YORK REGION CLIMATE CHANGE AND HEALTH VULNERABILITY ASSESSMENT

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York Region

SUMMARY REPORT

York Region Climate Change and Health Vulnerability Assessment

"Climate change will be the defining issue for health systems in the 21st century. Health professionals have the knowledge, cultural authority and responsibility to protect health from climate change."[1]

World Health Organization

Climate change is unequivocally occurring and poses severe risks to the natural environment and human populations worldwide. As the impacts of climate change are no longer avoidable, government agencies and communities need to take measures to adapt to future climate conditions and protect the environment and human health.

The purpose of this assessment is to better understand how York Region communities may be vulnerable to the impacts of climate change from a health perspective. The findings highlight how climate change may potentially impact a wide range of health issues through various pathways. In particular, there is strong evidence that climate change will increase the risk of extreme heat events, vector-borne diseases and extreme weather events. Certain populations will be more impacted from climate change than others, including seniors and low-income individuals. Local factors such as urban heat islands, floodplains, and an aging population can increase this vulnerability for York Region residents.

This vulnerability assessment will help inform adaptation planning, ensuring greater resiliency to future climate change impacts in York Region.

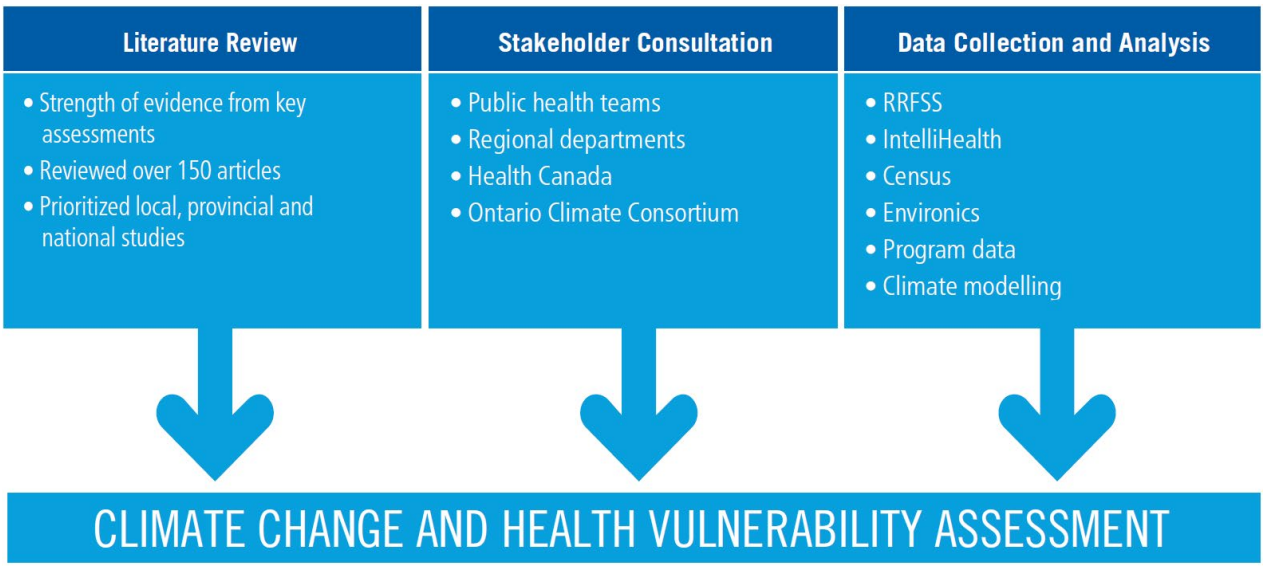
ASSESSMENT APPROACH

Using a framework developed by the World Health Organization and Ontario Ministry of Health, and through the review of literature, health data and analysis of local programming (Figure A), this assessment provides an analysis of potential climate change impacts to human health within York Region. This assessment covers a broad range of topic areas, including: extreme temperatures, extreme weather events, air quality, vector-borne disease, food safety and security, safe water and UV exposure.

Mitigation: Measures to reduce or capture greenhouse gas emissions to help reduce the severity of future impacts from climate change.

Adaptation: Measures to prepare for and cope with the negative impacts of climate change that are expected to occur.

Figure A: Examples of research, consultation and data that informed the assessment.



When assessing climate change impacts on health, three determinants of vulnerability were considered:

1. **Exposure** of populations to climate change impacts such as extreme heat
2. **Sensitivity** or degree in which populations are affected, such as seniors who are more sensitive to extreme temperatures
3. **Adaptive capacity** of populations or institutions to respond to climate change impacts, such as having home air conditioners or access to cooling centres

CLIMATE CHANGE IMPACTS EXPECTED IN YORK REGION

"Canada's climate has warmed and will warm further in the future, driven by human influence."[2]

Canada's Changing Climate Report, 2019

The Intergovernmental Panel on Climate Change (IPCC) stated that current atmospheric levels of key greenhouse gases are the highest in at least the last 800,000 years. The influence of human systems is clear with climate change impacting the earth's atmosphere, weather patterns, oceans and glaciers. With the persistence of greenhouse gases already released into the atmosphere, climate change impacts will continue for hundreds of years even if emissions are completely eliminated. Continued emissions will result in more severe impacts on the global climate. As a result, in addition to efforts to reduce greenhouse gases, communities will need to adapt to future changes in climate that are unavoidable.[3]

In recent decades, York Region has experienced changes to local climate conditions. Warming trends are evident in many areas across Canada contributing to more extreme heat, longer growing seasons and reduced snow and ice-cover periods, with trends projected to

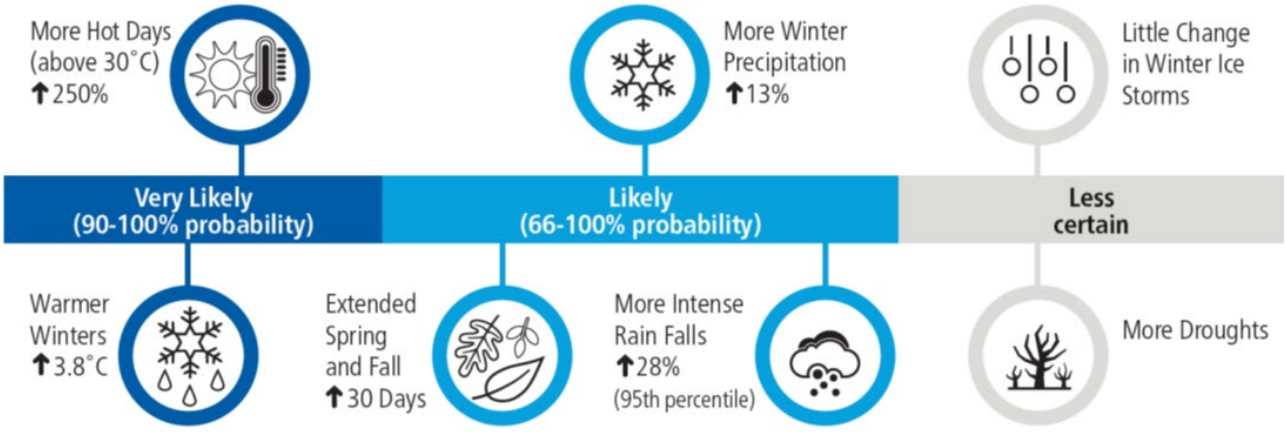
continue. The recent spread of blacklegged ticks and Lyme disease across southern Ontario and within York Region is also largely attributed to changing climate conditions.

Historically, York Region has experienced extreme weather events resulting in property damage or loss, major power outages, damage to infrastructure and ultimately, impacts on human health. For example, on December 21 and 22, 2013, a significant ice storm event in York Region resulted in loss of power to more than 92,000 homes, road closures and tree damage. More recently, an extreme rainfall event on June 23, 2017 resulted in severe flooding and impacted multiple water and wastewater facilities across York Region.

Climate change is expected to impact York Region in numerous ways by the 2050s.

- Temperatures will very likely increase, with the largest increase occurring during the summer and winter seasons
- Precipitation levels will likely increase in most months and annually, with most precipitation taking place during the winter and spring seasons
- Extreme precipitation events, particularly during the summer, are likely to increase in frequency
- The growing season will likely extend by approximately 30 days per year
- Projections for droughts and ice storms are limited, but suggest an increase in drought conditions and minimal changes in ice storm conditions[4] (Figure B)[a]

Figure B: Climate change impacts projected for York Region by the 2050s.



Source: Fausto E et al. Historical and Future Climate Trends in York Region. Toronto: Ontario Climate Consortium; 2015. Fig.B, Climate change impacts projected for York Region by the 2050s. Adapted and modified with permission from the copyright holder.

Future climate change adaptation planning should consider a wide range of climate scenarios to ensure greater resiliency and better preparedness for future events. These projections provide an understanding of how climate change will impact York Region on average, but a range of future weather conditions are still possible. For example, while York Region will experience warmer winters, it is still possible to experience extreme cold events. Additionally,

[a] Projections used Representative Concentration Pathway (RCP) 8.5 scenario which assumes growing emissions continuing until the end of the twenty-first century.

while certain weather conditions may not occur frequently (e.g. drought, major storms) their impacts can have serious implications to human health.

HOW CLIMATE CHANGE CAN IMPACT HUMAN HEALTH IN YORK REGION

There is strong, supportive scientific evidence that climate change will impact extreme heat events and heat-related illnesses, the spread and activity of vector-borne diseases and mental health impacts from extreme weather events. However, due to multiple mediating factors - environmental, behavioural and existing institutional - it is difficult to apply the research findings to York Region's context for other impacts such as food safety and security, water safety for drinking water and recreational beaches, air quality and extreme weather events, and their impact on disease and injuries (Table A).

Floodplains and urban heat islands are important local factors that can influence health risks from climate change. York Region floodplains can play an important role in multiple health impacts including food safety and security, water safety, mental health, injury and property damage. Current floodplain maps provide an understanding of river and lake flood risk in York Region with the largest area of the floodplain located in the major river systems connecting to Lake Simcoe (e.g. Holland Marsh and Black River). Other areas, such as significant groundwater recharge areas, may also be vulnerable as the soil and groundwater systems are more sensitive to heavy rainfall events. These impacts would be most relevant to smaller drinking water systems and private well users, which tend to be located in more rural communities.

Urban heat islands (UHI) can also play a significant role in intensifying extreme heat events. Urban areas and higher density suburban communities in York Region tend to have the greatest UHI impacts.

Table A. Overview of climate change health impacts within York Region

	Climate Drivers	Exposure Route	Potential Impacts on Human Health
 **Extreme Heat**	Increase in frequency and severity of heat events.	Elevated temperatures with larger impacts in urban heat islands. Decrease in cold days may reduce exposure to extreme cold conditions. **Areas most impacted by UHI include Richmond Hill, Markham and Vaughan.**	More heat-related illnesses and deaths and can contribute to other health outcomes. **From 2007 to 2017, there were 497 heat-related and 410 cold-related emergency department visits in York Region.**
 **Outdoor Air Quality**	Increase in temperature, changes in precipitation, and longer growing season.	Lead to poor air quality episodes, extended and more active pollen season and wildfire events creating smoke plumes. **York Region air quality has improved but more modelling is needed to determine future impacts.**	Increased respiratory and cardiovascular outcomes and premature deaths. **In recent years, common air pollutants have resulted in over 250 annual non-accidental deaths in York Region.**
 **Vector-Borne Infection**	Changes in precipitation, increased temperatures and longer growing season.	Longer seasons with greater vector activity and expansion of vectors range. **Blacklegged tick populations are increasing with most of York Region in an estimated risk area for Lyme disease.**	Increased risk to existing vector-borne diseases such as West Nile virus and Lyme disease, and the emergence of new diseases in Canada such as babesiosis, snowshoe hare virus. **Overall, Lyme disease activity has increased across Ontario with York Region experiencing 23 confirmed and probable cases in 2017.**
 **Water-Related**	Increase in precipitation, temperature, extreme precipitation and droughts.	Impact water sources, recreational beaches and risk of algal blooms. **Existing floodplains and significant groundwater recharge areas within York Region may be more impacted by heavy precipitation events.**	Potential increased risk of exposure to pathogens and contaminants in drinking water. **Most water- and foodborne illnesses in York Region show a seasonal trend, peaking during the summer months or early fall. However, it is difficult to determine what impact climate change will have in the future.[6]**
 **Food-Related**	Increase in precipitation, temperature, longer growing season, and extreme precipitation.	Impact growth and survival of foodborne pathogens and impact food security. **York Region has over 70,000 hectares of designated agricultural land and more than 3,000 food premises are inspected annually by Public Health.**	Increased risk of exposure to foodborne pathogens and risks to food insecurity, such as malnutrition. **Although the growing season in York Region is expected to increase by 30 days, it is difficult to determine how food safety and food security will be impacted locally.**
 **Extreme Weather**	Increase in extreme weather events such as extreme precipitation, flooding droughts and ice storms.	Major impacts on local infrastructure, disruptions of services and damage to residential properties. **Residents living in floodplains are at an increased risk from heavy precipitation and flooding events.**	Increased risk of injuries, death, mental health impacts and food- and waterborne disease outbreaks. **There is limited hospital data linked to extreme weather events in York Region.**

POPULATIONS VULNERABLE TO CLIMATE CHANGE

With the wide range of populations in York Region, the impacts of climate change will not be felt equally. In the context of climate change, vulnerable populations are those at greater risk for health impacts due to increased sensitivity, reduced capacity to respond and/or increased exposure. Seniors, children, those with low socioeconomic status, and those with mental health conditions have a higher vulnerability from multiple climate drivers and exposure routes (Table B). The proportion of seniors (65 years of age and older) in York Region is projected to increase to 20% by 2031.[8] Other vulnerable groups, such as new immigrants, also make up a large portion of York Region residents, particularly in the southern municipalities. A combination of factors (e.g. low socioeconomic status seniors with chronic disease), can also make certain individuals more susceptible to future climate change impacts.

It is important that health equity be considered for future adaptation planning. Building resiliency to climate change will require measures that address not only the needs of the general population but also those most vulnerable to climate-health impacts. It will require sufficient, accessible services and supports for those most impacted by climate change, and must be relevant for the diverse York Region population.

Currently, there is limited information on community resiliency related to climate-health impacts. While the current assessment provides valuable insight on how communities may better prepare for future climate change impacts, there is still limited information on perceptions and behaviours of local residents towards climate change and health and how these perceptions may differ between households and different climate-vulnerable populations.

Table B. Populations vulnerable to climate change impacts and York Region trends.

	Vulnerability to climate change[b]	York Region trends
 Children	Higher sensitivity to environmental exposures, behaviours that increase exposure risk and greater dependence on caregivers.	Children (0-15 years of age) represented around 20% of the population in York Region in 2016.[7]
 Seniors	Higher sensitivity to environmental exposures, more likely to have existing chronic diseases (e.g. cardiovascular disease) and increased risk of falls leading to fatal and non-fatal injuries.	York Region's senior population is growing faster than any other age group, with 1 in 5 residents predicted to be 65 years or older by 2031.[8]
 Low socioeconomic status (SES) individuals	Higher likelihood of suffering from chronic medical conditions. Reduced ability to adapt due to limited social support and/or financial resources. Tend to reside in areas with older infrastructure and increased exposure (e.g. urban heat islands).	Between 2000 and 2012, the number of low-income residents had grown faster compared to the overall population.[9]
 Recent immigrants	May speak limited or no English and/or French and have more barriers accessing community services related to climate change. May also experience lower SES compared to the general population and have greater exposure to climate change impacts.	Compared to Ontario, a larger portion of York Region new permanent residents had no ability to speak English or French in 2016.[10] New immigrants in York Region are more likely to be unemployed and have lower incomes compared to the general population.[11]
 Outdoor workers and activity	Likely to experience increased exposure to climate impacts (e.g., extreme heat, vector-borne diseases).	In 2016, there were approximately 130,000 people working in construction, manufacturing, accommodation and food service industry, and agriculture or primary industries in York Region.[12]
 Socially isolated individuals	Lack of social support and strong social networks, reducing adaptability and increasing susceptibility to climate change impacts.	Between 2011 and 2016, there was a 24% increase in the number of one person households in York Region, with 41% being seniors.[10]
 Individuals with existing chronic diseases	Increased susceptibility to environmental exposures such as temperature, poor air quality, vector-borne disease and food- and waterborne diseases.	Senior populations reported having relatively poorer health indicators such as perceived health, being overweight, arthritis and higher blood pressure.[12]
 Individuals with mental health conditions	Those with existing mental health conditions more likely to experience adverse mental health outcomes as a result of exposure (e.g. extreme heat). Extreme weather events can increase the risk of new cases of mental health illnesses.	Between 2012 and 2016 there was a 40% increase in mental health related calls to York Region Police and York Region Paramedic Services.[13]

[b] Note that individuals may fit into multiple categories that can increase their vulnerability.

ADAPTIVE CAPACITY: EXISTING SERVICES TO ADDRESS CLIMATE CHANGE HEALTH IMPACTS

York Region offers numerous programs and services that help address the current and future health impacts of climate change.

Early notification systems related to weather conditions

- Monitor extreme temperature or weather conditions and provide notification to the public and local stakeholders during periods of extreme heat and cold
- Monitor air quality alerts from the Ministry of the Environment, Conservation and Parks to provide notification to the public and local stakeholders

Provincially-mandated programs for addressing food and water impacts, and extreme weather events

- Conduct food and water safety inspections and investigations
- Emergency preparedness and response planning to address emergency events such as extreme weather

Surveillance programs that monitor diseases that can relate to climate change

- Surveillance activities for vectors and human cases of vector-borne diseases
- Surveillance programs that investigate infectious diseases related to food and water
- Conduct surveys on residents' behaviours and knowledge on various health issues

Health promotion activities that target topics and issues relating to climate change

- Vector-borne diseases promotional campaign Fight the Bite
- Extreme heat promotional material and resources
- Food safety promotional resources and campaigns to reduce or eliminate foodborne pathogen exposure
- Air Quality Health Index promotional material and resources

Regional Plans, initiatives, and strategies which support adaptation and address vulnerable populations

- Development of the Regional Climate Change Action Plan involving collaboration across York Region, local municipalities and communities
- The York Region Official Plan that includes important policies for incorporating health considerations into community design, such as adaptation measures for addressing urban heat islands and air quality
- The Regional Forest Management Plan and Greening Strategy that provide important measures for mitigating greenhouse gases and enhancing resiliency to climate change
- The Public Health Branch Mental Health Initiative which integrates mental health promotion into Public Health programs and services
- The Seniors Strategy, which examines the changing senior population, defines the Region's role in serving seniors, and sets the course for action to best support the aging population over the next 10 to 20 years

Stakeholders at provincial and federal levels are also invaluable in supporting local level resiliency and adaptation measures. Federal agencies such as Environment and Climate Change Canada provide weather information and climate modelling to support future planning (e.g., weather alerts, wildfire surveillance and climate change modelling), and federal health agencies (Health Canada and Public Health Agency of Canada) provide research and support to local health units. Provincial agencies such as the Ontario Ministry of Health provide protocols and guidelines for local health units that support addressing climate change health impacts. Additionally, Public Health Ontario provides research and assessment support on health impacts related to environmental exposures and provides direction to local health units on health surveillance needs based on national and provincial surveillance results.

STRENGTHS AND LIMITATIONS OF THE ASSESSMENT

This assessment provides a comprehensive overview of a wide range of potential climate change impacts on health. In particular, the strengths of the assessment include:

- Reviewing the latest research and data to understand impacts in York Region
- Highlighting local vulnerabilities and gaps in knowledge
- Identifying opportunities for future climate change adaptation planning

While this assessment provides valuable insight into climate change health risks for York Region, it also identifies multiple limitations:

- **Available scientific evidence**
  - Limitations in climate projection data including uncertainties in existing models predicting extreme weather events and uncertainties in future emissions
  - Limited evidence on more complex exposure pathways with multiple mediating factors such as food security, food and water safety and extreme weather events

- **Local information to better understand vulnerabilities in York Region**
  - Limited data on mediating environmental factors to climate change impacts - assessment of local air quality including pollen at a higher spatial resolution and updated floodplain maps that include urban flooding risk
  - Limited data to understand local population health and risk factors - health outcome data only focused on more severe cases such as hospital visits and admissions or limited information on vulnerability of private wells used for drinking water
  - Limited information on adaptive capacity - residents' knowledge, behaviours and barriers to adaptation measures

Many of the health outcomes have limited data available and are unable to be associated with a specific exposure route. Hospital and reportable diseases data are likely underestimating the health burden as many cases may go unreported or are challenging to link to climate change exposure route(s). Enteric disease rates provide an indication of potential food and water sources but attributing specific sources can be difficult. Similarly, asthma and allergies provide an

understanding of respiratory health outcomes but further analysis is needed to link climate change to local air quality health impacts.

Further analysis is required to help develop the most relevant indicators for future surveillance, including criteria for syndromic surveillance, and to model the future impacts of climate change on health. Future adaptation planning will need a strong understanding of the linkages between climate variables and health outcomes, such as heavy rainfall or flooding events with food- and waterborne illnesses, and extreme heat events with health outcomes such as mental health. Research has shown that many of these health outcomes may increase in volume and/or frequency, such as increased emergency room visits for heat-related illness due to longer and warmer summers.

Many of these datasets also involve other stakeholders such as diseases of public health significance and vector-borne disease surveillance from provincial Ministries or flood mapping from Conservation Authorities. As a result, it will be important to consult other agencies on available datasets and opportunities to advance data collection that can help inform future surveillance activities and better understand health impacts from climate change.

NEXT STEPS: ADAPTATION PLANNING FOR MORE RESILIENT COMMUNITIES

"Tackling climate change could be the greatest global health opportunity of the 21st century."[14]

Lancet Commission on Health and Climate Change

Following the next steps of the World Health Organization framework, this vulnerability assessment will help guide and inform adaptation planning to build resiliency to future climate change health impacts. There are also opportunities to align public health adaptation planning measures with existing initiatives such as the Regional Climate Change Action Plan, which covers mitigation and adaptation at a community and corporate level.

Health adaptation planning involves multiple approaches:

- Further research and analysis to better understand impacts and climate-vulnerable populations within the Region
- Establishing integrated, ongoing climate change and health surveillance
- Coordinating programming and collaborating with key stakeholders across sectors
- Health promotion activities
- Developing policies and measures that support climate change mitigation and adaptation

As conditions that increase or decrease vulnerability can change over time, adaptation needs to be an iterative approach that can adjust measures to different future scenarios.

Adaptation planning requires all levels of government, stakeholders and the community to work collaboratively to address future impacts from climate change. Ensuring a resilient

system will require activities from public health and stakeholders that are directly engaged with vulnerable populations (e.g. long-term care homes, community support organizations, schools, child care centres), and stakeholders addressing exposure routes (e.g. Conservation Authorities and water safety and emergency planning for extreme weather events).

Climate change is one of the most important public health challenges of this century but it also presents a public health opportunity. Addressing climate change health impacts can also provide important co-benefit opportunities:

- Climate change mitigation - reducing air pollutants that are also greenhouse gases
- Supporting other public health issues - built environment, health equity, healthy living
- Better engagement and collaboration with stakeholders such as community partners
- Supporting implementation of Regional Official Plan policies
- Supporting York Region initiatives - Health Equity program, Seniors Strategy, Greening Strategy and others

Addressing future impacts of climate change will present a public health opportunity to address multiple factors impacting human health including extreme temperatures and weather, water and food safety, vector-borne diseases, air quality and emergency preparedness. It is imperative for public health to continue its efforts to address the future health impacts of climate change to support the creation of more resilient communities in York Region.

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Acronyms

AAQC	Ambient Air Quality Criteria
ACES	Acute Care Enhanced Surveillance System
ADD	Accumulated degree days
AQHI	Air Quality Health Index
AR5	IPCC Assessment Report 5
CA	Conservation Authority
CANGRD	Canadian gridded data
CCHS	Canadian Community Health Survey
CCHVA	Climate change and health vulnerability assessment
CDC	United States Centers for Disease Control and Prevention
CFIA	Canadian Food Inspection Agency
CHS	York Region Community and Health Services
CO_2	Carbon dioxide
COPD	Chronic obstructive pulmonary disease
CPI	Consumer Price Index
DALYs	Disability-adjusted life years
ECCC	Environment and Climate Change Canada
ED	Emergency department
EHE	Extreme heat events
EEEV	Eastern equine encephalitis virus
EMCPA	*Emergency Management and Civil Protection Act*
GHG	Greenhouse gas
GTA	Greater Toronto Area
HGA	Human granulocytic anaplasmosis
HHWIS	Harmonized heat warning and information system
HIRA	Hazard Identification and Risk Assessment
HPPA	*Health Protection and Promotion Act*
HRI	Heat-related illness
HUS	Hemolytic uremic syndrome
IMS	Incident Management System
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization

LSRCA	Lake Simcoe Region Conservation Authority
LTCH	Long-term care home
MECP	Ontario Ministry of the Environment, Conservation and Parks (Formerly known as Ministry of the Environment and Climate Change (MOECC))
MNRF	Ontario Ministry of Natural Resources and Forestry
MOH	Ontario Ministry of Health (Formerly known as Ministry of Health and Long-Term Care (MOHLTC))
NO_x	Nitrogen oxides
O_3	Ground-level ozone
OCC	Ontario Climate Consortium
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
OPHS	Ontario Public Health Standards
PHAC	Public Health Agency of Canada
PHO	Public Health Ontario
$PM_{2.5}$	Fine particulate matter
ppb	Parts per billion
ppm	Parts per million
PTSD	Post-traumatic stress disorder
QMRA	Quantitative Microbial Risk Assessments
RCP	Representative Concentration Pathway
RECG	Regional Emergency Control Group
RRFSS	Rapid Risk Factor Surveillance System
SES	Socioeconomic status
SDOH	Social determinants of health
SDWS	Small drinking water systems
SGRA	Significant groundwater recharge areas
SO_2	Sulphur dioxide
T_{max}	Maximum daily temperature
T_{min}	Minimum daily temperature
TRCA	Toronto and Region Conservation Authority
UHI	Urban heat island
UVR	Ultraviolet radiation (solar)
VBD	Vector-borne disease
VOC	Volatile organic compound

VTEC	Verotoxin producing *E. coli*
WHO	World Health Organization
WNV	West Nile virus
YRPH	York Region Public Health

CHAPTER 1
Introduction

1.0 Introduction

"Climate change will be the defining issue for health systems in the 21st century. Health professionals have the knowledge, cultural authority and responsibility to protect health from climate change."[1]

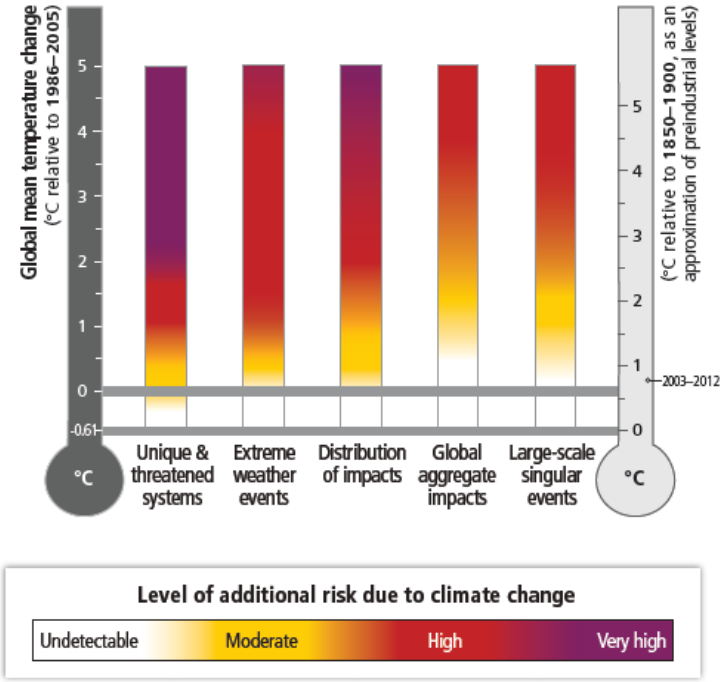
World Health Organization

Climate change is unequivocally happening and its impact poses severe risks to the natural environment and human populations worldwide. The Intergovernmental Panel on Climate Change's (IPCC) most recent assessment report (AR5) involved contributions and reviews of thousands of published research studies from more than 400 leading scientists. The report showed overwhelming evidence on the numerous ways that climate change is impacting the environment and society and how these impacts are expected to worsen in the future if actions are not taken to dramatically reduce greenhouse gas (GHG) emissions.[2]

The impacts of climate change are already observable today with strong evidence of changes to human, biological and physical systems.[2] The last three decades have been successively warmer at the Earth's surface than any other decade since the 1850s.[3] Certain regions have noticed more frequent extreme heat conditions, with the risk of heat events in Europe increasing four-fold from 1999 to 2008 due to climate change.[2]

Addressing climate change will involve mitigation and adaptation: The severity of climate change impacts on society and the natural environment greatly depends on the amount of GHG emissions released and subsequent temperature increases. For example, there is an increased risk of extreme weather events occurring when the global mean temperature increases 1 to 2°C compared to 1986 to 2005 (Figure 1.1). [2]

Figure 1.1. Summary illustrating how rising temperatures relate to risk for different natural and human systems. [c]



Source: Intergovernmental Panel on Climate Change. Climate change 2014: Impacts, adaptation, and vulnerability Part A: Global and sectoral aspects [Internet]. U.S.A.: Cambridge University Press; 2014. Assessment Box SPM.1 Figure 1, A global perspective on climate-related risks; p.13. Available from: https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf. Reproduced with permission from the copyright holder.

While mitigation efforts to reduce GHG emissions remain an essential component to address climate change, countries must adapt as certain impacts are no longer avoidable. Governments and communities need to prepare for climate impacts to minimize and/or eliminate risks from climate change.

Recent assessments highlight the need for greater coordination across sectors to build a more resilient, responsive and adaptive system. The IPCC defines climate change resilience as **"The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation."**[3] Building resiliency requires a better understanding of the impacts of climate change and engaging with key stakeholders in adaptation planning.

[c] **Unique and threatened systems** refers to cultures and ecosystems that are at risk. **Extreme weather events** refer to events such as extreme precipitation, heat waves, and coastal flooding. **Distribution of impacts** refers to uneven distribution of impacts to vulnerable groups including in developed countries. **Global aggregate impacts** refer to overall losses such as biodiversity and its impact on ecosystem services and goods. **Large-scale singular** events refer to abrupt or irreversible changes to physical and natural systems such as ice sheet disintegration, or long-term drought conditions (IPCC, 2014).

Climate change impacts on human health

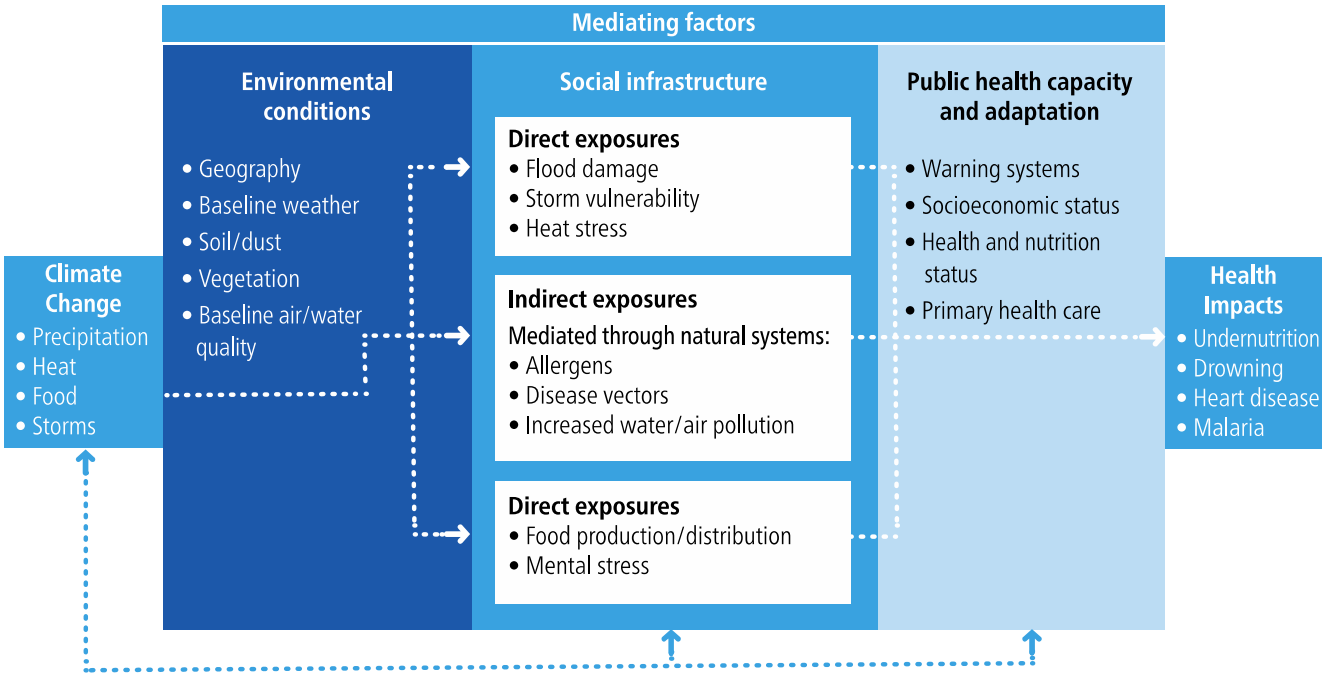
Since the release of the first IPCC assessment report in 1992, there has been a substantial increase in studies on the future impacts of climate change on society and human health. In addition to the IPCC reports, Canada and the United States have led assessments focused on the human health implications of changing climates in North America.[4,5] Both assessments highlighted the various ways in which climate change can impact human health including:[5]

- Warming temperatures leading to longer summers, which can result in an increased risk of extreme heat events and heat-related illnesses
- Longer growing seasons, which increase the risk and expansion of vector-borne diseases such as Lyme disease, West Nile virus and others
- Air quality impacts from longer growing seasons and associated pollen allergens, and forest fires that can result in the movement of wildfire smoke across large areas
- Extreme weather events that can result in significant damage to infrastructure and homes, injury, mental health stress, illnesses and disruption to health services
- Heavy precipitation and flooding events that can result in impacts on drinking water systems and recreational beaches

The extent to which climate change ultimately impacts human health will depend on various factors. Figure 1.2 illustrates how health impacts will also depend on mediating factors including the environmental context, social infrastructure and public health's ability to respond and adapt.

Some pathways may be more direct, such as extreme temperatures contributing to heat-related stress, while others will impact health indirectly by influencing natural and built environments and/or social conditions, such as flooding events that impact homes and mental health. Certain populations may also be more vulnerable to impacts of climate change due to their socioeconomic condition or sensitivity to certain climate pathways, such as seniors who are more vulnerable to heatstroke.

Figure 1.2. Mediating factors between climate change and health impacts.

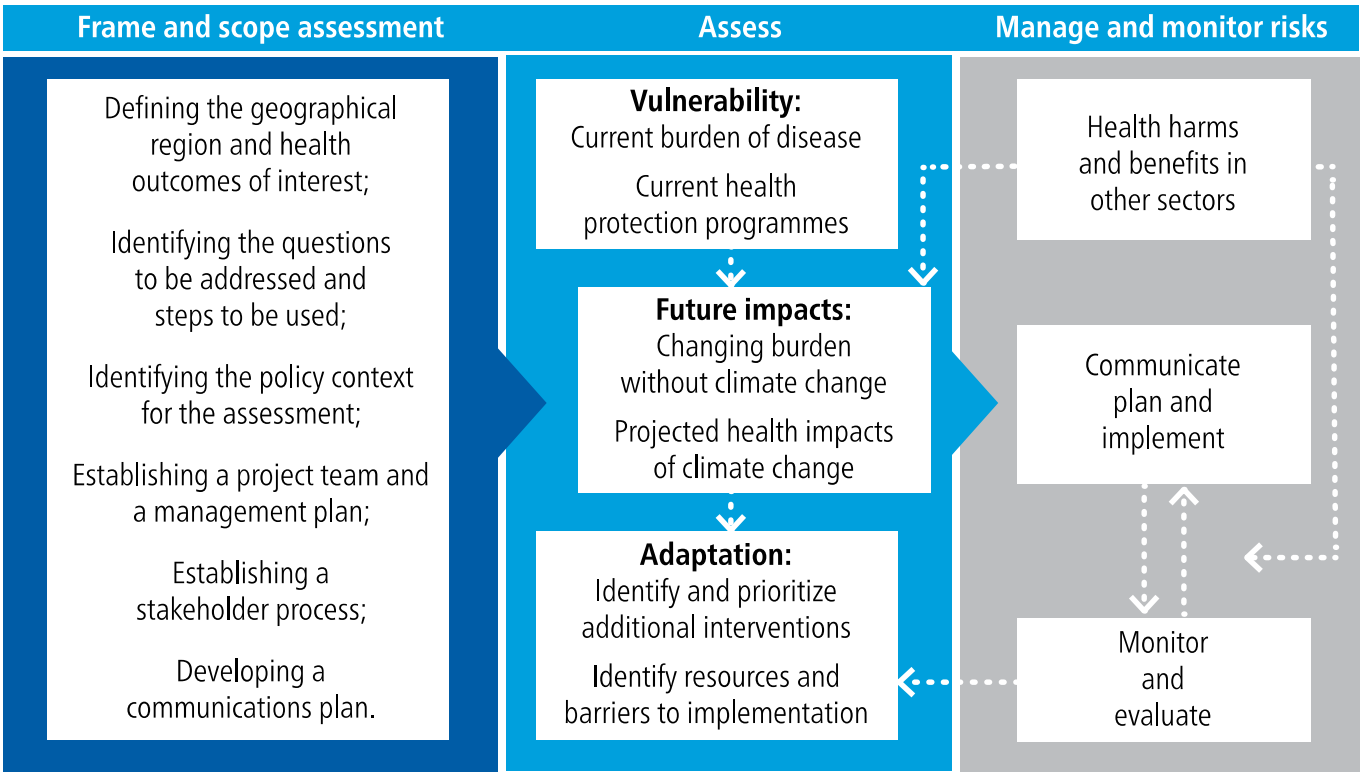


Source: Intergovernmental Panel on Climate Change. Climate change 2014: Impacts, adaptation, and vulnerability Part A: Global and sectoral aspects [Internet]. U.S.A.: Cambridge University Press; 2014. Fig 11-1, Mediating factors; p.716. Available from: https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-PartA_FINAL.pdf. Reproduced with permission from the copyright holder.

PURPOSE OF THE REPORT

The purpose of the Climate Change and Health Vulnerability Assessment (CCHVA) is to inform adaptation planning to build climate resiliency and reduce health risks associated with climate change in York Region. Recognizing the significant challenges that climate change presents on human health, York Region Public Health conducted a CCHVA. Completion of the CCHVA also serves to meet the Ontario Public Health Standards' requirement to assess the health impacts of climate change at a local level. This report follows the six-step process outlined in the Ontario Ministry of Health (MOH*)* **Ontario Climate Change and Health Toolkit**[6] and the framework[7] developed by the World Health Organization (WHO) on adapting to future climate change health impacts outlined in Figure 1.3.

Figure 1.3. Climate change and health vulnerability and adaptation assessment framework.



Source: World Health Organization. Protecting Health from Climate Change: vulnerability and adaptation assessment [Internet]. Geneva. WHO; 2013. Figure 2 Vulnerability and adaptation assessment p. 5. Available from: https://apps.who.int/iris/bitstream/handle/10665/104200/9789241564687_engpdf?sequence=1&isAllowed=y. Reproduced with permission from the copyright holder.

The **objectives** of this report were to:

- Identify and assess climate change health impacts relevant to York Region
- Determine populations vulnerable to climate change in York Region
- Identify existing services, programs and policies that support adaptive capacity in York Region
- Identify gaps and opportunities for future consideration in adaptation planning

Assessing climate change health impacts specifically for York Region will provide a better understanding of the key issues and opportunities for local action. This will include the engagement of relevant stakeholders to determine adaptation measures required to build resiliency to climate change.

York Region has also initiated a Regional Climate Change Action Plan that brings together Regional departments, local community members and external partners to strategically address the impacts of climate change. The Action Plan focuses on corporate and community level activities and covers adaptation and mitigation. York Region Public Health will align future adaptation planning with the Action Plan process.

CHAPTER 2
Methods

2.0 Methods

Various topic areas were considered as part of step one - **framing and scoping the assessment**. As the goal of the assessment was to inform future adaptation planning and help develop greater resiliency to climate change, it was necessary to explore a wide range of topic areas. The scope was based on topics identified in the Ministry of Health (MOH) toolkit, key resources such as the Health Canada climate change and health assessment[4] and vulnerability assessments completed by other health units in Ontario.[8,9]

The final scope of health topics covered in this assessment include the following:

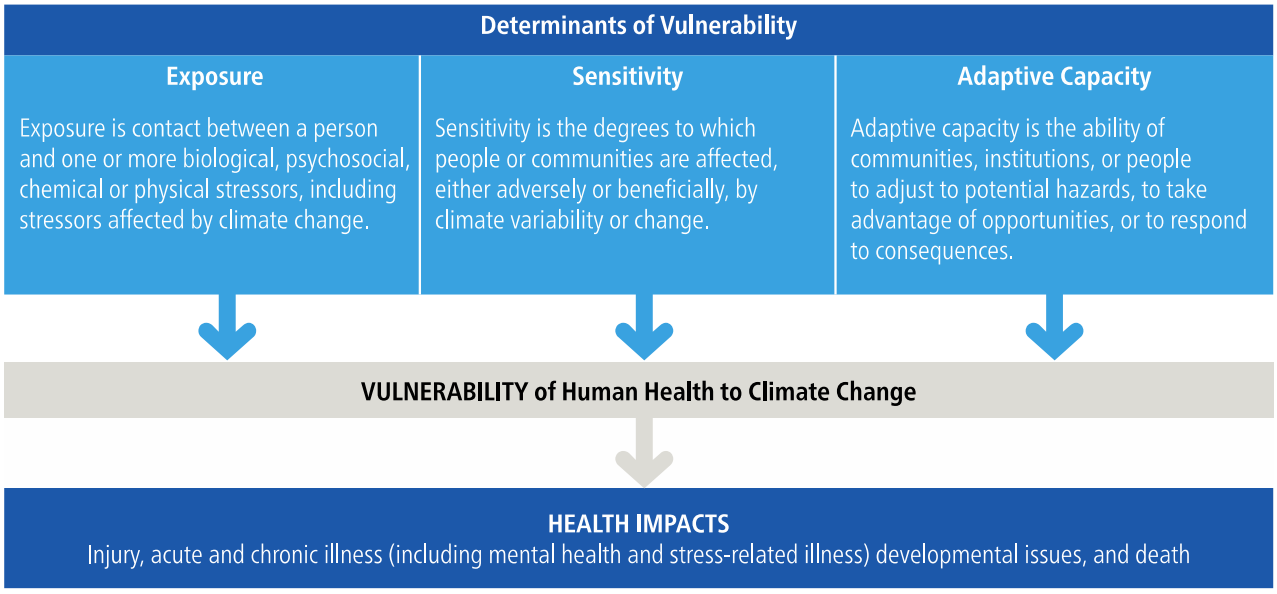
- Extreme temperatures
- Extreme weather events
- Air quality
- Vector-borne disease
- Water safety
- Food safety and food security

Step two - **assessing current health outcomes and programs**, was completed by summarizing key impacts from available research and relevant York Region data. This provided a baseline understanding of climate pathways impacting health, health outcomes and existing programs that support adaptive capacity within York Region.

Step three - **estimating future health outcomes from climate change**, was generally out of scope due to data and resource limitations in the available scientific evidence and resources. Future health impacts from climate change noted in the literature were included if relevant and generalizable to the context of York Region.

When assessing climate change impacts on health, three determinants of vulnerability were considered: Exposure, sensitivity and adaptive capacity (Figure 2.1).

Figure 2.1. Determinants of vulnerability for climate change health impacts.

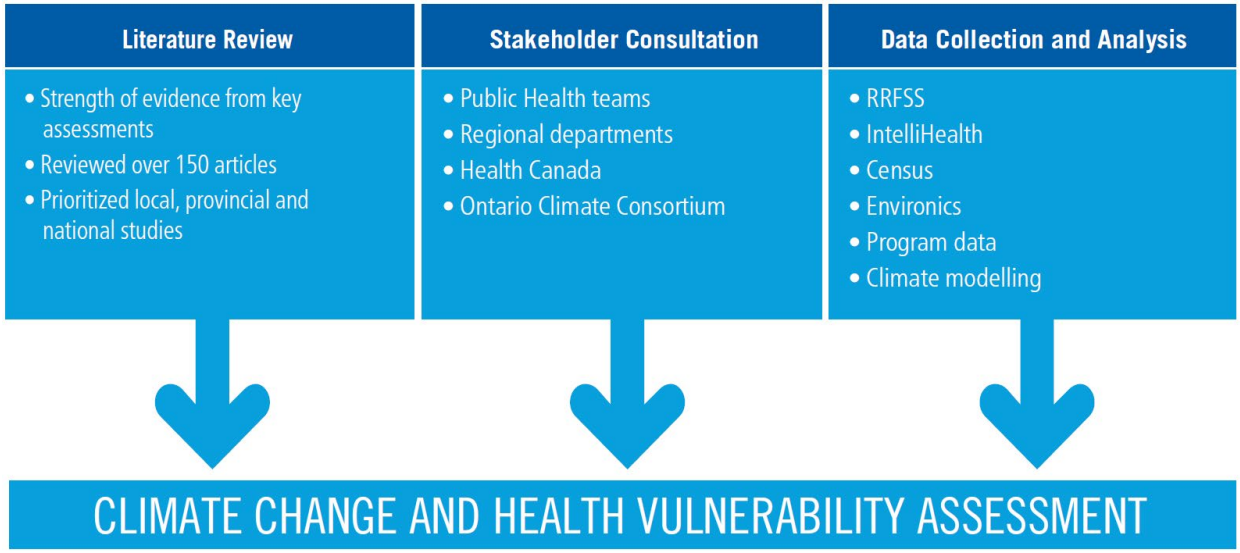


Source: Gamble JL, Balbus J et al. Ch. 9: Populations of concern. In The impacts of climate change on human health in the United States: a scientific assessment [Internet]. Washington: U.S. Global Change Research Program; 2016. Fig ES10, Determinants of vulnerability; p.250. Available from: https://health2016.globalchange.gov/. Reproduced with permission from the copyright holder.

In the report, the determinants are considered for each topic area and provide insight into the specific climate change health impacts in York Region. The focus of these components is on community impacts within York Region.

Multiple sources of information were reviewed and assessed to inform these components and to help better understand the health impacts of climate change in the Region. Information was collected by reviewing relevant academic and grey literature, public and private datasets and gathering feedback from stakeholders (Figure 2.2). The intent of the assessment is to present relevant information to support adaptation planning. Tables at the end of each chapter provide a summary of existing measures and opportunities to consider that can inform future adaptation planning activities.

Figure 2.2. Examples of research, data and information that informed the vulnerability assessment process.



Literature review

York Region Public Health conducted a literature review of scientific articles and grey literature. The literature review was not intended to be comprehensive; rather, it was completed to provide a better understanding of critical issues and factors contributing to vulnerability for each topic area. Additionally, the literature review focused on identifying articles that included climate change health impacts investigated in or significant to York Region.

Relevant grey literature was reviewed from Ontario health units, Public Health Ontario, the Public Health Agency of Canada, Health Canada, United States Environmental Protection Agency and Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO). Grey literature sources such as the Health Canada assessment[4], the U.S. Climate Change and Health scientific assessment,[5] and the IPCC AR5 report[2] assessed the strength of evidence based on more comprehensive literature reviews and/or development of consensus from expert opinions.

The National Institute of Environmental Health Sciences Climate Change and Health Portal was used to search for peer-reviewed studies published between 2007 and 2014 that were relevant to topic areas covered in this assessment, and geographic regions comparable to York Region, such as the Northeastern United States. Article abstracts were then reviewed for relevance to health impacts in York Region.

Additional searches through Google Scholar filtered for studies from 2015 to 2017. Emphasis was placed on publications that assessed climate change impacts in Ontario or studies from similar temperate conditions in North America such as the Northeast U.S. Health Canada was also consulted regarding the assessment process, and provided relevant and more recent articles to

help support the assessment. In total, approximately 150 articles from grey literature and academic studies were reviewed.

Local datasets relevant to York Region

While the literature review provided a stronger understanding of the key issues and evidence for climate change and health impacts, few studies were available to provide a sufficient local context. As a result, multiple datasets were explored to provide a greater perspective on vulnerabilities in York Region. This included reviewing federal, provincial and local municipal datasets relating to climate factors, vulnerable populations and adaptive capacity.

Stakeholder engagement

In addition to the literature and local data reviewed, Regional staff was consulted on various topics. This involved consulting with public health teams most relevant to the topic areas (Safe Water, Food Safety, Nutrition, Vector-Borne Disease, Healthy Environments, Healthy Living staff involved with vulnerable populations and Health Emergency Planning). Other departments within York Region were also consulted regarding issues such as impacts to water and natural systems. The consultations provided important information regarding existing capacities and additional datasets that could be considered for the assessment, as well as expert opinion regarding potential climate change impacts in York Region.

2.1 SCOPE OF THE ASSESSMENT

Geography

This report assessed climate change impacts in all of York Region's nine local municipalities. However, due to limitations of the spatial resolution of climate projection data, climate modelling data could not be distinguished between sub-regions. For certain topics, differences between rural/agricultural and urban/suburban areas are highlighted to illustrate differing impacts.

While international climate change impacts can contribute to local health outcomes (e.g., travel of residents and transportation of goods spreading vectors and diseases; contaminated food imported from international sources), these impacts were deemed out of scope for this assessment.

Timeframes

Multiple time periods were used for this assessment; where possible, the most current dataset was used. As climate models are well established, climate driver information was available for the 2050s and 2080s. In particular, climate change projections into the 2050s were primarily used as future planning will likely be revisited within this timeframe.

Due to limitations of resources and available evidence, health outcomes are generally presented as baseline data and health risk factor data ranging from 2000 to 2018 depending on topic areas.

Population projections were limited to the 2030s and 2040s due to limited reliability of population projection data beyond that date. Where possible, information on vulnerable populations, such as future population projections, was used to provide context on how populations may grow and shift within York Region.

Climate change projections

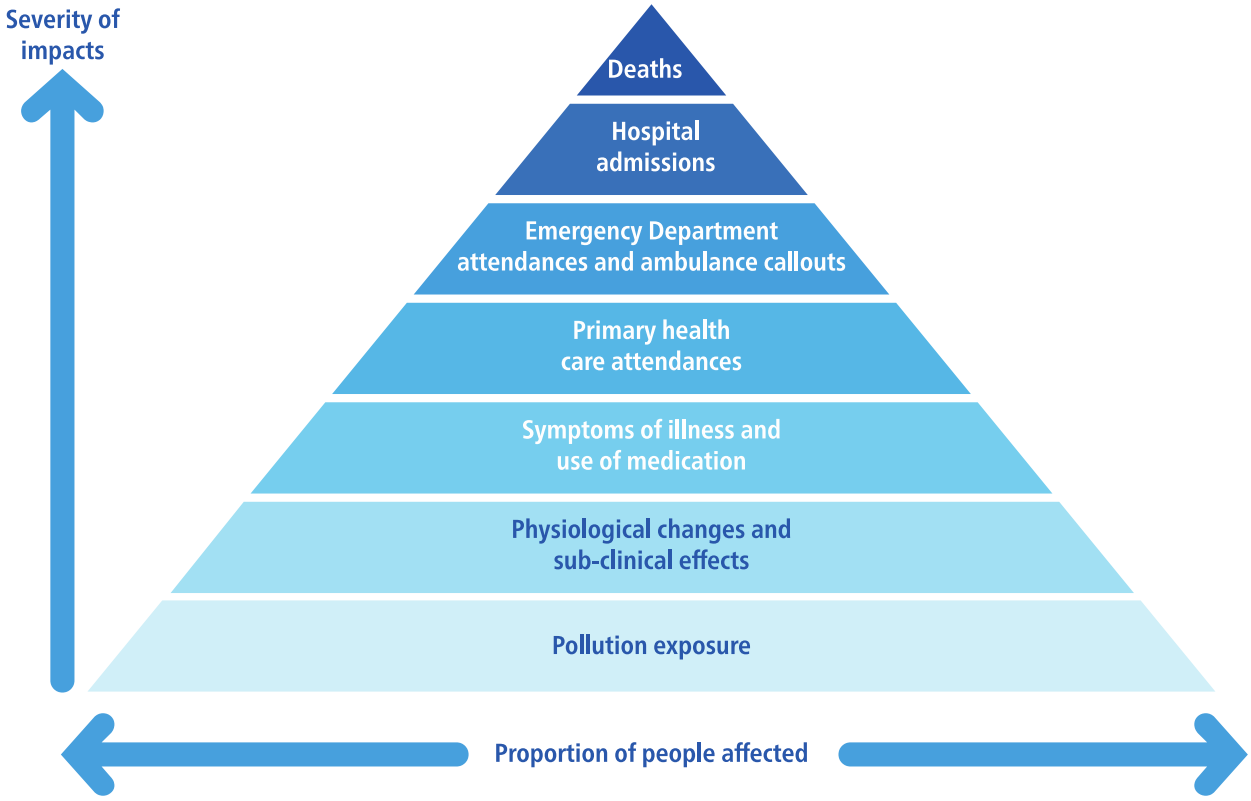
Climate drivers considered in this report are based primarily on the Ontario Climate Consortium (OCC) assessment of future climate change trends in York Region[10] and additional information from the MOH toolkit.[11] The OCC assessment uses Representative Concentration Pathway (RCP) 8.5[d] scenario and involves multiple projection models (Ministry of the Environment, Conservation and Parks Climate Change Data Portal Dataset; York University Laboratory of Mathematical Parallel Systems Dataset; University of Wisconsin Dynamically Downscaled Regional Climate Models; and Specialists in Energy, Nuclear and Environmental Sciences Consultants' Toronto Region dataset). Additional projection information from the MOH toolkit or academic studies was also considered, which used the RCP 8.5 pathway scenario. Due to the spatial resolution of climate models (25 km^2 or 50 km^2), geographical differences in climate projections across York Region were not included.

Health outcomes

Health outcomes were included based on the literature review and information in the MOH toolkit.[6] The following datasets were considered in the assessment: Emergency department visits (e.g., heatstroke, or injuries); emergency department triage (e.g., heat or air quality related symptoms); and diseases of public health significance, which are part of provincial Integrated Public Health Information System (iPHIS) surveillance programs (e.g., enteric diseases and vector-borne diseases). It is important to note these datasets likely underestimate the burden of illness. As illustrated in the pyramid of effects (Figure 2.3) mortality and morbidity cases relating to hospital visits or diseases of public health significance are reflective of more severe impacts and a smaller portion of the population. Local hospital data analyzed focused on morbidity, while mortality and hospital admissions were mostly based on published studies that analyzed health outcomes related to weather variables or vulnerable populations.

[d] RCP 8.5 is the greenhouse gas concentration scenario created by the IPCC based on the assumption emissions continue as usual. RCP 8.5 continues to show growing emissions continuing until the end of the twenty-first century.

Figure 2.3. Pyramid of effects.



Source: Adapted from Melody SM, Johnston FH. Coal mine fires and human health: what do we know? Int J Coal Geol. [serial online]. 2015; 152(B):1-14. Fig 5, The air pollution pyramid; p. 6. Available from: https://www.sciencedirect.com/science/article/pii/S0166516215300707. Reproduced under the terms of the Creative Commons Attribution-NonCommercial-No Derivatives License (CC BY NC ND).

While there are limitations with these datasets, they were selected as they provide a baseline of health outcomes that can also inform future surveillance and monitoring plans. As noted previously, estimating future health outcomes was out of scope for this report due to available resources and uncertainties in the literature.[11]

Populations assessed

This report focused primarily on individuals residing in York Region. For certain health topics, individuals working or visiting York Region were also considered (e.g., individuals working outside and visitors to recreational beaches). To better understand the impacts of climate change, the assessment also considers populations most vulnerable and with limited adaptive capacity. Vulnerable populations were identified in the MOH toolkit[6] and academic literature. Populations may be vulnerable because of social determinants of health (SDOH) such as socioeconomic status, demographic factors, and/or behavioural factors. Available data on York Region populations related to climate impacts were included from multiple sources, particularly the 2016 Census Survey, the Canadian Community Health Survey (CCHS), and the Rapid Risk Factor Surveillance System (RRFSS) survey.

CHAPTER 3
York Region Context

3.0 York Region Context

York Region and its nine local municipalities are part of the Greater Golden Horseshoe in southern Ontario (Figure 3.1). The Region stretches north from Toronto to Lake Simcoe, covering an area of 1,762 square kilometres. Over 1 million people reside in its nine local municipalities: Aurora, East Gwillimbury, Georgina, King, Markham, Newmarket, Richmond Hill, Vaughan and Whitchurch-Stouffville. Approximately 38% of York Region area is dedicated to farming activities while 25% are urban areas.[12]

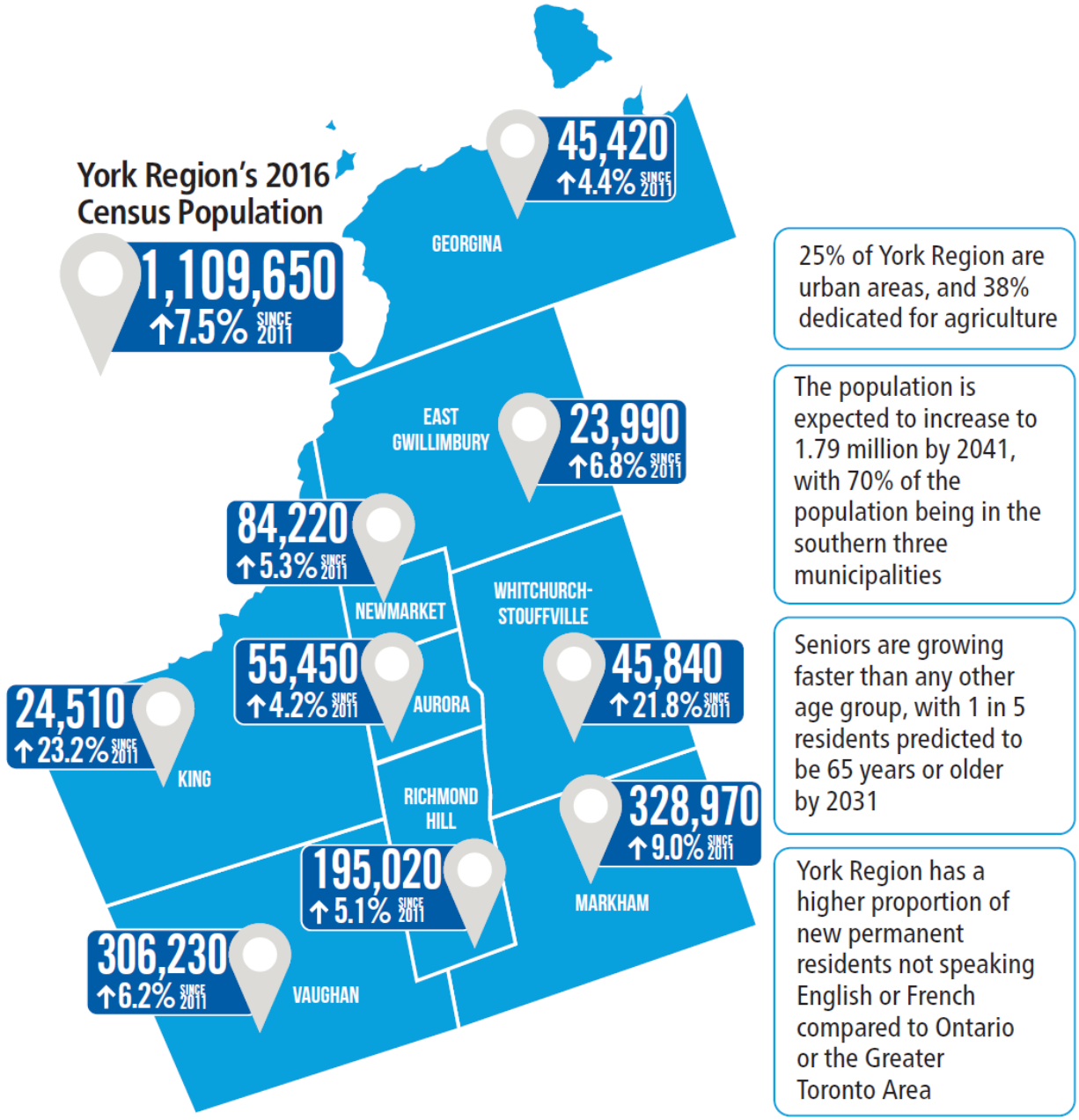
York Region is growing at a faster rate than the national and provincial averages. From 2011 to 2016, its population increased by 7.5%.[13] In 2016 it was home to 1,109,650 residents, with a population density of 629.9 people/km^2. The population of York Region is projected to increase to 1.79 million by 2041,[14] and approximately 70% of which is expected to occur in the Region's southern municipalities of Markham, Vaughan and Richmond Hill. York Region's growing population is also aging and diversifying with an influx of new permanent residents to Canada. The population in 2041 is expected to have a lower proportion of the population between ages 40 and 59 (~31 to 24.2%) but an increase in the proportion of the population above the age of 70 (~9.5% to 18.7%).

