics. This approach helped to identify population sub-groups that may be most vulnerable to flooding.

Overall, flooding-related characteristics were consistently associated with higher risk of mental health and alternate outcomes. Those who experienced less flooding (one or two floods) and those with property damage in their DA were found to be at greater risk of mental health service use and ED use.

Differential effects by sociodemographic characteristics differ depending on the outcome. Children and youth were at greater risk of mental health outcomes due to flooding, whereas this was not found in adults or older adults. The opposite was true for hospital service use, as

increased risk due to flooding was found in adults and older adults but not in children and youth. Shorter address duration was found to have important implications for mental health but not the other outcomes. Household composition was also found to have different effects depending on the outcome examined. Older adults who lived alone were more likely to visit the ED, whereas youth who lived with others were more likely to withdraw from post-secondary education.

Socioeconomic status (SES), as measured using the Canadian Index for Multiple Deprivation (CIMD), was found to have important impacts on all outcomes, though different aspects of SES (i.e., CIMD subscales) were associated with higher risk of specific outcomes. Higher risk sub-groups for mental health outcomes were identified for measures of social vulnerability, residential instability, economic dependency, and ethnocultural composition. Overall, higher risk was found in those living in areas defined as most and least deprived.

Social vulnerability was important for mental health, ED use, and hospital service use, but in different ways. Those in more socially vulnerable areas had higher rates of mental health and hospital service use, whereas those in the least vulnerable areas had higher rates of ED use. Results of economic dependency and residential instability also showed different impacts across the range of SES, with both those living in areas with highest and lowest deprivation found to have higher risk of negative mental health and ED use in the year following flooding. For ethnocultural composition, the least diverse areas were found to be at greater risk of mental health outcomes, and youth living in these areas were found to be at greater risk of withdrawal from post-secondary education.

4.2 Discussion of Findings

This research study used a population-based prospective cohort study design, with an unexposed control group, to inform on the mental health impact of flooding at the population level and in specific population sub-groups. This work fills an important gap in the scientific literature, as it is among the first studies to use population-based data to inform on this research question.

The previous research in this area has been primarily done using survey-based cross-sectional study designs, and when prospective designs are used, a control group of unexposed individuals is rarely considered. Without an unexposed population it is impossible to tease out the impact of the flooding from the impacts of other factors.

For instance, in other analyses, many population sub-groups were found to have higher rates of mental health outcomes; however, the impact was not found to be specifically related to flooding. Many studies find that females are at higher risk of poor mental health following flooding exposure. However, females are in general more likely to have poorer mental health, and therefore studies that only use data from exposed populations cannot identify the independent impacts of sex and of flooding. While females were found to have higher rates of mental health outcomes in the year following flooding, differences between males and females were found to be related to sex, not to flooding.

There are few studies in the literature that compare outcomes to an unaffected population, and fewer that use routinely collected administrative data.

The few studies that have also used administrative data report lesser or no impacts of flooding on mental health than studies that use primary data collection. In a well-controlled population-based administrative data study on the 2013 flood in Calgary, Alberta that used a similar methodology to define mental health outcomes, researchers did not find increases in diagnoses or prescriptions for anxiety or depression in a group of women post-partum.[12] This result was unexpected, as a complementary administrative data report in Alberta at the time[38] suggested increases in prescriptions for anti-anxiety medication and a sleeping aid among women highly exposed to flooding.

Another administrative data study on flooding in the UK identified a 10% increase in prescriptions for antidepressant drugs pre-post flooding in an exposed population; however, when results were compared to a control population, the percent increase due to flooding was less than 1%.[11] The authors emphasized the need for more population-based administrative data studies given the importance of controlling for confounding by time, such as was done in this study.

In this study, an increase over time in mental health outcomes was found in the exposed population, but similar increases were also found in those that were not exposed. Pre-flooding mental health was adjusted for in the final analysis. Prescription data were not used, given the short time that was available to complete the project; but since these data can be requested from the Department of Health, this could be a focus in future research.

While there are no administrative data studies to which the results of the present study can be directly compared, there are several population-based cohort studies that have also used an unaffected control group. Though, these samples were not sampled from population-based sources, and thus selection bias is a concern given low response rates. A prospective cohort study in the UK found that probable depression, anxiety, and PTSD were over six times higher in those directly flood-affected (i.e., flooding in their home), whereas those disrupted by flooding were found to have higher rates of probable PTSD but not of depression or anxiety. These are much higher effects than those observed in this study.

A smaller South Korean study also found poorer mental health in affected populations and observed differences in pre-flooding mental health between affected and unaffected populations, as well as changes over time.[39] Though it found better mental health in the unaffected population in the pre-flooding period but no changes over time, as was found in this study, it did not use regression modelling to adjust for population differences.

Suicide was examined in two studies, neither of which found differences comparing rates pre- and post-flooding.[40,41] In the present study, the exposed population had a lower rate of death by suicide, though adjusted estimates were not derived. A different methodological approach is needed to properly estimate the impact of flooding on risk of suicide.

A large longitudinal study of older adults living in rural Australia found that flood-exposed older adults were likely to have worse anxiety but similar depression scores compared to unexposed

older adults.[42] While it considered changes in mental health pre- and post-flooding in both groups, it did not adjust for other group differences (e.g., socioeconomic status).

Research on flooding suggests that certain population sub-groups may be more vulnerable to negative physical and mental health impacts – though, no well-controlled studies were found in a systematic review on risk factors associated with negative health impacts of flooding.[43]

A recent scoping review in the *Lancet* on climate change and mental health research methods called for greater use of population-based data sources to understand impacts of flooding in vulnerable populations.[44] The systematic review[43] suggested that results for age and sex are mixed, but in general, women and younger age groups are at greater risk of negative mental health. In the present study, children (<16 years) and youth (16-24 years) were at greatest risk from the impacts of flooding. While females were found to have a higher risk (than males) in the year following flooding, this was not a differential due to flooding.

Contrary to the findings of the present study, the systematic review[43] also highlighted the importance of prior health as a risk factor for mental illness following flooding. In the present study, those with chronic conditions at the time of flooding were not found to be at greater risk of a mental health outcome. This is also contrary to findings of a small UK study.[45] While flooding-specific predictors were more impactful on mental health, such as evacuation and problems with insurers, prior health was shown to be associated with poor physical and mental health.

In this study, those with chronic conditions were less likely to use the ED but more likely to use hospital services for physical illness. This finding may be due to better access to hospital care. However, this evidence suggests that as a result of flooding, those with chronic conditions, especially those who have multimorbidity, are negatively impacted, requiring them to use hospital services.

Overall studies (uncontrolled) also find that those with prior mental illness are at greater risk of mental health outcomes following flooding. Research on mental health impacts following natural disasters suggest that those with pre-existing mental illness have a higher likelihood of seeking further support than those without mental illness.[46] In the present study, those who had a pre-existing mental illness were at the highest risk of a mental health outcome in the year following flooding; however, no significant interaction with flooding exposure was identified. While half of those who had a mental illness record in the year prior to flooding also had one in the year following, this was similar to the unexposed population. The proportion of those who had a mental health record in the year prior to flooding but not in the year following was lower in the exposed population than in the unexposed population.

Flood-related characteristics such as flood depth, relocation, or evacuation could not be measured in this study but have been shown to have the most important impact on mental health following flooding.[42,45,47–50] Overall, studies find that among those with personal property, experiences of rising waters within their residence or needing to evacuate their homes are among the strongest predictors of negative mental health.

Prior flood experience and property damage were explored as modifiers of flood impact in the present study, and both were found to have differential impacts on mental health, as well on ED use. These findings are in line with a recent European econometric analysis that suggested previous flooding experience decreased distress, whereas physical damage increased distress.[48] While the aforementioned Australian study of older adults did not find previous flood experience to modify mental health, those with previous flood experience did have lower scores for anxiety, depression, and PTSD, on average, than those not previously exposed.[42]

ED use was explored in this study as an alternative outcome and was found to be higher in the exposed populations. This is contrary to the results of a study conducted in Texas after the 2017 hurricane, which found that ED use was lower among those in flooded areas.[51] Alternately, another study on flooding impacts from the 2019 Tropical Storm Imelda found increases in the rate of six cause-specific ED visits (i.e., asthma, insect bite, cardiovascular diseases, dehydration, diarrhea, and heat-related illness).[52] Cause-specific ED visits were not explored in the present study but could be explored (to a certain extent) in next steps as more detailed data on reasons for ED visits are available; though, no standardized coding system is used in these data systems.

Children and youth were found to have a higher risk of mental health outcomes than adults and older adults. A recent (2015) systematic mapping review of flooding and mental health concluded that more research is needed on vulnerable populations, such as children and youth.[5] A US study that reported on impacts in children suggested negative mental health due to flooding,[53] and a descriptive study in the Philippines on school absences and dropouts in children reported lower levels of absenteeism than were found in the present study.[53] No studies were found on the impact of flooding on withdrawal from post-secondary education. More research is needed to better understand the impacts of flooding in children and youth.