The two major landforms in York Region are the Oak Ridges Moraine and the Lake Simcoe Basin. The Oak Ridges Moraine is a massive ridge formed from glacial deposits constituting of gravel and sand. It crosses through the middle of York Region, covering approximately 31% of the geographical area. Much of the Region also includes the protected areas of the Greenbelt Protection areas and Oak Ridges Moraine (which covers 69% of the geographical area).

The Lake Simcoe basin consists of sandy and swampy lowlands which covers Georgina and East Gwillimbury. Some of the major river and stream systems feeding into Lake Simcoe include the Holland River and Black River. These river and wetland systems are areas of focus for riparian flooding events. The Oak Ridges Moraine runs through parts of Markham, Whitchurch-Stouffville, Newmarket, East Gwillimbury, Aurora, Richmond Hill, Vaughan and King.

York Region currently falls in the jurisdiction of two conservation authorities who are involved with local conservation and water protection, Lake Simcoe Region Conservation Authority in the north and the Toronto and Region Conservation Authority in the south.

Figure 3.1. York Region population trends and land use



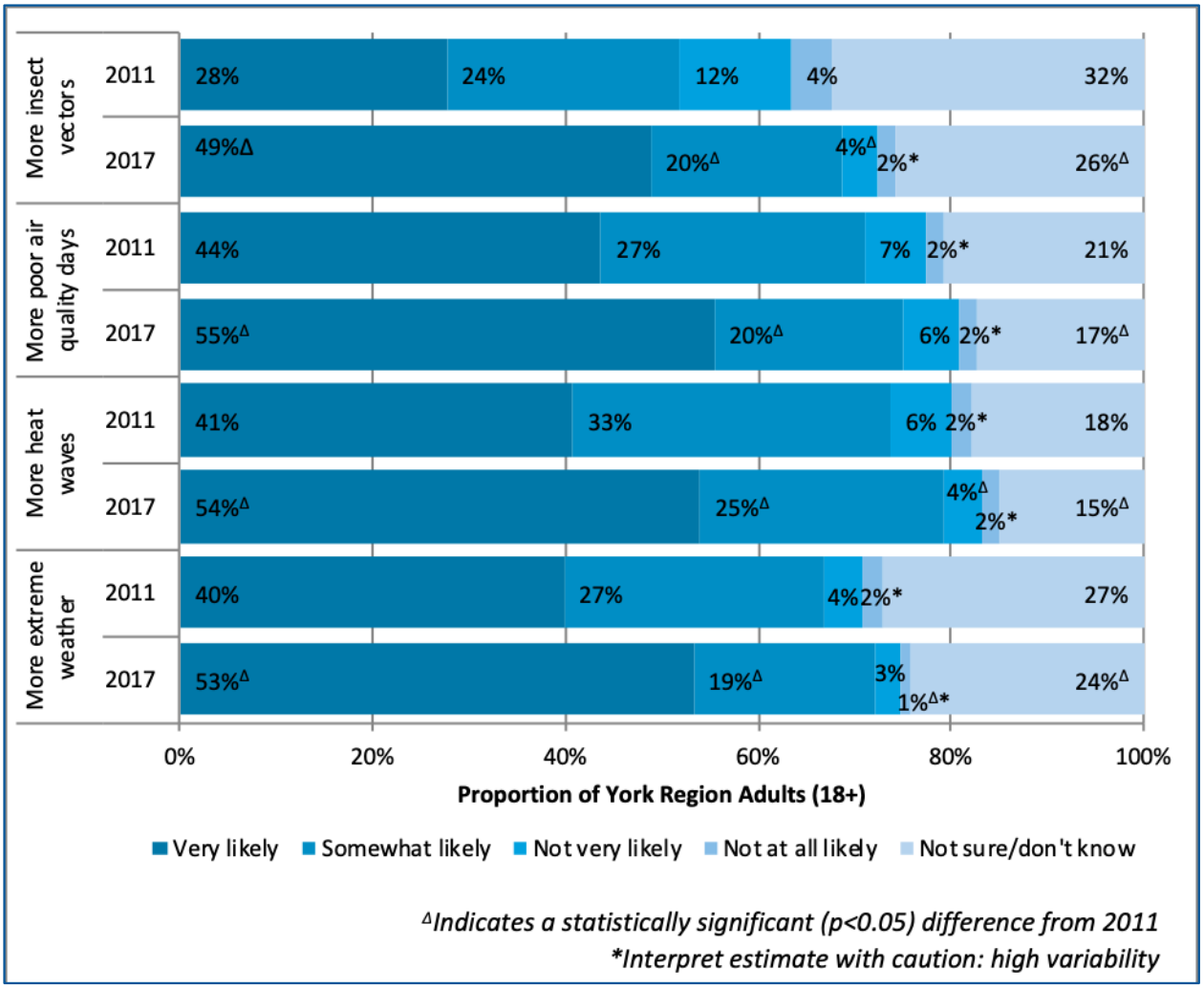
Sources: Regional Official Plan (link); 2041 population and employment forecasts (link); York Region Seniors Strategy (link); and New Permanent Residents in York Region, 2010-2014 (link)"

York Region residents increasingly recognize the impacts of climate change on communities and health. In a survey of 809 York Region residents conducted by Environics Research, 35% of respondents believe climate change is negatively affecting their community

now,[15] while 56% of respondents believe climate change is not currently affecting their community, but will in the future. [15]

Additional surveys have also been done on the impacts of climate change and human health risk. Telephone surveys were conducted in 2011 and 2017 asking residents which climate change health impacts were more likely to occur in York Region (Figure 3.2). Comparing survey results from 2011 and 2017, there was a substantial increase in the perception that climate change is very likely to impact the health risk within their community. The largest increase was for residents who believe insect vectors are very likely to increase due to climate change from 28% in 2011 to 49% in 2017. Only 51% of respondents believe York Region is somewhat prepared to deal with climate change.[16]

Figure 3.2. York Region residents' perception of the likelihood of climate change impacting their local community through increases in insect vectors, poor air quality days, heat waves and extreme weather in 2011 and 2017.



Data source: Rapid Risk Factor Surveillance System (RRFSS), 2011 & 2017. Regional Municipality of York, Community and Health Services.

3.1 HOW CLIMATE CHANGE WILL IMPACT YORK REGION

"Canada's climate has warmed and will warm further in the future, driven by human influence."[17]

Canada's Changing Climate Report, 2019

York Region is located in the Lake Simcoe-Rideau Ecoregion, which is characterized by a mild and moist climate.[18] This Ecoregion has a mean annual temperature range of 4.9°C to 7.8°C, a growing season of 205 to 230 days, mean annual precipitation of 759 to 1,087 mm, and mean summer rainfall of 198 to 281 mm.[19,20]

In recent decades, York Region has experienced increases in average temperature and precipitation. From 1948 to 2016, there was an increase of approximately 1°C and 2°C in the mean daily temperature for summer months and winter months respectively. Total precipitation increased by approximately 10% between 1948 and 2012.[21]

York Region has also experienced climate extremes and adverse impacts from extreme weather events. This includes ice storms, record-breaking mild temperatures in winter, record-breaking snowfall, very hot summers and intense rainfall events leading to flooding and drought.[10]

CLIMATE CHANGE FORECASTS IN YORK REGION

Climate change is expected to impact York Region in multiple ways (Figure 4.1). In 2016, the Ontario Climate Consortium completed a Historical and Future Climate Trends in York Region report. It used a Representative Concentration Pathway (RCP) 8.5[e] scenario and involved multiple projection models.[10] The following projections were noted in the Fausto et al. report for impacts into the 2050s:[10]

- **Annual and seasonal temperatures are very likely (90 to 100% probability) to increase in York Region.** During the summer months, extreme temperatures will increase significantly. Fausto et al. predict the mean annual temperature in York Region of 7°C will increase by 3.3°C in the 2050s. This will contribute to a substantial increase in the frequency of warmer daytime temperatures and tropical nights. The most pronounced average temperature increases are expected during the summer and winter, increasing by 3.6 to 4.0°C, and by 3.7 to 3.9°C, respectively. Warmer winter temperatures will also increase the amount of precipitation as rainfall during the winter season.
- **Cold temperatures are very likely (90 to 100% probability) to decrease but existing models do not account for shifts in the polar jet stream.** The number of days below -5°C is expected to decrease by 31 to 37 days per year from the baseline of 84 days by

[e] RCP 8.5 is the greenhouse gas concentration scenario created by the IPCC, based on the assumption that emissions continue as usual. RCP 8.5 shows growing emissions continuing until the end of the twenty-first century.

the 2050s. Projections for the number of days below -20˚C suggest a decrease of 0.5 to 4.9 days from the historical annual average of eight days.

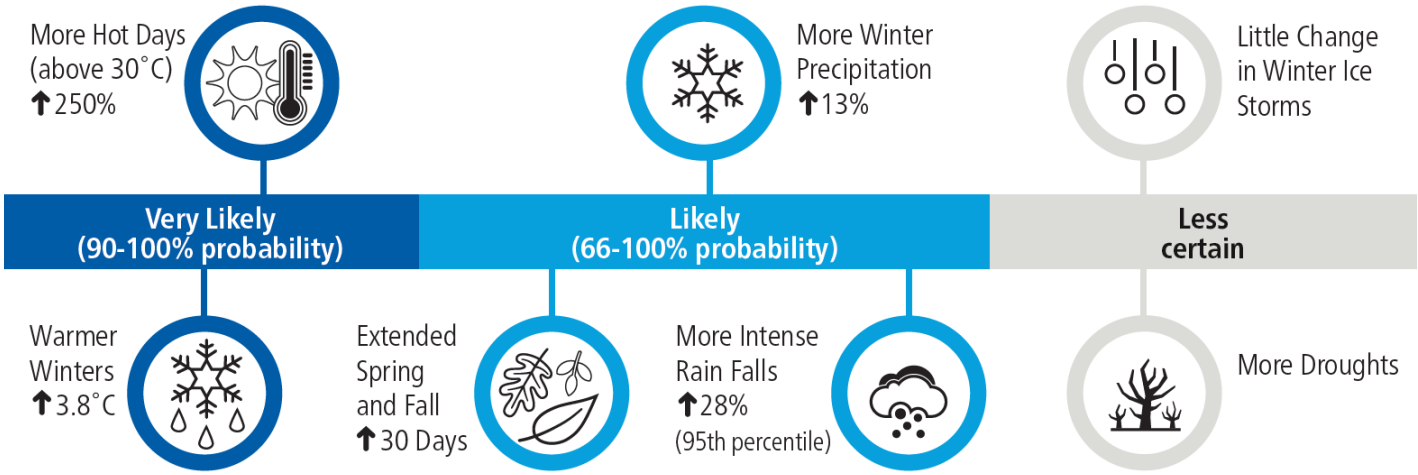
- **Precipitation levels will likely increase (66 to 100% probability) annually but levels in summer and fall are not expected to change significantly.** Annual precipitation levels in York Region are expected to increase an additional 48 to 70 mm[f] by the 2050s. This rise will be driven by increased total precipitation in the winter and spring. Precipitation levels for summer and fall are projected to remain similar to historical values.
- **Extreme precipitation events[g] are likely to increase in frequency and magnitude, particularly during the summer months (66 to 100% probability).** While it is unclear if the intensity[h] of extreme precipitation events will increase in the future, projected increases in temperature and moisture in the atmosphere could lead to an increased number of extreme precipitation events, particularly during the summer.
- **The growing season will likely be extended by approximately 30 days per year (66 to 100% probability).** In the past, the growing season in York Region generally occurred from May 17 to October 15. In the future, warming temperatures are expected to lead the growing season to begin potentially in early April and last into late November.
- **Drought conditions may become more common due to unchanging summer precipitation levels and increasing summer temperatures.** However, as drought conditions depend on multiple weather conditions, there are challenges in predicting future drought with high accuracy.
- **Winter ice storm potential will remain similar based on model projections.** However, there were limitations in the available data and modelling to accurately predict ice storm events in York Region.

[f] Based on Ministry of the Environment, Conservation and Parks CCDP Model projections

[g] Extreme precipitation events were modelled based on days of precipitation above 10 mm and 20 mm.

[h] Intensity is measured by the simple daily intensity index, which is calculated by the ratio of total precipitation amount with total number of wet days (days with greater than 1 mm precipitation) during the same time period.

Figure 4.1. Climate change impacts expected in York Region.



Source: Fausto E et al. Historical and Future Climate Trends in York Region. Toronto: Ontario Climate Consortium; 2015. Fig.4.1, Climate change impacts projected for York Region by the 2050s. Adapted and modified with permission from the copyright holder.

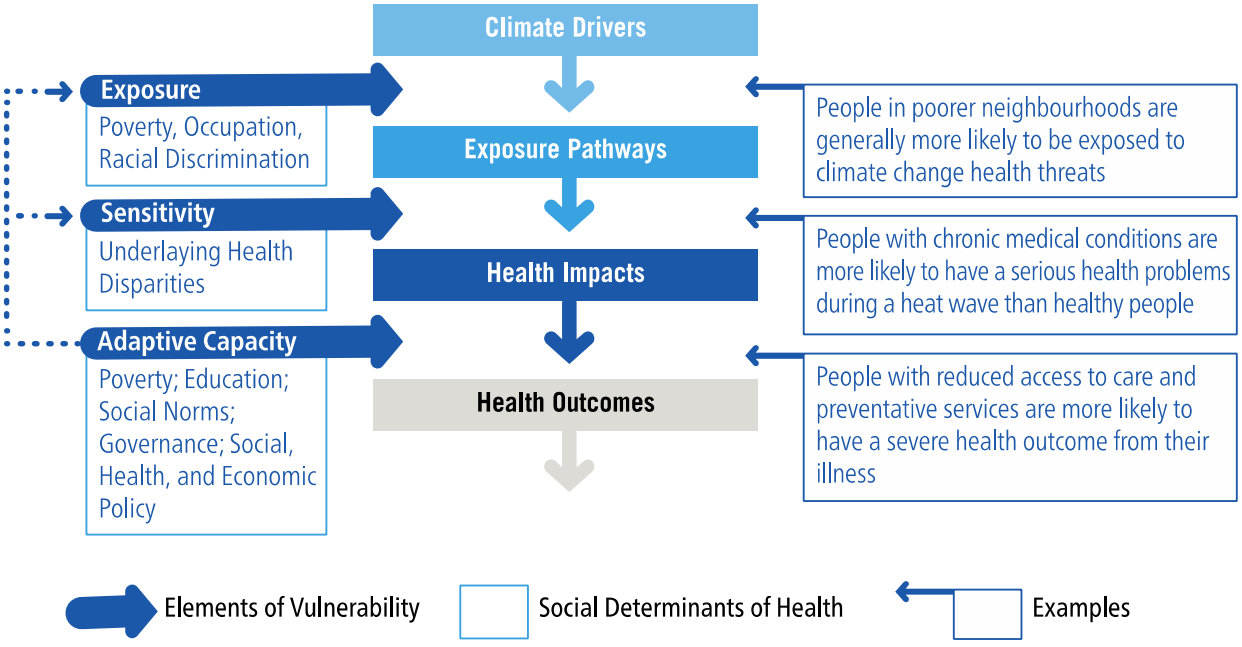
Adaptation planning will need to plan for a wide range of future conditions. Fausto et al.[10] explained that it is important to characterize the uncertainty associated with all variables presented in the report. It recommended not only the average future condition, but that a range of future conditions be considered for decision-making. It is important to note that trends will vary depending on the temporal scale examined (e.g., monthly temperature trends can differ from annual temperature trends) and the specific climate driver (e.g., temperature trends can differ from precipitation trends) as a result of atmospheric processes responding to climate change.

CHAPTER 4
Vulnerable Populations

4.0 Populations Vulnerable to Climate Change in York Region

It is unlikely that the impacts of climate change will be experienced equally amongst York Region residents, with certain subpopulations being more vulnerable. In the context of climate change, vulnerable populations are those at greater risk for health impacts due to increased sensitivity, capacity to respond and/or increased exposure. Considering the range of climate change impacts, incorporating a social determinants of health (SDOH) lens will help frame the potential impacts on vulnerable populations. Figure 4.2 illustrates the relationship of SDOH and climate vulnerability based on exposure, sensitivity and adaptive capacity.

Figure 4.2. The relationship between social determinants of health and climate change health impacts.



Source: Gamble JL, Balbus J et al. Ch. 9: Populations of concern. In. The impacts of climate change on human health in the United States: a scientific assessment [Internet]. Washington: U.S. Global Change Research Program; 2016. Fig 9.2, Intersection of social determinants of health and vulnerability; p.251. Available from: https://s3.amazonaws.com/climatehealth2016/low/ClimateHealth2016_09_Populations_small.pdf. Reproduced with permission from the copyright holder.

These SDOH factors can act individually and collectively and can contribute to climate change vulnerability from both exposure and adaptive capacity. Some examples include:[22]

- Populations that may have a greater risk of exposure to extreme weather events, such as outdoor workers, emergency responders and individuals who are active outdoors

- Individuals who spend more time in higher risk areas, such as individuals living in urban heat islands or flood plains or who regularly access trails with disease vectors present
- Infrastructure conditions that impact supply or availability of resources and services, such as limited availability and costs of food resources for low-income individuals during extreme weather events
- Individuals with low socioeconomic status (SES) who may experience challenges coping with stressors, or may have barriers to access services

Populations can also be more vulnerable due to factors such as age, life stage and general health status. Certain age groups, such as children and seniors and individuals with pre-existing conditions can be more susceptible to climate change impacts, including individuals with respiratory conditions who are more susceptible to aeroallergens. This refers to the **biological sensitivity** of populations that can contribute to the overall health status of populations.[22]

To better understand the potential impacts of climate change in York Region, the following sections provide an overview of vulnerable populations relating to SDOH and sensitivity.

Perceived health status of York Region residents

Good health and physical activity levels can also increase a population's resiliency to health impacts from climate change. The **Canadian Community Health Survey** (CCHS) collects information on self-reported health indicators for York Region.[23] Table 4.1 presents results from the 2015 to 2016 CCHS for different demographics based on age and gender. Overall, the majority of the population 12 years of age and older perceived their health to be very good or excellent.

Individuals with pre-existing diseases are also vulnerable to environmental stressors from climate change. Examples include heat stress impacting those with cardiovascular diseases. When considering York Region's aging population, it is likely that existing chronic diseases and mobility limitations will become larger issues in the future. Senior populations reported having relatively poorer health indicators such as perceived health, being overweight, arthritis and higher blood pressure. There are also some gender differences, with a higher percentage of males being smokers (Table 4.1).

Table 4.1. Self-reported health indicators, by age and gender, in York Region, 2015 to 2016.

Indicator	Percentage (%) of the total population (12 years of age and older)	Percentage (%) of youth (12 to 17 year-olds) population	Percentage (%) of senior 65 years of age and older) population	Percentage (%) of female population	Percentage (%) of male population
Perceived very good or excellent health	62.0	79.7	44.3	64.3	59.5
Perceived health fair or poor	9.7	≠	24.1	9.6	9.8
Perceived mental health, very good or excellent	71.1	83.8	61.4	69.5	72.9
Perceived life stress, most days quite a bit or extremely stressful	23.5	8.2*	14.8*	26.9	20.0
Life satisfaction, satisfied or very satisfied	94.7	100	90.7	96.0	93.3
BMI: Overweight (18 years of age and older)	32.6	N/A	44.8	26.8	38.4
BMI: Obese (18 years of age and older)	21.4	N/A	20.5	17.8	24.8
BMI: Overweight or obese (12 to 17 years of age)	N/A	18.3*	N/A	≠	≠
Arthritis (15 years of age and older)	16.6	≠	39.8	17.2	15.9
Diabetes	7.0	≠	20.4	5.0*	9.2
Asthma	6.2*	5.9*	4.4*	6.0*	6.5*
High blood pressure	16.1	≠	49.6	16.1	16.0
Mood disorder	5.7%	≠	8.2*	6.5*	4.9*
Fruit and vegetable consumption, 5x or more per day	29.7	19.0	31.2	35.8	23.1
Current smoker (daily or occasional)	12.6	≠	5.7*	9.5	15.7
Sense of belonging to local community, somewhat strong or very strong	68.8	84.4	69.9	70.8	66.8
Has a regular healthcare provider	92.7	92.6	96.7	96.0	89.2

Data Source: 2015 to 2016 Canadian Community Health Survey, Table 13-10-0113-01, Statistics Canada, 2017. Percentage of the population is based on 2016 population data.
* Interpret with caution
≠ Estimate too unreliable to report

Source: Self-reported health indicators by age and gender in York Region 2015-2016. Canadian Community Health Survey, 2017, Statistics Canada, Ontario Share File, Ontario Ministry of Health and Long-Term Care.

Socioeconomic status

Climate change can exacerbate health inequities by impacting those with low socioeconomic status (SES). SES is influenced by many factors, including the level of education, income, social status and connectedness with communities, and gender. Low SES individuals are more vulnerable as they have fewer resources and social supports to respond to current and future climate events.

Individuals considered low SES are more likely to have poorer health and are disproportionately affected by chronic medical conditions, such as mental health illnesses, asthma, diabetes and cardiovascular diseases.[24] These health status inequities can worsen as a result of climate change impacts.[22,25]

Many of these factors are considered in the Ontario Marginalization Index,[26] which looks at the geographic distribution of multiple variables related to SES, such as income, social isolation, dependency and ethnic identity. There are areas in York Region that consistently reported poorly on the Ontario Marginalization Index variables and also had poorer health outcomes. Examples include:[24]

- Higher rates of premature mortality in areas with the most material deprivation[i]
- Higher hospital admission rates overall in areas with the most material deprivation and residential instability[j]
- Higher hospital admission rates for injuries and cardiovascular disease in areas that had higher material deprivation and residential instability

Low-income

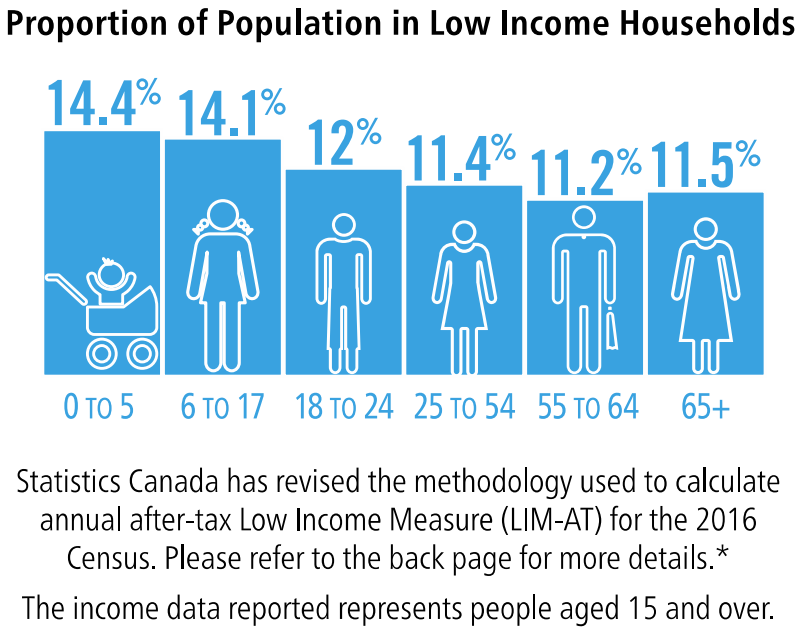
Low-income[k] populations are more vulnerable to environmental exposures and have a reduced capacity to adapt due to limited social support and financial resources. Income is a key determinant of health that can affect a person's vulnerability to multiple climate change health impacts, including food security, air quality, extreme heat and extreme weather events.[4,5] In addition, low-income populations tend to reside in areas with older infrastructure or poorer housing conditions. In 2016, 11,090 (3%) of York Region dwellings were in need of major plumbing, electrical wiring or structural repairs.[13] Around 14% of children and 11.5% of seniors resided in low-income households in York Region in 2016 (Figure 4.3).

[i] Material deprivation is based on multiple census variables that are reflective of refers to the inability or challenges in affording modern day goods and conveniences.

[j] Residential instability refers to the instability experienced in families and in housing.

[k] A person is considered low-income if the income of the census family they live in (or, in the case of a person not living in a census family, their individual income) fell below the Low Income Measure After, Tax (LIM-AT) for their census family size.

Figure 4.3. The proportion of the population in low-income households in York Region in 2016.



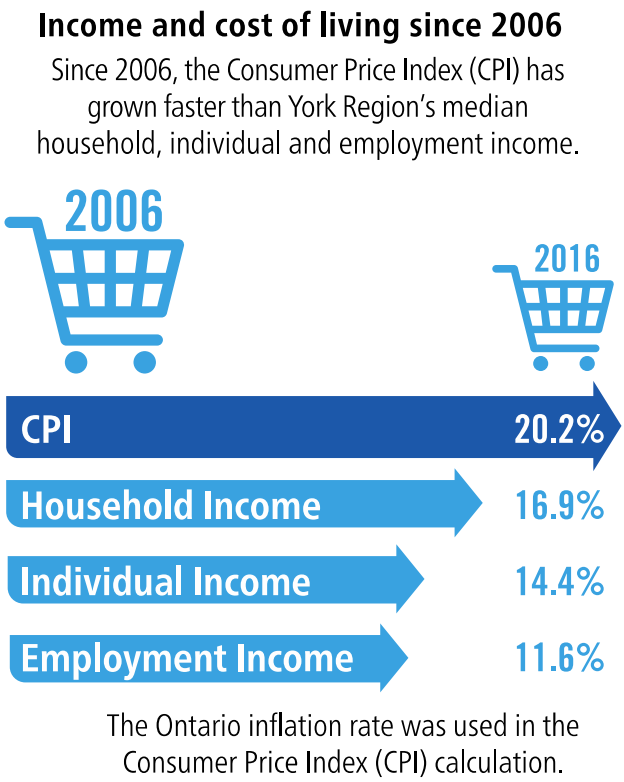
Source: The Regional Municipality of York. 2016 Census release reports [Internet]. Newmarket: Regional Municipality of York; 2018. Proportion of population in low income households; p. D3. Available from https://www.yorklink.ca/wp-content/uploads/2018/03/2016-census-release-york-region.pdf

While York Region had the second highest median household income in the Greater Toronto and Hamilton Area in the 2016 Census,[27] the number of low-income residents grew faster than the overall population between 2000 and 2012.[28] The majority of low-income populations reside in the most populated municipalities of Markham, Richmond Hill and Vaughan, with low-income rates as high as 25.1% to 35.5% in nine census tracts in 2012.[28] Neighbourhoods with the lowest income also reported having poor health, more residents who smoke and higher all-cause hospitalization rates.[24]

In 2016, there were 164,840 low-income residents in York Region, representing 15% of the population.[29] While the proportion of low-income seniors living in York Region is relatively low, the proportion has increased from 7% in 2000 to 11.5% in 2016.[27,30]

The cost of living has substantially increased in York Region relative to income levels. From 2006 to 2016, the Consumer Price Index (CPI) increased at a higher rate than income in York Region (Figure 4.4). In 2016, 28% of homeowners and 52% of renters were spending 30% or more of their income on shelter costs.[27] The CPI may also be an important consideration for individuals who are not considered low-income as they may have fewer resources to adapt to climate change impacts.

Figure 4.4. Growth in Consumer Price Index compared to income from 2006 to 2016 in York Region.



Source: The Regional Municipality of York. 2016 Census release reports [Internet]. Newmarket: Regional Municipality of York; 2018. Income and cost of living since 2006; p. D3. Available from https://www.yorklink.ca/wp-content/uploads/2018/03/2016-census-release-york-region.pdf

Homelessness

Individuals who are homeless are vulnerable to climate change due to:[31]

- Increased exposure to extreme temperatures and disease vectors
- High rates of poorly controlled chronic illness, respiratory illnesses and mental illnesses
- Limited resources to adapt to climate change impacts

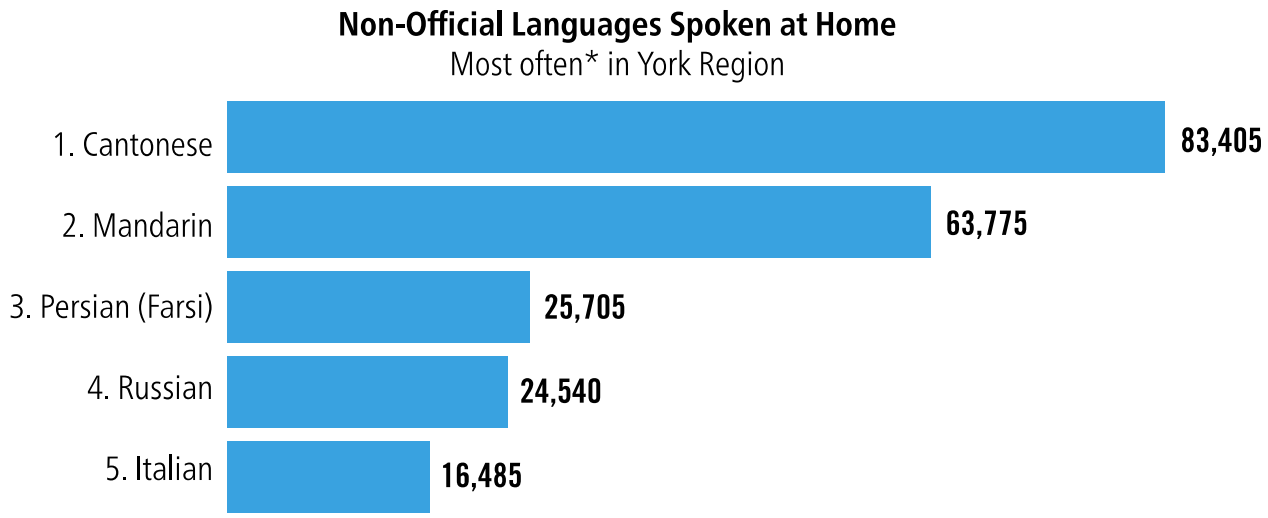
Individuals experiencing homelessness in York Region tend to be adults between the ages of 25 and 65.[32] A recent 2018 **I Count** homelessness survey conducted in April 2018 found 389 individuals experiencing homelessness in York Region.[32] The majority of those living unsheltered were male (82%) and were homeless for six months or more in the past year (79%). Around 1 in 3 individuals were 24 years of age or younger. Gender differences were less pronounced for those living in emergency housing or provisional accommodation.[32]

Of those surveyed, individuals reported having a mental health issue (48%), an existing medical condition (37%), an addiction (34%) or a physical disability (31%).[32]

New permanent residents

The inability to speak one of the official languages adds vulnerability as it presents a barrier to accessing services and connecting with the community. The most common non-official languages spoken in York Region homes are Cantonese, Mandarin, Persian (Farsi), Russian and Italian (Figure 4.5). From 2010 to 2014, 40% of new permanent residents who intended to settle in York Region arrived with no ability to speak English or French. This is a higher proportion than the average for Canada (29%), Ontario (28%) and the GTA (30%).[33] Approximately 72% of the seniors who arrived in York Region between 2010 and 2014 had no ability to speak English or French (Figure 4.6).[33]

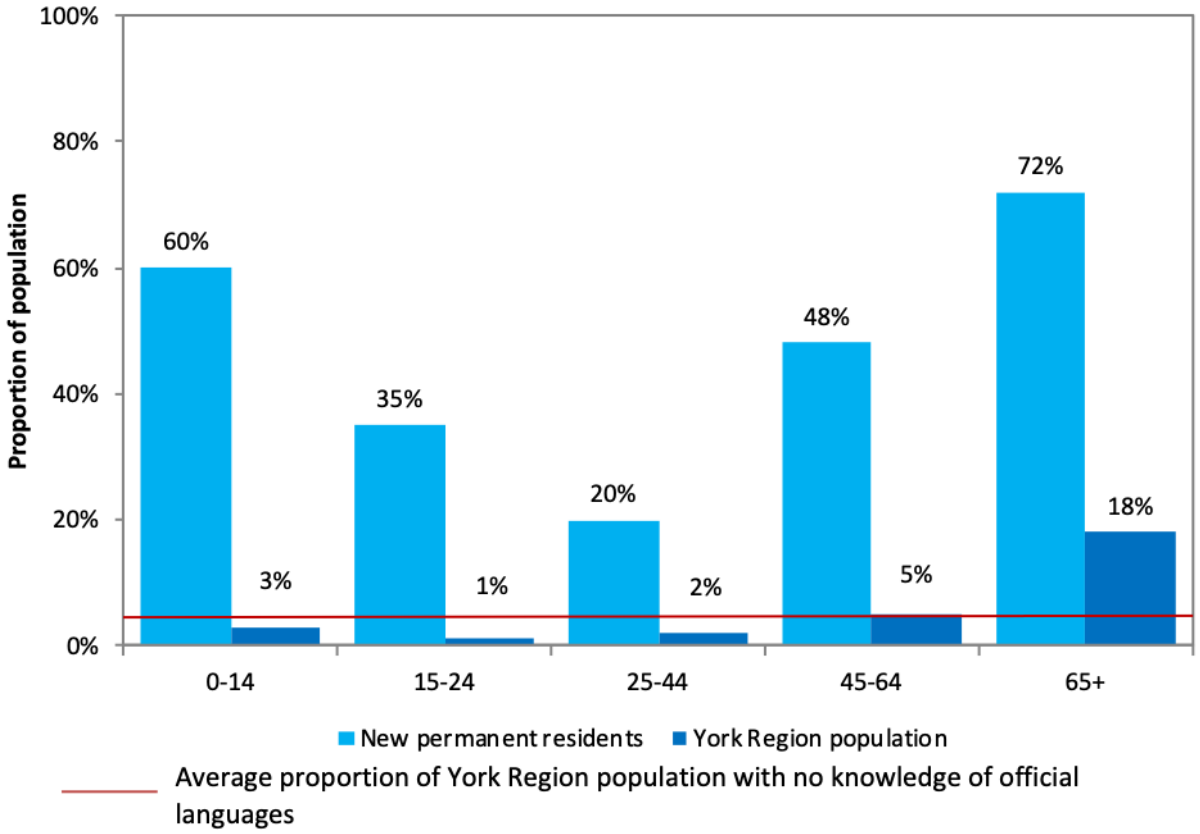
Figure 4.5. Most common non-official languages spoken at home by York Region residents in 2016.



*Numbers based on the total number of respondents who provided a single response at the time of data collection

Source: The Regional Municipality of York. 2016 Census release reports [Internet]. Newmarket: Regional Municipality of York; 2018. Non-official languages spoken at home; p.C3. Available from: https://www.yorklink.ca/wp-content/uploads/2018/03/2016-census-release-york-region.pdf

Figure 4.6 Proportion of new permanent residents and York Region residents with no knowledge of official languages, by age groups.

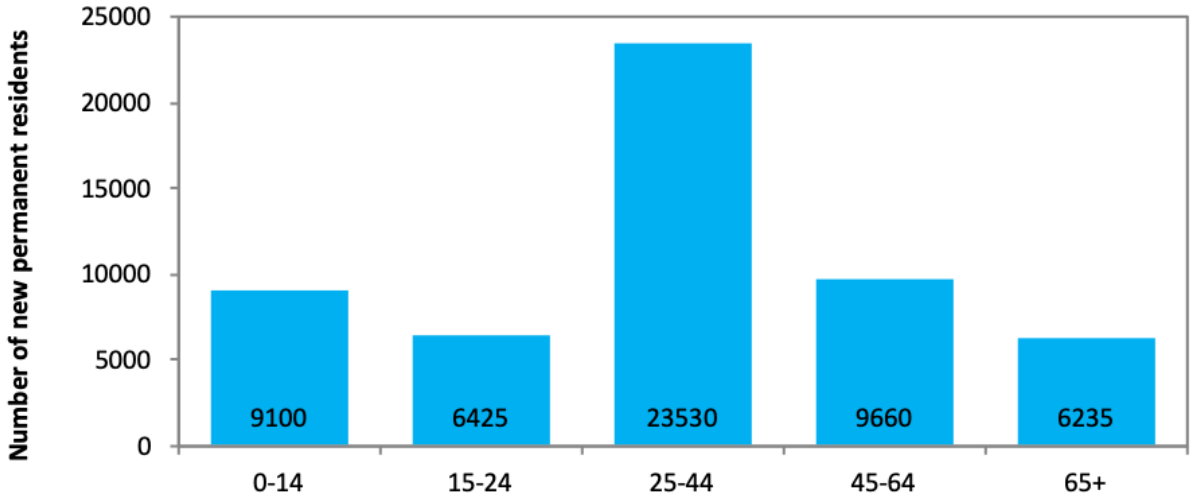


Data sources: Citizenship and Immigration Canada (RDM). New permanent resident population 2010-2014 [data file]. Ottawa: Government of Canada; 2015.
2011 Census, York Region Population. Toronto: Statistics Canada.

York Region's new permanent residents are diverse and experience multiple factors increasing their vulnerability. The majority of new permanent residents are settling in Markham, Richmond Hill and Vaughan.[33] Each year, approximately 10,000 of the 220,000 new permanent residents admitted to Canada intend to settle in York Region.[33] The top five countries of origin for residents were China, Iran, the Philippines, India and Pakistan.[27] Between 2010 and 2014, 60% of new permanent residents were between 25 and 64 years old, 29% were children/youth and 11% were seniors (Figure 4.7).[33] New immigrants also experience twice the unemployment rate and earn half the income compared to the general York Region population.[34]

Immigration also contributes to the growth of York Region's senior population. Seniors are the fastest growing age group of new permanent residents in York Region. The proportion increased from 6% in 2010 to 11% in 2014 and is higher than the rest of the GTA (6% in 2014).[34]

Figure 4.7. Number of new permanent residents, to York Region, by age group between 2010 to 2014.



Data source: Immigration, Refugee, and Citizenship Canada RDM. Number of new York Region permanent residents [data file]. Toronto: Statistics Canada; 2015.

Outdoor workers and recreational activity

Outdoor workers and those active outdoors may have a higher exposure to climate-related hazards such as extreme heat, solar ultraviolet radiation (UVR), air pollution, extreme weather events and vector-borne diseases. In 2016, there were 43,055 people working in construction, 54,185 in manufacturing, 33,525 in the accommodation and food service industry and 2,270 in agriculture or primary industries across York Region (Table 4.2).[13] These occupations may place individuals at a greater risk of exposure to climate-related hazards if appropriate measures are not taken, such as staying hydrated and taking breaks in cool spaces during hot days.

In addition, local residents and visitors may also be spending significant time outdoors for recreational activities, which can also increase the risk of exposure to extreme weather events, extreme temperatures and vector-borne diseases. While an estimated 1,623 individuals visit York Regional Forests daily, there is limited data to illustrate other outdoor activities, such as beach use, municipal parks and trails.[35]

Table 4.2: Number of workers in industries with increased exposure to climate-related hazards for York Region from 2016 Census.

Industry	Total	Males	Females
Construction	43,055	36,235	6,825
Manufacturing	54,185	35,295	18,895
Accommodation and food service industry	33,525	16,090	17,440
Agriculture, forestry, fishing and hunting	2,270	1,380	890

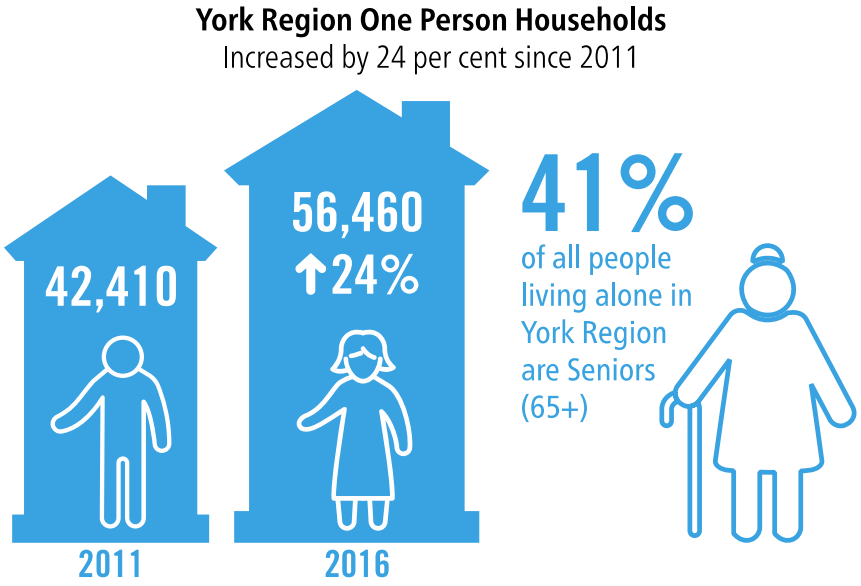
Socially isolated individuals

Social supports and strong social networks have an influence on mental and physical health, and increase the ability of residents to respond to climate change impacts. Those with the fewest social connections tend to experience more mental health problems, illnesses and higher mortality rates.[36]

Based on Statistics Canada's General Social Survey program, the proportion of Canadians having three or more close friends increased slightly from 70% to 75% between 2003 and 2013.[37] However, the percentage of people who saw their friends a few times a week decreased from 56% to 44% over the same period.[37] In the same survey, 6% of Canadians (15% of those 75 years of age or older) reported having no close friends.[37] In 2013, Canadians were also less likely to visit or communicate with family than they were in 2003 (26% versus 38% respectively).[37] Overall, the survey results suggest Canadians are becoming more socially isolated.[37]

In York Region, there has been a 24% increase in the number of one person households from 2011 to 2016, 41% of those being seniors (Figure 4.8). Additionally, there were 43,915 lone parent families, a 13% increase from 2011.[27]

Figure 4.8. The number of one person households in York Region.



Source: The Regional Municipality of York. 2016 Census release reports [Internet]. Newmarket: Regional Municipality of York; 2018. York Region one person households; p. c3. Available from https://www.yorklink.ca/wp-content/uploads/2018/03/2016-census-release-york-region.pdf

Children

Children are considered a vulnerable population for a number of reasons, including:[4]

- Being unable to fully care for themselves and reliant on caregivers

- Having developing systems with less mature immune systems that make them sensitive to diseases and environmental contaminants
- Having thermoregulatory abilities not fully developed

Children under 15 years of age represented 18% of York Region's population in 2016, totalling 195,575 individuals. The number of pre-school aged children (0 to 4 years of age) in York Region declined by 2.5%, or almost 1,500 children, since the 2011 Census.[27] However, five of the nine local municipalities experienced an increase in the number of preschool aged children, with the Township of King and the Town of Whitchurch-Stouffville recording the largest growth rates.[13]

Children from low-income households are particularly vulnerable due to a lack of resources to prevent and treat illnesses. In 2016 around 14% of children under 17 years of age were in low-income households in York Region.[27] Underweight/undernourished children are also more susceptible to infectious diseases that can lead to chronic diseases in later stages of life.[38]

Seniors

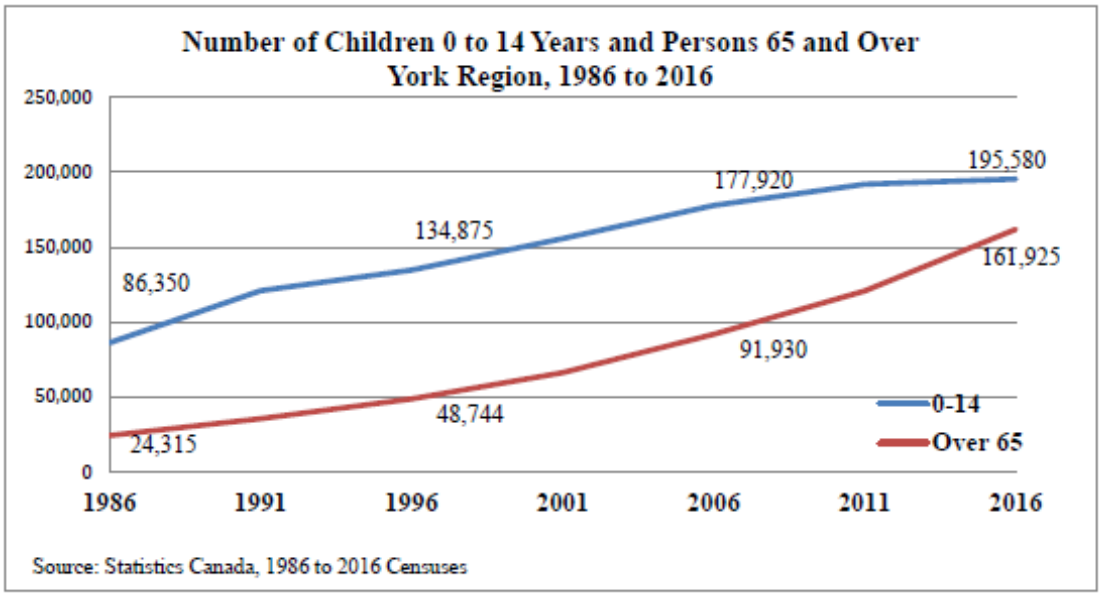
Senior citizens may be affected by limitations - functional, physiological, or psychological – that can impact their ability to adapt to climate change, including: [4]

- Reduced thermoregulatory capacity and heat tolerance
- Increased likelihood to suffer from additional chronic diseases, physical disabilities and infections
- Increased social isolation due to the low quantity and/or quality of contact with others, adversely impacting mental and physical well-being

However, it should be noted that seniors in York Region are some of the most affluent in Canada.[30] They also often have more resources at their disposal than other age groups. This may reduce their vulnerability compared to typical senior profiles traditionally discussed in literature. While York Region seniors are, on average, among the most affluent in Canada, the proportion of low-income seniors is increasing.

York Region's senior population is growing faster than any other age group. In 2016, there were 161,870 individuals 65 years of age and older in York Region, representing approximately 15% of the population (Figure 4.9).[27] From 2011 to 2016, the largest increases in senior population occurred in Whitchurch-Stouffville, Richmond Hill, Markham and Vaughan.[27] By 2031, it is estimated that 1 in 5 people in York Region will be 65 years of age or older.[39]

Figure 4.9. Population growth of children and seniors in York Region from 1986 to 2016.



Source: The Regional Municipality of York. 2016 Census release report - age and sex and type of dwelling [Internet]. Newmarket: Regional Municipality of York; 2017. Number of children 0 to 14 years and persons aged 65 and over; p. 2. Available from: https://www.york.ca/wps/wcm/connect/yorkpublic/1bb54839-83b9-44c8-9da6-6cba457fe7ea/2016_Census_Release_Report_YR_Population_Age_and_Sex.pdf?MOD=AJPERES

Senior citizens, particularly those 75 years of age and older, have greater health care needs. Seniors are at an increased risk of falls leading to fatal and non-fatal injuries, and need more supports, care and medication.[39] As such, they use health and social services disproportionately more than the rest of the population and are vulnerable to the disruption of these services.[40]

Recognizing the importance of mental health

Mental health is more than the absence of mental illness. Having good mental health can help individuals to cope during stressful life events and can mitigate the development of poor mental health or mental illnesses.[41] The Public Health Agency of Canada defines mental health as "the capacity of each and all of us to feel, think and act in ways that enhance our ability to enjoy life and deal with the challenges we face."[42] Mental illness refers to conditions that severely and negatively impact how we function in our lives.[43] Mental health and mental illness can be influenced by a mix of social, economic, psychological, biological and genetic factors.[41] The built environment is an important determinant of mental health and includes geography, climate, housing, water, air quality and transportation systems.[44]

Climate change is likely to have significant negative effects on mental health and well-being, especially for vulnerable populations and those with pre-existing mental illnesses. Climate change will affect the mental health of individuals and communities through three main pathways:

1. Increasing the frequency of natural disasters and extreme weather events
2. Increasing the risk of injury and the prevalence of physical injury and illness
3. Changing the environment people rely on for their income and well-being[45]

There is strong evidence that natural disasters lead to stress and poor mental health, such as post-traumatic stress disorder (PTSD), depression and anxiety.[45,46] In a review of 36 studies, increased psychological symptoms, such as anxiety, depression and phobias, were observed in 7% to 40% of individuals who experienced a natural disaster.[47] Depression, anxiety, PTSD, suicidal ideation and suicide rates also increase after a natural disaster. After the 2013 Alberta flood, there was a 64% increase in the number of mental issues reported, as well as a two-fold increase in sleep aid prescriptions and a three-fold increase in sexual assault cases.[48]

Individuals at greater risk for distress and mental health outcomes due to weather-related disasters include seniors, children, women (in particular pregnant and post-partum women), individuals experiencing homelessness, first responders and the economically disadvantaged.[45] Those with pre-existing mental illnesses are vulnerable to extreme heat as it may affect their ability to recognize and take heat-protective behaviours, such as ensuring adequate hydration, wearing appropriate clothing or seeking out cool places. Thermoregulation may also be affected by the use of medication, and individuals may be socially isolated and have deficits in self-care.[49]

Mental health is already an important issue in York Region. The York Region Community and Health Services (CHS) Department is seeing more residents with complex needs across all program areas, including mental health and addictions.

In 2017, the rate of selected mental illness-related emergency visits of York Region residents increased to a 10-year high of 1,860 emergency visits per 100,000 population.[50] In particular, those between the ages of 15 and 24 had the highest rates of mental illness-related emergency visits.[50] Additionally, mental health issues have been increasingly observed across York Region services, with a 40% increase in mental health-related calls to the York Region Police and York Region Paramedic Services between 2012 and 2016.[51] Consequently, the future impacts of climate change in York Region can potentially increase mental health related issues and add further strain to York Region services.

York Region Mental Health Matters: The York Region Mental Health Matters Initiative was launched to support the mental health needs of residents by improving the way that services are provided. It focuses on early intervention, prevention and effective responses to crises. The initiative aims to address mental health issues holistically by collaborating with York Regional Police to help build capacity in building resilience and preventing mental health issues within our communities, providing ongoing support to those living with a mental illness and providing effective crisis intervention. Increasing the effectiveness of mental health service delivery will also build resiliency to climate change.

CHAPTER 5
Changing Temperatures- Extreme Heat and Cold

5.0 Changing Temperatures: Key Findings

Climate change projections and exposure pathways

Extreme heat:

- Extreme heat events (EHEs) are expected to increase in duration, frequency and intensity. It is very likely (90% to 100% probability) that temperatures in York Region will increase in all seasons by the 2050s with winter and summer months experiencing the most warming
- Urban Heat Islands (UHIs) increase temperatures in urban areas, increasing exposure and exacerbating health risks. Areas most impacted from UHIs include Vaughan, Richmond Hill, Newmarket, Aurora and Markham
- Weather conditions such as humidity, air quality and solar ultraviolet radiation exposure can exacerbate heat impacts

Extreme cold:

- Climate projections indicate York Region will experience warmer winters with increased rainfall
- Even as winters warm, extreme cold events are still possible. Climate projections show days with temperatures below -20˚C will decrease from 8 days per year to 3.1 days per year by the 2050s

Population sensitivity

Extreme heat:

- Seniors are a fast growing population in York Region, and have increased vulnerability
- Future acclimatization to warming summers from the general population may help reduce vulnerability to EHEs

Extreme cold:

- Extreme cold tends to impact younger populations more than seniors in York Region
- Warming winters may reduce the acclimatization and adaptive behaviour for extreme cold events

Adaptive capacity

Extreme heat:

- The Extreme Heat Program provides EHE notifications to the public and stakeholders, including those who engage vulnerable groups such as child care centres and long-term care homes
- Based on surveys of local residents and long-term care homes, the majority of residents and local stakeholders have opportunities for cooling and relief from extreme heat
- Most residents own a home cooling device, such as an air conditioner, but the frequency of use during EHEs is unknown. A recent survey found that only 33% of residents checked on 'at risk' friends or family during heat events
- The majority of York Region residents adopt some protective behaviour during hot summer days. Improvement in practicing heat-protective behaviours would increase personal adaptive capacity

Extreme cold:

- The Extreme Cold Program provides notification of extreme cold events to the public and stakeholders
- York Region provides services for homeless individuals, including shelter services

Health impacts for extreme heat and cold

- There is strong scientific evidence that indicates heat-related illness will increase as a result of rising temperatures due to climate change, particularly impacting those most vulnerable to extreme heat
- Emerging research also indicates the impacts of moderate temperatures to human health

Recent Trends:

- Between 2007 and 2017 there were 497 heat-related illness emergency department (ED) visits in York Region
- Hospital data represents more severe heat-related illnesses, underestimating the burden of illness from extreme heat. EHEs may also exacerbate mental health, cardiovascular and respiratory diseases
- Between 2007 and 2017 in York Region there were 410 ED visits due to extreme cold

There is strong evidence that climate change will impact local temperatures and recent heat waves highlight the significant impact extreme temperatures can have on health. For example, the extended heat waves in Europe in 2003 were estimated to have contributed to up to 70,000 deaths.[52] Heat waves have also had impacts within Canada. Between June 30 and July 8, 2018, a heat wave was a factor in 66 deaths in Montreal alone[53], and contributed to a total of 86 deaths in the province of Quebec.[54]

In York Region, climate projections indicate warmer summer and winter temperatures are very likely to occur by the 2050s.[10] These shifting temperatures, combined with an increased likelihood of extreme temperature events[I], will have important implications for temperature-related health impacts in York Region.

This chapter provides an overview of extreme heat, followed by extreme cold, focusing on how climate change may impact York Region with respect to extreme temperatures. The information includes an overview of health impacts from extreme temperatures in York Region, which populations may be more vulnerable to these impacts, climate projections for York Region, how climate change may impact the future burden of illness based on existing research and what existing services are available to address extreme temperatures in York Region. Additional information on urban heat islands and solar ultraviolet radiation (UVR) exposure are presented within the extreme heat section.

5.1 EXTREME HEAT

5.1.1 Health impacts from extreme heat

Heat-related illness (HRI) can range from minor symptoms, such as heat rash and cramps, to more severe conditions such as heat exhaustion and heatstroke. These illnesses usually result from exposure to high temperatures, high humidity, lack of shade and minimal air movement, indoors and outdoors.

There is strong evidence highlighting the impacts of extreme heat on human health. Studies in multiple cities across North America and Europe have consistently shown extreme temperature contributes to HRI, particularly hospital admissions and mortality.[55] This has also been noted in recent Canadian studies.[56-59] This impact is more pronounced in cities that tend to have cooler climates, likely due to limited adaptation measures and acclimatization.[55]

Extreme heat not only leads to more heat-related illnesses but has been associated with other health outcomes. Recent research suggests extreme heat is associated with other health

[I] In York Region, extreme heat and cold conditions are defined by Environment and Climate Change Canada. Extreme heat warnings are issued when maximum temperatures are above or equal to 31°C and minimum temperatures are above or equal to 20°C; or Humidex is greater than 40 for at least two days. Extreme cold warnings are issued when temperature or wind chill reach -30°C for at least two hours.

outcomes such as mental health, cardiovascular disease, asthma, diabetes and more.[59] An Ontario study showed that every 5˚C increase in temperature was strongly related to an increase in respiratory-related deaths (5.4%) and cardiovascular-related deaths (5.1%).[59]

Other climate factors such as humidity can also contribute to the risk of heat-related illnesses. The risk of heatstroke and heat exhaustion was also found to increase when the combination of temperature and humidity exceed 34°C and 90% compared to 41°C and 30% respectively.[60]

Existing research demonstrates the association between mental health and extreme heat events. In particular, individuals with existing mental health illnesses may experience difficulty with thermoregulation as a side effect of certain medications.[55] A study in Toronto observed a strong association between the number of emergency department (ED) visits and hospitalizations for mental health issues with high daily temperature.[49] Similarly, ED visits for mental health issues in Montreal increased with more moderate temperatures (daily average between 22.5ºC and 25ºC) and humidity (70% to 90%). This trend was noted for all age groups but was highest for seniors.[61]

There is emerging research on contributions of non-extreme temperatures to morbidity and mortality. Emerging research indicates even small changes in temperature can impact mortality rates[55] and other health outcomes such as mental health or diabetes. For example, mild heat has been associated with more diabetes-related hospitalizations in Ontario than extreme heat temperatures.[62] Similarly, recent studies[63] suggest that climate change will also increase the risk of compounded heat wave events, which are heat events with limited days of cooler weather in between. This may increase the vulnerability for heat-related illnesses due to limited recovery time for the general population, particularly those most vulnerable to heat stress.[63]

Exposure to extreme heat in combination with air pollution may result in additive or synergistic health effects. Air quality and extreme heat can act together to increase risks to human health.

The relationship between temperature, air quality and health outcomes is complex and depends on the specific pollutant(s), its interaction with heat and other weather parameters, and individual sensitivity. For instance, Vanos and colleagues[64] found that the relative risk of mortality in 12 Canadian cities related to fine particulate matter and sulphur dioxide tripled in hot weather when compared to moderate weather, and the risks due to ozone and nitrogen dioxide doubled. However, in terms of relative impact, research by Cheng and colleagues[65] estimates extreme heat has a larger contribution to the overall health burden compared to air quality in the Toronto area.

Due to limitations in predicting climate change related air pollution events, it is difficult to determine the health impacts for York Region related to extreme heat and air quality interactions. More information on air quality impacts can be found in Chapter 7.

Vulnerable populations

Populations most vulnerable to extreme heat include those with a modified ability to thermoregulate and those with limited resources and means to adapt to extreme temperatures. The table below highlights key vulnerable populations with respect to extreme heat. See Chapter 4 for more information on vulnerable populations in York Region.

Table 5.1. Summary of vulnerable populations related to extreme heat.