4.3 Strengths and Limitations

There are several strength and limitations to this research study that are important to recognize in interpreting the study's findings.

4.3.1 Strengths

The main strengths of this study are the ability to use longitudinal administrative data, which allowed the design of a prospective cohort study to examine seven significant flooding events spanning a 15-year period in an unbiased population-based sample. This approach resulted in large sample sizes that enabled the exploration of differential impacts of flooding on mental health.

A key limitation of studies that report on mental health impacts of flooding exposure is the lack of a population-based sample. The ability to use administrative data allows sampling from the entire population. Previous research is mostly limited to studies using self-selected samples, and it demonstrates greater impacts on mental health than more recent studies that use population-based sampling. The recent availability of administrative health data for research purposes will enable more research to employ population-based sampling.

Selection bias in observational research studies results when individuals included the study are not representative of the population to which results are generalized. This is mitigated to a large extent in administrative data. The study cohort in this work was sampled from provincial health care (i.e., Medicare) data, which is universally provided and has nearly complete population coverage. In comparison, the sampling methodology commonly used in previous research studies incudes directly sampling from communities impacted by flooding. However, those that agree to participate in the study may be different from those that refuse. This is a major limitation of previous research that was mitigated in this study by use of population-based sampling from administrative data.

Another major advantage of using population-based data sources is the large sample of exposed individuals that can be included in the statistical analysis, which provides sufficient sample sizes to conduct sub-group analyses. Findings on the average effects of flooding help to understand the overall impacts at the population-level, but it is particularly important to identify sub-groups at greater risk of negative outcomes.

On average, 100,000 individuals were exposed to each of the seven floods investigated, and they were subdivided according to several flooding-related, sociodemographic, and health-related characteristics. Interaction analyses are notorious for being underpowered; however, with such a large sample, the size of any individual sub-group that was examined was sufficiently large.

The longitudinal study design used in this study is another key strength. With the use of administrative data, longer periods of follow-up are possible (e.g., two years, five years, etc.). A one-year follow-up was chosen in this study, as several floods happened in consecutive years, and thus the selected study design considered each flood's post-flooding period independently.

In addition, the use of longitudinal administrative data allowed the development of seven cohorts for flooding events ranging from 2005 to 2019. By combining data, the number of exposed observations available for analysis exceeded 700,000. The findings are thus not unique to a single flooding event.

4.3.2 Limitations

The main limitation of this research study was the inability to accurately define a flood-exposed population. Other limitations relate to the data sources used; especially the high potential for the undercounting of mental health outcomes and the inability to examine certain outcomes for certain flood years. In addition, the study design used was not well suited for rare outcomes, such as death by suicide.

Flooding is a dynamic physical process, and thus the ability to accurately define all flood-impacted areas is very difficult.[54] These types of data are not readily available. Several data sources were used to define a flood-exposed population, including Government of Canada flood maps and Department of Public Safety property damage claims data.

Flood maps are created by Natural Resources Canada (NRCan) upon request from provincial emergency response teams. These data are only available for certain days of flooding. Any flooding outside these days could not be captured.

For flood years 2012 and 2014, flood maps were not available, and flood exposure was defined using Department of Public Safety property damage data. Exposure in these years was defined as living in a Statistics Canada dissemination area (DA) that had a property damage claim. This approach excludes any areas that were exposed but did not have property damage claims.

Both of these flooding data sets were used to identify DAs in which there was any flooding, and they were linked to individual address data to identify the exposed population. DAs are the smallest level of Statistics Canada geography; however, some DAs can have a large surface area, especially in rural areas. Over 60% of the exposed population was living in rural areas. Flood maps provided in the Appendix show the overlap between flooded areas and DAs, though they do not provide a sense of population density. Flooding often impacted small areas of the DAs' total surface area. Over 80% of DAs included in the exposed population had 25% flooding or less, and only a small proportion had over 75% flooded surface areas. However, this variable does not capture where flooding occurred in the DA and how many people were impacted. Small areas of flooding could impact a large population.

Inaccurate assignment of exposure leads to regression estimates that are lower than would be expected had exposure assignment been more precise. With more detailed address information, flood exposure assignment could have been more accurate. This approach would reduce the sample size of the exposed population; however, having a more accurately defined exposed population would enable more robust estimation of the direct impacts of flooding.

Youth attending post-secondary education is another population for which defining flood exposure accurately was difficult. Youth may no longer live at their parents' residence but keep this address on file with the Department of Health; and thus, they may not be directly affected. Data used to define post-secondary education withdrawal are available for all universities in the province but do not contain information on current address (school address), which may be different than permanent address (parents' address). Alternatively, youth may be living in a flood-affected area but are not assigned to the exposed population, as their current address is not recorded in the Citizen Data. The latter is less of a concern, but the former may impact interpretation of results, given the potential heterogeneity in this population.

While administrative data provide many advantages, there are also limitations that need to be mentioned. A number of important mental health outcomes were considered in this study that have diagnostic validity, given they were derived from interaction with the health care system. However, there is a high potential for underdiagnoses given limitations in accessing mental health support services and the long duration of the process of receiving a diagnosis for mental illness. We may also expect that those living in flood exposed areas may have further limitations in accessing care. It is expected that the effects reported in this study are conservative and likely represent an underestimate of the true impact of flooding.

In addition to this limitation, the administrative data available to define certain outcomes were only available for certain flood years and areas of the province. Data for health service use for mental illness and mood and/anxiety disorders were not available for the 2019 flood. Suicide data were only available for floods in 2012 and thereafter. Horizon Health Network ED data were limited to the 2018 and 2019 floods and to populations living in the Fredericton and Saint John health regions. Data for NB colleges were only available after 2013 and were not combined with NB university data, which covered all flood years. Future work should include college data in the analysis of impact of flooding exposure, given findings for youth enrolled in university.

A final limitation discussed is that the study design methodology used was too complex for rare outcomes. Data on all residents in New Brunswick was used to design a prospective cohort study in the year following each of the seven flooding events. This required adjustment for sociodemographic and health-related characteristics, as well as area, given confounding due to differences in populations across the province. This was a lot of information to process, and each regression model took several hours to run using high processing power. Several models did not converge, and, in these cases, only unadjusted estimates are provided.

Regression modelling was not employed for death by suicide given there was a substantially lower number of outcomes than for other outcomes examined. A different study design, such as matched or nested case-control studies, that restricts the size of an appropriate control group should be used in future research to examine rare outcomes in administrative data, such as death by suicide.

4.4 Conclusions

This study provides a first look into the population-level impacts of major flooding events and identifies higher risk population sub-groups who are at greater risk following flooding, using among the most robust quantitative study designs in the existing literature. It thus fills an important knowledge gap, as the previous research in this area is limited to smaller studies with self-selected samples and uncontrolled statistical analyses.

The results support the findings of less robust studies in this area, which suggest that flooding exposure has negative impacts on mental health. This research study also adds to the limited literature on the negative impact of flooding exposure on health service utilization of relevant health services, including Emergency Department and hospital service use, and on children and youth, with a focus on health and educational outcomes.

Future research in this area should use population-based data sources to reduce the impacts of selection bias and should use multivariable regression analyses to control for confounding bias in comparison to the unexposed population and over time. Further research focused on children and youth is also needed, as the results of this study suggest these populations are at greater risk of negative mental health following flooding. More work is also needed to explore the flooding impact on post-secondary students.

Emergency Department use is another important area in need of more research to better understand reasons for visits and dynamic patterns of use in the shorter term (e.g., days, weeks) after flooding events. Given the higher risk of hospital service use for physical illness in adults, older adults, and those with multimorbidity, more detailed investigation of reasons for service use would be informative. Further research should also focus on impacts on prescriptions for antidepressant drugs and other relevant drugs, as this is an area with evidence for the population-level impact of flooding.[11]

While an extensive literature exists on the impacts of flooding, more robust research methodologies, such as those used in this study, are needed to better inform this knowledge base.

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Tables

Table 1: Summary of Previous Flooding Events in New Brunswick, Canada

Flood Year	Flood Start Date	Flood End Date	Evacuated	Registered with Red Cross	Power Outages	Property Damage	State of Emergency Declared
2005[55]	2005 -04-16	2005 -04-29	Yes (southern parts)	info not found	info not found	Yes	No
2008[56,57]	2008 -04-23	2008 -05-02	Yes	189 people	info not found	Yes	No
2012[25,29]	2012 -03-23	2012 -03-25	Yes	212 people	info not found	Yes	Yes (Perth-Andover)
2014[58]	2014 -04-14	2014 -04-20	Yes	info not available	info not found	Yes	Yes (Sussex area)
2015[26]	2015 -04-21	2015 -05-04	Yes	54 people	info not found	Yes	Yes (Perth-Andover)
2018 [28]	2018 -04-27	2018 -05-12	Yes	488 households	Yes (952 customers affected)	Yes	No
2019[31,59]	2019 -04-19	2019 -05-06	Yes	1,262 people	Yes (218 customers affected)	Yes	No

Table 2: Baseline Characteristics of the Flood-Exposed and Unexposed Populations

	Unexposed		Exposed	
Characteristic	**Number** (4,283,165)	**Percent** (85.58%)	**Number** (721,787)	**Percent** (14.42%)
Sociodemographic Characteristics				
Age group (years)				
<16	653,992	15.27%	116,123	16.09%
16-24	445,838	10.41%	75,951	10.52%
25-64	2,418,759	56.47%	402,493	55.76%
≥ 65	764,576	17.85%	127,220	17.63%
Marital status				

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	Unexposed		Exposed	
Characteristic	**Number** (4,283,165)	**Percent** (85.58%)	**Number** (721,787)	**Percent** (14.42%)
Marital status				
Married	1,707,392	39.86%	309,783	42.92%
Single	1,739,391	40.61%	288,812	40.01%
Other	836,382	19.53%	123,192	17.07%
Gender				
Male	2,096,325	48.94%	354,862	49.16%
Female	2,186,840	51.06%	366,925	50.84%
Household composition				
Lives alone	1,272,961	29.72%	196,860	27.27%
With others	3,010,192	70.28%	524,927	72.73%
Missing	12			
Address duration				
0-5 years	2,293,896	53.56%	346,349	47.98%
5-10 years	1,044,985	24.40%	178,113	24.68%
10+ years	944,284	22.05%	197,325	27.34%
Recipient of Social Development income assistance				
Active status	280,658	6.55%	38,281	5.30%
Community size				
<1,000	2,194,360	51.39%	449,496	62.35%
1,000 and 29,999	823,729	19.29%	91,062	12.63%
>30,000	1,252,051	29.32%	180,367	25.02%
Missing	13,025		13,887	
CIMD residential instability (quintile)				
1st (lowest)	790,515	18.52%	216,269	30.00%
2nd	851,944	19.96%	185,280	25.70%
3rd	842,263	19.73%	121,873	16.91%
4th	964,932	22.61%	103,563	14.37%
5th (highest)	818,569	19.18%	93,819	13.02%
Missing	14,942		983	

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Characteristic	Unexposed		Exposed	
	Number (4,283,165)	**Percent** (85.58%)	**Number** (721,787)	**Percent** (14.42%)
CIMD economic dependency (quintile)				
1st (lowest)	886,591	20.77%	201,875	28.01%
2nd	1,021,547	23.93%	205,786	28.55%
3rd	807,544	18.92%	131,274	18.21%
4th	881,814	20.66%	111,557	15.48%
5th (highest)	670,727	15.71%	70,312	9.75%
Missing	14,942		983	
CIMD situational vulnerability (quintile)				
1st (lowest)	1,068,254	25.03%	250,855	34.80%
2nd	830,578	19.46%	152,865	21.21%
3rd	834,683	19.56%	149,102	20.69%
4th	843,477	19.76%	105,636	14.66%
5th (highest)	691,231	16.19%	62,346	8.65%
Missing	14,942		983	
CIMD ethnocultural composition (quintile)				
1st (lowest)	788,204	18.47%	70,452	9.77%
2nd	802,245	18.80%	163,162	22.64%
3rd	904,415	21.19%	196,957	27.32%
4th	899,511	21.07%	148,873	20.65%
5th (highest)	873,848	20.47%	141,360	19.61%
Missing	14,942		983	
DA-level Income (quintile)				
1st (lowest)	898,598	21.04%	99,949	13.86%
2nd	899,018	21.05%	127,300	17.66%
3rd	855,555	20.04%	158,101	21.93%
4th	813,145	19.04%	168,286	23.34%
5th (highest)	803,824	18.82%	167,289	23.20%
Missing	13,025		862	

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	Unexposed		Exposed	
Characteristic	**Number** (4,283,165)	**Percent** (85.58%)	**Number** (721,787)	**Percent** (14.42%)
DA-level percent with high school		83.3% (4.0)		82.5% (3.7)
DA-level employment rate		68.1% (5.3)		69.0% (5.0)
Health-Related Characteristics				
Chronic condition*				
Yes	1,448,953	39.28%	230,239	39.52%
Multimorbidity*				
1 chronic condition	825,763	22.38%	129,493	22.23%
2+ chronic conditions	623,190	16.89%	100,746	17.29%
Social Development Long-Term Care client				
Yes	65,229	1.52%	7,560	1.05%
Flood-Related Characteristics				
Flood Year				
2005	667,480	15.58%	29,930	4.15%
2008	615,141	14.36%	82,254	11.40%
2012	706,104	16.49%	9,242	1.28%
2014	571,392	13.34%	145,194	20.12%
2015	594,311	13.88%	123,760	17.15%
2018	534,634	12.48%	192,186	26.63%
2019	594,103	13.87%	139,221	19.29%
Back-to-back floods (2018/2019)				
Yes	x	x	129,893	18.00%
DA-level house damage claims*				
Yes	x	x	248,029	51.05%
No	x	x	237,814	48.95%
DA-level other property damage claims*				
Yes	x	x	139,192	28.65%
No	x	x	346,651	71.35%

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	Unexposed		Exposed	
Characteristic	**Number** (4,283,165)	**Percent** (85.58%)	**Number** (721,787)	**Percent** (14.42%)
Percentage of DA flooded				
>0-<25%	x	x	466,796	82.28%
25% to <50%	x	x	48,404	8.53%
50% to <75%	x	x	31,946	5.63%
75% to 100%	x	x	20,205	3.56%
Missing	x	x	154,436	x

* Limited to 2008, 2012, 2014, 2018, and 2019 flood years.

Table 3: Descriptive Statistics for Mental Health Outcomes and Alternative Outcomes

Outcome	1 year pre-flood		1 year post-flood	
	Exposed	**Unexposed**	**Exposed**	**Unexposed**
Health service use for mental illness*				
n	79,153	503,935	82,744	527,810
%	13.59	13.66	14.2	14.31
Health service use for mood and/or anxiety disorders*				
n	55,537	362,728	57,330	374,508
%	9.53	9.83	9.84	10.15
Acute hospitalization for mental illness-related reasons				
n	5071	37408	5558	41027
mean	1.35	1.40	1.34	1.40
sd	0.84	1.18	0.86	1.14
%	0.7	0.87	0.77	0.96
Acute hospitalization for PTSD-related reasons				
n	500	4,603	478	4,830
mean	1.11	1.13	1.13	1.14
sd	0.50	0.50	0.47	0.49
%	0.07	0.11	0.07	0.11
Physician visits for counselling/psychotherapy				
n	37,692	247,834	38,741	255,563
mean	3.10	3.20	3.03	3.20

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Outcome	1 year pre-flood		1 year post-flood	
	Exposed	Unexposed	Exposed	Unexposed
Physician visits for counselling/psychotherapy				
sd	6.05	5.67	5.60	5.64
%	5.22	5.79	5.37	5.97
Death by suicide**				
n	x	x	63	385
%	x	x	0.01	0.01
Emergency Department use *				
n	x	x	98,155	101,934
mean	x	x	1.86	1.99
sd	x	x	1.69	1.96
%	x	x	29.8	30.26
Emergency Department use in older adults *				
n	x	x	19,978	21,873
mean	x	x	1.94	2.08
sd	x	x	1.65	2.12
%	x	x	32.32	32.76
Hospital service use				
n	62,372	391,103	62,781	400,047
mean	1.42	1.42	1.44	1.46
sd	0.86	0.88	0.90	0.94
%	8.64	9.13	8.7	9.34
Hospital service use in older adults				
n	24,773	153,685	25,585	161,078
mean	1.60	1.61	1.62	1.65
sd	0.96	0.99	1.01	1.05
%	19.47	20.1	20.11	21.07
Youth: Post-secondary education withdrawal				
n	x	x	1,749	9,063
%	x	x	16.15	15.61
Children: School absences **				
n	10,074	42,560	10,490	43,883
mean	8.01	7.71	8.57	8.24

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Outcome	1 year pre-flood		1 year post-flood	
	Exposed	Unexposed	Exposed	Unexposed
Children: School absences ****				
median	6	5	6	6
sd	8.81	8.56	9.41	9.46
%	50.77	55.15	52.87	56.86

*Not available for 2019 flood year.
** Only available for 2012, 2014, 2015, 2018, and 2019 flood years.
*** Only available for 2018 and 2019 flood years and health regions 2 and 3 (Saint John and Fredericton),
**** Only available for 2019 flood year.