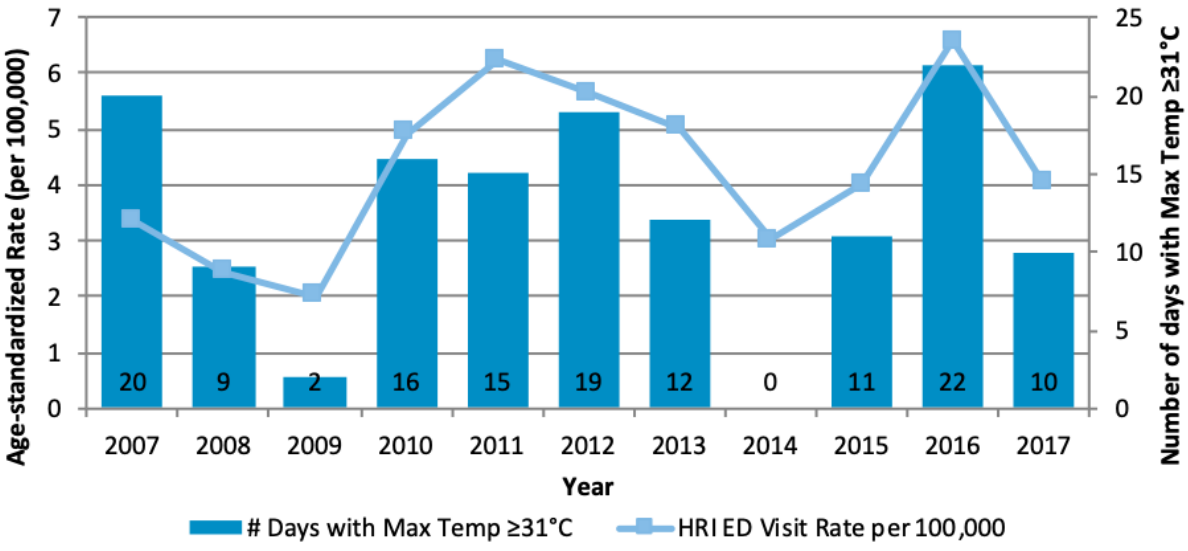
Seniors
Biological sensitivity Seniors have functional and physiological limitations that impede their ability to adapt to extreme heat and regulate body temperature. They are also at higher risk of chronic diseases. High mortality rates during the European heat waves occurred in elderly women with pulmonary diseases.[66] **Behavioural and social factors** Social isolation can increase risk. Older adults may be less likely to undertake protective actions during extreme heat events.[60]
Children
Biological sensitivity Children have less developed thermoregulatory systems than adults and higher metabolic rates. **Behavioural and social factors** Children are more likely to be active outdoors and are less likely to take precautionary measures to protect themselves from extreme heat.
Gender factors
Biological sensitivity Pregnant women are at higher risk of heat-related illness and dehydration. Extreme heat can be detrimental to the fetus, and can contribute to neural tube and heart defects due to maternal hyperthermia, pre-term birth, low birth weight and spontaneous abortion. **Behavioural and social factors** The effect of heat waves on hospitalization for stroke, out-of-hospital cardiac arrest, heat-related illness, and work-related injuries was higher for men than women.[67] This is also supported by RRFSS survey findings that men were less likely to change outdoor activity based on temperature.
Pre-existing conditions
Biological sensitivity There is a higher risk of heat-related illness for people with chronic conditions such as cardiovascular disease, respiratory diseases, overweight/obese, diabetes, renal diseases, gastrointestinal illness and individuals taking particular medications such as psychiatric medications. Li et al.[67] found hospital admission rates during heat waves were higher for people with cardiovascular and respiratory diseases. **Behavioural and social factors** Chronic disease combined with reduced socioeconomic status (SES) can increase susceptibility and reduce adaptive capacity.
SES and recent immigrant populations
Behavioural and social factors Low SES was associated with increased morbidity and mortality due to extreme heat.[67] Higher rates of mental illness are often observed in individuals living with low-income compared to the general public. Individuals living with low-income may lack access to air conditioning. Additionally, Li et al. [67] found individuals living in linguistically and culturally diverse communities were more vulnerable to extreme heat, possibly due to a reduced ability to access resources and information.

5.1.2 Local health impacts in York Region

Recent studies and available hospital data demonstrate the impacts of extreme heat in York Region. A recent study[59] examined impacts of hot and cold temperatures between 1996 and 2010 in Ontario. In York Region, a 5.4% increase in non-accidental deaths was observed for every 5°C increase in temperature between the months of June and August, an impact greater than the provincial average of 2.5%.[59] The heat effects occurred immediately, without a lag.[59] This study also observed higher heat-related mortality among hospital patients in Ontario. These increased rates may be due to a heightened vulnerability among patients and insufficient cooling in hospitals.

Between 2007 and 2017, there were 497 ED visits for HRI[m] in York Region during the summer months between May and September (Figure 5.1). When comparing summer seasons, higher HRI ED visit rates were observed during summers with more days above 30˚C. Consistent with Chen et al.,[59] seniors between 80 to 89 years of age had the highest HRI ED visit rates compared to other age groups. July had the highest HRI rates followed by June. Higher rates earlier in the summer may partly relate to a lack of acclimatization.

Figure 5.1. Annual trends in York Region in heat-related illness (HRI) emergency department (ED) visits during summer months and number of days with daily maximum temperature above or equal to 31˚C, from 2007 to 2017.



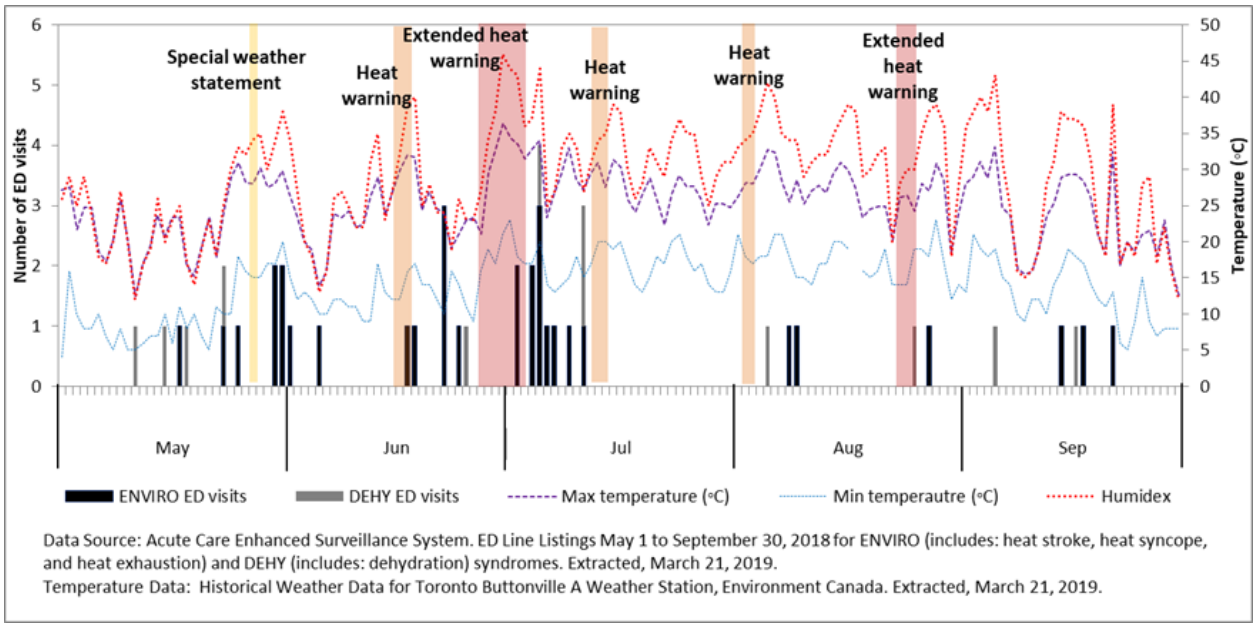
Data Sources: Ambulatory Visits & Population Estimates, 2007-2017, Ontario Ministry of Health and Long Term Care, IntelliHealth Ontario. Extracted December 7, 2018. Heat-Related Illness (HRI) defined as any unscheduled emergency department visits using ICD-10 CA codes X30 or T67. Rates were age-standardized using the 2011 Canadian Census Total Population by Age, from Statistics Canada, catalogue #98-311-XCB2011018.
Temperature Data: Historical Weather Data for Toronto Buttonville A Weather Station, Environment

[m] Heat-Related Illness is defined as any unscheduled emergency visit using ICD-10 CA codes X30 or T67.

Increases in ED visits for heat-related illness in York Region were not consistently observed during an extreme heat event. The relationship between EHEs and HRI was not clear when reviewing daily temperature and hospital data for York Region (Figure 5.2). This may be attributed to individuals not seeking medical attention for heat-related illnesses, and health outcomes exacerbated by extreme heat not coded as such when medical attention is sought (e.g., respiratory or cardiovascular health outcomes).

When examining York Region Acute Care Enhanced Surveillance (ACES) data from the 2018 heat season, a small number of HRI cases were observed following a heat warning. However, the health outcome trend following EHEs was not consistent. This rise in cases following heat events may relate to individuals not continuing with protective measures once a heat warning has ended and/or the cumulative impact from consecutive hot weather days. However, as this analysis only involves data from 2018, additional analysis is required to accurately evaluate temporal trends in heat-related illness rates in the summer season.

Figure 5.2. The number of emergency department visits, based on extreme heat and dehydration syndrome classifications, and weather data for May to September 2018 for York Region.



5.1.3 Climate change impacts on extreme heat and HRI

Climate change projected impacts on HRI

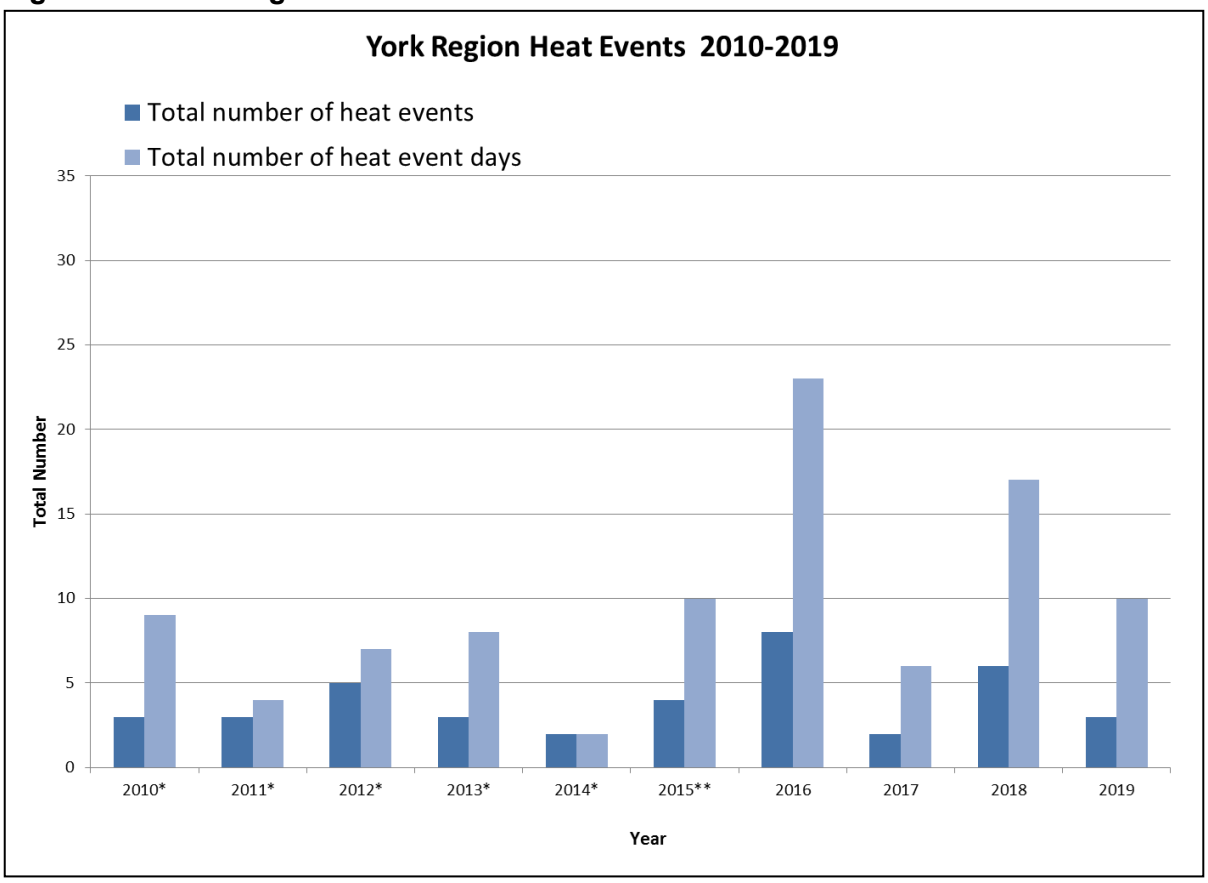
Research from North America consistently highlights the recent impact of extreme heat on human health. However, there are limited studies predicting future impacts in Ontario and in York Region. Martin and colleagues[58] predicted the average annual rate of heat-related mortality for 15 Canadian cities would increase from 1.37 per 100,000 from 1981 to 2000, up to 3.34 per 100,000 by the 2031 to 2050s. However, these projections do not include other related health impacts or cases that may go unreported from health care surveillance systems.

Ultimately, future impacts from extreme heat will depend on changes in the sensitivity and adaptive capacity of the population to extreme heat. In North America, there is strong research demonstrating an increasing tolerance to extreme heat, with acclimatization having the potential to reduce future impacts.[55] Cheng and colleagues[65] predict heat-related mortality in Toronto could increase by approximately 100% by the 2050s with no acclimatization within the population. However, if acclimatization of the population occurs, these projections are predicted to increase by 70 to 90% by the 2050s.

Climate change impacts on extreme heat in York Region

In recent years York Region has experienced varying numbers of heat events. Between 2010 and 2018, the most heat events and number of heat event days occurred in 2016 and 2018 respectively (Figure 5.3).

Figure 5.3. York Region Extreme Heat Events from 2010 to 2019.

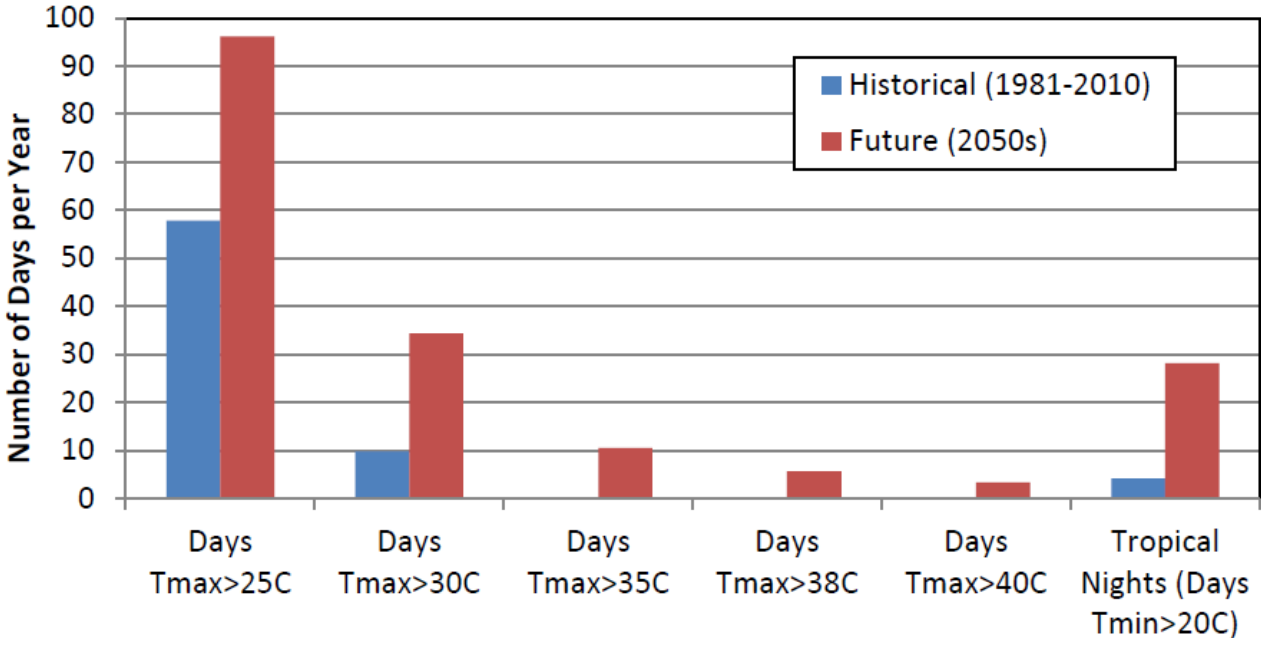


**Heat events were defined differently between 2010-2019. From 2010-2014, Environment Canada issued a Special Weather Statement Humidex Advisory when the temperature was expected to reach 30°C or more and humidex was expected to reach 40 or more OR a temperature of 40°C or greater. **In 2015, Environment Canada issued: Level 1 (Heat Advisory) when Tmax ≥ 31°C and Humidex ≥ 40 for 1 day; Level 2 (Heat Warning) when Tmax ≥ 31°C and Tmin ≥ 20°C OR Humidex ≥ 40 for 2 days; or Level 3 (Extreme Heat Warning) when Tmax ≥ 31°C and Tmin ≥ 20°C OR Humidex ≥ 40 for 3+ days. From 2016- 2019, Environment Canada issued a heat warning when Tmax ≥ 31°C and Tmin ≥ 20°C OR Humidex ≥ 40 for 2 days; and York Region Public Health an extended heat warning when Tmax ≥ 31°C and Tmin ≥ 20°C OR Humidex ≥ 40 for 3+ days.*

There is a high probability York Region will experience warmer summers with more extreme heat events. As a result of climate change, it is very likely (90 to 100% probability) temperatures in York Region will increase in all seasons by the 2050s, with the winter and summer months experiencing the most warming.[10] Currently, York Region experiences 58 days per year where the daily temperature reaches 25°C or higher. By the 2050s, this number is expected to increase by an additional 37 to 39 days (Figure 5.4).[10]

Notably, daily maximum temperatures (T_{max}) greater than 30˚C are expected to increase by 24.6 days annually by the 2050s in York Region. Projections also indicate maximum summer temperatures are very likely to reach over 40°C compared to a historical maximum temperature of 35.9°C. This would result in an increase in the number of heat events and days where extreme heat may pose a risk to health. Furthermore, the number of nights where the temperature remains above 20°C (referred to as "tropical nights") is expected to increase from 4.2 days per year to approximately 28.2 days.[10] This will reduce the important relief that cool nights provide from high daytime temperatures.

Figure 5.4. Projected changes to maximum and minimim temperatures for York Region in the 2050s compared to historical values (1981 to 2000).



Source: Fausto E, Milner G, Nikolic V, Briley L, Basile S, Behan K et al. Historical and future climate trends in York Region: summary report [Internet]. Newmarket: Regional Municipality of York; 2016. Fig C-8, Extreme heat climate indices in York Region using CANGRD (Historical) and MOECC ensemble median values (Future); p. 47. Available from https://climateconnections.ca/app/uploads/2015/02/Historical-and-Future-Climate-Trends-in-York-Region_Report-1.pdf. Reproduced with permission from the copyright holder.

Data uses Canadian gridded data (CANGRD) for historical values and MECP Ensemble Median Values for future projections. Tmax refers to maximum daily temperature.[10]

The Ministry of Health[11] predicts the average number of heat waves in York Region (at least three consecutive days exceeding 32°C) annually will rise from 0.28 (1971 to 2000) to 1.31 by the 2050s and 3.12 by the 2080s.[11] However, this projection does not consider two-day events, nor other weather variables such as humidex and tropical nights.

Urban heat islands in York Region

Urban heat islands (UHIs) can influence local temperatures and increase the risk from extreme heat. Urban heat islands are created when urban areas composed of dark, impervious surfaces, such as roads, parking lots and roofs that absorb the sun's radiation and release it slowly back into the environment. This warms the surface and ambient temperatures, creating a temperature gradient in urban areas ranging from 2°C to 10°C greater than rural areas.[60]

UHIs in combination with building properties - height, heat retention, insufficient ventilation or cooling options - can impact indoor environments. Without access to air conditioning, upper-stories of high-rise buildings can have higher temperatures, increasing exposure to extreme heat. UHI impacts could present a health hazard for residents when combined with buildings without sufficient means for cooling, especially in areas where urban design characteristics result in heat retention and limited airflow. Unfortunately, there is a lack of data on indoor building temperatures in York Region, which would help to better understand the vulnerabilities and exposures of residents.

In 2014, York Region completed an Urban Heat Island study. Through analyzing land surface temperature from Landsat 7 ETM+ taken on August 19, 2011, and using Census data from 2011, the report noted the following key findings:[68]

- Overall, UHIs exist as pockets across York Region, mainly in the larger, southern municipalities of Vaughan, Markham and Richmond Hill
- Cool islands also exist, mainly around parks, water bodies and open spaces or non-agricultural fields
- Vulnerable populations often resided in UHIs. Seniors were mostly living within more urban UHI areas, while children predominately resided in smaller towns and village areas
- Cool roofs were observed to have a dramatic impact on localized hot spot intensity

Using more recent data, Figure 5.5 shows the land surface temperature in York Region based on satellite imagery from August 22, 2015. As expected, the southern municipalities had some of the highest temperatures compared to the average for urban areas. Consistent with population growth, UHIs have expanded in newly developed commercial and residential communities, particularly in the southern municipalities, as well as in Newmarket and Aurora.

Figure 5.5. York Region Land Surface Temperature, 2015.

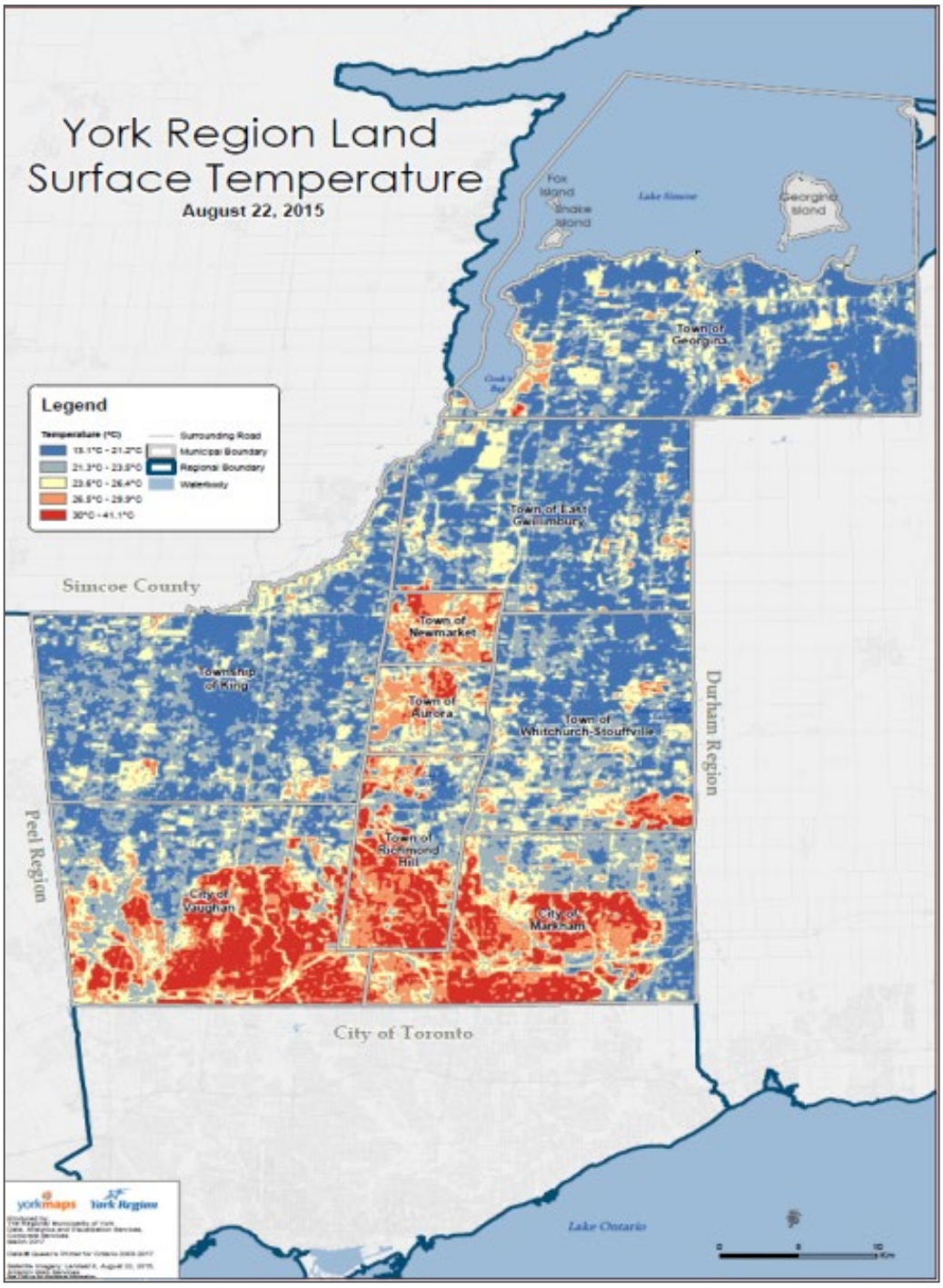
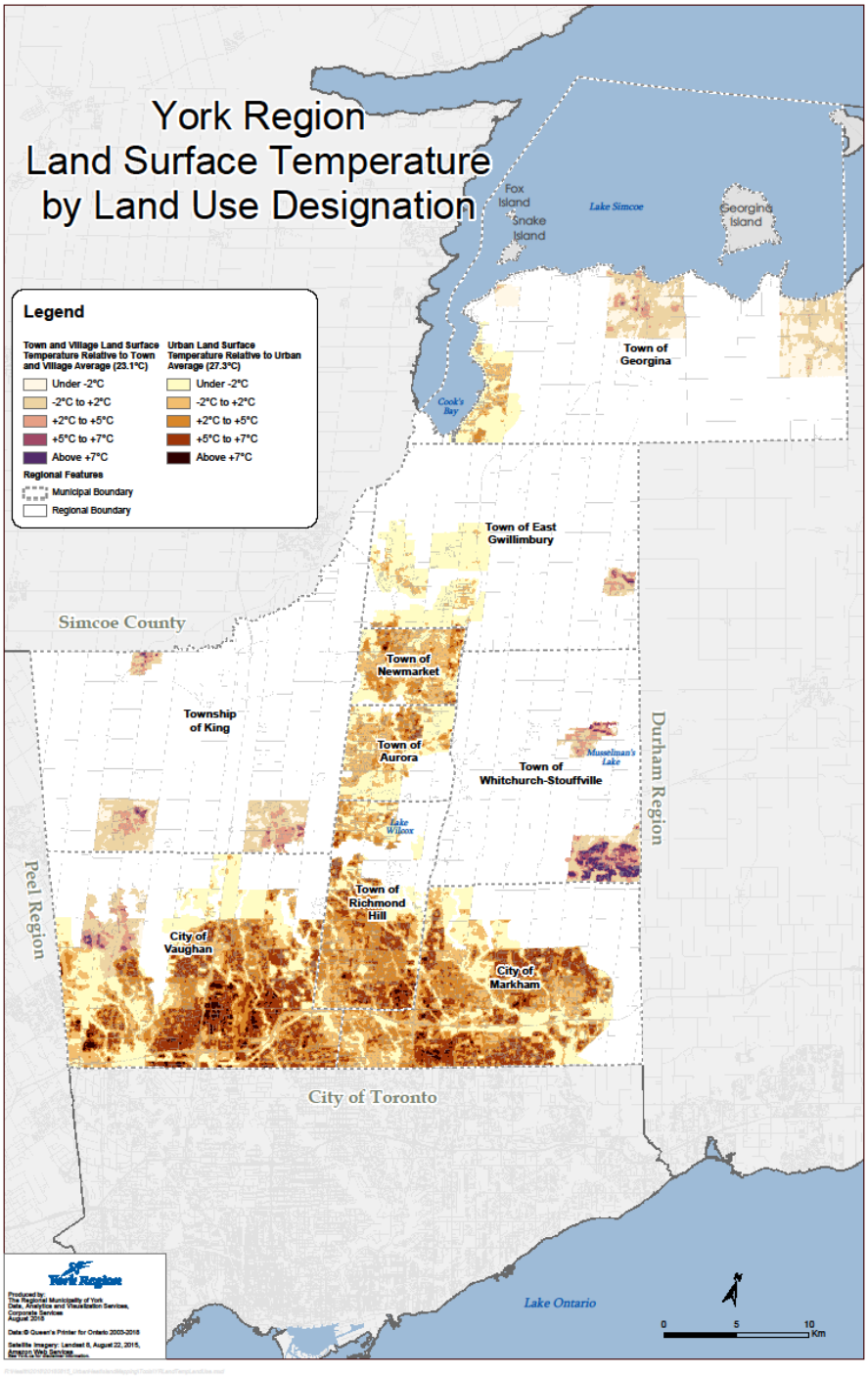


Figure 5.6 highlights how land surface temperature differs within urban areas and towns and villages. Overall, urban areas were 4.2˚C warmer on average than towns and villages. Within towns and villages, new residential and commercial development has likely increased land surface temperature compared to the average, particularly for the Town of Whitchurch-Stouffville.

Figure 5.6. York Region land surface temperature by land use designation, 2015.

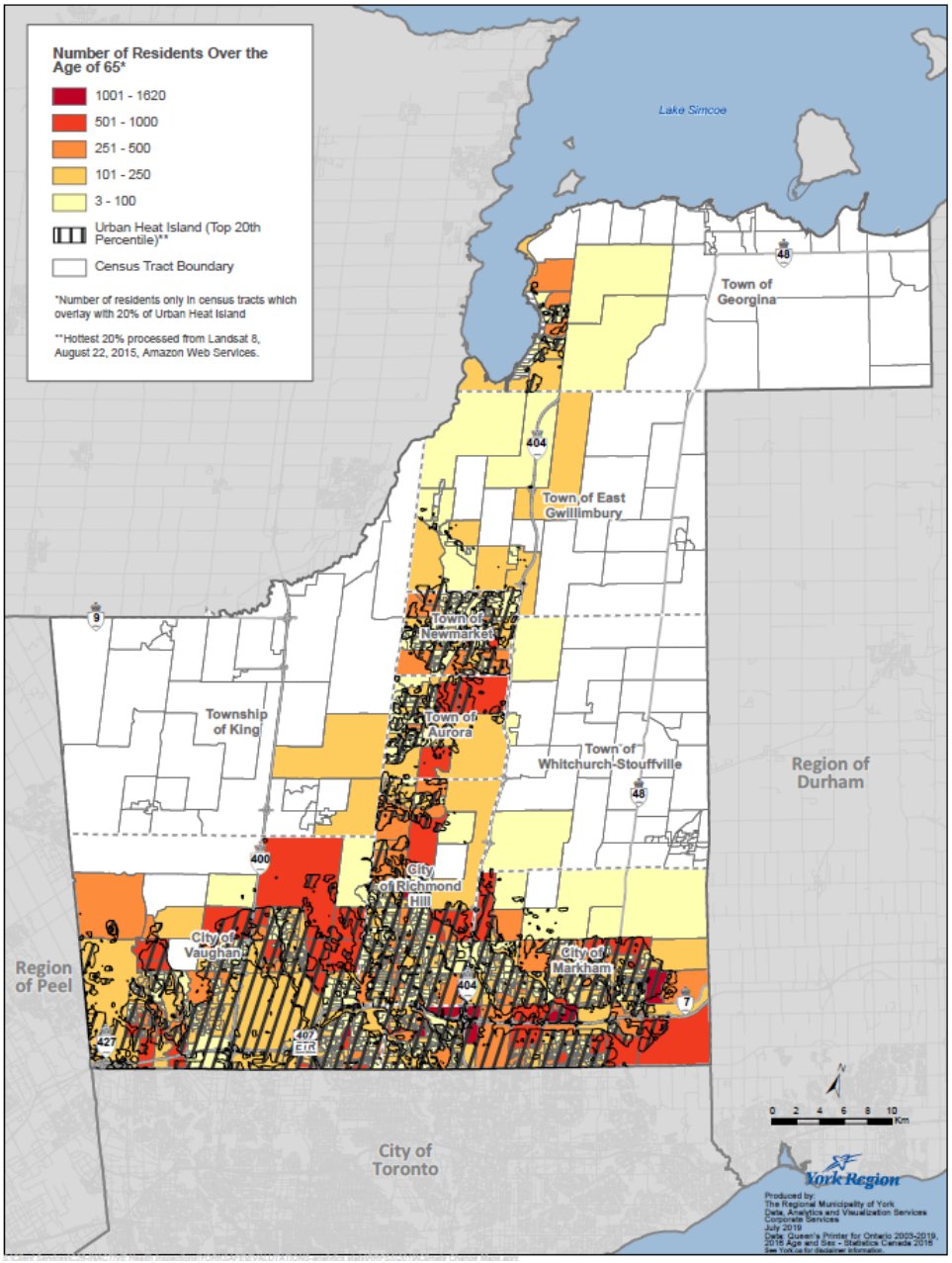


Vulnerable populations, such as seniors, low SES households and children, residing in UHI impacted areas may be at greater risk to heat-related illnesses. Using 2016 Census data and land surface temperature from August 22, 2015, Figure 5.7 highlights where there is a larger proportion of seniors residing in areas with the highest land surface temperature in the Region (top 20% of

UHI in the Region). In particular, the southern municipalities tend to have the highest land surface temperatures, and also have areas with a high proportion of seniors.

While this analysis provides an indication of vulnerability to extreme heat, the risk of heat-related illness also depends on the adaptive capacity of residents, such as owning an air conditioning system, and behavioural practices. Further research is still needed to assess the linkages between UHI and heat-related illness, and help inform future policy and programs.

Figure 5.7. Number of seniors within census tracts and top 20% of land surface temperatures.



5.1.4 Adapting to extreme heat

York Region Public Health's extreme heat program

To help prevent HRI and support stakeholders' response to extreme heat events, Ontario implemented a Harmonized Heat Warning and Information System (HHWIS) in 2016. The HHWIS helps to increase consistency in the way public health units respond to heat events to better protect residents, communities and visitors.

The Extreme Heat Program takes into account evidence-based triggers for intensity and duration of extreme heat. York Region Public Health's (YRPH) Extreme Heat Program runs annually from May to September, seven days a week. It involves collaborating with internal and external stakeholders to communicate risks from heat events. YRPH monitors weather and Environment and Climate Change Canada (ECCC) Heat Warnings for York Region. In York Region, a heat warning is issued when either of the following conditions are met for at least two days: The maximum daily temperature is expected to reach or exceed 31°C and the minimum nighttime temperature is expected to reach or exceed 20°C, or humidex values of at least 40 are expected. YRPH may issue an extended heat warning if these conditions are expected to last three days or more. ECCC may also issue a Special Weather Statement when no defined heat warning thresholds have been met. During heat events, YRPH issues communications through a variety of channels, such as email, media releases, news items and social media, to internal partners, external stakeholders and the public. This communication provides information on precautions to reduce heat-related illness and support residents and vulnerable populations in staying safe during the heat event.

Different actions may be taken by local municipalities during a heat event. Heat warning notifications have been used by local municipalities to determine appropriate responses for their communities, such as whether or not to open cooling centres or increase public pool hours. Actions implemented by local municipalities vary based on the heat event and the resources and risk for each individual municipality. Moving forward, the municipal responses will need to account for the increased length and frequency of heat events when determining appropriate responses for their communities. Further research on best practices would help inform and support local stakeholders in determining what responses may be suitable for different heat event circumstances.

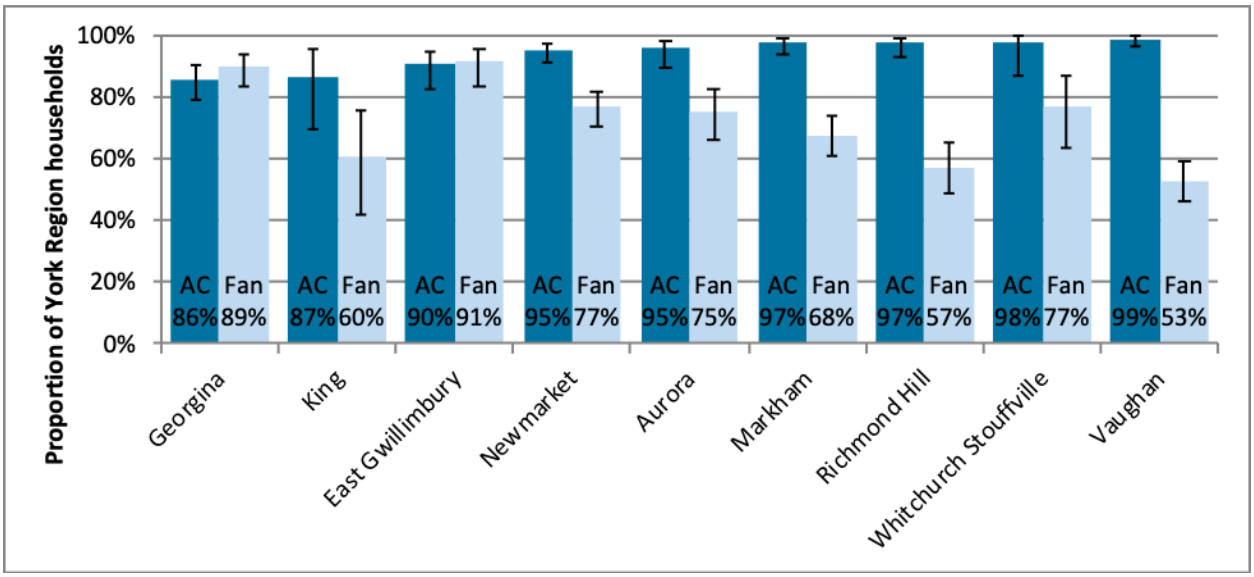
Long-term care homes (LTCHs) in York Region have plans and measures in place to address extreme heat and potential health impacts. LTCHs are considered stakeholders and are included in heat warning notifications by YRPH. In 2016, YRPH conducted a survey to access the adaptive capacity of LTCHs in York Region. All LTCHs have some form of cooling - central air, portable/window air conditioners or cooling areas. Most have backup generators and policies to adapt to poor air quality days.

Protective measures of York Region residents

Many residents have air conditioners or fans that can provide cooling in homes but it is still unclear how they are used during hot days. In 2016 and 2017, the RRFSS telephone survey asked about residents' capacity to adapt to extreme heat days. It was estimated that 95%

(95% CI: 93%-96%) of households have an air conditioner and 70% (95% CI: 68%-73%) have a fan, suggesting the majority of households have some means to cool their homes (Figure 5.8). However, this estimate does not reflect the use of air conditioners or fans during extreme heat events. Additionally, building design factors and UHIs are not accounted for, which can decrease the impact these measures may have in certain households.[16,69]

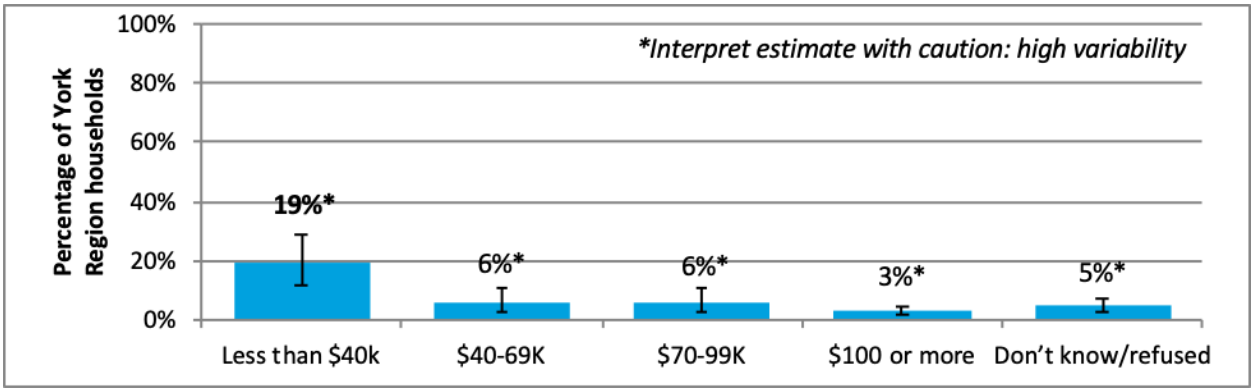
Figure 5.8. The proportion of York Region households, by municipality, that have an air conditioner (AC) or a fan.



Source: Rapid Risk Factor Surveillance System (RRFSS), 2016-2017, Regional Municipality of York, Community and Health Services.

Household income was found to be significantly associated with air conditioner ownership in York Region.[16,69] Almost 20% of low-income households reported lacking an air conditioner, compared to only 3% of high-income households (Figure 5.8).[16,69] Although access to air conditioners is high among York Region residents, operational costs may be prohibitive and reduce the likelihood of use. It must be noted that fan use in certain temperature conditions, such as in high temperatures with differing humidity conditions, can increase body temperatures and heart rates, reducing the ability to cool through sweating, and therefore may not reduce the risk of HRI.[70]

Figure 5.9. Proportion of York Region households without an air conditioner by income.



Source: Rapid Risk Factor Surveillance System (RRFSS), 2016-2017, Regional Municipality of York, York Region Community and Health Services.

The majority of York Region residents adopt some protective behaviours during very hot summer days. More than 75% of residents reported they drink more water, use curtains to block out the sun or spend time in air-conditioned environments during hot summer days (Figure 5.10).[16,69]

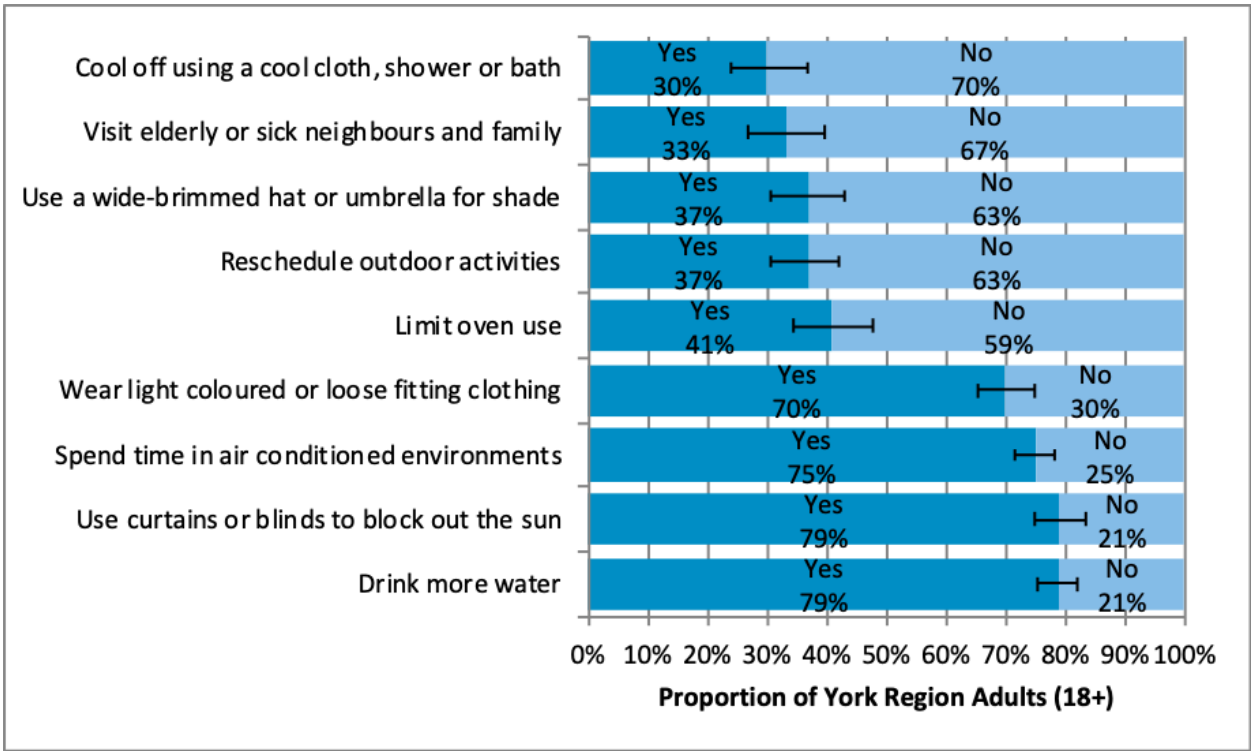
Protective behaviours and findings:

- 57% (95% CI: 45-68%) reported limiting oven use
- 82% (95% CI: 70-90%) reported wearing light and loose-fitting clothing
- 53% (95% CI: 51-65%) reported shading themselves by wearing a wide-brimmed hat or using an umbrella
- 53% (95% CI: 45-61%) reported rescheduling their outdoor activities to cooler parts of the day

Seniors were significantly more likely to take precautions against heat-related illness than younger age groups.[16,69] However, the survey was not able to compare behavioural differences that may exist within senior populations, such as low-income, socially isolated or new immigrants.

The least frequently reported heat-protective behaviours reported were cooling off with a cool shower, bath or cloth (30% [95% CI: 24-37%]) and visiting elderly or sick neighbours and family members to ensure they are cool and hydrated (33% [95%CI: 29-38%]) (Figure 5.10).[16,69] Recent research of HRI risk factors in Quebec found that high social participation was an important protective measure, suggesting the importance of decreased social isolation for seniors during extreme heat events.[71] Only 37% (95% CI: 33-41%) of residents reported they would reschedule activities to cooler times of the day, with men (30% [95% CI: 24-36%]) significantly less likely than women (43% [95% CI: 38-49%]) to do so.[16,69]

Figure 5.10. The proportion of York Region adults who adopt protective behaviours during very hot summer days.



Source: Rapid Risk Factor Surveillance System (RRFSS), 2016-2017, Regional Municipality of York, Community and Health Services.

SOLAR ULTRAVIOLET RADIATION AND CLIMATE CHANGE

While solar ultraviolet radiation (UVR) can have positive benefits such as synthesis of vitamin D, it is also a primary cause of skin cancer. In Ontario UVR is the leading environmental cause of skin cancer, contributing between 2,090 and 2,990 new cancer cases (mainly melanoma cases) per year.[72] There are three major types of skin cancer: Basal cell carcinoma, squamous cell carcinoma and melanoma. Melanoma is the most fatal and is linked to a history of sunburn, especially at a young age; however, non-melanoma skin cancers are 12 times more common than melanoma.[72]

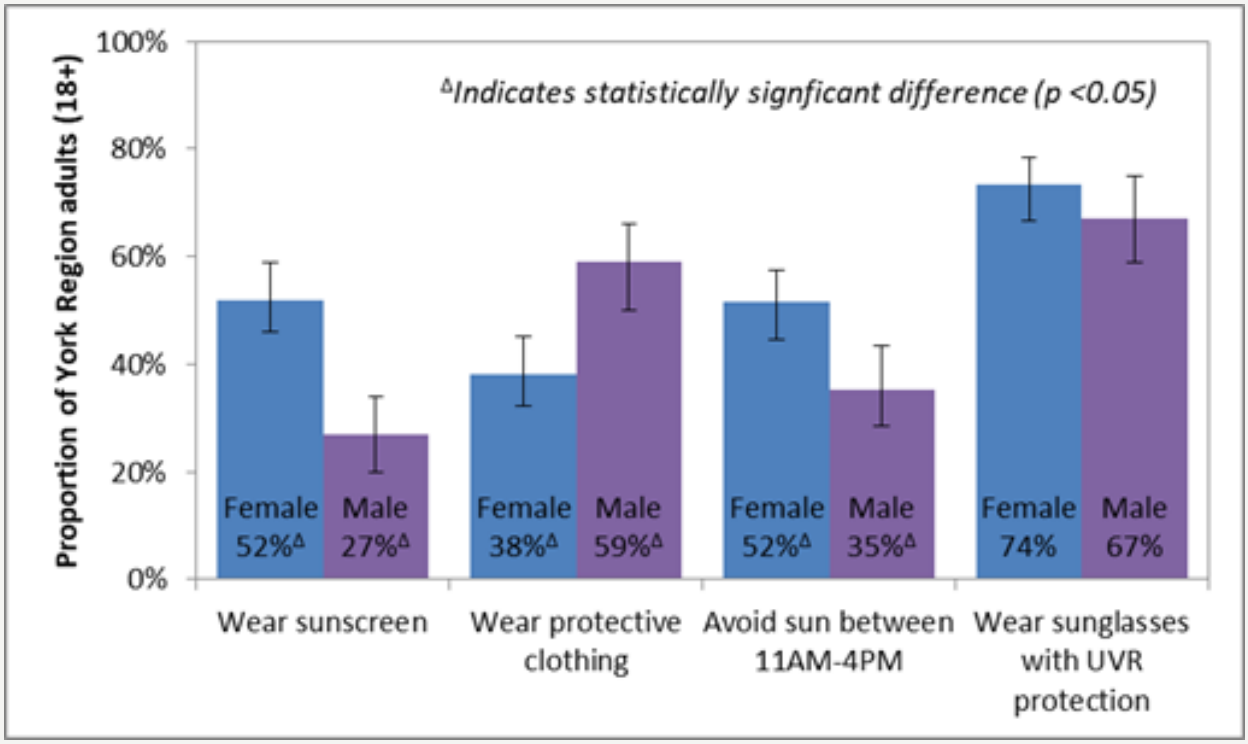
It is estimated that 80% of Ontario's melanoma cases are caused by UVR exposure.[72] The incidence rates of melanoma in Ontario are projected to increase significantly with age[73], with the highest incidence rate in 2018 in those 80 years of age or older, followed by the 60 to 79 year-old age group. In 2018, the incidence of new melanoma cases is projected to be higher in males than in females (2,372 versus 1,757; age-standardized rate of 32.5 for males, 21.6 for females).[73]

Exposure in York Region: Past telephone surveys of York Region adults found the younger populations reporting being sunburned in the past year.[74,75] Almost half (49% [95% CI: 41-57%]) of young adults reported they had been sunburned in the past year.[74,75] Males were more likely to report they had been sunburned in the past year (31% [95% CI: 28-34%]) compared to females (25% [95% CI: 23-28%]).[74,75]

York Region hospital data indicate individuals between 15 and 29 years of age consistently had the highest age-specific sunburn rates, with rates of 10 sunburn cases per 100,000 or higher, more than double the average for the overall population. Seniors (80+) had the highest rates of melanoma compared to all other age groups. Given York Region's aging population, it is likely melanoma rates will increase in the future.

Protective behaviours: In a telephone survey of York Region adults (aged 18+), approximately half of respondents indicated they have adopted various behaviours to protect themselves from UVR exposure, such as wearing sunscreen or protective clothing, avoiding sun exposure during peak UVR times (11 a.m. to 4 p.m.) and wearing sunglasses with UVR protection (Figure 5.11).[74,75] There were some significant gender differences identified with regards to the adoption of protective behaviours, with females more likely to report avoiding the sun during peak UVR periods and wearing sunscreen compared to males.[74,75] However, males were more likely to report wearing protective clothing in the sun compared to females.[74,75]

Figure 5.11. The proportion of York Region residents, by gender, who report adopting various behaviours to protect themselves from UVR exposure.



Source: Rapid Risk Factor Surveillance System (RRFSS), 2012-2013, Regional Municipality of York, Community and Health Services.

UVR and climate change: Exposure to UVR is influenced by latitude, geography, topography, altitude, ozone depletion, air pollution and weather conditions. Climate change is expected to affect UVR exposure by changing precipitation patterns, cloud cover, air pollution and ozone levels.

Gough et al.[11] estimate climate change may increase basal cell and squamous cell carcinoma rates in York Region by 7.8% and 13% respectively by the 2050s. However, there have been few studies providing a clear relationship with UVR levels of exposure and cancer risk, and tend to use temperature as a proxy measure.[11] As a result, there is insufficient information to adequately assess future UVR exposures and health impacts in York Region.

Adaptive capacity: Important measures for building adaptive capacity and climate resiliency for reducing exposure to UVR include conducting additional research to better assess UVR impacts on health, increasing surveillance screening of York Region melanoma rates, advocating for shade policies and integrating UVR protection messaging with existing extreme temperature program activities.

5.2 EXTREME COLD

5.2.1 Health impacts related to extreme cold

Serious health problems can result from prolonged exposure to the cold, such as frostbite and hypothermia.[4] Hypothermia is a serious cold weather injury that can lead to brain damage and even death. Hypothermia usually occurs in extremely cold temperatures, but can also occur at more moderate temperatures if a person loses heat due to exposure or submersion in water.

In York Region, cold temperatures have not been associated with excess mortality. A province-wide study examining mortality impacts of temperature found that cold temperatures generally have a greater impact on mortality than hot temperatures.[59] Specifically, a decrease of 5°C in the daily mean temperature during the cold season was associated with a 3.0% increase in non-accidental deaths, resulting in an estimated seven excess deaths per day in Ontario, with the effect persisting over seven days.[59] However, in York Region, the study observed that cold did not have a significant impact on excess mortality (0.2% (-3.7% to 4%) increase in non-accidental deaths).[59]

Similar to extreme heat, research suggests health outcomes from chronic diseases may be associated with extreme cold events. Research has found strong associations with cold mortality from a cardiovascular cause, ischemic heart disease, acute myocardial infarction and stroke.[59,76] Cold-related health effects are also associated with bronchoconstriction, which suppresses mucociliary defences and other immunological reactions, resulting in local inflammation and increased risk of respiratory infections.

Cold-related morbidity and mortality do not exclusively occur in extreme cold temperatures. Exposure to milder cold temperatures can have significant health impacts because they are more common than extreme temperatures.[77] Wang and colleagues[49] found a nine percent increase in the number of ED visits for neurotic disorders, such as phobias, anxiety, panic and stress, associated with cold in Toronto. Research suggests the immediate effect of two-day extreme cold events on mortality was insignificant. However, events lasting three or more days were significantly associated with an increased risk of mortality in a study conducted across the U.S.[78] Evidence on the relationship between cold-related mortality, mean winter temperature and adaptation over time is lacking.

Vulnerable populations

Individuals most vulnerable to cold are similar to those vulnerable to extreme heat. Although everyone can be affected by extreme cold, the following people are at a higher risk for cold weather injuries: Seniors, infants and children, people with pre-existing medical conditions, people who lack appropriate shelter, newcomers to Canada, outdoor workers and sport/outdoor enthusiasts.[4,55] In the Ontario study looking at cold temperatures and excess mortality, the impact were mostly for individuals under 65 years of age n York Region.[59]

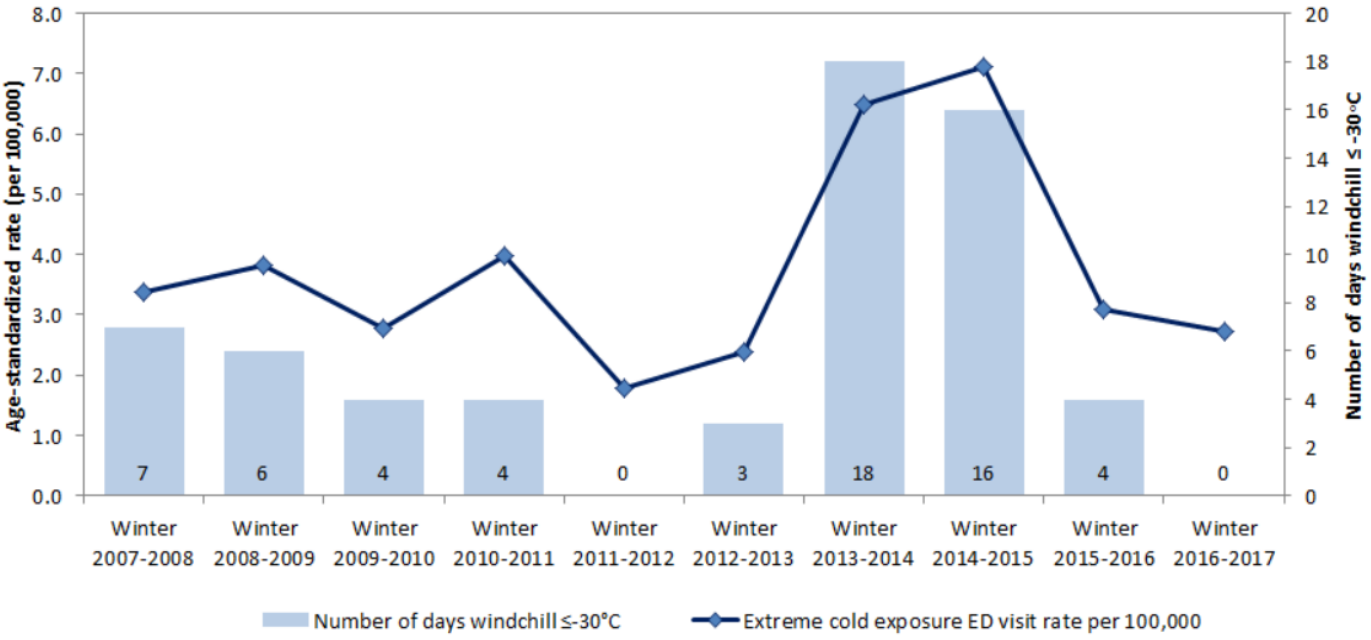
Populations most at risk of illness or mortality from exposure to extreme cold include those less able to regulate their body temperature. This may be due to age, pre-existing conditions or chronic

diseases, and the use of drugs and alcohol. Individual vulnerability to extreme cold has also been found to vary with sex and race.[55] See Chapter 4 for more information on vulnerable populations in York Region.

5.2.2 Local health impacts from extreme cold

Between 2007 and 2017, there were 410 ED visits from exposure to cold in York Region (Figure 5.12).[50] The highest rates across all age groups were for seniors, particularly those 85 years of age and older, and were often 10 times higher than the age-standardized rate for ED visits. The second highest rates were noted in youth 15 to 19 years of age. Certain years with extreme cold temperatures, such as winter 2013 to 2014 and winter 2014 to 2015, had much higher ED visit rates compared to other years.

Figure 5.12. Age-standardized rate of extreme cold emergency department visits from 2007 to 2017.



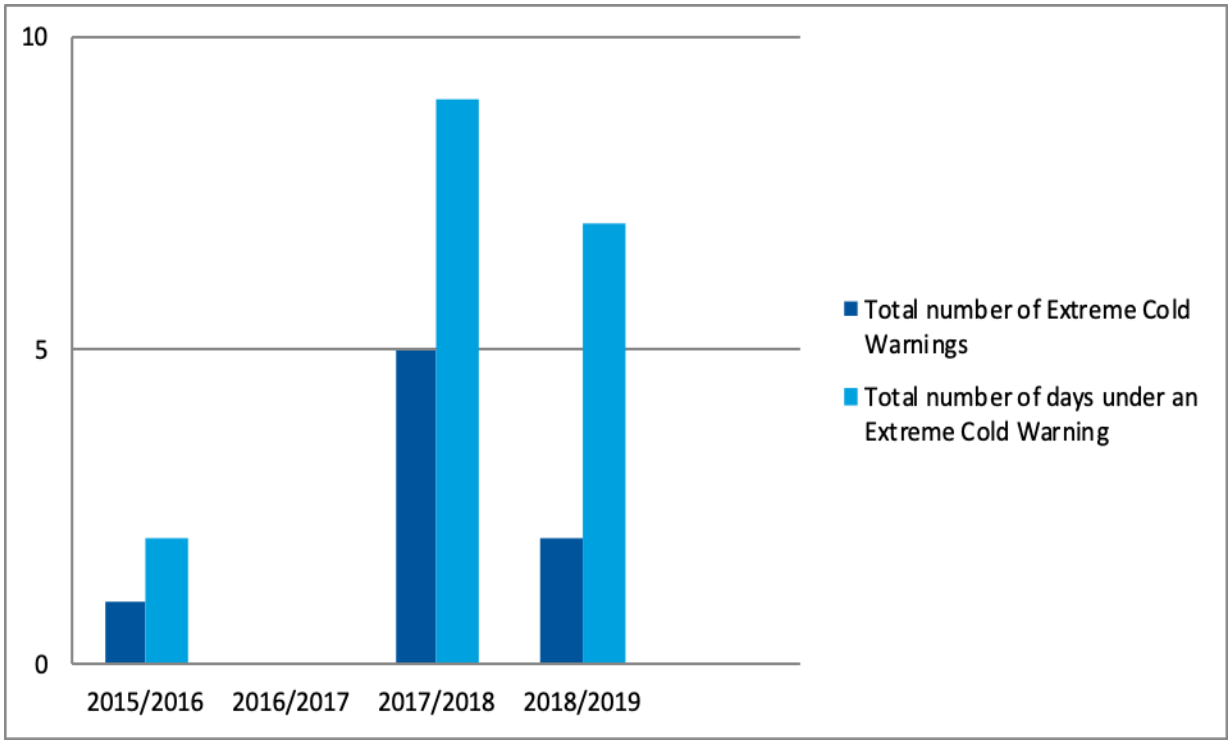
Data Source: Ambulatory Visits & Population Estimates, 2007-2017, IntelliHealth Ontario. Extracted April 30, 2019. Exposure to extreme cold was defined as any unscheduled emergency visit using ICD-10 CA codes T33-35, T68-69, and X31. Rates were age-standardized using the 2011 Candian Census Total Population by Age, from Statistics Canada, catalogue #98-311-XCB2011018.
Winter was defined as October to April.
Temperature Data: Toronto Buttonville A weather station via Environment Canada (climate.weather.gc.ca).

5.2.3 Climate change impacts on extreme cold

Climate change impacts on extreme cold in York Region

In recent years, there has been a wide range of extreme cold events in York Region. The winter season of 2017 to 2018 had one of the highest number of extreme cold days (14), while the preceding winter season did not reach extreme cold thresholds[n] at all (Figure 5.13).

Figure 5.13. York Region Extreme Cold Warnings, 2015 to 2019.



Climate projections indicate York Region will experience warmer winters with increased rainfall. The number of days below -5°C is expected to decrease by 31 to 37 days from the baseline of 84 days per year by the 2050s. Model projections vary in terms of the number of days annually below -20˚C in the 2050s but range from 0.5 to 4.9 days less than the historical annual average of 8 days.