Table 4: Impacts of Flooding on Mental Health and Alternate Outcomes

Outcome	Exposed	Unexposed	Unadjusted Odds Ratio (95%CI)	Adjusted*** Odds Ratio (95%CI)
Mental Health Outcomes				
Health service use for mental illness*	14.20% (82,744)	14.31% (527,810)	1.16 (1.15 – 1.18)	1.09 (1.08 – 1.10)
Health service use for mood and/or anxiety disorders*	9.84% (57,330)	10.15% (374,508)	1.14 (1.12 – 1.15)	1.07 (1.06 -1.08)
Acute hospitalization for mental illness reasons	0.77% (5,558)	0.96% (41,027)	0.95 (0.91 – 0.99)	0.92 (0.88 – 0.95)
Acute hospitalization for PTSD related reasons	0.07% (478)	0.11% (4,830)	1.05 (0.93 – 1.18)	0.85 (0.76 – 0.95)
Physician service claim for counselling/psychotherapy	5.37% (38,741)	5.97% (255,563)	1.04 (1.03 – 1.06)	1.02 (1.00 – 1.03)
Alternate Outcomes				
Emergency Department use**	29.80% (98,155)	30.26% (101,934)	1.11 (1.07 – 1.14)	1.11 (1.08 – 1.14)
Emergency Department use in older adults**	32.32% (19,978)	32.76% (21,873)	1.09 (1.03 – 1.15)	1.11 (1.05 – 1.18)
Hospital service use	8.70% (62,781)	9.34% (400,047)	0.97 (0.96 – 0.98)	0.93 (0.92 – 0.94)

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Outcome	Exposed	Unexposed	Unadjusted Odds Ratio (95%CI)	Adjusted*** Odds Ratio (95%CI)
Hospital service use in older adults	20.11% (25,585)	21.07% (161,078)	0.94 (0.92 – 0.96)	0.94 (0.92 – 0.96)
Post-secondary education withdrawal in youth	16.15% (1,749)	15.61% (9,063)	1.07 (1.00 – 1.16)	1.08 (1.00 – 1.16)

*Not available for 2019 flood year.
**Only available for 2018 and 2019 flood years and health regions 2 and 3 (Saint John and Fredericton).
***Adjusted for the influences of age, sex, and SES and for pre-flooding mental health for mental outcomes and for pre-flooding alternative outcomes if data were available.

Table 5: High-Risk Population Sub-Groups for Negative Mental Health Impacts Following Flooding

Characteristics	Number (%)	p-value	Odds Ratio	95%CI	
Flood-Related Characteristics					
Number of floods					
1 flood	52,460 (14.82%)	0.000	1.10	1.09	1.12
2 floods	25,364 (13.86 %)	0.001	1.03	1.01	1.05
Back-to-back floods (2018/19) *					
Yes	8,385 (6.46 %)	0.000	1.07	1.04	1.11
Flood damage reported in DA					
Yes	44,976 (14.63%)	0.000	1.13	1.12	1.15
Sociodemographic Characteristics					
Age group					
Children (<16)	9,715 (8.37%)	0.000	1.12	1.08	1.14
Youth (16-24)	11,590 (15.26%)	0.001	1.92	1.87	1.98
Address duration					
0-5 years	50,409 (14.55%)	0.000	1.05	1.04	1.07
Economic dependency					
1st quintile	26,512 (13.13%)	0.045	1.02	1.00	1.05
5th quintile	10,701 (15.22%)	0.000	1.20	1.15	1.26
Ethnocultural composition					
1st quintile	10,594 (15.04%)	0.000	1.12	1.09	1.15

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Characteristics	Number (%)	p-value	Odds Ratio	95%CI	
Situational vulnerability					
5th quintile	10,217 (16.39%)	0.000	1.27	1.22	1.34
Residential instability					
3rd quintile	17,511 (14.37%)	0.0000	1.13	1.09	1.18

* Mental health outcome is derived from DAD and NB physician billing datasets only

Table 6: High-Risk Population Sub-Groups for Increased Hospital Service Use for Physical Illness Following Flooding

Characteristics	Number (%)	p-value	Odds Ratio	95%CI	
Overall Population					
Age group (years)					
Adults (25-64)	30,243 (7.51%)	0.000	1.60	1.57	1.63
Older adults (65+)	25,585 (20.11%)	0.000	4.54	4.45	4.64
Chronic condition*					
Yes	34,907 (15.16%)	0.020	2.06	2.02	2.10
Multimorbidity*					
2+ chronic conditions	18,997 (18.86%)	0.020	3.13	3.06	3.19
Situation vulnerability					
5th quintile	5,967 (9.57 %)	0.025	1.11	1.06	1.15

* Data not available for 2019 flood year.

Table 7: High-Risk Population Sub-Groups for Increased Emergency Department (ED) Use*

Characteristics	Number (%)	p-value	Odds Ratio	95%CI	
Overall Population					
Number of floods					
1 flood	22645 (31.08%)	0.000	1.20	1.16	1.24
2 floods	30,192 (30.13%)	0.001	1.06	1.03	1.09
Flood damage reported in DA					
Yes	46,132 (28.44%)	0.000	1.15	1.11	1.19
No	52,023 (31.12%)	0.000	1.08	1.05	1.12
Residential Instability					
1st quintile	30,147 (27.71%)	0.000	1.10	1.04	1.15
Economic dependency					
1st quintile	29,905 (28.52%)	0.000	1.09	1.04	1.13
Situation vulnerability					
1st quintile	34,148 (26.59%)	0.005	1.06	1.02	1.11
2nd quintile	22,438 (30.59%)	0.031	1.45	1.26	1.67
Older Adult Population					
Number of floods					
1 flood	3,400 (32.84%)	0.000	1.15	1.07	1.24
2 floods	5,397 (32.97%)	0.007	1.10	1.03	1.18
Flood damage reported in DA					
Yes	9904 (31.25%)	0.000	1.13	1.06	1.21
No	10,074 (33.44%)	0.006	1.10	1.03	1.17
Household composition					
Lives alone	7,931 (35.44%)	0.053	1.19	1.11	1.28
Lives with others	12,047 (30.55%)	0.014	1.08	1.02	1.16

* ED use is limited to 2018 and 2019 flood years and to health regions 2 and 3 (Saint John and Fredericton).

Table 8: High-Risk Population Sub-Groups for Increased Withdrawal from Post-Secondary Education Among Youth

Characteristics	Number (%)	p-value	Odds Ratio	95%CI	
Flood-Related Characteristics					
Number of floods					
3+ floods	524 (16.47%)	0.018	1.17	1.03	1.33
Sociodemographic Characteristics					
Household composition					
Lives with others	490 (18.06%)	0.007	1.20	1.05	1.37
Ethnocultural composition (quintile)					
1st quintile	127 (16.87%)	0.047	1.29	1.00	1.66

Appendix

Flood maps for each flood year are provided below. For each flood year, the first map shows the Statistics Canada dissemination areas (DAs) defined as exposed, and the second map provides a more detailed view of the extent of flooding.