Although there has been an overall warming trend in winter, it should be noted southern Ontario has recently experienced extreme cold temperatures due to a shifting polar jet system.[10] These conditions have not been incorporated into climate modelling, resulting in uncertainty for future predictions. While the trend of warming winters decreases the probability of extreme cold days by the 2050s, extreme cold temperatures, such as due to a shifting jet stream, may be experienced more regularly in the short-term future.[10]

[n] Extreme cold warnings are issued for York Region when temperature or wind chill is expected to reach -30°C for at least two hours.

Climate change projected impacts on cold-related illness

There are limited studies in Ontario that have projected future cold-related morbidity and mortality. One study in Toronto predicted cold-related mortality to decrease by 60% by the 2050s due to warmer winter temperatures.[79] When assessing climate change impacts on cold and heat-related mortality in 15 Canadian cities, Martin et al.,[58] observed an overall decrease in mortality rates in most of the cities as a result of projected warmer winters. However, the use of protective measures during cold weather can impact the adaptive capacity of residents, and as such, it is unclear how warming temperatures will impact cold morbidity and mortality.[55]

5.2.4 Adapting to extreme cold

York Region Public Health's Extreme Cold Program

To help prevent cold-related illness and support stakeholders' response to extreme cold events, York Region Public Health provides notifications to stakeholders and the public during extreme cold warnings. York Region Public Health's Extreme Cold Program runs from December to March, seven days a week. The program is designed to alert stakeholders of extreme cold events, and involves collaborating with internal and external stakeholders to communicate risks from extreme cold events.

Extreme cold warnings are issued by Environment and Climate Change Canada for York Region when temperature or wind chill is expected to reach -30°C for at least two hours. During extreme cold warnings, York Region Public Health issues communications through a variety of channels, such as email, media releases, news items and social media, to internal and external stakeholders and the public. This communication provides information on precautions to reduce cold-related illness and helps residents and vulnerable populations stay safe during the extreme cold event.

5.3 CONCLUSION

With strong evidence of the health impacts and the high likelihood of increasing summer temperatures, climate change will likely play a significant role on health impacts from extreme heat in York Region. These impacts will be exacerbated by UHI conditions as the Region continues to grow and urbanize. In terms of extreme cold, projections for the winter months suggest fewer extreme cold days, but there is still emerging research on how climate conditions may impact polar jet streams and in turn extreme cold events in York Region.

While vulnerabilities remain present throughout York Region, such as decreased cooling options among low-income residents and a decreased social network among seniors, there are opportunities to enhance adaptive capacity, such as exploring health outcome data to inform future extreme heat and cold programming activities.

Certain gaps in understanding local impacts from extreme temperatures have been identified for York Region:

- Additional health data to better understand the health burden from extreme temperatures. This includes additional data (e.g., reported incidents at schools, workplaces, or long-term care homes), other health outcomes (e.g., mental health, cardiovascular disease) and the geographic distribution of cases
- Limited information on thermal comfort conditions in residential units, including vulnerable populations
- Understanding health impacts that may occur in conditions that do not meet warning criteria, such as moderate temperatures or impacts from multiple episodes of warm conditions
- Limited temperature layer maps to more accurately capture UHIs
- Determining if previously developed vulnerability indexes are valid measures of risk and assessing whether UHI areas correlate to greater exposure and health outcomes
- Better understanding of barriers of residents to address extreme temperatures, particularly for vulnerable populations

Addressing some of these gaps will provide valuable information to support adaptation planning, including a better understanding of UHI impacts and thermal comfort to inform policy and plans for land use development, recommendations to building codes and by-laws, and tree planting activities across the Region. Additionally, as the public health program relies on communication tools with stakeholders and the public, a better understanding of these gaps can inform the communication strategies that may be more effective in reaching target audiences.

While there is strong evidence of the increased risk of heat-related illnesses resulting from climate change, there are many factors that can shift vulnerabilities. For instance, future building and community designs may help alleviate some of the UHI conditions. As populations grow in York Region, shifts in demographics, such as more seniors and increases in low-income households, can create more climate-vulnerable populations. Impacts of extreme heat on health will also depend on how populations acclimatize to changing temperatures, which can reduce the sensitivity to extreme heat.

As mediating factors evolve, it is important for future adaptation planning to include continual surveillance of extreme heat and cold risks and York Region's adaptive capacity. Engagement of stakeholders will also be important to ensure the relevancy of identified strategies throughout the community and among partners. Table 5.2. provides a list of existing activities and potential opportunities that can inform future adaptation planning.

Table 5.2. Summary of extreme temperature related activities and adaptation planning opportunities.

	Ongoing and Completed Activities	Opportunities
Population Health Assessment and Surveillance	**Environmental monitoring:** Receiving and monitoring ECCC Alert Me notifications for extreme heat (including early notification stakeholder emails) and cold events. Completed UHI mapping assessment (2014). **Health surveillance:** Monitor extreme cold and heat-related hospital data (e.g., syndromic surveillance of extreme cold and heat-related hospital visits).	**Additional data and analysis:** Consider further analysis of past temperature related illnesses to provide better temporal and spatial resolution. • Explore observed heat-related illness cases occurring below heat event thresholds (e.g., mental health outcomes) • Consider trends relating to UHI areas. • Consider analysis methods from similar studies and available toolkits. Consider other data that can support better burden estimate (e.g., school-related cases, physician offices, 911 dispatch data, health line calls). Assess cases of sunburns in relation to extreme heat events and warmer summers. Surveillance planning: • Explore thresholds for real-time surveillance of the health impacts related to extreme temperature • Review updated climate change projections for extreme temperatures • Consider developing a plan for updating UHI maps
	Conducted RRFSS surveys (2016 to 2017) on extreme heat.	Consider modifying RRFSS Heat-Related Illness Protective Equipment to include other relevant health protective questions. Consider RRFSS questions for vulnerability factors (e.g., senior, low-income, socially isolated, thermal comfort).

Program and policy	Early warning system for extreme heat and cold notifications to stakeholders	**Health Equity:** Consider other methods to reach the most vulnerable populations.
	Recommending policy and program measures to reduce UHI effects • Supporting urban forest planning to increase shade in UHI priority areas • Supporting land use planning policy recommendations to reduce UHI (e.g., increasing tree coverage, retrofitting existing buildings with a high albedo and/or lighter coloured roof surfaces, ensuring buildings have air conditioning)	Explore effective built environment interventions for UHIs and increasing thermal comfort indoors (e.g., green infrastructure, cool pavements, and cool roofs). Continue advocating for built environment measures that reduce UHI and UVR exposure to the general public. Consider co-benefits of extreme heat best practices and interventions such as shade policies and guidelines. **Health Equity:** Incorporate health equity considerations in policy and programming to ensure all vulnerable populations are reached.
	Consulted with stakeholders on the York Region Public Health Extreme Heat program: • Survey of long-term care homes • Consultation with Regional partners and local municipalities	**Emergency Preparedness and Response:** Consider incorporating extreme heat adaptation measures for emergency plans relating to power outages.
Health Promotion	Extreme heat and cold key messaging and recommendations on York Region's website and social media. Cross-promotion of sun safety /checking UVR index through Extreme Heat program. **Forestry and Health Collaborative:** Promotion of the benefits of trees key messages, planting trees, build shade for your health and the environment factsheet as part of Local Enhancement and Appreciation of Forests' backyard tree planting program; social media messaging; articles; events.	Further public education on the health risks of extreme heat and cold resulting from climate change and measures to take to reduce exposure (for the general public and vulnerable groups). Integrate UVR exposure to Extreme Heat messaging. Health Equity: Targeted messaging for vulnerable populations (e.g., seniors).

Key stakeholder activities (outside of Public Health)	**Addressing extreme temperatures** Area municipality cooling centres and cooling options (e.g., splash pads, reflective pools, community centres and parks, community swimming pools). The Street Outreach Van (operated by Loft/Crosslinks) provides mobile services for homeless or street-involved people at no cost. York Region Public Health is one of several community partnering agencies that provide services through the Street Outreach Van. Winter shelters such as Inn from the Cold, Blue Door Shelters, Mosaic Interfaith Out of the Cold, Adult Emergency Housing Facilities, Family and Youth Shelters (360 Kids). **Addressing UHI** Assisting Forestry with the development of their tree planting prioritization tool, York Regional Forest management plan (2019-2038), York Region Forestry's Benefit of Trees strategy, and Urban Forest studies.	More effective engagement of key stakeholders in responding to extreme temperature events: • Consider additional consultations on response options for extreme temperature events (e.g., better understand health care system plans and measures to address extreme temperatures) • Consult on approaches and best practices to respond to extreme temperature events and reduce risk • Consider approaches to help address those most vulnerable and health equity considerations (e.g., subsidized air conditioning and fan distribution to provide cooling for vulnerable populations) Consider extreme heat impacts on the Mental Health Initiative and developing adaptive capacity for service delivery during extreme heat events.

CHAPTER 6
Extreme Weather Events

6.0 Extreme Weather Events: Key Findings

Climate change projections and exposure pathways

- Annual precipitation levels events are likely (66% to 100% probability) to increase in York Region by the 2050s, particularly in the winter and spring
- Extreme precipitation events are likely (66% to 100% probability) to increase in York Region by 2050s, particularly in the summer months
- York Region has experienced major rainfall and flooding events in recent years that have resulted in infrastructure damage and large recovery costs
- York Region floodplains are at an increased risk of flooding following heavy precipitation events. Current floodplain maps focus on riparian and lakeshore flooding but there is limited information on higher risk areas for urban flooding
- Due to limitations in climate models, there is insufficient evidence to suggest droughts and ice storms will increase in York Region by the 2050s

Population sensitivity

- Seniors are more vulnerable during and after extreme weather events due to chronic health conditions and medication use, greater risk of injury, limited mobility, difficulty managing during transportation and evacuations and limited capacity to recover following an event
- Residents living in floodplains are at an increased risk of injury and illness due to flooding, as well as property damage and loss. Low-income households may be more vulnerable to health impacts due to limited resources to recover from property damage or loss

Adaptive capacity

- Early warning and forecasting systems for extreme weather events from Conservation Authorities and Environment and Climate Change Canada provide critical information for emergency planning and response
- York Region Public Health has identified its primary emergency response roles and responsibilities within the Public Health Emergency Plan and the Regional Emergency Plan
- Emergency and business continuity plans need to adequately address climate and health risks at all levels
- In 2018, more than half of York Region households surveyed had taken measures for emergency preparedness and half have plans to check on family and friends during an emergency. However, additional research is still needed to understand the existing level of resilience to climate change

Health impacts

- Future health impacts in York Region from extreme weather events are difficult to predict. Impacts will vary depending on the magnitude, frequency and affected areas of extreme weather events, the local population exposed and the critical infrastructure impacted
- The health impacts of extreme weather events can be severe. They can include injury, death, mental health effects, population displacement and food- and waterborne illness
- Extreme weather events also impact human health through changes in service demand and operation of health services
- Health impacts can occur during an extreme weather event or can last for many years following an event, such as with mental health outcomes

Recent Trends:

- There is limited hospital data relating to past extreme weather events in York Region. However, a study observed an increased number of injury-related Emergency Department visits in Toronto following the 2013 ice storm

Extreme weather events can result in major health impacts such as traumatic injury and death and can also impact health after the event takes place, including ongoing mental health troubles and stress, or damage to home environments. Considering the severe impacts that can result from such events, it is important to assess how climate change can impact human health through extreme weather events.

This chapter provides an overview of the health outcomes and impacts specific to extreme weather events and their implications for emergency planning and preparedness in York Region. Impacts related to coastal flooding or hurricanes are out of scope. The following impacts are most relevant to the York Region context with respect to extreme weather events and the links to climate change:

- York Region has experienced a wide range of extreme weather events such as intensive storms and flooding with large impacts on the community. Recent events such as the December 2013 ice storm resulted in loss of power to 92,000 homes in York Region and over 35 million dollars in cleaning and repair costs[10]
- Climate change is expected to increase the frequency and intensity of extreme weather events, such as heavy precipitation, flooding and possibly droughts and ice storms[4,80-83]
- Extreme weather events, including floods, rainstorms, ice storms and droughts, can cause significant damage to local communities. This may result in the disruption of transportation networks, impacts on water and wastewater treatment activities, power outages and damage to residential homes[40,81,84-86]

6.1 HEALTH IMPACTS

The relationship between health and extreme weather events is complex and depends on the physical impacts from an event, as well as mediating factors in communities that can reduce or increase risks. Predicting the health impacts from climate change-mediated extreme weather events is challenging due to the number of factors to be considered and existing limitations in forecasting complex weather patterns. For instance, there is currently no consensus on the impact of climate change on tornadoes or high winds associated with thunderstorms.[25] Similarly, research is still emerging on the impacts of climate change on the frequency and intensity of storms.[80] There is also less emphasis in literature on how extreme weather events alter the sensitivity and coping capacity of human systems to future events.[82]

Health impacts can occur during extreme weather events but can also last for many years following an event, particularly with respect to mental health outcomes. The health impacts of extreme weather events can be severe and include injuries, death, mental health impacts (e.g., anxiety, depression, Post-Traumatic Stress Disorder (PTSD)) and food- and waterborne illnesses. Mental health outcomes have consistently been associated with extreme weather events.[45,47,87] From reviewing the aftermath of disasters, researchers have strong evidence that extreme events have been associated with acute stress, PTSD, higher depression rates and suicide.[45] With advanced warning and preparation, many of the health impacts from extreme weather events can

be decreased. While insufficient data exists to link impacts and specific events in York Region, Table 6.1. provides a general overview of health impacts associated with extreme weather events.

Extreme weather events also impact human health in other ways, through changes in service demand and operation of health services. In addition to having a direct impact on health, extreme weather events strain health and social care systems and reduce the adaptive capacity of public services to address the challenges faced by residents. This is due to the effects on built, social and institutional infrastructure and communication networks being compromised.[88] For example, cuts in the electrical power supply due to flooding may lead to the loss of refrigeration for medicines, reduced mobility through disruption to various types of mobility aid devices that are designed to assist walking or otherwise improve the mobility of people with a mobility impairment, loss of heating and cooking equipment and the loss of telecommunication technology services.[40]

The United States climate change and human health assessment indicate with high confidence that climate-related changes in extreme weather are associated with health impacts such as death, injury, or illness, exacerbation of underlying medical conditions and adverse effects on mental health.[45] However, there is limited evidence on increases in exposure to health hazards associated with increases in the frequency and intensity of extreme weather events. Qualitative studies have examined potential health hazards from these events,[80] but few draw strong or definitive conclusions that exposure to these hazards will increase due to climate change. However, due to the likely increase in the frequency and severity of extreme weather events, York Region residents might be at increased health risks in the future.

Table 6.1. Health Impacts of Extreme Weather Events.

Event Type	Health Risks and Impacts	Supporting Evidence
Heavy Precipitation and Severe Thunder-Storms	• Increased risk for injury, illness and mortality • Health risks related to infrastructure damages • Water quality impacts • Respiratory impacts • Mental health impacts	• Exposure to storm hazards, including falling trees, sheltering in inadequate conditions, utility outages and discharge of hazardous substances may result in injury, illness, electrocution and death[89] • Asthma cases have been significantly associated with thunderstorms during the pollen season due to the high levels of airborne pollen grain[90] • Extreme summertime precipitation events increased risk of hospitalization for asthma by 11% in Maryland, U.S. Risk was slightly more pronounced for those under four years of age[91]
Flooding	• Increased risk for injury, illness and mortality • Indoor air quality impacts and potential illnesses due to mould and sewage backflows in basements • Carbon monoxide poisoning related to power outages • Vector-borne disease risks arising from new mosquito breeding grounds • Mental health impacts • Water quality impacts	• The rate of injury increased by 28% up to six weeks following the 2013 Alberta flood that affected 100,000 people. There was a 1.64- and 2.34-fold increase in new prescriptions for anti-anxiety medications and sleep aids, respectively, for females[48]
Ice and Winter Storms	• Injuries, isolation, mental health impacts, potential disruption of health/social services • Elevated risk of carbon monoxide exposure from the improper use of combustion generators and stoves due to power outages	• During the 2013 ice storm in Toronto, emergency department hospitalizations increased by 10% compared to the previous five years, with hospitalization rates for environmental conditions being 2.6 times higher[85]
Droughts	• Food safety and security impacts • Water quality and quantity impacts • Vector-borne disease risks	• Outbreaks of waterborne disease have been observed following heavy precipitation events after a dry spell [92] • Hot and dry conditions often associated with drought may support the proliferation of some food-borne pathogens (e.g., *C. perfringens*, Campylobacteriosis)[84] • Drought has been strongly associated with increased risk from mosquito-borne infections, such as West Nile virus, in the Canadian prairies where crop irrigation creates new mosquito breeding grounds.[84] • Drought often causes dry, dusty conditions that increase the concentration of particulates in the air and increases risk of wildfires. Increases in particulate matter and wildfire smoke can exacerbate respiratory and cardiovascular conditions[90]
Wildfires	• Mental health impacts • Air quality and respiratory impacts • Fire safety impacts	• Wildfires have been associated with premature mortality and low infant birth weight, but the strongest evidence is for acute respiratory illnesses[80]

Vulnerable populations

Certain populations are likely to be disproportionally affected by extreme weather events. Those most vulnerable include seniors, children, people who are socially isolated, individuals with pre-existing chronic disease, low-income individuals, people who are experiencing homelessness or mental illness, outdoor workers, emergency workers and those with mobility issues. See Chapter 4 for more information on vulnerable populations within York Region.

Seniors are more vulnerable during and after extreme weather events. This is due to chronic health conditions and medication needs, greater risk of injury, limited mobility, difficulty transporting and limited capacity to recover following an event. Mortality rates have been shown to be higher for seniors, particularly males, following disaster events such Hurricane Katrina.[80] Emergency response efforts may have also unintended harms on vulnerable populations such as seniors. For example, response efforts for the 2011 tsunami in Fukushima, Japan, observed an increase in mortality with seniors evacuated compared to seniors that remained in their homes. This could be related to mental health impacts and stress from relocation or limited access to health care during the evacuation process.[93]

Low-income households and renters are also more vulnerable to extreme weather events. Homes in need of repair are vulnerable to damage from extreme weather events. As such, individuals and families living in substandard housing are at greater risk of illness or injury due to climate-related hazards.[45] Based on past extreme weather events, low-income populations tend to experience greater impacts with more adverse health outcomes and have more difficulty recovering after an event. Individuals residing and working in floodplains are more vulnerable to extreme rainfall and flooding events.[86] Those who rent may have a reduced adaptive capacity even if they have the money for repairs or upgrades as they often cannot make the changes to their homes.

While extreme weather events can have a large impact on mental health on the general population, individuals with existing mental illness or stress-related disorders (e.g., depression, anxiety, PTSD, drug and alcohol abuse) can experience worsening symptoms soon after extreme weather events.[45] Additionally, damaged infrastructure can impact communication systems, services and availability of mental health support networks, which can further contribute to the mental health impacts of individuals during, or soon after an extreme weather event.[45]

6.2 HEAVY PRECIPITATION AND FLOODING EVENTS

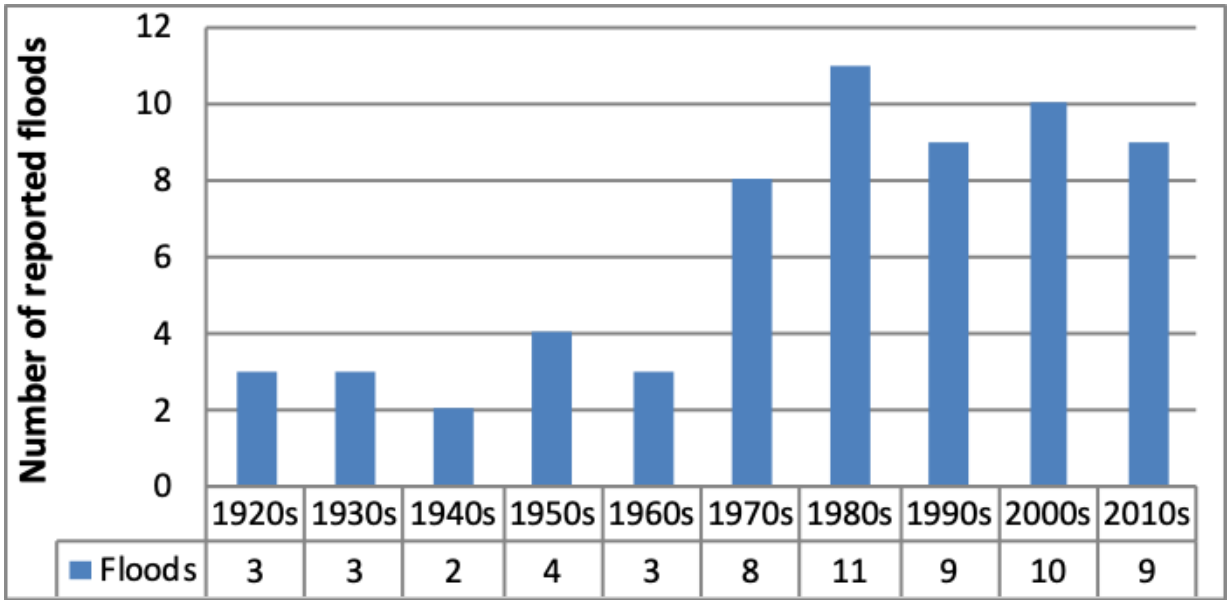
Flooding resulting from heavy precipitation events can create serious health and safety risks. Heavy rains, spring thaw, and quickly melting snow can cause rivers, creeks or streams to overflow and flood. Changing rainfall patterns and extreme weather can also increase the risk of flooding. Some floods develop slowly, while others develop in minutes. Floodwater can be exposed to many sources of pollution and it can carry diseases that impact human health. Floodwater can contaminate drinking water supplies, private wells, surface water, recreational water and public and private properties. People who live in low-lying areas tend to be at a greater

risk from damage caused by flooding.[86] Extreme precipitation and flooding events can influence cyanobacterial bloom development, toxin production and distribution within waterbodies due to altered water quality and nutrient concentrations.[94] Cyanobacterial blooms are a concern to human health due to the potential impacts on recreational and drinking water systems.

The frequency and severity of flood events have been increasing in Canada, and are often associated with spring snowmelt or severe precipitation. The Canadian Disaster Database has recorded more than 60 flooding events in Ontario since the beginning of the twentieth century.[95] The number of flood events appears to have increased since the 1920s. However, this frequency could be due to improved technology for communicating and detecting floods and changes in the built environment (Figure 6.1).

While climate change makes these events more likely, land-use change associated with urbanization adds to the issue. As the population in the Greater Golden Horseshoe continues to grow (estimated to increase by greater than four million people by 2040), associated development could exacerbate the frequency and intensity of urban flooding.[96]

Figure 6.1. The number of reported floods by decade in Ontario between the 1920s and 2010s.



Source: Public Safety Canada. Canadian Disaster Database. Reported floods in Ontario [data file]. Ottawa: Government of Canada; 2017.

6.2.1 Climate change impacts on heavy precipitation in York Region

Extreme precipitation events are likely to increase in York Region in terms of frequency and magnitude. By the 2050s, the annual one-day and five-day maximum precipitation amounts are expected to increase from 39.3 mm to 50.9 mm, and 61.4 mm to 78.4 mm, respectively in York Region.[10] The annual number of heavy and very heavy precipitation days (where

precipitation is greater than 10 mm and 20 mm respectively), is expected to increase by two or three days by the 2050s, particularly in the summer months.[10]

Precipitation changes are not expected to occur uniformly across the year. The amount of precipitation in the summer is expected to remain similar to historical levels, while precipitation in the spring and winter months will increase in the 2050s.[10] Precipitation events occurring over consecutive days are also expected to increase from 6.9 to approximately 7.4 days annually, which may continue to impact urban infrastructure.[10] More frequent rain events can saturate the soil and result in less area for water from subsequent storms to absorb, which leads to flooding.

6.2.2 Climate change impacts on flooding in York Region

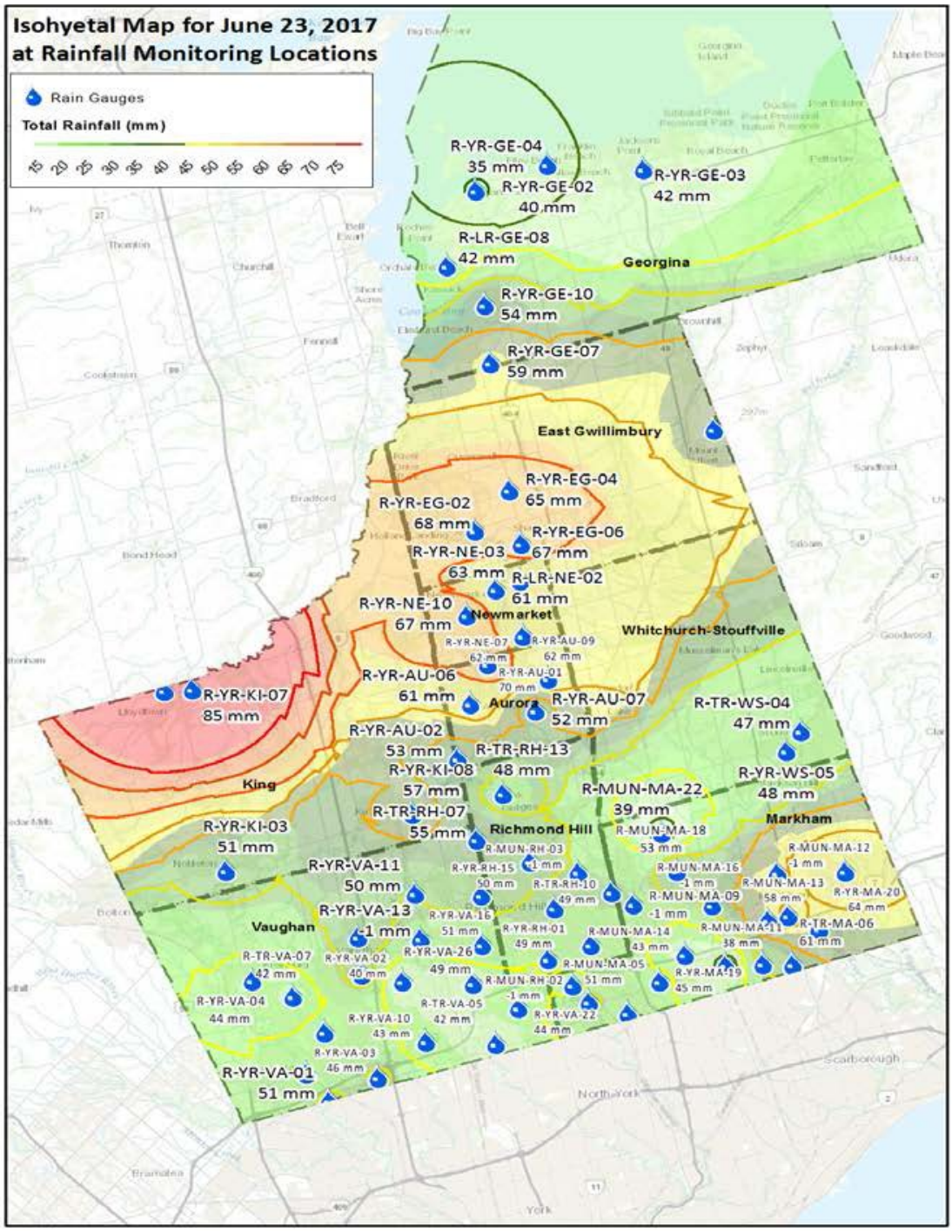
York Region has experienced major rainfall and flooding events in recent years that have resulted in infrastructure damage and large recovery costs. In August 2005, a three-hour extreme rainfall event resulted in as much as 175 mm of rain in the area of Yonge and Steeles, causing severe flooding, power outages and infrastructure damage. Numerous other areas in the City of Vaughan experienced flooding and sewer back-ups during the storm.[10]

An extreme rainfall event on June 23, 2017 caused severe flooding and affected a number of water and wastewater sites (pumping stations and wastewater treatment facilities) across the Region (Figure 6.2).[97] Although the storm was classified as a less than two-year event, certain areas experienced more substantial rainfall (Figure 6.3).[97] Areas greatly affected included Schomberg in the Township of King, which experienced rainfall levels comparable to a 1 in 100 year event. The Towns of Newmarket, Aurora, and East Gwillimbury experienced rainfall levels comparable to a 1 in 50 year event.[97] As part of the monitoring program following this major rainfall event, a map was produced to visualize the real-time data collected from rain gauges installed throughout the Region.[97]

Figure 6.2. Down-looking Ultrasonic Level Sensor Monitoring Creek Levels at Aurora Sewage Pumping Station on May (Left) and June 23, 2017 (Right) Extreme Rainfall Event.

Source: York Region. York Region inflow and infiltration reduction strategy annual report, March 31, 2018 [Internet]. Newmarket: Regional Municipality of York; 2018. Figure 17 – Down-looking ultrasonic level sensor monitoring creek levels at Aurora sewage pumping station in June 23, 2017; p. 31. Available from: https://www.york.ca/wps/wcm/connect/yorkpublic/b22ae2f3-5140-48f2-869e-a803d2552893/2017+Inflow+and+Infiltration+Reduction+Strategy+Annual+Report.pdf?MOD=AJPERES. Reproduced with permission from the copyright owner.

Figure 6.3. Isohyetal Map showing different localized precipitation amounts recorded on the June 23, 2017 extreme rainfall event.



Note**:** Isohyetal maps are used to estimate the mean precipitation across an area.

Source: York Region. York Region inflow and infiltration reduction strategy annual report, March 31, 2018 [Internet]. Newmarket: Regional Municipality of York; 2018. Figure 7, Isohyetal map for June 23 2017; p. 20. Available from: https://www.york.ca/wps/wcm/connect/yorkpublic/b22ae2f3-5140-48f2-869e-a803d2552893/2017+Inflow+and+Infiltration+Reduction+Strategy+Annual+Report.pdf?MOD=AJPERES.

York Region may experience more flooding due to an increase in daily precipitation levels, as well as an increase in the number of consecutive days with precipitation. Heavy rainfall can increase flood risk in floodplain areas, urban areas with impermeable surfaces and areas where stormwater management systems are overwhelmed. Areas at risk of sewage overflows and aging infrastructure are particularly vulnerable to adverse water quality impacts from increased precipitation events.[81]

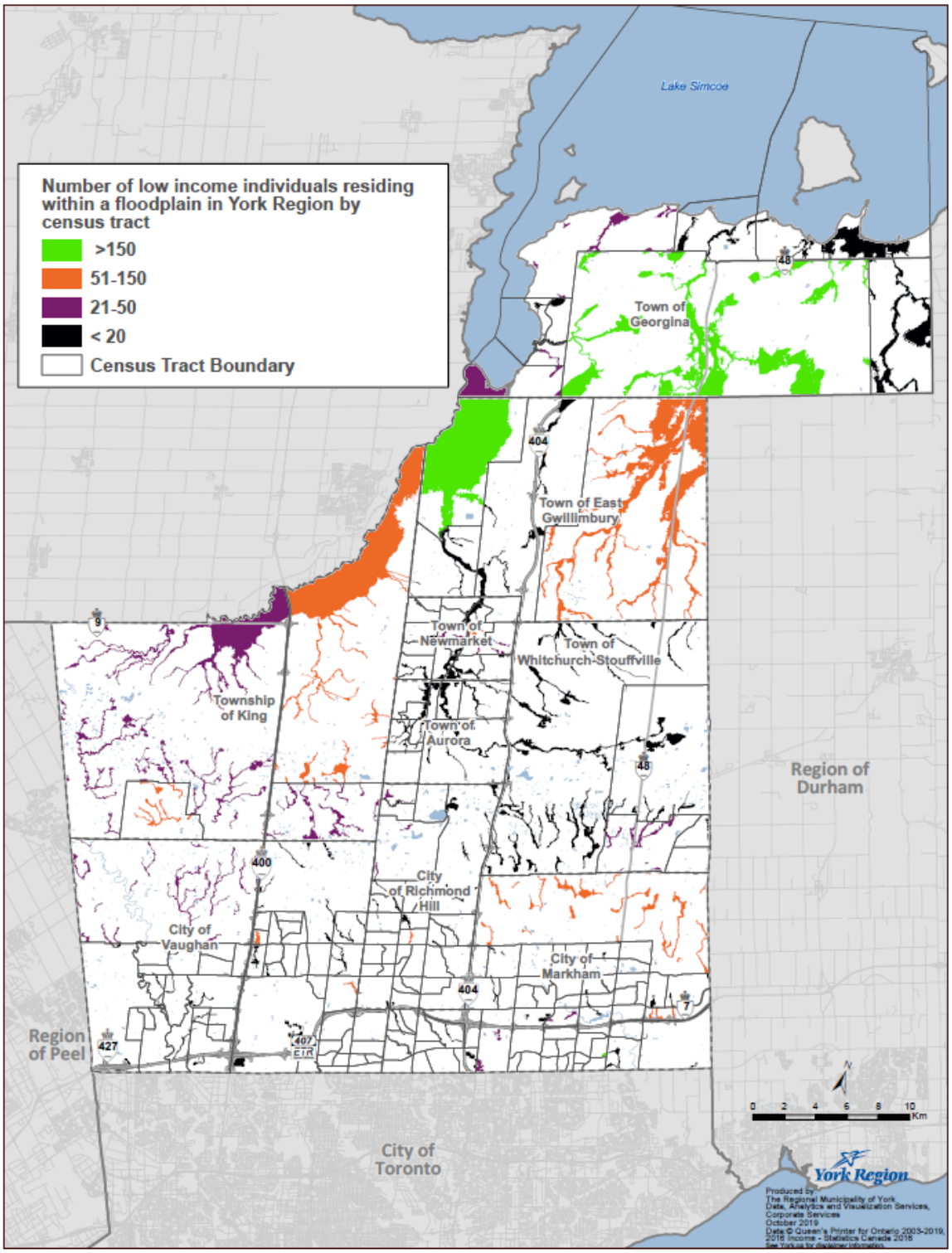
Increases in frequency and intensity of precipitation are likely to result in greater surface water run-off and sewage overflows, contributing to contamination of surface water, recreational water and drinking water supplies. York Region's sanitary sewers are affected by heavy rainfall and snowmelt.[98] Excess flow entering the sewers from household connections, footing drains and deteriorated sections of the sewer system can overwhelm the capacity of the sanitary sewer, causing basement flooding and sewage overflows.[98] Flooding of basements can lead to mould growth in homes, affecting indoor air quality, and sewage overflows can increase the risk of exposure to pathogens.

The York Region wastewater system was designed to handle wet weather flow from a 25-year storm event. The 2016 York Region Water and Wastewater Master Plan[98] modelled the 25-year storm based on an actual York Region rainfall event to provide an accurate picture of rainfall impacts on wastewater flow rates. The Plan indicates that as severe storms become more frequent, further adjustments to the model will likely be required.[98]

Residents living in floodplains are at an increased risk of injury and illness due to flooding, as well as property damage and loss. In Canada, the cost of insured losses from extreme weather events was approximately $1.8 billion per year between 2009 and 2017. Most of these losses were due to flooding.[99] The number of insurance claims and incurred economic losses due to flooding is predicted to increase 20% to 30% by 2065.[100]

Low-income individuals may be more vulnerable to flooding events due to limited resources and substandard housing conditions. Northern York Region, specifically Georgina and East Gwillimbury, have the largest number of low-income individuals who reside within a flood plain (Figure 6.4). However, it is important to note that existing floodplain maps only cover riparian and lakeshore flooding events and do not take urban flooding risks into account. Certain areas of the York Region watershed may also not be up-to-date as some flow hydrology and hydraulic models were completed before 2010. More research is needed to understand river system flooding and risks posed to urban and suburban areas, which represents a large proportion of York Region's population.

Figure 6.4. Number of low-income individuals residing within a floodplain in York Region by census tract.



Note: This map only includes riparian and lakeshore flooding scenarios

6.2.3 Adaptive capacity: Early warning and response to flood events

Municipalities, Conservation Authorities (CAs) and the Ministry of Natural Resources and Forestry (MNRF) share the responsibility for flood contingency planning in Ontario. Municipalities have the primary responsibility and authority for response to flooding and flood emergencies, and for the welfare of residents and protection of property. If a local emergency is declared, MNRF will work directly with the municipality in consultation with the Conservation Authority.

The Government of Canada also plays a role with respect to flooding. The Government Operations Centre monitors the flood situation across the country, coordinates the federal government's response to floods (should the province request assistance to deal with a flood) and has disaster assistance programs.[101] Environment and Climate Change Canada also issues public weather alerts to notify those in affected areas in the event of impending severe weather in order to take steps to protect themselves.

The MNRF and CAs are primarily responsible for operating a forecasting and warning system. The MNRF issues two types of provincial flood messages for areas not serviced by a CA: [102]

- Provincial Flood Watch: Provides consistent and timely technical information about the potential for flooding
- Provincial Watershed Conditions Statement: Provides information on provincial watershed conditions as they relate to flood potential and an outlook on expected spring flood conditions

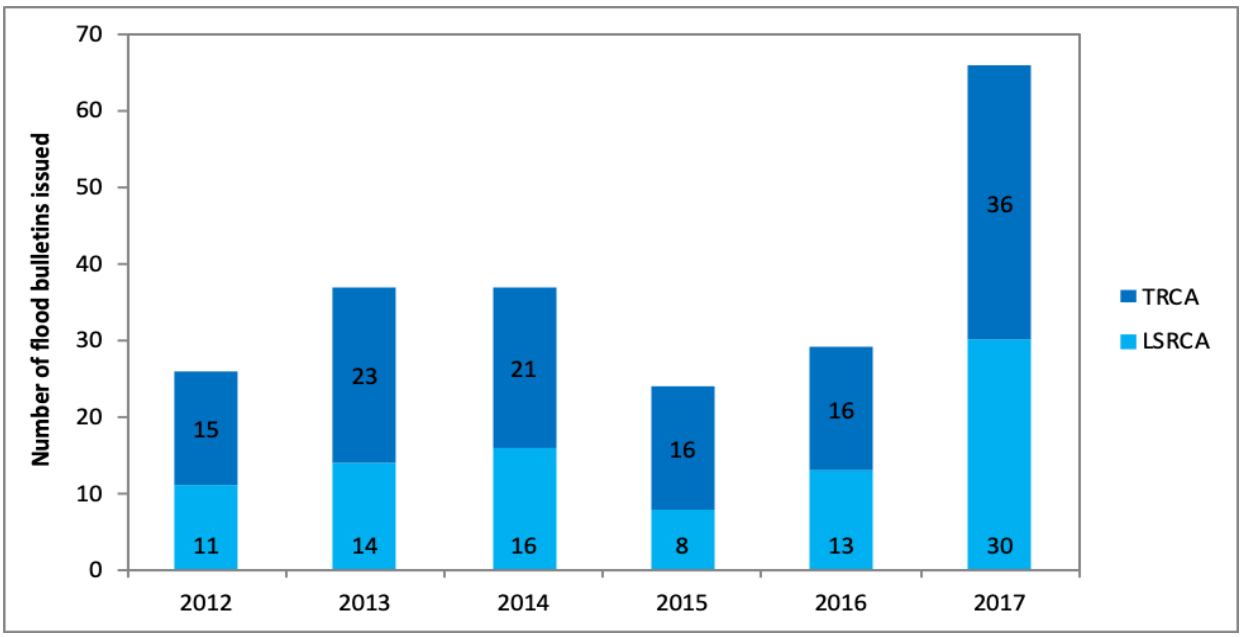
The CAs of the Greater Toronto Area (GTA) have developed a coordinated **Flood Forecasting and Warning Service** for municipalities and residents within their collective watersheds and the shoreline of Lake Ontario. Each CA monitors weather forecasts and watershed conditions, and uses this information to assess the potential for flooding. The two Conservation Authorities who provide Flood Forecasting and Warning Services within the collective watersheds of York Region are the Lake Simcoe Region Conservation Authority (LSRCA) and the Toronto and Region Conservation Authority (TRCA) (Figure 6.5).

When spring melts or severe storms are anticipated, the CAs estimate the severity, location and timing of possible flooding and provide these forecasts to local agencies.[103]

The LSRCA and TRCA communicate local flood messaging through a Flood Bulletin including:

1. Flood Warning: Flooding is imminent or already occurring
2. Flood Watch: Potential for flooding
3. Watershed Condition Statement (Flood Outlook): Early notice of potential flooding

Figure 6.5. Number of flood bulletins issued from 2012 to 2017 by the LSRCA and TRCA.



Sources: Toronto and Region Conservation Authority (TRCA). TRCA Flood bulleting data. TRCA annual reports from 2012 to 2017. Toronto: TRCA, 2017.
Lake Simcoe Region Conservation Authority (LSRCA). Flood Bulletin data from LSCRA Annual Reports from 2012 to 2017. Newmarket: LSRCA, 2016.

In addition to flood forecasts, other measures exist to prevent basement flooding in residential homes such as the installation of backwater valves. Currently, there are a variety of subsidy programs offered by local municipalities and York Region to support the installation of backwater valves.

6.3 DROUGHTS

In addition to increased flood risks, the risk of drought in Ontario is also expected to increase as a result of climate change.[96] There is no clear definition or criteria for droughts, generally described as long periods of abnormally dry conditions that stress water and environmental conditions.[84] Consecutive dry days[o] are used as a proxy measure of drought conditions. Historically, York Region has experienced an annual average of 14.4 consecutive dry days between 1981 and 2010.[10]

Droughts can contribute to a wide range of health impacts including poor air quality, food and waterborne diseases, food and water insecurity and vector-borne diseases. As identified in Table 6.1, droughts can potentially contribute to a wide range of health impacts. However, the relationship between droughts and health outcomes depends on multiple mediating factors, including: Local soil, vegetation and water sources, vulnerable populations and existing

[o] Consecutive dry days are considered to have less than 1 mm of rainfall during the period.

vector populations. Many correlational studies have shown an association between droughts and enteric diseases but there is limited evidence on the pathways in which droughts impact health.[84]

6.3.1 Potential impacts from climate change on droughts in York Region

The number of future consecutive dry days is not expected to change significantly in the 2050s[10]; however, studies conducted for the areas surrounding York Region have suggested there would be a drier growing season.[104] This increased risk of drought is based on temperatures that are expected to increase and summertime precipitation predicted to remain the same, which makes drier conditions more likely. However, additional data to project drought conditions, such as solar radiation and moisture index to project drought conditions, would be required and would need to be validated through comprehensive analysis.

Future drought scenarios on groundwater levels have also been modelled for a 10-year drought in York Region as part of the Source Water Protection work required under the *Clean Water Act 2006*.[105] The model found that while water levels stayed at sustainable levels, supply declined in four municipal production wells. The model also showed moderate impacts on some streams near municipal wells.

However, there are currently limited assessments that assess the wide range of health impacts from droughts in York Region, such as food and waterborne illnesses or air quality impacts.[106] Impacts on drinking water quality and quantity in York Region are discussed further in the water impacts chapter.

6.3.2 Adaptive Capacity: Addressing potential future drought impacts

There have been limited measures taken in York Region that focus on the potential health impacts of droughts. As droughts have a wide range of potential health impacts that depend on multiple local factors that impact risk - land use, existing infrastructure, vulnerable populations - adaptation planning will need to consider the health impact pathways that are of greater significance in York Region. Emerging research highlighting drought impacts relevant to York Region will also be important to inform disease surveillance activities.

Currently, Agriculture and Agri-food Canada monitors drought conditions across Canada. Using data from academic government sources, the Canadian Drought Monitor provides monthly maps showing drought ratings across Canada.[107] Adaptation planning can consider using this tool to monitor drought conditions. Additionally if possible, future assessments can explore any potential relationships between the drought measures with health outcomes, which can be used for surveillance planning.

Most adaptation measures identified in the research relate to ensuring water security.[84] While water quantity impacts have been modelled in York Region, the potential declines in water supply can be mitigated by adjusting the amount of water taken from those vulnerable locations and increasing water supply from other municipal wells in the area. Another factor that needs to be

considered is the increased pressure on water resources as a result of increased population growth.

6.4 WILDFIRES

Wildfires, such as forest or grass fires, are closely associated with droughts and thunderstorms. Droughts influence the amount of dry plant materials that burn easily and can serve as starter material for wildfires. Wildfires may occur in grass, peat, shrub and forest regions, but they tend to become large and more persistent in forests. It is estimated that lightning strikes associated with thunderstorms cause 45% of all forest fires.[108] On average, there are more than 8,000 forest fires in Canada annually that burn 0.7 million to 7.6 million hectares[4] of land.

Experts predict the fire season and the frequency and intensity of forest fires will increase if climate change continues to increase temperatures in North America. Higher temperatures can cause:

- Forests to be drier
- Fires that start easily and are harder to put out

6.4.1 Potential impacts from wildfires in York Region

York Region may be susceptible to periodic episodes of plumes from wildfire/forest fire smoke from neighbouring jurisdictions or out-of-province, but there is limited evidence to suggest forest fire risks within York Region. Factors affecting the plume and direction include the size of the fire, the amount of smoke produced and atmospheric conditions and wind direction. In August 2018, British Columbia's wildfire smoke plume travelled thousands of kilometres to the east and reached parts of Northern Ontario, Quebec and parts of the Maritimes.[110]

Forests in York Region include more than 29 million trees, contributing a total canopy cover of 31% and woodland cover of 23.2%.[112] Woodlands are heavily treed areas at least 0.2 hectares in size.[112] Canopy cover includes all woodlands, individual trees and small treed areas.[112] The York Regional Forest is made up of approximately 2,400 hectares of protected land located in different parts of the Region. York Region Forestry actively manages 23 tracts of the York Regional Forest for recreational use by the public.[113] Wildfire events are not likely to occur in York Region due to climate factors as fire is not the predominate process by which forests regenerate in the Region.

There is increasing research looking at the relationship of wildfires and water quality.[111] Emerging research is needed to study the relationship between drinking water safety and wildland-urban interface fires. This might include an examination of what gets released from industrial and commercial substances when exposed to extreme heat and how it impacts water quality, which has not yet been well researched.

6.4.2 Adaptive capacity: Responding to wildfire events

To help plan for potential wildfire impacts, York Region has provided local fire departments with forest firefighting equipment and Regional forestry staff has received formal training in firefighting. A fire escalation protocol is in place between Forestry and the local Fire Departments to identify and inform appropriate emergency fire response. As part of its Forest Management Plan, York Region is committed to assessing the York Regional Forest's vulnerability to climate change and developing an adaptation plan.[113]

Wildfire forecasting systems: Smoke forecasts are published during the Canadian wildland fire season (April to September) by the BlueSky Canada Smoke Forecasting System operating at the University of British Columbia. This system produces forecasts of hourly ground-level concentrations of smoke particles ($PM_{2.5}$) from wildfires up to 48 hours into the future. The forecast output is experimental and is subject to uncertainties that are inherent in weather forecasts, wildfire detection/emissions and smoke predictions. This system may be useful in the event of plumes of wildfire or forest fire smoke from neighbouring jurisdictions or out-of-province.

6.5 ICE STORMS

Ice storms have the potential to directly affect health through injuries and fatalities due to icy surface conditions, and indirectly through impacts to food safety from loss of power or carbon monoxide poisoning. Ice storms can also cause substantial damage resulting in power outages, leading to health impacts for those requiring electricity for medical devices.[4,85]

On December 21 and 22, 2013, a significant ice storm event in York Region resulted in loss of power to more than 92,000 homes, road closures and tree damage. During the ice storm, 20 mm to 25 mm of ice accumulated and resulted in downed branches, trees and power lines. York Region residents lost power, predominantly in Aurora, Markham, Richmond Hill and Vaughan.[10] Response to this event was estimated to have cost York Region $2.2 million, and an additional $35 million for local municipalities in southern York Region.[114]

Rajaram and colleagues[85] research assessed the acute health impacts of the 2013 ice storm in Toronto, Ontario. The study used a population-level database and regression modelling of emergency visit codes to evaluate emergency department (ED) visits during the storm period, comparing the data to rates occurring on the same dates in the previous five years, and to a major unaffected city (Ottawa, Ontario).[85] Results showed an increase in Toronto ED visits with the greatest number of health impacts from injuries. The authors recommended that municipal cold weather plans take into account the health impacts of ice storms, including physical and environmental injuries.[85] Future studies may benefit from taking a similar approach that uses population-level databases and regression modelling of emergency visit codes to assess health impacts from these large-scale events.[85]

6.5.1 Potential impacts from climate change on ice storms in York Region

Ice storm risk in York Region was evaluated using ice potential[p], a proxy indicator for favourable conditions for ice storms to occur.[10] Model results showed little expected change in ice potential in York Region, but Fausto et al.[10] note the projections are limited as ice potential does not capture all relevant weather variables for ice storms.

6.5.2 Adaptive capacity: Responding to ice storm events

York Region Public Health's involvement in the December 2013 ice storm event included sharing power outage information for food premise operators and the public on the York Region website and social media, disseminating extreme cold messages, conducting public health inspections of the warming centres and communicating warming centre information to the broader health sector and other agencies. Following the ice storm, Public Health conducted a debrief to increase the understanding of community needs and barriers and assess the public health response during the event. This information has been used to prepare and plan for future ice storm events.

The 2013 Southern Ontario Ice Storm Ontario After Action Report from the Office of the Fire Marshal and Emergency Management evaluated information from the ice storm event. It identified gaps and made recommendations for improvement in a number of areas to ensure that Ontario is better prepared for, and able to mitigate, the consequences of future emergencies.[115] The report identified the need to further utilize the Hazard Identification and Risk Assessment (HIRA) process for mitigation and preparedness, especially as they relate to climate change. The assignment of a lead Ministry responsible for planning for the needs of vulnerable populations was also highlighted. This would include leading the revision of the Emergency Preparedness Guide for People with Disabilities and Special Needs; developing tools, templates, policies and procedures that municipal emergency management programs can use to create a voluntary registry of vulnerable persons; and embedding wellness checks as part of the emergency management program.[115]

6.6 RESPONDING TO EXTREME WEATHER EVENT EMERGENCIES

Not all extreme weather events will result in an emergency. An emergency, as defined under the *Emergency Management and Civil Protection Act*, R.S.O.1990, c.E.9 (EMCPA or the Act), is "a situation or an impending situation that constitutes a danger of major proportions that could result in serious harm to persons or substantial damage to property, and that is caused by the forces of nature, a disease or a health risk, an accident or an act whether intentional or otherwise."[116] For an event to become an emergency, the day-to-day response capacity and the ability to access resources must be exceeded, hence requiring additional support.

[p] Ice potential is measured as total number of days where maximum temperature is less than 2°C, minimum temperature is greater than -2°C, and precipitation is more than 1mm.

Emergencies can only be declared by authorized governing authorities as outlined in the EMCPA (e.g., Mayor, Regional Chair, Federal or Provincial Minister). In York Region, the Chair of Regional Council, under the advisement of the Regional Emergency Control Group (RECG), has the authority to declare an emergency as do Mayors of the municipalities.

Climate change will result in more extreme weather events, increasing the likelihood of weather-related emergencies. Such events can require a wide range of emergency response activities, including the potential for evacuation or shelter in place orders and subsequent need for reception centres and other emergency social services.

6.6.1 Local residents' emergency preparedness

Survey data from the 2018 Rapid Risk Factor Surveillance System (RRFSS) suggests that some York Region residents have made emergency preparedness efforts. Overall, 62% of households reported taking at least some measures at home to prepare for an emergency situation.[117] Many households reported they felt they had adequate non-perishable food (78%) and water (65%) supplies for the recommended three days in case of emergency.[117] Approximately half of households noted that they have a plan to contact friends and family in an emergency situation. This survey finding is similar to RRFSS data on extreme heat,[16,69] which found a low proportion of residents who call senior family members and friends during heat waves.

Recent studies have highlighted the importance of social networks and communities in creating adaptive capacity, particularly for more vulnerable individuals.[86] Future climate change adaptation planning should consider opportunities for supporting community and family networks in responding to extreme weather events and emergencies.

6.6.2 Regional emergency response

Emergency management is one of the Ontario Public Health Standards' (OPHS) Foundational Standards. The OPHS specifies that "boards of health shall effectively prepare for emergencies to ensure 24/7 timely, integrated, safe and effective response to, and recovery from emergencies with public health impacts, in accordance with ministry policy and guidelines".[118]

York Region Public Health has identified its primary response roles and responsibilities within the Public Health Emergency Response Plan[119] as well as Annex 8 of the Regional Emergency Plan available at york.ca/emergencymanagement. The plans provide all hazards frameworks for strategic actions in partnership with the other Regional stakeholders to mitigate, prevent, prepare for, respond to and recover from emergencies.

As a member of the RECG, the Medical Officer of Health advises on public health issues and recommends specific responses to events impacting the health of the community.

In the event of an extreme weather emergency, York Region Public Health may implement measures such as population health surveillance, environmental health risk assessments, adverse drinking water response and health risk communication, and provide support through

inspections of emergency reception centres and broader multi-community emergency response efforts.

Each year, in collaboration with Regional stakeholders and subject matter experts, Public Health reviews and assesses locally relevant hazards to determine their potential significance as a community risk and identify emergency planning priorities. The 2019 Regional HIRA process identified extreme weather events, such as winter weather (ice storms), tornadoes, extreme heat, flooding and high wind as significant local hazards.

It is critical that emergency and business continuity plans adequately address climate and health risks at all levels. The increased risk of extreme weather emergencies will require the emergency management sector (Public Health, Emergency Social Services, Paramedics, long-term care, Regional Emergency Management, Community Emergency Management Coordinators (CEMCs), hospitals, Ontario Health, local nongovernmental organizations and Ministry of Health) to work collaboratively. This collaboration should focus on integrating climate change health impact considerations to build adaptive capacity and climate resiliency. This includes the understanding of what is required to adapt to the consequences of climate change, as well as acknowledgement of and preparation for the impact of climate change in all aspects of emergency management. This is particularly important for the impacts related to extreme weather events that require effective stakeholder collaboration, disaster response and contingency planning for vulnerable populations.

6.7 CONCLUSION

With the likely increase in the frequency and severity of extreme weather events, York Region will be faced with addressing extreme weather and health risks mediated by climate change. Annual precipitation levels and extreme precipitation events are likely to increase, leading to increased flooding concerns for some areas of York Region.

It is difficult to quantify all of the health impacts associated with extreme weather due to multiple risk factors. It is important to address climate and human health impacts as extreme weather events could potentially increase the vulnerability of individuals, communities and regions. Assessing how the population's health would be negatively affected by extreme weather requires an understanding of the vulnerability of the populations affected. There is sufficient literature on factors that increase vulnerability to extreme weather and climate events. However, the understanding of the potential impacts of recurring extreme weather and climate events on health vulnerability is limited.

Further research is critical to inform adaptation planning to reduce future extreme weather-related risks to health. Less attention has been paid to the impact of climate change on infrastructure that supports health and social service delivery, including health and social care facilities, private homes, communications, utilities and road networks**.**

Gaps exist in our knowledge and understanding of the impacts of extreme weather events. There are opportunities to conduct additional research to better assess extreme weather impacts on health. For example, psychosocial aspects need to be assessed to better understand risk perception, behaviour and mental health issues. Further research will be critical to informing adaptation planning to reduce future extreme weather-related risks to health.

Enhanced surveillance activities, strong social networks and the involvement of the community in emergency planning will also be critical adaptation measures to build community resilience. Extreme weather events have wide-ranging implications for the emergency management sector. Adaptation planning requires a multi-sector approach that integrates the increased risk of extreme weather emergencies across emergency management to build adaptive capacity and climate resiliency. Moving forward, emergency response, business continuity plans, exercises and the HIRA processes must factor extreme weather emergencies in the planning process to address climate and health risks at all levels. Table 6.2 provides an overview of existing activities and future adaptation planning opportunities.

Table 6.2. Summary of extreme weather-related activities and adaptation planning opportunities.

	Ongoing and Completed Activities	Opportunities
Population Health Assessment and Surveillance	**Environmental Monitoring:** Utilize extreme weather event monitoring conducted by ECCC (e.g., storms, tornadoes, wildfires, ice storms, etc.) through the EC Alert Me notifications and Conservation Authorities (e.g., flood bulletins).	**Emergency Preparedness and Response:** Engage other York Region departments on coordinated extreme weather monitoring and stakeholder notification. Explore other datasets such as the Canadian Drought Monitor and BlueSky forecasting for environmental surveillance planning. Explore the use of Public Health Information Management System technology to enhance real-time situational awareness and assist with evidence informed decision-making.
	Health Equity: Creation of maps of vulnerable populations such as seniors, children, low-income, etc.	**Health outcome surveillance:** Consider opportunities to utilize Paramedics' data and ACES data during, and soon after, extreme weather events/power outages. Consider future ACES use for mental health outcomes following events. Consider developing a plan to review health-related data following extreme weather events (e.g., carbon monoxide poisoning, injuries, mortality and mental health).
	Population survey: Conducted 2018 RRFSS survey on emergency preparedness of York Region residents.	**Health Equity and Emergency Preparedness and Response:** Assess emergency preparedness of different vulnerable populations within York Region. Consider including mental health as part of RRFSS modules on emergency preparedness. **Emergency Preparedness and Response:** Consider other survey tools to assess impacts and inform emergency response (e.g., Centers for Disease Control and Prevention Community Assessment for Public Health Emergency Response tool).

Program and Policy	**Emergency Preparedness and Response:** Annual HIRA process to inform top health risks for York Region.	**Emergency Preparedness and Response*:*** Provide climate change vulnerability assessment to help inform future HIRA processes. Consider how data and surveillance planning can inform HIRA process.
	The York Region Public Health Emergency Plan (an annex to the York Region Emergency Plan), with appendices addressing unique hazards that can impact the health of the population.	Consider incorporating climate change health impacts into the next revision of the York Region Public Health Emergency Plan. Review available resources developed from other jurisdictions for key messages and adaptation measures (e.g., wildfire resources from ECCC, National Collaborating Centre for Environmental Health, Oregon State). **Health Equity:** Consider mental health impacts in emergency planning and response plans.
	Emergency Preparedness and Response: Conducted extreme weather emergency event response debriefs including lessons learned on what did and did not work well. Participate in and conduct training and exercises on extreme weather-related emergencies.	**Emergency Preparedness and Response:** Continue debriefs and lessons learned following extreme weather events. Include climate change scenarios for future emergency response training.
	Emergency Preparedness and Response: Inspect emergency reception centres to ensure they meet food, water, sanitation, indoor air quality, sewage, garbage disposal and infection control standards.	**Health Equity:** Consult with mental health stakeholders on the impacts of extreme weather events and determine what support can be provided from public health (e.g., mental health messaging, communication to stakeholders during events). Consult with community organizations involved in extreme weather-related emergencies (e.g., Canadian Red Cross, Salvation Army) regarding potential public health support.

Health Promotion	Developed messaging for the public and stakeholders regarding power outages, the dangers of carbon monoxide poisoning, sewage back-ups and flooding, particularly during extreme weather events.	Consider incorporating health messaging to support coping with psychological impacts (e.g., emergency plans and kits for homes to support mental health including spiritual objects, blankets, toys, treats, recreational items). Support promotional activities from York Region and local municipalities for homeowners to take action to protect their home from flood events (e.g., disconnecting downspouts, fixing cracks in the foundation and installing window wells). **Health Equity:** Target landowner and rate-payers associations to communicate flood risks.
Key Stakeholder Activities (outside of Public Health)	Strategies and activities for existing water and wastewater systems for addressing extreme weather events (e.g., enhanced treatment options before a forecast event and building redundancy into water supply systems, including back-up power generators). York Region Water and Wastewater Master Plan which provides an overview of needs for 2041, including population growth and climate change impacts.	Consult stakeholders (e.g., York Region water and wastewater, Conservation Authorities) regarding residential flooding impacts to better understand mediating factors and the role of weather factors (e.g., prevalence of back-water valves to reduce flood risk in homes).
	York Region Forestry Fire Escalation Protocol for Responding to Wildfire events.	Consider supporting York Region Forestry on public health measures to reduce air quality impacts to local residents from wildfire events.
	York Region Data Analytics and Visualization development of maps for floodplains and potential vulnerable populations (e.g., location of community centres, shelters, schools, child care centres, long-term care homes).	**Emergency Preparedness and Response:** Review available GIS datasets and determine which information can be utilized to inform future extreme weather risk and emergency response. **Health Equity:** Review future urban flood risk maps created to better understand potential populations vulnerable to flooding in urban areas.
	Land use planning and building code policies (e.g., installation of mainline sanitary sewer backwater valve at homes, sump pumps, moisture resistant flooring and wall finishes, discouraging reverse slope driveways).	Review land use planning best practices to reduce climate change health impacts. Consider best practices for flood prevention and advocate for provincial building code and other regulations.
	Emergency Preparedness and Response: Using the Incident Management System (IMS) at the Regional and Departmental levels to ensure a standardized approach to emergency response.	Encourage strong social networks and involvement of the community in emergency planning (e.g., community emergency preparedness groups or resource teams to respond soon after an emergency).