Figure 1: 2005 Flood Map – Flood-Exposed Dissemination Areas

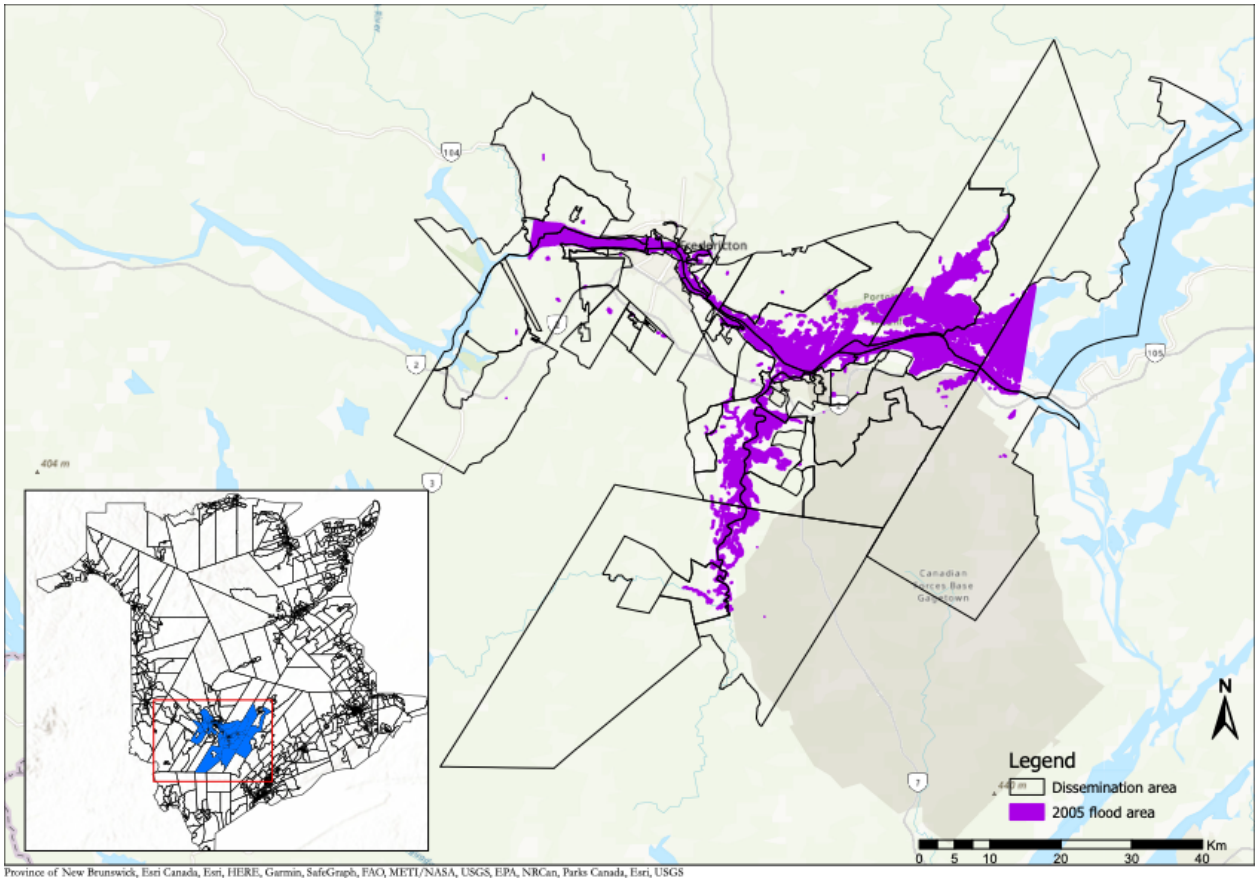
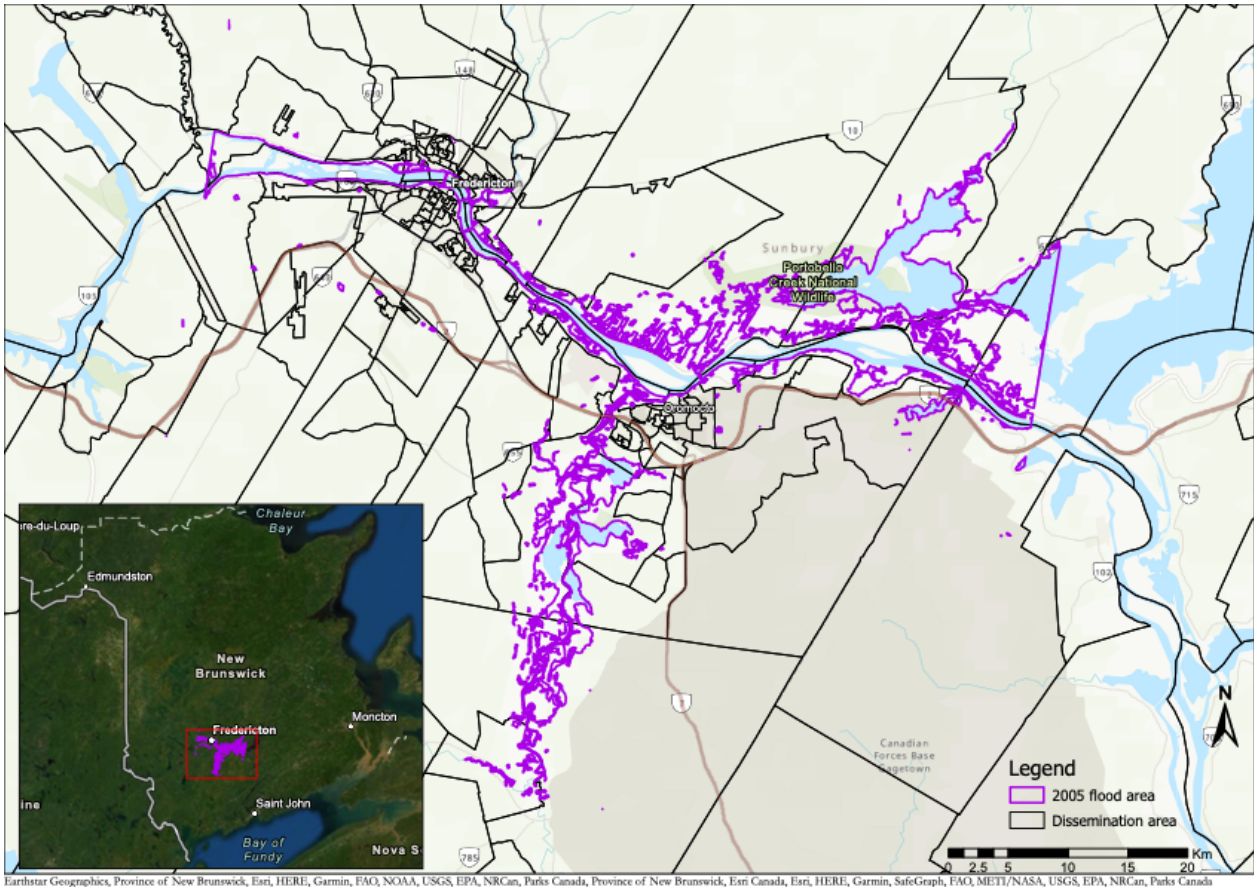
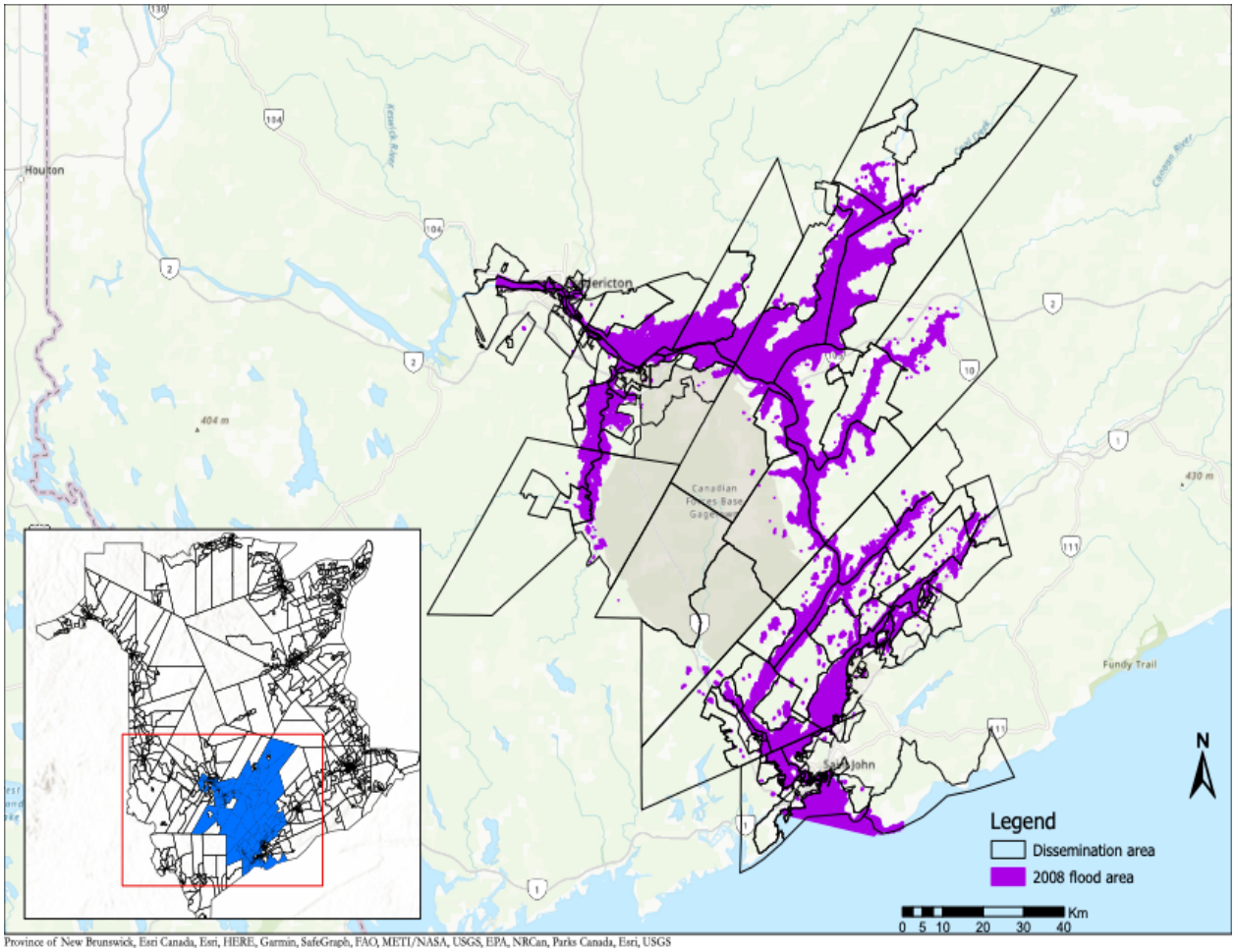


Figure 2: 2005 Flood Map



Earthstar Geographics, Province of New Brunswick, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada, Province of New Brunswick, Esri Canada, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NRCan, Parks Canada

Figure 3: 2008 Flood Map – Flood-Exposed Dissemination Areas



Province of New Brunswick, Esri Canada, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NRCan, Parks Canada, Esri, USGS

Figure 4: 2008 Flood Map

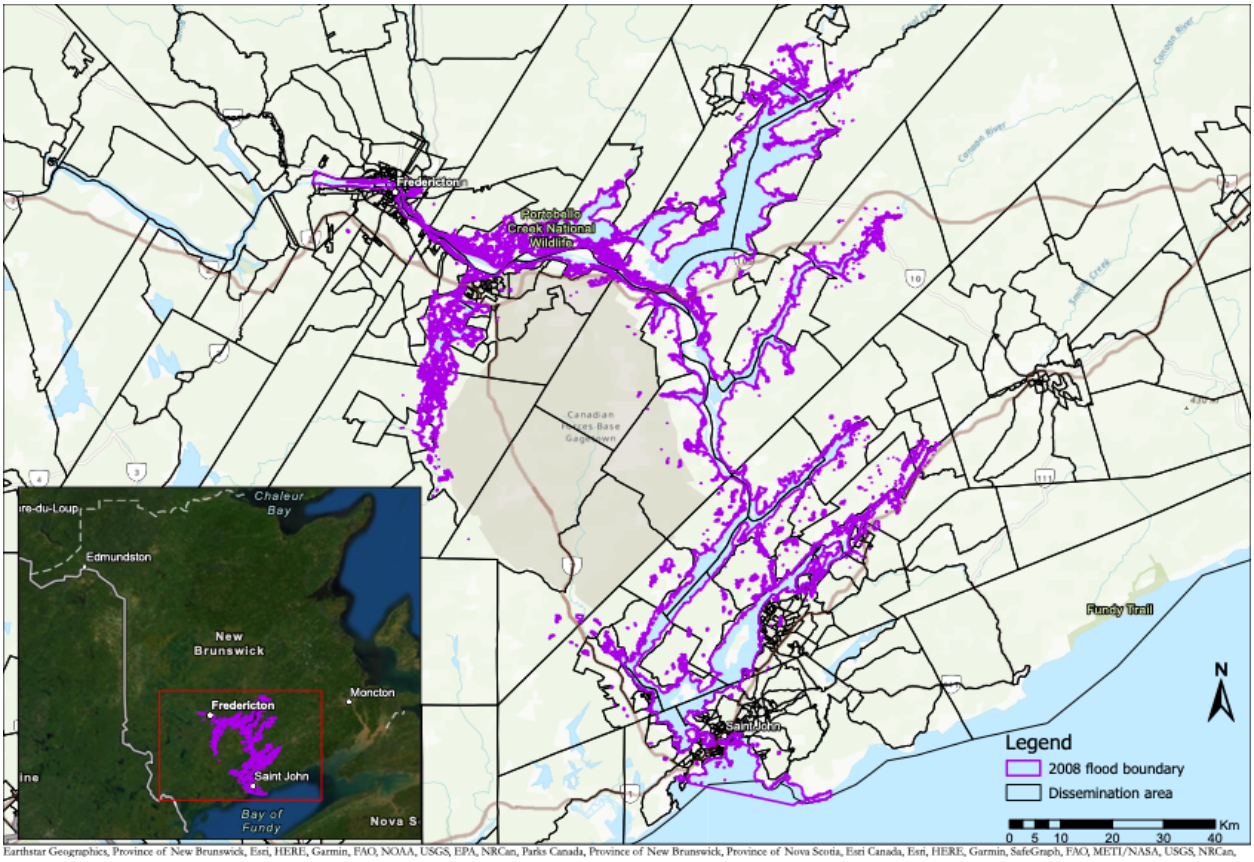


Figure 5: 2015 Flood Map – Flood-Exposed Dissemination Areas

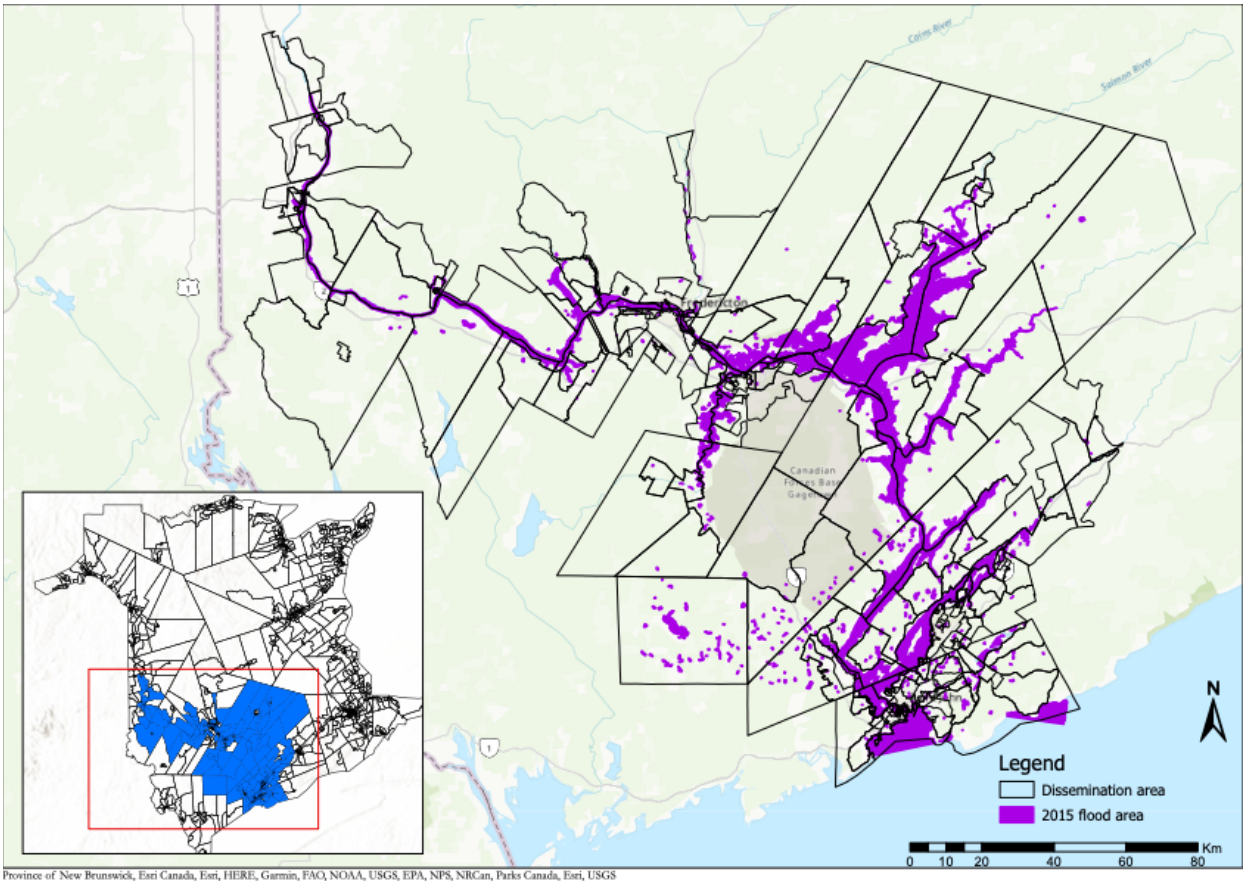
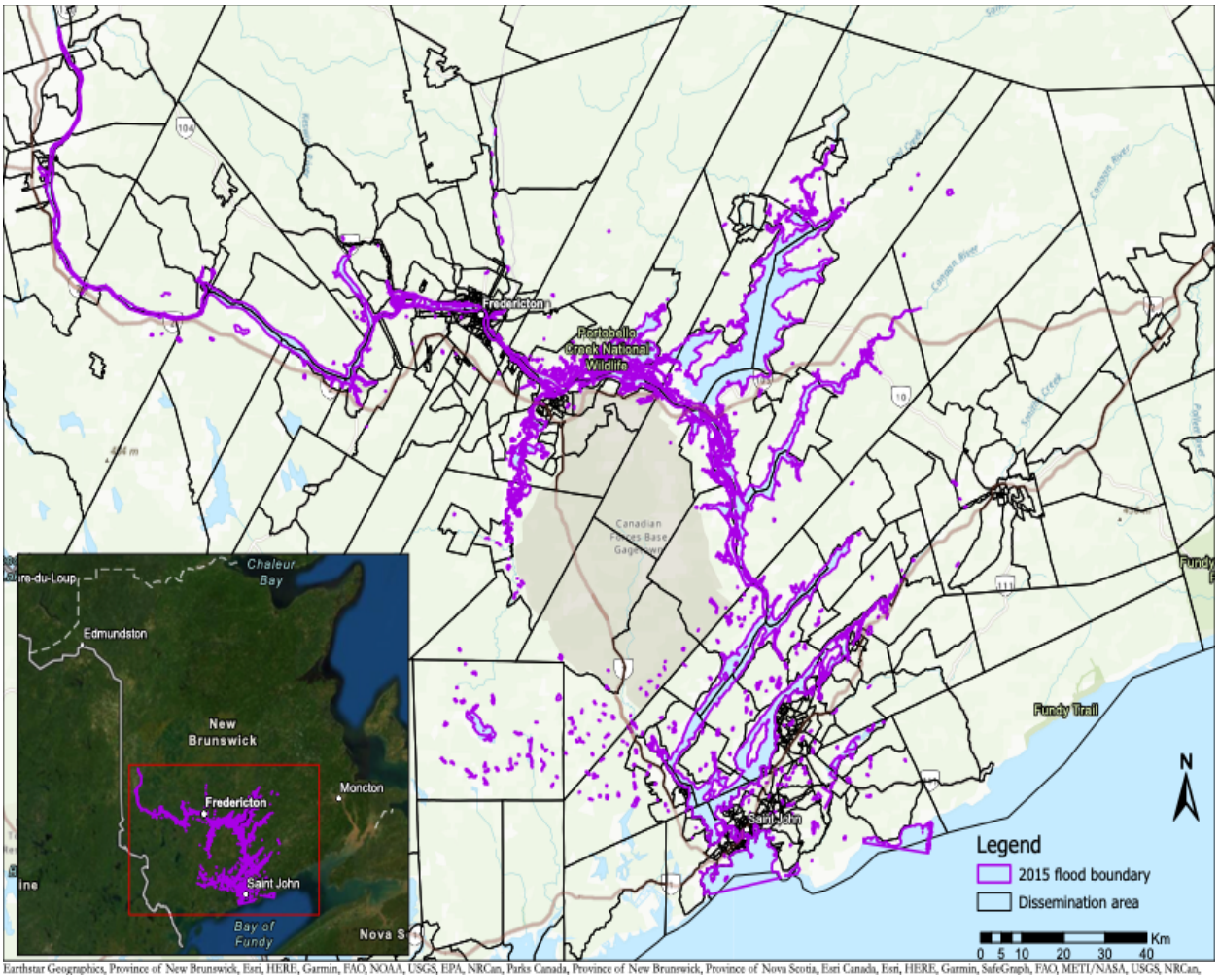