CHAPTER 7
Air Quality

7.0 Air Quality: Key Findings

Climate change projections and exposure pathways

- Climate change impacts (increased temperatures, longer growing seasons and precipitation patterns) to air quality relevant to York Region include:
  - Stagnant air masses during hot summer days contributing to poor air quality events
  - Long-range movement of air pollutants caused by wildfires
  - Increased allergenicity of pollen and length of pollen season
- The most common air pollutants associated with health impacts in Canada include ground-level ozone, fine particulate matter, nitrogen oxides and sulphur dioxide
- The main sources of air pollution in York Region include traffic-related air pollutants, industrial and residential emissions and transboundary pollutants
- Air quality in York Region has improved in the past few decades due to increased air quality regulations and decreasing emissions. However, ground-level ozone concentrations have remained similar over the past 10 years

Population sensitivity

- Substantial research highlights how individuals are at greater risk, particularly those with existing cardiovascular and respiratory conditions (e.g., asthma, allergies, and heart disease), seniors and children
- 70% of York Region residents are aware of the AQHI tool. 63% of York Region residents surveyed who were familiar with the Air Quality Health Index (AQHI) changed their behaviour at least half the time

Adaptive capacity

- Existing environmental monitoring activities include real-time AQHI conditions and short-term forecasts. Wildfire events are also integrated with federal air quality monitoring and forecasting
- Provincial and federal agencies provide notifications to the public and stakeholders for adverse air quality episodes
- Of 28 long-term care homes surveyed in York Region, 25 have reported that they have a plan to address poor air quality episodes
- Addressing local air pollution can have important direct and indirect co-benefits for health through supporting climate change mitigation

Health impacts

- Further analysis and modelling are required to estimate the burden of illness related to air quality and to estimate future climate change impacts

Recent trends:

- Health Canada estimates 230 annual non-accidental deaths attributed to above background levels of fine particulate matter; 25 annual respiratory deaths due to chronic exposure to ground-level ozone; 82 annual emergency department visits and 16 annual hospital admissions attributable to above background levels of ground-level ozone in York Region in 2010
- Fine particulate matter levels have decreased from 2000 to 2011 resulting in a 2.65% decrease in estimated premature mortality in York Region

Climate change will have important implications for air quality as weather conditions (e.g., temperature, wind, humidity and rainfall) play a large role on air pollutant chemistry, transport and build-up in the environment. Air quality can be impacted by chemical compounds or air pollutants and from the production of airborne allergens and/or aeroallergens (e.g., pollen from plant species and/or fungal spores from mould).

With respect to climate change impacts to air quality, the following impacts are most relevant to the York Region context:

- Stagnant air masses during hot summer days contributing to more favourable conditions for poor air quality events
- Longer growing season and thunderstorm events that may increase exposure to aeroallergens and fungi
- Longer dry and warm summer periods that may increase wildfire risk in other parts of Ontario or North America and contribute to increased smoke and levels of particulate matter that can impact air quality in York Region

This chapter provides information on existing air quality issues within York Region that relate to climate change, including current health outcomes and potential future impacts. Estimating current impacts from air quality and projecting future impacts of climate change in York Region is complex. It would require the use of climate change projection models, air quality models and understanding the projected exposure and vulnerability of the population. As a result, developing specific estimates within York Region was out of scope for this vulnerability assessment.

Additionally, wildfire events are noted in this chapter but are not discussed in detail due to the limited local information on wildfire risk in York Region. While an important consideration, wildfires are likely to occur in higher risk areas such as northern Ontario and western Canada. It should be noted that wildfire events in other parts of Ontario or Canada could also impact air quality in York Region depending on meteorological conditions. The Extreme Weather section of this report provides more context on wildfire events through an emergency planning lens.

This chapter notes the impacts of air quality on health and provides baseline health information relating to respiratory outcomes commonly associated with poor air quality exposure. However, recent hospital data for health outcomes, such as asthma and seasonal allergies, are not sufficient indicators for exposure to adverse air quality. The information is presented to provide a baseline understanding of potential respiratory outcomes as they may relate to air quality. Information is also provided on key air quality impacts, such as current air quality trends, poor air quality events and pollen, and how climate change may impact future air quality in York Region.

7.1 HEALTH IMPACTS FROM AIR POLLUTANTS

The wide-ranging health impacts from air pollution are well established, with substantial research supporting linkages between acute and chronic air pollution exposure and human health outcomes. Numerous studies have involved large populations and shown significant associations between various air pollutants and health outcomes such as the Canadian Census Health and Environment Cohort (CanCHEC) air pollutant exposure study.[120]

The most common health impacts associated with exposure to air pollutants include:

- Increased incidence of cardiovascular impacts and risk of myocardial infraction, angina, arrhythmia, hypertension, heart failure and stroke
- Respiratory impacts such as exacerbation of asthma and allergies, development of asthma in children and exacerbation of chronic obstructive pulmonary disease (COPD)
- Premature mortality, particularly for seniors[121]

Air pollution has also been categorized by the International Agency for Research on Cancer (IARC) as a carcinogen as a result of sufficient evidence on the mechanism causing cancer and from animal and human studies.[122]

7.1.1 Air pollutants of concern relating to climate change

While air pollution can be composed of thousands of different chemical compounds, certain pollutants are more common and there is strong evidence of their impact on human health. These common air pollutants include ground-level ozone (O_3), fine particulate matter ($PM_{2.5}$), nitrogen oxides (NO_x) and sulphur dioxide (SO_2). Even very low concentrations of air pollutants can result in adverse health impacts, particularly for vulnerable individuals. For many of these pollutants no threshold has been identified below which no adverse effects on health may occur.

From a climate change perspective, ground-level ozone and fine particulate matter are more commonly researched due to their influences on poor air quality episodes. Exposure to O_3 results in acute and chronic damage to the respiratory system through increased airway reactivity, airway permeability, airway inflammation, reduced lung function and increased respiratory symptoms.[123]

Ground-level ozone is produced when NO_x and volatile organic compounds (VOCs), which come from natural and human sources such as local traffic and combustion sources, react with sunlight and stagnant air.[124] Ground-level ozone formation increases with greater temperatures and sunlight. In general, O_3 levels can often be highest in areas surrounding large cities and towns.[123] Stable, dry and hot conditions result in the most pollution build-up and O_3 production as abundant sunlight and heat are present for photochemical reactions in Canada. Lower levels of O_3 are associated with moderate, cool and moist weather.[125]

Fine particulate matter ($PM_{2.5}$) refers to particulate matter that is smaller than 2.5 microns in diameter and has been commonly linked to adverse impacts to human health.[123] Due to its small

size, $PM_{2.5}$ is able to penetrate deep into the respiratory system when inhaled. In Ontario, residential fuel consumption (wood smoke for fireplaces and wood fueled stoves) accounted for 56% of $PM_{2.5}$ emissions in 2016.[123]

Exposure to $PM_{2.5}$ causes symptoms such as coughing or difficulty breathing, decreased lung function, aggravates asthma and COPD symptoms and development of chronic bronchitis, heart attack and arrhythmias.[126] The Environmental Burden of Cancer in Ontario report found that $PM_{2.5}$ in air pollution is one of the top three environmental carcinogens in Ontario, accounting for 290 to 900 new lung cancer cases annually.[72] The risk from exposure to $PM_{2.5}$ varies over a lifetime. It is higher in early childhood, lowering in healthy adolescents and young adults and increases again in middle age through old age as the incidence of heart and lung disease and diabetes increase.[126]

In general, local sources play a larger role in $PM_{2.5}$ levels in York Region with less impact from transboundary pollutants from the United States.[123] While these reflect the most common sources in Ontario, wildfire episodes can also increase $PM_{2.5}$ levels, with transboundary movement potentially playing a larger role.

7.1.2 Aeroallergens

Climate change is increasing the allergenicity of pollen, the amount of pollen produced and is potentially extending the length of the pollen season. Aeroallergens consists of organic particles, such as pollen and fungal spores, which are released from plants and mould. For individuals with pollen allergies, exposure results in congestion, sneezing, itchy eyes and allergic reactions. Existing allergies can also increase the severity of symptoms for those with asthma and other respiratory illnesses.[5] Each species has its own unique time period for the production and release of pollen. For example, tree pollen is released in the spring and ragweed in the fall.

Pollen has been associated with serious diseases, such as stroke and myocardial infarction.[127,128] Weichenthal et al.[128] found the risk of myocardial infarction was 5.5% higher on high pollen days than on low pollen days on same day exposures. This was based on data from Ontario cities collected during the pollen season (April to October) between 2004 and 2011. The study hypothesized that histamine responses may have contributed to coronary artery spasm. However, further analysis is required to better understand the relationship between aeroallergens and various health outcomes in York Region.

7.1.3 Combined effects

The combined effect of air pollutants, allergens and/or extreme temperatures can place individuals at greater health risk.[4] For example, exposure to aeroallergens and air pollutants significantly increased asthma hospitalization.[66] Additionally, Vanos et al.[64] found the relative risk of mortality for 12 Canadian cities related to $PM_{2.5}$ tripled in hot weather environments when compared to moderate weather while the risks from O_3 doubled. Similar studies have shown greater health impacts from O_3 with increasing temperatures.[5]

More research is needed to understand how exposures to allergens, air pollution and other weather variables such as extreme heat, interact to impact health risks. It is not currently clear which factors may act as precursors increasing sensitivity to other exposures, how individual sensitivities may differ for combined exposures or if a time lag can occur between different exposures. Some studies have suggested allergens combined with exposure to air pollutants may act synergistically to intensify allergic response and increase respiratory illnesses in the future.[129] Exposure to O_3, $PM_{2.5}$ and traffic-related air pollutants may alter the allergenicity of aeroallergens, increasing the frequency and severity of allergic reactions.[130] Exposure to O_3 has also been shown to increase airway responsiveness to allergens, while exposure to particulate matter and allergens has been linked to increased innate and adaptive immune responses implicated in the pathophysiology of airway disease.[66]

Heat, air pollution and aeroallergens can be significant to respiratory health when combined; however, their relative impacts on health may differ. Cheng et al.,[65] found the health burden due to heat is greater than air quality during extreme heat events.

Vulnerable populations

Air quality affects everyone's health, but certain groups are more likely to be adversely impacted. See Chapter 4 for more information on vulnerable populations in York Region. Populations more likely to be impacted by poor air quality include:

- **Individuals with pre-existing conditions**: Individuals with chronic diseases, particularly of the respiratory and cardiovascular systems, are at risk from exposure to air pollution that can result in increased chest tightness, coughing, wheezing and difficulty breathing.[4,5] Pre-existing conditions most at risk include asthma, COPD, hypertension and/or pre-existing heart conditions and diabetes. Air pollution levels that do not appear to affect healthy populations may cause trouble breathing for individuals in this group. Allergy sufferers may also experience more frequent and intense allergies due to changes in the pollen season

- **Children**: Children have faster breathing rates and smaller body sizes than adults, which can increase their exposure to airborne pollutants. Their lungs and immune systems are not fully developed, making them particularly sensitive to exposure from contaminants. Children who are active outdoors during the summer when air pollution is highest are particularly at risk[4,5]

- **Pregnant women**: Physiological changes, such as increased blood and plasma volumes and respiration rates can make women more vulnerable to pollutant exposure during pregnancy. There is also increased potential for adverse effects to the fetus during critical development stages. Long-term exposure to $PM_{2.5}$ has been associated with premature births and low birth weights[126]

- **Seniors:** Seniors may have functional and physiological limitations that impede their ability to acclimate. They may also suffer from pre-existing conditions that increase vulnerability to air pollution. Epidemiological studies of air pollutants show greater risk of

adverse health effects in senior populations, including hospital admissions and premature mortality[5]

- **Outdoor workers and recreational activity:** Occupational exposure to extreme heat and air pollutants can increase the vulnerability of individuals. Similarly, people who spend time working or exercising outdoors during poor air quality days have increased exposure to air pollution and may be more vulnerable[131]

- **Individuals with low socioeconomic status:** Low-income individuals and those living in densely populated, urban areas typically have increased exposure to air pollutants, particularly traffic-related air pollution, when compared to rural areas. Studies have shown that low-income neighbourhoods tend to have higher rates of poor health outcomes attributed to air quality[5]

7.2 LOCAL HEALTH IMPACTS IN YORK REGION

A 2017 Health Canada assessment modelled the health impacts attributed to O_3, $PM_{2.5}$ and nitrogen dioxide in Canada.[132] The study estimated the following health impacts within York Region:[132]

- 230 non-accidental deaths attributed to above background levels of $PM_{2.5}$
- 25 respiratory deaths attributed to chronic exposure to O_3
- 82 ER visits and 16 hospital admissions attributable to above background levels of O_3

Certain pollutants have decreased in concentration over time, such as $PM_{2.5}$. In York Region, fine particulate matter concentrations decreased by almost 3 $\mu g/m^3$ between 2000 and 2011 and premature mortality was estimated to decrease by 2.65%.[132]

Hospital cases in York Region: Health outcome data are presented to provide a baseline understanding of trends for respiratory outcomes in York Region. It should be noted the information is different from the Health Canada estimates that modelled health impacts using the latest scientific research.

Table 7.1 presents the rate of emergency department (ED) visits in York Region from 2007 to 2017 for asthma, seasonal allergies and exposure to air pollution. Over the 11-year period, there were 22,045 ED visits for asthma and 249 ER visits for seasonal allergies.[50] There were only 24 cases of ED visits related to air pollution exposure, likely due to challenges in linking health conditions to air quality.

In general, the yearly ED visit rate for seasonal allergies is increasing while asthma rates are decreasing. Asthma case counts are substantially higher than allergies. This may relate to the severity of asthma conditions that require emergency medical attention. Many cases of seasonal allergies may be less severe and involve contact with family physicians. In terms of seasonal allergies, children 1 to 4 years of age had the highest ED visit rates, followed by those 5 to 9 years

of age and those 85 years of age and older. Decreasing year over year asthma rates may be partly explained through improvements in air quality conditions, better management and treatment of asthma conditions or other changes in demographics other than age, such as increased immigrant populations.

Table 7.1. Case counts and age-standardized rates of emergency department visits for seasonal allergies and asthma between 2007 and 2017 in York Region.

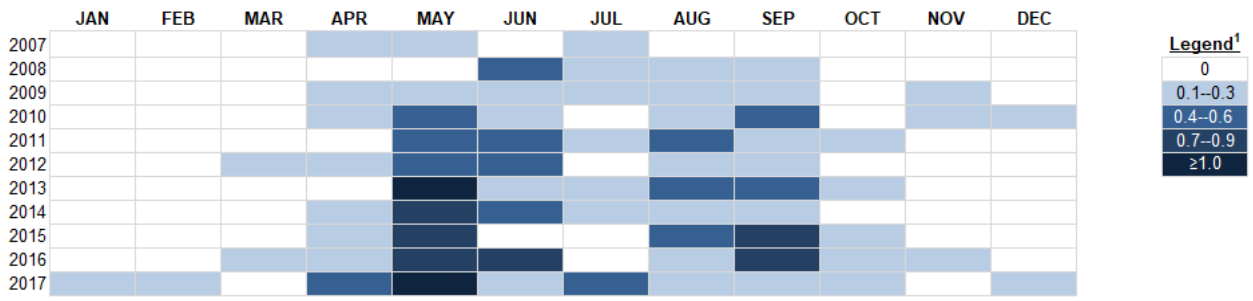
Case counts and rate per 100,000 population		
	Seasonal allergies (J301 and J302) [1, 2]	Asthma (J45)[2]
2007	5 (*)	2,296 (234.6)
2008	14 (1.4)	2,267 (225.2)
2009	13 (1.2)	2,056 (198.0)
2010	15 (1.4)	2,074 (196.5)
2011	17 (1.6)	1,949 (181.7)
2012	16 (1.4)	1,935 (176.9)
2013	32 (2.8)	1,952 (177.3)
2014	23 (2.0)	1,919 (170.4)
2015	27 (2.3)	1,859 (164.6)
2016	39 (3.5)	1,875 (164.5)
2017	48 (4.1)	1,863 (161.9)
Total	249	22,045

Case counts (rate per 100,000 population)
Data Source: Ambulatory Visits & Population Estimates, 2007-2017, IntelliHealth Ontario. Extracted May 2, 2019.
**** Rate too unstable to report***
[1] Any diagnostic code
[2]Age-standardized rate per 100,000

Source: Ambulatory Visits & Population Estimates, 2007-2017, Ontario Ministry of Health and Long Term Care, IntelliHealth Ontario. May 2019.

As expected, seasonal trends for allergies were observed that corresponded with pollen seasons. The rates were highest during the months of May and June (tree and grass pollen peak period) and September (ragweed peak) (Figure 7.1). Some years had lower rates, which may be reflective of differences in pollen levels over a year or differences in the number of people seeking medical attention. Overall, age standardized rates of seasonal allergies has increased in recent years (Figure 7.2).

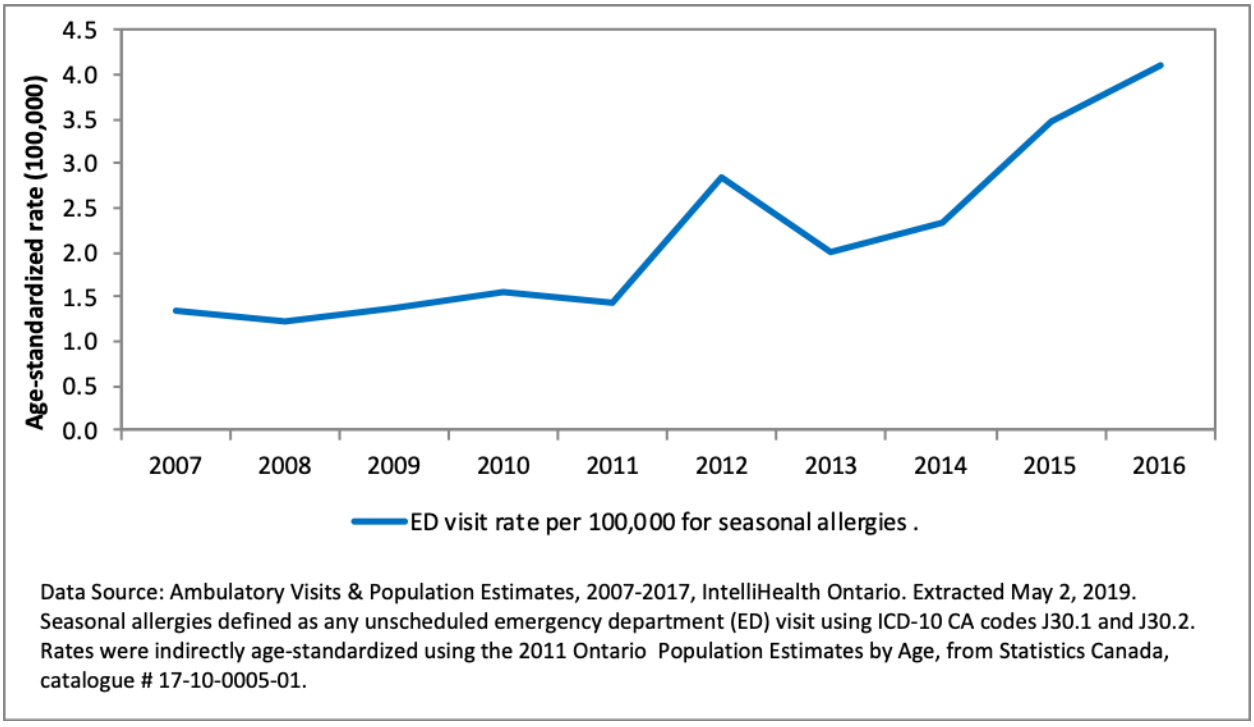
Figure 7.1. Monthly trends in emergency department visit rates for seasonal allergies between 2007 and 2017 in York Region.



[1] Rate of emergency department visits for seasonal allergies per 100,000 population.
Data Source: Ambulatory Visits & Population Estimates, 2007-2017, IntelliHealth Ontario. Extracted May 2, 2019. Seasonal allergies defined as any unscheduled emergency visit using ICD-10 CA codes J30.1 and J30.2.

Source: Seasonal allergies visits. Ambulatory Visits & Population Estimates, 2007-2017, Ontario Ministry of Health and Long Term Care, IntelliHealth Ontario. May 2019.

Figure 7.2. Emergency department visit rates for seasonal allergies between 2007 and 2017 in York Region.



Source: Emergency department visits for seasonal allergies. Ambulatory Visits & Population Estimates, 2007-2017, Ontario Ministry of Health and Long Term Care, IntelliHealth Ontario. May 2019.

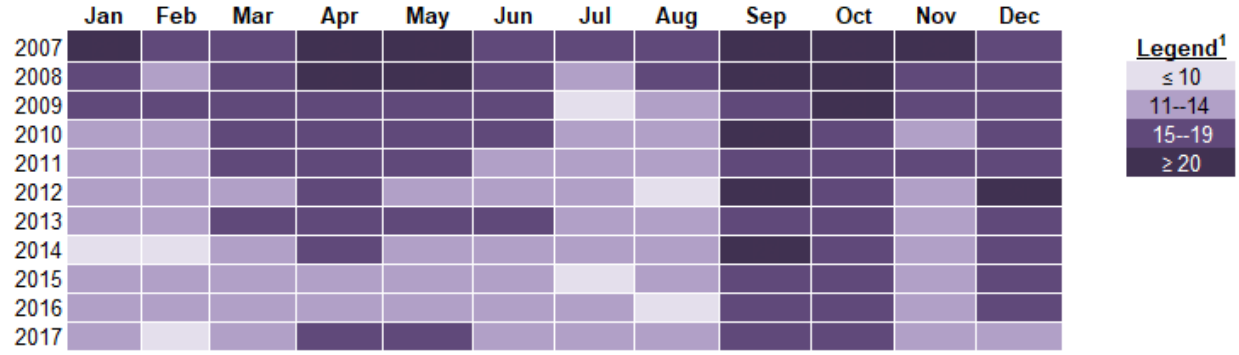
The observed asthma rates indicate a seasonal relationship and year-to-year variability (Figure 7.3). For example, asthma ED visit rates were generally high for 2007, but lower for 2015 and 2016. This may relate to generally poorer air quality in a given year, as 2007 had 11 smog

advisories lasting 29 days in York and Durham Region, mostly in the summer months.[133] However, other years with high rates such as 2008, only had five advisories lasting nine days.[133]

A trend is observable for higher asthma-related ED visit rates in September and October. Higher rates of ED visits relating to asthma were also noted in the spring and in the month of December.

Since asthma conditions can be aggravated by a wide range of issues, it is not possible to attribute the role of air quality conditions on ED visit rates. Additionally, recent research suggests that effects on health may be taking place below thresholds for air quality advisories.

Figure 7.3. Monthly trends in emergency department visit rates for asthma between 2007 and 2017 in York Region.



[1]Age-standardized emergency department visit rates for asthma per 100,000 population.

Data Source: Ambulatory Visits & Population Estimates, 2007-2017. Intellihealth Ontario. Extracted, May 2, 2019. Asthma cases defined the most likely diagnosis for any unscheduled emergency visit, based on ICD-10 CA code J45. Rates were age-standardized using the 2011 Candian Census Total Population by Age, from Statistics Canada, catelogue #98-311-XCB2011018.

7.3 RECENT AIR QUALITY TRENDS IN YORK REGION

7.3.1 Previous levels of O_3 and $PM_{2.5}$ in York Region

The main sources of air pollution in York Region include traffic-related air pollutants, industrial and residential emissions, and transboundary pollutants from neighbouring municipalities, and the United States. Overall, air quality in York Region has improved in the past few decades due to increased regulations and lower emissions in the United States and Canada.

The Ontario Ministry of the Environment, Conservation and Parks (MECP) monitors air pollutants across Ontario. There is one air quality monitor located in Newmarket, as well as a monitor located in North York that is used as a reference for southern York Region.[q] There has been an overall

[q] North York Station changed location on January 1, 2017, to 4905 Dufferin St., North York from the previous location at Hendon Ave and Yonge St., North York.

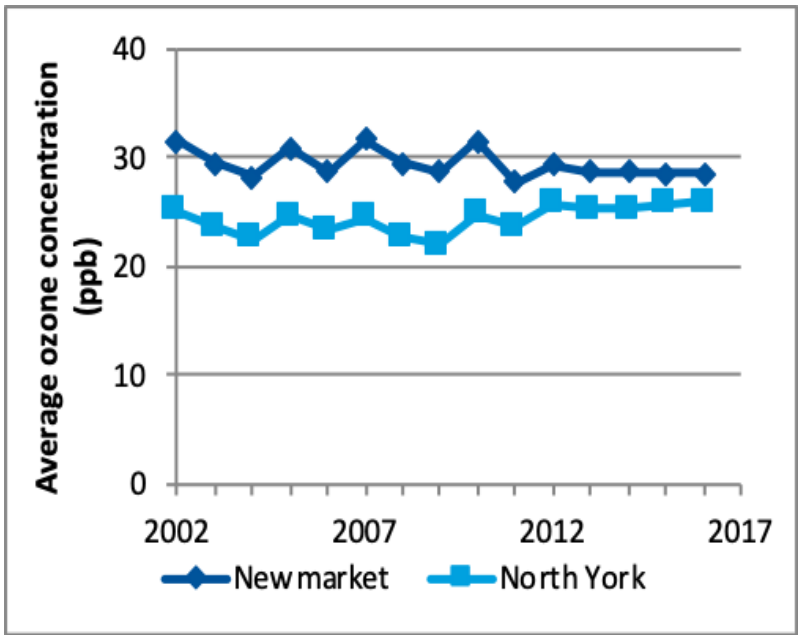
decreasing trend in the annual frequency of smog advisories and poor air quality days for the province since 2007.[123]

Since 2002 annual mean O_3 concentrations have remained relatively stable in York Region. While most pollutant concentrations have decreased in Ontario, O_3 has tended to remain relatively similar in recent years. From 2007 to 2016 annual mean concentrations for O_3 have decreased by 8% for the Newmarket station, but increased by 12% for the Toronto North station.[123]

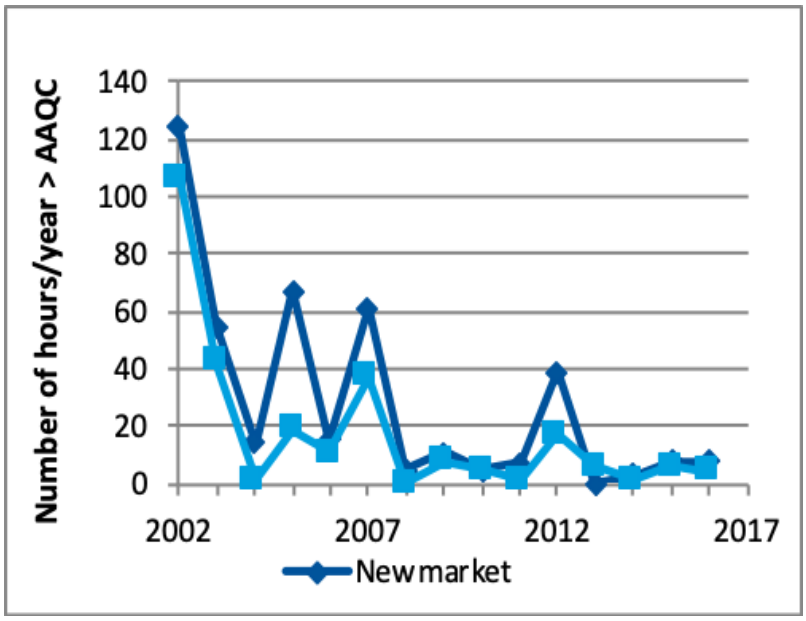
Additionally, there has been a decrease in the number of hours per year where the O_3 concentration exceeded the Ontario Ambient Air Quality Criteria (AAQC) of 80 parts per billion (ppb). For example, in Newmarket, the 1-hour AAQC for O_3 was exceeded for 124 hours in 2002 compared to eight hours in 2016 and no exceedances in 2013. The North York station showed similar results; the AAQC was exceeded for 106 hours in 2002, compared to four hours is 2016 (Figure 7.4).

Figure 7.4. Ground-level ozone data from the Newmarket and North York air quality monitoring stations from 2002 to 2016. A: Average annual concentration. B: Number of hours per year exceeding the AAQC (1 hour) (80 ppb for O_3).

A. Average O_3 concentrations in York Region from 2002 to 2016.

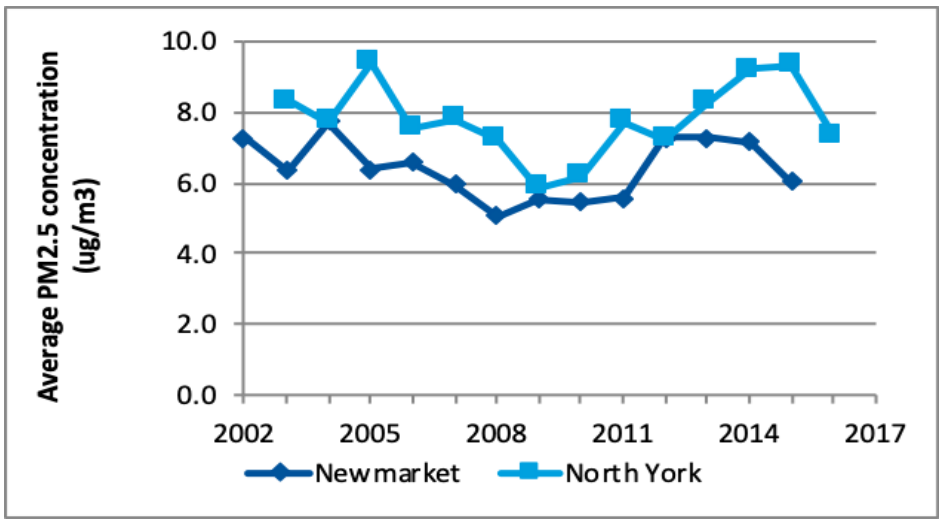


B. Number of hours/year exceeding ambient air quality criteria for O_3 from 2002 to 2016.



Overall levels of $PM_{2.5}$ have slowly declined in York Region, with levels varying slightly from year to year. Annual average $PM_{2.5}$ levels from 2002 and 2016 tend to vary between 5 to 10 µg/m^3 (Figure 7.5). It should be noted that the MECP upgraded its $PM_{2.5}$ monitoring network in 2013. As a result, the monitors were able to detect additional components of $PM_{2.5}$, especially during cold weather. This may have resulted in higher reported $PM_{2.5}$ concentrations due to more accurate measurements, but it does not necessarily reflect changing air quality. When correcting for the change in monitoring equipment, the annual mean concentration of $PM_{2.5}$ is estimated to have decreased by approximately 12% from 2007 to 2016 in Ontario.[123]

Figure 7.5. Average $PM_{2.5}$ concentrations in York Region from 2002 to 2016.

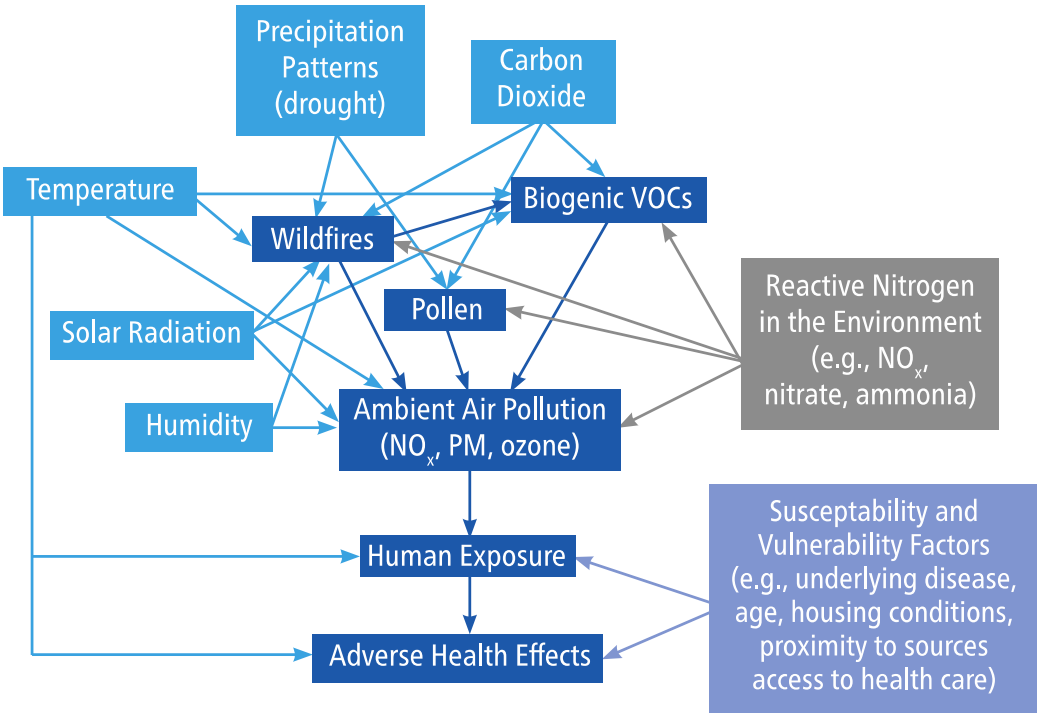


Data Source: Ontario Ministry of the Environment, Conservation and Parks. Air Pollutant data from 2002 to 2016 for ground-level ozone from Newmarket and North York monitoring stations. Toronto:Queen's Printer for Ontario; 2017.

7.4 CLIMATE CHANGE IMPACTS RELATED TO AIR QUALITY

Assessing the impacts of climate change on local air quality is challenging due to a multitude of factors. Figure 7.6 highlights some of the climate change and air quality factors that can interact to impact human health.[134]

Figure 7.6. Climate conditions and their impact on air quality.



Source: Peel JL, Haeuber R, Garcia V, Armistead G, Russle LN. Impact of nitrogen and climate change interactions on ambient air pollution and human health. Biogeochemistry [serial online]. 2013 114(1-3):121-134. Fig 1; Interactions of factors likely to change due to global climate change; p. 122. Available from: https://link.springer.com/article/10.1007/s10533-012-9782-4. Reproduced with permission from the copyright holder.

7.4.1 Climate change impacts on poor air quality days

Despite gains in air quality, future O_3 concentrations are expected to increase due to climate change. Across Canada, there is an increasing trend of moderate, moist and mild air masses and a decrease of dry, cold air masses. Moist tropical air masses with hot and humid air are expected to increase in the summer, which may contribute to poor air quality episodes in Canada.[125] The research suggests that nitrogen compounds such as NO_x will play an important role in the formation of ground-level O_3 during heat waves and stagnant air mass events.[134]

Cheng et al.[135] modelled future air pollutant days for four Canadian cities (Montreal, Ottawa, Toronto and Windsor) using data from 1981 to 2000, assuming pollutant emissions remained at the same level as at the end of the twentieth century. As this study is more than 10 years old, projections may need to be updated using more current data and updated models. The study found the number of days with high O_3 levels (1-hour maximum concentration $\geq$ 81 ppb) could

increase by 51% by the 2050s and 109% by the 2080s.[135] In addition, the number of days within the low O_3 level category (1-h maximum $\leq$50 ppb) could decrease from 1981 to 2000 levels by 6% by the 2050s and 9% by the 2080s.[135] Based on these predictions, daily mean O_3 concentrations could increase above 1990s levels by 2.7 ppb in the warm season (April to September) by the 2050s, and 4.0 ppb by the 2080s. Furthermore, Yue et al.[136] predict increases in forest fires in Canada could lead to a mean increase of 3 ppb of summertime O_3.

Between 1971 and 2000, York Region experienced an average of eight days per year with O_3 concentrations above 80 parts per billion (ppb). The Ministry of Health[11] predicts this number will remain the same into the 2050s, increasing by only one day per year by the 2080s. These changes were predicted based on temperature alone and do not take into account the potentially larger effects of transborder O_3 transport and precursors.

As noted previously the impacts of climate change on $PM_{2.5}$ are not clear, particularly related to seasonal trends and poor air quality episodes. Climate change is expected to increase concentrations of particulate matter in the air by increasing drought, leading to more intense and frequent wildfires and increasing air pollution levels. Wood smoke contains more than 100 atmospheric pollutants, including $PM_{2.5}$, greenhouse gases and precursors to O_3.[137]

7.4.2 Future projected health impacts from climate change on air pollutant exposure

Few studies have estimated the future health impacts from climate change relating to air pollutant exposure in Ontario. Cheng et al.[79] predicted air pollution-related mortality in Toronto would increase between 15% to 20% by the 2050s and between 20% to 30% by the 2080s, largely driven by O_3 concentrations. Similarly, Health Canada[4] examined climate change impacts across Canada and found future health impacts would primarily be due to increases in O_3 as particulate matter was expected to decrease.

It is important to note that future health projections are highly dependent on the assumptions made in the models used, and for the chosen emission scenarios. With existing progress to reduce air pollutant emissions from vehicles and other sources, emissions may be lower than current model assumptions. Additionally, changes in population structure and demographic factors can also play an important role in predicting future climate change impacts on air quality and health, especially with respect to the local level.

7.4.3 Climate change impacts on aeroallergens

Allergens can play a major role on the health outcomes of individuals with asthma and existing allergies. Sources of aeroallergens in the environment such as pollen, mould and fungal spores may be influenced by climate change.

Climate change may exacerbate the onset, duration and intensity of the pollen season along with the prevalence of mould and fungal spores.[5] There are three distinct pollen seasons in the floristic zone of southwestern Ontario: Tree pollen in the spring, grass pollen in spring and early summer, and ragweed pollen in the fall.[130]

A longer, warmer growing season may increase the duration of the pollen season, lengthening exposure to aeroallergens and exacerbating allergies and respiratory conditions.[129] Other important climate variables to consider are thunderstorms and heavy rainfall events that have been associated with higher pollen counts. In a recent Toronto study, aeroallergens were investigated to better understand the impacts of various allergens on respiratory health conditions.[130] The study suggests climate change will be associated with increased asthma, allergic rhinitis and bronchitis encounters in Toronto.[130] These health impacts are expected to increase due to climate change increasing maximum daily temperature, pollen counts and levels of O_3 and CO_2.

As pollen spores can travel substantial distances - over hundreds of kilometres - sources of pollen outside of York Region are important considerations for local aeroallergen concentrations.[130]

In recent decades, the length and timing for pollen season has shifted in North America and Europe. An analysis of 11 different plant taxa over a 21-year period found that 71% of taxa flowered earlier each year.[138] Allergenic plants may also shift their ranges northward due to warmer temperatures.[127]

While changes in pollen seasons have already been observed in North America, an extended growing season will likely increase the risk of public exposure to pollen from allergenic species. The growing season in York Region is predicted to increase by 30 days by 2050s.[10] The current growing season takes place from approximately May 17 to October 15 but could extend from early April to November.

The allergenicity of pollen will likely be affected by climate change. Ziska et al.[139] evaluated ragweed grown across an existing temperature/carbon dioxide (CO_2) gradient between urban and rural areas. They found CO_2 and temperatures at the urban site were 30% to 31% and 1.8 ^oC to 2.0^oC higher respectively than the rural site.[140] This resulted in ragweed that grew faster, flowered earlier and produced significantly higher above-ground biomass and pollen. Plants such as ragweed, grown in conditions with elevated temperatures and CO_2 produced larger amounts of pollen that were more allergenic.[138] Atmospheric pollen records worldwide have shown an increasing trend of pollen concentrations for allergens, including birch and alder, suggesting climate change is already having an impact.[138]

While there are many limitations in predicting the future impacts of climate change on aeroallergens in Toronto, Brubacher et al.[130] expect climate change to decrease weed pollen and increase tree pollen, grass pollen and certain fungi spores by the 2080s. Similar impacts may be possible in York Region, particularly in the southern municipalities closest to Toronto. However, the composition of species, differences in landscape, and differences in vulnerable population exposure that exists in York Region make it challenging to extrapolate to York Region.

7.5 ADAPTING TO FUTURE IMPACTS IN AIR QUALITY

7.5.1 Monitoring air quality in York Region

In Canada, multiple monitoring systems provide information on air quality conditions relevant to local stakeholders and the public, including those living in York Region. These include wildfire, pollen and air pollutant monitoring.

Adverse air quality conditions relating to air pollutant concentrations are monitored and forecasted at the provincial and federal level, and incorporate the Air Quality Health Index (AQHI) as part of public and stakeholder notifications. In the case of wildfire events, ECCC has integrated wildfire smoke into air quality forecasts that can be used to predict the movement of smoke plumes across the country. This tool can be valuable for determining wildfire risks that require emergency response measures and can highlight potential impacts to air quality from wildfires occurring in other regions.

There is limited monitoring data available for pollen. The closest monitoring stations to York Region are located in Brampton and Toronto. Pollen monitoring involves the daily collection of pollen samples that are analyzed through a microscope. This monitoring approach is not real-time, and may not be a relevant measure of levels found in York Region. With emerging research looking at the relationship between pollen and weather, synergistic effects with air pollution, and the spatial variability of pollen in communities, there may be more opportunities to consider how local public health activities could incorporate pollen monitoring.

7.5.2 Air Quality Health Index and air alerts

The AQHI was launched in 2015 to help the public make decisions about their health and activity levels based on outdoor air quality. Since the implementation of the AQHI in 2015, there has not been any high risk air quality warning in York Region.

The AQHI is also used for air quality alerts at the provincial level. Depending on the severity, MECP can issue a Special Air Quality Statement or Smog and Health Advisory. York Region Public Health currently monitors for such alerts and provides information to the public through social media platforms.

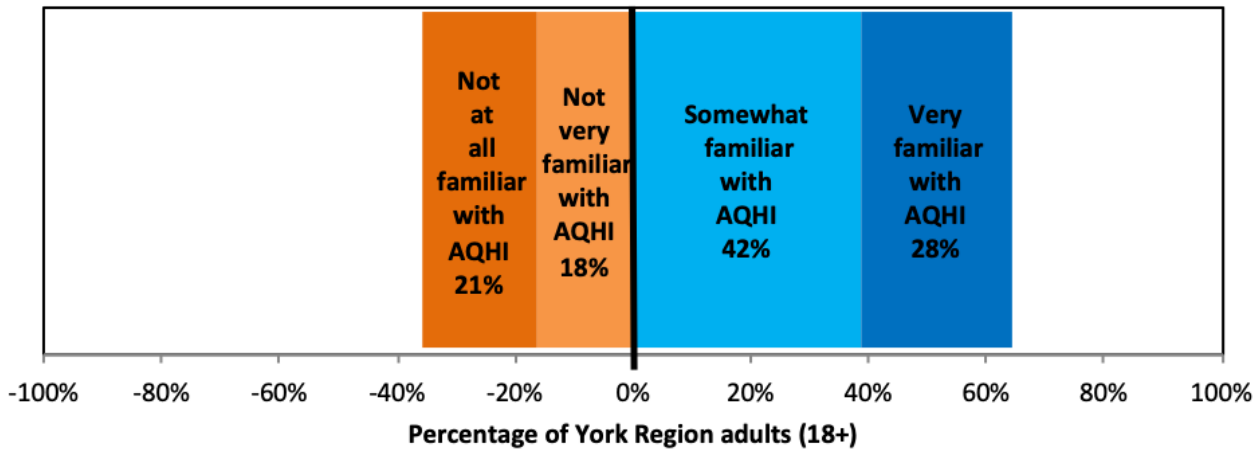
7.5.3 Adaptive capacity of local stakeholders and residents: Use of AQHI

The AQHI is a valuable tool that can be utilized by the general public and local stakeholders who work with vulnerable populations.

Certain stakeholders engaged with vulnerable populations have plans for poor outdoor air quality. In a 2016 survey of long-term care homes in York Region, 25 of 28 homes noted having a plan or policy in place to address days with poor outdoor air quality. Such programs by local stakeholders will play an important role in increasing adaptive capacity for vulnerable populations.

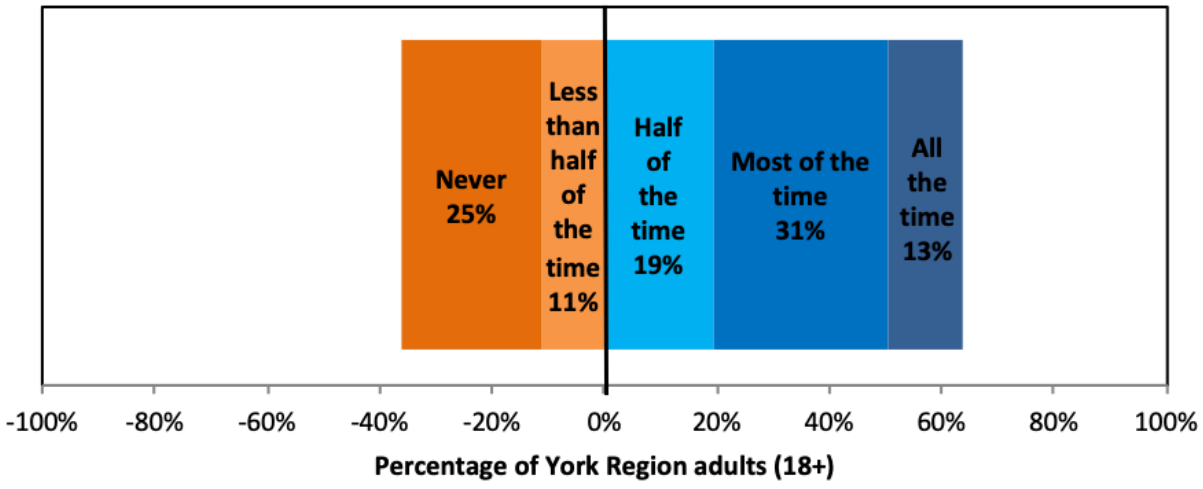
York Region residents are familiar with the AQHI. Approximately 70% of York Region adults reported they were somewhat or very familiar with the AQHI (Figure 7.7).[16] Only 25% of adults familiar with the AQHI reported checking the AQHI daily. Additionally, 36% of York Region adults familiar with the AQHI reported to never, or less than half the time change their outdoor activities based on the AQHI (Figures 7.8).[16,69]

Figure 7.7. Familiarity of York Region adults with the AQHI.



Data source: Rapid Risk Factor Surveillance System (RRFSS), 2016-2017, Regional Municipality of York, Community and Health Services.

Figure 7.8. York Region adults familiar with the AQHI who report changing their activities based on the AQHI.



Data source: Rapid Risk Factor Surveillance System (RRFSS), 2016-2017, Regional Municipality of York, Community and Health Services.

Raising awareness of the AQHI in York Region

In 2018, York Region Public Health partnered with the Ontario Lung Association and Health Canada to develop and implement a public education campaign on the AQHI across York Region. The campaign goal was to increase awareness about outdoor air quality and the AQHI, and

encourage York Region residents to regularly use the AQHI tool when planning their outdoor activities. A needs assessment and follow up workshop was conducted with more than 20 local stakeholders from school boards, health care, paramedic services, child care centres and long-term care homes. Some of the key recommendations identified by stakeholders to reach residents included effectively reaching vulnerable populations and the promotion of the AQHI App.

Various communication tactics were used to reach the target populations including social media, news media, transit and billboard ads, promotional videos and community events. Results of the campaign evaluation indicate there was an increase in awareness based on overall social media impressions, extensive reach and news media viewership, app downloads, engagement at public events, survey data from in-person outreach and level of key stakeholder engagement. Stakeholders reported that they found the engagement valuable and they intended to share and use the tools created as part of the campaign.

7.6 CONCLUSION

While there are significant linkages between climate change and air quality, more research is needed to better understand the impacts that climate change will have on air quality, and ultimately human health. Levels of O_3 are influenced by various climatic factors such as warming temperatures, stagnant air masses and greater emission of biogenic precursor pollutants due to changing temperatures. Longer summer seasons may also increase average O_3 levels. However, research is still limited in understanding how climate change may contribute to future levels of $PM_{2.5}$. Impacts may include increases in ambient $PM_{2.5}$ levels through other pathways such as from wildfire events.

There is insufficient information to assess the health impacts of air quality and related weather factors in York Region. Current work assessing the burden of illness from environmental hazards in Ontario may provide a better understanding of how many cases are attributed to air quality. Analyzing existing climate and air quality data related to health will be essential to inform future surveillance needs, and inform appropriate interventions.

While research has shown strong evidence of air pollutants' spatial and temporal distribution in urban communities, there is still limited information to assess potential exposures in York Region. There are limited monitoring stations in York Region and spatial variation in pollutant levels will likely differ between municipalities and areas, such as urban, suburban and rural communities. Information on pollen in York Region is currently limited, but emerging research may provide a better understanding of pollen risks in terms of spatial distribution and the additive effects of pollen with air pollutants.

Program activities, such as monitoring air quality conditions and communicating air quality notifications to the public, play an important role for public health and adaptive capacity. There is an opportunity to expand monitoring to different air quality issues such as wildfire and pollen issues, and to ensure notifications reach those most vulnerable to air quality impacts such as children and seniors. Health outcome surveillance programs and a better understanding of the

linkages between weather variables and air pollutant levels will help inform the criteria for notifications.

Addressing air quality offers multiple co-benefits that can support climate change mitigation and improvements to air quality. Certain GHGs, such as black carbon and O_3, are short-lived climate pollutants that contribute to climate change and reducing air quality. While addressing these impacts on climate change, important improvements in air quality can be achieved to help reduce the impacts on human health.

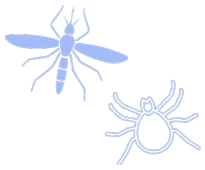
Nevertheless, air quality is an important consideration for future climate change adaptation planning. Existing traffic-related air pollutants and industrial emissions contribute to local air pollution and to greenhouse gas emissions. During morning peak hours the number of trips in York Region is expected to increase from around 300,000 to 500,000 trips between 2011 and 2041, the majority of which are automobiles.[141] Additionally, efforts to reduce vehicle traffic can also support health benefits such as greater physical activity. Work should continue to develop a healthy built environment in order to encourage active transportation, increase physical activity and decrease exposure to traffic-related air pollutants. Table 7.2 provides an overview of existing activities and adaptation planning opportunities.

Table 7.2. Summary of air quality related activities and adaptation planning opportunities.

	Ongoing and Completed Activities	Opportunities
Public Health Assessment and Surveillance	**Environmental monitoring:** Monitoring of AQHI levels in York Region based on two monitoring stations (Newmarket and Toronto North). Monitoring air quality alerts issued by MECP and ECCC.	Explore additional datasets related to pollen levels in York Region. Consider assessing the spatial distribution of air quality impacts across York Region, including $PM_{2.5}$ and O_3.
	Health surveillance: Monitoring health outcomes relating to air quality.	Consider further analysis of health outcome data relationship with air quality (pollutants and pollen) and weather variables to better understand impacts in York Region. After assessing health outcome data related to air quality, consider developing a syndromic surveillance plan for air quality related impacts.
	Population and stakeholder surveys: Completed RRFSS (2016, 2017) modules on the AQHI. **Health Equity:** Completed survey of long-term care homes in York Region (2016).	Consider surveillance plan to monitor the population and environmental related risk factors. **Health Equity:** Consider the analysis of responses related to demographic factors to better understand risk factors for vulnerable populations. Consider modules related to allergies and asthma to better understand vulnerable populations.
Program and Policy	Recommending and supporting policies and programs that promote active transportation, access to green space, healthy built environments, and local emission reductions. Reviewing relevant research to inform policy and programs.	Engage with York Region Forestry, community groups and homeowners regarding planting non-allergenic plants and trees. Consider recommendations for personal air monitoring or air purifier equipment that can be used by local residents.
	Public notification of poor air quality episodes.	**Health Equity:** Consider notification options that target vulnerable populations (e.g., seniors, children and individuals with certain pre-existing conditions).

Health Promotion	Social media messaging and webpage content relating to the AQHI and air quality alerts. Webpage content on outdoor air quality and AQHI. 2018 AQHI Awareness Campaign in York Region. Initiatives included multiple media platforms (e.g., radio, bus and newspaper ads, etc.) to inform the public and physicians on AQHI.	**Health Equity:** Consider targeting vulnerable populations as part of future health promotion activities. Incorporate climate change messaging into air quality health promotion resources where relevant. Consider additional key messaging to the general public for issues relating to pollen and wildfires. Consider educational opportunities for local medical professionals regarding climate change and health including air quality.
Key Stakeholder Activities (outside of Public Health)	ECCC monitoring and forecasting wildfires, including smoke plumes. MECP monitoring of air quality through local air monitoring stations and weather conditions.	Consult ECCC regarding aeroallergen monitoring opportunities and available data. **Emergency Preparedness and Response*:*** Incorporate consideration of smoke impacts from wildfires into emergency plans.
	Organizations supporting individuals with respiratory conditions (e.g., Asthma Canada, Ontario Lung Association, local asthma and allergy support programs).	**Health Equity:** Explore opportunities to understand existing support services for vulnerable populations to inform public health programs and promotion activities. Consider surveying other stakeholders engaged with vulnerable populations on plans relating to poor air quality events.
	Research on air quality impacts in Ontario from PHO and Health Canada.	Consult PHO and Health Canada regarding assessment opportunities and data limitations for assessing impacts within York Region.

CHAPTER 8
Vector-Borne Diseases



8.0 Vector-Borne Diseases: Key Findings

Climate change projections and exposure pathways

- Temperature, rainfall and humidity play an important role in the spread of vector-borne diseases (VBDs). As a result of climate change, conditions are expected to become more favourable for disease vectors, which can increase the risk of VBDs in Ontario
- The number of West Nile virus (WNV) human cases are seasonal and vary based on weather trends for a given year, with the highest levels of human cases occurring in August. Specifically, temperature and precipitation have played an important role in the presence of WNV in York Region
- Factors contributing to the risk for WNV include favourable habitat conditions for vector population growth, increased urbanization and the presence of local bird populations
- Warmer winter temperatures play an important role in the survival rate of ticks. It is expected that ticks, such as the blacklegged tick (which can transmit Lyme disease), will continue to expand their habitat range north through temperate climate regions such as Ontario
- Recent surveillance has shown a substantial increase in blacklegged ticks in York Region. The majority of York Region is now considered an estimated risk area for Lyme disease

Population sensitivity

- Individuals spending substantial time outdoors are more vulnerable to exposure to vectors that can transmit WNV and Lyme disease
- Between 2000 and 2015 most cases (60% to 63%) of WNV and Lyme disease were women
- Travel to endemic areas outside of York Region has been an important exposure route for York Region residents

Adaptive capacity

- Current surveillance activities in York Region focus on WNV, Lyme disease and Eastern equine encephalitis virus (EEEV)
- York Region Public Health and the province are working proactively to prevent the risk of VBDs through surveillance activities, prevention measures and awareness campaigns
- York Region Public Health works with municipalities to address mosquito larviciding activities (such as with municipal catch basins and stormwater management ponds) and with York Region Forestry regarding preventing Lyme disease

Health impacts

- There is strong supportive evidence that VBDs are likely to increase in York Region as a result of climate change
- Climate change may impact emerging VBDs from ticks (babesiosis, Powassan encephalitis and *Borrelia miyamotoi)* and mosquitoes (EEEV, Jamestown Canyon virus and snowshoe hare virus)

Recent trends:

- The highest number of human cases of WNV in York Region occurred in 2002, followed by 2012 and 2017. Lower number of human cases and positive mosquito pools found between 2012 and 2017 were likely due to temperature and drought conditions
- Ontario has seen a large increase in the number of Lyme disease cases since 2010. The number of confirmed and probable Lyme disease cases has also substantially increased in York Region in recent years

VBDs are transmitted by the bite of arthropod species, namely mosquitoes and ticks that are infected with disease pathogens. They also spread from human-to-human and animal-to-human contact by vectors that carry the disease. Multiple factors can influence the risk and presence of VBDs, including habitat for vectors and animal reservoirs[r], human populations with increased risk of contact or proximity to vectors and agricultural practices that can affect suitable habitat for vectors/animal reservoirs and climate conditions.[142] While vectors may currently exist, the number and proportion of vectors that carry infectious disease pathogens vary, making it difficult to estimate future changes in human cases.

Conditions are expected to become more favourable for disease vectors, which can increase the risk of VBDs in Ontario, including in York Region. Increases in temperature will create favourable conditions for vectors and expand their habitat range. Specifically, rising temperatures are expected to increase the ability of tropical and sub-tropical vector populations to survive in warming temperate regions.[142] Longer and warmer summer periods with more intense rainfall events and fewer extreme cold events will also support the survival and growth of vector populations in existing habitat ranges.[142]

The following sections focus on West Nile virus (WNV) and Lyme disease, two vector-borne diseases (VBDs) that are the focus of York Region Public Health's comprehensive and collaborative VBD program. York Region Public Health currently conducts surveillance programs focused on Lyme disease and WNV. Eastern equine encephalitis virus (EEEV) is also monitored as part of the surveillance/testing program for WNV in Ontario. Recent trends from vector surveillance and reported human cases provide an overview of the current status of VBDs in York Region. Recent research on climate change and VBDs are discussed to provide more context on future VBD risks in York Region. This report also provides an overview of York Region's program and policies related to VBDs to explain existing and future adaptive capacity.

8.1 WEST NILE VIRUS

WNV arrived in North America in 1999 and was first detected in Ontario in September 2001.[143] Dipteran mosquito species are the main vector that transmits disease to humans. In Ontario, *Culex pipiens/restuans* are the main species of mosquitoes responsible for transmitting WNV. Avian populations act as a reservoir for the disease and are an important factor in the risk of WNV infections in humans from vector populations.

Southern Ontario has been identified as a hot spot area for WNV activity due to the large number of residents, land type factors (e.g., urban areas, grasslands and wetlands) combined with favourable climate conditions (e.g., temperature and precipitation) resulting in increased vector activity.[143,144] The average temperature was shown to be an important indicator of seasonal activity of the vector for southern Ontario health units, including York Region.

[r] A reservoir refers to a living (e.g., animal, human, insect, or plant) or non-living (water, soil) entity where the pathogen carrying organism can survive and multiply. Reservoirs can support the survival and expansion of the pathogens, but are not directly responsible for transmission to human populations.

Since WNV was first detected in Canada in 2001, there have been more than 5,000 confirmed human cases. However, many cases go unreported as most individuals with WNV are asymptomatic. According to the Public Health Agency of Canada, there have likely been 18,000 to 27,000 human WNV cases that have gone unreported.[143] The first known human case in Ontario was reported in 2002, and WNV has been a reportable disease in Ontario since 2003. Positive WNV results from blood donation testing are also reported to Public Health by Canadian Blood Services.

Health effects of WNV

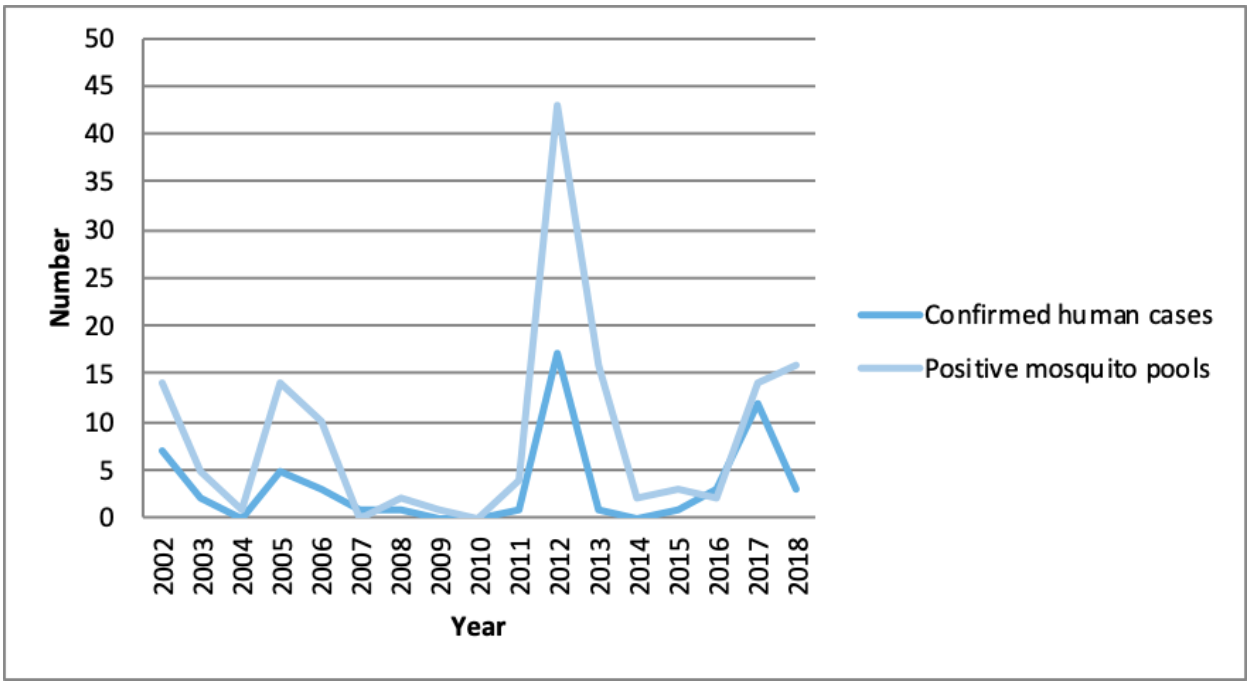
There are three clinical manifestations of WNV: Asymptomatic, non-neurological and neurological. Although up to 80% of WNV cases show no symptoms, approximately 20% develop mild, non-neurological symptoms ("WNV Fever") typically lasting a few days, which can include fever, headache, body aches, swollen lymph nodes and skin rash among other symptoms. Serious neurological infections impacting the central nervous system (e.g. encephalitis, meningitis) occur in less than 1% of infected people.[145] In rare cases, WNV can result in death.[145]

Recent trends in York Region

As mosquito populations are sensitive to weather conditions, the number of WNV human cases and positive mosquito pools vary based on weather trends for a given year. As WNV depends on favourable weather conditions, most cases show a seasonal trend peaking in August. Figure 8.1 provides an overview of the number of confirmed human cases and positive mosquito pools of WNV in York Region from 2002 to 2018.

The highest number of confirmed cases of WNV in York Region occurred in 2002, when it was first introduced to York Region, followed by 2012 and 2017. In other years, there was a median of one case reported per year.[146] The lower number of human cases and positive mosquito pools found between 2012 and 2017 were likely due to temperature and drought conditions.

Figure 8.1. West Nile virus surveillance activity in York Region between 2002 and 2018.



Source: Ontario Agency for Health Protection and Promotion (Public Health Ontario). Infectious disease trends in Ontario: West Nile Virus [data file]. Toronto: Queen's Printer for Ontario; 2019.

Vulnerable populations and WNV

See Chapter 4 for more information on vulnerable populations. Individuals most vulnerable to WNV are those who spend substantial time outdoors in the summer period and may be more exposed to WNV-carrying mosquitoes. Additionally, individuals may be more susceptible to serious complications when infected. These populations can include:

- Individuals who are active or work outdoors
- Individuals experiencing homelessness (sleeping outdoors increases the risk of exposure to WNV, as *Culex* species carrier mosquitoes are most active at dusk and dawn)[31]
- Individuals 55 years of age and older and those with compromised immune systems (these groups are at a higher risk of developing meningoencephalitis if infected with WNV)[31]
- Women, as approximately 60% of reported human cases of WNV in York Region between 2000 and 2015 occurred in females, with the majority reported in women 50 to 54 years of age.[146] Pregnant women may also be particularly vulnerable to VBD due to changes to immune function as a result of pregnancy[147]
- Individuals who travel to WNV-endemic areas

Climate factors and risk for WNV

Temperature, rainfall and humidity conditions play an important role in the spread of WNV. With the rapid reproduction rate and short life cycle of mosquito populations, short-term changes in weather can significantly influence the growth and survival of mosquito populations. These impacts can also occur within a few weeks of specific weather events. Research has found links between how the following weather patterns play an important role in mosquito vector populations:

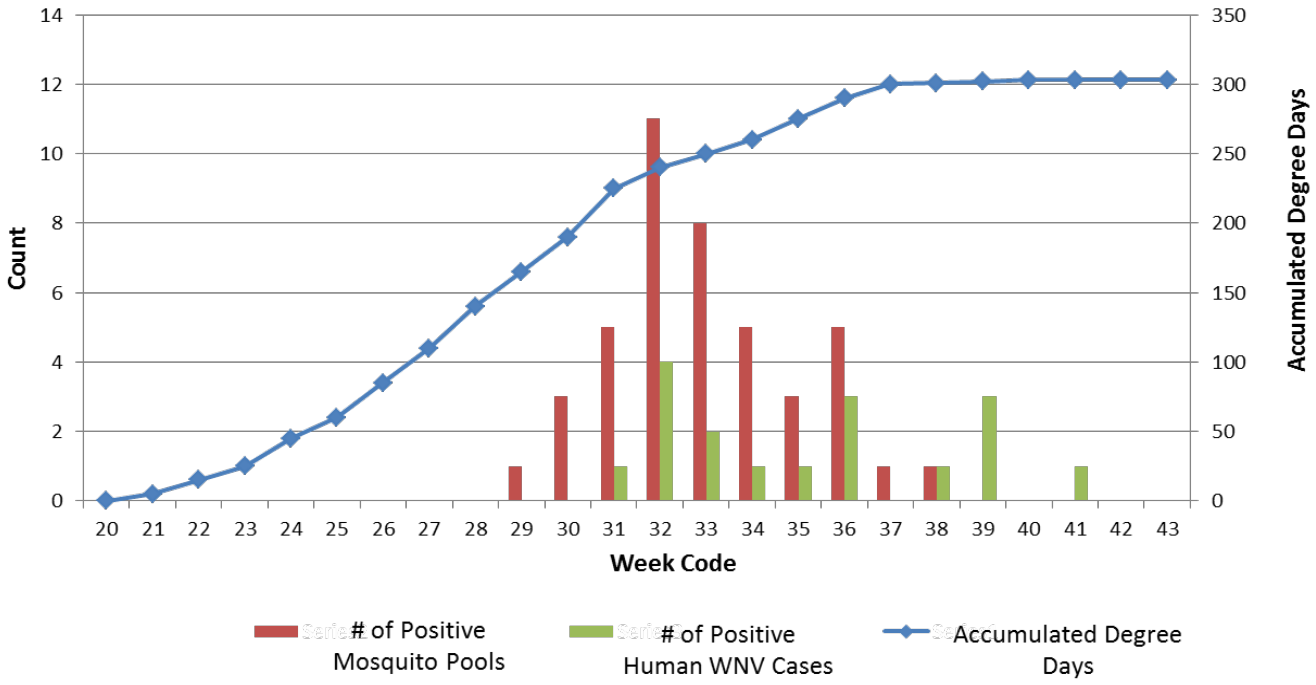
- **Temperature:** In low to medium temperatures, mosquitoes can have a shorter life cycle, increased activity and faster development. When temperatures are too high, mosquito activity can be reduced and mortality can be increased.[142] However, York Region surveillance data has revealed that an increase in the number of positive traps and human cases are associated with high temperatures. This increase was likely attributed to additional factors (e.g. warmer winter temperatures and an earlier spring) and highlights the importance of considering multiple weather variables
- **Humidity:** Dry conditions limits the available breeding habitat for mosquitoes and increases their need to return to water to rehydrate. In contrast, higher humidity can increase activity and indirectly reduce mosquito mortality[142]
- **Rainfall events:** Heavy rainfall can also cause an increase in *Culex pipiens* populations if temperatures are also suitable. However, heavy and sustained rainfall can also control mosquito populations by flushing larvae out of the catch basins. In contrast, *Culex pipiens* can respond to droughts in urban areas by reproducing in stagnant pools[142]

The higher number of human cases and positive mosquito pools observed in York Region in 2012 and 2017 were attributed to temperature and precipitation. In 2012 and 2017, warmer winter temperatures increased the chances of mosquito survival through winter and amplified mosquito populations during the summer season. The earlier start of spring and higher temperatures created favourable conditions for mosquitoes in 2012. By contrast, 2017 had cooler temperatures but greater precipitation, resulting in conditions suitable for mosquito breeding.

Figure 8.2. depicts positive mosquito pools and positive human WNV cases by week in 2012 along with accumulated degree days (ADD).[s] The first positive mosquito pools were detected during the third week of July at around 100 ADD, and the first human cases started to occur around 200 ADD. The 2012 mosquito season lasted a few weeks longer than typically seen in Ontario. Human cases were detected at the beginning of August, which was earlier than previously detected in other years. Warmer temperatures likely contributed to amplified virus replication in bridge vectors, which led to a greater risk to human health.

[s] Degree days is a measure of the quantity of heat needed for organisms such as mosquitoes to develop within certain life stages. For *Cx. pipiens/restuans* mosquitoes in Ontario, a degree day is 1˚C above 18.3˚C. For example, an average daily temperature of 20.3˚C would count as 2 degree days. Accumulated degree days (ADD) is the addition of consecutive degree days, which can help provide an indication for the start and intensity of a vector seasons. In general, the first positive mosquito pools tend to occur around 100 ADD, and there is a higher risk for WNV transmission to humans around 200 ADD.

Figure 8.2. York Region West Nile virus activity and accumulated degree days in 2012.

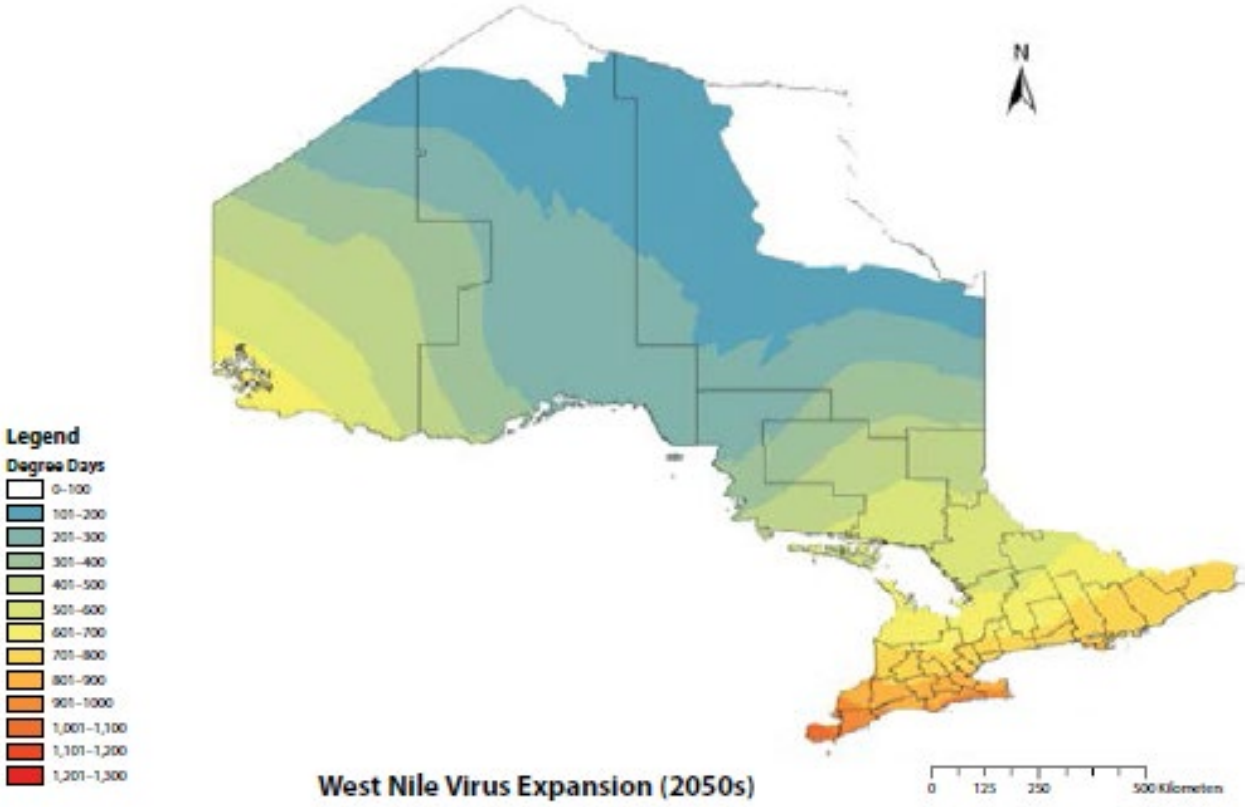


Source: Regional Municipality of York. West Nile active surveillance program. Newmarket: Regional Municipality of York; 2012.

Recent research has also looked at how weather variables during the transmission season (May to October) and the preceding winter can affect the risk of WNV in a given locality. When evaluating past surveillance activities in Ontario and potential links to weather variables, Mallya et al.[144] noted warmer temperatures in February played an important role in predicting the risk of WNV during the transmission season in Ontario.

Figure 8.3 highlights the expansion of WNV using degree days. This indicates when vectors may start reproducing and becoming more prevalent across Ontario. Accumulated degree days are expected to increase in York Region from 200 to 400 up to 600 to 800 by the 2050s. However, it should be noted that the definition of a degree day for this projection (minimum daily temperature threshold of 14˚C) differed from what is used by York Region.

Figure 8.3. Expansion of WNV in 2050 in Ontario. Increase in the number of degree days for *Cx. pipiens/restuans* (the degree day is defined by daily minimum and maximum temperatures between 14˚C and 35˚C).



Source: Ministry of Health and Long-Term Care. Ontario climate change and health modelling study [Internet]. Toronto (ON): Queen's Printer for Ontario; 2016. Fig 12 WNV. Favourable climatic conditions for the 2050s; p. 18. Available from: http://www.health.gov.on.ca/en/common/ministry/publications/reports/climate_change_toolkit/climate_change_health_modelling_study.pdf. Reproduced under the terms of this license: https://www.ontario.ca/page/copyright-information-c-queens-printer-ontario?_ga=1.192891053.642029082.1453497246. Reproduced with permission from the copyright holder.

Climate change is expected to increase the migration of other mosquito species from the United States into Canada.[148] As mosquitoes are more responsive to short-term climate conditions, it is difficult to predict how climate change will impact the risk of WNV over the longer term. However, as temperatures become warmer in higher latitude regions, the geographical range favourable for mosquito survival and reproduction will also increase.

Increased urbanization in York Region may provide more favourable conditions for mosquito population growth and risk of WNV transmission. Urban areas can create microclimates with more favourable conditions for mosquito populations to thrive. In urban and suburban communities, stagnant pools within catch basins can occur, creating urban heat islands that support mosquito population growth. Additionally, WNV mosquitoes can survive through the winter months in the sewer system where temperatures remain above freezing. While existing research illustrates the future impact climate change may have on the risk of WNV transmission,

there are other factors to consider. Favourable habitat conditions are needed for mosquito populations to be active and grow in population size. Additionally, the presence of local bird populations contributes to the risk of WNV during the transmission season.

Adaptive capacity

York Region Public Health activities addressing WNV

Since the first cases of WNV emerged in North America, York Region Public Health has been actively engaged in monitoring and controlling the risk of WNV transmission.

York Region Public Health's VBD program takes a comprehensive approach that includes surveillance, investigations, and protection measures. Activities include testing of mosquito pools across the Region, identification and monitoring of mosquito species, educational activities on the risks of WNV transmission, larviciding to control for mosquito populations and investigating standing water complaints to reduce mosquito breeding grounds (Table 8.2).

For much of these activities, provincial agencies play an important role in helping to address WNV in Ontario, particularly for surveillance and supporting public outreach. For example, local public health units, such as York Region Public Health, and Public Health Ontario (PHO) work together to ensure all relevant surveillance information is shared when assessing current WNV risk. York Region Public Health collects data on probable and confirmed human cases of WNV, which is shared with PHO. Active surveillance of mosquito populations is conducted through the weekly testing of mosquito traps. Information on cases and VBD surveillance data are shared with the province to support broader provincial surveillance activities and trend analysis.

Larviciding is conducted with local municipalities to support mosquito control in areas such as municipal catch basins, park basins, stormwater management ponds, roadside ditches and sewage lagoons. For larviciding, York Region Public Health uses methoprene and biopesticides (*Bacillus thuringinsis* and *Bacillus sphaericus*). It should be noted that UVB wavelengths inhibit the *Bacillus* bacterium. Increases in ultraviolet radiation due to climate change could reduce the effectiveness of larviciding in the future without changes in pesticides.[149]

York Region also provides WNV educational activities, supported by the province, to educate local communities on how to reduce their risk of WNV transmission. Resources target a wide population range and materials are distributed to schools and communities through tactics such as newspaper ads and social media.

8.2 LYME DISEASE

Lyme disease is a tick-borne illness spread by the bite of blacklegged ticks infected with the bacteria *Borrelia burgdorferi*. Since its emergence in North America in the 1970s, Lyme disease has become one of the most frequently reported VBDs in North America. The suitable habitat range for ticks has expanded from the United States into parts of Canada, with the range of some tick species increasing faster than predicted. There is now a significant risk of infection for Lyme disease in southern Ontario.[142,150,151]

Blacklegged ticks depend on animal hosts for their dispersal and reproduction rate. Within Ontario, white-tailed deer and white-footed mice are the main animal reservoir populations. In an assessment of tick populations in the Thousand Islands, an area with a higher presence of blacklegged ticks, the study found the abundance of white-footed mice and greater diversity in animal species were related to the presence of blacklegged ticks.[152]

Blacklegged ticks have a long life cycle that can last from months to years.[142] The blacklegged tick in the nymph life cycle stage has a higher risk of Lyme disease transmission to human populations. Blacklegged ticks in this life cycle are difficult to see, making it easier to attach to the human host unnoticed and feed for more than 24 hours, thereby increasing the risk of infection.[t]

In Canada, the number of Lyme disease cases reported increased from 144 in 2009 (when it became reportable) to 992 cases in 2016.[153] This represented an increase in the incidence of 0.4 to 2.7 per 100 000 population over the same time period.[153] The Centers for Disease Control and Prevention (CDC) estimates the number of people with Lyme disease in the United States to be approximately 10 times higher than actually reported.[154]

Health effects of Lyme disease

The symptoms of Lyme disease differ from person to person and there is a range of clinical manifestations Lyme disease typically presents in stages: Early localized, early disseminated and late disseminated. Symptoms of early localized infection typically include a rash (sometimes shaped like a “bull’s eye”) called Erythema migrans, and can include fever, chills, headache, fatigue, muscle and joint aches and swollen lymph nodes. If infection is untreated, the bacteria can spread in the body, causing more severe symptoms and disease to develop over time, which can last from months to years. These can include severe headaches, additional Erythema migrans rashes, facial paralysis, cardiac disorders, neurological disorders, intermittent body aches and arthritis (often in larger joints like the knees). In rare cases, Lyme disease can lead to death, usually related to complications involving infection of the heart.[153]

Recent trends in York Region

York Region Public Health uses active and passive surveillance methods to measure the local distribution and incidence of ticks in York Region. Table 8.1. provides a summary of surveillance activities for local blacklegged ticks in York Region from 2012 to 2018.

[t] A tick must be attached for a minimum of 24 hours (irrespective of life cycle) for transmission of the bacteria that causes Lyme disease.

Table 8.1. Lyme disease surveillance activity in York Region from 2012 to 2018.

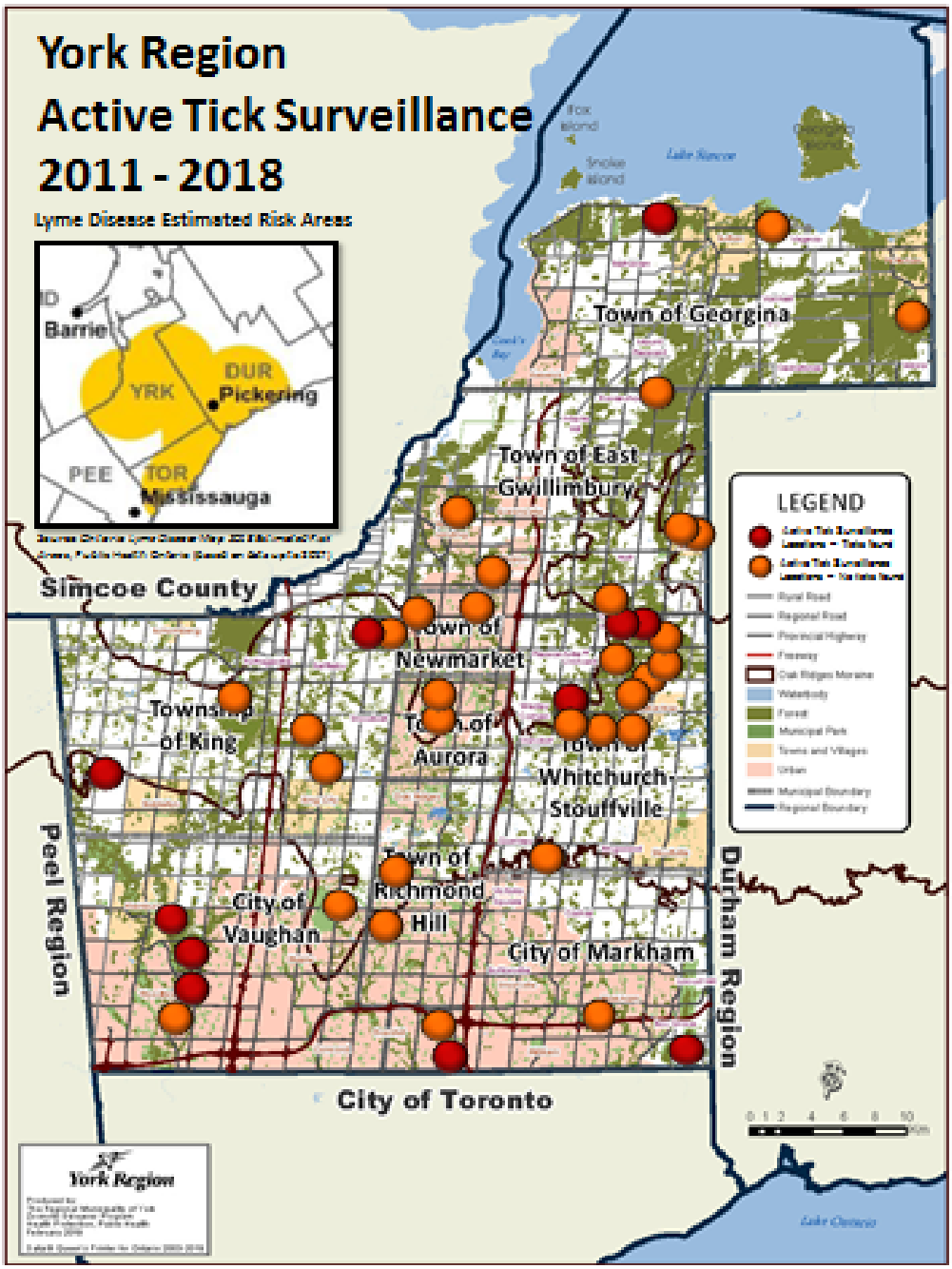
	2012	2013	2014	2015	2016	2017	2018
Local blacklegged ticks - passive tick surveillance	1	4	7	11	15	35	37
Local blacklegged ticks - active tick surveillance	0	0	2	4	0	10	28
Positive *Borrelia burgdorferi* local blacklegged ticks	0	0	1	0	1	2	1

Source: Regional Municipality of York. Lyme disease surveillance program. Newmarket: Regional Municipality of York; 2012.

- **Passive tick surveillance:** Residents can submit ticks to York Region Public Health for identification.[u] In 2017, 35 of the 113 passive tick submissions were locally acquired in York Region and identified as blacklegged ticks. One tick tested positive for the bacterium that causes Lyme disease.[155] The majority of submissions from residents reported travel to woodland habitats.
- **Active tick surveillance:** Ticks are collected from their habitat by dragging white cloth sheets over and around vegetation where ticks wait for a passing host. Locations for active surveillance are facilitated by information gathered during passive surveillance. Figure 8.4 summarizes the results of active tick surveillance in York Region from 2011 to 2018. In 2017, two new Lyme disease risk areas were identified; in the vicinity of Joker's Hill in King Township and in the vicinity of the York Region Forest North Tract in the Town of Whitchurch-Stouffville.[155] In 2018, York Region Public Health conducted tick dragging at 35 locations in the Region throughout the spring and fall in natural, forested public spaces (e.g., parks, conservation areas, river valley systems). Twenty-eight blacklegged ticks were found at nine locations, with one blacklegged tick testing positive for *Borrelia burgdorferi*.[155] This was a substantial increase in the amount of blacklegged ticks found through active tick surveillance and is likely due to the expansion of blacklegged tick habitat in southern Ontario. One new risk area was also identified in 2018 in the Humber Valley near the Boyd and Kortright Conservation Areas.

[u] As of January 1, 2020 the National Microbiology Laboratory will no longer be conducting diagnostic testing of passive tick submissions.

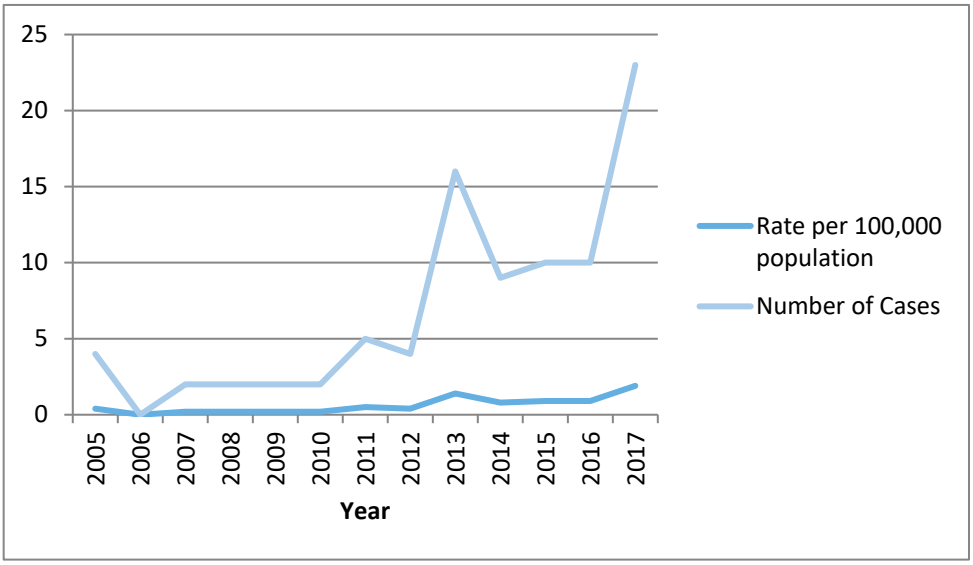
Figure 8.4. Summary of active tick surveillance from 2011 to 2018 in York Region.



The occurrence of blacklegged ticks and human cases of Lyme disease has increased in York Region. Reporting human cases of Lyme disease is integral to local and provincial surveillance programs. As a disease of public health significance, confirmed and probable human Lyme disease cases are reportable to York Region Public Health. Overall, the province has seen a rise in the number of cases of Lyme disease since 2010, particularly in eastern Ontario. Reported cases in York Region relate to potential local exposure but also to travel. Figure 8.5

shows the number of human cases of Lyme disease in York Region between 2005 and 2017. Notably, the number of probable and confirmed cases started increasing in 2011. In 2017 there were 18 confirmed and five probable cases of Lyme disease. The rates of Lyme disease in York Region have also increased from 0.2 to around 1 case per 100,000.

Figure 8.5. Number of human cases (probable and confirmed) and incidence rates of Lyme disease from 2005 to 2017 for York Region residents.



Source: Ontario Agency for Health Protection and Promotion (Public Health Ontario).Infectious disease trends in Ontario [data file]. Lyme disease cases and rate. Toronto: Queen's Printer for Ontario; 2018.

Vulnerable populations

See Chapter 4 for more information on vulnerable populations in York Region. Similar to WNV, those spending substantial time outdoors in wooded or brushy areas, or travel to endemic areas are more vulnerable to Lyme disease. Between 2000 and 2015, 63% of Lyme disease cases in York Region occurred in females across most age groups, but rarely in seniors or children.[146] Part of this may be due to limited mobility and activity on trails among seniors. However, submission rates of ticks in Ontario have tended to be highest for children 0 to 9 years of age and adults 55 to 74 years of age.[156]

Individuals active on trails may be at a higher risk of exposure to blacklegged ticks in York Region. Currently, the York Regional Forest consists of approximately 2,400 hectares of land, providing around 150 km of free trails for the public. Recent surveys conducted in 2017 suggest there are approximately 1,623 visitors per day in York Regional Forest tracts, peaking during the fall.[35] This survey only covered York Region Forest tracts and does not include the wide range of public green spaces in York Region, such as, municipal and provincial parks. Most visits (63%) occur in four tracts: Eldred King (24%), Hollidge (17%), Bendor and Graves (11%) and Brown Hill (10%).[35] The most common activity was walking, with or without a dog. The tracts most favoured for use are near population centres and users' residences. Most visitors are from households living in

close proximity to Regional Forest tracts (65%) and visitors driving in primarily from the closest local municipalities of Newmarket, Whitchurch-Stouffville, Markham and Georgina.[35]

Climate factors related to Lyme disease

Tick populations respond more to long-term trends in climate rather than short-term variability in weather. This is due to their longer life cycle, dependence on host populations, ability to withstand weather changes and use of soil/soil litter as refuge.[142,157] Public Health Ontario has noted that the expansion of blacklegged ticks into Ontario is largely driven by climate change and the increase in the mean annual degree days above 0°C.[157] Recent surveillance assessments have highlighted how recent changes in climate have played a factor in the spread of Lyme disease in Ontario. Cheng et al.[158] illustrated how warming temperatures from 1979 to 2013 have created more favourable habitat and host conditions for blacklegged ticks, particularly for southern and eastern Ontario.

Temperature, precipitation and humidity play an important role in the presence of ticks. An earlier seasonal occurrence of Lyme disease has been linked to warmer temperatures in previous seasons in the United States.[159] Similarly, changes in precipitation can impact ticks by creating more humid conditions in soil and litter, which provide refuge from changes in weather. However, heavy precipitation leading to persistent and deep flooding likely decreases tick survival rates.[142] During drought conditions, ticks will be able to return to humid soil and litter for protection. However, this will likely limit their spread into new territories.[142]

The climate in York Region is expected to result in longer and warmer summer periods with more intense rainfall events and fewer extreme cold events. Therefore, there is the potential for blacklegged tick populations to be present in greater numbers due to more favourable weather conditions.

As a result of warming temperatures and an increase in precipitation, it is expected ticks will continue to expand their geographic range north in temperate regions and have an earlier start and longer season of activity. Blacklegged ticks are active in the spring and fall when temperatures are above 0˚C and there is no snow. The reproductive rate is commonly looked at as an indicator of the expanding range of blacklegged ticks. Blacklegged ticks are expected to increase their reproductive rate by 2.2 to 4.6 times more from 2051 to 2065 when compared to historical reproductive rates (1970 to 2000), which is expected to contribute to the expanding range.[151]

Adaptive capacity

York Region Public Health activities addressing Lyme disease

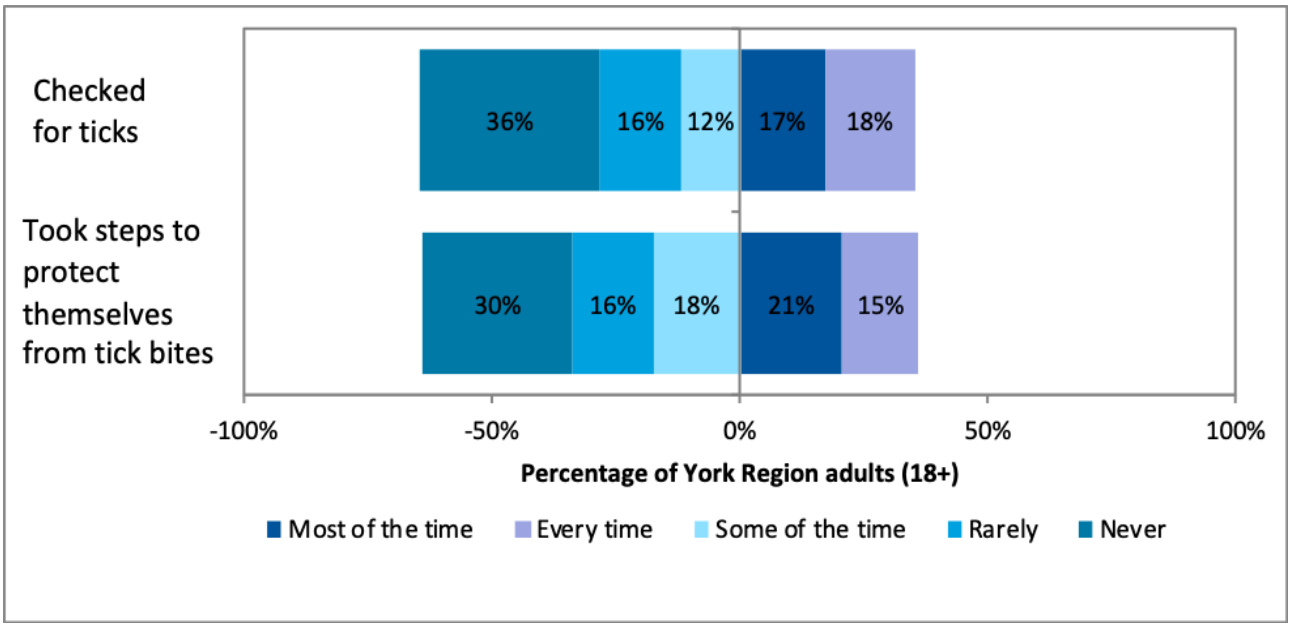
As part of provincial requirements for Lyme disease, York Region Public Health will continue surveillance activities for Lyme disease and blacklegged ticks.

While surveillance activities are essential to help address current and future Lyme disease risk, educating stakeholders and the public on the health risks and encouraging positive and protective behaviours are vital to reducing risk and decreasing exposure. Current educational activities

include promotional campaigns such as **Fight the Bite** (this includes messaging about personal protective measures and signage on Lyme disease at trails where blacklegged ticks were found), educational materials at community events and schools, social media messages and news releases.

However, results from the 2017 Rapid Risk Factor Surveillance System telephone survey suggest approximately one-third of York Region adults have not adopted behaviours to protect themselves against Lyme disease.[16] Approximately 30% of residents reported they never take steps to protect themselves from tick bites and 36% of residents reported they never check themselves for ticks after spending time outdoors (Figure 8.6).[16]

Figure 8.6. How often York Region residents reported taking steps to reduce their exposure to Lyme disease.



Source: Rapid Risk Factor Surveillance System (RRFSS), 2017, Regional Municipality of York, Community and Health Services.

Additional activities include working with Regional partners such as Forestry staff as part of their public outreach activities and informing the Forest Management Plan and Greening Strategy.

8.3 EMERGING VECTOR-BORNE DISEASES

Climate change and other factors could lead to an emergence of other VBDs that could pose serious health challenges to York Region communities.

Due to projected temperature and precipitation increases, there is the potential for the introduction of new vector species. Current York Region climates ensure exotic VBDs such

as malaria and dengue are not established locally. However, the risk of disease establishment is expected to change as a result of climate change. Climate change may support the migration of vectors, reservoirs into current temperate climate zones. This would affect the introduction of exotic mosquitoes and other mosquito-borne diseases into Canada.[160]

Mosquitoes found in Canada (e.g., *Aedes albopictus*) may be able to support the transport and transfer of pathogens currently not endemic to Canada.[160] Malaria is of particular concern, as vectors (*Anopheles species*) responsible for spreading the illness are common in Canada.[160] Of the 41 *Anopheles* species that transmit malaria, the two principal vectors are established in Canada (*Anopheles freeborni and Anopheles quadrimaculatus*).[160] Surveillance of species in positive pools of mosquitoes from 2002 to 2013 have shown *Culex pipiens/restuans* is the most prevalent species (87% of positive pools) followed by *Aedes vexans* (6.2%).[143]

Two mosquito species that can spread the Zika virus, *Aedes albopictus* and *Aedes aegypti*, have been observed in Windsor. These mosquitoes can also spread other diseases such as chikungunya, dengue and yellow fever. Currently, *Aedes aegypti* is not an established species in Ontario due to the relatively cooler temperatures, whereas *Aedes albopictus* is considered established in the Windsor area.

As a result of climate change, other mosquito-borne diseases, such as EEEV and two California serogroup viruses (Jamestown Canyon virus and snowshoe hare virus) may increase, particularly in rural areas.[161] EEEV has a high mortality rate and there has never been a human case in York Region. There has only ever been one human case reported in southeastern Ontario. To date, EEEV has not been detected in vectors through York Region Public Health's mosquito surveillance program.

There are currently no national surveillance programs that monitor other endemic mosquito-borne diseases, such as EEEV and California serogroup viruses in mosquitoes, reservoirs or human populations.[161] Surveillance and research activities need to be enhanced, and are critical to ensure timely and accurate evaluation of other endemic mosquito-borne disease risks to public health.[161]

The research also identifies other tick-borne diseases, namely babesiosis, anaplasmosis, Powassan encephalitis, human granulocytic anaplasmosis and Borrelia miyamotoi disease. Ticks infected with *Babesia microti* (the protozoa that causes babesiosis), and *Anaplasma phagocytophilum* (the bacteria that causes human granulocytic anaplasmosis, Powassan virus and Borrelia miyamotoi disease) have been found in Canada and are expected to increase as a result of climate change.[150,162] Increasing temperatures are expected to expand the number, activity and geographic area of ticks' animal hosts, resulting in increased tick abundance.[162] Additionally, other vectors may spread into Canada such as Amblyomma americanum (also known as the lone-star tick) and Dermacentor species vectors of Rocky Mountain spotted fever, known for their endemic transmission within Ontario, but likely not abundant in York Region.[162]

8.4 CONCLUSION

Weather conditions play an important role in the spread of vectors and VBD. Certain vectors are expected to extend their range and be more prevalent in areas such as Ontario due to climate change.

The two main VBDs of concern in recent years for York Region are WNV and Lyme disease. While most WNV cases show a seasonal trend peaking in August, it is more dependent on local weather conditions in a given year. Rates of Lyme disease and the presence of blacklegged ticks in York Region have shown a rise in recent years due to climate factors, such as temperature, precipitation and humidity.

While research shows climate change will increase the risk of VBDs, various social and environmental factors are also changing that can influence this risk. Expected land-use changes, including more urban and suburban communities, may impact the presence of vectors. While urban corridors are expected to grow, a substantial portion of York Region will remain agricultural or woodland areas (as part of the Greenbelt and Oak Ridges Moraine), which are known to support the presence of ticks and reservoir species.

To help address existing and future VBD issues, York Region Public Health and the province are working proactively to better understand and prevent the risk of VBDs through surveillance, prevention measures and awareness campaigns.

With municipalities, including York Region, working to develop climate change action plans, there are opportunities to incorporate VBD considerations into existing activities. Currently, York Region Public Health works with local municipalities on issues such as stormwater management ponds and WNV risks, and active tick surveillance of municipal parks. Maintaining collaborative relationships with local municipalities will continue to be important as the population continues to grow and communities urbanize across York Region.

York Region Public Health will continue to assess potential VBD risks to inform future adaptation planning. Table 8.2 provides a summary of completed/ongoing activities and opportunities for future planning. While research is relatively strong on climate change and VBDs, it is still important to better understand local factors that can increase risks in York Region.

Table 8.2. Summary of vector-borne disease related activities and adaptation planning opportunities.

	Ongoing and Completed Activities	Opportunities
Population Health Assessment and Surveillance	**Health Surveillance:** Reporting of WNV cases (confirmed and probable). Reporting of Lyme disease cases (confirmed and probable).	Consulting province on ensuring new and emerging VBD diseases that could be introduced to York Region from climate change are considered and monitored as needed.
	Vector Surveillance: <u>Mosquito vectors</u> Active surveillance through mosquito traps set weekly during the WNV and EEEV season. <u>Tick vectors</u> Active surveillance of ticks through annual tick dragging. Passive surveillance of ticks. • Additional tick dragging conducted based on tick submission results.	Explore datasets from other York Region Departments on stagnant water bodies. Explore urban flood risk maps when available to inform surveillance activities in urban and suburban communities. Explore datasets relating to reservoir populations, such as white-tailed deer and white-footed mice. Assess forest corridors and forest cover data that can impact wildlife movement and VBD risk. Consulting province on expanding surveillance and reporting of other mosquito and tick species (e.g., lone star tick) as needed.
	Completion of RRFSS modules for mosquito and Lyme disease personal protection (2014, 2017, 2018).	
Program and Policy	Investigation of standing water complaints to reduce mosquito breeding habitats. Larviciding conducted on municipal catch basins, stormwater management ponds with confirmed mosquito larvae, and sewage lagoons in summer months. **Health Equity:** Larviciding activities conducted near areas with potentially vulnerable populations such as long-term care homes.	Evaluate the effectiveness of biopesticides during longer and warmer summers with more high ultraviolet radiation days.

Health Promotion	Promotional activities include • Media releases and interviews of protection measures and surveillance findings • Social media and YouTube educational videos on Lyme disease, blacklegged ticks and personal protection • Posted ads in York Region Media Group publications, multicultural newspapers and municipal recycling calendars • Provided pamphlets and/or posters to municipal and Regional offices, libraries, community and recreation centres, municipal parks, garden centres, golf courses, Sibbald Point Provincial Park and conservation areas • Posted permanent "Fight the Bite!" tick signs in risk area trailheads **Health Equity:** Promotional messaging targeting children (storybooks and messaging for school board and child care guides), seniors (radio ads), trail users (trail Guide) and immigrants (multicultural newspapers).	Continue education efforts to reach the target groups (active seniors or adults 50 years of age and older). **Health Equity:** Ensure outreach and educational programs target other vulnerable groups (e.g., homeless populations, children through summer day camps and school boards). Advocacy to recommend areas for research and/or review by PHO such as assessing green infrastructure developments for WNV habitats such as bioswales. Educate health care providers on local risks for VBDs, including Lyme disease and testing for Lyme bacteria (two-step process).
Other Stakeholder Activities (outside of Public Health)	Surveillance and public health assessments conducted by PHO and PHAC. Land use planning measures to reduce urban flooding and stagnant pool conditions. Forestry department supporting sign postings and tick surveillance activities of trail areas in York Regional Forests.	Consult with researchers on appropriate weather variables to inform vector surveillance in a season, particularly mosquitoes. Explore best practices that minimize the risk of stagnant pools in green infrastructure developments (e.g., bioswales and rain gardens).

CHAPTER 9
Water Safety

9.0 Water Safety: Key Findings

Climate change projections and exposure pathways

- Within York Region, climate forecasts a likely increase in extreme precipitation, and a very likely increase in warmer temperatures. This can have significant impacts on drinking water and recreational waters
- Storms are expected to become more frequent, bringing higher amounts of precipitation that may stress local water systems
- The relationship between waterborne illness with climate change is complex with many factors impacting disease risk (e.g., sequence of weather events, time-lag effects, environmental factors, exposure), making it challenging to link York Region waterborne cases to climate change
- Temperature, rainfall, humidity and water turbidity were found to impact *Escherichia coli* concentrations in public beaches, but results varied greatly from month to month
- York Region sources drinking water mostly from Lake Ontario (90%) followed by Lake Simcoe (3%) and groundwater (7%)
- Local agriculture and urban surface run-off are the largest human sources impacting local rivers, lakes and groundwater systems
- Existing floodplains and significant groundwater recharge areas within York Region may be more impacted by heavy precipitation events
- Impacts of drought on groundwater sources have been assessed in York Region, and are unlikely to impact supply in the next 10 years

Population sensitivity

- There has been a declining trend in the number of private well submissions in recent years. Individuals using private wells that are dug, or in significant groundwater recharge areas, are more vulnerable to flooding and heavy precipitation events
- Food and waterborne illnesses may also indirectly relate to behaviour activity such as greater outdoor activity (e.g., visiting beaches) and hygiene practices during summer months (e.g., barbeques)

Adaptive capacity

- York Region Public Health, Regional Environmental Services, local municipalities and the Ministry of the Environment, Conservation and Parks are involved in monitoring and regulating drinking water within the Region
- There is an increasing number of York Region residents being serviced by municipal drinking water, reducing the number of residents relying on private wells and small drinking water systems
- Using a “One Water” perspective, York Region recognizes the need for protection throughout the water cycle, and the necessity to consider climate change impacts as part of the evaluation of future municipal water and wastewater needs
- Current projection models used for wastewater systems focus on 25-year storm events, but future models can consider other scenarios relating to expected climate change impacts

Health impacts

- Recent research has assessed how various weather conditions (air temperature, precipitation, flooding and droughts) have contributed to cases of enteric diseases

Recent trends:

- Most enteric diseases illustrate a seasonal trend, peaking during the summer months or early fall in York Region. The highest numbers of cases for enteric diseases are for *Campylobacter* enteritis and Salmonellosis

Numerous studies highlight the impacts weather variables can have on food- and waterborne illnesses.[4,92,140,163,164,165,166,167] With heavier rainfall events, increased air temperatures and a longer growing season expected for York Region, it is necessary to consider how future climate conditions may impact the incidence of food- and waterborne illnesses.

This chapter provides an overview of the various ways climate change may impact human health through water in York Region, including:

- Recent trends and patterns of enteric diseases in York Region
- Potential climate change exposure pathways relating to drinking water (municipal, small drinking water systems and private wells) and adaptive capacity
- Potential climate change impacts relating to recreational water (focused on beaches) and adaptive capacity

After discussing food- and waterborne illnesses trends in York Region (Section 9.1), subsequent sections review the potential exposure routes and the adaptive capacity for water safety (Section 9.2) and food safety and security (Chapter 10) respectively. Impacts relating to municipal water and wastewater systems are examined at a high level, but more information can be found in the 2016 Water and Wastewater Master Plan[98] and the Assessing and Mitigating Municipal Climate Risks and Vulnerabilities in York Region, Ontario report. [168] Food and water security are also discussed with a focus on food security.

9.1 FOOD- AND WATERBORNE ILLNESSES

Food- and waterborne illnesses can be caused by food and water contaminated with pathogens including bacteria, parasites, viruses and fungi, as well as the toxins they produce. Illnesses most commonly highlighted in climate change research include bacterial pathogens (e.g., vibrio, campylobacteria, listeria, salmonella, shigella, and *Escherichia coli*), parasites (e.g., cryptosporidia, giardia) and viruses (e.g., norovirus).[140,163] Many of these food- and waterborne illnesses are enteric diseases that result in gastrointestinal symptoms such as diarrhea, abdominal cramps, nausea and vomiting.[140,163] Enteric diseases can also be caused by other factors, such as person-to-person contact or exposure to animal sources through direct contact or consumption.

Recent research highlights the association between weather factors and food- and waterborne illnesses. Studies have assessed how various climatic variables (e.g., air temperature, precipitation, flooding and droughts) have contributed to cases of enteric diseases. In a systematic review, Levy et al.[164] found a high confidence level association between bacterial causes of diarrheal diseases with increased temperatures. They also found a moderate level association between heavy rainfall and diarrheal diseases and a low association with drought and diarrheal diseases.

Higher temperatures have been associated with an increased number of pathogens on food products. [4] In Montreal, Allard et al.[165] found the incidence of *Campylobacter* was two times

higher in the summer than in winter, and the risk of campylobacteriosis increased 0.8% with every 1°C rise in temperature above 10°C. The incidence of salmonellosis is also correlated to ambient temperature. The rate in which S*almonella* bacteria growth doubles on raw chicken increases from one hour to 22 minutes when the temperature increased from 21°C to 32°C.[140] A study of 10 European countries found there was a 5% to 10% increase in cases of salmonellosis for every 1°C increase in temperature above a 6°C threshold.[166] However, this association could be due to changes in human behaviour (e.g., increases in picnics or barbecues during the summer) rather than increased amounts and spreading of *Salmonella* in the environment.

Weather impacts to food- and waterborne illnesses can be complicated depending on the sequence of weather conditions and lag time between a weather event and when cases arise. Heavy rainfall after a dry period is associated with an increased incidence of diarrhea. This is likely due to the impacts on recreational water from pathogens becoming concentrated in reduced water levels during drought, which are then dispersed with heavy rain.[164] Chhetri et al.[92] found a significant increase in laboratory-confirmed cases of cryptosporidiosis and giardiasis in the Metro Vancouver population four-to-six weeks after extreme precipitation events, particularly after long dry spells.

Similarly, Galway et al.[167] highlighted how seasonal trends in diarrheal diseases in British Columbia can vary based on weather and ecosystem factors of local watersheds. For example, communities with snowmelt-dominated hydroclimates showed an earlier peak for rates of diarrheal diseases in the spring, while rain-dominated hydroclimates would peak later in the summer and fall.[167]

While research has shown an association between weather factors and food- and waterborne illnesses, pathogen survival and presence in the environment is a complex process based on many contributing factors. These factors include the animal and human populations that can carry pathogens, conditions that favour the growth and survival of pathogens, transportation and movement of pathogens and susceptibility and behaviour of human populations.[4,5] Similarly, the movement of contaminants in the environment depends on the environmental fate and transport through the soil, water and land that can impact water and food safety. With climate change expected to increase food- and waterborne illness risk globally, there is also the potential for pathogens to be introduced to the local environment through greater movement of individuals and goods, nationally and internationally.[140]

While enteric illnesses can be a result of food, water and other sources of contamination, enteric disease cases for York Region are discussed as a whole. More information on enteric diseases of public health significance is available on the York Region website, which includes the annual reports and monthly diseases of Public Health significance reports. Table 9.1 provides an overview of select enteric diseases and the potential climate factors identified in literature that can contribute to the risk of exposure.

Table 9.1. Summary of select enteric diseases in York Region and potential climate factors.

Enteric diseases identified in climate change research	Number of cases in York Region in 2018	Rate of cases in York Region in 2018 (per 100,000)	Potential climate factors noted in research[v]
Campylobacter enteritis	324	27.0	**Food-related impacts:** **Rising air temperatures and moisture**: Pathogens have favourable growth conditions in warm and humid conditions. Mould growth can be higher in warm and humid conditions, during production and after harvesting. Seasonal peak in enteric cases during summer months may be related to climate or to greater outdoor activity. Norovirus peaks during the winter months. Warmer winters may be associated with fewer cases, but this is still not clear. **Longer growing season:** An extended growing season for food crops can impact the timing of pathogen transmission. **Extreme weather events (flooding):** Flooding can contaminate water sources, which are used during the production, harvesting or processing of food. Norovirus cases are also associated with flooding events that can increase risk of transmission. **Water-related impacts:** **Rising air and water temperatures:** Increased temperatures may contribute to an increased risk of pathogens present in drinking and recreational waters. Rising water temperatures will increase the seasonal window and create favourable conditions for algal blooms. **Heavy rainfall and flooding:** Increased risk of contamination from pathogens into recreational and drinking water systems. Impacts will depend on the capacity and vulnerabilities of municipal systems, private wells and recreational water in specific areas. Lack of access to clean water can increase the risk of food- and waterborne illnesses.
Salmonellosis	214	17.8	
Norovirus	Most enteric outbreaks in York Region relate to norovirus.		
Verotoxin-producing *Escherichia coli*	18	1.5	
Giardiasis	80	6.7	
Cryptosporidiosis	36	3.0	

9.1.1 Trends in cases and incidence from 2000 to 2015 in York Region

The largest numbers of cases in York Region for enteric diseases are from *Campylobacter* enteritis and Salmonellosis. *Campylobacter* enteritis is a bacterial infection of the intestines and

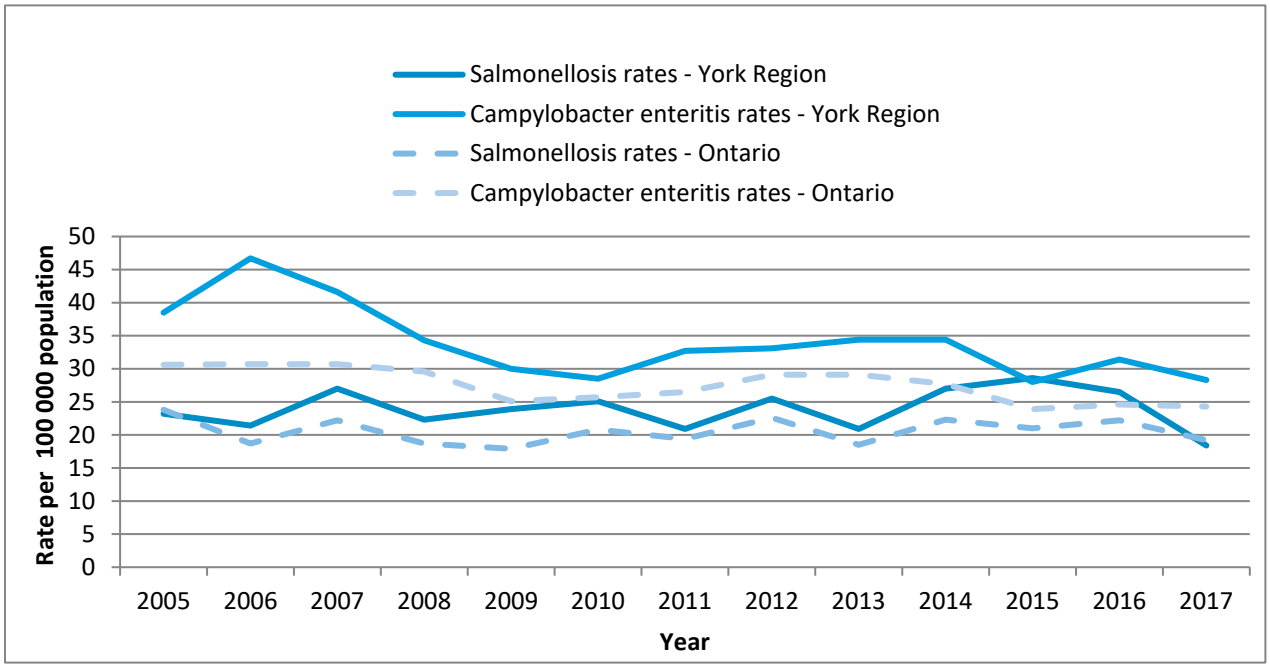
[v] Climate drivers from United States climate change and health assessment and Health Canada assessment. [4,5] Note: These potential climate factors are not specific to enteric diseases in this table or cases in York Region. These factors are based on research studies examining how climate conditions may contribute to food- and waterborne illness exposure and risk.

is the most commonly reported cause of gastroenteritis worldwide.[146] It is caused by contaminated food, such as uncooked or undercooked meat (especially poultry), and in some cases through contaminated water or by contact with infected animals. The incidence rate of *Campylobacter* in York Region decreased between 2000 and 2009 and has not varied much since this time.[146] The rates of *Campylobacter* enteritis in York Region were generally higher than Ontario incidence rates between 2005 and 2017 (Figure 9.1).[169]

Salmonellosis is caused by a bacterial infection from contaminated food or water, contact with infected animals or by person-to-person via the fecal-oral route. The incidence rate of salmonellosis varied slightly from year to year, with no clear trend between 2000 and 2015.[146] A slight decline was observed for 2017 and 2018, with the incidence rate of salmonellosis in York Region similar to Ontario.[170]

Although less common, other enteric diseases can pose serious health impacts to infected individuals. For instance, certain strains of *Escherichia coli* produce toxins (e.g., verotoxins) that can cause serious illness, such as hemolytic uremic syndrome (HUS). The incidence of verotoxin-producing *E. coli* (VTEC) infections in York Region decreased from 2000 to 2017. The incidence rates in York Region between 2000 and 2017 were similar to Ontario, aside from outbreaks in York Region in 2011 and 2012.[146] In York Region 6% to 7% of VTEC cases resulted in HUS in children below age 10, with HUS more rarely observed for those 10 year of age and older.[146] However, with better laboratory detection methods for VTEC introduced in 2018, more cases of VTEC are being detected and reported.

Figure 9.1. Rates of salmonellosis and *Campylobacter* enteritis in York Region and Ontario from 2005 to 2017.

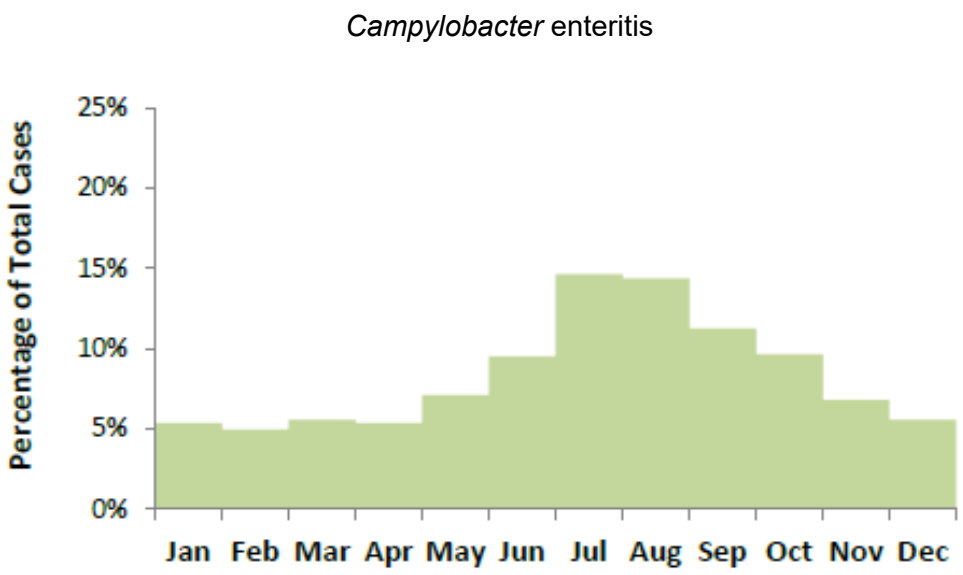


Data Source: Ontario Agency for Health Protection and Promotion (Public Health Ontario). Infectious disease trends in Ontario: Campylobacter enteritis and salmonellosis [data file]. Toronto: Queen's Printer for Ontario; 2018.

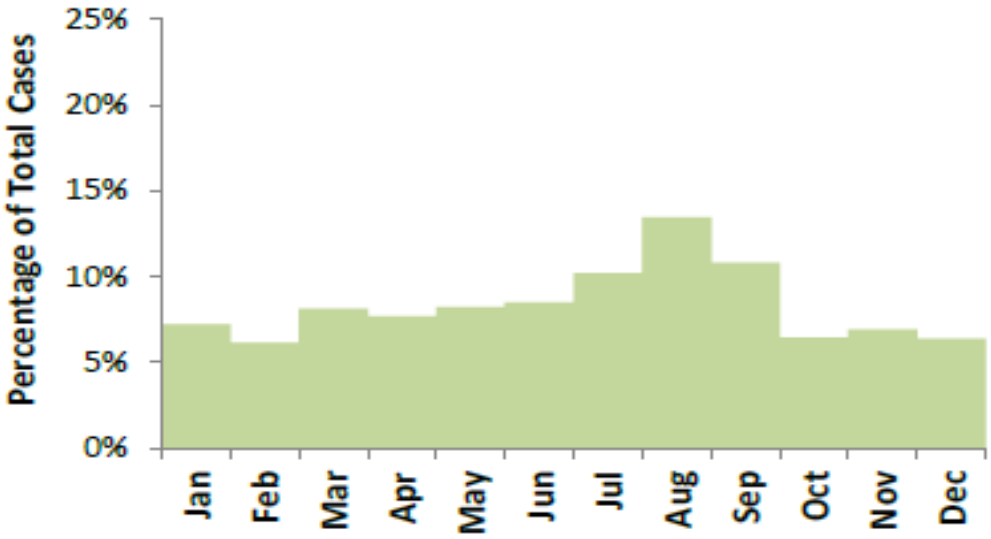
Environmental factors have also played a potential role in enteric diseases. Many of the cases reported in Ontario relate to environmental factors linked to food outbreaks, contaminated drinking water or contaminated recreational waters. Exposure to contaminated recreational water was noted as a risk factor for cryptosporidiosis between 2011 and 2015 and accounted for 36% of reported cases in York Region. Additionally, research highlights how livestock contact can also be a factor. This may explain why incidence rates of cryptosporidiosis in more rural areas (East Gwillimbury, Georgina, and King) were 1.8 times higher than in urban communities in York Region.[146]

Food- and waterborne illnesses show a seasonal trend. When reviewing food- and waterborne illness cases and incidence rates in York Region from 2000 to 2015, most enteric diseases illustrate a seasonal trend peaking during the summer months or early fall (Figure 9.2). This can be attributed to several behavioural factors such as increased outdoor summer activity, community events and festivals and recreational swimming. This seasonal trend aligns with increases of bacteria levels found in food products during this time period such as *Campylobacter* in chickens or peak shedding of VTEC from cattle livestock.[146] For giardiasis, a seasonal trend is observed, with a peak in September among cases who did not report travel during their possible exposure window.[146] Giardia parasites are commonly found in untreated water from rivers and lakes and are commonly transmitted to humans through recreational water. As a result, the increase in recreational swimming activities and associated exposures during the summer months corresponds with the seasonal trend and the local peak number of giardiasis cases.

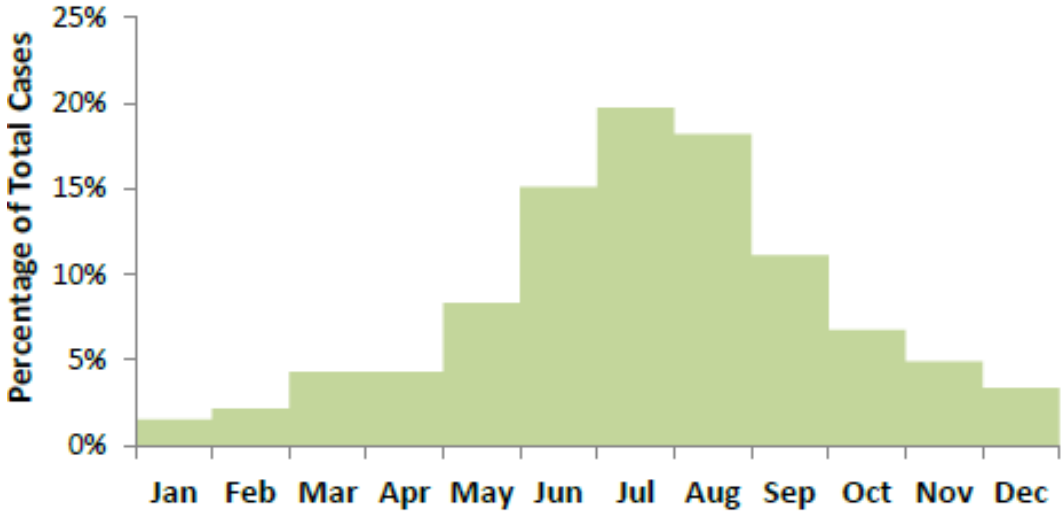
Figure 9.2. Percentage of total cases for each enteric disease by month in York Region from 2000 to 2015.



Salmonellosis



Verotoxin-producing *E. coli*



Source: The Regional Municipality of York. Reportable diseases in York Region 2000 to 2015 [Internet]. Newmarket: The Regional Municipality of York; 2016. Figure 2.2.3. Campylobacter enteritis; p.16. Figure 2.7.3. Salmonellosis;p.29. Figure 2.7.2 Salmonellosis; p. 29. Available from: https://www.york.ca/wps/wcm/connect/yorkpublic/c1dd6685-e886-45b5-ad4e-6808b5285e3c/Reportable_Diseases_in_York_Region_2000-2015.PDF?MOD=AJPERES

9.1.2 Enteric outbreaks in York Region

Enteric outbreaks reported in institutions and the community associated with norovirus were reported more frequently between December and February.[146] An institutional enteric outbreak investigation is initiated when two or more individuals experiencing symptoms within a

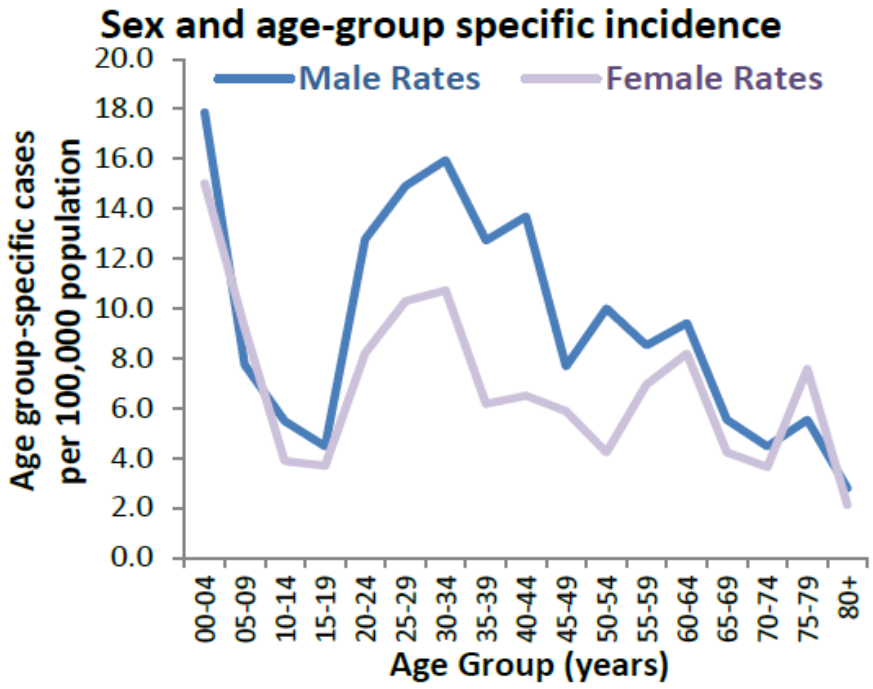
48-hour period; whereas a community outbreak investigation[w] occurs when two or more epidemiologically-linked individuals develop acute gastrointestinal illness. Each year, York Region Public Health investigates approximately 100 institutional enteric outbreaks, most often in the winter. Between 2008 and 2015, norovirus was responsible for the majority of enteric disease outbreaks in York Region. It caused 88% of the 169 institutional outbreaks (e.g., hospitals, long-term care homes, retirement homes or childcare centres) and 65% of the 34 community outbreaks.[146] *Salmonella* was responsible for 12% of community outbreaks.[146] This is consistent with data from the United States indicating most acute gastrointestinal illnesses are caused by norovirus, followed by bacterial pathogens such as *Salmonella.*[140]

Vulnerable populations

Demographic factors such as age and gender were found to have a greater impact for certain enteric diseases in York Region cases (Figure 9.3). Consistent with the literature, more cases of certain enteric diseases were reported among seniors (e.g., listeriosis) and children (e.g., salmonellosis). Young adults were largely impacted by giardiasis. Trends in gender differences were also observed, with listeriosis having relatively more female cases and giardiasis having more male cases.

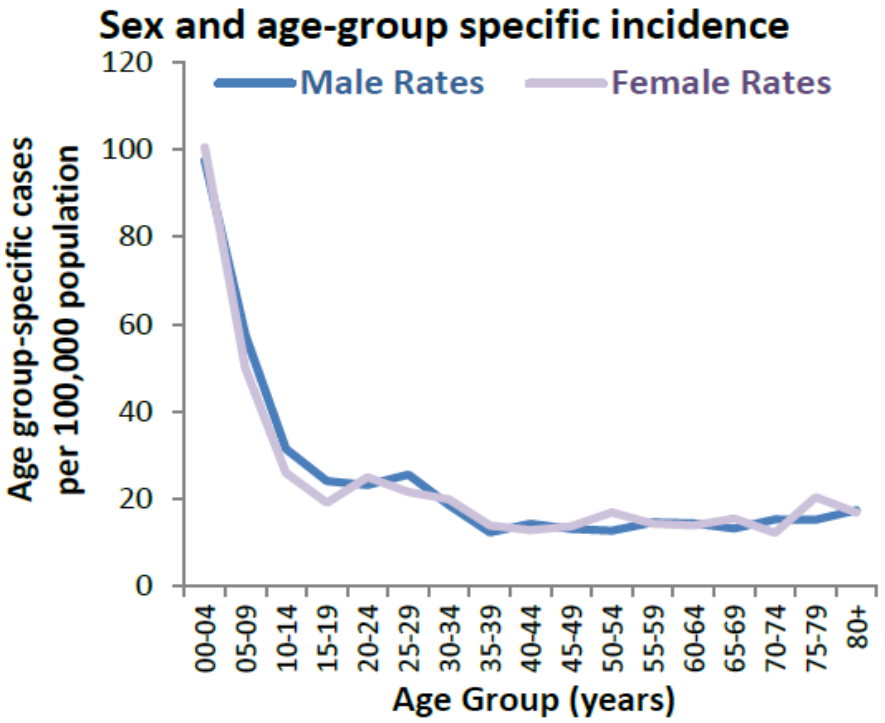
Figure 9.3. Age distribution of enteric disease cases in York Region from 2000 to 2015.

Salmonellosis

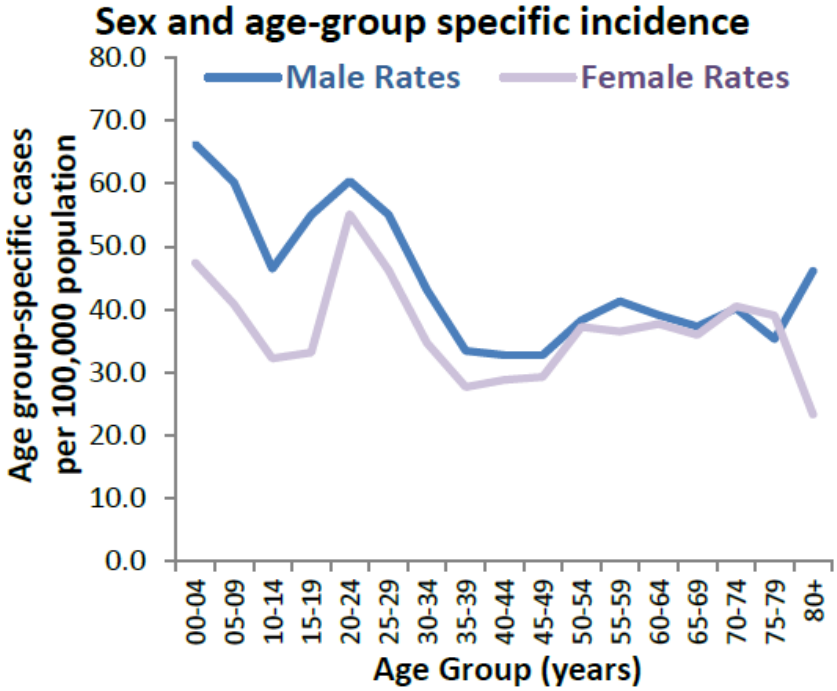


[w] There is no standardized case definition of a community outbreak, and are locally defined depending on multiple factors such as place, person and timing of cases.

Giardiasis



***Campylobacter* enteritis**



Source: The Regional Municipality of York. Reportable diseases in York Region 2000 to 2015 [Internet]. Newmarket: The Regional Municipality of York; 2016. Figure 2.5.2. Giardiasis;p.23. Figure 2.7.2 Salmonellosis; p. 29. Figure 2.2.2. Campylobacter enteritis;p.16. Available from: https://www.york.ca/wps/wcm/connect/yorkpublic/c1dd6685-e886-45b5-ad4e-6808b5285e3c/Reportable_Diseases_in_York_Region_2000-2015.PDF?MOD=AJPERES

Children are one of the most vulnerable groups for food- and waterborne illnesses due to a combination of factors such as immature immune systems, poorer hand hygiene and increased exposure when compared to adults. For example, they have higher consumption rates relative to body weight and are more likely to be exposed through play and contact with pathogen sources (e.g., in recreational beach water). Shigellosis, salmonella, cryptosporidiosis and VTEC were shown to have higher incidence rates among children under the age of 10, which can be attributed to a developing abdomen, poor hand hygiene and close personal contact in schools and child care centres.[146]

Seniors are also vulnerable to foodborne illnesses and their complications. In the U.S., children (1 to 4 years of age) and older adults (80 years of age and older) make up more than 25% of hospitalizations for gastroenteritis each. However, older adults account for 85% of deaths.[171] As the population of older adults grows, the public health and economic burden of enteric diseases will likely increase. Climate change may exacerbate this burden without public health interventions.

Other populations that may be vulnerable to food- and waterborne illnesses or may be at a higher risk of exposure to pathogens causing these infections include: [4,140,163]

- Individuals who are active outdoors and with outdoor activities such as barbecuing
- Frequent recreational water users (e.g., lakes, rivers, swimming pools)
- Individuals who get drinking water from a private water system
- Farm workers and individuals who are in contact with animals and livestock
- Individuals who travel to areas with a higher risk of exposure to food- and waterborne pathogens
- Pregnant women
- Individuals with pre-existing health conditions and/or those who are immune-compromised

See Chapter 4 for more information on vulnerable populations in York Region. The following sections will discuss the potential exposure pathways in which climate change can impact water, and current York Region activities that address these issues.

9.2 Water Safety

The public can be exposed to waterborne illnesses through many direct and indirect routes including direct skin contact and ingestion of contaminated drinking water, recreational water sources or seafood harvested from contaminated water sources. Climate change is expected to influence multiple pathways where water systems can potentially increase the risk of waterborne illnesses:[163]

- Rise in temperatures, increased evaporation and drought conditions may impact the quantity of drinking water supplies and reduce the dilution of pathogens and contaminants in water
- Rise in water temperatures can contribute to the growth of algae and the production of toxins, which can impact recreational and drinking water and contaminate fish species
- Heavy rainfall resulting in urban and agricultural run-off can increase nutrients, sediment and pollutants, which can impact drinking water sources, such as lakes and private well systems, and recreational waters
- Extreme weather events and storm surges can damage or impact water treatment activities

Waterborne illnesses and risk to human health will depend on many factors. Exposure of local populations, personal hygiene practices, prevention measures such as public health practices and interventions, water and wastewater treatment and local environmental conditions contribute to the risk of waterborne illnesses. Although many potential pathways have been identified, estimating future climate change impacts can be difficult due to limitations in current research and modelling required.[163]

The United States' recent Climate Change and Health Assessment[5] noted there is strong evidence climate change will impact water treatment infrastructure through flooding and impacts to surface waters. In a systematic review, Sterk et al.[172] found the concentrations of *Campylobacter* increased in rivers downstream of combined sewage system overflows during periods of heavy rainfall. Heavy precipitation can increase levels of pathogens, such as cryptosporidium and giardia, by reducing water treatment efficacy due to increased water turbidity, increased run-off into the water systems and resuspension of infectious cysts and oocytes from sediments.[92]

Climate conditions expected in York Region

In York Region, climate forecasts predict a likely increase in extreme precipitation and a very likely increase in warmer temperatures. Fausto et al.[10] found that 1-day and 5-day maximum precipitation amounts are likely to increase from 39.3 mm to 50.9 mm and 61.4 mm to 78.4 mm respectively by the 2050s.[10] It is important to note these estimates reflect average numbers across York Region and extreme precipitation events can lead to higher localized precipitation during an event. Storms are also expected to become more frequent in York Region, bringing higher amounts of precipitation that may stress local water systems.[10]

Temperatures are very likely to increase in York Region by the 2050s with maximum temperatures in summer months increasing by approximately 4˚C and an increase in days with temperatures above 25˚C.[10] These forecasted changes in climate can have significant impacts on drinking water and recreational waters in York Region.

9.2.1 DRINKING WATER AND WASTEWATER

Drinking water and wastewater issues involve multiple Regional and provincial stakeholders, each responsible for various aspects of drinking water safety in the Region.

The most common types of drinking water and wastewater treatment systems managed or supported by York Region include:

- Municipal drinking water and wastewater systems operated by York Region
- Local distribution and collection systems operated by each of the nine local municipalities in York Region
- Small drinking water systems (SDWS) and those under the jurisdiction of the Ministry of Health (MOH) and York Region Public Health
- Private wells

Private sewage systems under Part 8 of the Ontario Building Code are no longer managed by York Region Public Health. In 1999, the approval authority for private sewage systems was transferred to the jurisdiction of the local municipalities' building departments. Climate change impacts on private sewage systems are not discussed in detail in this chapter. Nevertheless, the discussion on adaptive capacity and vulnerabilities for smaller drinking water systems and private wells will cover factors relevant to private sewage systems impacts, including protecting groundwater supplies or identifying shallow aquifer groundwater.

This section is not intended to be a comprehensive analysis of water and wastewater infrastructure vulnerabilities to climate change. Rather, it provides a climate change and health perspective on these issues using available information on existing assessments, operations and programs within the Region. More information about York Region's municipal water systems can be found on the York Region Water and Wastewater webpage, which includes Annual Water Quality Reports and the 2016 Water and Wastewater Master Plan. Water systems regulated and monitored by MECP are not further discussed in this report.

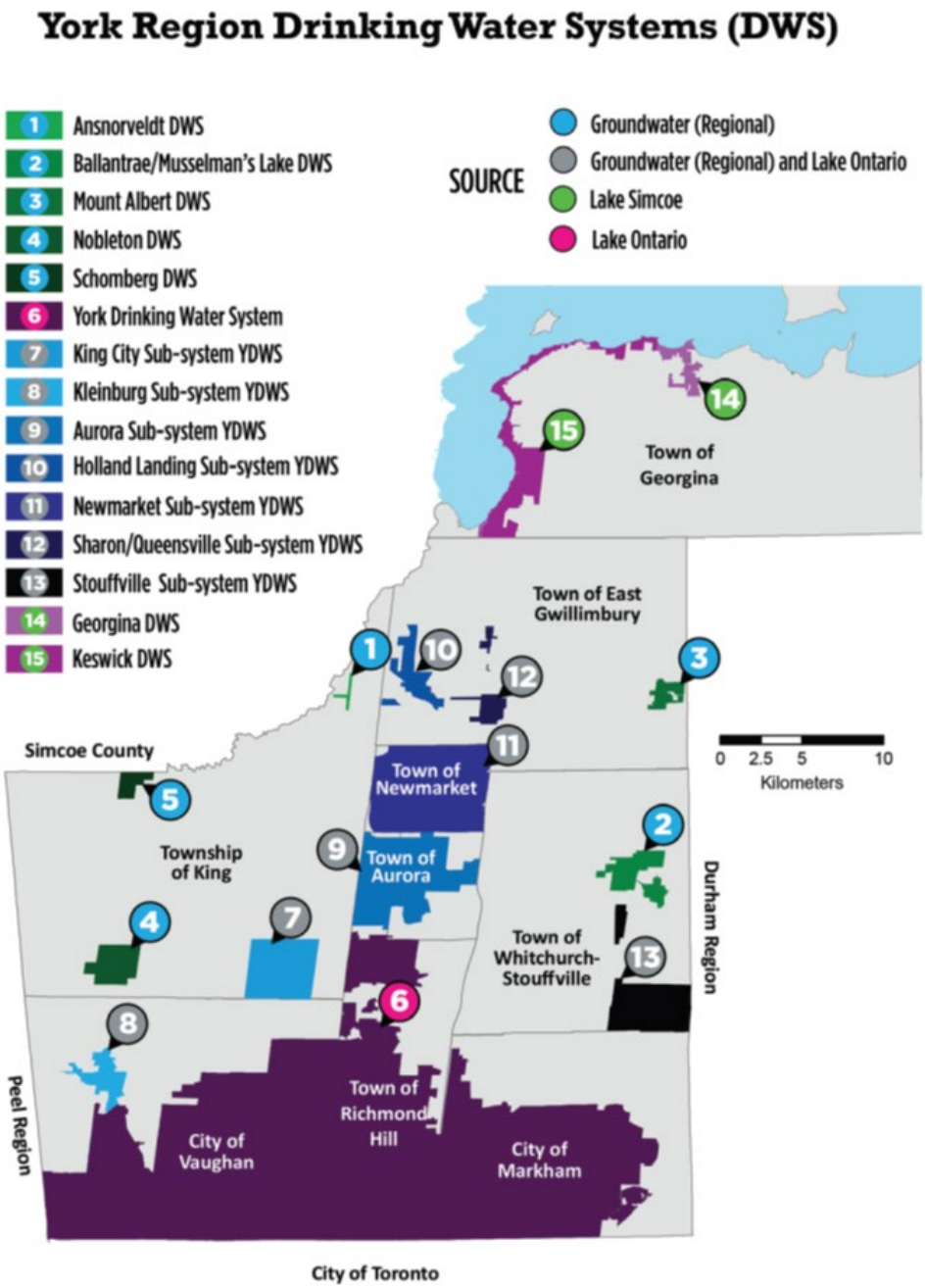
9.2.1.1 Municipal drinking water and wastewater systems

Overview of current systems and sources

Approximately 90% of York Region's water comes from Lake Ontario, which supplies all of Markham, Richmond Hill and Vaughan. Lake Simcoe supplies approximately 3% of York Region's water supply, primarily to the Town of Georgina.[173] The remaining 7% of source water is derived from groundwater wells in King Township, the Town of East Gwillimbury, and the Town of

Whitchurch-Stouffville.[173] Certain municipalities, such as the Town of Newmarket and Town of Aurora, use a blend of groundwater and water from Lake Ontario water (Figure 9.4).[173]

Figure 9.4. York Region municipal drinking water systems.



Source: The Regional Municipality of York, Environmental Services Department. Drinking Water Systems Report 2016 [Internet].Newmarket: The Regional Municipality of York; 2016. York Region Drinking Water Systems (DWS); p. 11. Available from: https://www.york.ca/wps/wcm/connect/yorkpublic/62103308-1634-4ff1-a153-7ffed2c2f22b/2016_Annual_Drinking_Water_Report.pdf?MOD=AJPERES

The majority of groundwater production wells used for municipal drinking water are north of the southern three municipalities (Vaughan, Richmond Hill and Markham). The Oak Ridges Moraine geology also acts as an important source for groundwater recharge.[173] Certain groundwater areas where shallow wells exist are more likely to be more impacted by heavy rainfall and have been identified as significant groundwater recharge areas (SGRA).

Agriculture and urban areas are one of the leading human factors impacting local water systems. Agricultural practices can impact local water systems through run-off into local rivers and lakes, or contamination of groundwater with pesticides, fertilizers and animal waste. Agriculture is the second largest land use around the Lake Simcoe watershed (37% of the area).[174] Additionally, certain areas in York Region such as the Town of Whitchurch-Stouffville, have high livestock densities.[174] As part of source water protection plans, agricultural activities are managed to reduce or eliminate impacts to local municipal water sources.[174]

Urban and suburban land also impact local water systems by increasing surface run-off into lakes and rivers and reducing water captured to recharge groundwater sources. Certain areas around Georgina, such as Keswick and Sutton, have more impervious sources that can contribute to run-off into Lake Simcoe. Municipalities in the north such as Newmarket can also contribute to surface run-off, impacting local streams and rivers connected to the Lake Simcoe watershed.[174] Land uses in urban areas can pose a risk to water systems following extreme weather events. Groundwater recharge is managed by Conservation Authorities, with an extra focus on the central portions of York Region that surround municipal wells.

Potential climate change impacts

Impacts of storms and surface run-off

York Region conducted an assessment of water and wastewater system requirements to better prepare for future heavy rainfall events. As part of the 2016 Water and Wastewater Master Plan[98], York Region rainfall data was used to model a 25-year storm[x] to provide a more accurate projection of rainfall impacts on wastewater flow rates. While the review assessed the current capacity of wastewater systems, it was based on current conditions, and climate change impacts will likely increase the frequency of extreme storm events. As a result, additional adjustments to the model will likely be required as severe weather events increase in frequency.

The assessment also identified possible impacts in York Region such as:

- the potential for algae blooms in Lake Simcoe
- increases in infiltration and inflow needs resulting in system backups and discharge of untreated sewage
- flooding impacts on facilities and pipe infrastructure
- extreme weather events damaging infrastructure.[173]

[x] A 25-year storm refers to a storm event that is only anticipated once every 25 years.

The literature recognizes challenges to water infrastructure, particularly from combined sewage overflows. However, York Region does not have combined sewers and relies on a separate sewer and stormwater system. York Region experiences issues with infiltration and inflow, where wastewater is infiltrated by other water sources, such as groundwater and stormwater. This can contribute to household basement flooding.[173] Basement flooding has been associated adverse health impacts from mental health stressors and indoor air quality issues relating to mould and dampness.[5]

Impacts relating to water supply

Certain impacts, such as a rise in water usage from increased temperatures, are not seen to have a significant impact on water supply quantities in York Region.[173] To assess impacts to groundwater sources in York Region, modelling was conducted as part of the Source Water Protection work to meet the *Clean Water Act*. Modelling predicted municipal water availability from four wells may decrease during a 10-year drought, but would not be below sustainable levels. The model was also able to provide recommended adjustments to prevent or mitigate that risk.[106] While these estimates provide an understanding of groundwater impacts that may result from climate change, it is also possible that climate change could increase overall water demand.[173]

Adaptive capacity and resiliency of municipal drinking water systems

Current activities

York Region provides drinking water to its nine local municipalities by operating and maintaining three water treatment plants, 45 water storage facilities, 40 production wells and close to 350 kilometres of transmission mains. The Region treats wastewater via seven water resource recovery facilities and one lagoon system (co-ownership of the Dufferin Creek Plant with Durham Region), 21 sewage pumping stations and approximately 330 kilometres of sewer mains.[173] York Region is currently using the Building Adaptive and Resilient Communities Tool developed by the International Council for Local Environmental Initiatives (ICLEI) Canada. This tool follows a five milestone framework to support adaptation planning and building resiliency of water and wastewater systems.[173]

In 2016, 99.87% of all tests conducted on water quality samples across York Region met the regulated standards.[173] Additionally, 25 of the 18,489 tests performed indicated a water quality parameter had fallen outside of the normal operating range.[173] However, none of these events posed a threat to public health or required corrective actions from the MECP or the Region's Medical Officer of Health.[173]

Source water protection also plays an important role in water quality. Using a "One Water[y]" perspective, York Region recognizes the need for protection throughout the water cycle and to consider climate change impacts in evaluating of future water and wastewater needs. Developing climate change adaptation and mitigation strategies are part of the Made-In-York One Water Action Plan.[98]

[y] "One Water" refers to a concept of efficiently using water from every source, which encourages conservation and reducing the burden on local water sources, while maintaining safe drinking water.

The 2016 Water and Wastewater Master Plan also includes an objective for creating a more resilient water and wastewater treatment plan to be able to service the anticipated population and employment growth that are expected to increase for York Region by approximately 50% in 2041.[173] As part of the Master Plan update, the Region completed a Climate Change White Paper, which includes a pilot study of wastewater impacts in a local municipality.[98] The Master Plan also recommends incorporating climate change considerations into the risk management framework for water and wastewater infrastructure. The Plan highlights how the increased demand for quantity cannot be met by using one water source alone (Lake Simcoe, Lake Ontario or groundwater).[98]

York Region's Long-term Water Conservation Strategy and multi-barrier approach support water safety and supply. York Region has a proven record of water conservation and efficiency programming spanning more than a decade. The Long-Term Water Conservation Strategy[175] expands on existing Regional plans, strategies and programs and sets the stage for innovative and jurisdiction-led water conservation and efficiency programming for the next 40 years. York Region's Water for Tomorrow program includes education and programs for residents, water-saving incentives for businesses, fusion gardening, inflow and infiltration reduction and student water conservation programs.

Following the Walkerton tragedy, a multi-barrier approach has been the standard to ensure that preventive and corrective actions are taken to protect drinking water quality. Many of the measures in the approach are likely to address concerns and adaptive capacity of existing services to the anticipated impacts of climate change. The multi-barrier approach currently used by York Region includes:

- **Measures for source water protection:** Source Water Protection is a program legislated by the Province of Ontario to protect municipal drinking water sources from contamination or overuse. York Region protects drinking water sources by conducting a groundwater monitoring program, conducting studies to better understand and manage municipal groundwater supplies, preparing water source protection plans, reviewing all development applications to make sure that drinking water sources are protected and helping businesses implement risk management measures
- **Operator training:** York Region continues to develop and participate in top quality operator training. These training priorities ensure staff is equipped to competently and efficiently manage drinking water systems in compliance with applicable rules and best practices
- **Drinking Water Quality Management Standard:** The Region implements this statutory management standard that protects public health through consistent practices for managing and operating water systems and by identifying and mitigating risks. It is also a tool for identifying and resolving inefficiencies. The Integrated Management System implements continual improvement efforts to proactively manage risks to drinking water systems. York Region Environmental Services' Integrated Management System also includes International Organization for Standardization (ISO) 14001 and ISO 9001 certification and Ontario's Drinking Water Quality Management Standard

In addition to the multi-barrier approach, recent infrastructure investments, such as the York Durham Sewage System Forcemain Twinning Project, will also help support adaptation to future climate change impacts and reduce the risk of spills from storm events.[176]

9.2.1.2 Small drinking water systems and private wells

Besides municipal drinking water systems, residents may also receive their water through smaller systems that supply drinking water to a specific property or building. In general, these smaller systems are SDWSs or private wells.

Significant improvements to drinking water regulations were established after the Walkerton crisis of 2000, which have improved the drinking water quality for smaller systems**.** Nonetheless, it is still important to note the potential impacts of climate change on these systems through heavy rainfall events, flooding and increased temperatures. For example, in 2005 the Holland Marsh (a local area vulnerable to flooding in York Region) had to prepare for potential drinking water advisories for local private wells and SDWSs in the area following a flooding event.

How climate change is expected to impact these smaller water systems remains unclear. Multiple variables need to be considered such as the source of water, type and condition of well, treatment level, sources of contamination, local hydrology factors and behaviours of water users. As these drinking water systems are more localized and smaller scale, climate change could have various impacts including:

- Heavy rainfall and flooding events impacting local groundwater (particularly shallow aquifers or dug wells) and surface water source quality
- Extreme weather events resulting in power outages that could impact treatment for SDWSs and private wells
- Warmer conditions that can influence the growth and survival of pathogens

Small drinking water systems

In 2018, there were just over 300 SDWSs regulated by the MOH. These systems obtained drinking water from Lake Simcoe or a groundwater well with treatment using filters, UV and/or chlorine. Facilities using SDWS are diverse and include recreational facilities, resorts, restaurants, campgrounds and parks. As of 2018, the majority of SDWS were within the municipalities of Georgina, East Gwillimbury, King Township and Whitchurch-Stouffville. There are less than 20 SDWS within Richmond Hill, Markham, and Vaughan due to protected lands within the Greenbelt and Oak Ridges Moraine. Two facilities presently use treated lake surface water as their source, mainly from Lake Simcoe. Twenty-nine facilities also fall within a floodplain.

The risks for each SDWS vary in terms of populations served, location of the facility, sources of drinking water and treatment operations. In past years, the most common adverse water quality incidents were related to treatment operation malfunctions such as ultraviolet lights not working and power outages. From a climate change perspective, SDWS with surface water or shallow groundwater sources, and water treatment options without back-up generators for power outages, can be cause for concern. However, risks to drinking water are reduced through existing regulations requiring SDWS to have sufficient water treatment in place.

There are challenges with available data relating to SDWS, such as inconsistencies in reported incidents between SDWS. There are also challenges with interpreting existing data with respect to climate change vulnerabilities. Currently, reporting is completed through separate datasets [risk categorization tool - RCat[z], and Laboratory Results Management Application[aa]], making data analysis and assessment more challenging.

Private wells

A number of York Region residents get their drinking water from private wells. According to provincial records, there are more than 40,000 private wells in York Region, but not all are used for drinking water. Private well testing is done voluntarily by property owners and public health recommends two-to-three tests per year and testing following a heavy rainfall event. York Region Public Health provides water sample bottles, forms and information to local residents who own private wells. Sample bottles are available for pick up and drop off at several locations. Samples are sent to Public Health Ontario laboratories to be tested for bacteria. Test results are received by telephone, mail or can be picked up directly from the Public Health Ontario laboratories. It is the owner's responsibility to maintain and monitor their well.

Table 9.2. summarizes private well testing in York Region from 2014 to 2018. Within the five-year period approximately 12% of all private well water testing results showed significant bacterial contamination.[177] In addition, 2% to 3% of all sample water results were deemed unsafe to drink due to fecal contamination.[177]

As private well testing is voluntary, it is difficult to know how many private wells are used for drinking water. There is also a general declining trend in the number of well water submissions. This may be a result of residents choosing not to submit samples or a growing number of properties being connected to municipal drinking water systems. In addition, limitations in the data create challenges in interpretation due to a variety of factors:

- The number of samples does not necessarily correspond to the number of private wells tested. Multiple submissions can be made by one private well owner
- Certain geographic areas within York Region have fewer sample submissions compared to other areas
- Follow up on adverse drinking water results does not obtain sufficient information to assess the risk relevant to climate conditions
- Although recommended, sample submissions may not be taken after heavy rainfall events

As such, current data collected is not a useful measure of potential climate change impacts due to many confounding factors. Future planning can consider data collection on well water testing following heavy rainfall events, or conducting risk assessments that incorporate climate factors for adverse results.

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[z] The risk categorization tool is approved by the Ministry of Health and designed for site specific risk assessments of SDWS.

[aa] Laboratory Results Management Application is an electronic database for SDWS water sampling test results, notifications or adverse water quality incidents.

Table 9.2. Summary of private wells sampled in York Region from 2014 to 2018 – WTISEN.[bb]

	Samples Processed	No significant evidence of bacterial contamination	%	Significant evidence of bacterial contamination	%	Unsafe to drink, evidence of fecal contamination	%
2014	3,667	2,918	80%	478	13%	69	2%
2015	3,694	2,939	80%	460	12%	93	3%
2016	3,800	3,113	82%	427	11%	63	2%
2017	3,396	2,699	79%	400	12%	89	3%
2018	2,902	2,318	80%	389	13%	59	2%

Source: Water Testing Information System Electronic Notification (WTISEN) [data file]. Toronto: Ministry of Health and Long-Term Care; 2019.

Wells located within floodplains may be at higher risk of treatment process disruption following heavy precipitation events. Of all private wells in the Region, approximately 2,600 are located within a floodplain and 1,500 are located in significant groundwater recharge areas. These areas may be more vulnerable to heavy rainfall events.

Drilled wells that are properly constructed and maintained are likely to be protected from impacts due to heavy precipitation and flooding, unless the flood water rises above the well cap. However, dug wells are more vulnerable to contamination as they obtain water from shallower aquifers, which are more susceptible to climate impacts such as heavy rainfall and flooding. Ontario's Regulation 903[178] requires all well types to be constructed under specified direction. Drilled wells are inherently more protected as dug wells do not have to follow the same standard. Drought conditions may also affect groundwater systems by impacting the supply of water in shallow wells, which can lead to water treatment challenges.

In total, there are 32 dug wells across York Region; however, it is not clear if all of them are in operation. While no dug wells were located within a floodplain, 13 are located within significant groundwater recharge areas.

While uncertainty remains regarding the impacts of climate change on private wells in York Region, it is important to note existing regulations and legislation help protect local drinking water. Recognizing the emerging issues stemming from climate change, the recent OPHS revisions now include climate change adaptation as part of the Safe Drinking Water and Fluoride Monitoring Protocol, 2019.[179] Preventative measures were also developed as part of the *Safe Drinking Water Act*, and include monitoring, risk assessment and management of incidents to help reduce or eliminate the potential risk from waterborne illnesses.

[bb] Water Testing Information System Electronic Notification database. Note total will not add to 100% as other result categories are not included.

9.2.2. RECREATIONAL WATER

Exposure to recreational waters contaminated by algal blooms or pathogens has been associated with gastrointestinal infections.[4] With projected increases in temperatures and longer summer weather periods due to climate change, cyanobacteria blooms (blue-green algae) may become a more significant issue. This may also increase the risk of exposure to toxins related to cyanobacteria, particularly microcystin-LR. Research including modelling studies, laboratory studies, field surveys and a review of historic and current freshwater lakes provide strong supportive evidence of the risk of algal blooms.[163] The only human cases of death involved dialysis patients in Brazil exposed intravenously to microcystins in water.[180] Microcystins have not been found in any municipal water systems in Ontario to date.

There are other issues that may arise as a result of increased outdoor activities during the warmer summer months, which could indirectly contribute to a higher risk of exposure from recreational water use. For instance, one splash pad located at the Toronto Zoo was associated with an enteric outbreak in 2007.[146]

Public beach surveillance activities

York Region Public Health monitors public beach water quality and developed a predictive beach model to inform beach advisories and closures. In total, there are 14 public beaches monitored by York Region Public Health. There are 13 public beaches on Lake Simcoe and one at Musselman's Lake in Whitchurch-Stouffville. Water sampling is done annually beginning in mid-June and continues until the end of August. A minimum of five samples are collected from each beach once a week and tested for levels of *E. coli* bacteria. As bacteria can increase after heavy rainfall events, there is signage posted that warns swimmers not to swim for two days after a heavy rainfall. In more serious cases, a beach closure can be issued. Since 2006, there have been two temporary beach closures in York Region; one at Lake Wilcox in 2008 relating to the redevelopment of the land area, and a second at Glenwood Beach in 2011 due to weed and algae growth.

Modelling the relationship between beach water and environmental factors

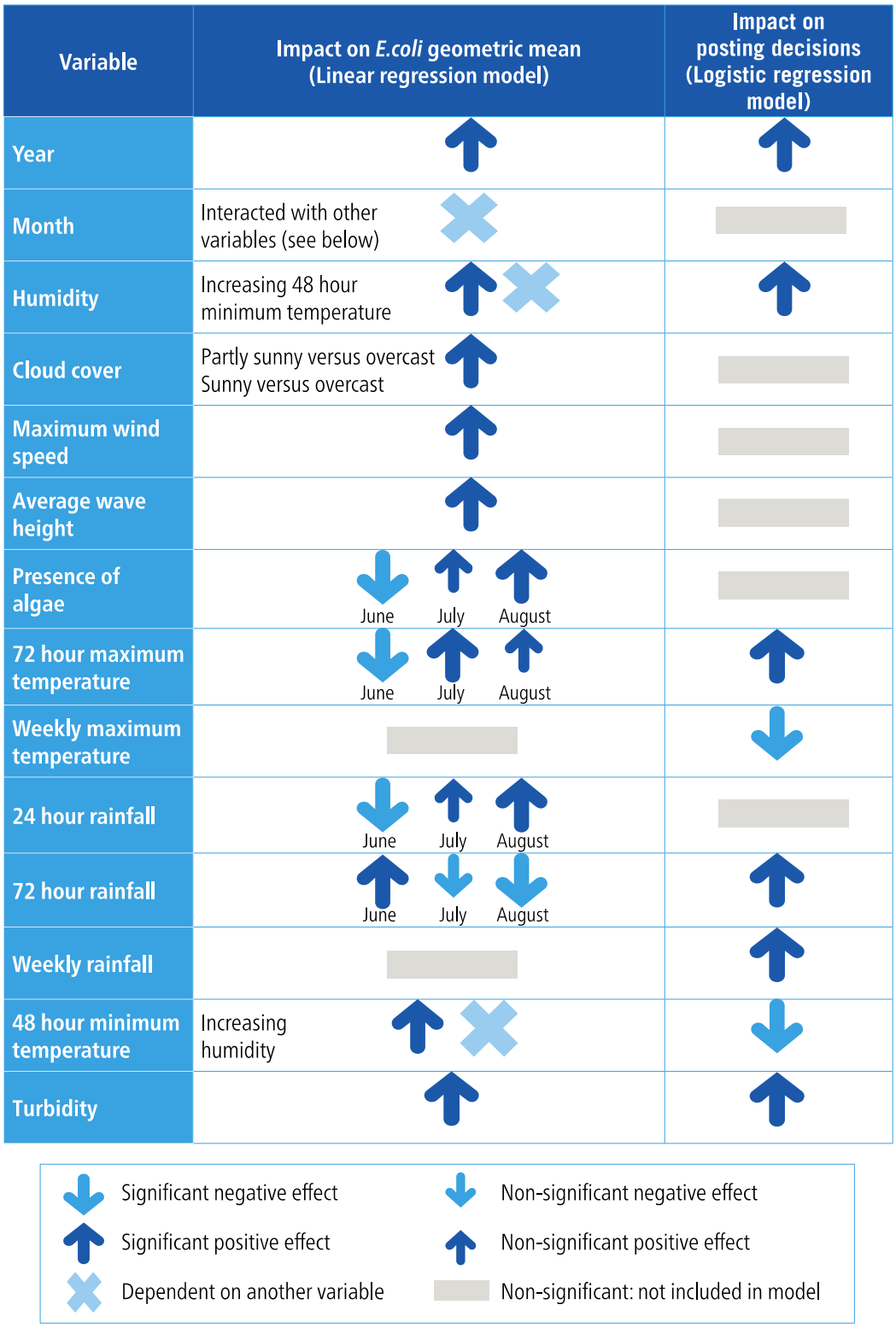
Multiple parameters can contribute to adverse water conditions in recreational beaches. These include the presence of animal sources of pathogens (e.g., waterfowl populations) and nearby farms, local geography, temperature, turbidity, wind conditions and rainfall. York Region Public Health developed predictive models for certain beaches to determine when to issue a beach post.

A recent York Region study examined factors that influenced *E. coli* geometric mean concentrations and posting decisions at York Region beaches during the 2013 to 2018 beach seasons by constructing statistical regression models.

In both models, temperature, rainfall, humidity and water turbidity were found to have a statistically significant relationship with *E. coli* concentrations and posting decisions.

However, in examining *E. coli* concentrations, many of these effects varied significantly by month (Figure 9.5). It was also noted that the majority of variation in the models occurred between samples, not between beaches. This reflects the difficulty in developing consistent predictive models for informing beach posting decisions.

Figure 9.5. Results of statistical regression models examining the impact of climatic, hydrologic and anthropomorphic factors on the *E. coli* geometric mean and posting decisions at York Region beaches from 2013 to 2018, inclusive.



Potential climate change impacts on recreational beaches in York Region

The projected increase in heavy rainfall events, higher water temperatures and lower lake levels (due to increased evaporation) are expected to contribute to beach water contamination.[181] With the increase in rainfall events, there is also potential risk of run-off contributing to adverse water conditions.

With York Region expecting to have a rise in one- and five-day heavy rainfall events, there is potential for more run-off, flooding and storm events that could contribute to poor recreational water quality conditions. Beach contamination events for the Great Lakes Region of the United States generally occur when precipitation exceeds 5 cm to 6 cm.[11] Annual one-day maximum precipitation events are anticipated to increase from around 4 cm to 5 cm in York Region by the 2050s,[10] which may contribute to poorer beach quality days. Recent heavy rainfall events in York Region have also had an impact on bacteria counts measured the day after a heavy rainfall event. More information is needed to assess the potential linkages with heavy rainfall events and bacteria counts at beaches in York Region.

While climate change may increase exposure to pathogens and toxins, cases of waterborne illnesses will still depend on variables such as hygiene practices and the extent of beach use by local populations. There is limited information on potential sources of water contamination and how this may change with future population growth and land-use changes. There is also limited data on beach users in York Region to provide context on the number and demographics of people potentially impacted by beach water quality.

9.3 CONCLUSION

York Region takes a comprehensive approach to water safety through a multi-barrier approach to protect human health and the environment and complies with regulations and requirements in the *Safe Drinking Water Act* and Ontario Public Health Standards. York Region's water systems are ISO certified and follow an international standard management practice. This approach incorporates multiple layers of protection throughout the water cycle including source water protection, water and wastewater treatment, management of water systems and supportive policies.

York Region Public Health takes proactive measures to ensure the safety of residents who use public beaches, private wells and small drinking water systems. These measures include existing recreational beach monitoring activities, development of a predictive beach model to anticipate future impacts, promotion of private well water testing and education to reduce risk of exposure.

While climate drivers are expected to increase in York Region, such as extreme precipitation and warmer temperatures, there is limited information available to estimate the future health burden associated with climate change and water safety. Existing health data for York Region shows how some reportable enteric diseases such as Shigellosis were at higher rates than Ontario averages, but others such as cryptosporidiosis and giardiasis were lower. Consistent with other jurisdictions

and the research, there is a seasonal trend peaking in the summertime; however, it is not clear whether this peak relates to beach water activity, drinking water consumption or other exposure routes such as contaminated food.

While smaller water systems (e.g., private wells, SDWS) may be more susceptible to the impacts of climate change, it is not clear if future weather conditions will likely result in adverse drinking water quality conditions. It is important to note that more households and facilities are now linking to larger municipal water systems. This will play an important role in the reduction of private well water risks related to climate change. Nonetheless, more information is needed to assess the risk of climate change to smaller water systems.

Certain climate change impacts related to combined sewer overflows and drought conditions identified in the literature are not likely to pose challenges to water safety and security in York Region. Other areas identified as potential issues include algal blooms, vulnerability for dug well users, infiltration and inflow into sewer systems, flooding and extreme weather impacts on water treatment systems and impacts to beach water quality. With York Region expecting to have a rise in heavy rainfall events, there is a potential for more run-off, flooding and storm events contributing to poorer water quality conditions.

More information is needed to assess complex exposure pathways and to estimate health impacts. Currently, various datasets capture information that may be relevant to assessing exposure such as boil water advisories, drinking water advisories, adverse water quality incidents, bacterial counts and beach closures. More research is needed to interpret the results and to be able to associate the data with climate events such as flooding, water temperature and heavy rainfall.

While climate change may increase exposure to pathogens and toxins, potential cases of waterborne illness will still depend on other variables such as hygiene practices and beach use. There is limited information on potential sources of water contamination and how this may change due to future population growth and land-use changes.

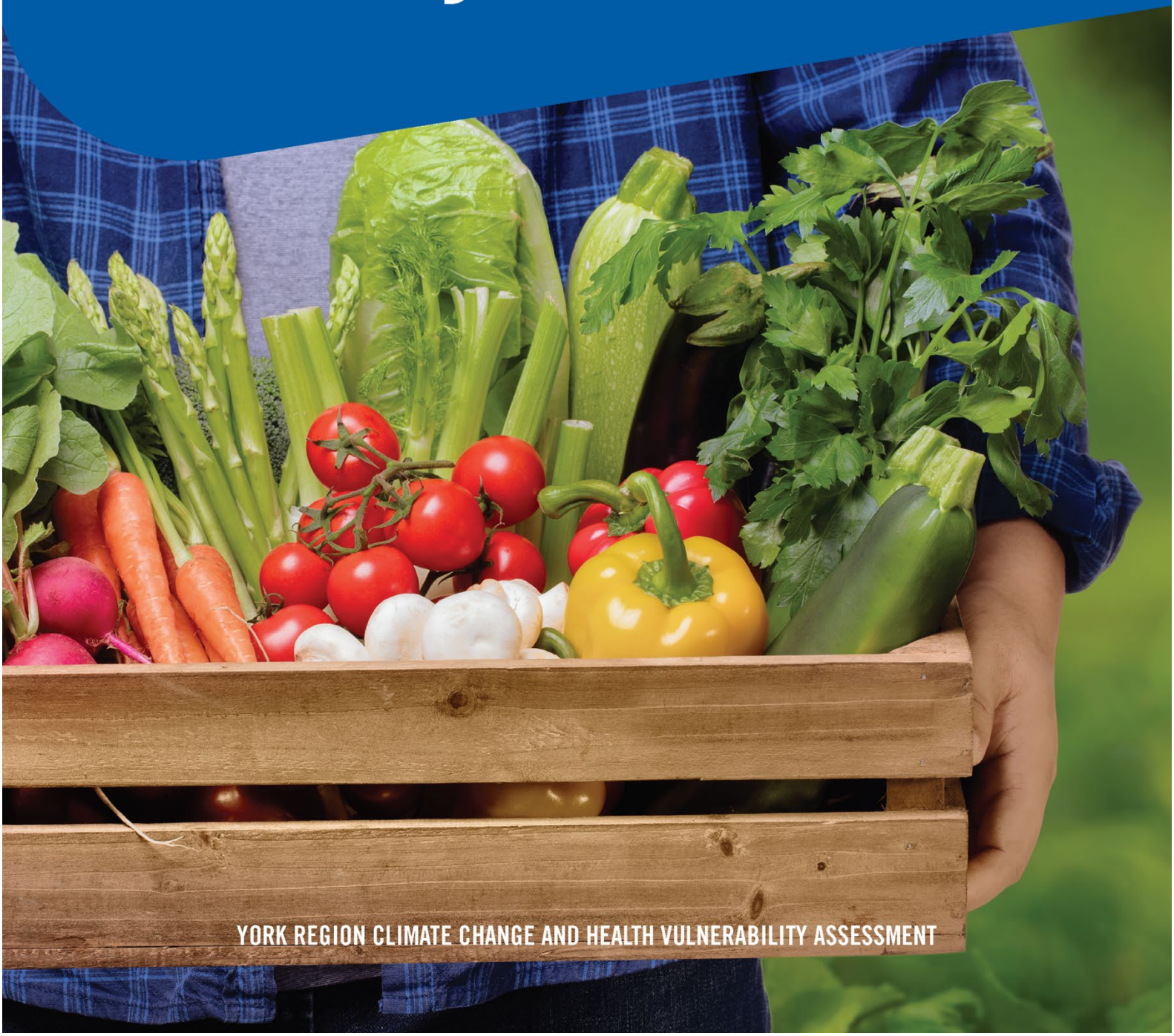
Lastly, multiple challenges have been identified in assessing waterborne illnesses including underreporting and many potential sources for transmission of the diseases such as food, travel and contact in the environment. This makes it difficult to identify a definitive cause of infection for cases. York Region residents' activities outside the Region can also impact local health surveillance data. Current York Region initiatives and opportunities that support adaptation to climate change are summarized in Table 9.3.

Table 9.3. Summary of water safety activities and adaptation planning opportunities.

	Ongoing and Completed Activities	Opportunities
Population Health Assessment and Surveillance	**Health Surveillance:** Diseases of public health significance and outbreak case investigation and management as part of provincial requirements.	Explore potential data for other health endpoints, such as swimmers itch and conjunctivitis. Explore ACES surveillance for potential climate change impacts on waterborne disease. Consult agencies with research expertise (e.g., PHO, PHAC) on assessing relationship between health outcomes and weather patterns.
	Environmental Monitoring: Beach monitoring at 14 public beaches for bacteria counts from mid-June to the end of August, with minimum five samples per beach once a week. Private well water testing (voluntary and encouraged at least three times per year). Monitoring of algal blooms and information shared from key stakeholders.	Explore available data and assessments from other jurisdictions (e.g., lake water quality and algal bloom monitoring). Collect relevant data to determine which SDWS and private wells are most vulnerable to changes in weather conditions (e.g., MECP private well data). Provide additional training to SDWS operators to ensure consistent reporting and potential impacts relating to weather conditions.
		Consult private well owners (e.g., regarding groundwater use, use of dug wells, water quality testing following heavy rainfall events). Survey beach users on how they prefer to receive beach posting information. Explore beach use data with municipalities to assess potential population exposure.

Program and Policy	Respond to complaints, inquiries and investigations as needed for private wells and SDWS (e.g., water main breaks, 24/7 response). Issue boil water advisories and drinking water advisories, beach advisories and/or beach closures as needed. Predictive beach modelling which used data collected from beach sampling to determine conditions at the beach. Completion of SDWS workshops.	Assess potential weather linkages with results relating to poor water quality (e.g., adverse water quality incidents, boil water advisories, drinking water advisories and bacterial counts) and consider time-lag effects. Determine suitable criteria for beach closures (e.g., % of time beach requires advisory). Assess how heavy rainfall events can be incorporated into predictive beach modelling to inform beach closures. Consider one-to-one SDWS operator/owner education opportunities.
Health Promotion	Existing webpage content on private well water testing and beach monitoring. Safe water key messaging and social media included as part of emergency response (e.g., ice storms, flooding, power outages, etc.). Completed Test Your Well campaign.	Consider evaluating beach sign effectiveness for public beach users. Consider health promotion approaches and key messaging for testing well water on social media and other media channels following heavy rainfall events to ensure it is safe to drink. Consider community events for future promotion activities related to private well use and recreational waters.
Key Stakeholder Activities (outside of public health)	Long-Term Water Conservation Program and source water protection initiatives. 2016 York Region Water and Wastewater Master Plan that provides an overview of needs for 2041, including population growth and climate change impacts. York Region Environmental Services Inflow and Infiltration Reduction Strategy to ensure capacity and optimal operation of wastewater treatment facilities. Assessment of water quantity impacts for local municipal groundwater sources. Developed by-laws for water use restriction during drought or low water conditions. **Emergency Preparedness and Response*:*** Development of a Public Notification Procedure by York Region Environmental Services during overflows, bypasses from wastewater treatment. MECP monitoring and response to designated facilities and monitoring algal blooms.	Review relevant information on source water protection measures that may inform private well water and small drinking water systems in York Region, and beaches (e.g., promotional material to reduce run-off). Future assessments may look at different storm conditions to determine water and wastewater infrastructure design, which could inform Public Health program and policy development. Discuss potential opportunities to address health impacts on basement flooding with other departments such as Environmental Services.

CHAPTER 10
Food Safety and Security



10 Food Safety and Security: Key Findings

Climate Drivers and Exposure Pathways

- Climate change will result in increased temperatures, expanded growing seasons, extreme weather and changing precipitation patterns. This can impact local farm production, distribution and supplies. York Region has more than 70,000 hectares of designated agricultural land
- York Region is expected to expand the growing season by 30 days. The number of days above 25˚C is expected to increase by 38 days in the 2050s, which may contribute to growth and survival of foodborne pathogens in locally produced food and the risk of food spoilage
- Extreme weather events such as extreme heat and ice storms can result in power outages that impact the safety of food products by compromising refrigeration, which can also affect local food supplies
- While local food systems may benefit from longer growing seasons, food security is dependent on global food systems, which climate change will adversely impact
- Floodplains within York Region can impact sanitation and storage conditions in food premises, which may increase the risk of exposure to foodborne pathogens. Less than 10% of premises fall within the floodplain, but risks of urban flooding are unknown

Population Sensitivity

- Food insecurity is associated with other determinants of health including existing chronic disease, low-income and mental health
- Food prices and cost of living are increasing close to or above income for low-income populations, which may increase the risk of food insecurity

Adaptive Capacity

- Adaptations to climate change need to be considered at all levels of the food system to increase resilience, including at the production, processing, distribution, preparation and consumption stages
- Food safety currently involves agencies from federal, provincial and local health unit levels and industry working to prevent foodborne illnesses. Food safety depends on human behaviour and the effectiveness of food safety regulatory, surveillance, monitoring and communication systems
- In 2018 York Region inspected approximately 3,000 food premises across York Region and has food safety promotional campaigns to reduce the risk exposure to foodborne pathogens
- York Region programs also target food insecurity and support local food systems within the Region

Health Impacts

- The relationship between climate change, food systems and food security is complex and involves multiple sectors within and outside of York Region. As a result, future estimates of foodborne illnesses or other outcomes are difficult to calculate for York Region
- Enteric disease cases may also be affected by altered human behaviour and activity such as greater outdoor activity (e.g., barbeques), travel and hygiene practices

Recent trends:

- The largest numbers of cases for enteric diseases are for *Campylobacter* enteritis and Salmonellosis in York Region. Most enteric diseases illustrate a seasonal trend peaking during the summer months or early fall
- Between 2009 and 2014, an estimated 7% of York Region households (approximately 24,700 households) experienced food insecurity

Climate change will have important implications for food safety and security within York Region and globally. This chapter provides an overview of food safety, food security and food insecurity implications due to climate change. While food safety is connected to elements of food security, each topic is discussed separately with food safety impacts focusing on risks to foodborne illnesses. As enteric diseases can be caused by food and water exposure routes, local health impact trends in York Region are discussed in the previous chapter (see Section 9.1). Food security is discussed from a local perspective, and does not include global or international impacts from food systems (see Section 10.2).

The focus of this chapter is on climate change impacts relevant to the geographical context of York Region and local activities relevant to food safety and security. Coastal seafood and international food safety are important climate change impacts to consider due to a global food supply system that can impact York Region. However, these are not discussed further as they occur outside of York Region and fall under the mandate of other agencies. Additionally, issues relating to contaminants are not discussed due to limited research.[140,163]

10.1 FOOD SAFETY

Food sources have been a commonly attributed route of exposure to enteric disease cases in York Region. For instance, contaminated foods such as meats, raw vegetables and unpasteurized dairy have been sources for salmonellosis and verotoxin producing *E. coli* (VTEC) infections in York Region and Ontario.[146]

Climate impacts on food safety can appear across the food system in production, processing, distribution and preparation and consumption of food products. Changes in temperature and precipitation are expected to shift in the geographic range, seasonal occurrence and proliferation of pathogens. Some of the ways that climate change could impact food safety are listed below.[140]

- Higher air temperatures can lead to greater spoilage rates during transportation and storage
- Higher temperatures, CO_2 levels and drought conditions impact the proliferation of pests and pathogens, such as the growth of mould and mycotoxins in crop production and bacterial shedding of livestock
- Higher sea surface temperatures contribute to a higher risk of exposure to pathogens in seafood products such as *Vibrio*
- Heavier precipitation contributes to potential contamination of irrigation water
- Flooding events contribute to contamination of crops with toxins and pathogens
- Changes in soil properties impact production and presence of contaminants such as heavy metals in soils
- Extreme weather events or high energy demands lead to prolonged power outages, which could lead to food spoilage

10.1.1 Climate change impacts on foodborne illness outcomes in York Region

Some expected climate change impacts will have greater implications for York Region Public Health's Food Safety program. There are many potential impacts relevant to food safety in York Region, including an expanded growing season, increased temperatures and extreme weather events. However, impacts with greater implications on food safety could include:

- A potential increase in the number of food recalls within the Region, province or country
- Increased risk of foodborne illness from outdoor recreational activities such as barbecues and picnics
- Increased risk of foodborne illness from farmer's markets and other special events as a result of improper food storage and the proliferation of pathogens in warmer weather. Additionally, the preparation and handling of food outdoors without thermostat-controlled cooking or proper washing facilities can increase the risk of food contamination
- New pathogen risks to human health arising in local food produced in the Region
- Food premises non-compliance issues due to extreme heat, as premises may be faced with challenges in maintaining temperatures needed for food safety
- Extreme weather events contributing to power outages that can impact maintaining the correct temperatures of food stored in cold and/or hot holding units, food contamination/adulteration, or food safety concerns in emergency reception centres

Since food is sourced from local and international markets, food safety in York Region can be impacted by changes at the local, provincial, national and international levels. However, only a few studies have estimated the potential future risk climate change may pose on food safety. One study used a quantitative microbial risk assessment (QMRA) to estimate the increase in disability-adjusted life years (DALYs) from mycotoxins in wheat grown in Saskatchewan and *Vibrio parahaemolyticus* in oysters from Chrome Island in British Columbia.[182] The model found an increase in DALY by 14% and 33% for mycotoxins and Vibrio respectively by 2050 based on an annual air temperature increase of 0.04˚C.[183] However, with an annual air temperature increase of 0.08˚C, the DALYs for mycotoxins increased by approximately two-fold, while for vibrio the increase was much less, highlighting the model's sensitivity to temperature for mycotoxins.[182]

Climate change may also increase contaminants such as heavy metals in soils or create a greater need for pesticides. Some research suggests contaminants and toxins may be introduced into crops during flooding or drought through deposition of contaminated dust, but exposure is difficult to predict.[140] Other possible impacts, such as potential rise in food allergens or new insect vectors, are emerging topics with limited research.[4,140]

The impact of climate change on food safety is difficult to quantify as it can be buffered by a number of existing processes in York Region and Canada, including surveillance, preventive measures and food safety regulations. Resulting health impacts will not depend

solely on greater exposure to pathogens and contaminants, but on multiple factors that influence pathogen survival and growth, as well as human exposure. Future estimates of foodborne illnesses or other outcomes are difficult to model due to the many factors involved in investigating foodborne illnesses.

In addition, warmer temperatures may alter human behaviour, which may impact foodborne illness rates. An extended warm season is likely to lead to more barbecuing and gatherings. This could lead to an increase in foodborne illnesses if foods are not handled, prepared or stored safely while outdoors.[4,140] Climate change may also lead to changes in animal husbandry and animal-to-animal transmission that could affect existing pathogens in food or lead to the emergence of new ones (e.g., increase in bacterial shedding of animals in warmer temperatures).[4,140]

10.1.2 ADAPTIVE CAPACITY: EXISTING PROGRAMS ADDRESSING FOOD SAFETY

Food safety challenges range from local to international, and require the development of coordinated program activities across municipal, provincial and federal agencies. These agencies address the various stages of food safety, from production and transportation, to local consumption and handling. At the federal level, the Canadian Food Inspection Agency (CFIA) is responsible for the inspection of imported foods and local products from federally registered food establishments. The Public Health Agency of Canada also conducts investigations when more than one province or territory is involved or impacted by an outbreak. In addition, Health Canada provides standards and policies supporting the safety and quality of all food sold in Canada.

Provincial agencies such as the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) and the Ministry of Natural Resources and Forestry (MNRF) provide services that reduce food safety risks and maintain food safety standards for food produced and distributed for sale in Ontario. Additionally, through the *Health Protection and Promotion Act*, the MOH develops standards and protocols for food safety of food premises inspected by local public health units.

York Region Public Health inspects more than 3,000 food premises annually. In addition to established premises, York Region Public Health also investigates and assesses food safety standards for farmers' markets, special events involving mobile food trucks and events involving wild game dinners as needed (Table 10.1). There are also other facilities in York Region focused on food processing or production, which are regulated by other agencies such as the Canadian Food Inspection Agency.

Table 10.1. The number of food premises inspected by York Region in 2018.

Food Premises in York Region	Total Number of Inspections as of December 31, 2018
Food processing facilities:	
Food plant / production	41
Food distribution facilities:	
Food warehouse / depot	44
Food retail facilities:	
Supermarkets	179
Convenience / Variety	585
Restaurants	2,096
Potential Outdoor Food Vendors:	
Street food vending cart	18
Mobile preparation premises and catering vehicles	214
Farmers markets	8
Special events from May 1 to September 30, 2018	272
Food facilities focused on vulnerable populations:	
Child care: On-site preparation or catered	341
Group / Lodging home for more than nine individuals	42
Long-term care homes	26
Hospitals	4
Retirement homes	37

Currently, risk assessments are conducted on food premises to determine risk levels and frequency of inspections completed each year (one, two or three inspections). Inspections are also conducted on a complaint basis to ensure hygiene practices and foodborne pathogen risks are managed according to current best practices and regulatory requirements (e.g., maintaining appropriate temperatures, eliminating contaminated food sources or disposing of spoiled food due to power outages). These current best practices and regulatory requirement measures will also help to address future climate change impacts.

In addition to inspections, York Region Public Health has programs to reduce the risk of foodborne illness through food handler certification, which requires all food service premises to have a certified food handler on site at all times. York Region Public Health also has promotional material encouraging York Region residents to adopt food safety practices at home using the Home Food Safety Guide. Residents can also check YorkSafe.ca, an online platform for food premise inspection reports in York Region. Food safety messaging can include climate change adaptation measures, but more research is needed on effective interventions at the individual level and on linking current foodborne illness events to climate conditions.

10.1.3 CONCLUSION

The research highlights many ways climate change is expected to impact food systems and food safety around the world. In York Region, climate change will result in increased temperatures, extreme weather and increased precipitation. These factors can increase the local risk of foodborne pathogens and food spoilage at food premises.

Many factors must be considered when assessing the effects of climate change on increased exposure risks and cases of foodborne illnesses. Data from previous cases of foodborne illness in York Region highlight the various associated sources and factors leading to exposure and subsequent illness. With the challenges of underreporting, multiple potential sources of pathogens in the food system and complex linkages between climate and food safety, it is difficult to predict how reported cases of foodborne illness may increase or decrease in York Region due to climate change. Recent QMRAs provide some perspective on how foodborne illnesses may change, but it will depend on a wide range of assumptions.

Under existing regulatory requirements and current practices, many of the potential impacts relating to weather will likely be addressed. For example, impacts from increasing temperatures and extreme heat events are addressed through regulatory requirements and inspections or investigations of food premises. Future climate adaptation measures could consider including climate factors that may be more relevant for risk assessments for certain types of premises (e.g., outdoor premises, farmers markets, special events).

Behavioural aspects also play an important role in enteric disease cases, such as outdoor activity and cooking practices during summer months. Thus, health promotion activities including tailored messaging may need to be updated to address some of these potential exposure pathways.

More information is needed to understand the relationship between climate factors and local cases. This includes accounting for other contributing factors such as hygiene practices and travel, which can be related to enteric disease cases. Surveillance programs should consider reported cases and additional data that can support an understanding of climate variables and linkages to foodborne illness risk.

There are currently a number of measures in place at the municipal, provincial and federal levels to reduce the risk of foodborne illness across the food system. These include federal agencies responsible for the inspection of food products, ensuring compliance with regulations and food safety standards and provincial agencies ensuring farming and agricultural practices eliminate and reduce health hazard risks during production. As part of the Ontario Public Health Standards (OPHS), public health units must also meet the requirements of the food safety protocol as well as the requirements of the *Health Protection and Promotion Act* and Ontario *Food Regulation 493/17 (Food Premises)* to prevent health hazards. This implementation involves investigating cases of suspected foodborne illness and outbreaks, and regular inspections of food premises to ensure the protection of the public.

It is important to consider how health units can address future impacts and better prepare for climate change challenges. Adaptive capacity as it relates to food safety depends on human behaviour and the effectiveness of food safety regulatory, surveillance, monitoring and communication systems. Table 10.2. summarizes current activities that potentially address future climate change impacts and identifies opportunities to further support climate change adaptation planning.

It is important to note that climate change impacts to food safety can also involve disruptions to the supply and distribution of food. Impacts that contribute to food spoilage are just some factors that relate to issues of food security. Other important aspects to consider include nutrition, transportation of goods and vulnerable groups. The following section (Section 10.2) will discuss some of the food security and food insecurity issues in York Region.

Table 10.2. Summary of food safety activities and adaptation planning opportunities.

	Ongoing and Completed Activities	Opportunities
Population Health Assessment and Surveillance	**Health Surveillance:** Diseases of public health significance and outbreak case investigation and management as part of OPHS/HPPA requirements.	Exploring additional local data relating to risk factors or emerging foodborne pathogens relating to climate, which may be available from other agencies (e.g., OMAFRA, PHAC, and MNRF). Explore trends in inspection infractions and complaints related to environmental variables (e.g., outdoor temperature or heavy rainfall events).
	Completion of RRFSS module on Food Safety at Home (2014, 2016, 2017, 2018).	Consider adding questions to RRFSS relating to climate factors impacting foodborne pathogen risk for individuals.
Program and Policy	Inspections and investigations of food premises to ensure measures are in place to maintain sanitation and prevent contamination of food products. System to notify stakeholders of food recall warnings. 24/7 response for food safety concerns and food recall warnings. **Health Equity:** Food handler certification program for vulnerable populations.	Consider how climate factors can be incorporated to relevant food premise risk assessments (e.g., farmers markets and outdoor temperatures). **Emergency Preparedness and Response:** Food premises should consider adopting a plan for addressing food safety concerns during power outage events. Explore opportunities to incorporate messaging on relevant climate factors that can contribute to foodborne risk for food premises. Consult OMAFRA on issues relating to • Livestock stress from extreme temperatures and impacts to meat facilities • Impacts of flooding on local farms (e.g., Holland Marsh) Consider future opportunities for food handler training programs that are approved by the Ministry of Health.

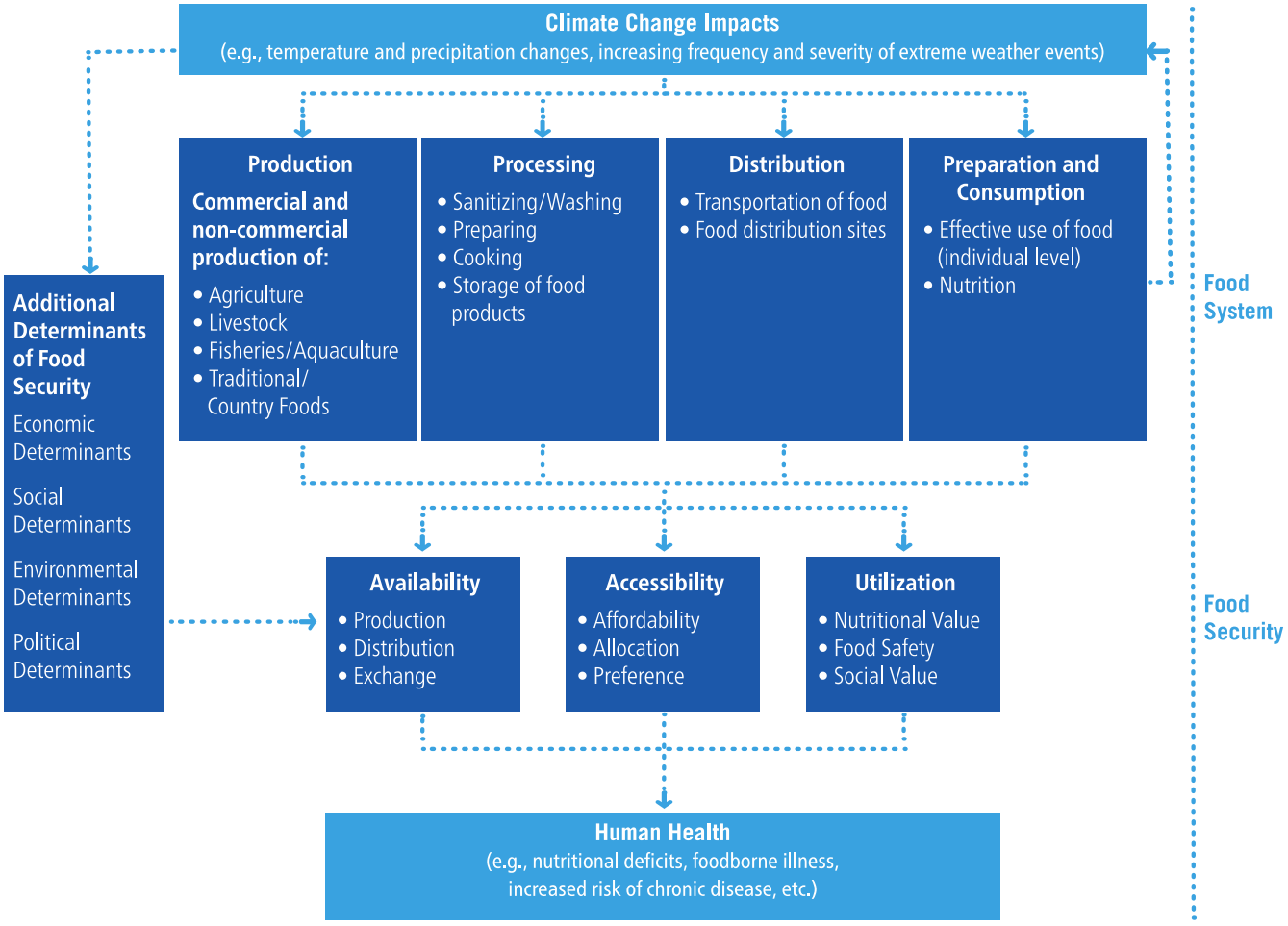
Health Promotion	**Health Equity:** Food Safety at Home campaign targeting families. YorkSafe disclosure system providing public information on inspection results for food premises across York Region.	Increase social media messaging on warm days on barbecuing and food safety risks.
Key Stakeholder Activities (Outside of Public Health)	MOH and PHO play a lead role in multi-jurisdictional outbreak surveillance and investigations. PHAC surveillance and investigation of outbreaks across provinces and/or territories. Conduct research and use of QMRA to assess future impacts of climate change on foodborne pathogen risk. CFIA inspection of federally registered establishments and food products, and issuing food recalls. OMAFRA management and assessment of local farms within York Region.	Consult relevant agencies regarding hazard analysis and critical control points (HACCP) plans for climate change impacts and implications for local public health functions. Reviewing and incorporating information from climate change and food safety assessments completed by other agencies (e.g., Additional QMRA assessments relevant to local health unit). Develop processes for dealing with emerging or novel food safety issues relating to other jurisdictions such as CFIA and/or OMAFRA. Increase understanding of food safety impacts related to climate change and local production within York Region (e.g., Holland Marsh).

10.2 FOOD SECURITY AND INSECURITY

The previous section noted how climate change can impact food safety across the food system. However, climate change is also expected to impact the food system and food security by reducing the nutritional content of certain agricultural crops and by disrupting the production, harvest, distribution and supply of food systems in Canada and globally.[140]

Food security is made up of three elements: Availability, accessibility and utilization of food.[184] When one of these elements is missing or impacted, food security is not met. The following components of food systems can also impact food security (Figure 10.1):

Figure 10.1. Framework of the relationship between food systems, food security and human health.



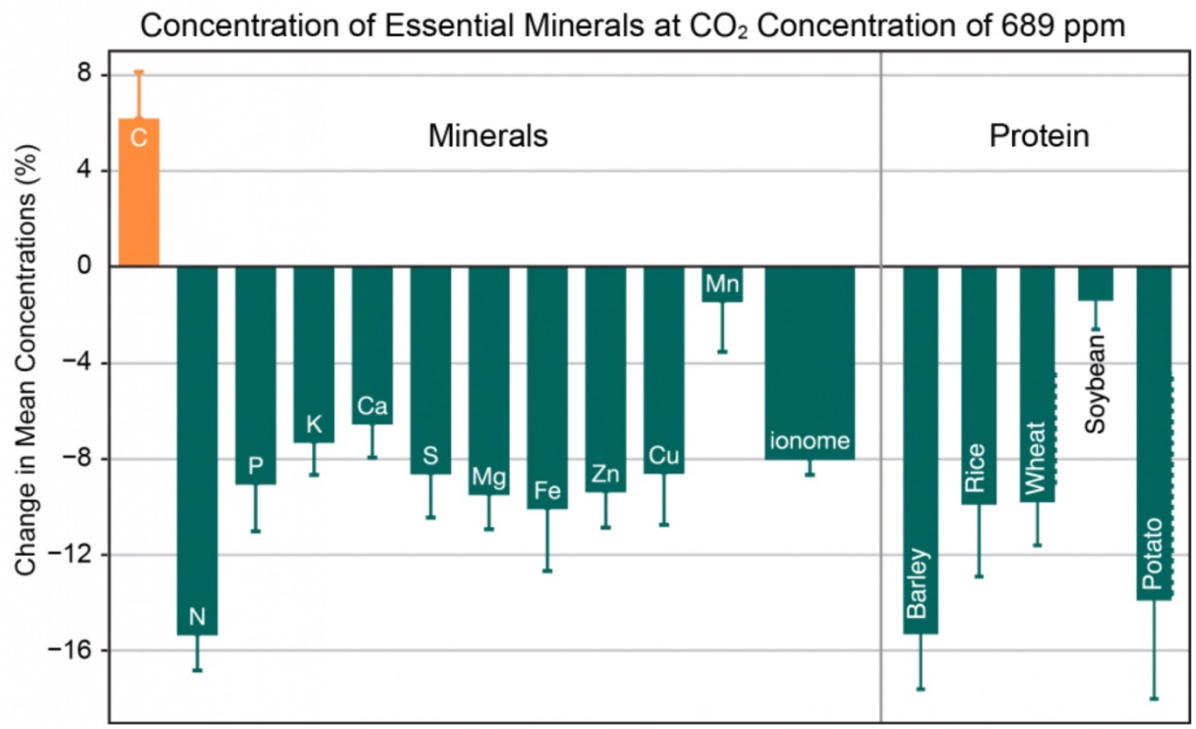
Source: Schnitter R., Berry P. The climate change, food security and human health nexus in Canada: a framework to protect population health. Int. J. Environ. Res. Public Health [serial online]. 2019;16(14): 1-16. Fig.2. Food security, climate change, and human health nexus framework; p. 6. Available from: https://www.mdpi.com/1660-4601/16/14/2531/htm. Reproduced under the terms of the Creative Commons Attribution-NonCommercial-No Derivatives License (CC BY NC ND)

Ultimately, food security depends on many factors including the production and supply of nutritious food locally and internationally, transportation and storage networks, food retail locations and an understanding of vulnerable communities in York Region. The following is an overview of the available information relating to food security. This section includes an outline of how climate change is expected to impact food security from a health lens and linkages to vulnerable populations.

10.2.1 CLIMATE CHANGE LINKAGES TO FOOD SECURITY

Rising atmospheric carbon dioxide levels will have an impact on the nutritional value of important crops such as wheat and rice. Many plant species produce lower concentrations of protein and essential minerals when grown at elevated carbon dioxide (CO_2) levels.[140] Loladze[185] provides a summary of the anticipated impact on 125 plant species with projected CO_2 levels in 2100. Crops such as rice, soybeans, wheat and barley will have 6% to 15% lower protein concentrations, but other crops such as corn will not likely decrease in protein content (Figure 10.2).[140]

Figure 10.2. The concentration of nutrients in 125 plant species in the year 2100 at CO_2 concentrations of 689 ppm.



Source: Ziska L, Crimmins A. Ch. 7. Food safety, nutrition, and distribution. In: The impacts of climate change on human health in the United States: a scientific assessment [Internet]. Washington: U.S. Global Change Research Program; Fig. 4. Effects of carbon dioxide on protein and minerals; p. 198. Available from https://health2016.globalchange.gov/. Reproduced by permission from the copyright holder.

Disruption of food systems due to climate change

In some regions, climate models suggest potential benefits to food systems by creating conditions more favourable for crop yields. The results of the fourth Intergovernmental Panel on Climate Change report indicate increases in local temperature of 1°C to 3°C in North America, along with concurrent increases in CO_2 and rainfall can benefit rain-fed crops in the early decades of the twenty-first century, increasing yields between 5% and 20%.[186] There will likely be little change in grain prices up to a global temperature change of 3°C, after which prices will rise due to declines in production.[187] This is consistent with Austin et al.[25] noting how southern Canada is relatively food secure and expected to be less vulnerable to global yield fluctuations. However, it is important to note that climate change impacts are likely to have an adverse impact on food security globally, which can have important implications for local food systems in York Region.

While general climate trends such as longer growing seasons may support food production, other climate impacts such as extreme weather events (e.g., floods and droughts) can adversely impact farms and local food supplies. Furthermore, changes in temperature and precipitation patterns will require that farmers adapt their methods to maintain productivity. This may pose a critical challenge for many farmers.[188] Food prices, which are an important factor for food security, can be impacted as extreme weather events caused by climate change worsen, particularly as global temperatures rise more than 3°C.[187]

Additionally, it is important to note that extreme weather events not only impact production, but can have temporary impacts on distribution routes and accessibility. In Toronto's recent vulnerability assessment of climate change impacts on food systems, the top issues identified include the impacts of flooding, risks to the Ontario Food Terminal, disruptions to infrastructure and vulnerable neighbourhoods that have limited access to major food retail stores.[189]

10.2.2 FOOD SYSTEMS IN YORK REGION

A large portion of York Region is used for agricultural purposes. York Region has 74,058 hectares of designated agricultural land, with 4,992 hectares designated as specialty crop land.[190] Corn, soybeans and wheat are the largest crops in York Region with more than 25,890 hectares of production; however, fruit, vegetable crops and livestock are also important contributors to the agricultural sector.[190] The Holland Marsh area is also the largest cultivated marsh in Ontario at 2,800 hectares, and is dependent on a system of dykes and canals controlling the amount of water entering the area.[174] In total there are more than 700 agriculture-based businesses in York Region.[191]

In addition to agriculture, York Region has approximately 270 manufacturers and distributors of food and beverages.[191] York Region Public Health inspects approximately 42 facilities involved in the processing and preparation of food. In terms of food retail sites, there are more than 180 grocery stores that are located mostly in urban areas, towns and villages across York Region. While not within York Region boundaries, the Ontario Food Terminal in Toronto also plays a key role in the distribution of fresh fruits and vegetables across the Greater Toronto Area.

Assessments of food systems require a detailed understanding of the production, processing and distribution of food throughout York Region. It is unclear how climate change impacts could contribute to the three key elements of food security (availability, accessibility and utilization) and how other factors such as social determinants of health may play a role. Further assessments should consider how the local food system can better support food security experienced in York Region.

Vulnerabilities to the local food system in York Region

Flooding can have important implications for local food security. A substantial number of farms fall within the floodplain in York Region. There are more than 7,500 properties with farm-related activities falling within floodplains, whereas less than 7% of food premises are within a floodplain. However, these estimates are only reflective of riparian flooding and do not consider urban areas where most food premises currently exist in the Region[cc]. While there is a significant amount of food production in York Region, it is not clear how much is distributed and available for consumption within York Region.

As there is limited information on urban floodplains, the number of potentially impacted properties from flooding events is likely underestimated. Within Toronto, urban and river flooding was identified as the largest risk to food retail, processing and suppliers compared to other extreme weather events.[189] Heat waves and ice storms were noted to potentially play an important role in power outages, which could impact local food security.[189] Infrastructure impacts relating to disruptions in electricity, road networks and access to fuel were also noted as key areas that could impact potential vulnerabilities.[189]

10.2.3 HEALTH IMPACTS RELATING TO FOOD INSECURITY

While the IPCC reports highlight how climate change will contribute to food insecurity, particularly for developing countries, food insecurity is also an existing and important issue for Canadian populations. Inadequate or insecure access to food due to financial constraints results can lead to difficulties in meeting the dietary needs of individuals and families.[192] Food insecurity status is defined in three categories ranging from marginal to severe. Marginal food insecurity is defined as worrying about limited food selection or not having enough food due to a lack of money. Moderate food insecurity is defined as having to compromise the quality or quantity of food due to lack of money. Severe food insecurity results in having to reduce food intake, skip meals or go without food due to lack of money.[192]

When assessing climate change impacts on food insecurity, it is important to consider how extreme weather events can disrupt access to adequate food for the general public, in particular

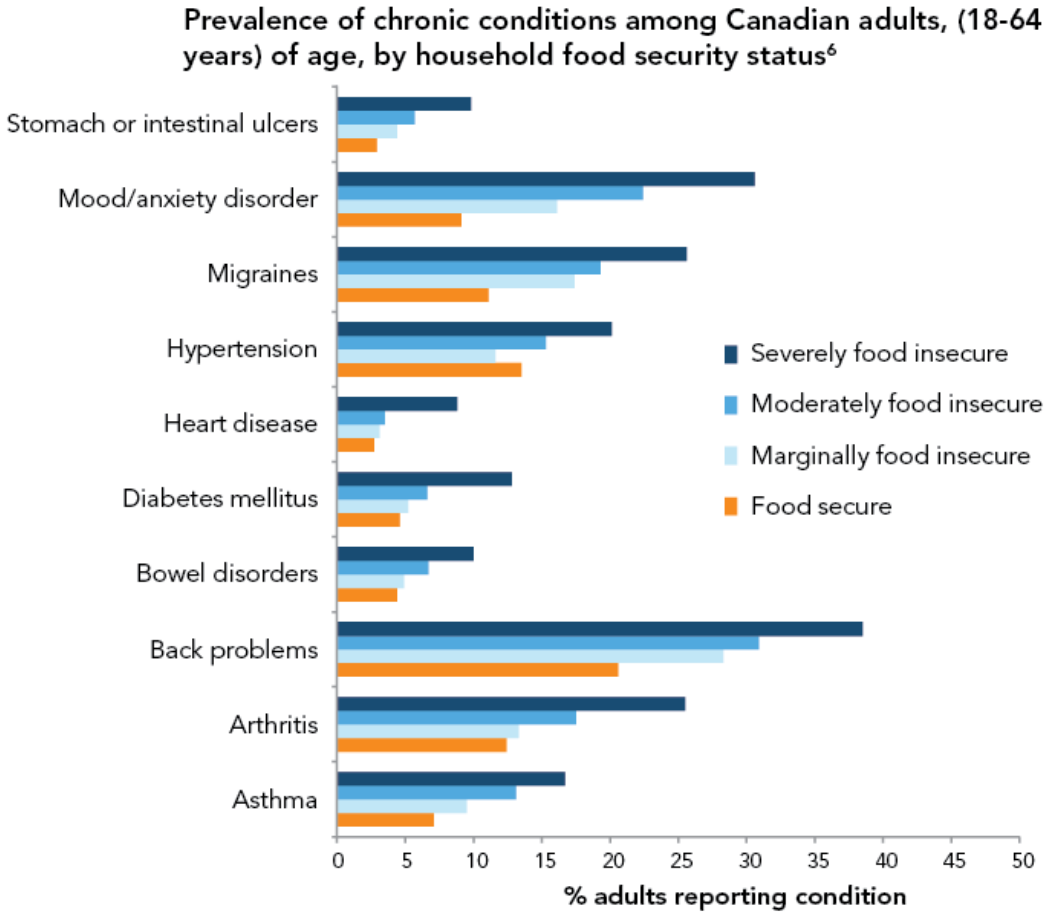
[cc] Note: Floodplain data is provided by Conservation Authorities and are based on watershed hydrology assessments that consider large storm event scenarios. Certain parts of the floodplain maps were created in the early 2000s and may not accurately reflect current conditions.

to those most vulnerable (e.g., individuals or families living on low-income who meet marginal, moderate and severe food insecurity status).

In Ontario, annual health care costs were 49% higher for those living in moderately food insecure homes and 121% higher for severely food insecure homes, even when accounting for social determinants of health such as education and income levels.[193] Food insecurity is also associated with higher mortality rates, which are especially large for individuals in the most severe food insecurity category.[194]

Food insecurity can be a risk factor for chronic diseases. Research shows potential associations with inflammation markers for chronic health conditions such as diabetes, hyperlipidemia and cardiovascular disease.[195] Figure 10.3 highlights how food insecurity status is commonly linked to a wide range of chronic health conditions.

Figure 10.3. Prevalence of chronic conditions among Canadian adults (18 to 64 years of age) by household food security status.



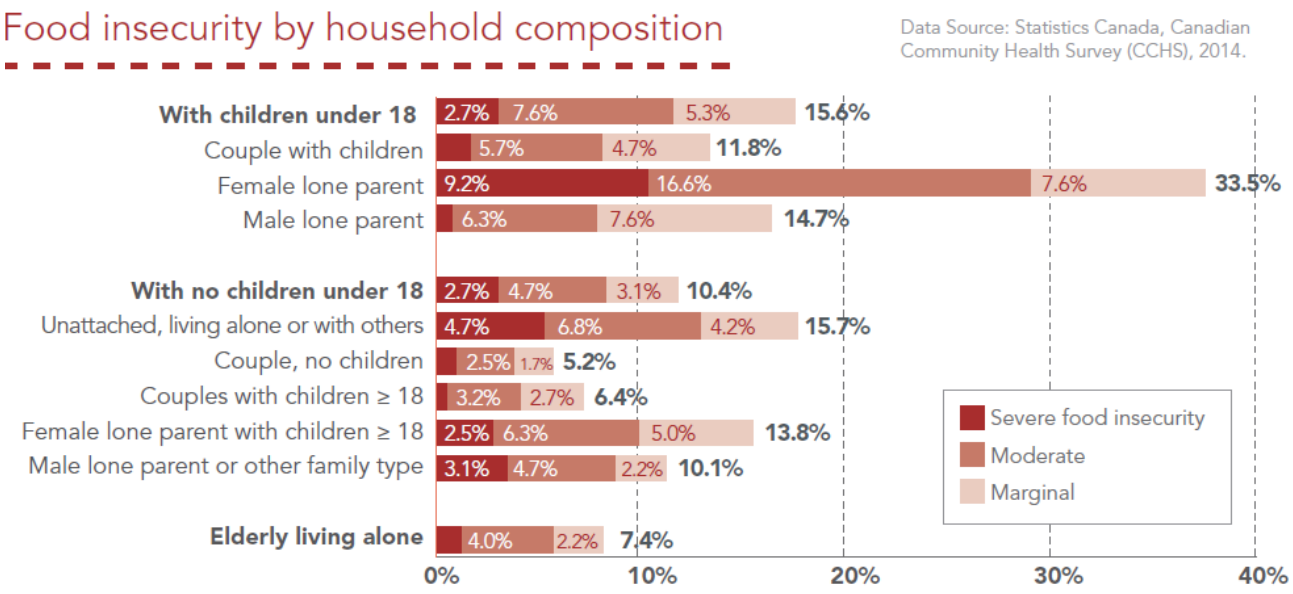
Source: PROOF Food Insecurity Policy Research. The impact of food insecurity on health [Internet]. Toronto: PROOF; 2015. Prevalence of chronic conditions among Canadian adults, (18-64 years) of age, by household food security status. Available from: https://proof.utoronto.ca/wp-content/uploads/2016/06/health-impact-factsheet.pdf. Reproduced under the terms of the Creative Commons 4.0 Attribution International License

Rising food prices due to climate change can also amplify existing health inequities. Increasing food costs are likely to cause even more food insecurity for people already struggling to buy food and may lead to eating cheaper food sources.[187] In many cases, cheaper food options are less nutritious, more processed with higher sugar and fat content. These foods are also less likely to be affected by agricultural price increases, because the majority of their costs come from processing and marketing.[187] This might lead to an increased risk of obesity in children, young adults, smokers and seniors who already have marginal nutritional status, and may contribute to other chronic conditions.[187]

Vulnerable populations

Households in York Region living on low-income will be hardest hit by increased food prices as a nutritious diet will become increasingly unaffordable and less available. As a result of climate change impacts on food systems, certain populations may be more vulnerable due to rising food prices and limited availability of nutritious food. Figure 10.4 highlights findings from the Canadian Community Health Survey, which notes the households most impacted by food insecurity. In particular, one third of households with a single female parent and children under the age of 18 experience some form of food insecurity in Canada.[192]

Figure 10.4. Food insecurity by household composition in Canada.

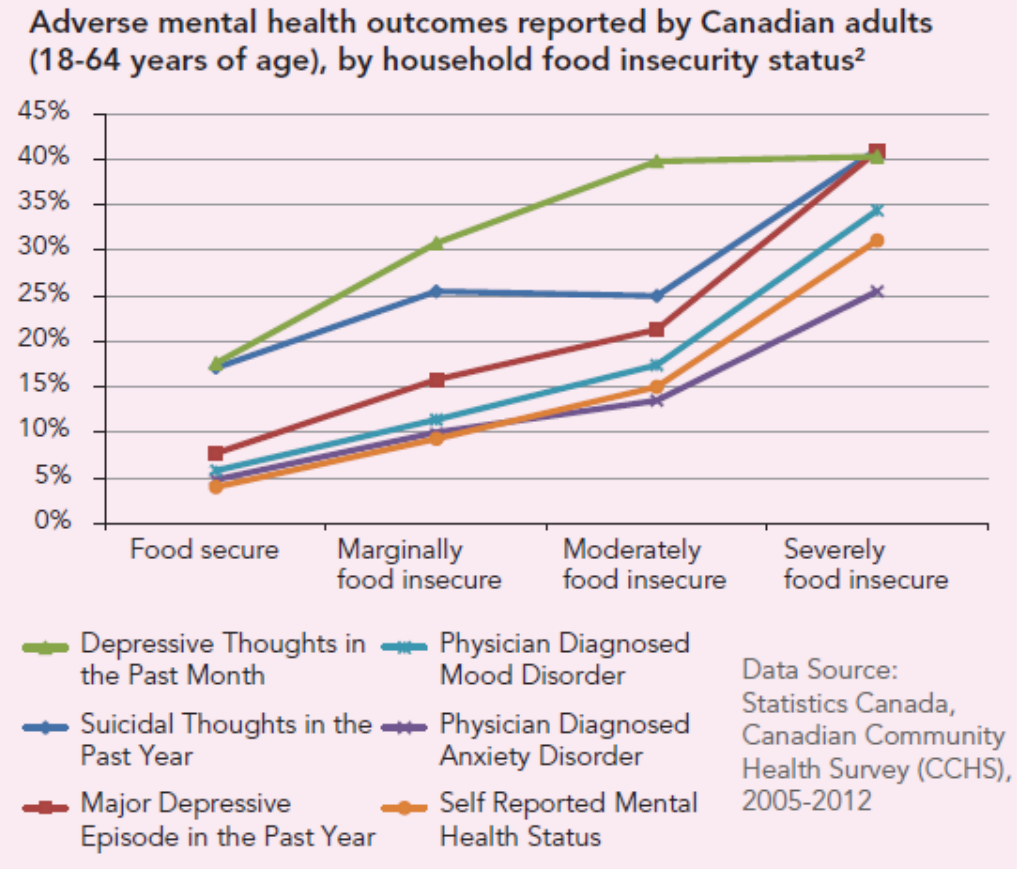


Source: Tarasuk V, Mitchell D, Dachner N. Household food insecurity in Canada 2014[Internet]. Toronto: PROOF; 2016. Food insecurity by household composition. Available from: https://proof.utoronto.ca/wp-content/uploads/2016/04/Household-Food-Insecurity-in-Canada-2014.pdf. Reproduced under the terms of the Creative Commons 4.0 Attribution International License

Mental health has been found to be associated with food insecure households, particularly with increasing severity of food insecurity status. While 1 in 8 households in Ontario is considered food insecure, adults that live in food insecure homes make up more than 1 in 3

hospitalizations related to mental health problems.[196] Figure 10.5 provides an overview of various mental health outcomes by food insecurity status.

Figure 10.5. Adverse mental health outcomes reported by Canadian adults (18 to 64 years of age) by household food insecurity status.



Source: PROOF Food Insecurity Policy Research. Food insecurity and mental health [Internet]. Toronto: PROOF; c2018. Adverse mental health outcomes reported by Canadian adults (18-64 years of age), by household food insecurity status. Available from: https://proof.utoronto.ca/resources/fact-sheets/#mentalhealth. Reproduced under the terms of the Creative Commons 4.0 Attribution International License

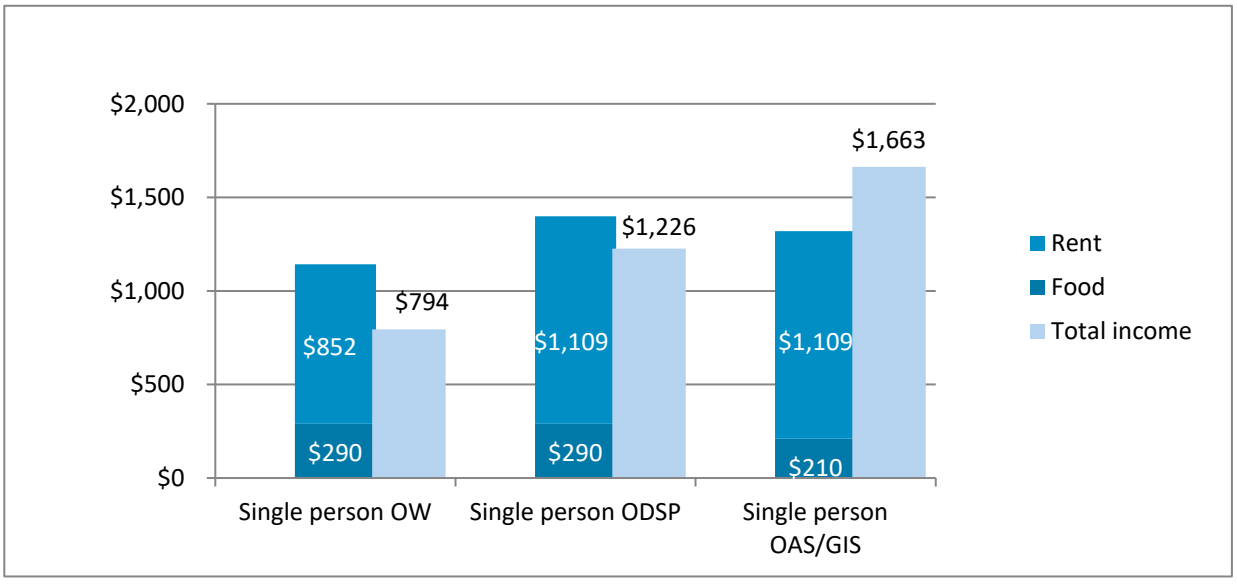
Climate change can also have long-term impacts on children that last into their adult lives.[197] There are also long-term consequences of child malnutrition on education and income as an adult. Children are most vulnerable to malnutrition when they are younger than two years of age. Malnutrition during gestation and during the first three years of life often results in severe and irreversible effects (physical deformity and weakness, delayed motor, cognitive, and behavioural development, increased susceptibility to infection and disease and premature mortality) and leads to reduced productivity and costs to society.[198] Nutrition is also essential for a healthy pregnancy and for breastfeeding. Poor nutrition during pregnancy is linked to problems during delivery, low birth weight, difficulty with breastfeeding and newborn death.[147] See Chapter 4 for more information on vulnerable populations in York Region.

10.2.4 FOOD INSECURITY IN YORK REGION

Between 2009 and 2014, an estimated 7% of York Region households (approximately 24,700 households) experienced food insecurity.[199] Teens and adults in food insecure households eat fewer fruits, vegetables and dairy. They are at risk for inadequate intake of nutrients including protein, vitamin A, folate, B vitamins, magnesium, phosphorus and zinc.[200]

The results from the 2017 Nutritious Food Basket Survey, which measures the cost for healthy diets, indicate that low-income households in York Region often cannot afford a nutritious diet, as shown in Figures 10.6 and 10.7.[201] When comparing income to the cost of food and rent,[dd] a single parent plus two children receiving Ontario Works assistance would need to spend 82% of their income on food and rent, while a family of four with one full-time minimum wage earner would need to spend 68% of their income.[201] Rent and food costs would exceed income for a single person receiving Ontario Disability Support Program assistance or receiving Ontario Works assistance.[201] In contrast, seniors receiving the Guaranteed Income Supplement and Old Age Security would have some remaining money after paying for rent and food. This is consistent with research that indicates the rate of food insecurity in Canadians 60 to 64 years of age is double the rates of those 65 to 69 years of age.[201] Rising food costs stemming from climate change impacts will exacerbate this problem. Additionally, this may cause food-secure households to become food insecure in the future, putting additional individuals at risk.[195]

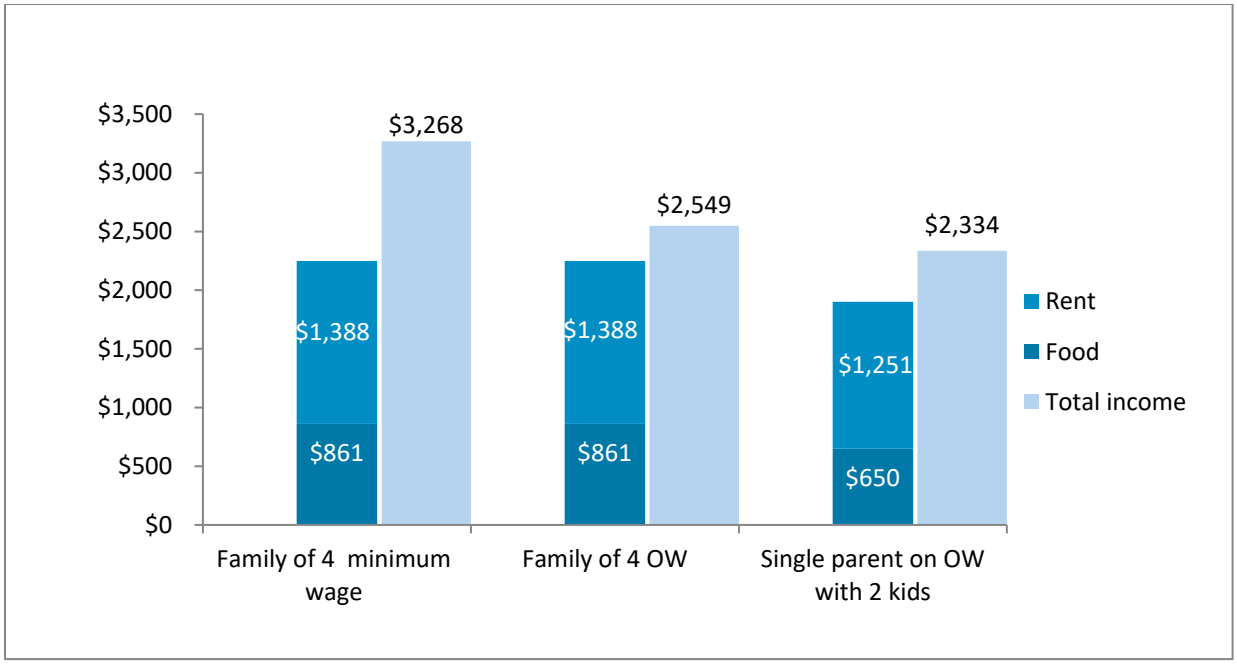
Figure 10.6. Monthly income compared to monthly rent and food costs for individuals in York Region, 2017. OW: Ontario Works, ODSP: Ontario Disability Support Program, OAS: Old Age Security, GIS: Guaranteed Income Supplement.



Source: Regional Municipality of York. York Region nutrition food basket – 2017. Newmarket: The Regional Municipality of York; 2018. Fig.1, Monthly income compared to monthly rent and food costs for individuals in York Region, 2017.

[dd] Rent cost is based on the Canada Mortgage and Housing Corporation average market rents for York Region reported in 2017, and food costs are based on the 2017 Nutritious Food Basket Survey.

Figure 10.7. Monthly income compared to monthly rent and food costs for families, 2017. OW: Ontario Works, ODSP: Ontario Disability Support Program, OAS: Old Age Security, GIS: Guaranteed Income Supplement.



Source: Regional Municipality of York. York Region nutrition food basket – 2017. Newmarket: The Regional Municipality of York; 2018. Fig.1, Monthly income compared to monthly rent and food costs for families, 2017.

10.2.5 ADAPTIVE CAPACITY

Adaptation to climate change needs to be considered at all levels of the food system to increase resiliency. Adaptive capacity for sustainable eating habits depends on human behaviour. Various food banks and pantries[ee] are available across York Region to provide short-term/emergency support to individuals and families that are food insecure. While food banks, pantries and other services targeting food insecurity are critical for those most vulnerable, adequate incomes are needed to address the root cause of food insecurity. As well, building a more resilient food system in terms of production, processing, distribution and preparation will be essential to address the key elements of food security (utilization, accessibility and availability) for all York Region residents. To ensure a more resilient food system, it is important to encourage more sustainable diets and farming practices to help reduce stress on the environment and on food systems.

Current initiatives such as the York Region Food Council support the development of coordinated food-related programs and policies with stakeholders in York Region. The Council also recognizes a multi-pronged approach is needed, guided by the following values from the York Region Food

[ee] Food banks and food pantries collect, store and distribute food to individuals and agencies.

Charter: Health and well-being, environmental sustainability, economic opportunities, equity and social justice, and education and skills.[202]

There are also other initiatives that support building a stronger local food system and mitigate food insecurity issues in York Region including:[201]

- The Good Food Box program, which provides fruit and vegetables at an affordable price, offering food packages focused on local produce
- Food banks and pantries across York Region that provide food to individuals and families in need
- Development and promotion of a local food map in York Region where residents can purchase local products directly from farmers
- Community gardens where residents can grow their own produce
- Community meal events where residents can join others in the community to have meals
- Promotion of land use planning policies and programs that support food access in communities

10.2.6 CONCLUSION

Food security is a complex subject involving multiple variables across sectors (e.g., demographics, economic factors, environmental factors, etc.) and at multiple scales (local, regional, international and global). Based on currently available information, it is difficult to determine the likely impacts from climate change on food security in York Region. Some of the limitations include:

- Limited information on food systems in York Region (e.g., linkages between production, processing, distribution preparation within the Region) and dependence on food systems outside of York Region
- Floodplain maps only consider river and lake flooding with certain watershed areas updated prior to 2010
- How other climate drivers (e.g., extreme weather events, temperature) will impact local food systems and food security
- How local food systems impact food security (availability, accessibility and utilization) for York Region residents, and how other factors such as social determinants of health contribute to food insecurity

Similar to Toronto, weather events that can have important implications for food systems in York Region include flooding, ice storms and heat waves. Additionally, there is limited information on other vulnerabilities that are important to assess climate change impacts on food security. These include:

- Fuel, electricity and transport infrastructure impacts from extreme weather events that could impact distribution and supply of food in York Region

- Impacts on food production from extreme weather events, and capacity of existing food assistance organizations to support food supply challenges during emergency events
- The ability of the general public to shift their consumption to more sustainable diets

To better address food insecurity impacts resulting from climate change, further research is needed to better understand food systems, food security and other determining factors such as social determinants of health. Additionally, efforts to address food safety may also impact food systems and local food security. Table 10.3. provides a summary of activities in York Region relating to food systems and food security, and identifies opportunities for future consideration.

Table 10.3. Summary of food security activities and adaptation planning opportunities.

	Completed and Ongoing Activities	Opportunities
Public Health Assessment and Surveillance	**Population Survey:** Monitoring food intake and nutritional status of the population (e.g., Canadian Community Health Survey Vegetable and Fruit Consumption, Nutritious Food Basket data).	Consider additional food intake data (beyond vegetable and fruit consumption) to inform food security in York Region. **Emergency Preparedness and Response:** Determine information needs for food security issues in York Region (e.g., vulnerability maps, evaluation of components to food security and contributing factors). **Emergency Preparedness and Response:** Consider assessment of food systems in York Region, including local production and supply, and reliance on processing and suppliers outside of York Region. Review transportation climate assessment to better understand potential disruptions in transportation networks that can impact food distribution.
	Completed RRFSS Survey on food security (2016).	Consider additional questions on local food consumption activities and behaviours to better understand vulnerabilities.
Program and Policy	Advocate for adequate incomes for all families. Establishment of York Region Food Charter that aims to "create a thriving, resilient, healthy and just food system for all." Public health nutrition programs and partnerships tailored to most vulnerable populations.	**Health Equity:** Advocate for addressing food insecurity issues for those low-income individuals and families receiving financial assistance and who are potentially food insecure. **Emergency Preparedness and Response:** Ensure key elements of food security (access, availability and utilization) are considered in emergency planning. **Health Equity:** Consider how food security can be incorporated into mental health activities, and better understand the linkages between mental health and food security in York Region. Enhance policy measures for resilient agriculture and local agriculture/horticulture (e.g., processing, storage, food hubs) to support food security as part of the York Region Municipal Comprehensive Review of the Regional Official Plan and the Agri-Food Strategy.

Health Promotion	Promotional activities to increase awareness of the importance of and ways to eat according to Canada's Food Guide, including eating plenty of vegetables and fruits, and plant-based protein foods. Promotion of urban agriculture such as backyard gardening, community gardens, rooftop gardening and local farms in York Region. Fact sheet that discusses built environment factors contributing to food access.	Provide additional messaging to the public to better understand the linkages between climate change and the food system. Support Canada's Food Guide messaging that encourages plant-based protein foods and sustainable diets (which can also be relevant to different cultural and religious dietary preferences) to mitigate the negative health effects of climate change. Expand promotion of food literacy, food waste reduction and backyard composting. Review components of the food system to better understand how the built environment and land use planning policies in York Region can support a more resilient food system and greater food security. Act on findings from this review.
Key Stakeholder Activities (Outside of Public Health)	Initiatives from York Region Food Network that promote food security (e.g., community garden programs, Good Food Box program, Community Cooks program and supporting the York Region Food Council).	Public health consultation with stakeholders on what information could support the York Region Food Council relating to climate change impacts (e.g., food security vulnerability maps). Public health expands support for community agencies in York Region working on food security and climate change issues.

CHAPTER 11
Next Steps

11 Addressing climate change health impacts: Moving towards adaptation planning

"Tackling climate change could be the greatest global health opportunity of the 21st century."[203]
Lancet Commission on Health and Climate Change

This assessment provides a comprehensive overview of a wide range of potential climate change impacts to health. In particular, the strengths of the assessment include:

- Reviewing the latest research and data to understand impacts in York Region
- Highlighting local vulnerabilities and gaps in knowledge
- Identifying opportunities for future climate change adaptation planning

A wide range of topics were addressed to capture the different pathways in which climate change may impact human health. These include direct pathways such as extreme temperatures, and indirect pathways such as vector-borne disease or food and water safety.

There is strong supportive scientific evidence that climate change will impact extreme heat events and heat-related illnesses, the spread and activity of vector-borne diseases and mental health impacts from extreme weather events. Floodplains and urban heat islands are also important local factors that can influence health risks from climate change in York Region. However, due to multiple mediating factors, it is difficult to apply the research findings to York Region's context for other impacts: Food safety and security, water quality (drinking water and recreational beaches), outdoor air quality and extreme weather event impacts on disease, injury and indoor air quality.

11.1 LIMITATIONS

While this report provides a comprehensive overview of the climate change health impacts in York Region, there were limitations in assessing vulnerabilities. These include:

- **Limitations in available scientific evidence**
  - Limitations in climate projection data (e.g., uncertainties in existing models predicting extreme weather events and uncertainties in future emissions)
  - Limited evidence on more complex exposure pathways with multiple mediating factors (e.g., food security, food and water safety and extreme weather events)

- **Limited local information to better understand vulnerabilities in York Region**
  - Limited data on mediating environmental factors to climate change impacts (e.g., assessment of local air quality including pollen at a higher spatial resolution and updated floodplain maps to include urban flooding risk)
  - Limited data to understand local population health and risk factors (e.g., health outcome data which focused exclusively on more severe cases such as hospital visits and admissions, and vulnerability of private wells used for drinking water)

- Limited information on adaptive capacity (e.g., residents' knowledge, behaviours and barriers to adaptation measures)

Hospital and reportable diseases data are likely underestimating the health burden as many cases may go unreported or are challenging to link to climate change exposure route(s). Enteric disease rates provide an indication of potential food and water sources, but attributing specific sources can be difficult. Similarly, asthma and allergies provide an understanding of respiratory conditions, but further analysis is needed to link climate change to local air quality impacts.

Further analysis is also required to help develop the most relevant indicators for future surveillance, including criteria for syndromic surveillance and to model the future impacts from climate change on health. Future adaptation planning will need a strong understanding of the linkages between climate variables and health outcomes, such as heavy rainfall or flooding events with food and waterborne illness, and extreme heat events with health outcomes such as mental health. Research has shown many of these health outcomes may increase in terms of volume and/or frequency (e.g., increased emergency room visits for heat-related illness due to longer and warmer summers).

Many of these datasets also involve other stakeholders (e.g., diseases of public health significance surveillance from provincial Ministries and flood mapping from Conservation Authorities). As a result, it will be important to consult other agencies on available datasets and opportunities to advance data collection that can help inform future surveillance activities and better understand health impacts from climate change.

11.2 ADAPTATION ASSESSMENT AND PLANNING

While gaps in available information and research presently exist, this assessment provided an overview of how climate change is expected to impact human health in York Region. Using the World Health Organization vulnerability assessment process, this report supports the first steps in assessing climate change health impacts and existing adaptive capacity within York Region.

The next steps in the adaptation assessment and planning process are to identify and prioritize adaptation measures and create an iterative process for monitoring and managing health risks. Public health adaptation measures may include surveillance, additional research, health promotion activities, policy development and coordinating activities with stakeholders.

Part of this process may involve filling knowledge gaps identified in the assessment. For example, more analysis of existing health data sets is needed to inform future surveillance planning and indicator development. Additional information is also needed to better understand community needs, barriers and opportunities for adaptation. This will help support the development of an iterative management and monitoring process to tackle climate change health impacts.

Identifying and prioritizing adaptation measures could include developing an inventory of options to be explored by public health and relevant stakeholders. Existing government agency reports provide valuable information on the strength of evidence of various climate change and health interventions, such as a systematic review of interventions Bouzid et al., [204] and the United States CDC Climate and Health Intervention Assessment.[205] These assessments of available intervention options also note the limitations in the strength of evidence. The limitations can provide important insight on how existing measures can

be evaluated to inform future public health best practices and interventions. After determining suitable options, cost benefit analysis or multi-criteria analysis can be considered.[171]

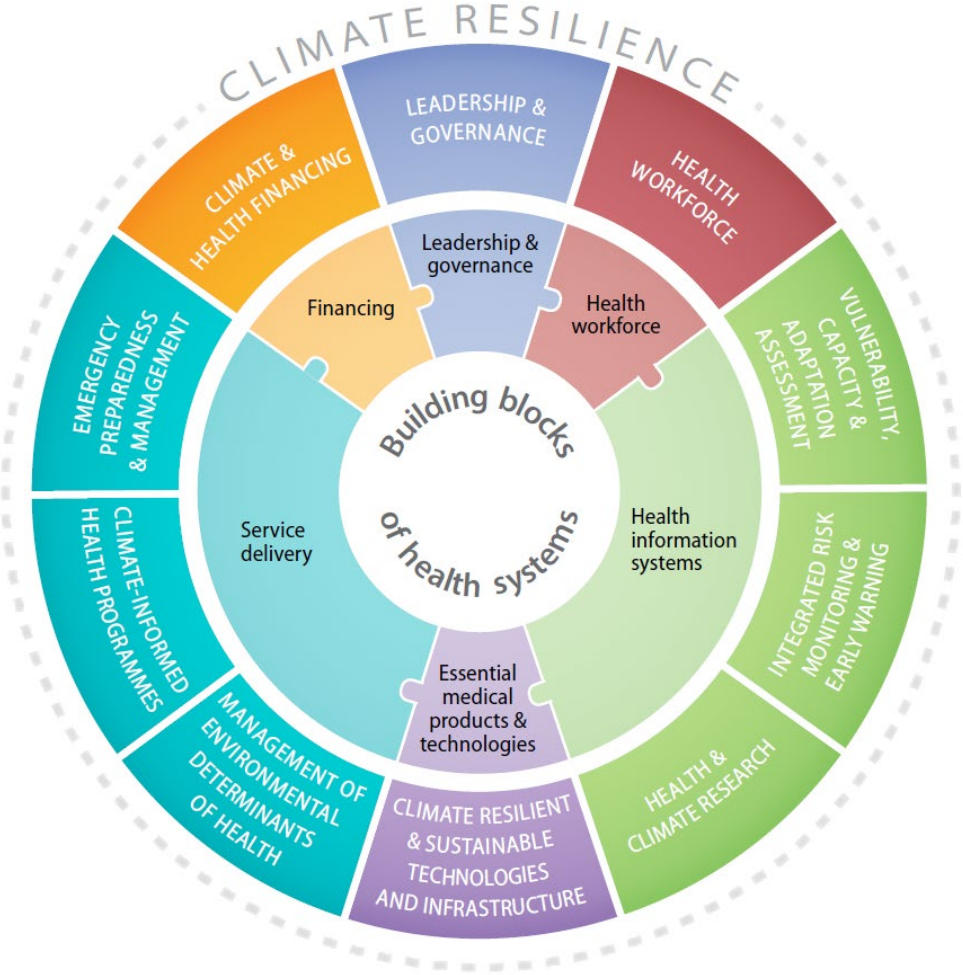
Adaptation planning and building greater resiliency to climate change health impacts requires the engagement of multiple stakeholders. This vulnerability assessment has identified the important role other stakeholders play in addressing climate change health impacts. The successful implementation of adaptation measures will depend on the involvement of multiple stakeholders across various sectors and is a key component of the adaptation assessment and planning process.

The World Health Organization Operational Framework for Building Climate Resilient Health Systems[206] (2015) notes the importance of building resilient health systems – the capacity of health system stakeholders to cope with and address health risks that climate change will pose without compromising the existing functions of health system organizations. As future climate conditions and impacts are difficult to predict, there needs to be an increase in the capacity of the health system to allow greater preparation and adaptation to different future scenarios.

Figure 11.1 illustrates the 10 components of a resilient health system. These components will involve stakeholders from various sectors as well as stakeholders at the local, provincial and federal levels. Federal agencies such as Health Canada, Environment and Climate Change Canada and the Public Health Agency of Canada provide early warning systems (e.g., weather alerts, wildfire surveillance, Air Quality Health Index) and valuable support on health and climate research.

Provincial agencies such as the Ontario Ministry of Health provide protocols and guidelines for local health units that help address and support climate change health impacts. Additionally, Public Health Ontario provides research and assessment support on health impacts related to environmental exposures, and provides direction on health surveillance needs based on national and provincial surveillance results.

Figure 11.1. Building blocks for health system resiliency.



Source: World Health Organization, Public Health and Environment Department. Operational framework for building climate resilient health systems [Internet]. Geneva: WHO; 2015. Fig.3, Building blocks of health systems; p.12. Available from: https://apps.who.int/iris/bitstream/handle/10665/189951/9789241565073_eng.pdf?sequence=1. Reproduced with permission from the copyright holder.

While the 10 components of a resilient health system are valuable to help address health impacts from climate change, adaptation planning should also consider other sectors (e.g., forestry, municipal infrastructure and transportation). These sectors may also be addressing climate change impacts through mitigation or adaptation, which may have co-benefits or unintended impacts to health (e.g., tree planting initiatives can reduce urban heat islands, but could also impact allergen levels or wildfire risk).[171] Identifying linkages with other sectors will help support the creation of effective public health adaptation measures and reduce barriers. The Ministry of Health toolkit provides a number of suggested steps, including identifying existing efforts from other jurisdictions, such as at the provincial and federal level.[6]

11.3 EXISTING INITIATIVES SUPPORTING CLIMATE CHANGE AND HEALTH

Mitigation and other health co-benefits as important to consider for adaptation planning. While the focus of this assessment was to support future adaptation planning, it is important to continue to consider opportunities for mitigation (i.e. reduction of greenhouse gas emissions). The recent Intergovernmental Panel on Climate Change report highlights how increased emissions will continue to

increase average global temperatures, with more damaging impacts occurring at 2˚C compared to 1.5˚C.[207] The recent Lancet Report on climate change also recognizes the co-benefits "no regret" mitigation and adaptation responses provide, which will ultimately support reducing the health burden.[203]

Regional Climate Change Action Plan

York Region committed to developing a Regional Climate Change Action Plan to help maintain community health and address climate change locally. The Action Plan will cover mitigation and adaptation, and consider actions at the corporate and community levels. This assessment and future health adaptation planning support and align with the Action Plan.

Many other Regional plans and initiatives currently support climate change mitigation and adaptation and provide important opportunities to align with the Regional Climate Change Action Plan. These initiatives occur across different sectors and can also support Public Health adaptation planning:

- **The Corporate Energy Conservation and Demand Management Plan** supports Regional services to reduce GHG emissions
- **The Regional Official Plan** provides important opportunities for incorporating health co-benefits such as design conducive to active transportation, or addressing urban heat islands and air quality
- **The Regional Forest Management Plan and Greening Strategy** provide important measures for mitigating greenhouse gases and enhancing resiliency to climate change
- **The Transportation Master Plan** and the **Streetscape Program** provide opportunities for community mitigation, reducing exposure to climate drivers such as extreme temperatures and ensuring resiliency to extreme weather events
- **The Water and Wastewater Master Plan** considers climate change and future extreme weather impacts that can impact the supply and treatment of water and wastewater across the Region

Other initiatives also offer opportunities to support populations vulnerable to climate change:

- **York Region Seniors Strategy:** The Seniors Strategy looks at the changing senior population, defines the Region's role in serving seniors and sets the course for action to best support the aging population over the next 10 to 20 years
- **Mental Health Initiative:** The Public Health Branch Mental Health Initiative was created to develop a sustainable strategy to integrate mental health promotion into Public Health programs and services, including partnering with community agencies to help access supports
- **Health Equity Program:** The goal of this program is to apply a health equity perspective to the planning and implementation of Public Health programs and services to assist in the reduction of social inequities in health for the residents of York Region

11.4 NEXT STEPS

Additional work will be completed to address some of the gaps identified in this vulnerability assessment and determine the next steps in the health adaptation planning process. This work will determine the most appropriate public health measures needed to address future impacts from climate change and increase resilience.

Opportunities for adaptation measures that could be explored include:

- Further research and analysis to better understand climate change health impacts and vulnerable populations within the Region
- Establishing integrated, ongoing climate change and health surveillance
- Health promotion activities on climate change health impacts and adaptation measures
- Coordinating programming and collaborating with key stakeholders across sectors
- Integrating climate change considerations into existing public health programs and activities
- Advocating for and developing policies and measures that support climate change mitigation and adaptation

York Region is well-positioned to address the multiple health impacts of climate change with opportunities to align public health adaptation planning with existing initiatives such as the Regional Climate Change Action Plan.

Climate change is one of the most significant public health challenges of this century. Addressing future impacts of climate change will present a public health opportunity to address multiple factors impacting human health, including extreme temperatures and weather, water and food safety, vector-borne diseases, air quality and emergency preparedness. Public Health must continue efforts to address the future health impacts of climate change and support creating more resilient communities in York Region.

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