Figure 6: 2015 Flood Map



Earthstar Geographics, Province of New Brunswick, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada, Province of New Brunswick, Province of Nova Scotia, Esri Canada, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, NRCan,

Figure 7: 2018 Flood Map – Flood-Exposed Dissemination Areas

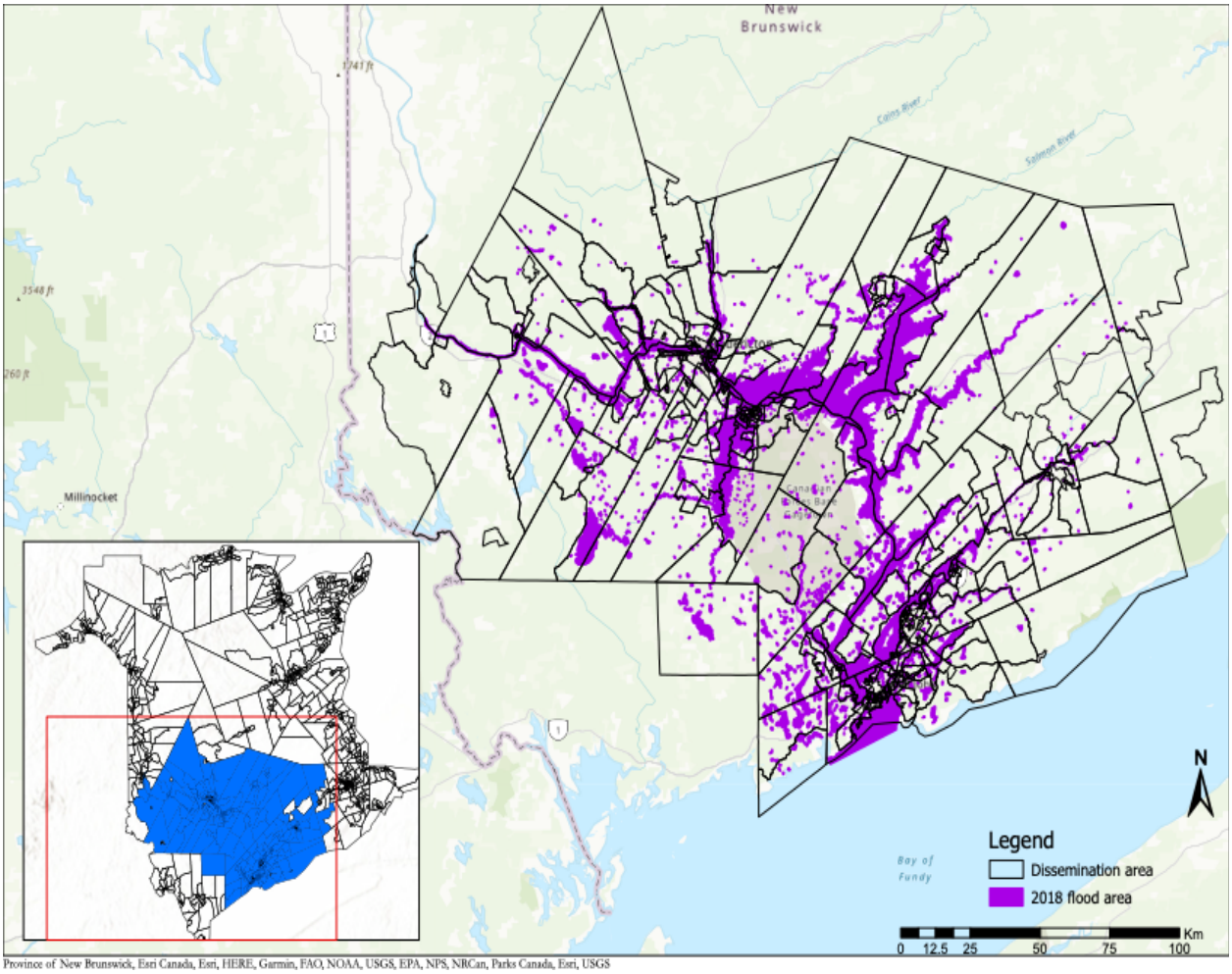
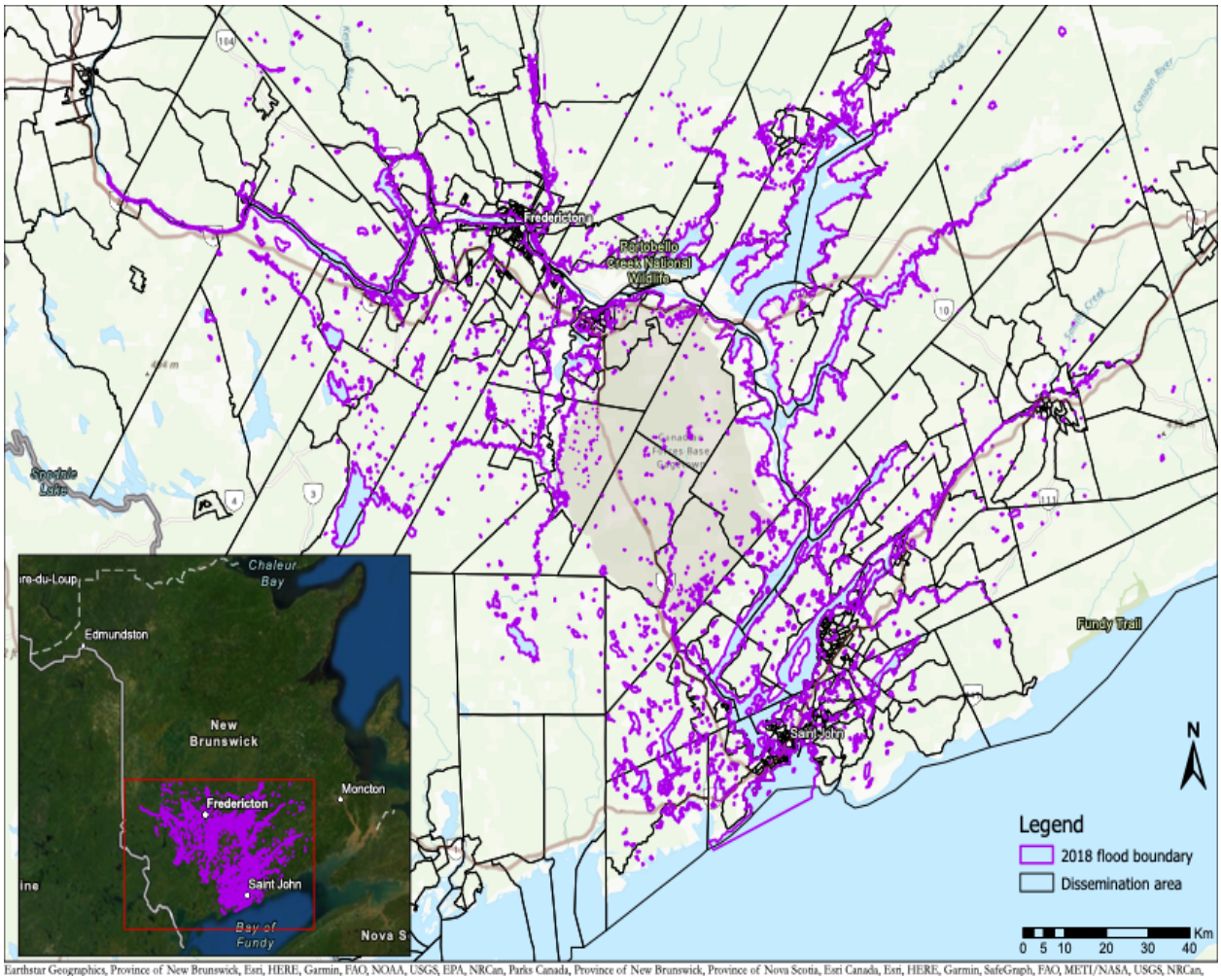


Figure 8: 2018 Flood Map



Earthstar Geographics, Province of New Brunswick, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada, Province of New Brunswick, Province of Nova Scotia, Esri Canada, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, NRCan,

Figure 9: 2019 Flood Map – Flood-Exposed Dissemination Areas

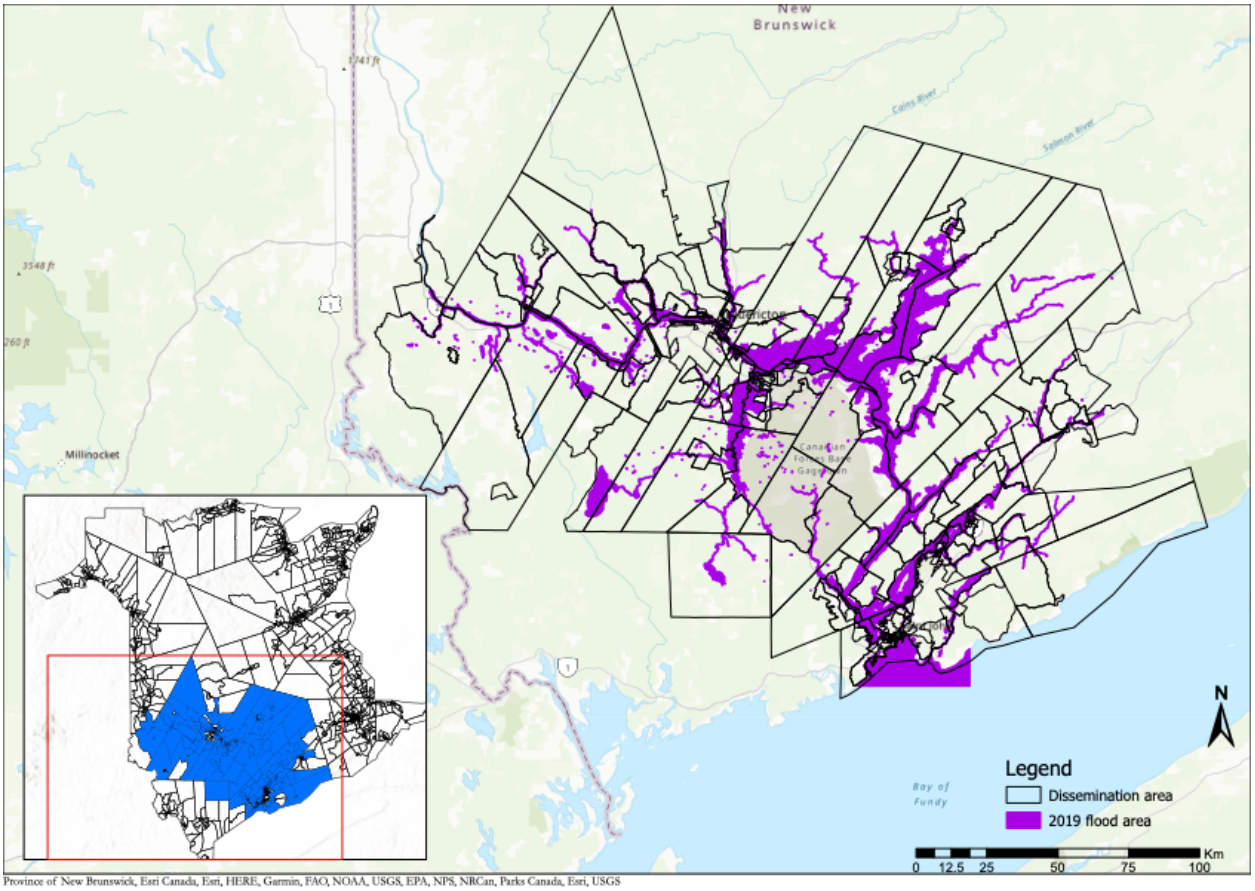


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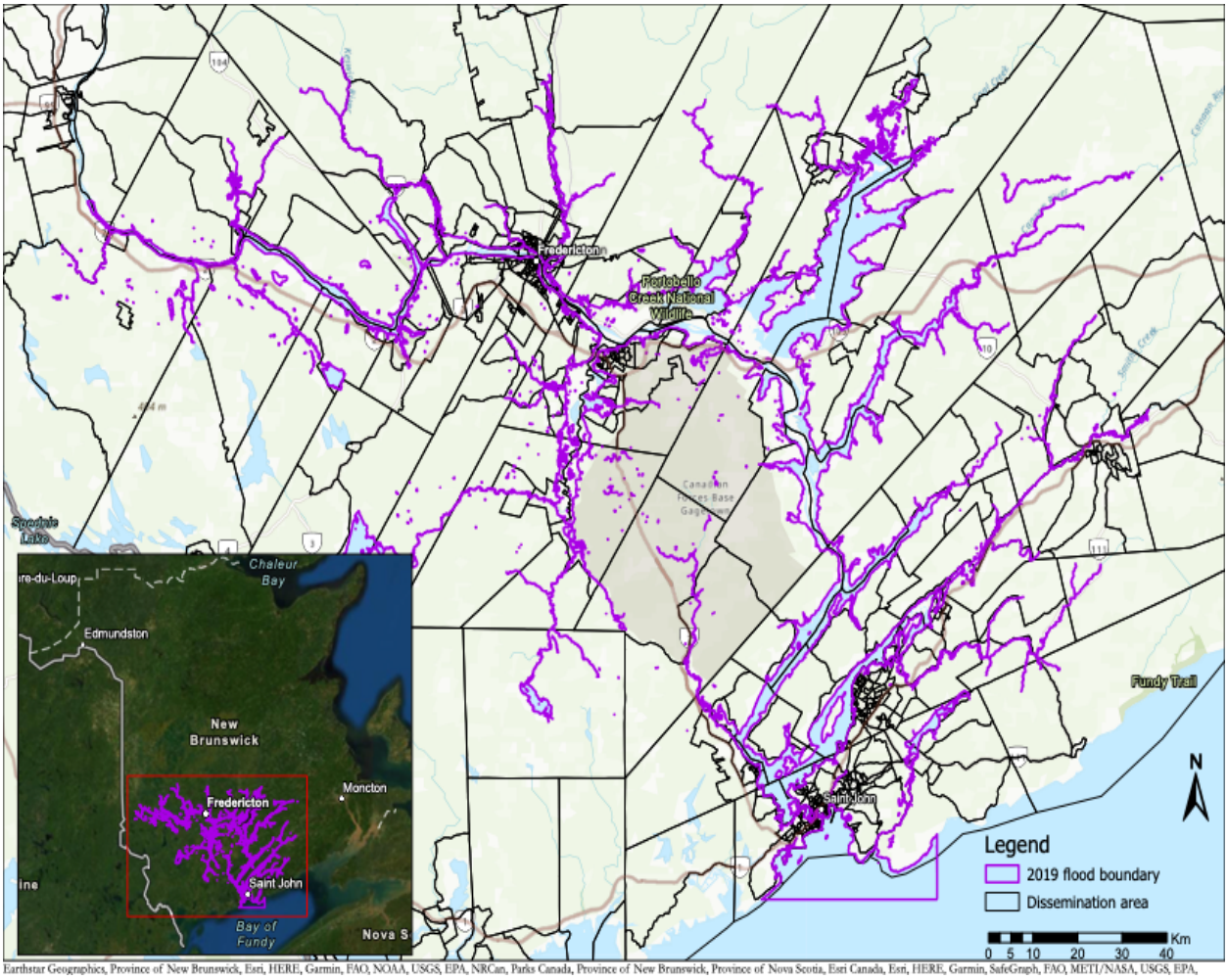
Figure 10: 2019 Flood Map



Earthstar Geographics, Province of New Brunswick, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada, Province of New Brunswick, Province of Nova Scotia, Esri Canada, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA,