

Climate Change and Health Vulnerability Assessment

for Waterloo Region,
Wellington County,
Dufferin County, and
the City of Guelph



About This Report

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How to Read This Document

This report describes several key areas to support the assessment of climate change and health vulnerability to support the development of adaptation options for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph.

The report is structured according to three primary goals. First, it begins by outlining the overarching scope and focus of the assessment before outlining the methodology that supported the assessment of health vulnerability to climate change locally. Second, it provides a review of public health evidence related to climate change, including evidence-based reviews of health risks, population vulnerabilities and adaptive actions for extreme temperatures, ultraviolet radiation, extreme weather, food- and water-borne illnesses, air quality, vector-borne diseases, and mental health. Each of these stand-alone subject matter chapters contains a key findings section which is available for download and has additionally been adapted as an infographic depicting key statistics, and trends on the health impacts of climate change locally. Third, it utilizes information from each topic specific chapter to present the results of a rapid risk assessment to help support adaptation planning through the consideration of programs, practices and policies that can reduce vulnerability. Supporting documentation is included in the appendices.

The report is organized according to key health impact areas associated with climate change. While it is anticipated that the report in its entirety will be of use to many stakeholders, each chapter is designed to be a standalone resource that provides best available research evidence and data for the study area. The report also communicates spatial evidence and patterns of risk according to climate-sensitive health outcomes for municipalities across the study areas and depicts risk maps associated with existing population-level vulnerability characteristics, for where spatial data is available. The authors encourage partners to use the evidence presented in this report to further support the development of climate change adaptation and mitigation initiatives, and to consider how health impacts of climate change can be reduced through appropriate community actions.



Executive Summary

Climate change is a defining public health challenge of the 21st century is already impacting the health of Canadians. To better understand baseline vulnerabilities to climate change and health risks under future climate scenarios, public health agencies around the world are conducting climate change and health vulnerability assessments to synthesize available data and evidence to help inform public health action(s) through the lens of climate change, with the goal of reducing climate-related health risks and impacts, and to reduce health inequities.

The purpose of this vulnerability assessment is to evaluate the climate-related health risks to people who live, work and play in the jurisdictions of Wellington-Dufferin-Guelph Public Health (WDGPH) and Region of Waterloo Public Health (ROWPH). The report focuses primarily on identifying vulnerable populations, understanding patterns of climate-related vulnerability, providing baseline health information, and outlining existing adaptive capacity. The report also explores how climate change interacts with the social determinants of health and health inequities, and how unequal distribution of income, education and social and environmental conditions affect these inequities. This assessment covers climate-related health impacts of concern (including physical, mental and community health impacts), including extreme temperatures, ultraviolet radiation exposure, extreme weather, air quality, vector-borne and zoonotic diseases and food- and water-borne illnesses. While mitigation is largely beyond the scope of this report, it should be noted that when done well, reducing greenhouse gas emissions through energy transitions is an opportunity to reduce vulnerability to a changing climate, especially for vulnerable populations. Key recommendations of this report can be used to strengthen core functions of health systems to explicitly consider the health risks posed by a changing climate, and to modify current health risk management activities to maintain and improve current levels of population health.

Assessment Approach

Climate Change and Health Vulnerability Assessments (CCHVAs) assess vulnerability through an assessment of exposure, physiological sensitivity, and adaptive capacity, which is also reflected in current burden of illness and associated health protection programs. This CCHVA was guided by several key tools, including the *Ontario Climate Change and Health Toolkit*,⁽⁵⁾ Health Canada's *Climate Change and Health Vulnerability and Adaptation Assessment: Workbook for the Canadian Health Sector*,⁽²⁾ as well as the World Health Organization's (WHO) *Protecting Health from Climate Change: Vulnerability and Adaptation Assessment guide*.⁽³⁾ ROWPH and WDGPH also looked to other Ontario Public Health Units that have completed similar CCHVAs.

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

1. **Exposure** of populations to climate-related hazards,
2. **Physiological sensitivity** of individuals or populations to climate-related hazards, and
3. **Adaptive capacity** of individuals, populations and/or systems to cope with climate-related hazards.



The report also considers adaptive actions that already exist in the study area to address climate-related health impacts of concern. These include public health-related actions and community-driven actions.

The assessment is comprised of numerous research methods including literature reviews, surveys, focus groups, and analyses of secondary data. Key methodological tools used to complete this assessment include:

- Literature review – Targeted literature reviews were conducted for each climate-related health risk identified by the Ontario Climate Change and Health Toolkit. The report used PubMed, MEDLINE, and Web of Science, limiting results to the past 10 years.
- Stakeholder engagement – Surveys, focus groups, and workshops were used to collect insights from key Public Health staff, sustainability and/or climate change teams or departments from municipal and regional governments in the study area, Conservation Authorities, Health Canada, and local academic institutions.
- Statistical analysis – To track trends in health data over time, where appropriate, Pearson's R correlation tests were undertaken; other specific methods are outlined for relevant data points in the chapters that follow.

Limitations of the Assessment

Notwithstanding the deployment of the evidence-based approach utilized to conduct this assessment, there are still several limitations of the report that should be taken into consideration as they relate to data and stakeholder engagement.

Data

The data presented in each subsequent chapter should be conceptualized as a reflection of the best available data at baseline for each health unit, which was completed from 2018-2020. Despite the comprehensive nature of this report, there are still challenges associated with data, including:

- Health data are often not recorded in relation to climate-related phenomena. This makes tracking health outcomes from a specific event (e.g., heat wave, heavy rainstorm) challenging without appropriate data. Given that most historical baselines in this assessment go back to 2010 for health data, this temporal frame may not be long enough to establish trends related to climate phenomena.
- Despite reporting on the spatial distribution of health data for many health outcomes discussed in the chapters that follow, not all health data is able to be displayed at the level of census-subdivisions, primarily due to the small number of cases for some health outcomes. This limits the ability to generate spatially driven hypotheses around vulnerability factors and human health.
- While each chapter provides an exhaustive list of known factors that modify vulnerability for specific climate-related health outcomes, it is not currently possible to stratify health-related outcomes for all demographic data (e.g., income, race/ethnicity).



Engagement

Notwithstanding the engagement activities that were undertaken to support this assessment, engagement strategies had several limitations, including:

- Given the time and resource constraints, it was not possible to engage a representative sample of participants from the study area.
- Due to the on-going COVID-19 pandemic, subsequent engagement activities beyond the activities undertaken in 2019 and early 2020 were limited.

Climate Change Projections

The climate is changing. According to recent studies, Canada has been warming at roughly double the global average over the last six decades. This means that an increase of 2°C in average temperatures globally could mean that Canada could see a change of 3 to 4°C. Over the past half-century, Canada has already experienced an increase in temperatures, altered precipitation patterns, and an increase in the frequency, intensity, and duration of extreme weather events. These changes are expected to continue, with implications for future vulnerability.

To prepare for the health outcomes of climate change it is important to understand how the climate is expected to change within the study area in the immediate, short, and long-term. The climate in the study area is expected to change in congruence with the national changes outlined above. More specifically, the study area can expect an overall increase in the extreme and average temperatures across all seasons, increases in the duration, frequency, and intensity of precipitation events, and an increase in other acute extreme weather events, such as freezing rain or storms. According to local projections, the study area may experience the following climatic trends over the next century:

Temperature

- Increase in average minimum, maximum, and mean temperatures across all seasons.
- Increase in the number of tropical nights (nighttime temperatures >20°C) and extreme heat days (daytime temperatures >30°C).
- Increase in the frequency of heat waves.
- Decrease in the frequency of extreme cold days (daytime temperatures <15°C).
- Temperature increases will be more apparent in urban areas due to the urban heat island effect (UHI). Air temperatures in larger cities might be 1 to 3°C higher than those of rural surroundings.

Precipitation

- Increase in average seasonal rainfall in winter and spring, and a decrease in summer and fall.
- Increase in extreme precipitation, especially during one-time events.



Extreme Weather

- Increase in the number of freezing rain events, particularly in December, January, and February

It is important to note that uncertainty is an integral part of the study of climate change. Uncertainty is factored into climate change scenarios, models, and data, and reflects the complex reality of environmental change and the evolving relationship between humans and the planet. Climate change cannot be predicted with absolute certainty in any given case, and all data must be considered with this in mind.

More detailed climate change projection data for the study area can be found in the Climate Science Report for the Climate Change and Health Vulnerability Assessment for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph,⁽⁴⁾ which was developed as part of this project. All data for ensemble climate modeling contained in the report were accessed from the Ontario Climate Change Data Portal utilizing data from Climatedata.ca in October of 2019.

Climate-related Health Impacts

According to Health Canada's 2014 assessment of climate change and health, "all Canadians are at risk from the health impacts of climate change." Without appropriate actions to mitigate greenhouse gas emissions and adapt to changing climate conditions, the health impacts of climate change could lead to overburdened healthcare (e.g., increases in hospitalization) and public health systems (e.g., increased response to outbreaks, disease investigation, and need for emergency response), avoidable deaths and illnesses, and billions of dollars in damages.

Ontario's Climate Change and Health Toolkit provides an overview of six key climate-related health impact categories of concern for Ontario's public health organizations. These include extreme heat and cold, UV radiation, extreme weather events, air quality, water- and food-borne illnesses, and vector-borne disease. For this assessment, a seventh category that encapsulates the mental health impacts of climate change was also included. Executive Summary Table A below provides a summary of the climate-related impacts in the study area, including climate projections and exposure routes. More information about these impacts and exposure routes can be found in the following chapters of this assessment.



Executive Summary Table A: Overview of Climate Change Related Health Impacts in Wellington-Dufferin-Guelph and Waterloo Region

	Climate Projections	Exposure Route	Key Impacts to Human Health
Extreme Heat and Cold	<p>Increase in extreme and average temperatures across all seasons.</p> <p>Lower frequency of extreme cold events, however, increased severity of cold weather events (e.g., flash freeze, freezing rain).</p>	<p>Urban areas will be more acutely affected by increases in temperature as heat rises and radiates from these surfaces.</p> <p>Areas potentially most impacted by UHI include the most densely populated urban areas within the study area. These areas also have higher percentages of the population living in apartment buildings with 5 or more storeys.</p>	<p>Increased heat-related illnesses and deaths.</p> <p>Emergency department visits for heat-related illnesses are higher today than they were in 2008 in the study area, and roughly follow trends of observed heat warning occurrences.</p>
Ultraviolet Radiation	<p>Depletion of stratospheric ozone by some of the same gases responsible for climate change (e.g., chloro- and fluorocarbons).</p> <p>Temperature-related changes to stratospheric ozone chemistry, delaying recovery of the ozone hole.</p>	<p>The study area experiences consistently higher than national average UVR due to its southern geographical location within the country.</p> <p>Areas with low tree cover may be more exposed to UVR due to reduced shade cover, including Kitchener, Cambridge, and Guelph.</p>	<p>Sunburns and skin damage (e.g., wrinkling), skin and eye cancers, DNA damage, immune suppression, cell atrophy, and cataracts.</p> <p>Emergency department visits between 2008-2018 for sunburn are higher in Wellington-Dufferin-Guelph (ranging between 13.1 to 21.9 per 100,000) than Waterloo Region, (ranging between 3.7 to 10.8 per 100,000).</p>



	Climate Projections	Exposure Route	Key Impacts to Human Health
Extreme Weather Events	Increase in the frequency and severity of extreme rainfall and freezing rain events.	Increase the risk of flooding, slippery conditions and flash freeze events. Residents living in floodplains are at an increased risk from heavy rainfall and flooding events.	Injuries, illness, and death from violent storms, floods, and ice. Crude hospitalization rates from falls are increasing throughout the study area, but not all falls will be weather-related.
Water- and Food-borne Disease	Increase in extreme and average temperatures across all seasons. Increases in the frequency and severity of rainfall events.	Impacts to drinking water systems (particularly private wells) and recreational beaches. Residents living in floodplains with private wells may be at higher risk of water-borne illnesses.	Increased risk of exposure to pathogens and contaminants in drinking water and food due to increasing temperatures driving higher replication and survival rates of pathogens. Bacterial lab analysis of private drinking wells between 2015-2019 indicated that 10.7% of samples submitted from wells tested in WDGPH and 12.2% of samples submitted from wells tested in ROWPH had “evidence of bacterial contamination.” ¹ In 2018, among wells that were tested in Wellington-Dufferin-Guelph, 21% showed evidence of bacterial contamination.

¹ Evidence of bacterial contamination” includes both “significant evidence of bacterial contamination” and “unsafe to drink” results as defined by Public Health Ontario (see: <https://www.publichealthontario.ca/en/laboratory-services/well-water-testing?tab=4>)



	Climate Projections	Exposure Route	Key Impacts to Human Health
Vector-borne Diseases	<p>Increases in average and extreme rainfall events.</p> <p>Increase in extreme and average temperatures across all seasons.</p>	<p>Longer disease transmission season as temperatures increase.</p> <p>More stagnant water – enabling mosquito population growth.</p>	<p>Increased risk of existing vector-borne diseases such as West Nile virus and Lyme disease.</p> <p>2020 data for Ontario shows an expansion of Lyme disease estimated risk areas into the study area.</p>
Air Quality	<p>Increased temperatures increase the intensity, frequency, and severity of smog events (ozone).</p>	<p>Increase in moderate to high-risk air quality days with smog episodes for urban areas, and reduced air quality near large transportation routes.</p> <p>Residents living near major transportation routes or who commute to the greater Toronto area may be more exposed.</p>	<p>Increased respiratory and cardiovascular diseases, worsened allergies, and premature death.</p> <p>The annual number of premature deaths associated with air pollution (PM_{2.5}, ozone and nitrogen dioxide) in 2016 was 257 in ROWPH and 138 in WDGPH.</p>
Mental Health	<p>Increase in severity and frequency of extreme weather.</p>	<p>Destruction to the physical environment, reduction in services, and destruction to social fabric through abrupt events or gradual consequences of climate change.</p>	<p>The consequences of climate change may lead to decreased mental health and aggravation of the root causes of mental illness, including possible increases in crime, violence, and substance misuse.</p> <p>Emergency department visits for both depression and suicide/self-harm have increased in study area between 2010-2018.</p>



Vulnerable populations

The impacts of climate change are not experienced equally by all populations. While Canadians are already experiencing the ill-health effects of climate change, Health Canada notes that seniors, children and infants, people experiencing social or economic disadvantage (e.g., low-income, housing insecure), Indigenous Peoples, residents of northern and remote communities, and those with chronic diseases and/or compromised immune systems are particularly vulnerable. Climate change will also interact with the social determinants of health—the social, cultural, and economic conditions that influence individual and group differences in health. Around the world, climate change has been found to disproportionately impact low-income communities and communities of colour, many of whom already experience poor health outcomes. Thus, climate change is expected to worsen existing health inequities without appropriate action. Accounting for existing disparities within and between populations can therefore help us understand the nuances of vulnerability for specific populations.

Executive Summary Table B below outlines key vulnerable populations of concern within Wellington-Dufferin-Guelph and Waterloo Region. They include populations that are both physiologically sensitive to climate change impacts, those who may be more exposed to climate change and its impacts due their occupation or physical location, as well as populations who may lack the ability to adapt to climate change impacts due to varying circumstances. More information about these vulnerable populations and how they are affected by climate change can be found in the following chapters of this report.

Executive Summary Table B: Populations Vulnerable to Climate Change in Wellington-Dufferin-Guelph and Waterloo Region

	Vulnerability to Climate Change	Study Area Socio-demographics
Children	<p>More time spent outdoors than the average population as well as physiological sensitivity mean that children experience a higher burden of preventable illnesses and death from environmental hazards.</p> <p>Developing immune systems also translate to higher risk of poor air quality related asthma.</p>	<p>The proportion of children aged 0-14 relative to the total population is identical across both health unit regions at 17.8%.</p>
Seniors	<p>Older adults may be more vulnerable to higher temperatures and chronic dehydration by virtue of natural physiological changes.</p> <p>Reduced lung function also leaves older adults more vulnerable to air quality related health complications.</p>	<p>Wellington-Dufferin-Guelph contains a senior population of 15.8% while that number in Waterloo Region is 14.4%.</p> <p>The proportion of seniors in Ontario is projected to double by 2030.</p>



	Vulnerability to Climate Change	Study Area Socio-demographics
Individuals with Low Socioeconomic Status	Those with fewer material resources tend to have less access to health and social services, higher stress, are more likely to be underemployed and may struggle to access housing and nutritious food. These factors can lead to a lower capacity to adapt to the impacts of climate change.	After-tax low-income prevalence rates are 9.9% in Wellington-Dufferin-Guelph and 12.2% in Waterloo Region compared to 14.4% provincially as of 2016.
Recent Immigrants	Linguistic isolation and misunderstanding of climate related alerts may increase vulnerability.	The proportion of recent immigrants (immigrated 2011-2016) is 9.7% in Wellington-Dufferin-Guelph, 11.8% in Waterloo Region, and 3.6% provincially.
Outdoor Workers and Activity	Those who spend long periods of time outdoors for work or leisure are more exposed to the impacts of climate change including extreme weather, extreme temperatures, ultraviolet radiation, low air quality, and vector-borne diseases.	Outdoor workers account for 10.8% of the Wellington-Dufferin-Guelph population and 8% of Waterloo Region.
Socially and Physically Isolated Individuals	<p>Social connectedness may strengthen resilience and adaptive capacity by creating access to health promotion resources and social supports.</p> <p>Isolation may be experienced due to a host of factors including language barriers and mental health conditions which may increase vulnerability.</p> <p>Physical isolation may present itself in areas which are rural or remote and may create challenges when people attempt to leave impacted areas (e.g., during flooding events).</p>	<p>Social isolation is difficult to quantify as it may affect all sections of the population and is quite fluid. However, linguistic isolation may be used as a partial indicator of total social isolation. In the Waterloo Region 1.8% of the population speaks neither English nor French while this number is 0.9% in Wellington-Dufferin-Guelph.</p> <p>Physical isolation can present risks to residents of the study area who may require medical services only offered in major urban centres.</p>
Individuals with Existing Chronic Diseases	Chronic conditions may present a wide range of challenges which may impede adaptive capacity including dependence on caregivers, mobility challenges, cognitive impairments, and others.	<p>50.2% of the population of Wellington-Dufferin-Guelph and 50.8% of the Waterloo Region are living with a chronic condition as of 2016.</p> <p>80% of Ontarians 45 years of age and older live with at least one chronic condition.</p>



	Vulnerability to Climate Change	Study Area Socio-demographics
Individuals with Mental Health Conditions	Those with mental health conditions may encounter increases in social isolation and stigmatization leading to increased vulnerability.	According to the CMHA , 20% of Canadians will experience a mental health problem or illness in a given year; however, stigmatization and underreporting leave the topic difficult to quantify.

Adaptive Actions

In addition to identifying vulnerable populations of concern, this report summarizes key existing adaptive actions within the study area that address climate-related health outcomes of concern. Executive Summary Table C below provides a high-level summary of key actions that are underway both from Public Health and from community organizations in the study area. These actions contribute to the study’s area adaptive capacity, and its ability to reduce harm from climate-related impacts. Recognizing existing actions will be important in the next phase of the assessment when identifying new actions or interventions to address climate-related health risks, and opportunities for integrating climate considerations into ongoing initiatives.

Executive Summary Table C: High-level Summary of Adaptive Actions to Address Climate-related Health Impacts in Wellington-Dufferin-Guelph and Waterloo Region

Health-Impact Category	Current Adaptive Actions
Extreme Heat and Cold	<p>Extreme heat warning notifications are shared with the public and stakeholders through email, websites, and social media.</p> <p>Public Health supports municipal and regional partners with incorporating extreme heat and cold considerations into strategic planning.</p> <p>Warming and Cooling Centres and air-conditioned public spaces are provided by municipalities and community organizations within the study area, and each Public Health Unit offers input into their planning. These are activated by extreme temperature protocols.</p> <p>Surveillance systems, such as the Acute Care Enhance Surveillance (ACES) system are available to obtain alerts and track heat-related illnesses and cold-related injuries in the community.</p>



Health-Impact Category	Current Adaptive Actions
<p>Ultraviolet Radiation</p>	<p>Public Health activities include epidemiological surveillance (i.e., cancer incidence) and health promotion activities (including risk communication and policy development).</p> <p>Each Health Unit shares information on sun safe practices on its website with associated information links, and Public Health actors can circulate or share UV and other climate-related information as it is made available.</p> <p>Each Health Unit also works with partners to develop local Ultraviolet Radiation exposure reduction strategies by taking an approach rooted in strategies of awareness raising, creating supportive environments and healthy built environments through consultations and policy development.</p>
<p>Extreme Weather</p>	<p>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.</p> <p>Local Ontario Health Teams develop surge plans in consultation with key stakeholders to plan and budget for potential surge capacity on healthcare systems and create accountability systems for all facilities potentially impacted by a surge in demand or usage.</p> <p>Local conservation authorities across the study area complete flood mitigation studies, which estimate average annual flood damages and review options to mitigate flood risk by conducting a cost-benefit analysis to investigate the feasibility of implementation options.</p> <p>Upper-tier and lower-tier municipalities have mutual aid agreements to support one another during weather-related events or emergencies.</p>
<p>Water- and Food-borne Illnesses</p>	<p>Public Health assessment and surveillance actions include monitoring incidences of water- and food-borne illnesses, monitoring costs of healthy eating (Nutritious Food Basket), disease and outbreak case investigation, and investigation of enteric diseases and exposure sources.</p>



Health-Impact Category	Current Adaptive Actions
<p>Water- and Food-borne Illnesses</p>	<p>Public Health undertakes education, advocacy, and policy-support initiatives, including supporting safe food-handler training, providing support and funding for peer support programs (including food skills for people living with low income and newcomers), supporting the creation of community and school gardens to create access to locally grown food, and advising on policy statements regarding local food systems and protection of agricultural land.</p> <p>Public Health also supports disease prevention through food safety inspections, monitoring of small drinking water systems, and issuing boil water advisories and receiving notifications from municipal drinking water partners on Adverse Water Quality Incidents.</p>
<p>Vector-borne Diseases</p>	<p>Public Health activities include public education and outreach, disease and vector surveillance programs, and biological treatments (e.g., larvicide) on both known and possible reservoirs of mosquito vectors.</p> <p>Prior to COVID-19, both Health Units in the study area conducted passive tick surveillance to identify black-legged ticks that test positive for Lyme. As of 2020, ROWPH no longer conducts passive tick surveillance. WDGPH continues to conduct active tick surveillance via tick dragging and passive surveillance through supporting tick identification for local residents.²</p> <p>Identification of populations at greatest risk to vector-borne disease and assessment of changes to population health status over time through regular reporting.</p>
<p>Air Quality</p>	<p>Public Health participates in health promotion activities, including sharing information about the Air Quality Health Index, participating in Official and Master Plan reviews and strategic initiatives on built environment and shade policies, supporting policy development and community engagement on active transportation, and preparing position statements on wood smoke.</p>

² For more information, see: <https://wdgpublichealth.ca/blog/lets-talk-ticks>



Health-Impact Category	Current Adaptive Actions
<p>Air Quality</p>	<p>Community actions to address air quality concerns include using tree planting and urban forest strategies to address extreme heat and air pollution, as well as working with Public Health to include air quality considerations in municipal and regional planning activities. These include energy transition plans that are being developed by municipalities across the study area which highlight the important roles of reducing particulate matter from burning fossil fuels, and encouraging more trips be taken using active transportation (e.g., walking, cycling, or rolling) by 2050.</p>
<p>Mental Health</p>	<p>Public Health staff at WDGPH developed an opioid tracking system (Flexible, Accessible, Scalable, and Timely (FAST) Overdose Alert Platform) that works to quickly identify overdose patterns in the community and enhance response time.</p> <p>Staff from ROWPH participate as members of the Waterloo Region Integrated Drugs Strategy to prevent, reduce, or eliminate problematic substance use and its consequences with an emphasis on prevention and harm reduction.</p> <p>A host of initiatives that aim to promote mental health through the provision of education and services (e.g., suicide prevention, crime prevention, child, and youth services, etc.) are present across the study area, many of which are offered by local partners.</p>

This report is an initial step in understanding baseline vulnerabilities to climate change in the study areas of Wellington-Dufferin-Guelph Public Health and Region of Waterloo Public Health. It focuses primarily on identifying climate-related health impacts, analyzing baseline health information, identifying vulnerable populations of concern, and outlining existing adaptive capacity. It is anticipated that the information synthesized in this report will be used to support a variety of public health and community-led adaptation interventions in the future.

Adaptation is a multi-sector issue, and future adaptation interventions must be designed with a collaborative, iterative approach in mind. Reducing local sensitivities to climate change and increasing adaptive capacity will require a joint effort among Public Health, all levels of government, community service organizations, and other key stakeholders. While climate change represents a fundamental challenge to public health now and in the future, this assessment will provide a solid foundation to guide resilience planning and implementation in the study area.



1.0 Introduction

Climate change is a defining public health challenge of the 21st century.⁽⁵⁾ Climate change is already impacting the health of Canadians.^(6–8) According to Health Canada’s 2014 assessment of climate change and health, “all Canadians are at risk from the health impacts of climate change.”⁽⁶⁾

Without appropriate actions to mitigate greenhouse gas emissions and adapt to changing climate conditions, the health impacts of climate change could lead to an overburdened health care (e.g., increases in hospitalization) and public health system (e.g., increased response to outbreaks, disease investigation, and other emergencies), avoidable deaths and illnesses, and billions of dollars in damages.⁽⁹⁾ While there are some mitigating activities that public health agencies can conduct by ‘greening’ public health practice and reducing emissions from core business and advocating for climate action, most actions within the purview of public health are focused on adapting to climate change. While mitigation is largely beyond the scope of this report, it should be noted that when done well, reducing greenhouse gas emissions through energy transitions is an opportunity to reduce vulnerability to a changing climate, especially for vulnerable populations.

To better understand baseline vulnerabilities to climate change and health risks under future climate scenarios, Public Health agencies around the world are conducting climate change and health vulnerability assessments to synthesize available data and evidence that will help inform Public Health action(s) through the lens of climate change, with the goal of reducing climate-related health risks and impacts, and to reduce health inequities.

This report is an initial step in this process whereby it conceptualizes health vulnerability under a changing climate. Accordingly, its focus is primarily on identifying vulnerable populations, understanding patterns of climate-related vulnerability, providing baseline health information, and outlining existing adaptive capacity. While climate change mitigation and adaptive measures being undertaken by other community groups within the study area are out of scope of this report, it is anticipated that the information synthesized in this report will support a variety of public health and community-led adaptation efforts into the future.

1.1 Rationale for Climate Change and Health Vulnerability Assessments

In 2018, the Ontario Public Health Standards (OPHS)—the provincially mandated requirements for Public Health services and programming—were updated. The OPHS require Public Health Units to “use surveillance data to communicate information on risks” with the goal of mitigating existing and emerging risks to the impacts of climate change.⁽⁶⁾ The OPHS also require public health units to assess health impacts related to climate change in accordance with the Healthy Environments and Climate Change Guideline, 2018. The guideline requires Health Units to monitor the impacts of climate change within their jurisdiction to inform local vulnerability plans, engage in multisectoral collaboration, and communicate identified health risks.

Following this policy guidance, and with funding support from Health Canada’s HealthADAPT program, this report seeks to understand the health impacts of climate change in a study area of southwestern Ontario that includes



geographic regions served by two public health units: Region of Waterloo Public Health (ROWPH) and Wellington-Dufferin-Guelph Public Health (WDGPH). The project goals for the assessment include:

- Increasing public and stakeholder awareness of the health impacts of climate change in our community;
- Providing recommendations, based on local evidence, on priority areas to focus adaptive measures for decision makers and stakeholders to strengthen overall resilience of local health systems to respond to the impacts of climate change; and
- Collecting and sharing local information that supports creating and strengthening policy and programming that reduces health risks and builds resiliency to current climate variability and future climate change in our community.

A climate change and health vulnerability assessment (CCHVA) aims to: 1) understand which population groups within a bounded geographic area are more or less at risk at present and into the future; 2) assess climate-sensitive health outcomes and the determinants of health that make an individual more vulnerable to the impacts of climate change; and 3) identify adaptive capacity in the form of community assets, programs, plans and/or policies that may reduce identified risks.(3) CCHVAs have added benefits of shining a light on health equity considerations; they can create partnership opportunities with allied organizations, and provide evidence to support future planning opportunities for municipalities.(10)

1.1.2 Climate change health vulnerability, health inequalities and health equity

Vulnerability to climate change is expressed as a function of 1) exposure to climate-related hazards; 2) physiological sensitivity of individuals or populations to climate-related hazards; and 3) adaptive capacity of individuals, populations and/or systems to cope with climate-related hazards. While Canadians are already experiencing the ill-health effects of climate change, Health Canada notes that seniors, children and infants, people experiencing social or economic disadvantage (e.g., low-income, housing insecure), Indigenous Peoples, residents of northern and remote communities, and those with chronic diseases and/or compromised immune systems are particularly vulnerable.(6) Despite Canada ranking as one of the top countries to live in terms of quality of life, health inequities still exist, and the unequal distribution of income, education, social and environmental conditions influences these inequities.(11)

Health vulnerability is similar to health inequalities, which refer to the unequal distribution of the burden of disease across certain populations. Health equity refers to health inequalities that are avoidable, and which therefore reflect unfair or unjust societal conditions. In other words, health inequalities (and health vulnerability) are driven by health inequities.(12,13)

Climate change will interact with the social determinants of health—the social, cultural, and economic conditions that influence individual and group differences in health. Around the world, climate change has been found to disproportionately impact low-income communities and communities of colour, many of whom already experience



poor health outcomes.(12) Thus, climate change is expected to worsen existing health inequities without appropriate action.

In the Canadian context, it is important to note that intersectional features of individual and group identities (e.g., race/ethnicity, sex/gender, sexual orientation, education, etc.) may lead some populations to be either differentially exposed to climate hazards, more physiologically prone to suffering the ill-health consequences of climate change or lacking the ability to adapt during periods of exposure. Moreover, populations that experience systemic forms of stigmatization, discrimination (e.g., ableism, sexism, racism, classism, discrimination according to sexual preference) or oppression (e.g., colonialism) may also be more vulnerable to climate change due to the political, social, and cultural marginalization of certain communities. Accounting for existing disparities within and between populations can therefore help understand the nuances of vulnerability for specific populations. For example, reporting on health inequities in Canada highlights that low-income status is 2.2 times higher among recent immigrants relative to non-immigrants, 2.7 times higher among Black Canadians relative to their white counterparts, and 2.6 times higher among Indigenous children than non-Indigenous children.(14) Similar patterns of material inequalities for marginalized groups in Canada can be found in terms of food access, access to health services, and access to education.(13)

Thus, a full accounting of the unique and interacting identity categories that make individuals vulnerable to climate change is beyond the scope of this report, but the following chapters attempt to unpack key groups that may be more vulnerable based on their exposure, sensitivity, and adaptive capacity. The information provided can serve to guide future research into the nuances of these vulnerabilities within and between communities.

1.2 Study Area in Context

The study area for this assessment comprises two Public Health jurisdictions: Region of Waterloo Public Health (ROWPH) and Wellington-Dufferin-Guelph Public Health (WDGPH). The study area is in southwestern Ontario and is characterized by a mix of larger urban centres (Waterloo, Kitchener, Cambridge, and Guelph) and rural communities (see Figure 1). The region is among Canada's fastest growing communities because of Ontario's Places to Grow Act and given its proximity to the Greater Toronto Area. In particular, the Tri-Cities area of Kitchener, Waterloo, and Cambridge, as well as the City of Guelph have seen recent densification. The Grand River Watershed covers the majority of the study area, although other major watersheds in southwestern Ontario also overlap (e.g., the Saugeen, Credit Valley, Nottawasaga Valley, and Maitland Valley watersheds).

Health service delivery does not fall within the purview of Public Health Units in Ontario. In 2019, the Government of Ontario began transforming the provincial health care system by combining the 14 Local Health Integration Networks (LHINs) in Ontario with a number of provincial entities including Cancer Care Ontario, Health Quality Ontario, eHealth Ontario, Health Shared Services Ontario, and HealthForceOntario Marketing and Recruitment Agency into Ontario Health. Currently, Ontario Health oversees health care delivery (including planning and funding) across the province, which involves ensuring front-line providers and other health professionals have the tools and information they need to deliver the best possible care within their communities. Ontario Health is divided into 24 teams, with Ontario Health West covering the study area.



Throughout the transition to Ontario Health, the Government of Ontario also established Home and Community Care Support Services (HCCSS). This organization includes 14 branches that focus on delivering local health care services such as home and community care, access to community services, and long-term care home placement.

There are two branches of HCCSS that cover the study area: Waterloo Wellington (which includes the geographic areas of Waterloo Region, Wellington County, the City of Guelph, and the southern part of Grey County) and Central West (includes the geographic areas of Dufferin County as well as Peel Region).

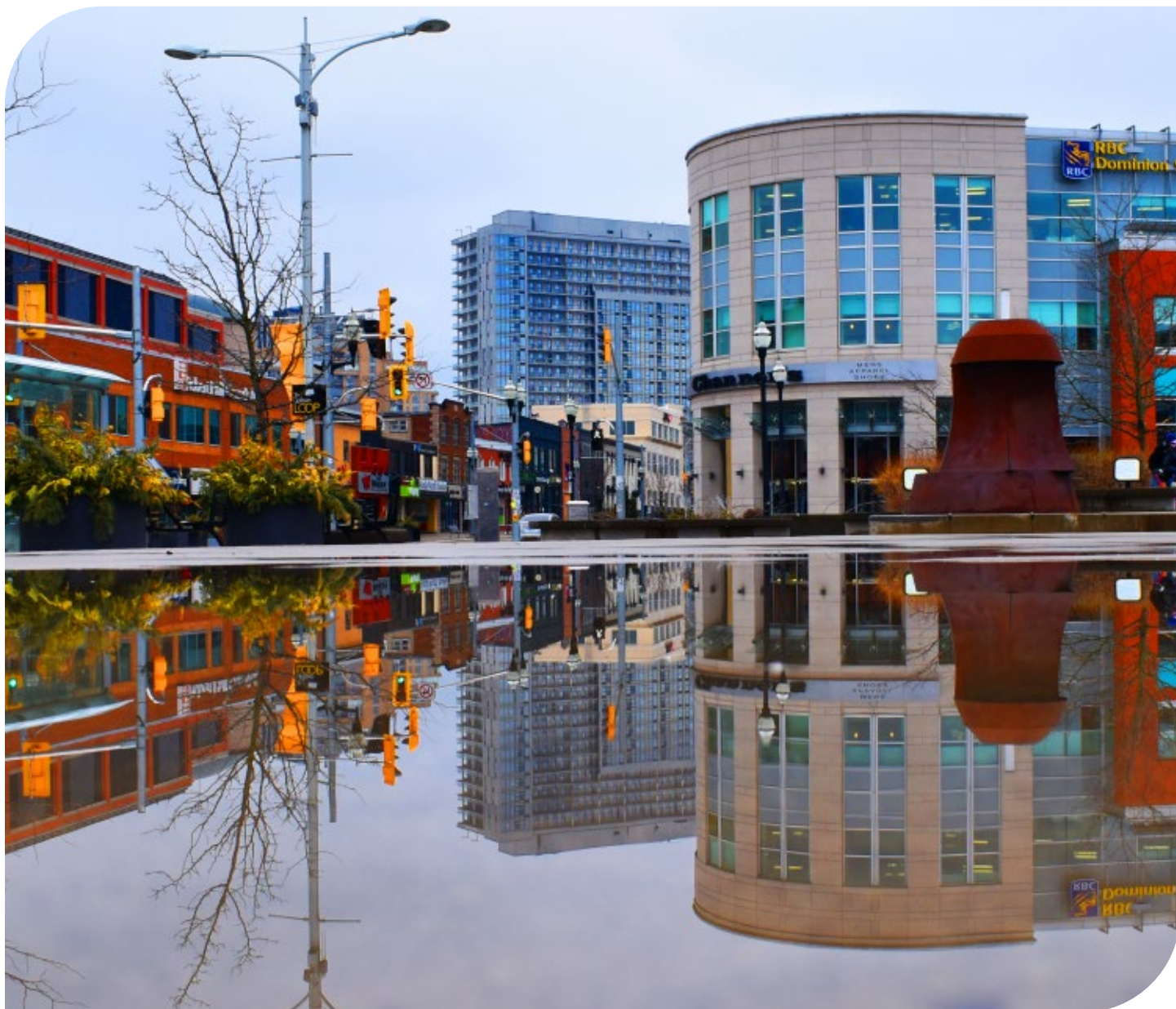




Figure 1. Study area: Communities in the Regional Municipality of Waterloo, the Counties of Wellington and Dufferin, and the City of Guelph



Basic demographic information for each Health Unit reveals several similarities and differences between the Health Units, and as compared to Ontario (Table 1). While these differences are elaborated upon within each subsequent chapter, highlights include that the population within the study area is, on average, younger than Ontario and Canadian residents more broadly; the study area has a high proportion of working age population (second) highest in Ontario); and is a popular receptor site for immigrants to Canada.



Table 1. Demographic information for each Health Unit jurisdiction in the study area compared to Ontario

Variable	Categories	WDGPH	ROWPH	Ontario
Total population		284,460	535,150	13,448,495
Sex	Female	50.8%	50.6%	51.2%
	Male	49.2%	49.4%	48.8%
Age	0-14 years	17.8%	17.8%	16.4%
	15-64 years	66.5%	67.8%	66.8%
	65 years or older	15.8%	14.4%	16.7%
Total occupied private dwellings		107,195	203,830	5,169,175
Immigrant status		16.4%	22.6%	29.1%
Recent immigrants (arrived 2011-2016) expressed as proportion of all immigrants (2011-2016)		9.7%	11.8%	12.3%
Indigenous or Aboriginal identity		1.6%	1.7%	2.8%
Proportion of visible minority populations		11.6%	19.0%	29.3%
Education	No high school diploma	18.4%	18.7%	17.5%
	High school diploma or equivalent	29.2%	28.8%	27.4%
	Apprenticeship or trades certificate or diploma	6.6%	6.3%	6.0%



Variable	Categories	WDGPH	ROWPH	Ontario
Education	College or non-university certificate or diploma	21.5%	21.1%	20.8%
	University certificate; diploma or degree at bachelor level or above	22.3%	23.4%	26.0%
Median total income in 2015 (\$)		37,882	35,714	33,539

Source: 2016 Census of the Canadian Population, Statistics Canada

Notably, there are many government and civil society organizations actively engaging with climate change mitigation and adaptation across the study area. Many municipalities have corporate climate change adaptation plans and/or have hired climate change coordinators to lead important work in this area. The development of several climate action plans to support adaptation and mitigation are also present across the study area, and this report should be seen as a complement to the important work being led by community partners, with a particular focus on health and well-being at the population level. These include, but are not limited to, the Region of Waterloo's Community Climate Adaptation Plan, Corporate Climate Change Adaptation Plans led by municipalities, Climate Action Waterloo Region, Guelph's Strategic Plan oriented towards "Sustaining our future", The Town of Orangeville Climate Change Adaptation Plan, The Dufferin Climate Action Plan and Climate Change Collaborative, and the Wellington County Climate Change Mitigation Plan, among others.





2.0 Methodology for Conducting the Climate Change and Health Vulnerability Assessment

This chapter outlines the series of research methods utilized to conduct the literature review, to describe baseline population health vulnerabilities to climate change, and to spatially analyze those vulnerabilities. The chapter also describes the project governance, and our process for engaging regional stakeholders to support the assessment.

2.1 Climate Change and Health Vulnerability Assessment Methodology

Climate change and health vulnerability assessments (CCHVAs) are an evidence-based process that articulate health impacts of climate change in a given geographic area.(10) They aim to identify health risks of climate change, vulnerable populations and adaptive measures with the goal of bolstering public health programming and regional planning with health-related evidence.(10) In producing this assessment of the study area, we followed existing guidance from best practices in the field of climate change and health vulnerability assessments.(1,3,15–19)

This CCHVA was guided by several key tools, including the [Ontario Climate Change and Health Toolkit](#),(1) *Health Canada's Climate Change and Health Vulnerability and Adaptation Assessment: Workbook for the Canadian Health Sector*,(2) as well as the World Health Organization's (WHO) [Protecting Health from Climate change: Vulnerability and Adaptation Assessment guide](#).(3) Authors also looked to other Ontario Public Health Units that have completed CCHVAs for guidance and information, including Peel Public Health, Middlesex-London Health Unit, Simcoe-Muskoka District Health Unit and York Region.

CCHVAs generally follow several distinct steps to inform the assessment. These include framing and scoping the assessment by defining geographical regions, policy contexts and health outcomes of interest, and establishing engagement and reporting processes. A CCHVA then assesses vulnerability, which is a function of exposure, physiological sensitivity, and adaptive capacity, which is also reflected in current burden of illness and associated health protection programs. Future impacts are predicted based on climate change projections, and adaptation measures are identified. The final step is to use the synthesized information to manage and monitor risks through evaluation, program development, and communication strategies (see Figure 2).



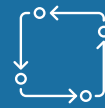
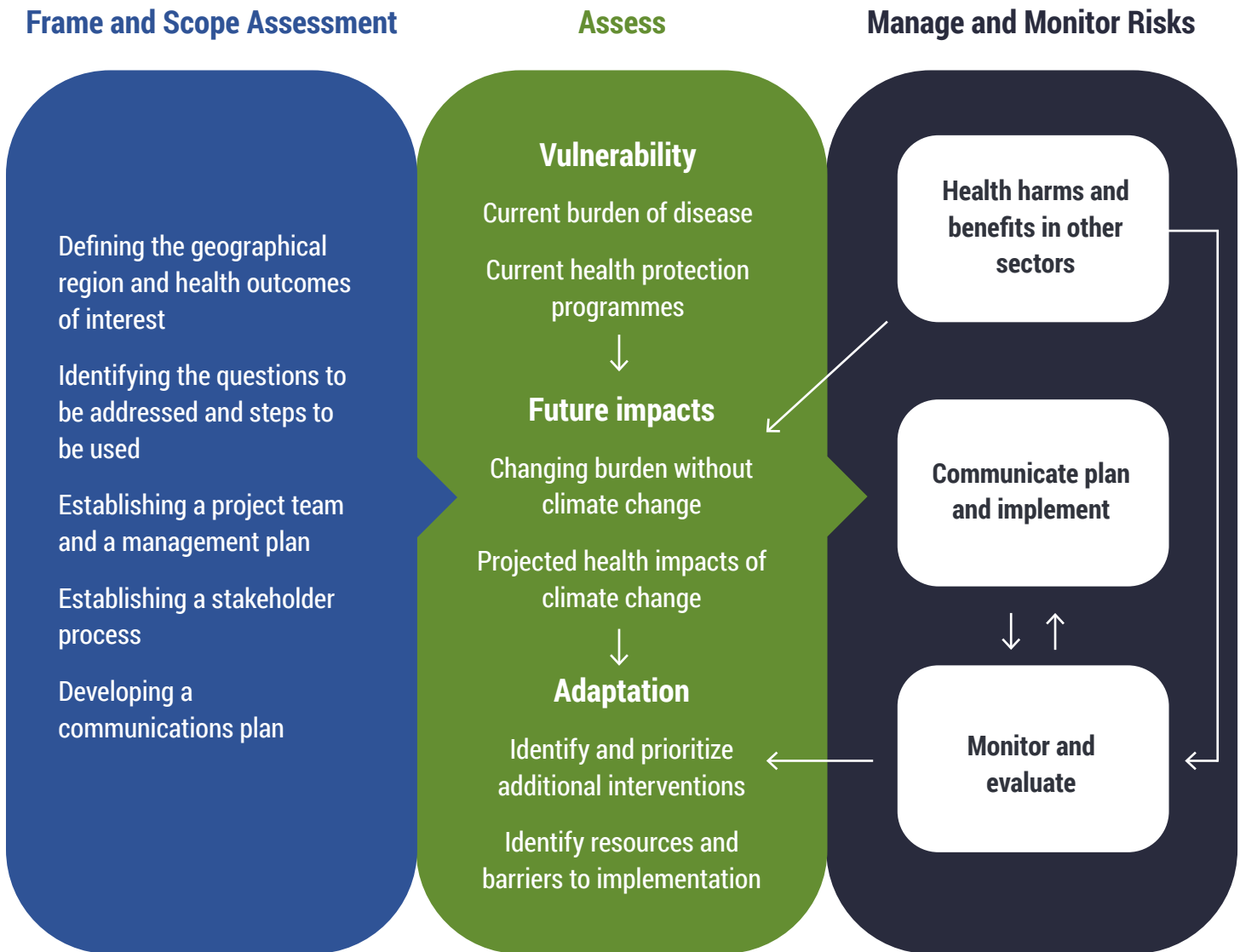


Figure 2. Framework for vulnerability and adaptation assessment in the health sector



Source: World Health Organization (WHO), Pan-American Health Organization (PAHO). Protecting health from climate change: vulnerability and adaptation assessment [Internet]. World Health Organization; 2013 [cited 2015 May 8]. Available from: <http://apps.who.int/iris/handle/10665/104200>

This assessment was scoped at the level of ROWPH and WDGPH jurisdictions. The approach of the study team was to examine baseline climate-related health concerns, identify future impacts based on projected climate change, and to document population-level vulnerabilities based on exposures, sensitivity, and adaptive capacity. The report also examines adaptation initiatives that are ongoing throughout the study area with the intent of using this report to engage in intersectoral prevention, communication, and evaluation. CCHVAs can comprise numerous research methods including literature reviews, key informant interviews, surveys, focus groups and analyses of secondary data.(3) Methodological tools utilized to complete this assessment are outlined below.



2.2 Climate Change Projections

To prepare for the health outcomes of climate change, it is important to understand how the climate is expected to change locally in the immediate, short, and long-term. Much of the climate projection data for this assessment was collected through the Ontario Climate Data Portal (OCDP), produced by the Laboratory of Mathematical Parallel Systems (LAMPS) from York University. Data was also collected from the [Canadian Centre for Climate Services \(CCCS\) Climate Data tool](#) and the [Climate Atlas of Canada](#). Other variables pertaining to freezing rain, air quality, and UV index were taken from the literature and cited where applicable. Additional climate change projection data for the study area can be found in the Climate Science Report for the Climate Change and Health Vulnerability Assessment for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph,(4) which was developed as part of this project.

Many different methods exist to construct climate change projections, however, global climate models (GCM) are the most conclusive tools available for simulating responses to increasing greenhouse gas concentrations, as they are based on mathematical representations of atmosphere, ocean, ice cap, and land surface processes. Both the OCDP tool and [climatedata.ca](#) use an ensemble approach, which refers to a system that runs multiple climate models at once. Research has shown that this provides a more accurate projection of annual and seasonal temperatures and precipitation than a single model would on its own.(20)

It is unknown what future greenhouse gas (GHG) emissions will be. In order to account for multiple possible futures, the Intergovernmental Panel on Climate Change (IPCC) developed four emissions scenarios called Representative Concentration Pathways (RCP).(21) RCP2.6, 4.5, 6.0 and 8.5 reflect various levels of climate change mitigation efforts and business-as-usual GHG emissions scenarios, ranging from stringent mitigation activities (RCP2.6) to very high emission levels (RCP8.5). For the purpose of this assessment, the RCP8.5 emission scenario was utilized for climate projections, as it represents the business-as-usual scenario, which is the current path that global emissions trends are following.(21,22) Global surface warming associated with the various RCP scenarios is highlighted in Figure 3.



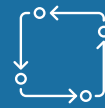
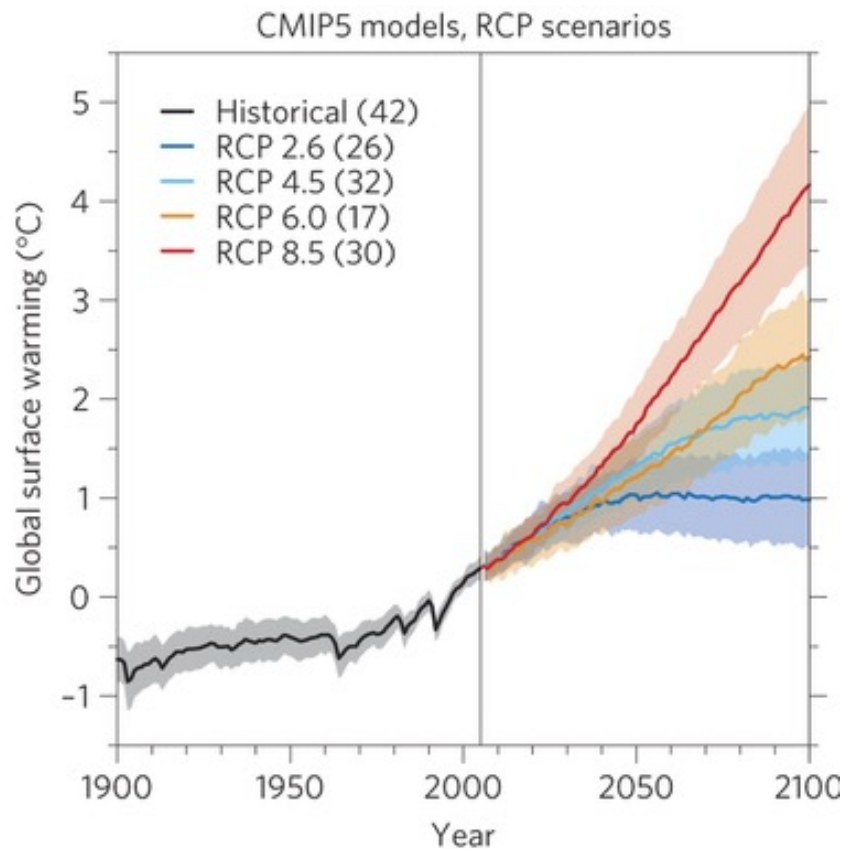


Figure 3. RCP greenhouse gas emissions scenarios



Source: IPCC. Climate Change 2015: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA; 2014.

2.2.1 Timeframes

Climate projections are typically provided within time periods of 30 years. A consistent baseline period is established so that projections can be accurately compared with historical trends. For the OCDP data, future projected time periods include 2040-2069 (referred to as the 2050s) and 2070-2099 (referred to as the 2080s). Baseline data from the OCDP is from 1986-2005. For data from climatedata.ca, each climate model simulates the climate for the historical period, 1950-2005, and for plausible futures, 2006-2100. Thirty-year averages are currently not available from climatedata.ca. For other qualitative data retrieved from various literature, different time periods and baselines are identified.

Some of the climate indices are divided into seasons (defined in Table 2, below) along with annual totals or averages (e.g., temperatures, total precipitation), however, others only have a single annual value (e.g., temperature extremes).



Table 2. Seasons and months

Season	Months
Winter	December, January, February
Spring	March, April, May
Summer	June, July, August
Autumn	September, October, November

2.3 Project Governance

Two key stakeholder groups guided and advised the creation of this assessment – the Project Team and the Expert Task Force (ETF) group. These groups are overseen by the project Leads, which include representatives from WDGPH, ROWPH, and the Consulting Team (see Figure 4).

Figure 4. Organizational Structure of the Research Team



The core project team is comprised of individuals from both Wellington-Dufferin-Guelph Public Health, Region of Waterloo Public Health, and ICLEI Canada. This group led the development, input, and review of the assessment at all stages and contributed technical knowledge to the project.

The ETF is comprised of community experts from a wide range of organizations whose activities directly or indirectly affect the burden and pattern of climate-sensitive health outcomes. These include individuals:



- Working on issues relevant to the mandate of the assessment in other departments or organizations;
- Supporting initiatives for and/or working with populations affected by climate change risks; and
- Working in departments where there may be potential to support adaptive capacity to climate change risks.

Examples of participating organizations include Public Health, sustainability and/or climate change teams or departments from municipal and regional governments in the study area, Ontario Health (formerly Local Health Integration Networks), conservation authorities, Health Canada, and local academic institutions. The Expert Task Force specifically aided in identifying climate change-related health impacts, taking stock of community programs to increase adaptive capacity to health impacts, and in providing data to inform sensitivity and exposure information for the assessment.

2.4 Stakeholder Engagement

Building on project governance, the production of this report was informed by three different engagement activities, including meetings with the ETF group, a stakeholder survey, and several focus group sessions, which are outlined below.

2.4.1 Expert task force (ETF) workshop

A meeting was held with the ETF in June 2019 to introduce the project to ETF members, share and discuss climate change impacts and health priorities from a public health standpoint, and identify the current health and climate change policy context within WDGPH and ROWPH. The meeting began with a series of introductory presentations, covering the HealthADAPT program, climate change adaptation work in the two public health regions, and an overview of the vulnerability assessment project. The remainder of the workshop focused on tabletop exercises intended to collect insights from participants and relevant information on policies, plans, or activities underway in the study area that directly or indirectly address climate change and health-related risks. This information was used to inform initial data gathering on community climate change work and relevant datasets.

2.4.2 Stakeholder survey

Following the ETF meeting, an online stakeholder survey was developed to inform local perceptions of climate change impacts on health, and associated recommendations or actions to mitigate those impacts. The survey was created using the University of British Columbia's Qualtrics survey tool roughly modeled after past risk perception surveys(23–27) and contained 15 questions with the purpose of:

- Engaging with a diversity of perspectives across the study area to assist us in prioritizing response(s) to the health impacts of climate change; and
- Better understanding policies and related work already underway on climate change to identify future partnerships that will enhance the health and well-being of vulnerable populations across the study area.

One key aspect of the stakeholder survey was to collect information on vulnerable populations of concern.



Participants were asked about population groups that they work with who may be vulnerable (either differentially exposed, physiologically sensitive, or who have low adaptive capacity) to the health impacts of climate change. Participants were also asked a series of questions regarding climate change and health risks across the region that were identified by the literature review – namely their perceptions on current levels of vulnerability, and how they perceive climate change could exacerbate those health risks. While ‘risk’ can be understood as the possibility of something bad happening, it is also conceptualized as a function of the severity of impact and likelihood of impact.

Results of the survey were tabulated in the Qualtrics tool, and analysis of relevant data was completed using Microsoft Excel and SPSS. Narrative information on specific policies and community initiatives related to specific health impacts of climate change are listed in their corresponding chapter(s) of this report. More information on the results of the stakeholder survey can be found in Appendix 1.

2.4.3 Stakeholder focus groups

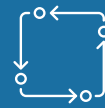
A series of seven focus groups were held to engage stakeholders in order to discuss existing data for the study area on an array of climate-related impacts; discuss unique vulnerable populations that may be differentially affected by climate change in the study area; identify potential data and knowledge gaps; and to share stories of successful adaptation (e.g., on-going program implementation, public health surveillance activities, community engagement, etc.) to climate-related health risks.

Participants were invited to participate in one or more of the seven focus group sessions, which were organized according to key health risks: temperature and ultraviolet radiation exposure; air quality; extreme weather; enteric and zoonotic disease; and mental health. Two sessions were also held to address the entire suite of health risks of climate change: one targeted towards climate change specialists working across the study area, and another targeted at individuals who had experience working with vulnerable population groups. More than 50 individuals from 12 different organizations were engaged in the focus groups, representing a variety of Health Unit staff, conservation authorities, local/regional planners, sustainability offices and other regional partners. Narrative results from the seven focus groups were compiled and synthesized, and lessons learned are included in each relevant corresponding chapter throughout this report.

2.5 Literature Reviews

Targeted literature reviews were conducted for each climate-related health risk identified by the *Ontario Climate Change and Health Toolkit*.⁽¹⁾ We utilized PubMed, MEDLINE and Web of Science, limiting our results to the past 10 years. We conducted a series of searches using health risk specific key words (e.g., ‘air quality’, ‘extreme heat’, etc.), vulnerability (including ‘exposure, sensitivity, and adaptive capacity’) and geographic key words (e.g., Waterloo, Kitchener, Cambridge, Wellington, Dufferin, Guelph, southwestern Ontario, Ontario, Canada) to limit literature. Additional references were utilized based on the authorship team’s expert understanding and familiarity with the Public Health and climate change literature.

References were reviewed according to title and abstract. Articles were included if they were written in English, and either conceptualized or measured aspects of vulnerability relevant to the following climate-related health risks:



extreme temperatures, ultraviolet radiation, extreme weather, air quality, vector-borne disease, food, and water-borne illness. These climate-related health risks form the basis for each subsequent chapter of this report. Articles were sorted based on their topical focus, and key vulnerability indicators and co-variates were analyzed for relevance to the study area. Relevant articles also included reference list searches for additional resources for this assessment. Grey literature was identified by web searches and through material shared with us by our collaborating authors and stakeholders who provided input to this report.

2.6 Statistical Analysis

To track trends in health data over time, where appropriate, Pearson's R correlation tests were undertaken, and other specific methods are outlined for relevant data points in the chapters that follow. Data processing and statistical analyses were conducted in R version 4.0.2 and spatial visualization was performed in QGIS version 3.10.9. Statistically significant associations are flagged in subsequent chapters.

2.7 Limitations

Notwithstanding the deployment of the evidence-based approach utilized to conduct this assessment, there are still several limitations of the report that should be taken into consideration.

2.7.1 Data

The data presented in each subsequent chapter should be conceptualized as a reflection of the best available data at baseline for each health unit. Despite the comprehensive nature of this report, there are still challenges associated with data.

First, health data are often not recorded in relation to climate-related phenomena. This makes tracking health outcomes from a specific event (e.g., heat wave, heavy rainstorm) incredibly challenging without appropriate data. Yearly data is provided, and trends are tested for available health data, but specific epidemiological studies pertaining to attributive links between a climate-related event and human health outcomes is beyond the scope of existing and available data. Indeed, even the relatively short historical baseline established between 2010-2018 may be unable to detect trends related to climate change, and thus reporting of trends should be reported with caution. Moreover, age-standardized rates of morbidity and mortality (i.e., those that account for the distribution of health outcomes according to age) are reported where possible, but time and capacity resource limitations did not enable all reporting to adjust for the influence of age. Non-age standardized data should therefore be interpreted with caution. This baseline assessment is intended to be the foundational step to enable each Public Health Unit to engage with more sophisticated analysis in the future.

Second, despite reporting on the spatial distribution of health data for many health outcomes discussed in the chapters that follow, not all health data is able to be displayed at the level of census-subdivisions (the lowest possible geographic unit of analysis for most health data across the study area), primarily due to the small number of cases for any given health concern. This limits the ability to generate spatially driven hypotheses around vulnerability



factors and human health, and instead required the study team to rely on coarse-level data across the entirety of each Health Unit. Missing data and challenges are described in greater detail in each subsequent chapter.

Third, while each chapter provides an exhaustive list of known factors that modify vulnerability for specific climate-related health outcomes, it is not currently possible to stratify health-related outcomes by key demographic data. As per Section 1.1.2 of this report which introduces the idea of health equity, there are risks associated with labeling a particular population group as vulnerable, when individuals who belong to that group may have the adaptive capacity that others do not which enables them to be resilient to climate change. Future analyses should work to examine the burden of illness across identified groups, stratifying by key sociodemographic variables to improve the local understanding of vulnerability and distribution of risk across specific populations, and at the nexus of multiple determinants of health (e.g., age, sex, race/ethnicity, income, etc.). This may not necessarily address the problem of ‘outlier’ individuals within a specific identity group but would add additional nuance to the reporting that follows in this report. Such analysis could inform how existing health inequities influence climate related vulnerability and vice versa.

Fourth, correlations seen at the level of a geographical area or demographic group may not reflect associations seen in individual level analysis. In other words, it should not be ‘taken for granted’ that because an individual has identity features (e.g., old age) which, based on the existing evidence base, may suggest higher vulnerability. It does not necessarily mean that any given individual will be vulnerable because vulnerability is moderated by individual-level adaptive capacities.

2.7.2 Engagement

Notwithstanding the engagement activities that were undertaken to support this assessment (see Appendices 1-3), engagement strategies had several limitations. First, it should not be assumed that a representative sample of participants from the study area was engaged in this project. Given the time and resource constraints, engagement was necessarily targeted to include existing partners and institutions actively working on climate change. However, future engagement with other allied groups and organizations could work to enhance program development and delivery as it relates to climate change and the trends outlined in this report.

Second, due to the on-going COVID-19 pandemic, subsequent engagement activities beyond the ETF workshop, focus groups, and the survey were not possible. This is jointly due to the challenges associated with Public Health staff being redeployed, and due to the changing realities of work life for community partners. Certain aspects of the vulnerability assessment methodology, such as consulting experts to assess future impact and prioritization of key health risks were therefore not undertaken in conjunction with the development of this report.



3.0 Extreme Temperatures



3.0 Extreme Temperatures: Key Findings

Climate change projections

Extreme Heat

- The study area expects to see increases upwards of 5°C in the minimum, average, and maximum seasonal temperatures by the 2080s, including an increase in the frequency and duration of heat warnings.
- The number of extreme heat days (above 30°C) is expected to increase from 7 to 60 by 2080s for Wellington-Dufferin-Guelph, and from 10 to 61 by the 2080s for Waterloo Region.
- The number of tropical nights (above 20°C) is also expected to increase.

Extreme Cold

- Climate projections indicate that the study area will experience a decrease in the frequency of extreme cold days, and overall milder, wetter winters.
- Despite the overall warming trend that will result in fewer extreme cold events, climate change may still exacerbate the severity of extreme cold events (such as freezing rain and ice storms).

Population-level exposure

- Urban heat islands (UHIs) increase temperatures in urban areas, increasing exposure and exacerbating health risks. Areas most impacted from UHIs include the of Waterloo, Kitchener, Cambridge and Guelph, and Township of Wilmot. These areas also have a higher degree of impermeable surfaces, and lower tree cover, which further exacerbate UHI effects.
- Individuals who work outdoors or participate in outdoor recreation or active transportation may be more exposed to extreme heat.

Population-level sensitivities

- Both children and older adults have physiological sensitivities to extreme heat, which reduce their ability to regulate body temperature. In the study area, the proportion of people aged 65 and older is growing.
- Those with pre-existing health conditions, including mobility limitations, psychiatric illnesses, and those with circulatory and respiratory diseases, are more sensitive to extreme heat.



Population-level adaptive capacity

- Individuals experiencing physical or social isolation may lack the capacity to respond to or prepare for extreme heat events.
- Those who speak neither English nor French (0.9% in Wellington-Dufferin-Guelph and 1.8% in Waterloo Region), new immigrants (16.4% in Wellington-Dufferin-Guelph and 22.6% in Waterloo Region), and other visible minorities (11.6% in Wellington-Dufferin-Guelph and 19.0% in Waterloo Region) may have limited adaptive capacity in the face of extreme temperatures.
- People experiencing housing insecurity and insufficiency are particularly vulnerable to extreme heat and cold. Data for the study area suggest that housing insufficiency is 5.1% in Wellington-Dufferin-Guelph relative to 5.0% in Waterloo Region, both of which are lower than the provincial average of 6.1%.

Adaptive actions

- Individual actions include limiting exposure by seeking out warm environments on cold days, and cool environments on hot days. Additional strategies include knowing the weather forecast before going outside and modifying plans according to weather; wearing weather appropriate clothing (e.g., layers in cold weather, light colored clothes in hot weather); staying hydrated; and knowing the signs and symptoms of temperature related illness (e.g., frostbite, hypothermia, heat stroke). Frequently checking in on vulnerable neighbours, friends, and family can also help to identify early signs of temperature-related illnesses.
- ROWPH updates and circulates the Waterloo Region Heat Warning Response Plan (a key component of the Heat Alert Response System for Waterloo Region) and the Waterloo Region Extreme Cold Warning Response Plan.
- WDGPH implements a Heat Warning and Information System, and offers support to local stakeholders (including, but not limited to municipalities, long-term care facilities, childcare facilities, and school boards) for the development of local Heat Alert Response Systems.
- Extreme heat alert notifications from Environment and Climate Change Canada are shared with the public and stakeholders through websites and social media.
- Public Health supports municipal and regional partners in incorporating extreme heat and cold considerations into strategic and land use planning, and community program and public space design.
- Warming and Cooling Centres are provided by member municipalities, the Region of Waterloo, and community partners within the study area, and each respective health unit is available to provide input into their planning and coordination.



- Public Health collaborates with a variety of local, regional, and provincial partners to institute novel programming and share information, wherever possible.
- Surveillance systems, such as the Acute Care Enhanced Surveillance (ACES) system are available for receiving alerts and tracking heat-related illnesses in the community.

Baseline health impacts

- Temperatures are strongly associated with a variety of human health impacts, and heat-related morbidity in Canada is typically associated with elevated temperature and humidex values during summer months.
- Emergency department visits seem to be generally higher today than they were in 2008 for temperature-related illnesses, and roughly follow trends of heat warning occurrences.



3.0 Extreme Temperatures

Climate change is already altering temperatures across Canada, with the country warming faster than most other regions on the planet.(7,28) As temperatures change, the frequency, duration, timing, and intensity of extreme temperatures is expected to be altered.(29) This chapter briefly describes the existing warming trend across the study area, the human health impacts of extreme temperatures (i.e., heat and cold), population vulnerabilities related to temperature, the existing burden of disease to those impacts, and existing adaptive capacity across the study area. For more information on the scope of this report and its methodology, see Chapters 1 and 2.

3.1 Historical Extreme Temperature Events

Southwestern Ontario has a history of extreme heat events. In the study area comprising the boundaries of two health units—Region of Waterloo Public Health and Wellington-Dufferin-Guelph Public Health—these events typically occur during summer months, but incidences of extreme heat can also be observed in spring (May/June) and autumn (September). Each Health Unit in the study area maintains records of the number of Humidex Advisories/Heat Warnings issued by Environment and Climate Change Canada (ECCC). Prior to 2015, ECCC issued Humidex Advisories on days when the humidex was forecasted to reach 40°C or higher. Currently, Environment and Climate Change Canada will issue a Heat Warning when one or both of the following conditions are met, and heat waves are defined as meeting these criteria for three or more days:

- Two consecutive days where the temperature is forecasted to be 31°C or higher during the day AND 20°C or higher overnight; and/or
- Two consecutive days where the humidex values—a unitless measure of humidity and temperature that acts as an expression of how hot it feels—is forecasted to be 40 or higher.

Data from the past ten years from five weather stations located within the study area are provided in Table 3 from ECCC's Historical Climate Data Records. Additional information on temperature patterns is available in the Climate Science Report for the Climate Change and Health Vulnerability Assessment for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph.(4) The table shows the number of times in a given year where current heat warning criteria were met according to historical data. Waterloo/Kitchener weather station records have the highest number of days meeting heat warning criteria in the study area. The data do not necessarily show a rising trend of heat warnings over time, but as noted in the limitations section in Chapter two, baseline data with a relatively short historical tenure may be unable to detect broader changes in climate which is why a more fulsome accounting of these changes is outlined in the aforementioned *Climate Science Report*.



Table 3. Number of occurrences where criteria were met for a heat warning for five weather stations located across the study area

Location	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Waterloo/ Kitchener	8	8	14	7	0	3	8	0	8	2	4
Mount Forest	2	3	0	2	0	0	2	0	2	0	2
Elora	2	2	0	4	0	0	2	0	4	0	0
Guelph	0	2	5	4	0	0	6	0	5	2	0
Mono	NA	NA	NA	NA	0	0	4	0	2	0	0

Source: Data provided by Environment and Climate Change Canada using historical records from weather monitoring stations located across the study area, available: https://climate.weather.gc.ca/historical_data/search_historic_data_e.html

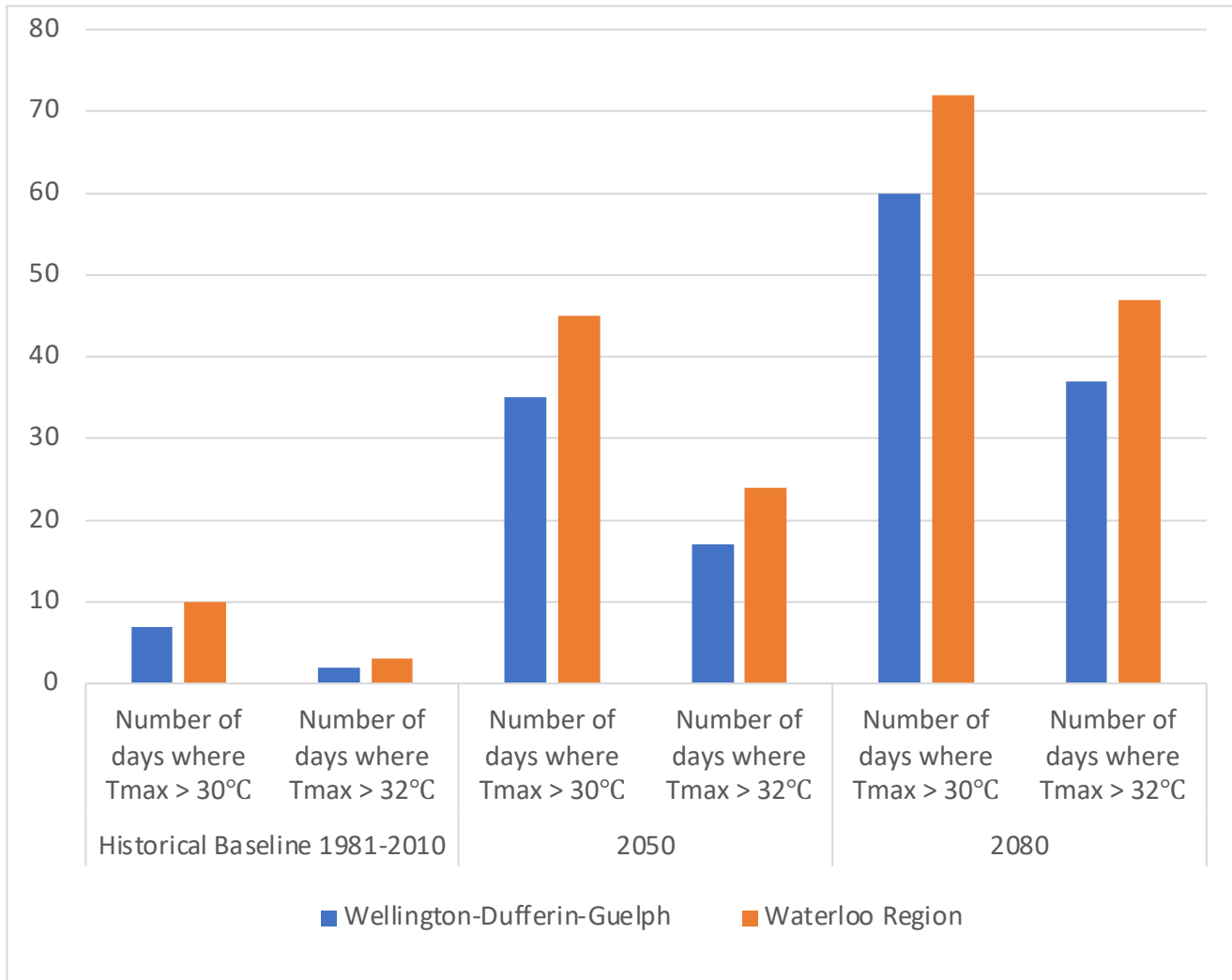
3.2 Future Climate Change

A full articulation of expected climate change under a variety of scenarios can be found in the Climate Science Report for the Climate Change and Health Vulnerability Assessment for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph.⁽⁴⁾ The report provides an in-depth overview of anticipated changes to local and seasonal climates under three different emissions scenarios. Results from the RCP8.5 scenario (reported on throughout this chapter) indicate that the study area will experience higher seasonal temperature highs and lows, and an increase in the number of hot days through to 2080. The report further highlights:

- Using the current 'business-as-usual' scenario for global emissions, the study area expects to see increases upwards of 5°C in the minimum, average, and maximum seasonal temperatures relative to a 1986-2005 reference period, including an increase in the frequency and duration of Heat Warnings and heat waves (i.e., three or more days of prolonged exposure to heat).
- The number of extreme heat days (i.e., days where temperatures exceed 32°C, and which may or may not comprise a period of Heat Warning or heat wave) is expected to increase from a historical 1981-2010 baseline of 2 annually to 17 by the 2050s, and 37 by the 2080s for Wellington-Dufferin-Guelph; and from a historical 1981-2010 baseline of 3 to 24 by the 2050s and 47 by the 2080s for Waterloo Region (see Figure 5).
- The number of tropical nights (above 20°C) is expected to increase from 2 (1981-2010 baseline) to 16 by the 2050s and 34 by the 2080s in Wellington-Dufferin-Guelph, and from 3 (1981-2010 baseline) to 21 by the 2050s and 41 in the 2080s in Waterloo Region (see Figure 6).
- Average minimum temperatures are expected to increase by 4.4-5.4°C across Wellington-Dufferin-Guelph and Waterloo Region by 2080.



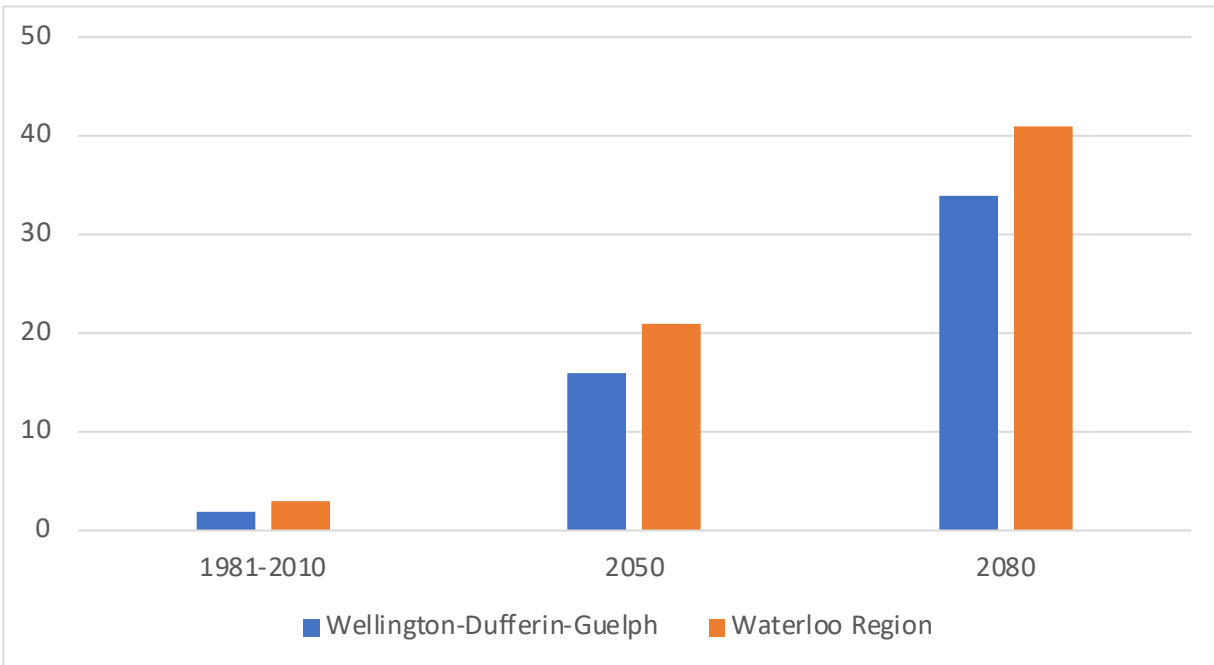
Figure 5. Projected average number of days where temperature maximums are greater than 30°C and 32°C are expected across the study area – RCP 8.5



Source: Climatedata.ca; Kitchener Zone future climate data



Figure 6: Projected average number nights where minimum temperatures are greater than 20°C for the study area – RCP8.5



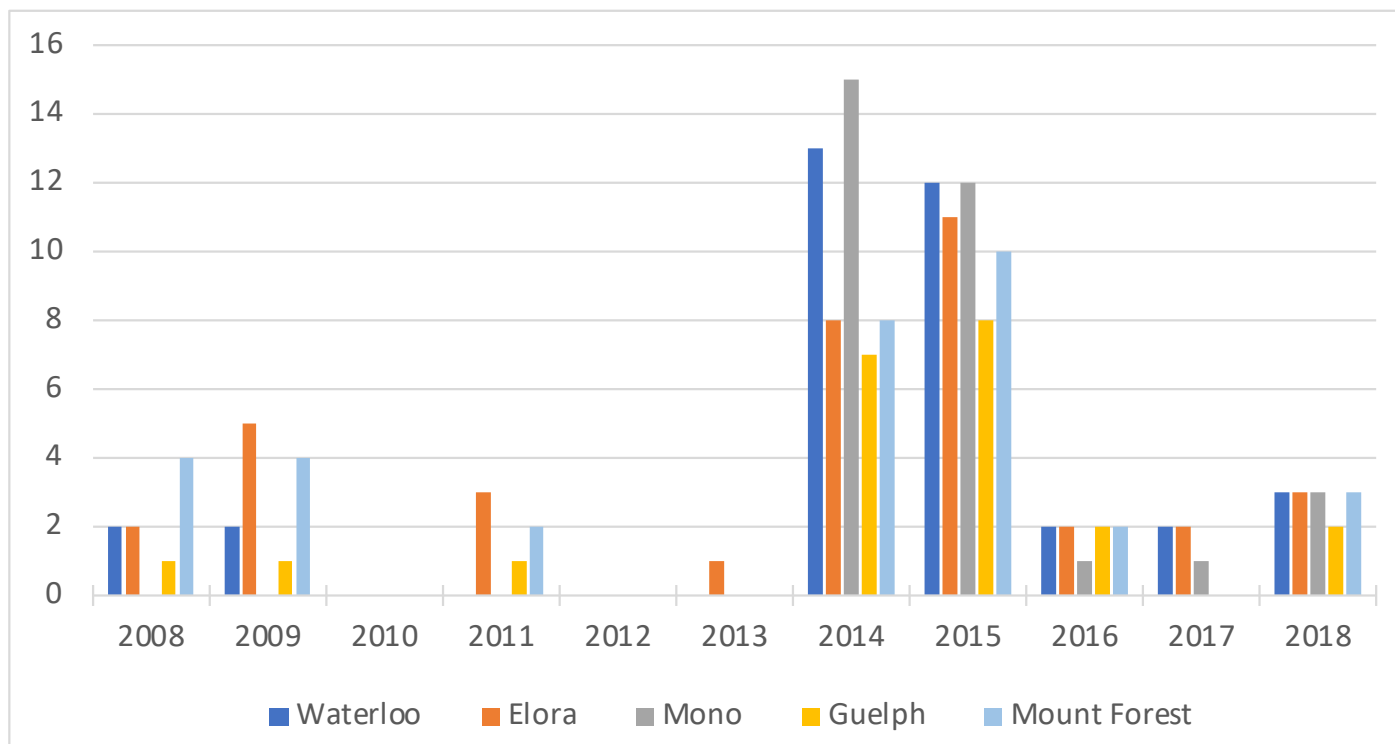
Source: [Climatedata.ca](http://climatedata.ca), Kitchener Zone future climate data

Despite the overall warming trend that will result in fewer extreme cold events, it is prudent to adequately prepare and manage the health impacts of extreme cold. Climate projections indicate the number of cold days (where temperatures are below -15°C) is expected to decrease from 19 at baseline to between 0 to 17 in Wellington-Dufferin-Guelph and fall from 21 at baseline to between 0 to 12 in Waterloo Region by 2080. Additionally, Environment and Climate Change Canada issues extreme cold warnings when the temperature or wind chill is expected to fall below -30°C for at least two hours. Figure 7 provides data on extreme cold, recording the number of days where temperatures were below -30°C with wind chill.





Figure 7. Number of days per year where temperatures were below -30°C from five weather stations located within the study area



Source: Environment and Climate Change Canada, Historical Weather Data, available: https://climate.weather.gc.ca/historical_data/search_historic_data_e.html

3.3 Health Impacts of Exposure to Extreme Temperatures

3.3.1 Extreme heat

Temperatures are strongly associated with a variety of human health impacts, Heat-related morbidity and mortality in Canada is typically associated with elevated humidex values during summer months, although extreme maximum and minimum temperatures without high humidity values are also associated with excess morbidity and mortality.(29) Hot temperatures impact human health by affecting the thermoregulation of the human body. An inability to regulate core body temperature can lead to heat rash, heat cramps, dehydration, heat fainting, exhaustion, and heat stroke.(29) Exposure to extreme heat has also been found to exacerbate pre-existing health conditions affecting the circulatory, respiratory, and cerebrovascular systems.(30) Heat can have an acute effect on those living with hypertension (i.e., high blood pressure) which can raise the risk of myocardial infarction (i.e., heart attacks) and stroke.



Heat waves have been responsible for many deaths worldwide, including 70,000 who died during the 2003 heat wave in Europe.(31) Just beyond Ontario's borders, a 2018 heat wave (June 30 to July 5, 2018) led to 66 deaths in Montreal.(32) Studies indicate that in Canada, the relationship between temperature and heat-related mortality risk is not linear. For example, an analysis of Canadian municipalities found that some cities in southwestern Ontario begin to experience higher rates of mortality above 26°C, while for others it was 30°C or higher, but that generally, these trends follow an exponential curve where higher temperatures correspond to higher mortality risk.(29) Across Ontario, a study of ambient temperature and mortality found that in warm seasons, each 5°C increase in daily mean temperature was associated with a 2.5% increase in non-accidental mortality on the day of exposure demonstrating that even moderate temperature changes are associated with increased mortality.(33) While limited evidence currently exists in the Canadian context examining the role of tropical nights in contributing to health outcomes, a recent epidemiological analysis of age-specific daily mortality in London, UK between 1993 and 2015 suggests that nighttime exposures make an important contribution to heat-related mortality.(34) This impact was found to be highest on tropical nights preceded by a hot day, which adds further significance to the heat alert criteria for Ontario described above.

3.3.2 Extreme cold

Exposure to cold temperatures can also impact health and is potentially life-threatening. Common health impacts of extreme cold include hypothermia and frostbite, and exposure to extreme cold can also exacerbate the circulatory conditions referenced above.(35) Hypothermia refers to the increasing inability of the human body to stay warm, and a low body temperature (less than 35°C) can result in shivering, confusion, drowsiness, and unconsciousness. Hypothermia can lead to death. As the body loses heat, organs begin to shut down and the heart can stop.(36) Frostbite refers to the freezing of human skin and typically affects extremities (e.g., hands, feet, nose, ears) and can permanently damage tissue if not treated immediately. In Ontario, analysis of cold season mortality and temperature found that each 5°C decrease in temperature was associated with a 3% increase in non-accidental mortality which persisted for seven days beyond initial exposure.(33) Cold-related ill-health effects tend to be stronger for cardiovascular-related deaths, particularly for people aged 65 and older.(33)

3.4 Baseline Historical Assessment of Population Health Outcomes Related to Extreme Temperature

Between 2003 and 2014, there were 35 reported temperature-related deaths in Ontario. While number of temperature-related deaths for each Health Unit are too small to be reported, it is important to recognize that many deaths associated with temperature may not list extreme temperature as the cause of death. Data for Wellington-Dufferin-Guelph and Waterloo Region suggest that emergency department visits and hospitalization for heat-related illnesses are elevated in years with higher occurrences of heat alerts (see Figures 8 and 9), where emergency department visits for heat-related illnesses are highly correlated with the occurrence of extreme heat warning days (Waterloo Region $r=0.824$, $p<0.01$; Wellington-Dufferin-Guelph $r=0.799$, $p<0.013^1$). While hospitalizations for a variety of heat-related illnesses per 100,000 have remained stable across the study area, emergency department visits are

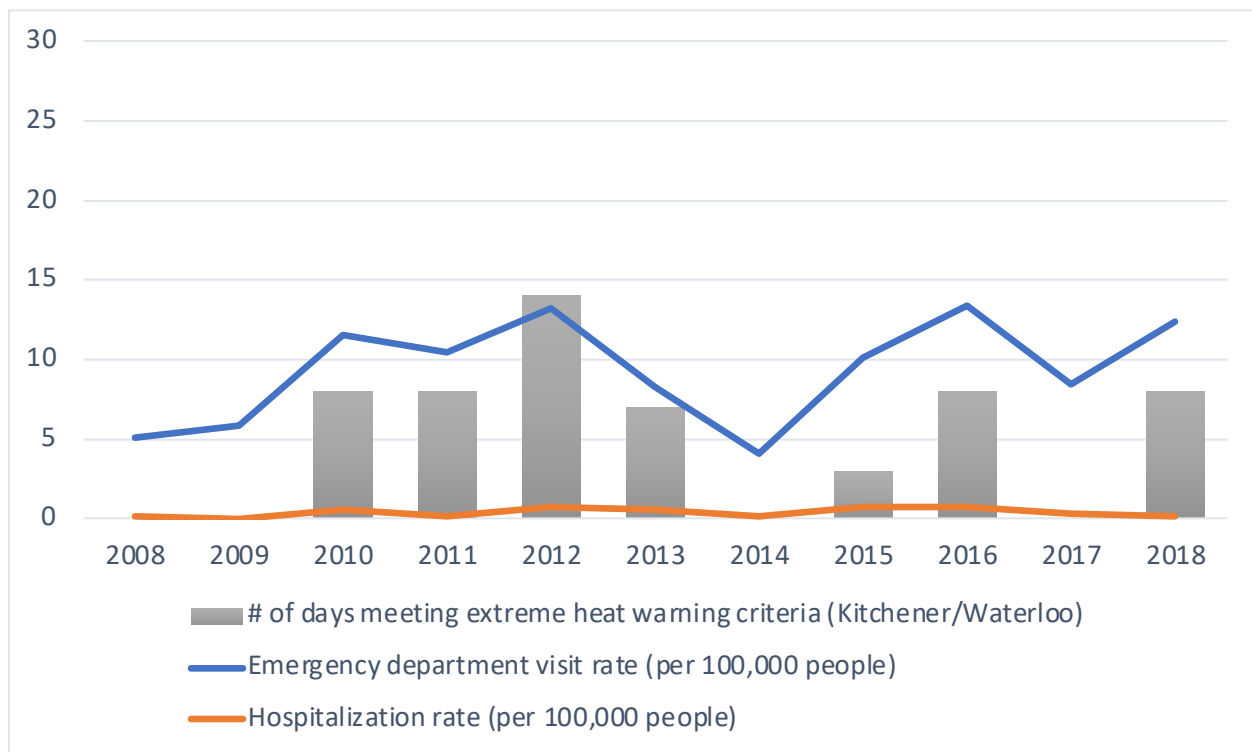
¹ WDGPH correlation calculation conducted using extreme heat warning days from Guelph monitoring station.



generally higher today than they were in 2008. However, this data should be interpreted with caution, and based on the 10 years of data presented below, there is not a statistically significant trend detected in annual changes to heat-related illness.

It should be further noted that health systems around the world—including Canada’s—are challenged in collecting data on heat-related morbidity and mortality, and research suggests that existing tracking systems such as syndromic surveillance tend to under-report heat-related illness due to missing attributive links during hospital intake and disease characterization.(37) Thus, the data presented below is likely an underestimate of the actual burden of heat-related illness.

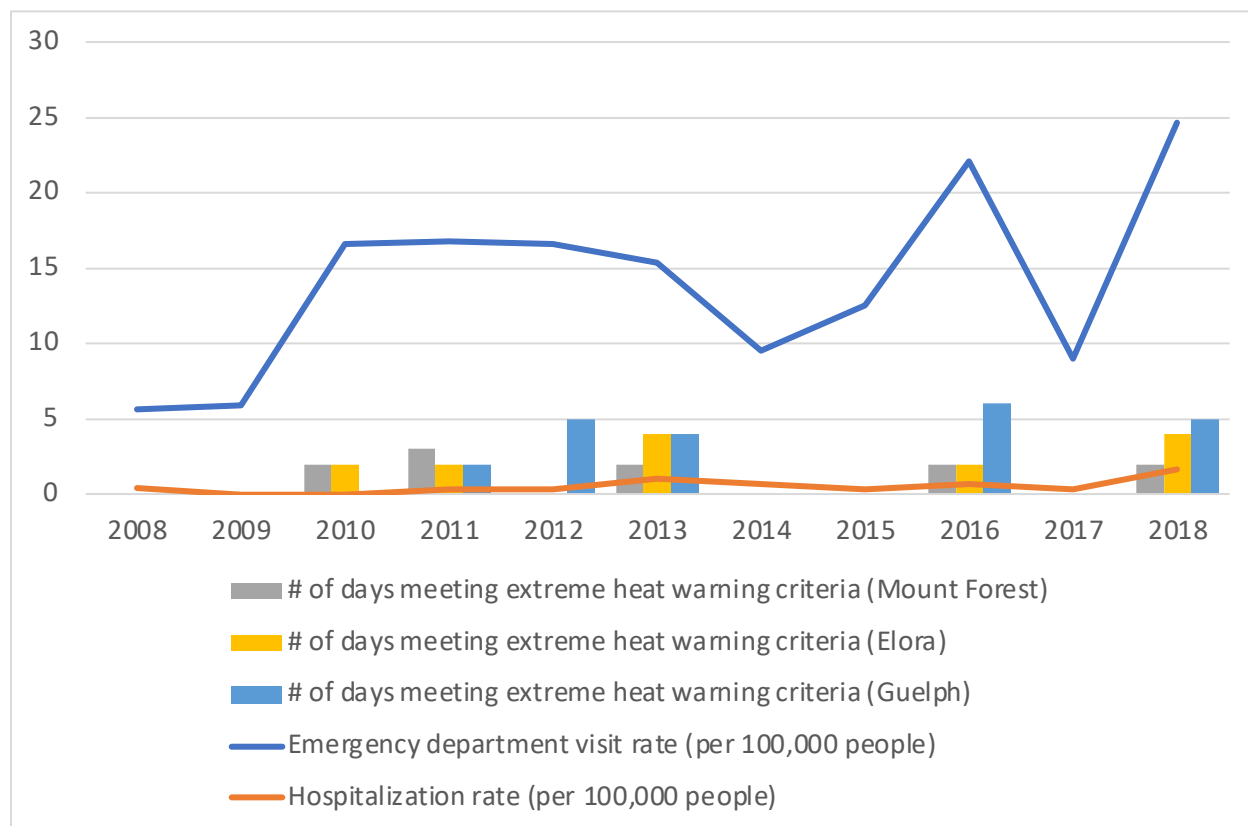
Figure 8. Crude rates for emergency department visits and hospitalizations for heat-related illnesses (per 100,000 people) and extreme heat occurrences, Waterloo Region, 2008-2018



Sources: Data for heat-related illness includes ICD-10-CA codes for T67 [effects of heat and light], X30 [exposure to excessive natural light], X32 [exposure to sunlight], extracted, and all Dx problem codes, rather than MPDx used, NACRS, IntelliHealth, Ministry of Health, extracted 2019-10-08 & 2019-10-15; Data for heat warning criteria from Environment and Climate Change historical climate data, available: https://climate.weather.gc.ca/historical_data/search_historic_data_e.html



Figure 9. Crude rates for emergency department visits and hospitalizations for heat-related illnesses (per 100,000 people) and extreme heat occurrences, Wellington-Dufferin-Guelph, 2008-2018

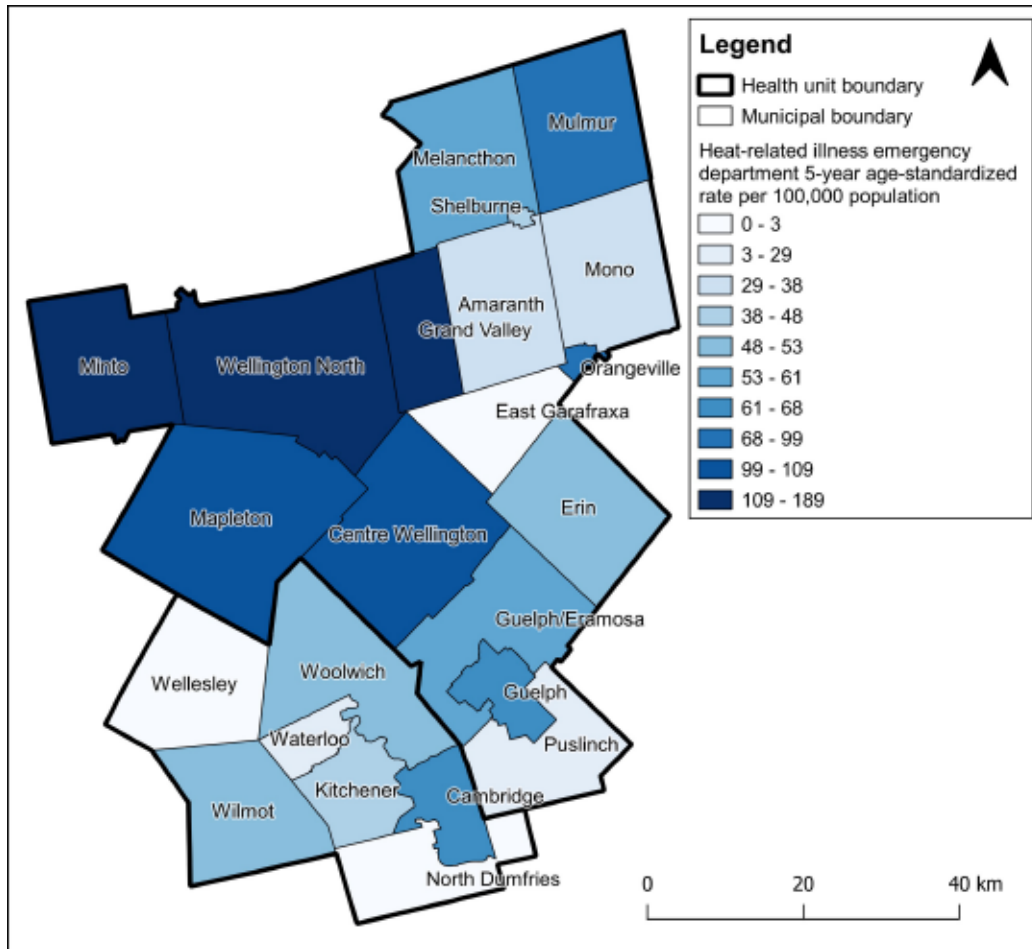


Sources: Data for heat-related illness includes ICD-10-CA codes for T67 [effects of heat and light], X30 [exposure to excessive natural light], X32 [exposure to sunlight], extracted, and all Dx problem codes, rather than MPDx used, NACRS, IntelliHealth, Ministry of Health, extracted 2019-10-08 & 2019-10-15; Data for heat warning criteria from Environment and Climate Change historical climate data, available: https://climate.weather.gc.ca/historical_data/search_historic_data_e.html

Temperature-related illnesses were also mapped to correspond to lower-tier geography across the study area (see Figure 10). Here, we find that the census sub-divisions of Minto, Wellington North, and Grand Valley in the northwest of the study area had among the highest rates of heat-related emergency department visits when averaging visits over the period of 2014-2018. This may be due to lower rates of tree canopy cover (particularly in Wellington North and Grand Valley) and a higher proportion of residents aged 65 and older in this area. However, based on this data, it is not possible to discern which factors contribute to spatial patterns of risk without further study.



Figure 10. Spatial depiction of age-standardized heat-related emergency department visits (per 100,000 people), across municipalities within the study area, 2014-2018



Source: Data for heat-related illness includes ICD-10-CA codes for T67 [effects of heat and light], X30 [exposure to excessive natural light], X32 [exposure to sunlight], extracted, and all Dx problem codes, rather than MPDx used, NACRS, IntelliHealth, Ministry of Health, extracted 2019-10-08 & 2019-10-15

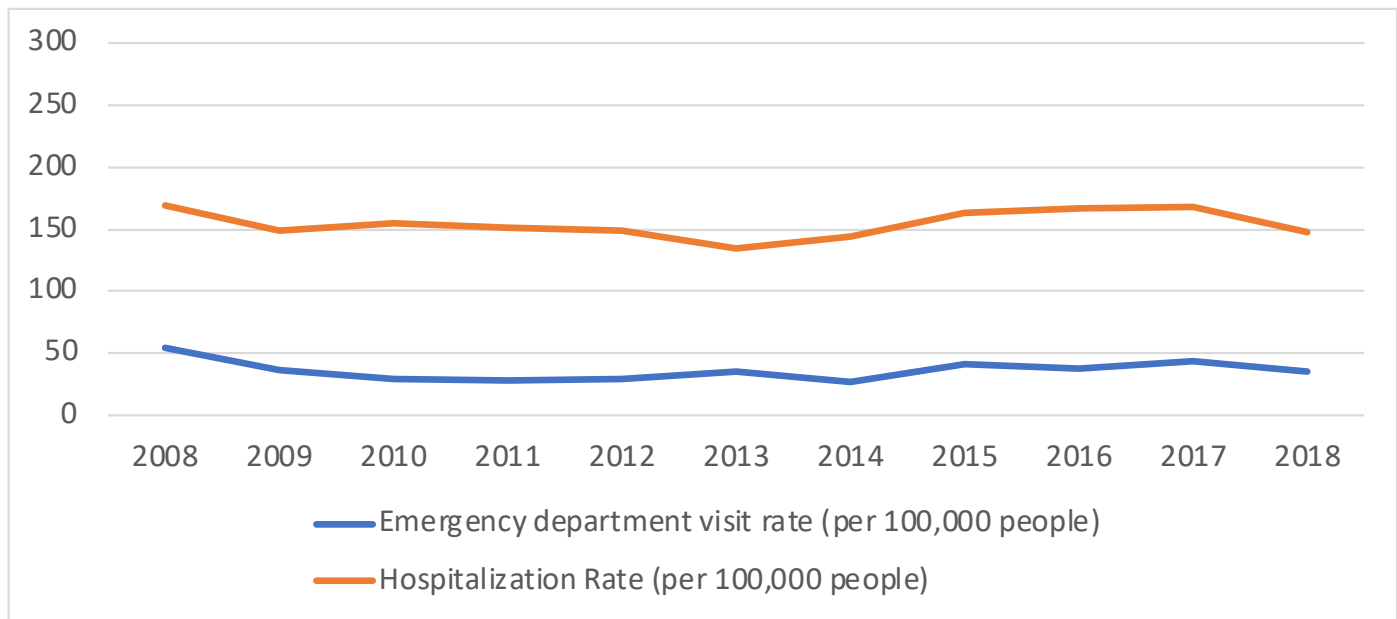
Higher temperatures can exacerbate pre-existing cardiovascular and cerebrovascular conditions, particularly for older adults.(33) This makes establishing historical baselines for key health outcomes such as myocardial infarction (i.e., heart attack) pertinent to an assessment of heat-related illness, although definitively attributing extreme heat to a heart attack is challenging because of other biological and risk factors.

Figures 11 and 12 show hospitalization rates and emergency department visits for each health unit within the study area. A decreasing trend in Emergency department visits for myocardial infarction in Waterloo Region was found to be statistically significant over time ($p < 0.05$), but no trend was detected for other measures. WDG's rates of hospitalization for myocardial infarction tend to be higher than that of Waterloo Region. In 2015, according to



data from the Statistics Canada Canadian Community Health Survey 2015/2016, 4.9% and 6.35% of the population indicated they had some form of heart disease in Waterloo Region and Wellington-Dufferin-Guelph, respectively. Both Health Unit areas also had 1.1% of their respective populations self-identify as having previously had a stroke. It has been previously noted that a 10-year trend for disease may be a challenging temporal period to measure trends related specifically to climate change when other confounding factors (e.g., changes in health behaviours, aging population, etc.) may influence changes in emergency department visits and hospitalization over time, and thus, attributing these trends to climate change should be done with caution.

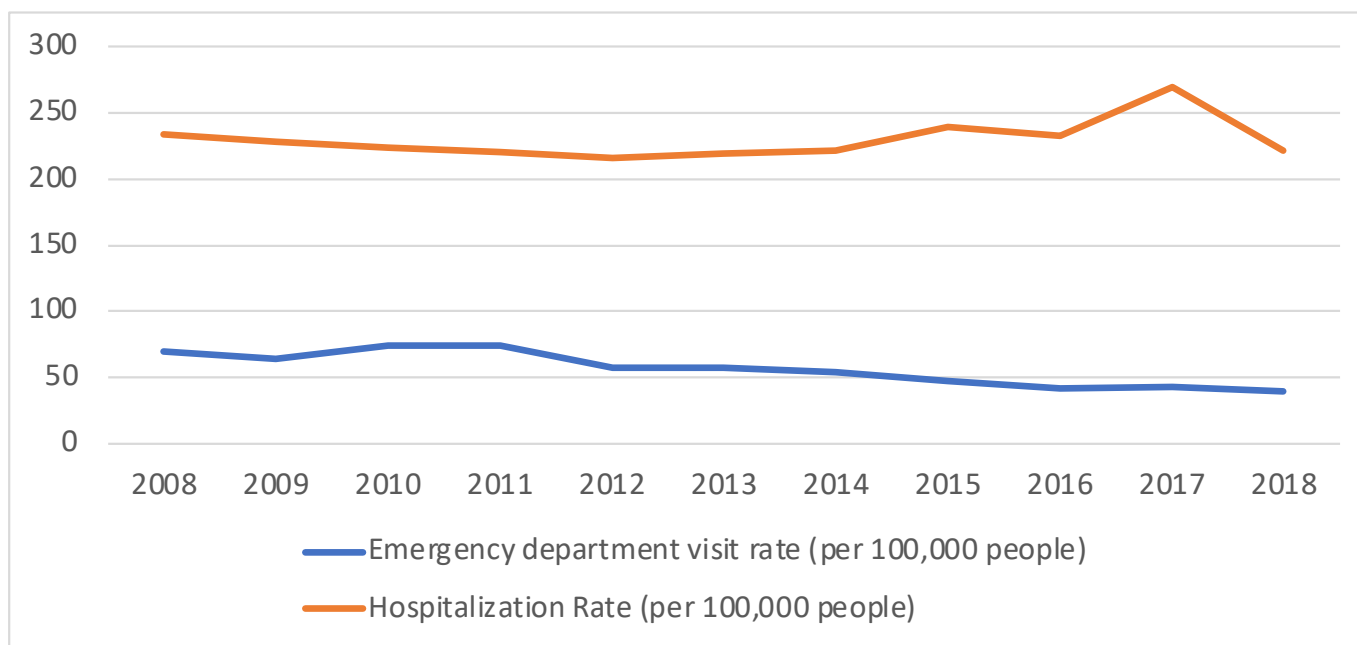
Figure 11. Crude rates for emergency department visits and hospitalization for myocardial infarction (per 100,000 people) in Waterloo Region, 2008-2018



Source: Includes ICD-10-CA codes for I21NACRS & DAD, IntelliHealth, Ministry of Health, extracted 2019-10-09 & 2019-10-15NACRS & DAD, IntelliHealth, Ministry of Health, extracted 2019-10-09 & 2019-10-15.



Figure 12. Crude rates for emergency department visits and hospitalization for myocardial infarction (per 100,000 people) in Wellington-Dufferin-Guelph, 2008-2018



Source: Includes ICD-10-CA codes for I21NACRS & DAD, IntelliHealth, Ministry of Health, extracted 2019-10-09 & 2019-10-15NACRS & DAD, IntelliHealth, Ministry of Health, extracted 2019-10-09 & 2019-10-15.

3.5 Populations Vulnerable to Extreme Temperatures in Wellington-Dufferin-Guelph and Waterloo Region

Some populations are more vulnerable to temperatures than others due to increased exposure, sensitivity, or a lack of adaptive capacity. This section reviews the literature for population characteristics that may increase vulnerability to extreme temperatures caused by climate change according to these categories. The literature suggests that population living in highly urbanized areas with limited natural land cover; working outdoors (e.g., farmers, construction workers) or in high-heat environments (e.g., bakeries); being physically active outdoors; and outdoor event goers may be differentially exposed to extreme temperatures. Children (aged 0-5), older adults (aged 65+), and people with pre-existing and/or chronic health conditions may be more physiologically sensitive to extreme temperatures. Further, people experiencing social/physical isolation and/or material deprivation (e.g., those with lower incomes, lower education, not speaking English/French, newcomers, or visible minorities) may have limited adaptive capacity in the face of extreme temperatures. Summary statistics for these population groups based on available data are provided in Table 4. The following sections briefly describe the literature for each population vulnerable to extreme temperatures and recent statistical representations of each population of interest.



3.5.1 Populations vulnerable to extreme temperatures due to exposure

Some populations are differentially exposed to extreme temperatures. Exposure is largely driven by the places people interact with daily, including where we live, work and play. This section briefly outlines population-level exposures to extreme temperatures.

3.5.1.1 Urban areas

People who live in urban neighbourhoods with high degrees of non-permeable surfaces (e.g., concrete roadways and buildings) may be particularly vulnerable to the health impacts of climate change and extreme heat. Urban environments tend to have high proportions of heat-trapping impermeable surfaces (e.g., concrete and asphalt) that magnify heat present in ambient air temperatures to create urban heat islands.(38) Surface areas that are comprised of non-permeable surfaces (e.g., pavement, roofing) can be 10-15°C higher than those covered by permeable surfaces (e.g., tree canopy cover), and urban areas can be 1-3°C hotter than their surroundings (see Figure 13).(39)





Table 4. Population statistics for vulnerability to extreme heat for Wellington-Dufferin-Guelph and Waterloo Region, 2016

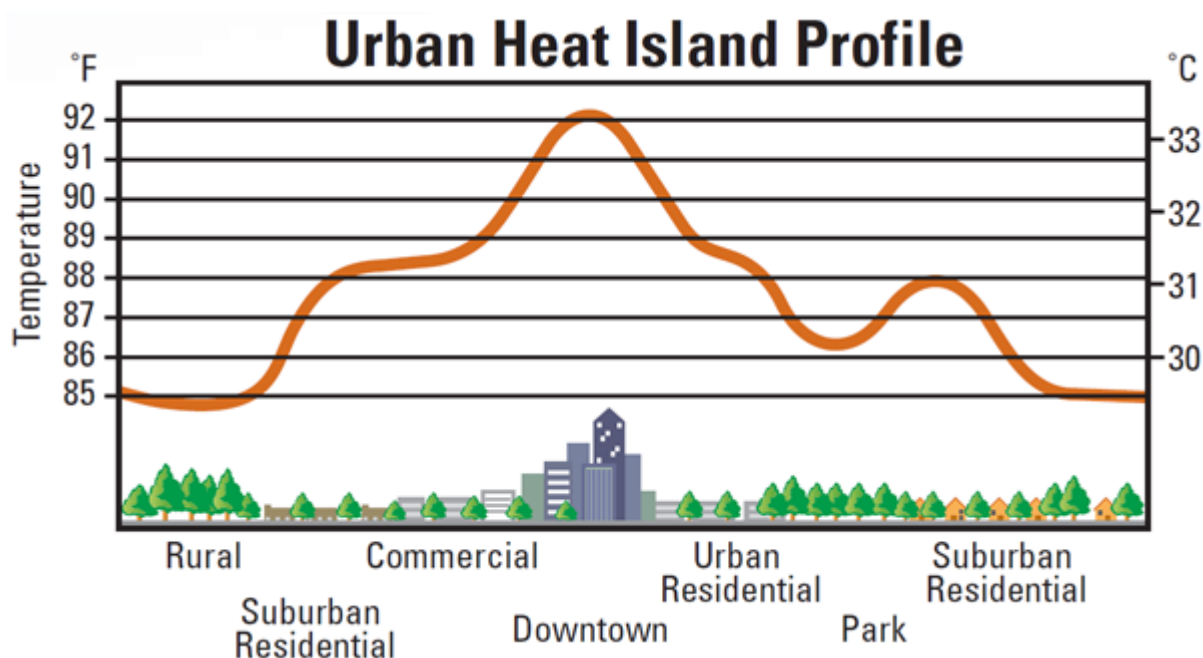
Vulnerability Category	Population Characteristics	Wellington-Dufferin-Guelph % of total population	Waterloo Region % of total population	Ontario % of total population
Exposures	Employed in Agriculture, Forestry, Fishing or Hunting	3.4%	1.4%	1.5%
	Employed in Construction	7.4%	6.6%	6.8%
	Active Transportation - Walking	5.3%	4.4%	5.3%
	Active Transportation - Bicycle	1.1%	1.1%	1.2%
Sensitivity	Age 0 to 14 years	17.8%	17.8%	16.4%
	Age 65 years and over	15.8%	14.4%	13.9%
	Prevalence of chronic conditions	50.2%	50.8%	--
Adaptive Capacity	Prevalence of low income after-tax	9.9%	12.1%	14.4%
	No high school certificate, degree or diploma	11.1%	18.7%	10.4%
	% of owner households spending 30% or more of income on shelter costs	17.2%	14.6%	19.8%
	Dwellings requiring major repairs	5.1%	5.0%	6.1%
	Housing unsuitability (crowding)	3.4%	4.5%	6.0%
	Apartment in a building that has five or more storeys	5.7%	10.8%	17.2%



Vulnerability Category	Population Characteristics	Wellington-Dufferin-Guelph % of total population	Waterloo Region % of total population	Ontario % of total population
Adaptive Capacity	Speaking neither English nor French	0.9%	1.8%	2.5%
	Immigrants	16.4%	22.6%	29.1%
	Recent immigrants - 2011 to 2016	9.7%	11.8%	12.3%
	Visible minority population	11.6%	19.0%	29.3%

Source: Statistics Canada 2016 Census of the Canadian Population; Canadian Community Health Survey 2015/2016

Figure 13. Example of the urban heat island profile



Source: Karl et al., 2009(40)

Trees cast shade which mitigates human exposure to extreme heat, whereas impermeable surfaces such as roadways and buildings absorb and radiate heat. Two data sets were used to spatially depict the degree of



impermeable surfaces across the study area. Figures 14 and 15 present tree canopy cover and an indexed value of natural climate zones, respectively (i.e., a spatial measure of ‘greenness’) across the study area. Findings indicate that Guelph, Orangeville, Shelburne, Grand Valley, and Amaranth had the least amount of tree canopy coverage as a proportion of total area, and that the more densely populated areas of Guelph, Waterloo, Kitchener, and Cambridge had lower proportions of natural climate zones than surrounding areas. Figure 14 utilizes a 2019 Annual Crop Inventory database, a composite database of numerous types of crops, trees, and plants, made available from the Government of Canada to create an area-based estimation of total tree cover according to municipality (i.e., census sub-division). However, it should be noted that upon cross-referencing with satellite imagery, a limitation of this dataset is that it does not appear to register single trees or small clusters of trees such as those found along urban streets, in back yards, or planted in thin strips adjacent to fields. Tree canopy coverage is therefore likely underestimated in both rural and urban environments, and future analysis should seek to improve an understanding of local tree canopy taking these factors into consideration. Further, while the natural climate zone map (Figure 15) resolves the under-counting problem by utilizing satellite imagery, it also measures a variety of green space such as low plants and other forms of natural areas which may not provide shade to mitigate against ultraviolet radiation (for more information, see Chapter 4), but can still reduce the radiative forcing of impermeable surfaces. It should be further noted that tree canopy coverage does not necessarily equate to any level of population protection, particularly if it is not located near users of particular spaces (e.g., pedestrian walkways), which was a finding from shade audits conducted in Waterloo Region.

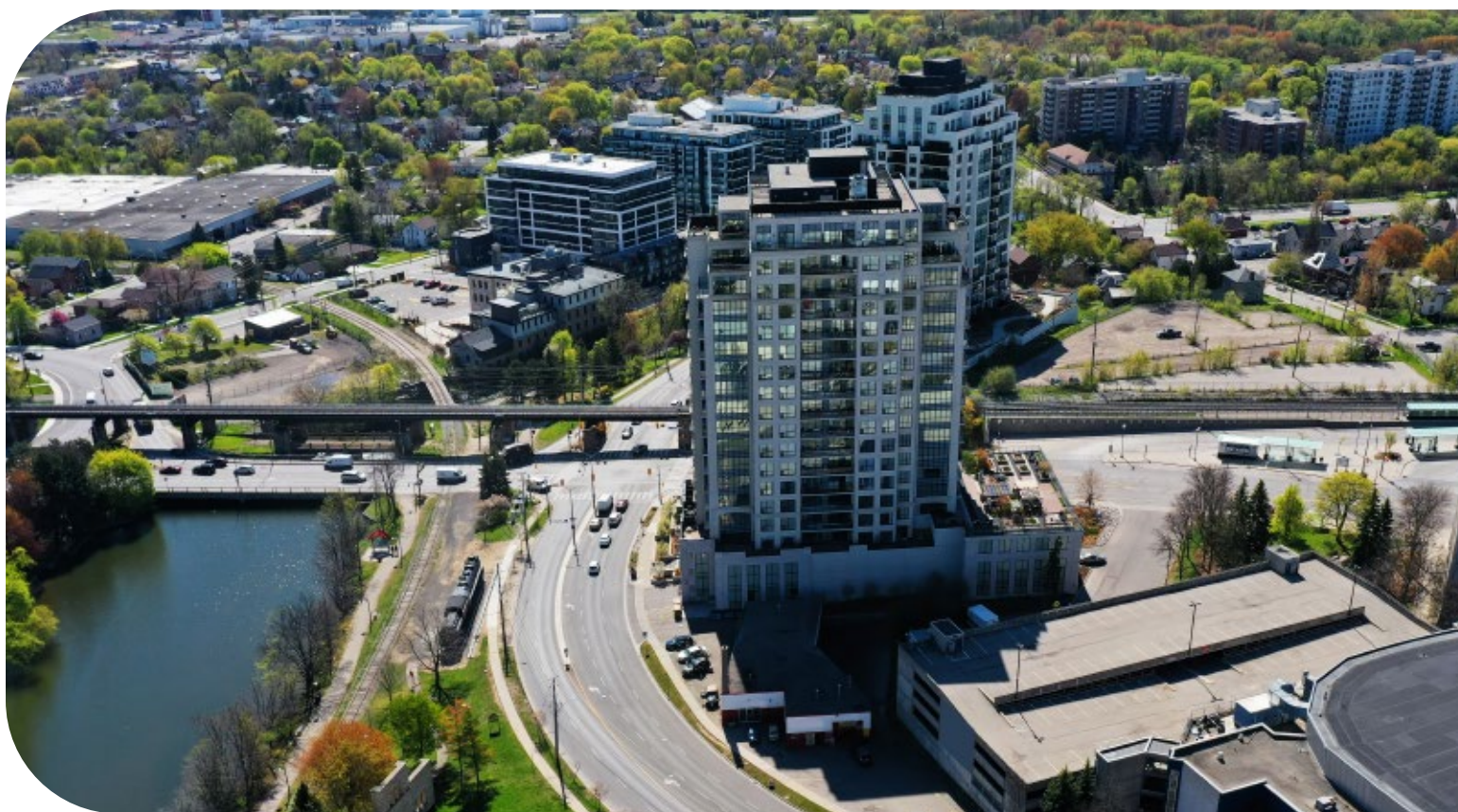
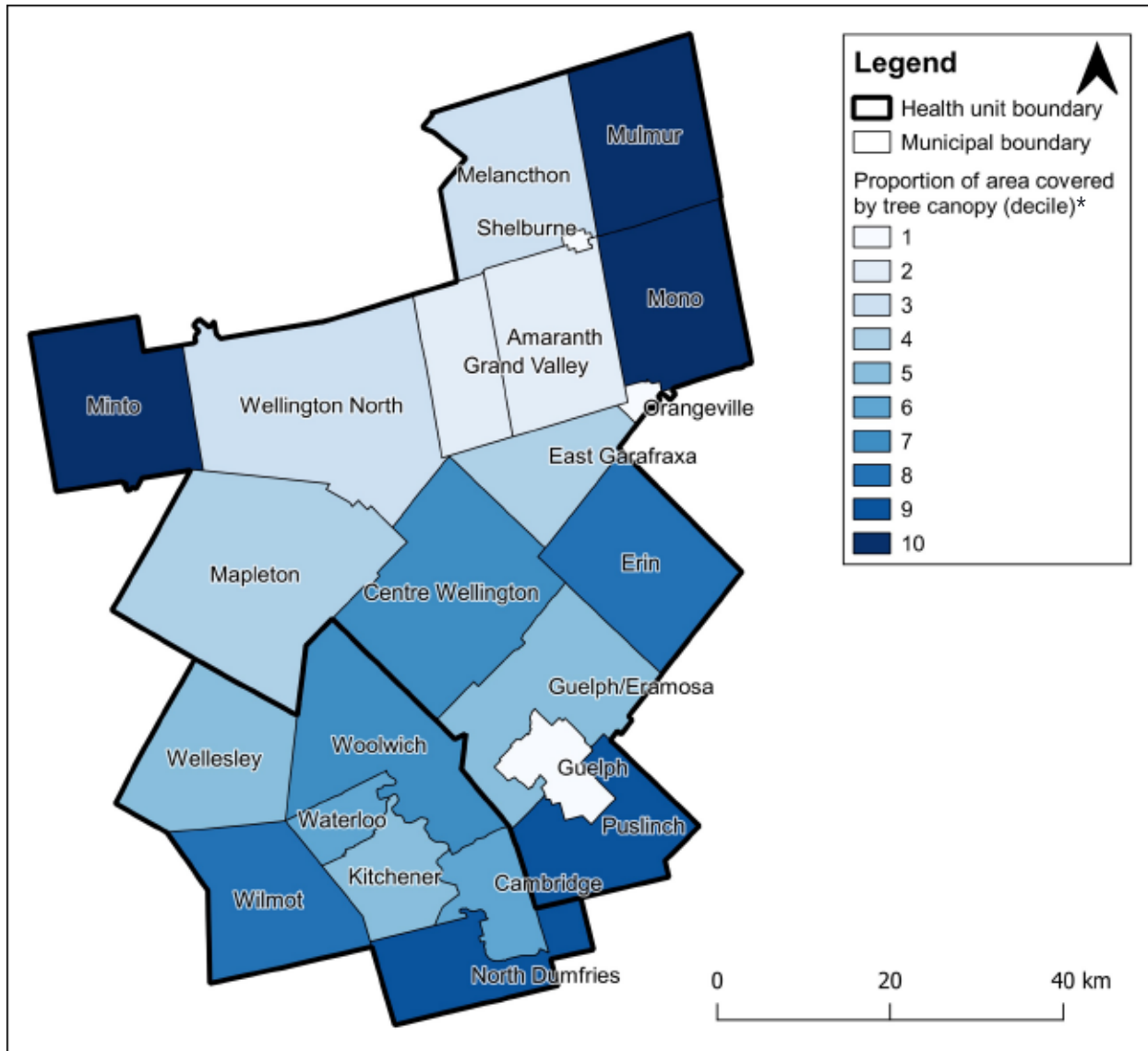




Figure 14. Tree canopy cover as a proportion of total area of municipalities within the study area, depicted by decile*, 2019

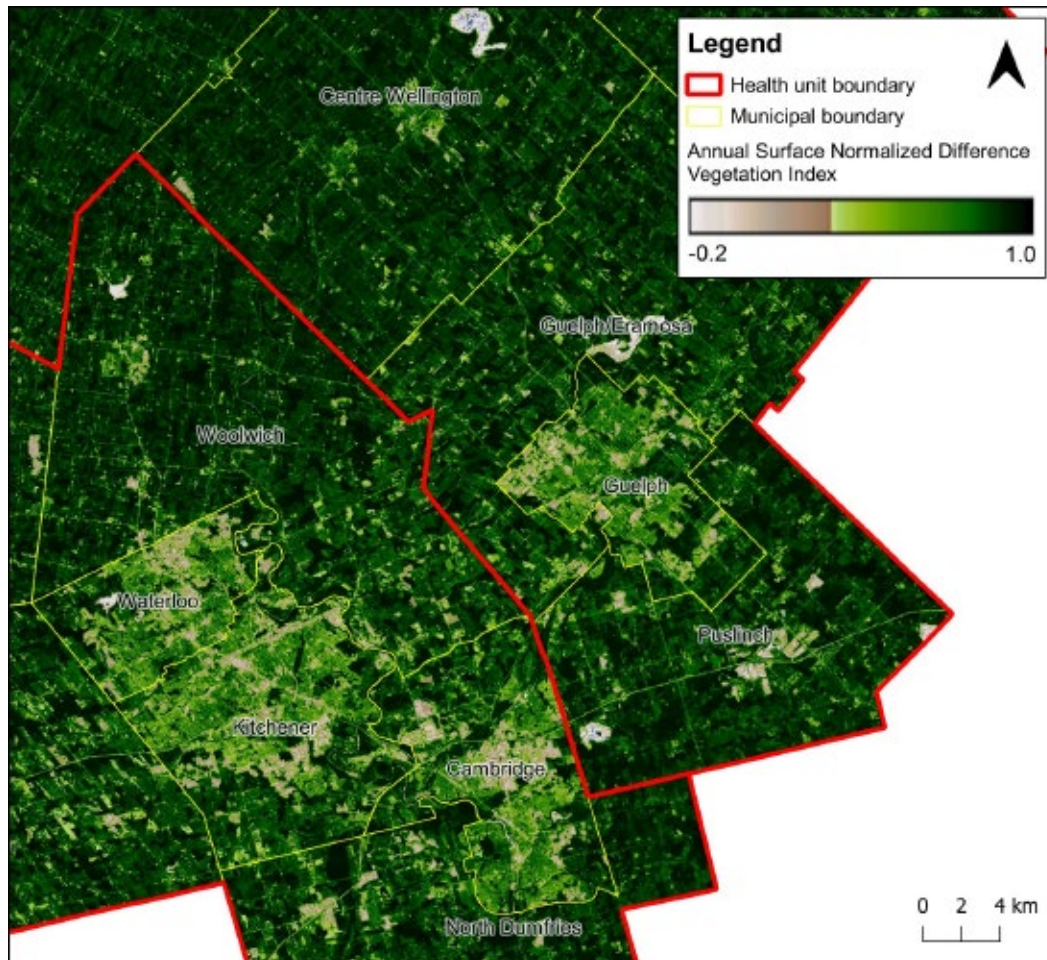


Source: 2019 Annual Crop Inventory Dataset, data subset of Coniferous, Broadleaf and Mixedwood to estimate tree cover: <https://open.canada.ca/data/en/dataset/d90a56e8-de27-4354-b8ee-33e08546b4fc>.

* Deciles refer to ten equal groups by which tree canopy coverage is represented, where 1 represents the lowest canopy coverage and 10 represents the highest canopy coverage.



Figure 15. Surface normalized difference vegetation index measuring permeable and impermeable surfaces in the urban areas of the study region, 2008-2010



Source: Surface Normalized Vegetation Index (NDVIA) to estimate 'greenness' of urban regions of the study area, <https://lpdaac.usgs.gov/products/gweldyrv031/>

Table 5 describes temperature differences between the most urban and population-dense areas of the study area, where exposure to heat is anticipated to be greatest, relative to their rural counterparts under RCP8.5. Findings indicate that the larger metropolitan areas in the study area, based on population, are approximately 1°C hotter than smaller municipalities, except for Wilmot Township.

Densely populated areas are also more likely to have high-rise buildings, and because heat rises, people living in upper levels of apartment buildings in urban areas may experience greater exposure to extreme heat.(29,39) Census data from 2016 for each Health Unit jurisdiction indicate that the more densely populated Waterloo Region has a higher proportion of people living in apartments that have five or more stories (10.8%) relative to 5.7% of the less densely populated Wellington-Dufferin-Guelph area (individual community proportions are presented in Table 5).



Table 5. Population size, the proportion of 2016 population living in apartments with five or more storeys, and days above 32°C for select study area municipalities* under RCP8.5

Municipality	Population size	Proportion (%) of 2016 population living in apartments with 5 or more storeys	Historical days above 32°C in 2005	Projected days above 32°C in 2050	Projected days above 32°C in 2080
Kitchener	242,368	14.5	2	18	45
Guelph	135,474	10.6	2	17	42
Cambridge	129,920	5.4	3	21	45
Waterloo	113,520	14.7	2	18	45
Orangeville	30,734	4.8	1	8	35
Centre Wellington	20,767	1.0	1	11	35
Wellesley	11,260	0.0	1	13	38
Wilmot	20,545	0.0	2	16	43

Source: Lapp et al. 2022, Climate Science Report

*Note: Insufficient data for North Dumfries and Woolwich Townships.

3.5.1.2 Unique occupations

People who work outdoors (e.g., construction workers, people working in parks or outdoor recreation facilities, farmers, migrant workers) may be more vulnerable to extreme temperatures. Additionally, those employed in high-heat environments (e.g., bakeries) can be differentially exposed to extreme heat through the outdoors and their work environment.⁽⁴¹⁾ Extreme heat can lead to heat-related illnesses, raising the risk of work-related injury and making it difficult to maintain productivity.^(42,43)

While no regularly collected data exist to conceptualize how many people in Canada work in high-heat environments, estimates for outdoor occupational exposures can be derived from census data for occupations typically associated with outdoor work, including agriculture and construction. In 2016, 3.4% of those aged 15 or older in the labour force and living across the WDGPH jurisdiction worked in agriculture, forestry or fishing and hunting sectors, and 7.4% worked in construction. In comparison, in Waterloo Region, 1.4% of the labour force worked in agriculture, forestry or fishing and hunting, and 6.6% worked in construction in 2016.



3.5.1.3 People who are physically active outdoors or engage in active transportation

People who exercise vigorously outdoors may temporarily experience increases in body temperature, and when coupled with exposure to extreme heat, have an elevated risk of dehydration and heat stress on the body.⁽²⁹⁾ They may also be differentially exposed to extreme cold, and more prone to frostbite and hypothermia depending on outdoor air temperature, and whether, after vigorous physical activity, sweat is allowed to collect and freeze.⁽²⁹⁾

Data on active commuting are captured in the 2016 Canadian census, and physical recreation data are available via the 2015/2016 Canadian Community Health Survey. Data suggest that, for people aged 15 years and over and who are employed in the work force, Waterloo Region and Wellington-Dufferin-Guelph have a high proportion of people who drive cars, trucks, or vans as their main mode of commuting—81.0% and 82.1%, respectively. The proportion of people who utilize active transportation strategies for commuting such as walking or cycling is 6.4% in Wellington-Dufferin-Guelph and 5.5% in Waterloo Region, although it should be noted that this data is limited only to commuting and may underestimate the overall modal share of active transportation utilization. Indeed, additional 2016 data from the Transportation Tomorrow survey of 2016 indicate that the modal share of walking or cycling for all trips made by residents in a 24-hour period was 7% for the Regional Municipality of Waterloo, 9% for the City of Guelph, 2% for the County of Wellington, 8% for the Town of Orangeville, and 3% for Dufferin County.² Further, while active transportation is an ideal way to reduce individual carbon emissions, high output activities on hot days, particularly when individuals are exposed to both heat and direct sunlight can create conditions for heat-related illnesses.

Data from the CCHS indicate that 41.7% of people in Waterloo Region self-reported to have engaged in physical activity in the past seven days, and 24.2% had engaged in vigorous physical activity. In Wellington-Dufferin-Guelph, 39.0% had engaged in some form of physical activity, and 22.6% of the population engaged in vigorous physical activity. The CCHS does not collect whether physical activity occurred outdoors or indoors, or the season, raising important data limitations about the risks associated with indoor versus outdoor exercise during periods of extreme heat.

3.5.1.4 Outdoor event goers

It is difficult to estimate the total number of attendees at outdoor summer events who may be exposed to extreme heat. However, several farmers' markets and outdoor food, drink, and music festivals (e.g., Craft Beer Festival, Bluesfest, Hillside Festival, Uptown Waterloo Jazz Festival, Ever After Music Festival, etc.) are regularly hosted each year. Large outdoor events are often held in large open areas with limited shade or access to free drinking water.

3.5.1.5 Additional exposures identified through focus groups

Participants in focus group discussions identified that the Mennonite population may be a unique population of concern for extreme temperatures because of a lower reliance on mechanical heating/cooling, and a high degree of outdoor exposure. However, participants also raised that local Mennonite populations may also be uniquely able to adapt to extreme temperatures through their existing familiarity with local weather patterns and dispositions

2 For more information on the Transportation Tomorrow survey and associated data, please see: http://www.dmg.utoronto.ca/pdf/tts/2016/2016TTS_Summaries_TTSarea.pdf



towards helping neighbours and community connections. More information is required to ascertain how vulnerable this group will be to the impacts of extreme temperature.

3.5.2 Populations vulnerable to extreme temperatures due to sensitivity

3.5.2.1 Children

Children are both directly and indirectly impacted by climate change, and children already experience up to two-thirds of preventable illness and death from environmental health hazards.(44) This can include exposures by virtue of spending more time outdoors than adults,(45) and be reflected by their physiological sensitivity. Children's physiological systems are not fully developed, create more body heat per body mass, experience faster heat gain from their environments, and have reduced sweating and an inability to increase cardiac output making them particularly sensitive to heat.(29) Children at greatest risk include those with asthma, heart conditions, kidney problems, and other forms of developmental disorders, mental and physical disabilities, and those who take certain medication.(29) Children also are more sensitive to cold weather because they are less able to regulate their body temperature compared to adults. Further, children are more likely to rely on adults and caregivers to prepare and protect them from extreme temperatures.

Heat additionally poses challenges for infants and unborn children in utero:

- Maternal exposure to temperatures of 30°C and higher for 10 days or more in early pregnancy increases the risk of congenital heart defects in the fetus.(46,47)
- A 5.6°C increase in weekly average temperature was found to lead to an 8.6% increase preterm delivery rates.(48)
- Exposure to higher temperature is correlated with low birth-weight, increases in stillbirth, and neonatal stress. (49,50)
- Higher temperatures during pregnancy are anticipated to predict further health problems throughout child development in terms of impacts to intellectual development, language performance, and emotional regulation. (51,52)

Concerns raised during stakeholder engagement flagged that school-aged children who use active transportation to and from school may be particularly exposed to extreme heat and cold, both during their commute, and then in schools that lack adequate air conditioning, heating, or other strategies to lower indoor temperatures. Similar concerns were raised around un-air-conditioned school buses. A complete list of all institutions that serve children in the study area without cooling interventions is not currently available.

Current population data from the Canadian census indicate that the distribution of children aged 0-14 and 0-4 relative to the total population is identical across both Health Unit jurisdictions at 17.8% and 5.7% respectively. These figures represent 95,385 people aged 0-14 years in Waterloo Region, with 30,395 being aged 4 or less, and 50,565 aged 0-14 years in Wellington-Dufferin-Guelph and 16,210 aged 0-4. As noted above, while children aged 0-1 are identified as being particularly vulnerable to extreme cold, data on this age group is unfortunately not publicly reported by



Statistics Canada, nor is the number of pregnant mothers. According to [Ontario Population Projections](#), it is expected that the number of children aged 0-14 in the study area will increase by as much as 30% by 2046.

3.5.2.2 Older adults

Human physiology changes as we age. Older adults are less able to regulate body temperature through sweating and may have reduced thirst sensation, sweating and fitness levels, making them more sensitive higher temperatures and chronic dehydration.(29,32,53) For example, a meta-analysis found that all-cause mortality in an older population increased 2-5% for every 1°C increase in temperature.(54) Other heat-related illnesses for older adults include a variety of cardiovascular and respiratory illnesses, renal insufficiency related to dehydration and poor kidney function, retinal detachment, and circulatory issues.(55) Older adults also may be on certain medications that make them more light- or heat sensitive (e.g., anticholinergics (inhibit nerve impulses), anti-Parkinson's agents, antihypertensive medications, diuretics, or antihistamines). Similarly, older adults' response to cold tends to diminish over time, and certain conditions or medications can also limit the ability of the body to stay warm when exposed to cold temperatures.

Older populations may also experience compounded vulnerability to extreme temperature events if they are socially isolated (e.g., not having someone check-in on them or have a caregiver to help to relocate during emergencies), living with low-income (e.g., lacking material resources to support adaptive behaviours such as accessing air conditioning) or have pre-existing, chronic illnesses and/or visual, cognitive or hearing impairments that may inhibit their ability to mobilize during periods of crisis or emergency.

Data for the study area suggest that the proportion of people aged 65 and older is growing from census year to census year. In 2016, of Wellington-Dufferin-Guelph's total population, 15.8% were aged 65 and older, relative to 14.4% in Waterloo Region. Moreover, the number of seniors is projected to more than double across the province of Ontario by 2030.(56) Older adults comprise the fastest growing population segment across Ontario. In 2016, 2,251,655 people (16.5% of the provincial population) were aged 65 years or older, but by 2041, it is expected this population group will more than double and comprise as many as 4.6 million older adults. Estimates suggest that by 2031, one in five people in Waterloo Region will be aged 65 or older,(57) and 23.6% of all people in Wellington-Dufferin-Guelph are expected to be aged 65 or older.(56)

3.5.2.3 Populations with pre-existing health conditions

Many Canadians have pre-existing and chronic conditions that influence their sensitivity to extreme temperatures and their ability to adapt. While not all chronic conditions make someone vulnerable to extreme heat in Ontario, 80% of people aged 45 and older identify as living with at least one chronic condition.(58) People with mobility limitations, psychiatric illnesses, those who are confined to a bed or dependent on caregivers, and people with other forms of sensory or cognitive impairments may be unable to relocate during an emergency, or to seek out cooler environments during periods of extreme heat.(32,59) High temperatures may differentially affect people with diabetes or obesity as high temperatures are associated with mortality in these groups at very high and very low temperatures.(60) Research has also examined the health impacts of heat events across nine Canadian cities and found a direct relationship between the number of reported chronic conditions and the likelihood of experiencing



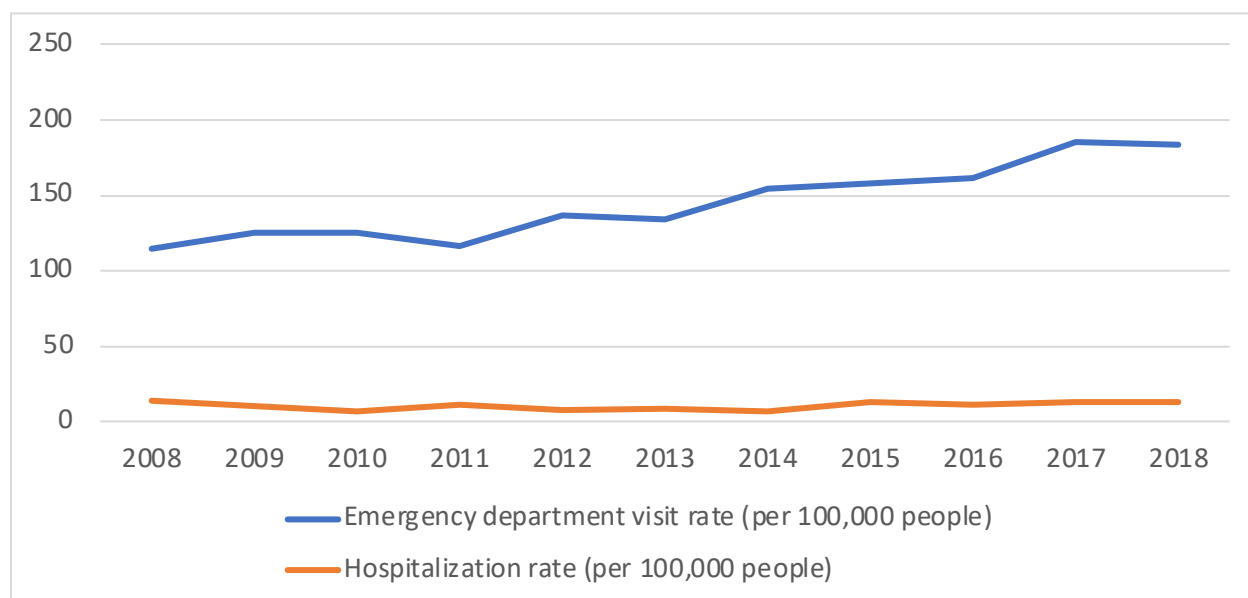
heat-related health impacts.(61) People with renal and respiratory diseases are also at greater risk, as are those with circulatory disease as outlined earlier in this chapter.(62)

Pre-existing conditions also interact with material capabilities to adapt to new conditions. Past research conducted in the study area indicates that people are more likely to have a chronic condition if they have household incomes of less than \$40,000, have less than a high school education, are Canadian-born, female, and over the age of 50.(63)

Data from the Canadian Community Health Survey suggest that the proportion of the total population aged 12 years and older living with one or more chronic conditions is 50.2% (CI: 59.9-53.5) in Wellington-Dufferin Guelph, and 50.8% (CI: 47.0-54.6) in Waterloo Region. However, in terms of population vulnerability, these data should be interpreted with caution as not all chronic conditions will be exacerbated by or will increase vulnerability to extreme heat.

For example, people with pre-existing cardiovascular disease have been found to be at elevated risk of health complications during extreme heat events.(33) Hospitalizations for hypertension have remained stable in both Public Health jurisdictions, with no significant trend detected. In 2015, 18.9% of residents in Waterloo Region self-identified as having high blood pressure, compared to 20.5% in Wellington-Dufferin-Guelph. Both regions have seen more than a 50% increase in emergency department visits due to hypertension since 2008 ($p < 0.05$, see Figures 16 and 17). This is likely attributable to the growing number of older adults throughout the study area, a population that is projected to double across Ontario by 2030.(56)

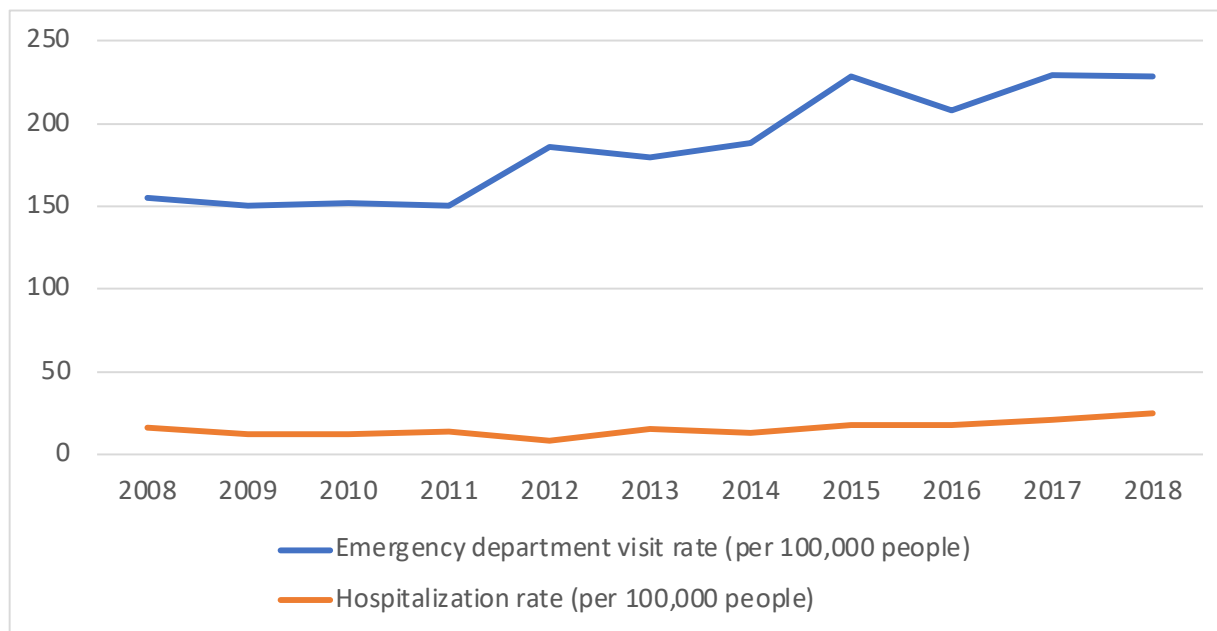
Figure 16. Crude emergency department visit and hospitalization rates for hypertension (per 100,000 people) in Waterloo Region, 2008-2018



Source: Includes ICD-10-CA codes for I10-I13, I15, NACRS & DAD, IntelliHealth, Ministry of Health, extracted 2019-10-10 & 2019-10-16



Figure 17. Crude emergency department visit and hospitalization rates for hypertension (per 100,000 people) in Wellington-Dufferin-Guelph, 2008-2018



Source: Includes ICD-10-CA codes for I10-I13, I15, NACRS & DAD, IntelliHealth, Ministry of Health, extracted 2019-10-10 & 2019-10-16

3.5.3 Populations vulnerable to extreme temperatures due to adaptive capacity

Some populations are more vulnerable to extreme temperatures because they lack adaptive capacity. This section highlights known aspects of adaptive capacity that can influence temperature-related health outcomes.

3.5.3.1 Physical and social isolation

People may be unable to buffer climate change's health impacts due to either physical or social isolation. Physical isolation refers to the degree of rurality or remoteness of a particular community, or the distance that people need to travel to remove themselves from a climate-related emergency to access appropriate services or supports. Rural communities may be more exposed to severe weather events as a result.(64) Social isolation refers to having limited contact with other community members. Social connectedness may strengthen resilience and adaptive capacity by creating access to health promoting resources and social supports. Social isolation may also be prominent among newcomers experiencing linguistic isolation (e.g., speaking neither French nor English) or other forms of material deprivation, and disproportionately impacts those with pre-existing mental health issues by limiting adaptive capacity.(65)

Given the proximity of most rural surroundings to larger urban areas and the density of transportation networks across the study area, risks associated with physical isolation of rural areas throughout the study area may be lower, relative to far northern and remote communities. However, physical isolation can still present risks to residents who may require access to medical services offered in major urban centres.(32) Social isolation can be difficult to assess.



Here, we rely on proxy measurements of social isolation such as the degree of connectedness to community, the proportion of new immigrants (who may not fully comprehend heat alert messaging) and language insecurity.

Social isolation can be mitigated by a strong sense of connection to community. Canadian Community Health Survey data for 2015/2016 suggest that the proportion of people with a somewhat or very strong sense of connection to community was 68.2% for Waterloo Region and 68.8% for Wellington-Dufferin-Guelph. Census data suggest that of the 46,070 immigrants across Wellington-Dufferin-Guelph (16.4% of the total population), 9.7% immigrated between 2011 to 2016 (1.6% of total population). Waterloo Region receives comparatively more immigrants as the second largest receptor site for newcomers in Ontario after the Greater Toronto Area. Waterloo Region has 119,335 immigrants (22.6% of the total population), and 11.8% of those are newcomers who arrived from 2011-2016 (2.7% of total population). This difference may be partly responsible for a slightly higher degree of linguistic isolation in Waterloo Region, where 1.8% of the population speak neither French nor English relative to 0.9% across Wellington-Dufferin-Guelph.

3.5.3.2 Material deprivation and health inequities

Individual health is significantly influenced by socio-economic status,(66) where persons or populations that have proportionately lower material resources (e.g., income, housing, etc.) are more likely to experience chronic illness and complex health care needs.(67) Climate change compounds this inequity. Low-income populations already have elevated health disparities compared to higher-income population groups,(68) making them more likely to be impacted due to limited ability to access essential resources or support adaptive behaviours in cases of extreme temperatures.(69–71)

For example, people experiencing poverty tend to have less access to health and social services, higher levels of stress, are more likely to be underemployed, and may struggle to access housing and nutritious foods.(72,73) Higher temperatures have also been found to be related to increasing incidences of violent crime experienced in the United States,(74,75) and may also be a risk associated with temperature change in Canada.(39) Urban neighbourhoods experiencing material deprivation in the form of underinvestment, poor infrastructure, poor housing conditions, and limited access to services may contribute to a lack of public safety,(76) posing risks for low-income individuals in the face of extreme temperatures and other climate-related risks (e.g., flooding, poor air quality).(61,77)

There is an array of 2016 census data to conceptualize material deprivation in the study area, including the proportion of population receiving social assistance (9.9% in Wellington-Dufferin-Guelph, 10.3% in Waterloo Region), after-tax low-income prevalence (9.9% in Wellington-Dufferin-Guelph, 12.1% in Waterloo Region), and childhood (aged 0-17) and senior (aged 65+) after-tax low-income prevalence (12.1% and 9.4% respectively in Wellington-Dufferin-Guelph; 15.3% and 10.5%, respectively, in Waterloo Region).

People experiencing housing insecurity or insufficiency are particularly vulnerable to extreme events due to inherent exposure, stigmatization, pre-existing illnesses (particularly mental health and substance use disorders), poverty, a lack of structural safety, and an associated lack of access to essential services.(78) Two metrics account for housing-related adaptive capacity. First is unsuitable housing—a measure of whether a private household is suitable according to National Occupancy Standards based on the size and composition of the dwelling and household.



The proportion of total dwellings that were deemed unsuitable based on these standards was 3.4% in Wellington-Dufferin-Guelph and 4.5% in Waterloo Region. Second is a measure of the condition of housing, or the proportion of dwellings requiring major repairs. Census data suggest 5.1% of all dwellings in WD require major repairs relative to 5.0% in Waterloo Region, both of which are lower than the provincial average of 6.1%. However, housing insecurity and homelessness are significant concerns for the study area. In 2019, between 211 and 289 people experienced chronic homelessness in Waterloo Region and between 115 and 137 people experienced chronic homelessness in Guelph/Wellington.⁽⁷⁹⁾ Focus group participants identified downtown Kitchener, Cambridge (Galt), and Guelph as having higher rates of people experiencing homelessness and/or low-income than other parts of the study area.

Education is also related to material deprivation, and several studies note associations between the level of educational attainment and health vulnerability or resilience to extreme heat,⁽³³⁾ whereby higher educational attainment correlates with a greater understanding of climate risks and adaptive behaviours.^(71,80–82) In Wellington-Dufferin-Guelph, 11.1% of the 2016 population had no certificate, diploma or degree relative to 18.7% in Waterloo Region.

Race/ethnicity may also be a factor that determines vulnerability to extreme temperatures. This may stem from the fact that historical processes of marginalization influence where racialized minorities live and/or work and how much material resources they have access to in order to adapt.^(83,84) Census information suggests that 19.0% and 11.6% of the Waterloo Region and Wellington-Dufferin-Guelph population, respectively identify as a visible minority, relative to 29.3% of the Ontario population.

3.5.4 Sex and gender-based vulnerabilities

Climate change may pose differential risks based on sex and gender in Canada.⁽⁸⁵⁾ While still a growing research area,⁽⁴⁹⁾ there is good evidence suggesting extreme heat exposure poses risks to maternal morbidity and mortality which may be exacerbated by climate change,⁽⁸⁶⁾ and recent analyses in the US indicate that extreme heat leads to increased maternal hospitalization rates.⁽⁸⁷⁾

Further, communication challenges associated with risk messaging may also be present according to sex/gender. While women make up just over 50% of the total population (50.8% in Wellington-Dufferin-Guelph and 50.6% in Waterloo Region), the 2016 census demonstrates that, of those with no knowledge of either official language, 58.6% were women Wellington-Dufferin-Guelph and 58.7% were women in Waterloo Region. In other words, women are more likely than men to have no knowledge of either official language in the study area. Women across the study area also receive higher rates of social assistance and have higher prevalence of after-tax low-income rates relative to men, with a marked difference for those aged 65 and older.

Occupational exposures to extreme heat in outdoor settings may be greater for males.⁽⁸⁵⁾ There are seven times more men in construction jobs and 50% more men in agricultural jobs than women across the study area. Finally, 2016 Census data from Statistics Canada for the study area suggest that there are approximately 80 men for every 100 women aged 65 and older, suggesting the population of older women is greater than that of men.



3.6 Programs, Policies, and Related Actions Taken to Improve Adaptive Capacity to Extreme Temperatures

This section outlines existing Public Health activities directed towards adapting to (or promoting adaptive capacity) to extreme temperatures.

3.6.1 Individual actions

Importantly, there are several activities that individuals can pursue to reduce temperature-related health risks. These include limiting exposure by seeking out warm environments on cold days, and cool environments on hot days. Simple strategies such as knowing the weather forecast before going outside and modifying plans according to weather, planning weather-appropriate clothing (e.g., layers in cold weather, light colored clothes in hot weather), staying hydrated, and knowing the signs and symptoms of temperature-related illness (e.g., frostbite, hypothermia, heat stroke) can all help reduce the severity of exposure and illness. Frequently checking in on vulnerable neighbours, friends, and family can also be particularly helpful for identifying early signs of temperature-related illnesses. Active transportation is an ideal way to reduce an individual's carbon footprint. However, caution should be utilized during episodes of extreme heat if using active transportation strategies, particularly for transportation corridors with limited shade cover.

Statistics Canada has recently begun measuring the prevalence of different types of mechanical cooling as a percentage of all households. This data is only available at the level of the provinces and census metropolitan areas (i.e., large cities with greater than 100,000 population). The 2019 data show that the study area had high rates of households with access to any type of air conditioning (81% for Kitchener-Cambridge-Waterloo and 90% of Guelph), relative to the provincial rate of 82%.

3.6.2 Public Health actions

Public Health activities implemented by WDGP and ROWPH that address extreme temperatures cut across the requirements for programs, services and accountability established by the Ontario Public Health Standards (OPHS), 2018 guidance framework. The OPHS define the responsibilities of all Ontario boards of health in an integrated health system and are informed by core Public Health functions of: assessment and surveillance, health promotion and policy development, health protection, disease prevention and emergency management, with the goal "to improve and protect the health and well-being of the population of Ontario and reduce health inequities." The core Public Health standards and associated actions for each Health Unit can be found in Table 6, below.



Table 6. Ontario Public Health Standards and on-going Public Health activities to adapt to the health impacts of extreme temperatures

Ontario Public Health Standard – Core Public Health Function	Existing Activities
Population Health Assessment and Surveillance	<ul style="list-style-type: none"> • Identify vulnerable populations. • Monitor changes to population health status over time (e.g., board of health reports). • Monitor Environment Canada and Climate Change forecasts for heat and cold alerts. • Monitor hospitalizations and emergency department visits for heat-related illnesses and key heat-related health outcomes, including asthma, dehydration, and cardiovascular conditions.
Health Promotion and Policy Development	<ul style="list-style-type: none"> • ROWPH updates and circulates the Waterloo Region Heat Warning Response Plan (a key component of the Heat Alert Response System for Waterloo Region) and the Waterloo Region Extreme Cold Warning Response Plan. • WDGPH implements a Heat Warning and Information System protocol, and offers support to local stakeholders to develop organizational Heat Alert Response Systems. • Provide public education via website, social media, media interviews. • Provide education and recommendations for precautions for extreme temperatures for the general public and high risk/vulnerable populations.



Ontario Public Health Standard – Core Public Health Function	Existing Activities
Health Promotion and Policy Development	<ul style="list-style-type: none"> • Participate in Official Plan reviews and key strategic documents to include considerations towards health-impacts of land-use planning policy (i.e., policies that relate to green space, trees, shade, built environment, etc.). • WDGPH worked with local planning departments in urban areas within Wellington-Dufferin-Guelph to <u>collect baseline data on physical form indicators to measure local built environments</u>, including, where available, spatial data that supports measuring street tree canopy coverage and urban greenness. • Provide consultation to municipalities on outdoor public space projects which may include conducting shade audits. • Participate in partners' climate change planning. • Participate in strategic planning to incorporate health impacts of climate change.
Health Protection	Activate local protocols to open warming and cooling centres during extreme cold and heat warnings
Disease Prevention	Coordinates the Waterloo Region Extreme Heat and Cold Partnership with community partners to communicate health risks of extreme heat to the public and work with community partners to support community adaptation initiatives
Emergency Management	Provide input into emergency response planning

3.6.3 Actions led by community partners

Each Public Health Unit in the study area has benefited from significant community partnerships to support a local response to extreme temperatures. The activities below, while not intended to be comprehensive, signal the increasing attention directed towards building resilience to extreme heat and cold.

3.6.3.1 Environment and Climate Change Canada risk messaging

Extreme temperature alerts are issued by Environment and Climate Change Canada (ECCC). The thresholds used by ECCC are health-based and customized to different parts of Ontario. An Extreme Cold Warning is issued when the temperature or wind chill is expected to reach minus 30 degrees Celsius for at least two hours. A Heat Warning is



issued when one of two conditions are met: a) when 2 or more consecutive days of daytime temperature maximums are expected to reach 31°C or hotter and nighttime minimums are expected to be 20°C or warmer; or b) when two or more consecutive days of humidex values of 40°C or higher are expected (ECCC 2020).

3.6.3.2 Warming and Cooling Centres

Warming and Cooling Centres provide space for residents to cool down during Heat Warnings and warm-up during Extreme Cold Warnings. Community partners in Waterloo Region provide free access to a number of public buildings during regular hours with no expectation of extra amenities or services at these locations (see Table 7). Locations include regional and municipal buildings, recreation centres, libraries, local community health centres, and community centres. Pools and splash pads offer additional opportunities for residents to get relief from the heat. For a current list of Warming and Cooling Centres in Waterloo Region, click here: www.regionofwaterloo.ca/coolingandwarmingcentres

Table 7. Warming and Cooling Centres in Waterloo Region by municipality, 2019 (pre-COVID)³

Municipality	Number of Warming and Cooling Centres
Cambridge	9
Kitchener	27
North Dumfries	2
Waterloo	9
Wellesley	6
Wilmot	5
Woolwich	6
TOTAL	65

Similarly, WDGPH shares information about precautions to take as well as notification about Heat Warnings from Environment and Climate Change Canada with local partners as well as the general public. Cooling centres may not be labeled as such, instead public messaging issued by both Public Health and local partners encourages residents to visit air-conditioned public spaces, including libraries, community centres and shopping centres – as well as splash pads and pools – for a break from the heat. A list of air conditioned spaces in the City of Guelph

³ Note: During the COVID-19 pandemic, cooling/warming centres continued to operate, but not at the total number of locations listed here.



can be officially found on their website: [City Cooling centres - City of Guelph](#). Other local municipalities also make information and hours for air-conditioned spaces on their websites during heat events.

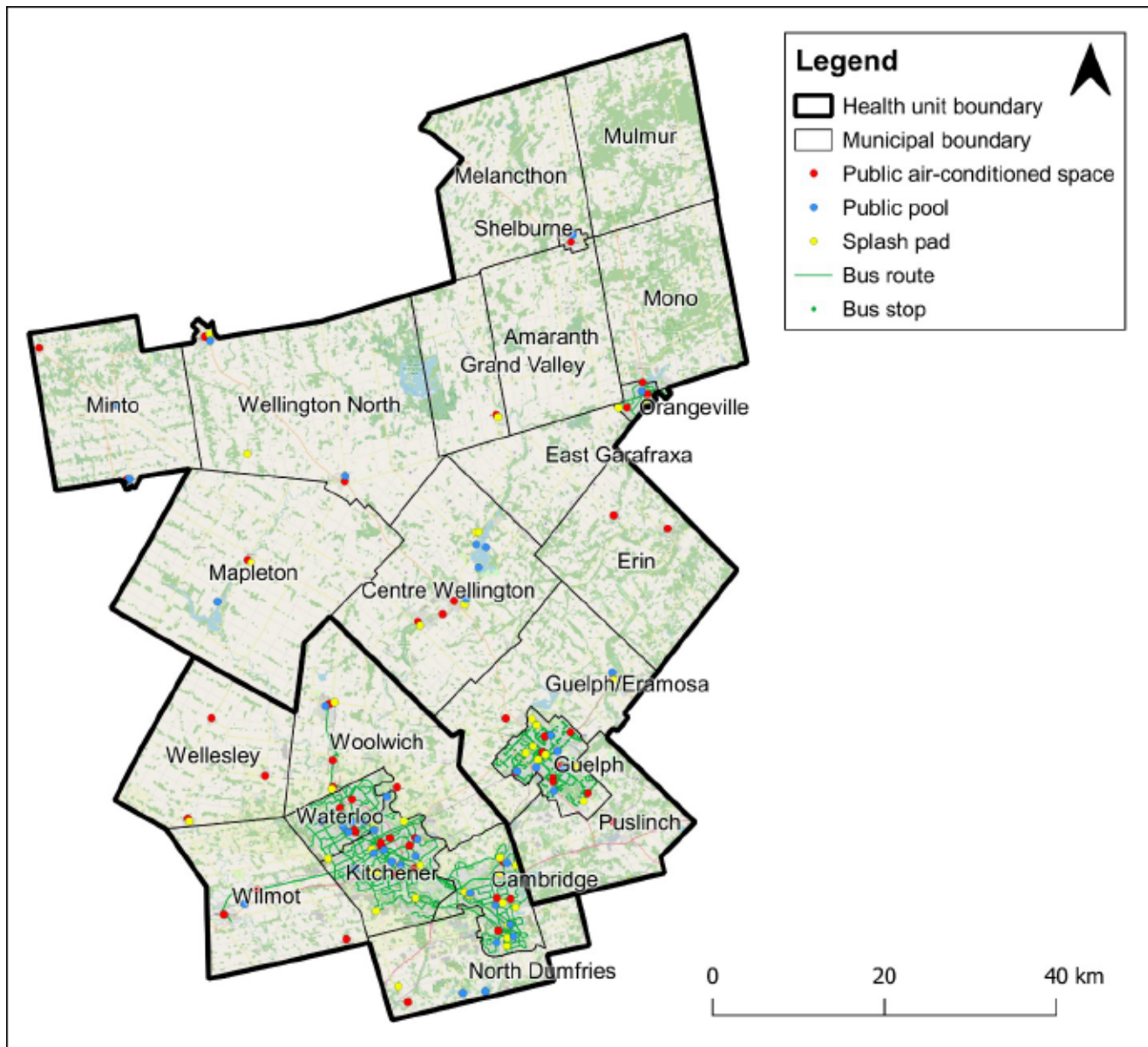
3.6.3.3 Other publicly available cooling options

While Cooling Centres provide a vital role for communities providing access to cool spaces during episodes of extreme extended heat, there are a variety of other public spaces that the public can access to reduce exposure to high temperatures. These include public buildings such as malls, recreational facilities, splash pads and public pools. Figures 18-20, depict publicly available cooling spaces for the whole study area as well as a series of maps showing more urban areas within the study boundaries. The data indicate that more than 90% of public cooling spaces in communities with public transit are located within 500 metres of a major transit route.





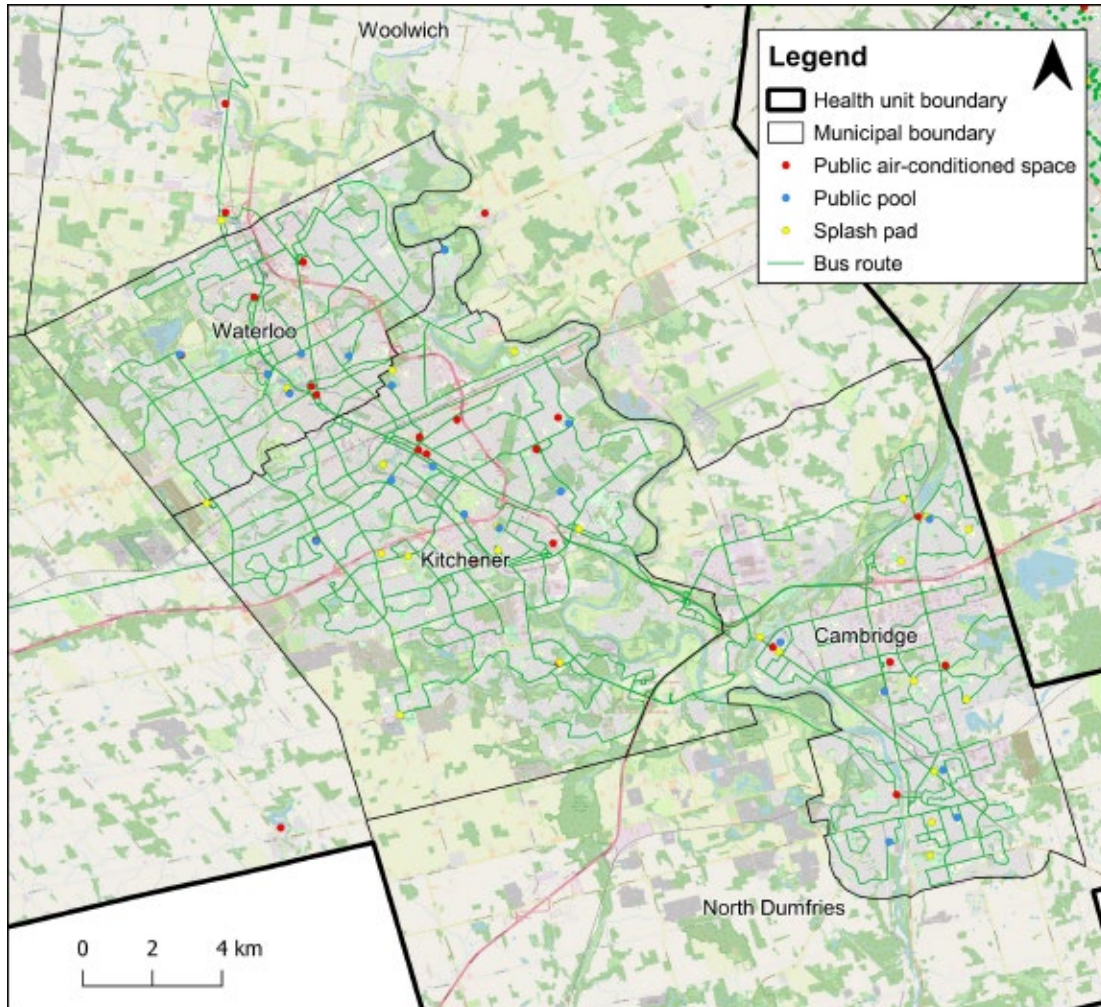
Figure 18. Presence of public air-conditioned spaces[†], public pools, and splash pads by transit accessibility for Wellington-Dufferin-Guelph and Waterloo Region



[†]Public air-conditioned spaces were estimated based on an online search and refer to buildings which are accessible to the public, either freely (e.g., air-conditioned malls, libraries, community centres, etc.) or as pay-per-use (e.g., recreational facilities). This map likely underrepresents the number of existing public air-conditioned spaces.



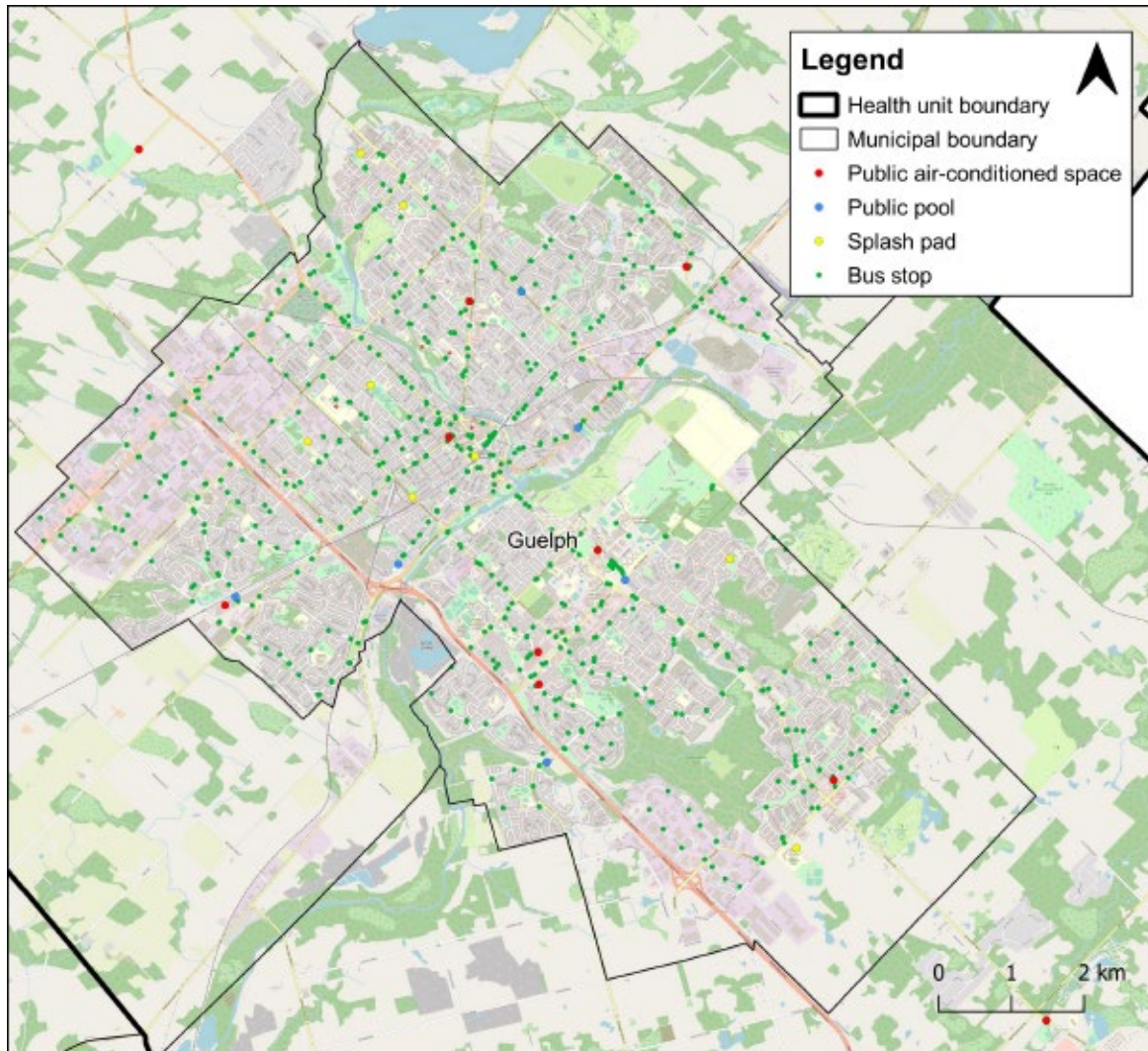
Figure 19. Presence of public air-conditioned spaces †, public pools, and splash pads by transit accessibility for the Cities of Waterloo, Kitchener, and Cambridge



†Public air-conditioned spaces were estimated based on an online search and refer to buildings which are accessible to the public, either freely (e.g., air-conditioned malls, libraries, community centres, etc.) or as pay-per-use (e.g., recreational facilities). This map likely underrepresents the number of existing public air-conditioned spaces.



Figure 20. Presence of public air-conditioned spaces †, public pools, and splash pads by transit accessibility for the City of Guelph



† Public air-conditioned spaces were estimated based on an online search and refer to buildings which are accessible to the public, either freely (e.g., air-conditioned malls, libraries, community centres, etc.) or as pay-per-use (e.g., recreational facilities). This map likely underrepresents the number of existing public air-conditioned spaces.

3.6.3.4 Community services

A variety of community services exist across the study area, including emergency shelters and street outreach programs to people experiencing homelessness and those who are housing insecure. These programs are intended to support agencies that provide services to people experiencing homelessness with resources during extreme weather conditions. These programs are coordinated by an array of local social service providers and housing



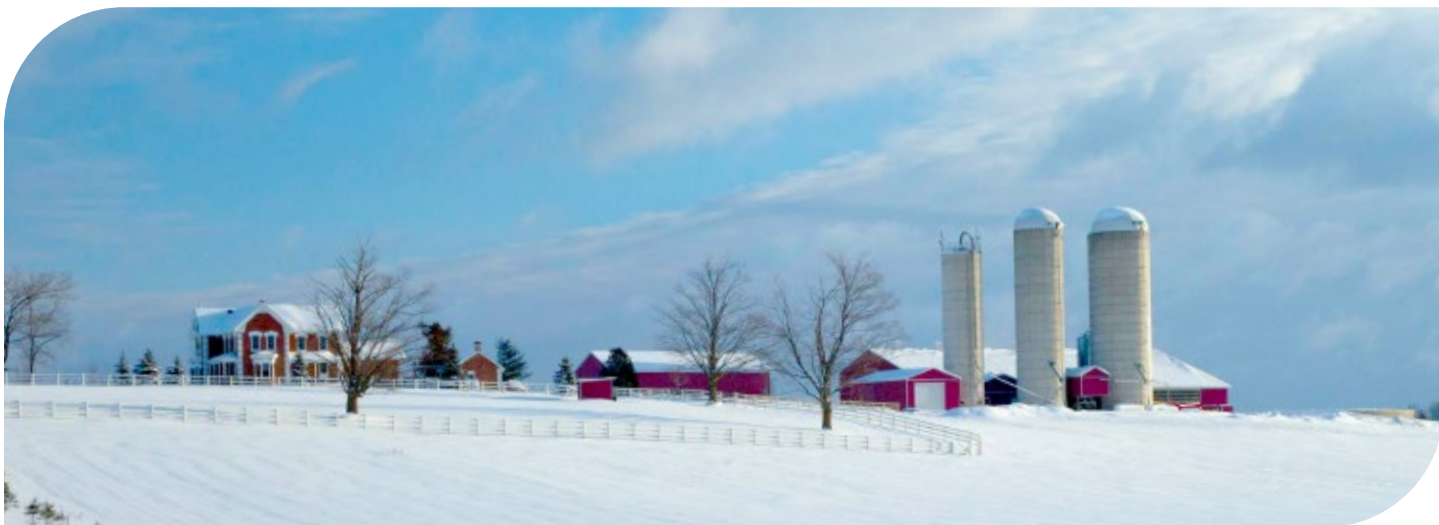
services during extreme heat and cold events.

3.6.3.5 Planning-related activities

The Waterloo Region Extreme Heat and Cold Partnership meets annually to discuss and evaluate program implementation and other community initiatives that address community needs during extreme heat and cold. The partnership includes representation from Public Health, regional and municipal staff including Community Emergency Management Coordinators, paramedic services, parks and recreation offices, regional call centres and communication teams across organizations.

Several other community-level activities were identified through focus groups with key stakeholders that are oriented towards reducing exposure to extreme temperatures. These include:

- Incorporating climate change into the Region of Waterloo's regional strategic planning to anticipate community growth, opportunities to promote active transportation and reduce greenhouse gas emissions, and supporting infrastructure development that reduces the urban heat island effect (e.g., ensuring more shade trees, especially in urban and sub-urban planning).
- Various partners have forest strategies in the study area, including Dufferin County, the Town of Orangeville, the City of Guelph, the Township of Centre Wellington, and the City of Kitchener.
- An Urban Forest Canopy Assessment in Cambridge which has assessed the current tree cover canopy and possibilities for promoting further urban greening.
- ROWPH has conducted shade audits with the goals of increasing shade in areas frequented by people.
- Many municipalities have a frozen pipe policy and emergency management protocols to provide immediate emergency response, and to encourage sharing among residents. However, focus group participants from Wellington-Dufferin-Guelph indicated that their area has infrastructure above the frost line which could pose additional risks for emergency management due to extreme cold in the future.
- ROWPH actively targets schools to circulate heat and ultraviolet radiation resources to students to support the curriculum.
- Guelph and Wellington Task Force for Poverty Elimination has developed a Community Cold Weather Response Plan for Individuals Experiencing Homelessness



3.7 Conclusion

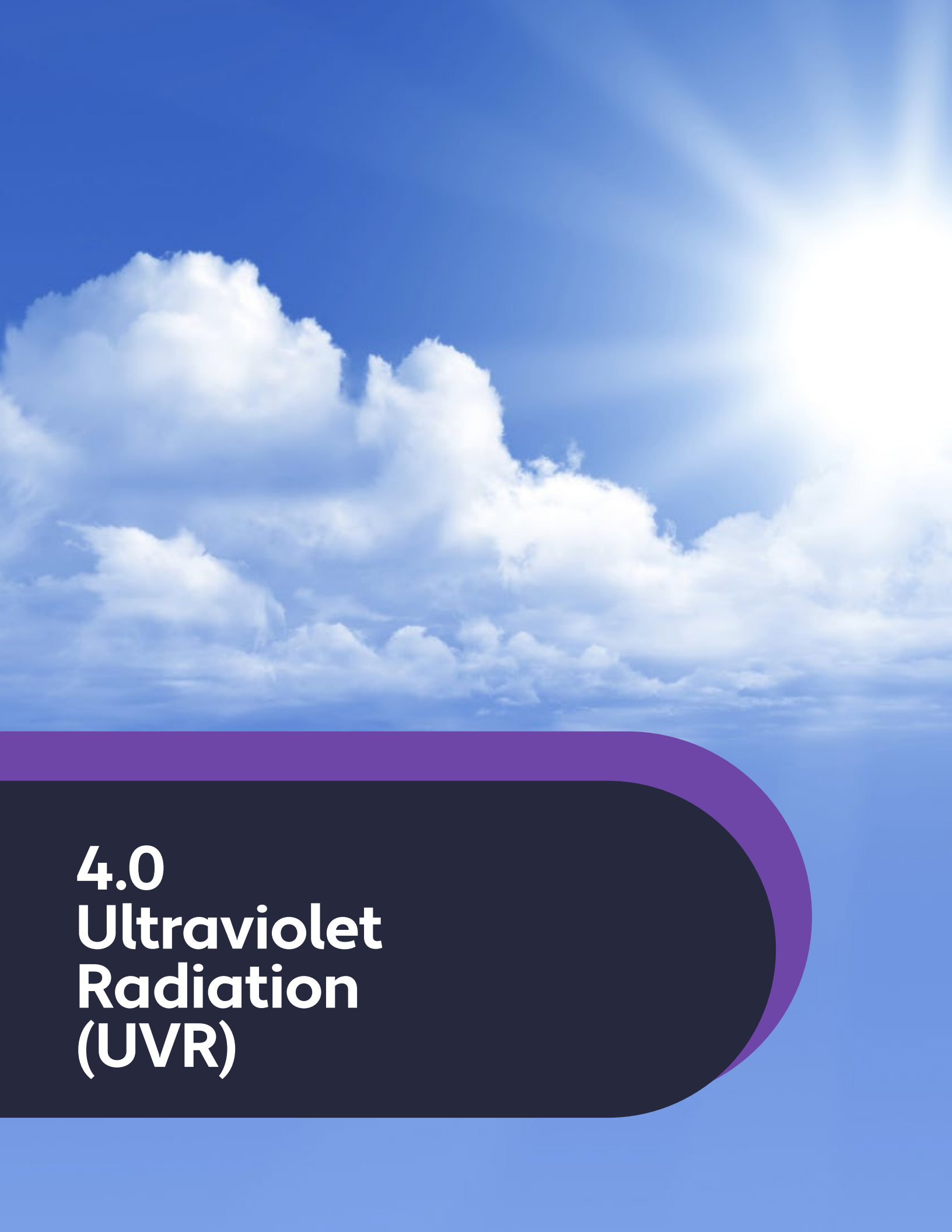
There is significant and growing evidence that extreme temperatures are already affecting the health of those who live, work, and play in Wellington-Dufferin-Guelph and Waterloo Region. Extreme cold is linked to a variety of health outcomes and will remain a population health concern into the future, particularly for prolonged bouts of cold weather and winter storms. While the likelihood of these events is projected to decrease in the future as the climate warms, the severity of winter storms is still likely to be of concern for the study area, signalling the continued need for emergency planning, preparedness, and response, particularly for populations who experience material deprivation and are more likely to be impacted by extreme cold temperatures.

Extreme heat events are already occurring multiple times per year, and area projected to increase in frequency, duration, and intensity as the climate continues to warm. Given that extreme heat:

1. Affects a broad base of study area population—notably in urban areas where urban heat islands create greater opportunity for population-level exposures;
2. Interacts with common health problems such as hypertension; and
3. Differentially impacts a wide variety of population groups who are particularly vulnerable to extreme heat;

the severity of these impacts is projected to increase in the future without appropriate adaptation efforts.

Accordingly, extreme heat exposure is among the greatest threats to Public Health under a changing climate at present and into the future. Future monitoring and analysis of real-time hospital admissions during and immediately following extreme temperature events will enhance each Public Health Unit's understanding of the risks posed to population health and how to continue to tailor risk messaging to promote behaviours that increase adaptive capacity to extreme heat and cold to their communities and partnering agencies.



4.0 Ultraviolet Radiation (UVR)



4.0 Ultraviolet Radiation: Key Findings

Climate change projections

- Climate change is not expected to exacerbate the relationship between ozone depletion and UVR exposure, and there is currently low confidence that climate change will appreciably alter conditions that influence UVR exposure.
- High UV index in the summer, spring, and autumn, will continue to be an issue of concern as people spend more time outdoors during projected warmer than average weather across all seasons and have not increased their personal sun protection practices.
- Areas with low tree canopy cover may be more exposed to UVR due to reduced shade cover. Guelph, Orangeville, Shelburne, Grand Valley, and Amaranth, have lower tree canopy coverage as a proportion of total area, and the more densely populated areas of Guelph, Waterloo, Kitchener, and Cambridge have lower proportions of natural climate zones (i.e., a spatial measure of 'greenness') than surrounding areas.

Population-level exposure

- The study area experiences consistently higher than national average UVR due to its southern geographical location within the country.
- The stratospheric ozone layer provides protection from radioactive energy from the sun. Previous depletion (pre-1987) of the layer translates to a 3% reduction of this protective layer compared to historical normal levels above Canada.

Population-level sensitivities

- Infants, children, and youth have thin skin and their eyes allow more UVR light in, and therefore are more susceptible to long-term harms associated with UVR exposure. This can magnify their cancer risk and related health risks over the course of a lifetime. Children are also more likely to rely on caregiver support to engage with sun safety behaviours.
- While those with immigrant status who have darker skin pigmentation tend to be at lower risk for damaging effects, when skin cancer does develop in people with darker skin pigmentation, it is often in a later stage when diagnosed.
- People who work outdoors or those who participate in physical activity outdoors can have higher exposure to UVR and are at heightened risk for negative health impacts, especially as sweating can increase photosensitivity of the skin.



Population-level adaptive capacity

- People with lower incomes, education, or who are facing other forms of material disadvantage (e.g., poverty, homelessness) may be inadequately able to protect themselves from UVR.

Adaptive actions

- Individual actions include actively seeking information on the UV index value, seeking shade, covering up exposed skin, wearing a hat and UV sunglasses, and using a water-resistant sunscreen with a sun protective factor (SPF) rating of 30 or higher.
- Public Health activities include:
 - » Epidemiological surveillance of cancer incidence and health promotion activities (including risk communication and policy development);
 - » Sharing information on sun safe behaviours on their websites with associated information links;
 - » Working with partners to develop local UVR exposure reduction strategies by taking a comprehensive approach rooted in strategies of awareness raising, creating supportive environments (such as shade), skill building, and policy development;
 - » Participating in reviewing municipal strategic plans, including official plans and other land-use planning documents to promote inclusion of healthy land-use planning policies (i.e., policies that relate to trees, shade, green spaces, etc.); and
 - » Providing support to municipalities on outdoor public space projects, which may include conducting shade audits.

Baseline health impacts

- UVR is associated with an array of health impacts stemming primarily from exposure to UV-A and UV-B, including sunburns and skin damage (e.g., wrinkling), skin and eye cancers, cataracts, DNA damage, immune suppression, and cell atrophy.
- Emergency department visits for sunburn are slightly higher in Wellington-Dufferin-Guelph than Waterloo Region, ranging between 13.1 to 21.9 per 100,000 (relative to 3.7-10.8 per 100,000).
- Respondents living within the study area self-reported slightly higher likelihood to have had a sunburn in the past 12 months (36.0% for Wellington-Dufferin-Guelph and 37.2% for Waterloo Region, respectively) relative to the Ontario average (31.6%).



4.0 Ultraviolet Radiation (UVR)

This chapter briefly describes historical baseline exposure to ultraviolet radiation (UVR) patterns across the study area—including a description of the human health impacts of UVR, the historical burden of disease for select health outcomes, future impacts based on climate change projections, current population vulnerabilities, and existing adaptive capacity among Health Units and community partners.

4.1 Historical Population Exposure to UVR

In Canada, UVR is generally highest in southerly latitudes closest to the Canada-US border. The study area occupies one such area with consistently higher than national average UVR.(88) Global concern over stratospheric ozone depletion—the atmospheric layer that provides protection from radioactive energy emitted by the sun—led to the signing of the Montreal Protocol in Canada in 1987 which committed countries around the world to phase out ozone-destroying chemicals.(89) While the ozone layer has shown recent signs of recovery outside of polar regions, the layer has stabilized at about 3% less than historical normal above Canada.(90) Average summer UVR values across Canada are now marginally higher relative to pre-1980, and a complete ozone recovery is not expected to occur until the 2050s over northern latitudes.(3) However, observed growth in rates of ozone destroying chemicals continue to be highly variable, limiting the ability to make accurate predictions about future concentrations.(91)

There is no correlation between temperature and UVR. UVR can be further divided into UV-A which is present all year, and UV-B which is responsible for skin burns and primarily present through spring, summer, and fall. UVR is measured using an international index of the strength of UV-B at a specific place and time. The index ranges from 0-11+, with risk of skin damage occurring in approximately 30 minutes at moderate levels, and as little as 15 minutes or less under high levels.(92) The UV index values are grouped into five levels of risk: Low (0-2), Moderate (3-5), High (6-7), Very High (8-10), and Extreme (11+). Higher UVR index rankings tend to be observed between the months of May and August in Canada.(93) This is a result of being closer to the sun relative to the winter. However, very high UV index scores are possible in April, September, and October as well.(92) Figure 21 displays maximum UVR index values as forecasted by Environment and Climate Change Canada, confirming higher UVR index rankings in summer months.



Figure 21. Maximum UVR index values forecasted by Environment and Climate Change Canada for Kitchener-Waterloo, 2014-2020



Source: Environment and Climate Change Canada, 2014-2020.

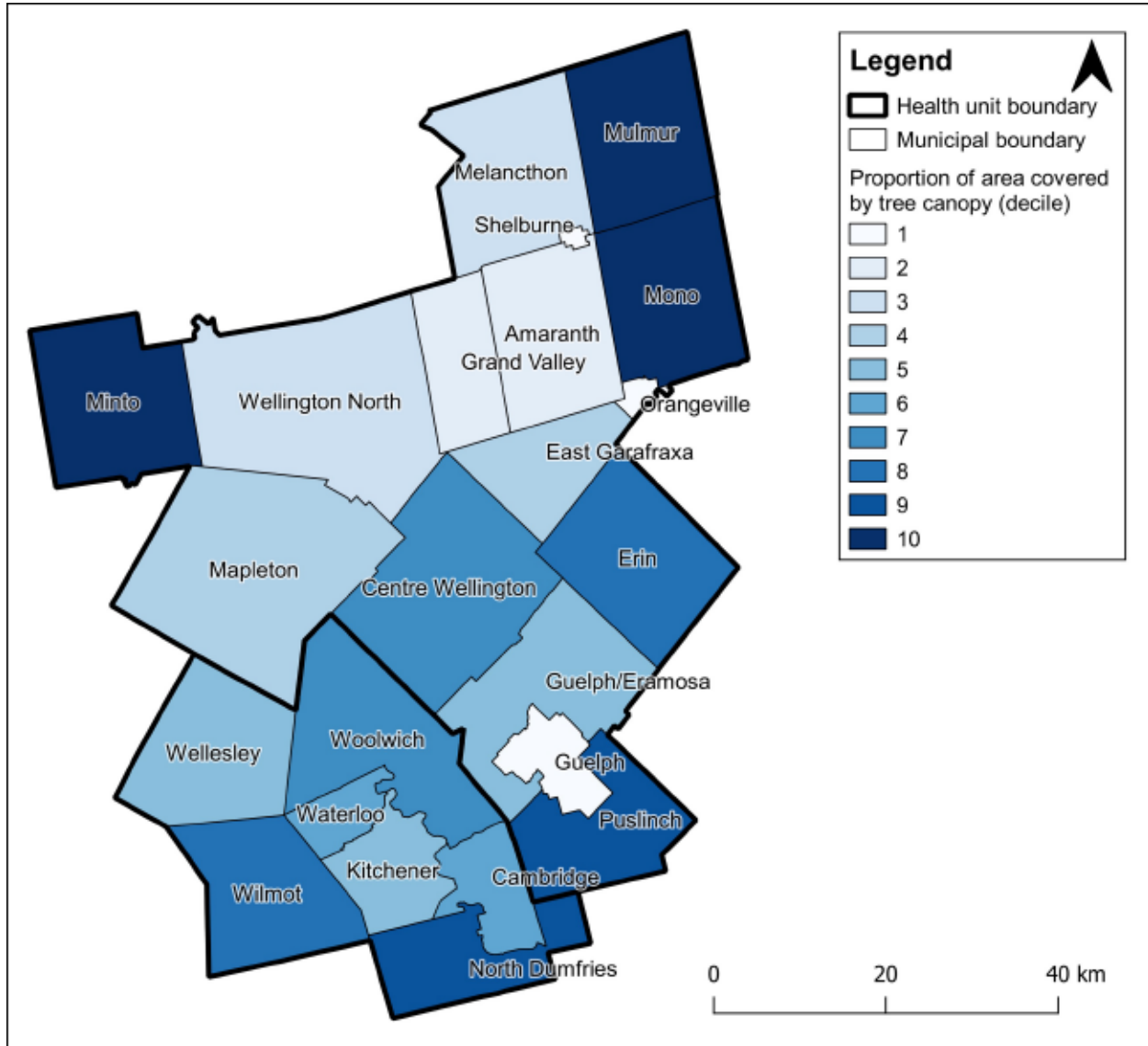
4.1.1 Tree canopy and exposure to UVR

Trees cast shade which mitigates human exposure to UVR. Figures 14 and 15 in Chapter 3 (also displayed below) present tree canopy cover and an indexed value of natural climate zones (i.e., a spatial measure of ‘greenness’) across the study area.





Figure 14. Tree canopy cover as a proportion of total area of municipalities within the study area, depicted by decile,[†] 2019

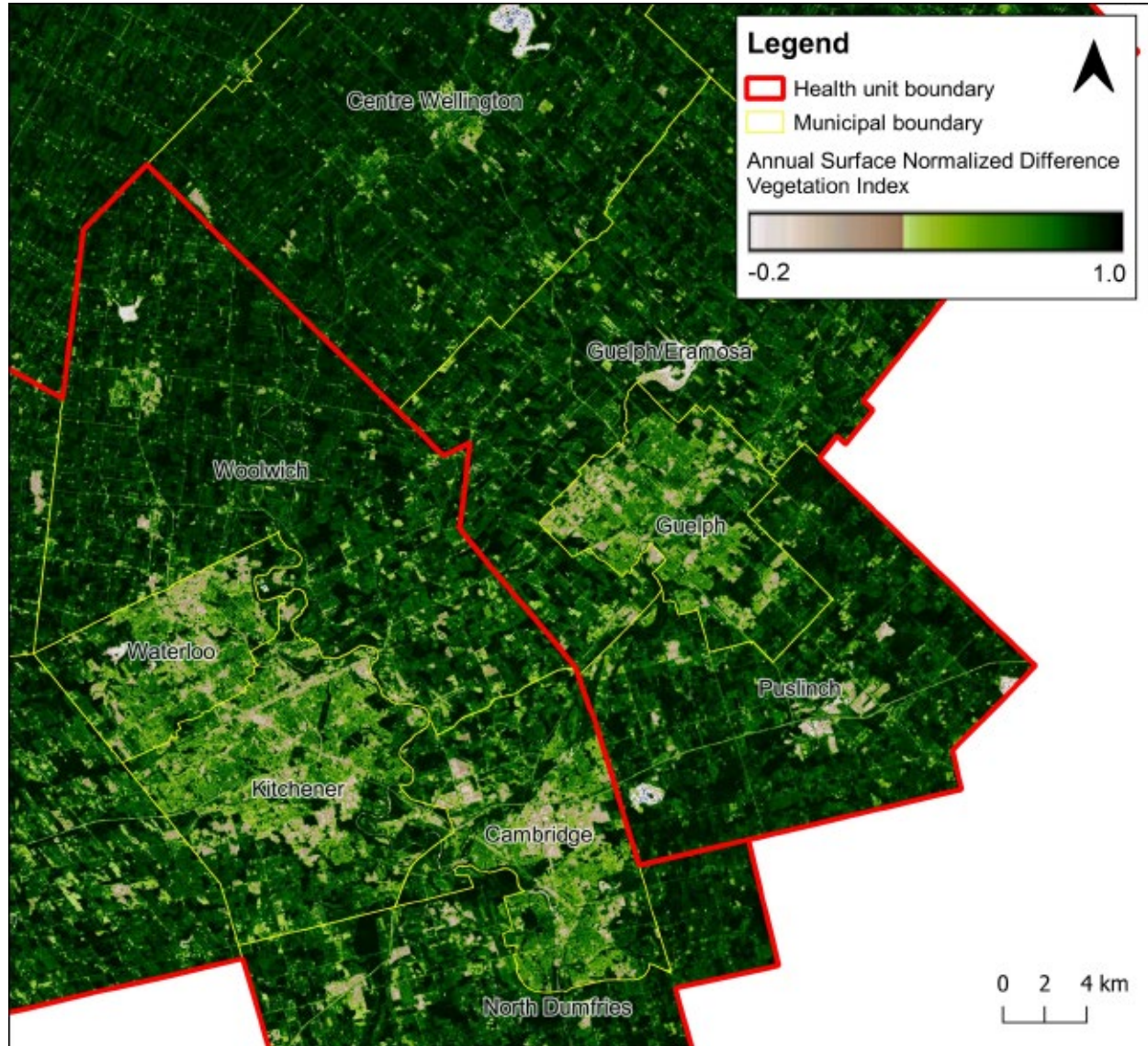


Source: 2019 Annual Crop Inventory Dataset, data subset of Coniferous, Broadleaf and Mixed wood to estimate tree cover <https://open.canada.ca/data/en/dataset/d90a56e8-de27-4354-b8ee-33e08546b4fc>.

[†] Deciles refer to ten equal groups by which tree canopy coverage is represented, where 1 represents the lowest canopy coverage across the study area, and 10 represents the highest canopy coverage.



Figure 15. Surface normalized difference vegetation index measuring permeable and impermeable surfaces in the urban areas of the study area, 2008-2010



Source: Surface Normalized Vegetation Index (NDVIA) to estimate 'greenness' of urban regions of the study area, <https://lpdaac.usgs.gov/products/gweldyrv031/>



Findings indicate that Guelph, Orangeville, Shelburne, Grand Valley, and Amaranth had the least amount of tree canopy coverage as a proportion of total area, and that the more densely populated areas of Guelph, Waterloo, Kitchener, and Cambridge had lower proportions of natural climate zones than surrounding areas. Table 8 utilizes the same 2019 Annual Crop Inventory—a composite database of numerous types of crops, trees, and plants—made available from the Government of Canada to create an area-based estimation of total tree cover across the study area, according to municipality (i.e., census sub-division). However, it should be noted that upon cross-referencing with satellite imagery, a limitation of this dataset is that it does not appear to register single trees or small clusters of trees such as those found along urban streets, in back yards, or planted in thin strips adjacent to fields. Tree canopy coverage is therefore likely underestimated in both rural and urban environments as depicted in Table 8, and future analysis should seek to improve an understanding of local tree canopy. Further, while the natural climate zone map (Figure 15) resolves the under-counting problem by utilizing satellite imagery, it also measures a variety of green space such as low plants and other forms of natural areas which may not provide shade. It should be further noted that tree canopy coverage does not necessarily equate to any particular level of population protection, particularly if it is not located near users of particular spaces (e.g. pedestrian walkways), which was a finding of some shade audits conducted in Waterloo Region.





Table 8. Approximate tree canopy coverage by municipality in Wellington-Dufferin-Guelph and Waterloo Region, 2019

Public Health Jurisdiction	Municipality Name	Total Area Covered by Municipality (km ²)	Approximate Area Covered by Tree Canopy (km ²)	Tree Cover as a % of Total Area
WDGPH	Amaranth	265.4	13.3	5.0
	Centre Wellington	416.0	44.9	10.8
	East Garafraxa	167.1	15.5	9.3
	Erin	299.7	39.9	13.3
	Grand Valley	162.8	9.3	5.7
	Guelph	88.3	4.1	4.7
	Guelph/Eramosa	296.1	28.6	9.7
	Mapleton	542.8	47.6	8.8
	Melancthon	311.1	21.7	7.0
	Minto	301.8	51.1	16.9
	Mono	280.6	70.8	25.2
	Mulmur	287.9	94.0	32.7
	Orangeville	15.9	0.7	4.2
	Puslinch	219.7	35.5	16.2
	Shelburne	6.6	0.2	3.6
Wellington North	535.5	45.9	8.6	



Public Health Jurisdiction	Municipality Name	Total Area Covered by Municipality (km ²)	Approximate Area Covered by Tree Canopy (km ²)	Tree Cover as a % of Total Area
ROWPH	Cambridge	115.8	12.2	10.5
	Kitchener	138.4	13.8	10.0
	North Dumfries	191.0	31.4	16.4
	Waterloo	65.1	6.6	10.1
	Wellesley	278.7	25.9	9.3
	Wilmot	266.3	34.9	13.1
	Woolwich	330.0	39.3	11.9

Source: 2019 Annual Crop Inventory Dataset: <https://open.canada.ca/data/en/dataset/d90a56e8-de27-4354-b8ee-33e08546b4fc>.

4.2 Future Climate Change

Climate change is not expected to exacerbate the relationship between ozone depletion and UVR exposure, and there is currently low confidence that climate change will appreciably alter conditions that influence UVR exposure (e.g., cloud cover, surface reflectivity, influence over ozone depleting substances).^(8,89,94,95) The principal pathway by which climate change will influence UVR exposure in Canada is that people may spend more time outdoors as temperatures warm.⁽⁸⁾ A full articulation of expected climate change under a variety of scenarios can be found in a supplemental report titled Climate Science Report for the Climate Change and Health Vulnerability Assessment for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph.⁽⁴⁾ That report provides an in-depth overview of anticipated changes to seasonal climates in the study area under three different emissions scenarios. In terms of ultraviolet radiation, the report highlights:

- Forecasting future UVR is difficult and highly dependent on future cloud cover, increasing concentrations of GHGs, changes in tropospheric UV-absorbing aerosols, and decreases in surface reflectivity at high latitudes.
- Aerosols are likely the most important factor for determining UV levels over heavily populated areas, but projected effects are uncertain;⁽⁸⁹⁾
- For the study area, high UV index in the summer and shoulder seasons in spring and autumn will continue to be an issue of concern, particularly if people spend more time outdoors during projected warmer than average weather across all seasons.



4.3 Baseline Historical Assessment of Population Health Outcomes Related to UVR

UVR is associated with an array of health impacts stemming primarily from a cumulative exposure to UV-A and UV-B, including: sunburns and skin damage, skin and eye cancers, DNA damage, immune suppression, cell atrophy, and cataracts.(96–98) Skin cancer is the most common cancer in Canada. Non-melanoma skin cancer (NMSC) is not reported in Ontario, due to the ease of treatment(99), but based on data from other Canadian provinces, NMSC accounts for approximately 40% of all new cancers, and when combined with malignant melanomas, will account for nearly the same number of new cancer cases as the four major cancers combined (lung, breast, colorectal, and prostate).(101)

Malignant melanomas are generally more dangerous than NMSCs and can lead to death. Eighty percent of malignant melanoma cases in Ontario are attributable to UVR.(100) The most recent data for malignant melanoma incidence is from 2014. Ontario's overall rate was 25.9 per 100,000, Waterloo Region's rate was 25.4 cases per 100,000, and Wellington-Dufferin-Guelph had slightly elevated incidence rates of 35 cases per 100,000.(102)

Data is not available for all identified health outcomes across the study area for smaller geographic areas. To establish a baseline understanding of health risks, selected data for frequency of melanoma of the skin and emergency department visit rates for UV-related causes are presented in Table 9, with the exception of melanoma data for Wellington-Dufferin-Guelph which was unavailable. We purposefully have not reported on emergency department visits for chloasma, freckles and other melanin hyperpigmentation, pterygium, macular degeneration, early onset cataracts, actinic keratosis, eye and orbit cancer, or other acute skin changes due to UVR because those rates of emergency department visits have been consistently less than 2 per 100,000 over the past decade.

Table 9. Selected health risks associated with UVR exposure per 100,000, Wellington-Dufferin-Guelph and Waterloo Region, 2007-2018

Year	Waterloo Region		Wellington-Dufferin-Guelph
	Frequency of Melanoma of the Skin (age-adjusted) ¹	ED Visits for Sunburn (crude) ²	ED Visits for Sunburn (crude) ²
2007	23.7	n.d.	18.3
2008	20.4	10.8	14.5
2009	18.5	8.0	18.1
2010	25.9	7.5	19.4
2011	22.7	10.1	18.8



Year	Waterloo Region		Wellington-Dufferin-Guelph
	Frequency of Melanoma of the Skin (age-adjusted) ¹	ED Visits for Sunburn (crude) ²	ED Visits for Sunburn (crude) ²
2012	21.9	8.1	18.3
2013	22.9	9.0	21.9
2014	23.7	6.3	12.2
2015	25.5	3.3	15.0
2016	28.4	5.8	13.1
2017	n.d.	3.7	15.8
2018	n.d.	6.4	18.3

¹ SEERStat, ICD-0-3/WHO Recode: Melanoma of Skin (includes C44.0-44.9 along with morphology codes M-8720-M-8790 only)

² Source: Includes ICD-10-CA codes for L55, NACRS and DAD, IntelliHealth, Ministry of Health

Historical data suggest that rates of melanoma of the skin range between 18.5 per 100,000 and 28.4 per 100,000 in Waterloo Region. Emergency department visits for sunburn are slightly higher in Wellington-Dufferin-Guelph (13.1 to 21.9 per 100,000) than Waterloo Region (3.7 to 10.8 per 100,000).

Data are also available for an array of sun safety behaviours taken by residents in each Health Unit jurisdiction. Self-reported data on the proportion of the study population that has been sunburnt, spent time in the sun during days off in the summer, and overall personal sun safety protection is provided in Table 10. In general, respondents living within the ROWPH and WDGPH jurisdictional boundaries were slightly more likely to report having had a sunburn in the past 12 months (36.0% and 37.2%, respectively) relative to the Ontario average (31.6%) (CCHS 2015/2016). Self-reported data for the amount of time spent outdoors in the sun on days off in the summer shows that data from the study area are typically within 1-2% of the provincial average in each category. According to a variable derived from a composite of several sun safety questions in the CCHS, Statistics Canada found that about 68.2% and 67.6% of residents in Waterloo Region and Wellington-Dufferin-Guelph, respectively, appropriately protect themselves from the sun. This is not discernibly different from the provincial average of 67.4%, but demonstrates that at a population-level, improvements to personal sun safety behaviours can be made across the study area, such as reinforcing sun safe messaging and enhancing public awareness and education campaigns.



Table 10. Frequency data on select UVR health risks

Survey Question	Categorical Survey Responses	Waterloo Region	Wellington-Dufferin-Guelph	Ontario
In the past 12 months, has any part of your body been sunburnt	Yes	36.0%	37.2%	31.6%
	No	61.7%	59.5%	65.1%
Time spent daily in the sun (10am-4pm) on days off in the summer	None	8.3%	7.4%	8.8%
	Less than 30 minutes	15.3%	12.9%	15.3%
	30 to 59 minutes	13.9%	12.9%	11.6%
	1 hour to less than 2 hours	19.8%	19.6%	17.3%
	2 hours to less than 3 hours	16.3%	16.9%	15.9%
	3 hours to less than 4 hours	9.8%	9.3%	9.9%
	4 hours to 6 hours	13.4%	17%	16.8%
Statistics Canada derived variable on personal sun safety protection	Protects self appropriately from sun	68.2%	67.6%	67.4%
	Does not protect self appropriately from sun	24.9%	24.6%	24%

Source: Canadian Community Health Survey 2015/2016, Variables SSB_005, SSB_010, SSBVPRPT

4.4 Populations Vulnerable to UVR in Wellington-Dufferin-Guelph and Waterloo Region

The literature suggests that the population groups outlined in the following sections are potentially more vulnerable to UVR according to their exposure, sensitivity, or adaptive capacity.

Key population health vulnerability demographics are provided in Table 1 based on available data. Data for people with genetic predispositions and history of severe sunburn are unavailable at the time of producing this report.



Table 11. Populations sensitive to ultraviolet radiation in Wellington-Dufferin-Guelph and Waterloo Region

	Proportion of Total Population, 2016		
	Wellington-Dufferin-Guelph	Waterloo Region	Ontario
Infants, children, and youth (aged <15 years old)	17.7%	17.8%	16.4%
Outdoor workers (agriculture and construction)	10.8%	8.0%	8.3%
People who speak neither French nor English	0.9%	1.8%	2.5%
Prevalence of low-income after tax	9.9%	12.1%	14.4%
Population with less than high school education	11.1%	18.7%	10.4%
Chronic homelessness (# October 2019) [§]	134	228	-

[†]Unless otherwise indicated, all data are derived from the Statistics Canada 2016 Census of Canadian population

[§] Built for Zero Canada point-in-time estimate for October 2019. Chronic homelessness “refers to individuals who are currently experiencing homelessness AND who meet at least one of the following criteria: a) they have a total of at least 6 months (180 days) of homelessness over the past year b) they have recurrent experiences of homelessness over the past 3 years, with a cumulative duration of at least 18 months (546 days) <https://bfzcanada.ca/wp-content/uploads/BFZ-C-Data-Dashboards.pdf>

4.4.1 Populations vulnerable to UVR due to exposure

Outdoor workers can have higher exposure to UVR than those working indoors.(103–105) Farmers, construction labourers, and landscapers in Canada are particularly at risk because they may spend upwards of 75% of their workday outdoors.(106)

People who participate in physical activity outdoors (in both summer and winter) may be at heightened risk because sweating can increase photosensitivity of the skin,(107) and as little as 15 minutes of sun exposure has been correlated with skin-related damage in runners.(108)

People experiencing homelessness may also be differentially exposed due to spending a greater proportion of time outdoors. See additional information below concerning adaptive capacity for this population.

Like exposure to extreme heat, outdoor event goers may be differentially exposed to UVR. It is difficult to estimate the total number of attendees at outdoor summer events who may be exposed to UVR. However, across the study area several farmers’ markets and outdoor food, drink, and music festivals (e.g., Craft Beer Festival, Bluesfest,



Hillside Festival, Uptown Waterloo Jazz Festival, Ever After Music Festival, etc.). Large outdoor events are often held in large open areas with limited shade, which may increase exposure to UVR.

4.4.2 Populations vulnerable to UVR due to sensitivity

Infants, children and youth are more susceptible to long-term harms associated with UVR, and can magnify cancer risk and related health risks over the life course.(109) Children are also more likely to rely on caregiver support to engage with sun safety behaviours.(110,111) Ontario Regulation 137/15 under the Child Care and Early Years Act, 2014 mandates two hours of outdoor time per day for those in child care facilities. There is limited data available for youth who may spend more time tanning, and this is an area that could be supported by further research.

Those with particular genetic predispositions (i.e., people who are fair-skinned, have a large number of moles, a family history of skin cancer, or a history of a severe sunburn) have demonstrated higher risk of sunburns and longer-term health risks attributable to UVR due to physiological susceptibility.(112,113) Further, people who have darker skin pigmentation tend to be at lower risk for damaging effects, but when skin cancer does develop in people with darker skin pigmentation, it is often in a late stage when diagnosed.(114,115)

4.4.3 Populations vulnerable to UVR due to adaptive capacity

People with lower income and/or education or who are facing other forms of material disadvantage (e.g., low income, poverty, homelessness) may be inadequately able to protect themselves from UVR. Recent research suggests that people with lower levels of educational attainment and income are at greater risk of UVR exposure in Canada.(88)

4.4.4 Sex and gender-based vulnerabilities

Pinault et al.(88) found that Canadian men tend to have higher exposure to UVR. Men tend to spend more time outdoors, and compared to women, are at 2.25 times greater risk of melanoma of the head or neck ($p < 0.01$) and 2.53 times greater risk of melanoma of the trunk ($p < 0.01$). Previous studies suggest that this may reflect differences in clothing choice according to sex/gender.(116) Indeed, the 2015 CCHS indicates that 22% of Canadian men spend more than four hours a day in the sun compared with 12.1% for women, and that men are less likely than women to use sunscreen on the face and body or seek shade, but men were more likely than women to wear a hat or long pants.(112)

4.5 Programs, Policies, and Related Actions taken to Improve Adaptive Capacity to UVR

4.5.1 Individual actions

Individual actions to reduce health risks of UVR are to primarily follow sun-safe behaviours. These include actively seeking out information on UV index values prior to spending time outdoors and in direct sunlight, as well as wearing sun screen, UV protective sunglasses, seeking shade, or covering up exposed skin. Current best practice advice for sunscreen is to use a water resistant sunscreen with a sun protective factor (SPF) rating of 30 or higher.(110) Parents, caregivers and care workers should exercise particular caution in assisting children and adolescents in following appropriate sun-safety practices.



4.5.2 Public Health actions

Both WDGPH and ROWPH conduct an array of activities to reduce vulnerability to UVR. Actions are outlined in Table 12, with supporting narrative text below.

Table 12. On-going Public Health activities to adapt to the health impacts of UVR

Public Health Standard	Existing Activities
<p>Population Health Assessment/ Surveillance</p>	<ul style="list-style-type: none"> • Identify vulnerable populations and monitor changes to population health status over time through regular reporting (e.g., board of health reports). • Public Health surveillance of heat-related illnesses described in the preceding sections of this chapter, including rates of hospitalization and emergency department visits for key heat-related health outcomes related to UVR (i.e., sunburn). • Provide consultation to municipalities on outdoor public spaces projects which may include conducting shade audits.
<p>Health Promotion (including policy contributions, education and advocacy)</p>	<ul style="list-style-type: none"> • Sharing information on websites about the health risks of UVR exposure, behaviours that can mitigate risks, and resources that address the built environment (i.e. shade). • Collaboration with more-than-health-sector partners, and develop programs and communication strategies to communicate the risks of UVR to vulnerable populations. • Participate in reviews of official plans and key strategic documents to encourage considerations towards health-impacts of land-use planning policy (i.e., policies that relate to trees, shade, built environment, etc.).



Public Health Standard	Existing Activities
<p>Health Promotion (including policy contributions, education, and advocacy)</p>	<ul style="list-style-type: none"> Supporting heat-mitigation initiatives such as <u>City of Kitchener’s Sustainable Urban Forestry Strategy</u> that aims to improve canopy cover and reduce urban heat islands. Additional municipalities that have included this focus in the study area are <u>Dufferin County</u>, the <u>Town of Orangeville</u>, the <u>Township of Centre Wellington</u>, and the <u>City of Guelph</u>. <u>A tree canopy study in the City of Cambridge</u> has assessed the current tree cover canopy and possibilities for promoting further urban greening. ROWPH targeted schools and students to circulate heat and ultraviolet radiation information.
<p>Health Protection</p>	<ul style="list-style-type: none"> Supporting community partners by reviewing core planning documents to identify possibilities to reduce UVR exposure, completing shade audits on outdoor public space projects, and providing consultations. Supporting other activities led by community partners (e.g., providing evidence and consulting on community program development).

Public Health activities include epidemiological surveillance of cancer incidence and health promotion activities (including risk communication and policy development) for settings which Health Departments play an advisory, collaborative, or regulatory role (such as in the case of tanning salons).(103)

Surveillance primarily relates to monitoring and assessing changes or trends to the health outcomes identified earlier in this chapter. Additional surveillance could be completed by engaging the Ontario Cancer Registry to track basal cell and squamous cell carcinomas.

Health promotion activities include a range of programs and communication strategies to share information about the health risks associated with UVR and actions that individuals and institutions can take to lower that risk. Each Health Unit shares information on safe behaviours on their websites ¹ with associated information links.

Public Health activities include working with partners towards developing a comprehensive approach to reducing risks that is rooted in strategies of awareness raising, creating supportive environments, skill building and policy advocacy. Both health units provide public health advocacy through consultation and support on planning documents for municipalities to reduce the health impacts from exposure to UVR and extreme heat.

1 See <https://www.wdgpulichealth.ca/your-community/extreme-weather/extreme-heat>, <https://www.regionofwaterloo.ca/en/health-and-wellness/shade.aspx> and <https://www.regionofwaterloo.ca/en/health-and-wellness/sun-safety.aspx>



WDGPH worked closely with local planning departments in urban areas within Wellington-Dufferin-Guelph to collect baseline data on physical form indicators to measure local built environments, including spatial data where available that supports measuring street tree canopy coverage and urban greenness.

ROWPH collaborated with community partners and created shade resources (including an audit tool, videos, shade policy fact sheet and, shade design fact sheet, shade tree list, and an educational webpage) to assist planners in increasing shade structures and the urban tree canopy. ROWPH provides consultations on outdoor public space projects which may include conducting shade audits.

At the time of writing this report, ROWPH staff were in the process of completing a community development model pilot with four neighbourhood associations focused on improving sun safety for children and youth who participate in summer recreational programming. The model includes sun safety policy development, funding towards implementing shade on their outdoor space, and resources to support knowledge and skill development for the staff and participants.

4.5.3 Actions led by community partners

Numerous community organizations, social service agencies, and institutions all play critical roles in coordinating sun safety campaigns to educate relevant stakeholders on the health risks associated with UVR exposure. Day care centres, elementary schools, and tourism organizations are notable community partners that have a strong history of evaluated success in education and behaviour change to support sun safety activities,(103,117) while there is insufficient evidence that similar programming works as effectively for outdoor workers who tend to have higher exposure than non-outdoor workers.(103–105)

4.5.3.1 Risk messaging

Extreme weather alerts are issued by Environment and Climate Change Canada. The UV index is additionally shared by other weather service and information websites, and recommends risk reduction activities depending on its forecast. The UV index is broken down into five risk-based scores:

- Low: 2 or less
- Moderate: 3 to 5
- High: 6 to 7
- Very High: 8 to 10
- Extreme: 11 or higher

In situations where the UV index rating is three or higher, it is recommended that people protect their skin as much as possible through sun-safe behaviours (see section 5.6.1).



4.6 Conclusion

Despite signs of ozone recovery, average summer UVR values across Canada are still marginally higher relative to pre-1890. The study area experiences consistently higher than national average UVR index values due to its southern geographical location relative to the rest of the province and country. UVR exposure is greatest during the summer months, particularly for people who spend long amounts of time outdoors. UVR exposure is also greater in areas with lower amounts of tree canopy cover, highlighting the importance of shade trees and shade structures as an adaptive mechanism.

UVR exposure across the study area is slightly higher than provincial averages and given that rates of sunburn are slightly higher than provincial average, the present likelihood and severity of exposure illustrates a significant risk at the population level. Fortunately, individual actions for reducing exposure are well-practiced at the population level, which can help reduce the severity of corresponding ill-health outcomes.

Climate change is not expected to significantly alter the strength or occurrence of high-UV index days across the study area. However, due to the warming trend being observed, it is possible people will spend more time outdoors, particularly in the spring and autumn, thereby increasing exposure risk. It is anticipated that given each Health Unit's focus on sun safety campaigns, risk communication, and participation in advisory and regulatory processes related to sun safety, that continued activities and awareness can help to reduce future risks associated with potential changes in seasonal exposure patterns.



5.0 Extreme Weather





5.0 Extreme Weather: Key Findings

Climate change projections

- Annual precipitation levels are expected to increase marginally by the end of the century. Most increases would occur in the spring and winter season.
- Extreme precipitation events – where total rainfall is in the 95th or 99th percentile - are likely to increase in the study area.
- Severe freezing rain events (those lasting longer than six hours per day) are projected to increase up to 30% by 2100.

Population-level exposure

- The study area has recently experienced increasing precipitation in the spring, fall, and winter that can increase the risk of flooding, slippery conditions, and flash freeze events.
- While changes to local climates have been observed across the study area, current climate models do not accurately predict changes to flood risk, tornadoes, or other extreme weather events, making projections for human health and well-being difficult to predict.

Population-level sensitivities

- Older adults may be more physiologically sensitive to extreme weather. Falls are the most common cause of injury and a leading cause of hospitalization among older Canadians, and it is estimated that one in three people aged 65 or older are likely to fall at least once. Extreme weather can increase the risk of falls.

Population-level adaptive capacity

- Children and older adults are more dependent on caregivers than working aged populations. This translates into a greater reliance on others during an emergency to engage in adaptive behaviours or remove oneself from harm, and can be particularly acute for older populations with mobility restrictions.
- People who are underhoused, housing insecure, or experiencing homelessness may be differentially exposed to climate-related health hazards by virtue of not having safe housing during an emergency.
- Commuters to and from the study area may experience greater exposure to extreme events, particularly when commuting on highways at high speeds, or rural roads where risk of getting stranded or being in an collision may be higher.



Adaptive actions

- Individual actions to reduce health risks of extreme weather primarily involve listening to weather alerts and following safety orders issued by emergency agencies, checking in on vulnerable neighbours, having an adequate supply (typically three days) of essential supplies in the event of power outages and service disruptions, and removing oneself from a disaster affected area.
- 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.
- Local Ontario Health Teams develop surge plans in consultation with key stakeholders to plan and budget for potential surge capacity on healthcare systems and create accountability systems for all facilities potentially impacted by a surge in demand or usage.
- Local conservation authorities undertake a variety of flood mitigation work. For example, the Grand River Conservation Authority (GRCA) completed a [flood mitigation study](#) with aid from the National Disaster Mitigation Program. This study estimates average annual flood damages and reviews options to mitigate flood risk along the Nith River in New Hamburg, conducting a cost-benefit analysis to analyze feasibility of implementation options.
- Upper-tier and lower-tier municipalities have mutual aid agreements to support one another during weather-related events or emergencies.

Baseline health impacts

- In recent years, crude hospitalization rates from falls are increasing throughout the study area. Falls are intended to be proxy measure of accidental morbidity resulting from extreme weather given their association with bouts of cold weather and ice formation, but caution should be utilized as the source of falls is not able to be distinguished.
- From 2015-2019 significant evidence of bacterial contamination has been found in about 11% of the samples submitted from private wells in the study area. However, multiple samples are frequently submitted for the same well. A closer analysis of samples submitted in the Wellington-Dufferin-Guelph area indicated that in 2018, 21% of wells that were tested showed evidence of bacterial contamination. Moreover, the wells that were sampled only represented 10% of the wells in Wellington-Dufferin-Guelph. This suggests that testing rates are low and contamination rates may be significant. Water quality can be affected by flood events.
- Disasters documented across the study area from 1950-2020 include nine significant events since 1973, resulting in 13 deaths, more than 500 persons with injuries, and almost \$100 million in damages.



5.0 Extreme Weather

Climate change will alter the frequency, duration, and severity of extreme weather events and episodes across Canada with implications for human health.(4,7) This chapter briefly describes the historical baseline exposure to extreme weather across the study area—including a description of the human health impacts of extreme weather, the historical burden of disease for select health outcomes, current population vulnerabilities, and existing adaptive capacity across the study area.





5.1 Historical Population Exposure to Extreme Weather Events

Southwestern Ontario has a history of extreme weather events and episodes that include flooding, severe winter storms (including freezing rain), flash freezing events, tornadoes, droughts, and wildfires. Similar to other parts of Canada, the study area has recently experienced increasing precipitation in the spring, fall, and winter that can increase the risk of flooding, particularly when rain falls on ice or snow (also known as a 'freschet').⁽⁴⁾ Increased precipitation during winter months can also create slippery conditions and flash freeze events when warmer daytime conditions cool below freezing at night.

The [Canadian Disaster Database](#) documents and geolocates all 'significant' disaster events that conform to the [Emergency Management Framework for Canada](#). A 'significant' disaster meets one or more of the following criteria:

- 10 or more people killed;
- 100 or more people affected/injured/infected/evacuated/or made homeless;
- An appeal for national/international assistance is made;
- The event has historical significance; and/or
- Significant damage/interruption of normal processes such that the community affected cannot recover on its own.

Table 14 provides a list of disasters documented across the study area from 1950-2020. This includes nine significant events since 1973, resulting in 13 deaths, more than 500 persons with injuries, and almost \$100 million in damages, not including millions of people impacted by loss of power and impacts to essential infrastructure. In addition, it is notable that due to extreme weather events elsewhere in the world, the study area can often be involved in the reception of evacuees, and the broad impacts of displacement are not captured in Table 14.

Notwithstanding the broad population exposures to the disaster events in Table 14, smaller events that do not meet the threshold for the Canadian Disaster Database also pose unique and significant challenges to population health under a changing climate. Locally, these have included ice jams on major waterways that increase flood risks across the study area. The remainder of this chapter section outlines extreme weather-related events and associated health risks for the study area.





Table 13. Disasters recorded in the study area by the Canadian Disaster Database, 1950-2020

Date	Event Type	Estimated Damages	Injuries	Deaths	Notes	Impacted Municipalities
May 17-21, 1974	Flood	Unknown	0	0	Business closures, some damage to dams and utility service disruption	Cambridge/ Waterloo Region
May 31, 1985	Tornado	\$83,992,000	500	12	Northern portion of study area affected	Hopeville to Barrie (including northern Dufferin County)
August 28, 1992	Flood	\$4,738,539	0	0	None	Elmira
April 20, 1996	Tornado	\$9,404,772	9	0	2,894,455 people's utilities affected	Wellington and Dufferin County
January 1, 1996	Winter Storm	\$99,870	0	0	None	North Dumfries
August 20, 2009	Extreme winds	\$100,000,000	0	1	207,000 without power	Southern Ontario
August 2-3, 2015	Tornado	Unknown	6	0	150,000 people without power	60km North of Waterloo
July 8, 2016	Severe Thunderstorm	\$47,063,000	not known	not known		Southern Ontario
June 22-23, 2017	Severe Thunderstorm	\$29,188,000	not known	not known	300,000 without power	Southern Ontario

Source: Canadian Disaster Database, 2021. Available: <https://www.publicsafety.gc.ca/cnt/rsrscs/cndn-dsstr-dtbs/index-en.aspx>.



5.1.1 Severe thunderstorms, tornadoes, and flooding

Extreme precipitation events and thunderstorms can lead to localized flooding and be accompanied by high winds that can damage infrastructure and property, or lead to injury. For example, between June 22-23, 2017, a record rainfall event across the study area saw more than 100mm of rain falling in three hours in some parts of the Grand River watershed. This was the highest one-day total rainfall event since record keeping began in 1950.(118) It was only forecasted to rain 5-10mm the day of the event, and Environment and Climate Change Canada worked quickly to put out a severe thunderstorm warning before midnight on June 22, 2017. Emergency services coordinated a series of seven flood warning messages across the Grand River watershed.(118) The storm caused major flooding that led to road closures and home evacuations for low lying areas, and also resulted in power outages for local residents.(119)

As the climate continues to change, events like this are expected to become more common. Additionally, there are expected alterations to the frequency, duration, and intensity of precipitation events including extreme precipitation and associated flooding, which are the most common natural disasters in both developing and developed countries. (120,121) While changes to local climates have been observed across the study area, current climate models do not accurately predict changes to flood risk, tornadoes or other extreme weather events, making links to human health and well-being difficult to predict.(8,69) The information provided here is therefore provided to support more robust analysis in the future and to establish baseline conditions for extreme weather events and expected changes to those patterns over time. Attributive statements between extreme events and human health should therefore be approached with caution and interpreted carefully.(122)

Severe thunderstorms pose few direct health risks beyond accidental morbidity and mortality from being struck by debris in high wind conditions. However, health risks associated with extreme storms can also be indirect in terms of impacts to infrastructure and service delivery and impacts of flooding. For example, the Grand River watershed runs throughout the study area, and flooding is a regular occurrence in this watershed. Low-lying areas adjacent to rivers and streams are typically areas of highest risk of flooding in the watershed during late spring and early fall.(123)

Heavy rainfall leading to flooding is strongly associated with drinking water-related illness outbreaks, especially for individuals who drink from private wells. According to a systematic review of international extreme precipitation events, the most common pathogen observed during heavy rainfall and flooding events is *Vibrio*, although it should be noted that other pathogens are more common in the study area.(10) For more information on pathogens in food and water that are driven by climate change, see Chapter 6.0 Food- and Water-borne Illnesses.

Another potential concern for individuals with underlying respiratory issues is exposure to mould after flooding, as evidenced by studies in the United Kingdom and United States.(124–126) Health Canada suggests that flooded buildings can stay damp even after floodwater has receded, creating conditions for mould and fungi spores to spread, resulting in allergic reactions, coughing, wheezing, and asthma attacks.(127) Flooding can also lead to accidental morbidity and mortality from contact with debris in flood waters; create conditions for accidental drowning and hypothermia; and indirectly affect the delivery of health services.(128) Flooding is expected to become a more likely occurrence due to increases in precipitation during spring and winter, posing significant risks for freshet conditions where water collects on snow and frozen ground.



Extreme weather conditions can create additional challenges for health and emergency service delivery (e.g., road conditions, power outages) and associated social and economic disruption.(129,130) An example of an extreme event not found in the Canadian Disaster Database which was shared during focus groups is an ice jam in Cambridge on the Grand River which caused major flooding in February 2011 where ice piled up and caused water to back up and spill across areas that are atypical of the river's course. The ice jam caused local flooding and power outages and affected a water line supplying drinking water to over 100,000 residents. The Grand River Conservation Authority identifies that ice jam flooding is most likely in areas where the river is shallow and goes through twists and turns. Grand Valley, Drayton, West Montrose, New Hamburg, Ayr, and Cambridge are the most vulnerable communities to ice jams in the Grand River watershed.(123)

During focus groups with community partners, certain parts of the study area were identified as being particularly vulnerable to flooding from extreme precipitation. These include Ayr, New Hamburg, Cambridge (Galt, Hespeler, Preston), Minto (specifically Harriston which is in a floodplain), Mapleton (specifically Drayton), Hockley Valley near Mono, Grand Valley, and Amaranth/East Garafraxa. Participants also identified vulnerabilities with dams that exist across the study area and pointed out that significant rainfall causing flooding could overwhelm existing infrastructure.

5.1.2 Drought

Drought typically refers to abnormally long and persistent dry weather.(8) There are four types of drought: meteorological, hydrological, agricultural, and socioeconomic. Meteorological drought is a measure of degree and duration of dryness; hydrological drought is a measure of how precipitation shortages impact surface or groundwater supplies; agricultural drought is a measure of moisture insufficiency for a particular crop; and socioeconomic drought refers to when the demand for a particular good exceeds supply due to weather-related shortfalls of water supplies, or when agricultural shortages impact communities.(131)

The health impacts of drought primarily occur through processes of food and water insecurity and loss of livelihoods—especially for those who are reliant on local harvesting. In contexts with long histories of dry spells, drought has also been linked to food-, water-, and vector-borne illness, dust-related respiratory diseases, and mental health impacts,(132,133) all of which are covered in subsequent chapters.

5.1.3 Winter storms, flash freezes, and freezing rain events

Winter storms are a regular occurrence throughout the study area and can lead to significant snowfall and high winds. While winter storms are expected to diminish in their frequency due to an overall warming trend across the study area, the intensity and duration of extreme snowfall events can still create significant impacts on health and social service delivery.(4) Moreover, as the climate continues to warm, it is anticipated that the study area will see fewer freeze-thaw cycle conditions.(2) Orangeville, Arthur, and Shelburne all have a history of snow squalls, and focus group participants highlighted how these events have historically created staffing challenges and service delivery issues linked to road closures and safety concerns over icy road conditions.



5.1.4 Wildfires

Ontario experienced more than 1000 wildfires a year over the past decade, with most fire activity taking place in the northwest and northeast regions of the province.⁽¹³⁴⁾ Southwestern Ontario is considered outside the principal fire regions of the province, and wildfire risks are generally low for the study area.⁽²¹⁾ However, transboundary air pollution in the form of particulate ash has been observed throughout southwestern Ontario. In July 2019, smoke from 18 wildfires burning across northern Ontario spread across the southwestern part of the province through prevailing western winds.⁽¹³⁵⁾ Appearing as a 'smoky haze', particulate matter exacerbated poor air quality posing respiratory risks to the community, particularly those most vulnerable to poor air quality such as children, the elderly, people with pre-existing respiratory conditions, and people who participate in physical activity outdoors. Given that the risks of wildfires to the study area are mostly driven by wildfire smoke from other jurisdictions, this topic is covered in Chapter 7 Air Quality in this report. However, the impacts to local health, social, and emergency services may still be impacted if evacuations relocate affected communities to Waterloo Region or Wellington-Dufferin-Guelph.

5.2 Future Climate Change

A full articulation of expected climate change under a variety of scenarios can be found in a supplemental report titled Climate Science Report for the Climate Change and Health Vulnerability Assessment for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph.⁽⁴⁾ That report provides an in-depth overview of anticipated changes to seasonal climates in the study area under three different emissions scenarios. In terms of extreme weather, the report highlights:

- The number of frost days for Wellington County, Dufferin County and Waterloo Region is expected to decrease under all future climate change scenarios (see Table 14).
- The number of icing days—the number of days where the air temperature does not rise above freezing, is expected to decrease under all future climate scenarios (see Table 15).
- The number of freeze-thaw cycles, where temperatures are expected to be above and below freezing within a 24-hour period, is expected to decrease under all future climate change scenarios (see Table 16).
- Total annual precipitation is expected to increase marginally or stay approximately the same, with any increases in precipitation occurring in spring and winter seasons.
- Projected extreme precipitation events—where total rainfall is in the 95th or 99th percentile—are expected to increase across each community in the study area by the end of the century meaning a higher percentage of all yearly precipitation that falls in the future will occur during extreme events.
- There is no significant projected change in dry periods—the greatest number of consecutive days with daily precipitation of less than 1mm.



- Severe freezing rain events (those lasting longer than six hours per day) are projected to increase by 15-20% by 2050, and as much as 30% by 2100.(136) Looking toward 2100, the risk of freezing rain events will:
 - » Significantly increase in January;
 - » Have slight to minimal increase in December and February; and
 - » Decrease for November, March, and April.(136)

Table 14: Projected frost days for Wellington, Dufferin, and Waterloo Region – RCP2.6, 4.5, and 8.5

Frost Days (days)	Baseline 1986- 2005	2050s			2080s		
		RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Wellington	135	114	108	101	114	101	78
Dufferin	140	119	114	107	120	106	83
Waterloo Region	128	107	101	94	107	93	71

Source: Adapted from Lapp et al. 2022, Climate Science Report

Table 15: Projected icing days for Wellington County, Dufferin County and Waterloo Region – RCP2.6, 4.5, and 8.5

Icing Days (days)	Baseline 1986- 2005	2050s			2080s		
		RCP2.6	RCP4.5	RCP8.5	RCP2.6	RCP4.5	RCP8.5
Wellington	54	38	33	30	39	29	16
Dufferin	57	41	36	33	42	32	18
Waterloo Region	51	36	31	28	36	27	15

Source: Adapted from Lapp et al. 2022, Climate Science Report

Table 16. Projected freeze-thaw cycles for the study area – RCP 4.5, and 8.5

Freeze-thaw cycles	Baseline 1976-2005	2050s		2080s	
		RCP4.5	RCP8.5	RCP4.5	RCP8.5
Kitchener/Waterloo	64.9	60.2	57.2	59.1	51.4

Source: Data presented are from the large cell grid for the “Kitchener Region” from climateatlas.ca. The large grid is the best approximation of the entire study area to represent projected freeze/thaw cycle data.



5.3 Baseline Historical Assessment of Population Health Outcomes Related to Extreme Weather

All-cause injury is a measure of the overall burden of disease from all injuries that occur within the study area. Here, it is used to approximate injuries caused by extreme weather events, although it should be noted that this health outcome is unable to be directly attributed to extreme weather events. According to data from the National Ambulatory Care Reporting System collected by IntelliHealth Ontario, across the study area, age-standardized all-cause injury-related hospitalization rates have shown small increases between 2010-2017 (Wellington-Dufferin-Guelph: $r=0.848$, $p<0.01$; Waterloo Region: $r=0.645$, $p>0.05$). Given future freeze-thaw patterns and historical risks associated with winter storms, falls are utilized as a proxy measure of accidental morbidity resulting from extreme weather given their association with bouts of cold weather (i.e., ice and snow). Again, these data should be interpreted with caution as local data cannot be attributed to specific weather conditions and may reflect the aging nature of the local population more than changing climate. According to Canadian Institute for Health Information, almost 8,800 annual fall-related hospitalizations in Canada occurred from people slipping on ice (approximately 5% of all hospitalization-related falls in Canada per year).⁽¹³⁷⁾ In recent years, age-standardized hospitalization rates from falls show a statistically significant increase in Wellington-Dufferin-Guelph ($r=0.890$, $p<0.01$). Waterloo Region data suggests a similar statistically significant increase during the same time period ($r=0.728$, $p<0.05$) (see Figures 22 and 23).

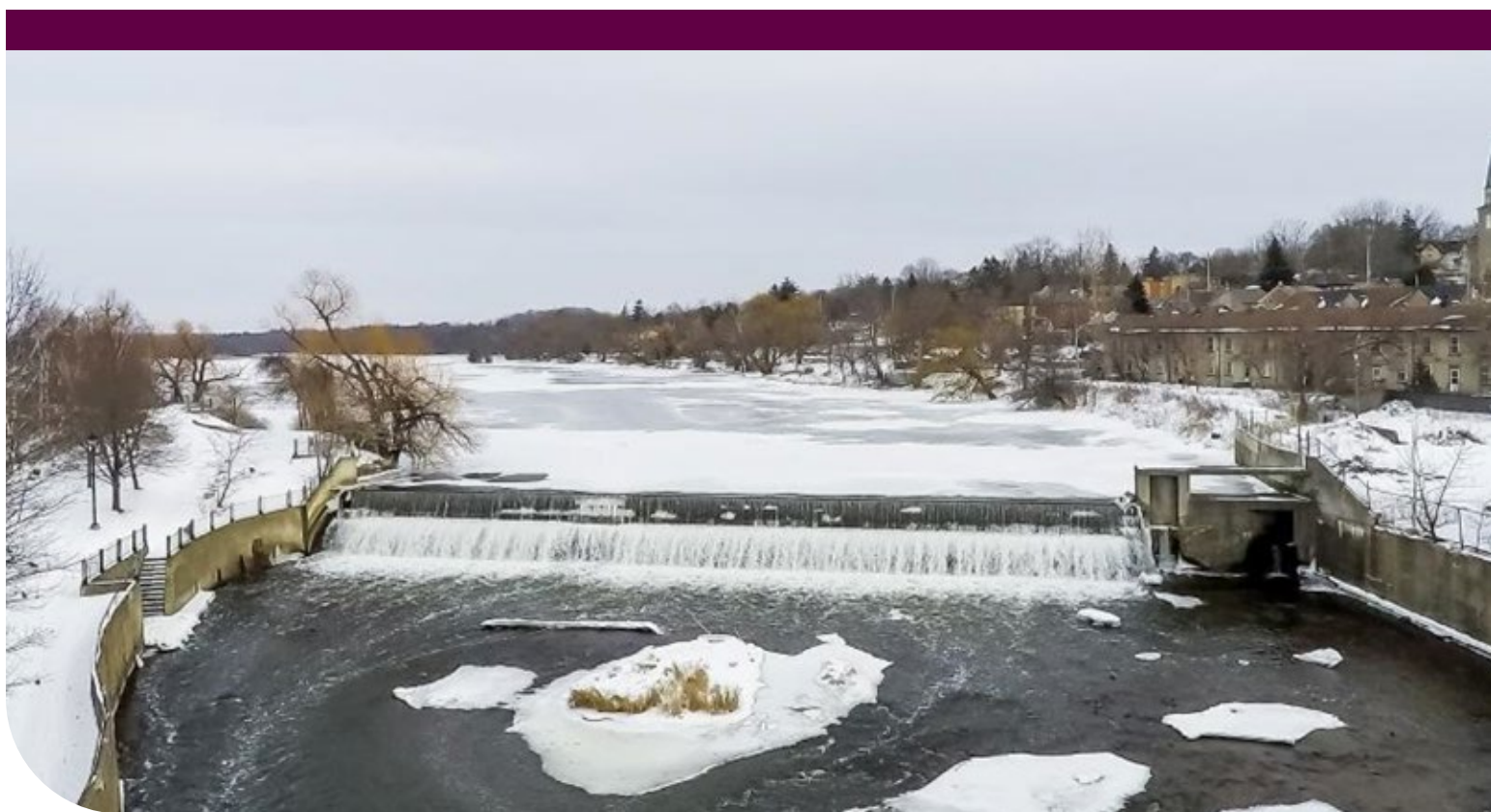
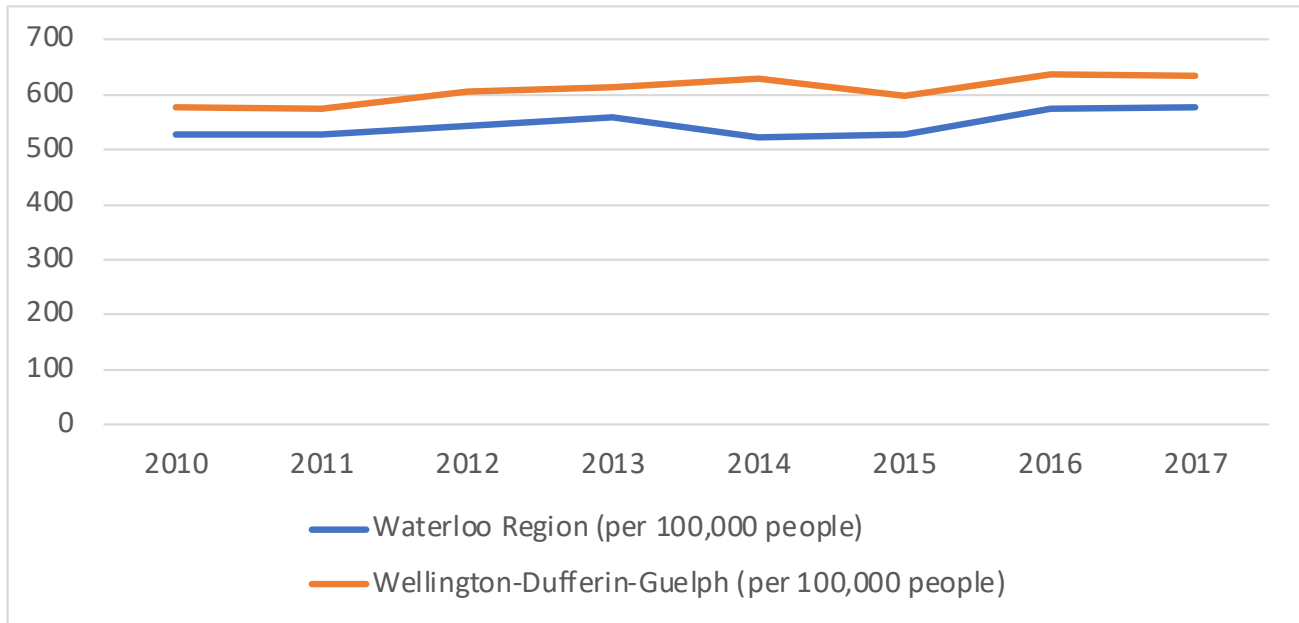


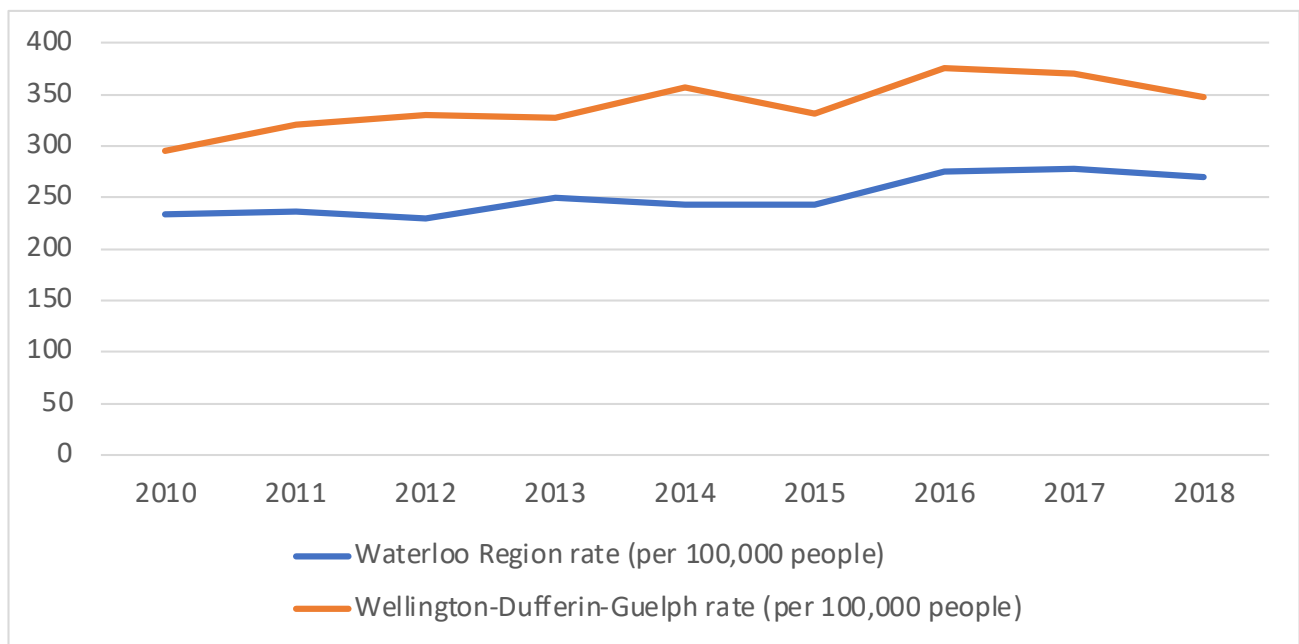


Figure 22. Age-standardized all-cause injury related hospitalization rates (per 100,000 people) across the study area, 2010-2017



Source: DAD data, Injury-related hospitalization count

Figure 23. Age-standardized emergency department visit rate for falls (per 100,000 people) across the study area, 2010-2018

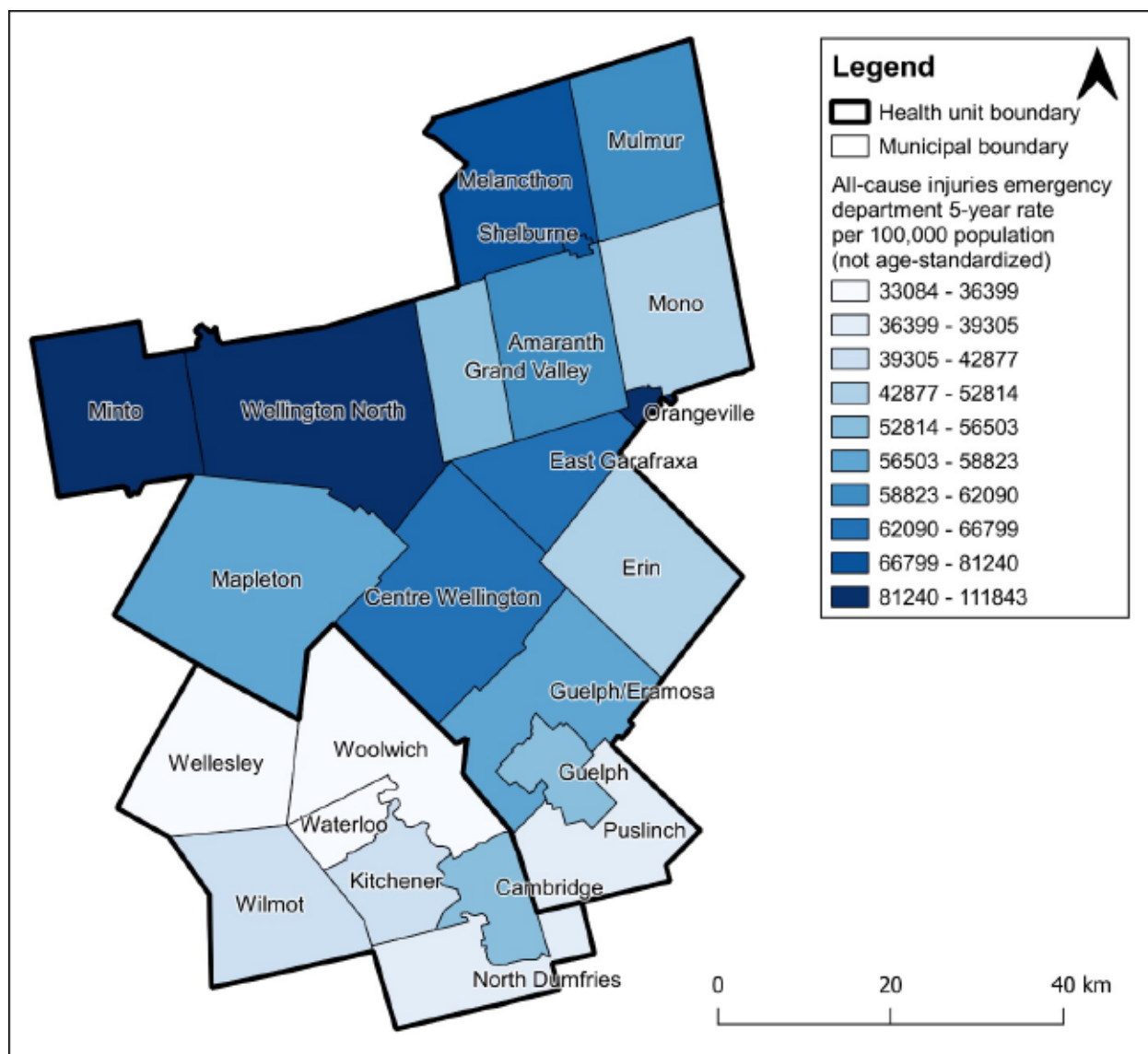


Source: DAD data, Injury-related hospitalization counts



Baseline risks of falls and all-cause injury rates are also able to be displayed spatially using a five-year rate of all-cause injury emergency department visits across the study area to not over or underestimate falls or injuries based on a single year’s observation (see Figures 24 and 25), and therefore, should not be compared to single year observations elsewhere in the report. These values were calculated by adding the total number of occurrences between 2016-2018, dividing them by the 2016 population, and then multiplying the result by 100,000 to calculate a rate. Findings suggest that Minto, Wellington North, and Orangeville have elevated emergency department use for both all-cause injury and falls.

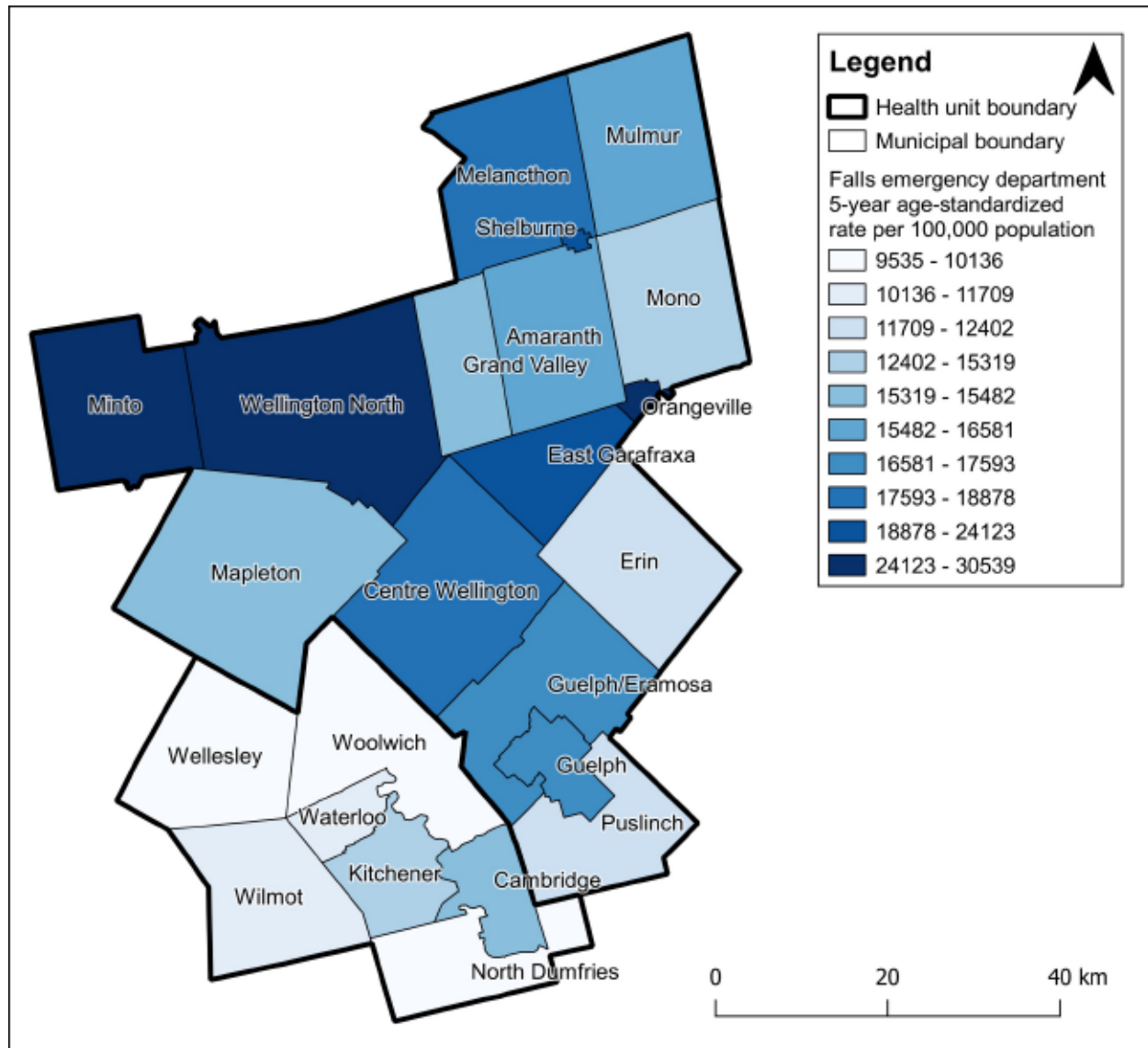
Figure 24. 5-year crude rates of all-cause injury emergency department visits per 100,000 residents by municipality, 2016-2018



Source: DAD data, Injury-related hospitalization counts



Figure 25. Five-year age-standardized rates of emergency department visits for falls per 100,000 residents by municipality, 2016-2018



Source: DAD data, Injury-related hospitalization counts

Extreme weather events also pose risks to drinking water sources if flood waters or severe storm runoff impact drinking water sources, especially for private wells as demonstrated by the Walkerton tragedy.(138) Flood waters can increase risks of water- and food-borne contamination through the transmission of *E. coli* and other harmful bacteria. A more fulsome accounting of water quality risks and flood water interaction with wells is provided in Chapter 6: Food- and Water-borne Illnesses.



5.4 Populations Vulnerable to Extreme Weather in Wellington-Dufferin-Guelph and Waterloo Region

Some populations are more vulnerable to extreme weather events due to their exposure, sensitivity, or lack of adaptive capacity. The literature suggests that the following groups are potentially more vulnerable: dependent children and older adults (particularly those with mobility impairments, and pre-existing or chronic health conditions), newcomers, people living in or adjacent to floodplains, pregnant women, socially and economically disadvantaged populations, and those under the influence of substances causing sedation or impairment of cognitive functioning (e.g., excessive alcohol use, illicit substance use).^(7,41)

Focus groups further identified that commuters to and from the study area (due primarily to motor vehicle collision risks and road conditions), people in institutionalized settings, people living in substandard housing, and those living in high-rise buildings (where potable water access is dependent on pumps that shut off during power outages) may be at additional risk. This section briefly describes exposure and sensitivity pathways for known vulnerable populations, providing recent statistical representations of each population of interest.

5.4.1 Populations vulnerable to extreme weather due to exposure

Exposure is driven by coming in contact with extreme weather which may elevate risks for accidental morbidity and mortality. Key population groups that may be differentially exposed to extreme weather include commuters and people living within the boundaries of a floodplain.

5.4.1.1 Commuters

Commuting is an important driver of economic development across the study area, particularly for the large economic centres of Guelph, Kitchener, Waterloo, and Cambridge.⁽¹³⁹⁾ Focus group participants identified that commuters to and from the study area may experience greater exposure to extreme weather events, particularly when commuting on highways at high speeds, or rural roads where risk of getting stranded and/or risk of crashes or collisions due to poor road conditions may be higher (e.g., during periods of extreme rain or blowing snow). Limited data exist for the number of commuters to each Health Unit jurisdiction from other areas outside Health Unit boundaries, or where they commute to. However, Canadian Census data indicates that a higher proportion of people living in Wellington-Dufferin-Guelph (50.7%) and Waterloo Region (52.4%) commute to either different census sub-divisions within their census division, or to a different census division entirely relative to the provincial average (41.2%) (see Table 17).



Table 17. Proportion of population aged 15 years or older by commuting destination

	WDGPH	Waterloo Region	Ontario
Commute within municipality of residence	49.0%	47.3%	58.0%
Commute to different municipality within county or region of residence	16.1%	35.8%	16.0%
Commute to a different county or region within province or territory of residence	34.6%	16.6%	25.2%

Source: Statistics Canada 2016 Census of Canadian Population

5.4.1.2 Populations living in floodplains

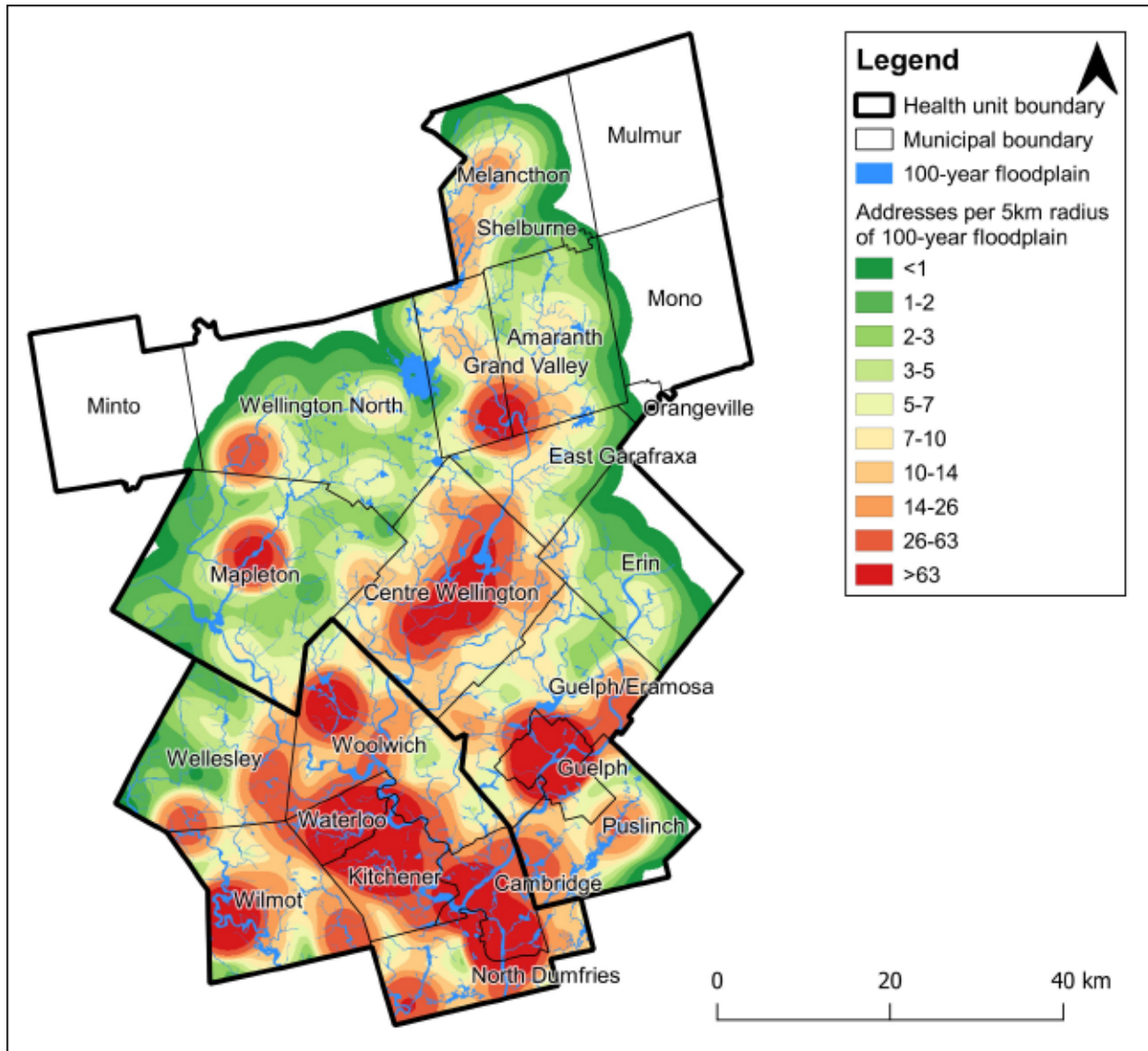
The *Ontario Building Code, 2018* prohibits new developments in floodplains of watersheds across the province. However, there are some dwellings that pre-exist these zoning changes. Populations that live in floodplains can be differentially exposed to risks associated with extreme rainfall events where flood risks are higher. These include accidental morbidity and mortality from coming in contact with flood waters, or the risk of waterborne contamination if flood waters contaminate drinking water sources, namely private residential wells.(7)

The study area overlaps with the boundaries of five watersheds: the Grand River, Credit Valley, Nottawasaga, Maitland Valley, and Saugeen Watersheds. A full depiction of regional flood risks is beyond the scope of this assessment, but the vast majority of the study area is covered by the Grand River watershed. Figure 26 depicts the density of registered addresses within the 100-year floodplain boundary of the Grand River. The 100-year floodplain depicts where flood waters would be expected to reach during a once in a 100-year flood event. The figure demonstrates that the southern area of the study area (principally covered by the Region of Waterloo) has the greatest density of addresses within the floodplain, and that the communities of Grand Valley, Mapleton, Centre Wellington, Woolwich, Wilmot, Waterloo, Kitchener, Cambridge, and North Dumfries have the greatest density of dwellings exposed to 100-year flood risks.

As noted above, a full depiction of regional flood risks is beyond the scope of this assessment and floodplain data for watershed areas outside of the Grand River Watershed are not included. Consequently, several areas identified by workshop participants as experiencing significant flooding impacts historically are not covered in this analysis, including Minto (Harriston), Hockley Valley in Mono, and parts of Amaranth/East Garafraxa. Expanding the analysis shown in Figure 26 to include those key areas may be a recommendation put forward for future steps, pending input from local stakeholders. Local tracking of historical flooding events and experiences should play a role in subsequent adaptation planning steps. A more comprehensive investigation of water-borne illness present across the study area can be found in Chapter 6.0 Food- and Water-Borne Illnesses.



Figure 26. Address density (total addresses per 5km radius) within the Grand River watershed 100-year floodplain, 2020



Source: Civic address files provided by WDGP and ROWPH. Regulatory floodplain (100-year flood): <https://data.grandriver.ca/downloads-geospatial.html>

5.4.2 Populations vulnerable to extreme weather due to sensitivity

Older adults may be more physiologically sensitive to extreme weather. Falls are the most common cause of injury and a leading cause of hospitalization among older Canadians, and it is estimated that one in three people aged 65 or older are likely to fall at least once.(140) Further, a recent literature review identified that older adults account for high levels of morbidity and mortality from extreme weather related to climate change.(53)



5.4.3 Populations vulnerable to extreme weather due to adaptive capacity

There are a number of population level vulnerabilities that may reflect a lack of adaptive capacity in dealing with extreme weather events. Those most relevant to the study area include people who are dependent upon caregivers, people who are socially isolated, people living in institutional settings, people experiencing socioeconomic disadvantage, and people who consume alcohol and/or illicit drugs.

5.4.3.1 People dependent on caregivers and those who are socially isolated

Children (<15 years old, 17.7% of the Wellington-Dufferin-Guelph population and 17.8% of the Waterloo Region population in 2016) and older adults (aged 65 and older, 15.8% of the Wellington-Dufferin-Guelph population and 14.4% of the Waterloo Region population in 2016) are more dependent on caregivers than working age populations. This translates into a greater reliance on others during an emergency to engage in adaptive behaviours or remove oneself from harm, and can be particularly acute for older populations with mobility restrictions, for which data is limited across the study area. Warning older adults to stay indoors during extreme weather events may also cause cyclical health problems by exacerbating isolation issues that may negatively impact mental health.(141,142) Flooding in particular is strongly associated with increasing incidence of post-traumatic stress, depression and anxiety, irrespective of age.(31) The number of older adults is projected to increase significantly by 2030 across the study area (see Chapter 3: Extreme Temperatures for additional population projections).

The ability to adapt during extreme weather be further compounded for those experiencing social isolation which can limit access to social services and related supports during an emergency. Social isolation may disproportionately impact people who speak neither French nor English due to an inability to understand emergency communications. The Canadian Community Health Survey, 2015 data suggest that the proportion of people with a somewhat or very strong sense of connection to community were 68.2% for Waterloo Region and 68.8% for Wellington-Dufferin-Guelph, and that 1.8% of the population speak neither French nor English in Waterloo Region relative to 0.9% across Wellington-Dufferin-Guelph.

5.4.3.2 People living in institutional settings

Older adults may also be more likely to live in institutional settings such as long-term care facilities. Focus group participants identified populations in long-term care facilities as a potentially vulnerable population, and the Ontario Long-term Care Association publishes yearly updates on the state of long-term care facilities. In 2017/2018, the Home and Community Care Support Services Waterloo Wellington geographic catchment area had 36 long-term care facilities with 4,142 beds (4106 for long stays and 36 for short stays). The proportion of people in long-term care with worsening physical function in 2017/2018 was 37.3% for this catchment area, which could severely limit evacuation procedures during extreme weather emergencies, in the event they are ordered. Comparatively, in 2017/2018, the Home and Community Care Support Services Central West geographic area (which includes Dufferin County and Peel Region) had 23 long-term care facilities with 3481 beds (3430 for long stay and 51 for short stays). In 2017/2018, 28% of residents reported worsening physical function.

The figures above do not, however, capture all populations within the study area that live in institutional settings. These may include people regularly living in shelter systems, in public or private group homes (e.g., for people



living with developmental disabilities), or in prisons (e.g., Grand Valley Women’s institute). To better understand the inherent risks to these populations, a more comprehensive accounting of these facilities’ population composition, emergency management and evacuation plans, and physical vulnerabilities related to their location and core infrastructure is required.

5.4.3.4 People experiencing socio-economic disadvantage

In relation to extreme weather, people who are underhoused, housing insecure, or experiencing homelessness may be differentially exposed to climate-related health hazards by virtue of not having safe housing during an emergency. (143,144) People with low-income may be additionally vulnerable, as they may lack insurance to support the costs associated with damages to property and belongings, or lack the ability to relocate in the event of an emergency. Focus group participants identified that downtown Kitchener, Guelph, and Cambridge were particularly vulnerable areas, with relatively large populations of people experiencing homelessness. Additionally, focus group participants indicated that there may be rural/urban disparities in terms of differential access to services, but particularly for low-income individuals and families. Similarly, people living in substandard housing may be at higher risk of injury due to falling debris, or from flooding in instances where neighbourhoods have inadequate storm water management or individual buildings have pre-existing structural issues.(120,145) Table 18 describes current data for these populations drawing from 2016 Canadian Census data (relative to the 2011 National Household Survey), and Built-for-Zero Canada point estimates of homelessness collected in October 2019 (for more information on this data source, see Table 18, below).

Table 18. Key socio-economic population health vulnerabilities related to extreme weather

	Proportion of Total Population, 2016 (Change Relative to 2011)		
	Wellington-Dufferin-Guelph	Waterloo Region	Ontario
Prevalence of low-income after tax	9.9% (-0.6%)	12.1% (-1.8%)	14.4% (+0.5%)
% of housing requiring major repairs	5.1% (-0.3%)	6.1% (-0.4%)	6.1% (-0.5%)
Chronic homelessness (October 2019) [†]	134	228	-

Source: Statistics Canada 2016 Census of Canadian Population

[†]Built for Zero Canada point-in-time estimate for October 2019. Chronic homelessness “refers to individuals who are currently experiencing homelessness AND who meet at least one of the following criteria: a) they have a total of at least six months (180 days) of homelessness over the past year b) they have recurrent experiences of homelessness over the past three years, with a cumulative duration of at least 18 months (546 days) <https://bfzcanada.ca/wp-content/uploads/BFZ-C-Data-Dashboards.pdf>



5.4.3.5 People who drink alcohol and/or consume illicit drugs or medications altering cognitive capacity

People who drink alcohol and/or who are dependent upon drugs or medications that alter their cognitive capacity may be at elevated risk during emergencies.(7) Inhibiting cognition can impair decision-making, contribute to potential misunderstandings of risk communication messaging, and potentially cause impairment that inhibits the ability of a person to remove themselves from an area affected by an emergency. The proportion of the population that self-identified as a regular drinker (defined as anyone who drinks once a month or more) in 2016 was slightly higher for both Health Unit areas when compared with the provincial proportion (see Table 19). A higher proportion of people in the study area also indicated they used illicit drugs in the past 12 months compared with the Ontario rate.

Table 20. Regional drinking status and illicit drug use relative to provincial averages

	Wellington-Dufferin-Guelph	Waterloo Region	Ontario
Regular drinker [†]	60.8%	58.9%	57.0%
Increased long-term health risk due to drinking [‡]	34.4%	32.3%	35.2%
Increased short-term health risks due to drinking [‡]	30.4%	28.7%	31.9%
Illicit drug use (12 months)	9.8%	9.5%	8.7%

Source: 2015/16 Canadian Community Health Survey

[†]Defined as someone who, during the past year, drank at least one drink or more per month

[‡]Composite measures that describe short and/or long-term health risks according to *Canada's Low-risk Alcohol Drinking Guidelines*

5.4.4 Sex and gender-based vulnerabilities

Recent evidence suggests that pregnant women may be more vulnerable to extreme weather events.(146) For example, floods can limit access to essential specialized health care when needed. Pregnant women are at higher risk for severe stress to weather-related disasters than the general population.(147,148) However, birth outcomes associated with various disasters vary widely and require additional research to better understand perinatal outcomes from specific extreme events.(146,149)

Communication challenges associated with risk messaging during extreme events may also be present according to sex/gender. The 2016 Census demonstrates that in Wellington-Dufferin-Guelph, 1,525 women (0.5% of the total population) had knowledge of neither official language relative to 1,075 men (0.4% of total population), compared with 5,460 women (1.0% of the total population) and 3,845 men (0.7% of the total population) in Waterloo Region. Women across the study area also experience higher rates of receiving social assistance and have higher prevalence of after-tax low-income rates relative to men, with a marked difference for those aged 65 and older. Finally, data suggest that there are approximately 80 men for every 100 women aged 65 and older across Ontario,(74) suggesting older women may be a population of concern to target health risk messaging associated with extreme weather.



5.5 Programs, Policies, and Related Actions Taken to Improve Adaptive Capacity to Extreme Weather

The broad-based population exposures to the weather events described above can be modified by multiple environmental, social, and economic dimensions.(150) These include:

- Environmental dimensions: geography, settlement patterns, location-specific contexts of human-environment interactions.
- Social dimensions: demographic/cultural variables, institutions, and governance; and
- Economic dimensions: access to science and technology, affordability of adaptation options.(131)

Building resilience—the ability to bounce back or transform in the face of system shocks such as those posed by extreme weather—is key to developing local capacity to respond to emergencies and minimize morbidity and mortality risks during natural disasters.(151) Because many actions to build resilience to extreme weather are required to occur at the community-level, Public Health agencies are uniquely situated to contribute to emergency preparedness.(151)

5.5.1 Individual actions

As per the section on adaptive capacity above, some individuals may lack the ability to respond due to limitations on physical capabilities or material inequalities. These inequalities should be considered when attempting to support the individual actions outlined below.

Individual actions to reduce health risks of extreme weather primarily involve listening to alerts and following safety orders issued by regional agencies, checking in on vulnerable neighbours, having an adequate supply (typically three days) of essential supplies in the event of power outages and service disruptions, and removing oneself from a disaster affected area (e.g., flooded housing or buildings located near floodplains), if necessary.

Focus group participants identified that an area for future research is to better understand adaptive capacity and assets among the Mennonite population that resides within the study area. Participants identified that a sophisticated understanding of local climate and its interactions with the land, in combination with strong social connectedness would likely enhance this population's resilience to extreme weather events in terms of preparation and recovery.

5.5.2 Public Health actions

Public Health activities implemented by WDGP and ROWPH that address extreme weather events, are outlined in Table 20 according to the Ontario Public Health Standards. As stated in section 4.6, under the Ontario Public Health Standards, Ontario Health Units are primarily involved in disease prevention activities and surveillance, rather than acute response.



Table 21. Public Health roles and responsibilities for responding to extreme weather events

Public Health Standard	Key Roles and Activities
Population Assessment and Surveillance	<ul style="list-style-type: none"> Identify populations and communities at risk Monitor extreme weather events forecasted by Environment and Climate Change Canada
Health promotion and Policy Development	<ul style="list-style-type: none"> Participate in municipal and regional emergency response planning and specific plan development for vulnerable populations during extreme events. Provide public education on health risks of extreme weather and flood risks via web pages, social media and media releases, and information on personal and neighbourhood emergency preparedness (e.g., WDGPH's flood prevention and recovery guide). Share extreme weather alerts issued by Environment and Climate Change Canada on an 'as-needed' basis. Participate in and contribute feedback on Official Plan reviews (with particular focus on permeable surface creation (e.g., greenspaces) and storm water management).
Health Protection and Disease Protection	<ul style="list-style-type: none"> Support community emergency management in planning for emergencies (e.g., emergency response exercises, vulnerable populations notification processes, hazard identification and risk assessments) Coordinate with staff from Ontario Health and the Ministry of Health, where appropriate Issuing boil/drinking water orders and advisories where appropriate Business continuity planning
Emergency Management	<ul style="list-style-type: none"> Contribute health expertise during periods of emergency and participate in coordinated response as designated by regional emergency management operations

5.5.3 Actions led by community partners

Each Public Health Unit in the study area benefits from many partnerships that work together to support a community response to extreme weather events. Numerous community organizations, social service agencies, and institutions all play critical roles in coordinating emergency response and preparedness.



5.5.3.1 Risk messaging

Extreme weather alerts are publicly issued by Environment and Climate Change Canada through their [EC Alert Me](#) and [WeatherCAN](#) mobile weather app.

In addition, municipalities collaborate in sharing risk messaging with the public. For example, in Waterloo Region, representatives from the local municipalities and the Region of Waterloo collaboratively share emergency messaging to the public through the [Alert Waterloo Region](#) program. Alert Waterloo Region is a new emergency alerting system with three goals: sharing emergency management alerts; supporting emergency management at the individual and community level; and identifying and sharing local risks during emergencies.

Dufferin County conducted a risk profile that identified flooding as a high-risk event with high likelihood of impacting vulnerable populations.⁽¹⁵²⁾ Subsequently, Dufferin and Wellington Counties worked closely with WDGPH to create a [Guide to Flood Prevention and Recovery](#) to support local residents.

The Grand River Conservation Authority (GRCA) and other conservation authorities that are part of the study area (i.e., Credit Valley, Nottawasaga, Maitland Valley, and Saugeen Watersheds) also provide comprehensive information about flood risk throughout these watersheds. The GRCA covers the majority of the study area, and they manage seven dams and reservoirs to hold water and reduce flood peaks and maintain dikes to protect low lying areas in Bridgeport and Galt. GRCA also makes detailed flood risk maps available for Ayr, Drayton, New Hamburg, and West Montrose which it identifies as the highest risk communities in the watershed. The flood risk maps are available on the [GRCA flood resources website](#). However, the GRCA does not cover several other high risk flooding areas identified by stakeholders as experiencing significant flooding impacts, historically, and future analysis of flood mapping for neighbouring conservation authorities and watersheds is recommended. Areas identified by workshop participants as experiencing significant flooding impacts historically, that fall outside of the Grand River watershed but within the study area, include Minto (Harriston) and Hockley Valley in Mono. In addition to these community-specific resources, the GRCA shares [numerous flood-related resources on its website](#).

Flood warning systems run by the GRCA, Credit Valley, Nottawasaga, Maitland Valley, and Saugeen Watersheds are circulated with municipal flood coordinators, and shared on their website, via Twitter, and through email subscription. These updates are regularly shared with local media. These include watershed condition statements about potential hazards indicating high flow events, unsafe riverbanks, and potential flood outlook statements; flood watches where municipalities and individuals should engage in preparatory actions; and flood warnings where flooding is occurring or about to occur which trigger municipal actions to close roads and evacuate certain flood-prone areas.

[Reep Green Solutions](#)—an environmental charity focused on enhancing sustainability across Waterloo Region—has also been working with neighbourhood associations in Waterloo Region using different flood scenarios to engage community members and identify possibilities to reduce flood risk.

5.5.3.2 Health and social services

Ontario Health Teams (formerly Local Health Integration Networks) provide health and social service care to the study area. Under emergency situations, members of Emergency Control Groups, including Public Health and other



community partners, coordinate with Ontario Health for all health services required, particularly during evacuations and at emergency reception centres.(153) Ontario Health Teams are responsible for complying with provincial mandates for emergency preparedness protocols for their operations to ensure health and safety of employees and patients on or in ambulatory transit to any and all of their facilities. Ontario Health Teams also develop surge plans in consultation with key stakeholders to plan and budget for potential surge capacity on healthcare systems, and create accountability systems for all facilities potentially impacted by a surge in demand or usage.(153) Hospitals and other critical assets (e.g., water purification plants) have backup generators and power systems on site for emergencies. However, a full review of climate change resilience of local health care facilities is beyond the scope of this assessment.

5.5.3.3 Police, fire, and ambulatory services

Each municipality has an emergency management program, and a Community Emergency Management Coordinator who advises and informs the appointed members of Emergency Control Groups. Each municipality has an Emergency Operations Centre for coordinating resources and information sharing during a time of emergency. Core roles and responsibilities are established in emergency response plans. These plans provide for the delivery of essential public safety functions during emergencies or associated large-scale events.

5.5.3.4 Planning-related activities

Numerous planning actions are currently underway across the study area to bolster adaptive capacity to extreme weather. A scoping review of these activities and those raised by focus group participants are described below:

- Building in floodplains is currently limited by the Ontario Building Code, 2018 to minimize property damage from flooding and erosion and protect human health. The GRCA has a series of online tools that enable homeowners to determine if permitting regulations are required before construction or development activities.
- Following consultations with flood affected residents in New Hamburg and Township of Wilmot Staff, the GRCA applied for and received \$90,000 in funding from the National Disaster Mitigation Program to complete a flood mitigation study. This study estimates average annual flood damages and reviews options to mitigate flood risk along the Nith River in New Hamburg, conducting a cost-benefit analysis to analyze feasibility of implementation options. More information about this program is available on the [GRCA website](#).
- The Town of Orangeville is developing a seniors' strategy for extreme weather events and in the past has run programs delivering essential medication to seniors who are housebound during extreme events.
- Official plan commenting periods receive feedback on how to account for extreme weather for future development, and communities across the study area are beginning to incorporate climate change into official community plans as per the 2020 Provincial Policy Statement.
- Region of Waterloo and Wellington-Dufferin-Guelph have business continuity plans across the respective regional and municipal areas during emergencies, and to redirect staff and assets as required.



- Dufferin County in partnership with the Institute for Catastrophic Loss Reduction developed an incentive program for local homeowners to install hurricane clips that secure roofs to walls to keep them intact during high wind events. While not currently a building requirement, the program has seen uptake and most new buildings in Dufferin County have these clips installed.
- City of Kitchener implemented the first Sustainable Urban Forest Strategy in the study area that will increase the amount of permeable surfaces across Kitchener to reduce flood risk.
- Upper-tier and lower-tier municipalities have mutual aid agreements to support one another during weather-related events or emergencies.
- Community services agencies across the study area may employ the Vulnerable Persons Registry—a voluntary registry that supplies information on key routines and behaviours of known vulnerable community members to enable supportive actions in the event of an emergency.

5.6 Conclusion

Climate change will increase the incidence of extreme weather events across the study area in the form of extreme precipitation events, flooding, droughts, and winter storms (e.g., flash freeze events, freezing rain, ice storms, high wind, and snow events). These events may lead to accidental morbidity and mortality across the study area, and may have major impacts on local infrastructure, cause disruption to essential services, and damage residential and commercial properties. Residents living on floodplains are at increased risk during heavy precipitation and flooding events. The occurrence of extreme weather can interact with other health risks described in subsequent chapters of this assessment (e.g., increased risk of illness outbreaks, as well as mental health impacts).

Extreme weather already occurs regularly across the study area, with broad population-level exposures. While the predictive capacity of acute events is relatively low into the future, it is expected that climate change will alter the severity, duration, and intensity of these events in the future. The general warming trend may lower the future risk of extreme winter weather; but increasing precipitation during fall, winter, and spring seasons is expected, as is an increased occurrence and severity of summer storms. This, in addition to the fact that there are multiple modifiable risk factors that determine vulnerability to extreme weather, makes it difficult to quantify all health impacts associated with extreme weather. Future monitoring of emergency department visits and hospitalizations during and after extreme weather events will significantly enhance Public Health's ability to both attribute extreme events to ill-health outcomes and prioritize actions for vulnerable populations that can mitigate those risks.



6.0 Food- and Water- borne Illnesses



6.0 Food- and Water-borne Illnesses: Key Findings

Climate change projections

- In general, temperature is expected to increase, resulting in warmer winters and hotter summers. Hotter and drier summers, when punctuated by extreme precipitation events, are more likely to increase the risk of outbreaks of both food- and water-borne illnesses.
- Precipitation is expected to increase in the spring and the fall, and extreme rainfall events are projected to increase across the study area through the spring, summer, and fall. Extreme rainfall can increase the risk of outbreaks of drinking water-related illness through contaminated flood waters.
- Climate change is expected to alter precipitation patterns and water flows and increase risk of drought which may impact future seasonal produce/food availability.
- Climate change is expected to increase the incidence of harmful algal blooms across Ontario, which could impact the safety of recreational waters and beaches in the study area.

Population-level exposure

- People who live in rural areas and those who live in flood plains may be at greater risk of water-borne illnesses, particularly if they rely on private wells or small drinking water systems that may not be adequately treated or regularly monitored, and which can be impacted by intense precipitation and flooding.

Population-level sensitivities

- Older adults (aged 65 and older) are at higher risk of health complications due to the diminished functionality of their immune response, and older populations are more likely to have chronic conditions.
- Children under the age of five are sensitive to food- and water-borne illnesses as they have developing immune systems and may be more reliant on caregivers to translate risk messaging and engage in protective behaviours.
- Individuals with compromised immune systems (e.g., cancer and transplant recipients on immunosuppressive drugs) are more susceptible to serious illness due to suppressed immune response.

Population-level adaptive capacity

- University students tend to experience higher incidents of food-borne illnesses due to a lack of food safety knowledge and appropriate food safety practices.



- Newcomers to Canada may lack the adaptive capacity to address food- and water-borne illnesses due to language barriers that reduce the effectiveness of Public Health communications.

Adaptive actions

- Individuals can take a variety of precautions to protect themselves from the spread of food- and water-borne illnesses, such as ensuring proper food preparation and avoiding suspected contaminated food and water sources. For individuals on private well water supply systems, proper maintenance and regular well testing is strongly encouraged.
- Public Health assessment and surveillance actions include monitoring incidences of water- and food-borne illnesses, monitoring costs of healthy eating (the Nutritious Food Basket), disease and outbreak case investigation, and investigation of enteric diseases and exposure sources.
- Public Health undertakes several education, advocacy, and policy-support initiatives, including supporting safe food handler training, providing support and funding for peer programs that support food skills for people living with low income and newcomers, supporting the creation of community and school gardens to create access to locally grown food, and advising on policy statements regarding local food systems and protection of agricultural land.
- Public Health also supports disease prevention through food safety inspections, monitoring of small drinking water systems and wells, and issuing boil water advisories.
- WDGPB conducted a survey of private well owners to collect data on well characteristics and well owner attitudes towards water safety and testing. WDGPB has also been analyzing well water testing results to assess local testing rates and well contamination rates.

Baseline health impacts

Food-borne Illnesses & Food Security

- Food-borne illness stems from consuming contaminated or improperly prepared foods and is expected to increase under climate change, due to more people spending time outdoors or attending outdoor events where food may not be prepared with appropriate risk mitigation practices in place.
- Climate change poses a risk to global food security, and food insecurity is strongly related to nutritional deficiency and the risk of chronic conditions. As an agricultural producing region, food security is not only a household issue, but one of strategic concern for the long-term sustainable development of agricultural industries, and overall community resilience.



Water-borne Illnesses

- Extreme weather events and flood waters may pose risks to drinking water sources, especially for private wells via the transmission of *E. coli* and other harmful bacteria.
 - » Between 1974 and 2001, two-thirds of waterborne outbreaks in Canada occurred in private or semi-private systems, with *Campylobacter spp.*, *Cryptosporidium spp.*, *Giardis spp.*, and *E. coli 0157* being responsible for 58% of these outbreaks.
 - » Bacterial lab analysis of private drinking wells between 2015-2019 in the study area indicated that 10.7% of samples submitted from wells in Wellington-Dufferin-Guelph and 12.2% of samples submitted from wells in Waterloo Region were found to have “evidence of bacterial contamination”.¹ However, multiple samples are often submitted for the same well. A closer analysis of samples submitted in the Wellington-Dufferin-Guelph area indicated that in 2018, 21% of wells tested showed evidence of bacterial contamination. Moreover, the wells that were sampled only represented 10% of the wells in Wellington-Dufferin-Guelph. This suggest that testing rates are low and contamination rates may be significant.
 - » Project mapping indicated that Centre Wellington, Puslinch, the southwest region of Wellington North, southern Grand Valley and Amaranth, central and southwest Melancthon, and the southeastern area of Guelph/Eramosa are higher risk areas for flood water contamination of wells in Wellington-Dufferin-Guelph. Similarly, Waterloo, Kitchener, and Cambridge have the highest risk of flood water contamination of wells in Waterloo Region, although further floodplain modeling is required to ensure an accurate representation for watersheds other than the Grand River. Additional areas identified by workshop participants as experiencing significant flooding impacts historically, that fell outside of the areas mapped in floodplain analyses, include Minto (Harriston) and Hockley Valley in Mono.



¹ “Evidence of bacterial contamination” includes both “significant evidence of bacterial contamination” and “unsafe to drink” results as defined by Public Health Ontario (see: <https://www.publichealthontario.ca/en/laboratory-services/well-water-testing?tab=4>)



6.0 Food- and Water-borne Illnesses

Food and water sources contaminated by micro-organisms such as bacteria, parasites, and viruses can cause intestinal illness, which can be spread from person to person. It is estimated that a relatively small proportion of food- and water-borne illnesses are reported to public health officials.(154)

Climate change is expected to alter the frequency, seasonality, and intensity of contamination events and the potential for food- and water-borne illnesses.(7,155,156)

This chapter describes baseline population exposure and incidence of climate-sensitive food- and water-borne illnesses, anticipated future changes to climate and its implications for food- and water-borne illnesses; identifies sensitive and/or vulnerable populations to food- and water-borne illnesses; and describes existing adaptive capacity across the study area.

6.1 Climate-sensitive Food- and Water-borne Illnesses and Associated Health Surveillance Data

Every year, about one in eight Canadians are affected by food-borne illnesses, resulting in 11,600 hospitalizations and 238 deaths.(157) Norovirus, *Clostridium perfringens*, *Campylobacter spp.*, and non-typhoidal *Salmonella spp.* are the leading pathogens that account for approximately 90% of the pathogen-specific total in Canada.(158) In Ontario, *Campylobacter*, *Salmonella*, *Giardia*, *Cryptosporidium* and Verotoxin-producing *E. coli* (VTEC) are the most common pathogens causing food-borne illness.(154) Several food- and water-borne illnesses are particularly sensitive to climatic conditions. These include:

- **Campylobacteriosis** is a common bacterial disease caused by *Campylobacter* causes intestinal illness resulting in diarrhea, abdominal pain, nausea, and vomiting. Direct contact with animals, drinking contaminated water, and consuming undercooked meat, poultry or unpasteurized dairy products all pose risks of campylobacter contamination. Symptoms can be particularly severe for the elderly, those who are very young, and those who are immunocompromised.
- **Salmonellosis** is caused by ingesting food or water contaminated by feces or through contact with a person already infected by the bacteria *Salmonella*. Cramping, fever, and diarrhea are common symptoms, and infection can be avoided by adequately cooking meats and eggs, avoiding unpasteurized dairy products, and practicing proper hand hygiene after touching live animals, raw meat, and/or uncooked eggs.
- **Giardiasis** is an enteric disease caused from food or water sources contaminated with the parasite *Giardia lamblia*. Person-to-person transmission has been observed in childcare settings. Symptoms typically include diarrhea, gas, stomach pain from bloating, nausea, and vomiting. Giardiasis can be prevented through hand washing and avoiding drinking untreated water.
- **Cryptosporidiosis** is typically caused by a person consuming water or food contaminated with feces, for example, swallowing water from swimming pools, lakes, and rivers. *Cryptosporidium* can transmit person-to-person. Symptoms typically include nausea, abdominal pain, and diarrhea.



- **Verotoxin-producing *E. coli* (VTEC)** is a form of *E. coli* bacteria that causes gastrointestinal illness which can be spread person-to-person. It is typically found in animal populations and is spread to humans through ingestion of contaminated food or water, or through contact with animals and their surrounding environments (e.g., farms, zoos). Diarrhea is the most typical symptom. It is particularly prevalent in summer months, during barbecue season. Those most at risk are the immuno-compromised, the elderly, and young children.

(Adapted from Public Health Ontario)(151)

6.2 Future Climate Change and its Relationship to Food- and Water-borne Illnesses

A full articulation of expected climate change impacts under a variety of scenarios can be found in a supplemental report titled *Climate Science Report for the Climate Change and Health Vulnerability Assessment for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph*.(4) The report provides the following highlights for the study area in relation to food- and water-borne illnesses:

- In general, temperatures are expected to increase, resulting in warmer winters and hotter summers. Hotter and drier summers, when punctuated by extreme precipitation events, are more likely to increase the risk of outbreaks of both food and water-borne illness. This risk may also be tightly coupled with: [1] warmer temperatures lead to higher likelihood of pathogen survival; [2] warmer weather leading to higher-risk cooking practices (e.g., barbecues, picnics); and/or [3] disruptions to power infrastructure (e.g., overload in demand) that compromise refrigeration and food preparation requiring power and/or water.
- Precipitation is expected to increase in the spring and the fall, and extreme rainfall events are projected to increase across the study area through the spring, summer, and fall. Extreme rainfall can increase the risk of outbreaks of drinking water-related illness through contaminated flood waters, where cumulative rainfall exceedances are significantly associated with outbreaks.(157,158)
- While future climate change may modify the risk associated with food- and water-borne illnesses, these relationships are complex and uncertain, and there is considerable uncertainty as to which pathogens will be most affected, and at what geographic and temporal timeline.(161) Moreover, because of the international nature of the food supply, there may be elevated risks associated with contaminated imported food.

Despite under-reporting and under-diagnosis of food- and water-borne illnesses,(162) ROWPH and WDGPH are mandated to regularly collect surveillance data on a number of common food- and water-borne illnesses. More evidence is needed to understand whether climate change will play a role in altering transmission of *Norovirus* and *Listeria*.(163) However, several food- and water-borne illnesses have well-established connections to changing climatic conditions:(164,165)

- *Giardiasis* increases under conditions of extreme precipitation (>90th percentile events) with preceding dry periods that can cause soil compaction, increased risk of run-off and higher levels of water turbidity and pathogen load following precipitation.(160,166)



- *Campylobacteriosis* is significantly associated with increases in ambient air temperature, possibly because it thrives at temperatures between 30-45 degrees Celsius.(167,168)
- *Salmonellosis* tends to have seasonal peaks in June and July driven not by precipitation, but by warmer ambient temperatures.(167) Salmonellosis is also associated with barbequing and gardening before disease onset. (167,169)
- *Cryptosporidiosis* risk increases with heavy rain fall, particularly in instances of 30 or more dry days in the 60 days preceding extreme rain.(166,170) This seems to be driven by higher occurrence of *Cryptosporidium* oocytes following rainfall, is consistent with the latency of disease, and may also be influenced by soil compaction during prolonged dry periods which, when followed by heavy precipitation, can facilitate overland runoff into drinking water reservoirs and systems.(160)
- *Gastrointestinal illness associated with VTEC infection* is strongly associated with warmer ambient temperatures that enable rapid growth and increase by as much as 6% for every degree increase in weekly mean temperature above 0 degrees Celsius.(167) It is also more common in the summer when people are more likely to prepare food outdoors.

6.2.1 Climate-sensitive exposure pathways for food- and water-borne illnesses

The types of enteric illnesses described above can be acquired from both water and food sources. This chapter section identifies key climate-related pathways of exposure for commonly reported and acquired enteric diseases of relevance to the study area.

6.2.1.1 Food-borne illness

Food-borne illness stems from consuming contaminated or improperly prepared foods, and is expected to increase under climate change.(163,171) This is principally because warmer temperatures may lead to people spending more time outdoors or attending outdoor events where food may not be prepared with appropriate risk-mitigation practices in place. As per the information above, VTEC reproduce more rapidly with warmer temperatures. Moreover, there are already seasonal patterns to food-borne outbreaks in Canada, which mostly correspond to summer and increased incidence of outdoor cooking (e.g., during barbeques, picnics, or while camping, where cross-contamination during cooking, poor handwashing, and poor-food handling can lead to increased risk of contamination).(167,172)

Increasingly warm summers will continue to pose risks at large outdoor events that distribute food, which, by virtue of being outdoors during warm summer months, may lead to increased risks of food-borne illness. Global-level changes in temperature, precipitation, extreme weather patterns, and ocean warming and acidification will all influence food-borne illness transmission in the future.(163,173) These trends are relevant to the study area insofar as global food supply chains can be altered by climate change in other parts of the world. Indirect effects—such as food spoilage due to power outages driven by extreme weather causing power outages—may also pose risks to food-borne illness.(174,175) However, there is not enough Canadian evidence to understand the precise impact of climate change impacts on the burden of food-borne disease.



6.2.1.2 Food security

Climate change has been implicated in rising food prices in Canada over the past seven years, and given that economic access to food is a primary measure of food insecurity in Canada, it connects with the broader issue of poverty across the study area.(176) A full assessment of community food security for the study area is beyond the scope of this report. However, it should be noted that food insecurity is strongly related to nutritional deficiency and the risk of chronic conditions. Climate change will impact the nutritional value of global food supplies, with implications for the social value and impact on the environment.(177,178) The mechanism for these trends is still unclear, but there is a clear association between rising concentrations of carbon dioxide and reductions in zinc, protein, iron, and key vitamins in wheat, rice and other staple legumes.(178,179) Canada does fortify some of these staple crops; however, it is uncertain what impact there will be on nutritional concentrations for these staple crops in Canada, but fortification of vitamins and minerals may be a key adaptive practice moving forward.



The study area is home to a vibrant agriculture industry, and therefore, food security is not only a household issue for the study area, but one of strategic concern for the long-term sustainable development of agricultural industries, and overall community resilience.(180) A comprehensive assessment of local food supply and international supply chains (where most people acquire groceries) may therefore be warranted under different climate change scenarios. While it is expected that growing season length will increase under future climate change, it may also be exposed to an increase in severe drought, precipitation events and/or invasive species and pests which may need to be treated with herbicides and pesticides and have their own health implications.(4) Future analysis of food security should seek to take a systems-based perspective on climate drivers, impacts (e.g., on water availability and quality), and their interface with agricultural requirements and outputs in relation to human health.(181)



At the household level, a common metric of food availability is the Nutritious Food Basket (NFB)—a consumer-oriented survey assessment tool that approximates the cost of 60 nutritious foods across various age and sex/gender groups. As per Table 21 below, in 2018 the cost of the NFB in Wellington-Dufferin-Guelph for a reference family of four was \$210.09 per week, representing an increase of 27% since 2009. It is estimated that approximately 14% of the Wellington-Dufferin-Guelph population experiences some degree of food insecurity (5% marginally food insecure, 6% moderately food insecure, and 3% extremely food insecure). The cost of the NFB in Waterloo Region during 2019 for a reference family of four was \$218.98, representing a 4.9% increase relative to 2017, and a more than 30% increase since 2009.(182) For purposes of comparison, approximately 12% of Ontarians experience food insecurity (3% marginal, 6% moderate, 4% extreme).(183)

Table 21. Key measures of food insecurity, Wellington-Dufferin-Guelph and Waterloo Region

Food Security Measures	Wellington-Dufferin-Guelph	Waterloo Region
Cost of Nutritious Food Basket (NFB) – Family of 4	\$210.09 (2018) (27% increase since 2009)	\$218.98 (2019) (30% increase since 2009)
% of Population Who Are:		
Marginally Food Insecure	5% (2018)	N.D.
Moderately Food Insecure	6% (2018)	4.6% (2014)
Extremely Food Insecure	3% (2018)	2.3% (2014)

Source: Nutritious Food Basket for WDG 2018 [Internet]. WDG Public Health. [cited 2020 Aug 7]. Available from: <https://www.wdgppublichealth.ca/nutritious-food-basket-wdg-2018>; and Affordable Food [Internet]. 2020 [cited 2020 Aug 7]. Available from: <https://www.regionofwaterloo.ca/en/living-here/affordable-food.aspx>

6.2.1.3 Water-borne illness

Increases in precipitation can pose threats to drinking water sources by overwhelming storm- and/or wastewater infrastructure.(184) Most of the above referenced risks of water-borne illnesses are driven by extreme rainfall events following extended periods of dry weather.(160,164,166) Moreover, a review of water-borne outbreaks in Canada between 1974-2001 found disease outbreaks were mainly attributed to impacts on surface water quality due to severe weather, proximity to livestock, treatment system malfunctions, and/or poor maintenance and treatment practices.(185)

6.2.1.4 Small drinking water systems and private wells

A relatively high proportion (up to 75%) of water-borne disease outbreaks in Canada occur in small drinking water systems supplying populations of 5,000 people or less, or private wells, and typically result from a lack of source water protection or inadequate treatment, particularly for areas with high precipitation, turbidity, run-off and flood



risk.(186) Between 1974 and 2001, two-thirds of water-borne outbreaks in Canada occurred in private or semi-private systems (e.g., small drinking water systems), with *Campylobacter spp.*, *Cryptosporidium spp.*, *Giardia spp.*, and *E. coli* O157 being responsible for 58% of these outbreaks.(187) An analysis of drinking water-related outbreaks in the United Kingdom, United States, and Canada found that water system size and treatment type drive most of the differences in outbreak frequency, cases of illness, and attack rate.(31) Private wells typically have increased disease burden and likelihood of outbreak relative to larger and more heavily regulated large municipal drinking water systems.(188)

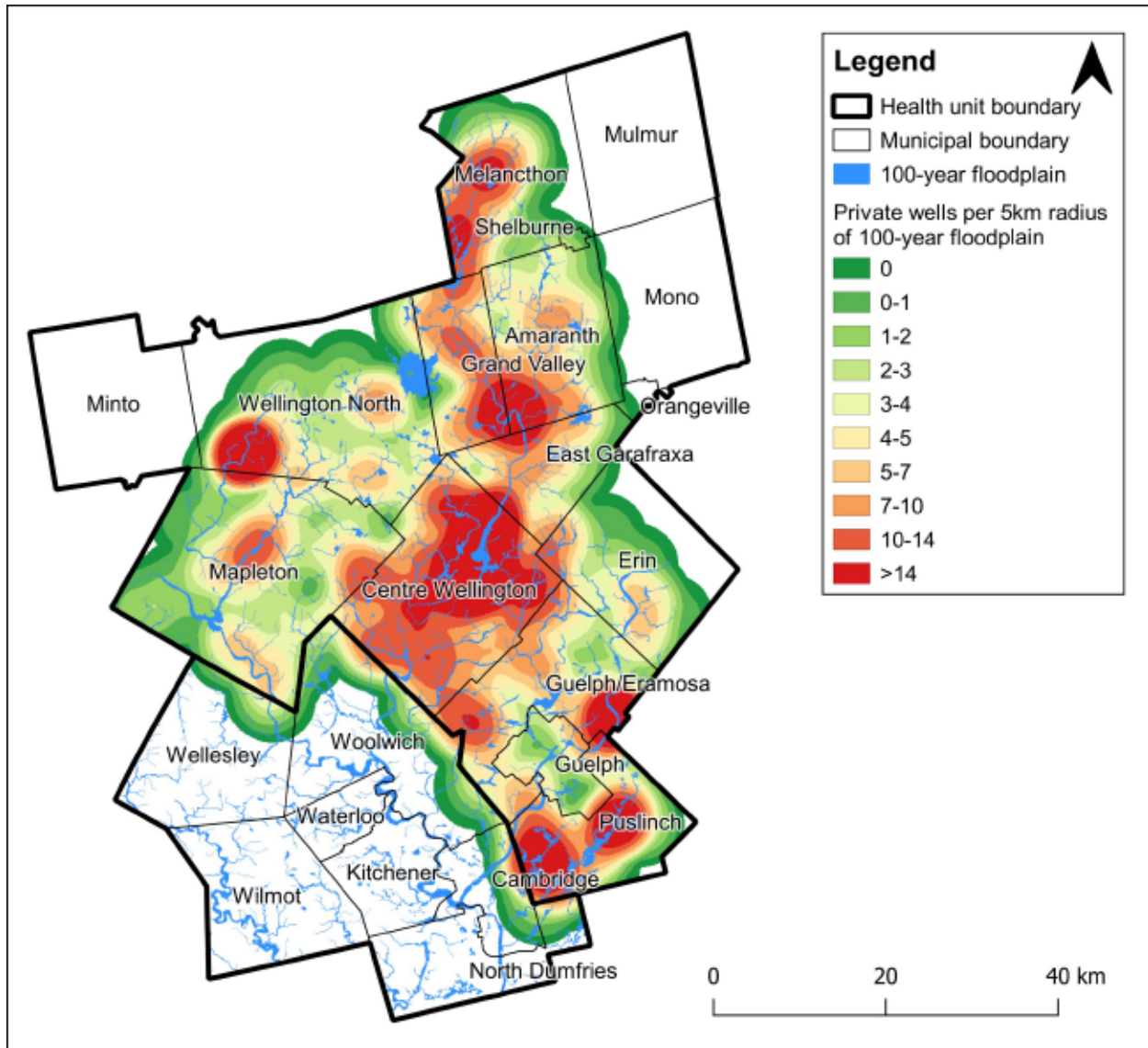


Drinking water that is made available to the public (non-residential) but not provided by the municipal supply is considered a small drinking water system. These systems are generally used by rural facilities such as restaurants, community centres, golf courses, resorts, seasonal trailer parks, and churches. Wells are the most common source for small drinking water systems.

Private wells across the study area (see Figures 27 and 28) are able to be displayed spatially in terms of their density and location relative to the 100-year flood plain of the Grand River. Given that the Grand River covers the majority of the study area, and the challenges associated with gaining access to flood plain data for all conservation areas, only density in relation to the Grand River flood plain is displayed. Findings demonstrate that Centre Wellington, Puslinch, the southwest region of Wellington North, southern Grand Valley and Amaranth, central and southwest Melancthon and the southeastern area of Guelph/Eramosa are higher risk areas for flood water contamination of wells in Wellington-Dufferin-Guelph. Similarly, Waterloo, Kitchener, and Cambridge have the highest risk of flood water contamination of wells in Waterloo Region. More research is required to adequately map the floodplains of other watersheds in the study area to adequately project flood risk. Additional areas identified by workshop participants as experiencing significant flooding impacts historically, that fell outside of the areas mapped in floodplain analyses, include Minto (Harriston) and Hockley Valley in Mono.



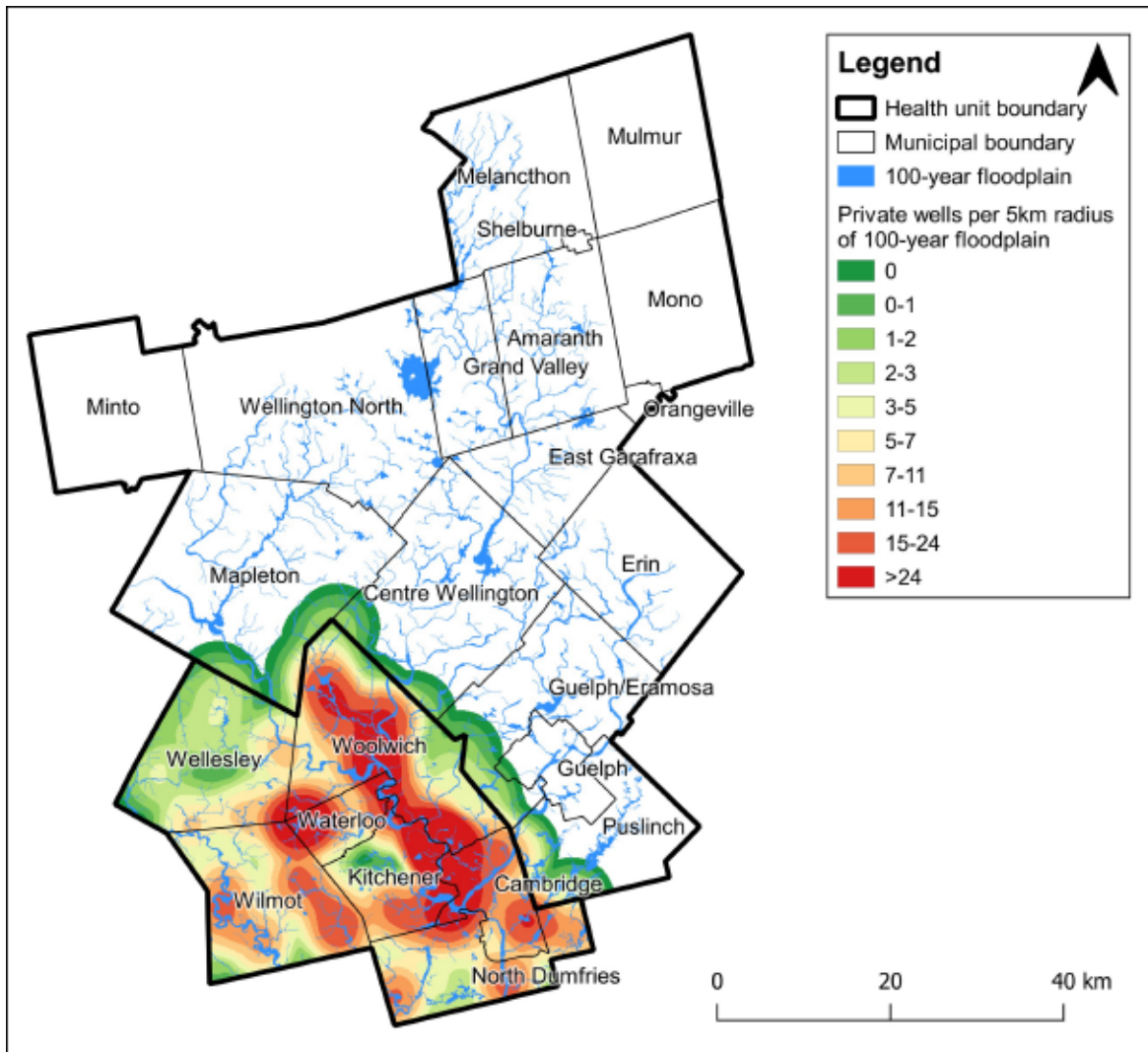
Figure 27. Private well density (number of wells per 5km radius) within 100-year floodplain of the Grand River, Wellington-Dufferin-Guelph



Source: WDGPH Private Water Well Information System, complete civic address dataset subsetting out all addresses listed as having a private well. Regulatory floodplain (100-year flood): <https://data.grandriver.ca/downloads-geospatial.html>



Figure 28. Private well density (number of wells per 5km radius) within 100-year floodplain of the Grand River, Waterloo Region



Source: Well data (provincial water well information system) sub-setting out only addresses on private wells (<https://data.ontario.ca/dataset/well-records>). Regulatory floodplain (100-year flood): <https://data.grandriver.ca/downloads-geospatial.html>

6.2.2 Water security

A comprehensive assessment of ground and surface level water availability is beyond the scope of this assessment. However, climate change is expected to alter precipitation patterns and water flows and increase risk of drought which may impact future seasonal resource availability.(133)

6.2.3 Recreational water contamination and harmful algal blooms

Recreational water users, but particularly children who frequent recreational areas may be at increased risk of



water-borne pathogens after heavy rainfalls. Additionally, climate change is expected to increase the incidence of harmful algal blooms across Ontario.(161,189) Blue-green algae, also referred to as cyanobacteria, occur naturally in freshwater sources such as streams, lakes and rivers. While not typically visible, algae can multiply under appropriate conditions to form a large mass referred to as a 'bloom'. Blooms typically occur in the late summer and fall, and tend to occur repeatedly in the same water bodies.(161) Not all blue-green algae blooms are capable of producing toxins, but some can be harmful to human and pet health through direct skin contact, drinking untreated water, eating a fish caught in blue-green algae contaminated water, and/or inhaling mist of the algae cells or toxins while participating in physical activity or showering. Exposure can cause itchy skin and eyes, headaches, nausea, vomiting, and abdominal pain. Children under the age of six are most at risk of developing health problems associated with cyanobacteria. (190) Beach contamination can result from extreme precipitation events, which correspond to high bacteria counts linked to ear, nose, and throat infections which may result in beach closures.(184) For the Great Lakes region, contamination events typically occur when daily rainfall exceeds a threshold of five to six centimetres.(191)

The study area is home to a number of parks with sandy beaches on reservoirs and quarries. Water quality is tested and updates are posted on conservation authority beach conditions webpages, although testing for the microcystin toxin –the harmful element in blue-green algae–only occurs during the visual presence of algae.

6.3 Baseline Population Health Characterization for Food- and Water-borne Illnesses

Extreme weather events, as described in Chapter 5, may pose risks to both private and municipal drinking water sources if flood waters or severe storm runoff impact drinking water sources, as demonstrated by the Walkerton tragedy.(138) Flood waters can increase risks of water- and food-borne contamination through the transmission of *E. coli* and other harmful bacteria.

Municipal water systems in both Health Unit jurisdictions have extensive testing to ensure safe drinking water for residents and clear protocols on advising the public if Adverse Water Quality Incidents occur. Private well owners are at a higher risk of private well contamination due to flooding as private well owners are responsible for testing their own water to ensure its safety. Public Health recommends that private residential drinking water wells are tested at least three times per year for bacterial contamination. Public Health also provides specific messaging for private residential well owners to take extra precautions after a flood, and to test private well water to ensure it is safe to drink.

Lab data is available for wells tested in the study area in the past five years to establish a baseline for potential changes in bacterial contamination (see Table 22). A recent research study led by WDGPH found that between May 1, 2018 and April 30, 2019, 11.7% of 820 respondents tested their well water three or more times a year, and that 68.3% reported not testing their well water at least once a year.(192) However, it should be noted that multiple samples are often submitted for the same well. Consequently, a closer analysis of samples submitted in the Wellington-Dufferin-Guelph area indicated that in 2018, of the wells that were tested, 21% showed evidence of bacterial contamination. Moreover, the wells that were sampled only represented 10% of the wells in Wellington-Dufferin-Guelph. This suggests that testing rates are low and contamination rates may be significant. Future research should analyze time series data to determine if outbreaks due to private well water contamination follow extreme weather events.



Table 22. Bacterial lab analysis of all submitted samples from private drinking wells between 2015-2019, Wellington-Dufferin-Guelph and Waterloo Region

Water Sampling Result Classification*	Wellington-Dufferin-Guelph Count (% of all submitted samples) [†]	Waterloo Region Count (% of all submitted samples)
No significant evidence of bacterial contamination (5 or less colony forming units per 100mL)	20,568 (80.4%)	7,229 (75.8%)
Significant evidence of bacterial contamination (more than 5 colony forming units per 100mL)	2,592 (10.1%)	946 (9.9%)
Unsafe to drink	152 (0.6%)	221 (2.3%)
Total number of water samples submitted	24,914	9,531

Source: Hedgehog database, WDGPH and ROWPH

*For additional details on water sampling result classification, see <https://www.publichealthontario.ca/en/laboratory-services/well-water-testing?tab=4>

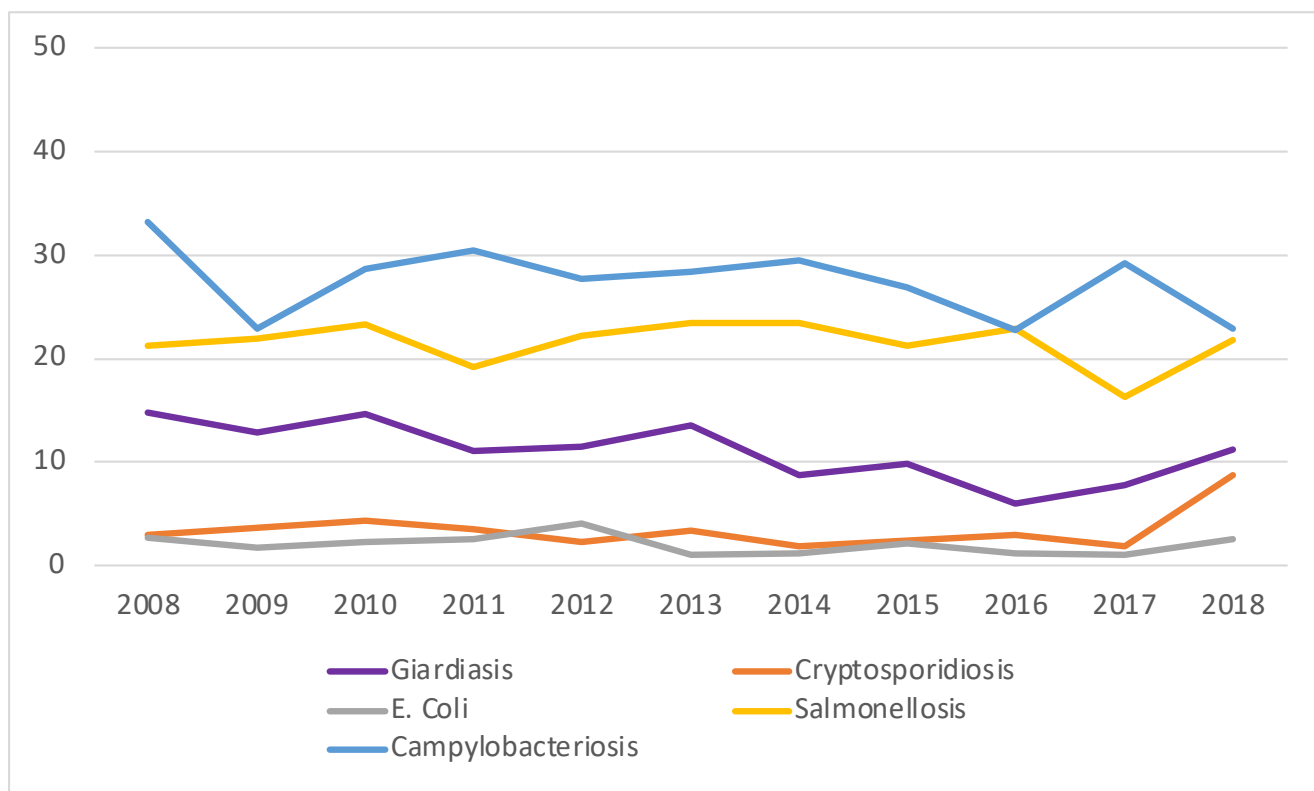
[†] For additional information from the WDGPH Well Water Research Project and Program, see <https://wdgpublichealth.ca/board-health/board-health-meetings/october-2-2019-agenda/bh01oct0219r19-well-water-research-project>



Key climate-sensitive enteric illnesses of relevance to the study region are displayed in Figures 29 and 30. In general, food- and water-borne illnesses across Waterloo Region have exhibited little variation, and in some cases a decreasing trend between 2008-2018. Despite these consistencies, Waterloo Region did experience a small, but statistically insignificant increase in the incidence of Cryptosporidiosis between 2017-2018.

Wellington-Dufferin-Guelph also experiences little historical variation across most food- and water-borne illnesses, notwithstanding the increase in incidence of Cryptosporidiosis between 2017-2018. With the exception of *E. Coli*, Wellington-Dufferin-Guelph tends to have higher rates of food- and water-borne illnesses when compared with Waterloo Region.

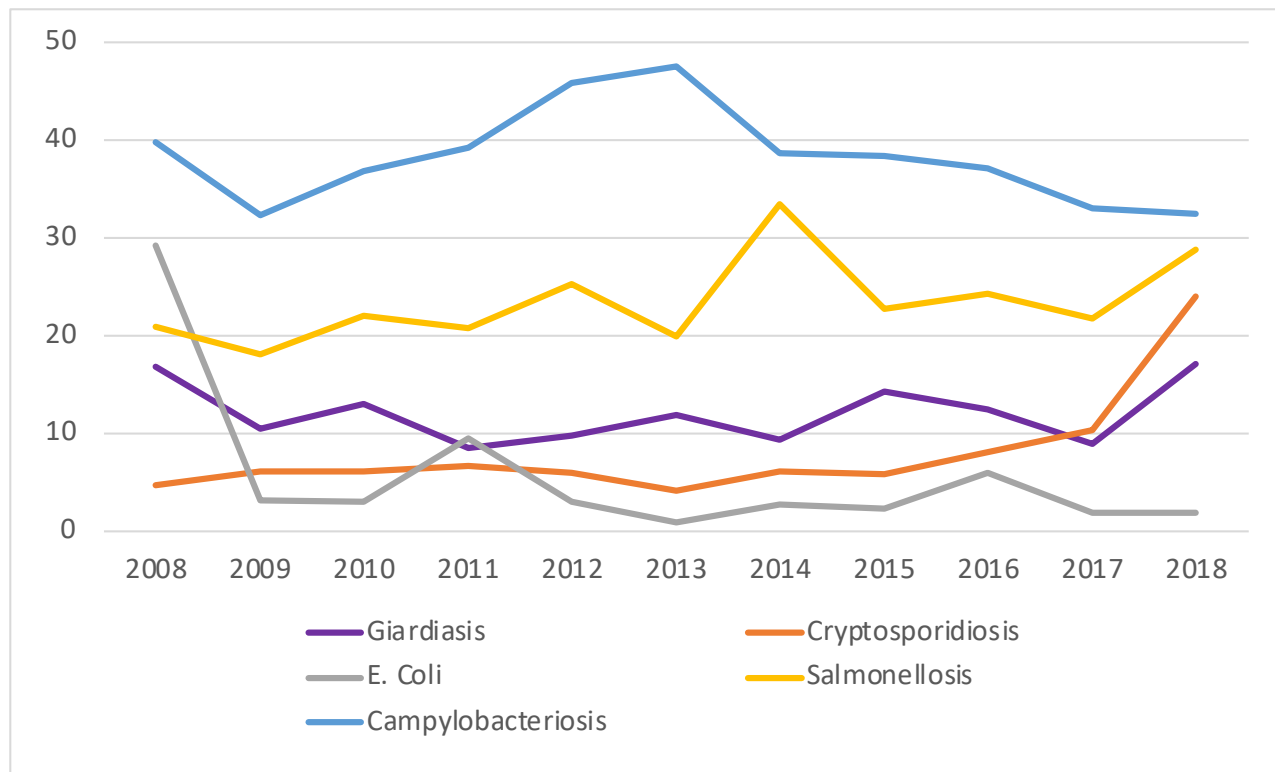
Figure 29. Age-standardized rates of enteric illnesses (per 100,000 people), Waterloo Region, 2008-2018



Source: iPHIS, extracted November, 1 2020



Figure 30. Age-standardized rates of enteric illnesses (per 100,000 people), Wellington-Dufferin-Guelph, 2008-2018



Source: iPHIS, extracted November, 1 2020

6.4 Populations Vulnerable to Food- and Water-borne illnesses

Different population groups have varying levels of vulnerability to food- and water-borne illnesses. These risks are modified based on their exposures, physiological sensitivities, and ability to adapt to changing environmental conditions, as outlined below. Key sub-populations and exposure pathways are characterized below, with demographics for each group in Table 23.

Table 23. Key population health vulnerabilities to food- and water-borne illness in Waterloo Region and Wellington-Dufferin-Guelph, 2016

	Proportion of Total Population, 2016		
	Wellington-Dufferin-Guelph	Waterloo Region	Ontario
Children aged < 5	5.7%	17.8%	5.2%
Adults aged 65+	15.8%	14.4%	16.7%



	Proportion of Total Population, 2016		
	Wellington-Dufferin-Guelph	Waterloo Region	Ontario
Young adults (aged 15-24)	13.3%	13.7%	12.7%
Newcomers (immigrated 2011-2016)	1.6%	2.7%	3.7%
Private wells (estimate)†	30,712	8,000	-

Source: Statistics Canada 2016 Census of Canadian Population

†Private well estimates do not necessarily imply wells are used as a drinking water source

6.4.1 Populations vulnerable to food- and water-borne illnesses due to exposure

People who live in rural areas may be disproportionately at risk if they rely on private wells that may not be adequately treated or regularly inspected/tested. Additionally, people who live in floodplains may also be at greater risk of water-borne illnesses, particularly if they rely on a private well that is impacted by storm water after an extreme weather event (for more information on extreme weather, see Chapter 5). People who are inadequately housed or who do not have equipment for proper food handling and preparation may also be at higher risk of exposure due to an inability to store food safely.

6.4.2 Populations vulnerable to food- and water-borne illnesses due to sensitivity

There are three population groups who are more physiologically sensitive to food- and water-borne illnesses:

- Older adults (aged 65 and older) are at a higher risk of health complications due to the diminished functionality of their immune response, and the fact that older populations are more likely to have chronic conditions;(167)
- Children under the age of five are sensitive to food- and water-borne illnesses as they have developing immune systems and may be more reliant on caregivers to translate risk messaging and engage in protective behaviours such as avoiding potentially contaminated water sources;(167) and
- Individuals with compromised immune systems (e.g., autoimmune disorders) are more susceptible to serious illness due to a suppressed immune response,(193) however data for this population are not regularly reported in Ontario.

6.4.3 Populations vulnerable to food- and water-borne illnesses due to adaptive capacity

Our focus groups with community stakeholders identified that there are a relatively high number of food-borne illness cases among university / post-secondary students. This confers with existing evidence suggesting food safety knowledge and appropriate food safety practices could be improved among university / post-secondary students.(194,195) The number of university-aged individuals for each Health Unit is presented in Table 23.



Participants also identified challenges of communicating risks of enteric disease to newcomers, which is particularly important given Waterloo Region is the second highest receptor site for new immigrants in Ontario after the Greater Toronto Area.

6.4.4 Sex and gender-based vulnerabilities

There is currently limited evidence to suggest that sex and/or gender plays a role in modifying vulnerability to food- and water-borne illnesses in Canada.(196) In the United States, research has shown that males had higher rates of food-borne illness derived from beef, pork, game, dairy and shellfish, and that females were more likely involved in outbreaks stemming from contaminated grains, beans, nuts, seeds, fruits, sprouts and vegetable row crops.(197) However, a recent scoping review of the evidence among Indigenous populations in Canada found that botulism, *E. coli* and hepatitis A are evenly distributed among men and women.(198)

6.5 Programs, Policies, and Related Actions Taken to Improve Adaptive Capacity to Food- and Water-borne Illnesses

6.5.1 Individual actions

As indicated above, individual actions can significantly reduce the risk of food- and water-borne illnesses. Ensuring proper food preparation and avoiding suspected contaminated food and water sources (e.g., during or after power outages) are best practices. This could include ensuring there is adequate sanitation and safe food handling practices at these events or avoiding consumption of food at outdoor events on hot days if it is impossible to know whether foods are safely prepared or stored.

For individuals on private well water supply systems, proper maintenance and regular testing is strongly encouraged. Small drinking water systems are routinely inspected by public health officials, but private wells are not. Finally, because enteric diseases are believed to be underreported,(162) suspected cases of food- and/or water-borne illness should be communicated to public health units to enable more accurate surveillance and monitoring.

6.5.2 Public Health actions

Public Health takes numerous actions to protect the population from enteric illnesses through population health assessment, surveillance, health promotion, and health protection (see Table 24), with additional information provided below.



Table 24. Key Public Health activities that build adaptive capacity for the health risks of enteric illnesses associated with climate change

Public Health Role	Activities
Population Assessment and Surveillance	<ul style="list-style-type: none"> • Disease and outbreak case investigation. • Characterization of populations vulnerable to enteric illness. • Monitoring costs of healthy eating (Nutritious Food Basket). • Monitoring incidence of food- and water-borne illnesses. • Investigations of enteric disease, including most likely exposure source. • Collaborating with regional and municipal partners to ensure appropriate inspection of drinking water systems. • WDGPH conducted a survey of private well owners to collect data on well characteristics and well owner attitudes towards water safety and testing. The health Unit has also been analyzing well water testing results to assess local testing rates and well contamination rates.
Health Promotion (including education, advocacy and policy development)	<ul style="list-style-type: none"> • Supporting safe food handler training. • Providing support and funding for peer programs, such as those delivering food skills training for people living with low income and newcomers. • Support creation of community and school gardens to create access to locally grown food. • Review official and other master plans – policy statements regarding local food systems, protection of agricultural land. • Providing educational resources through websites and social media on known health risks for enteric illness.
Health Protection (disease prevention)	<ul style="list-style-type: none"> • Conducting food safety inspections – premises and special events. • Inspection and monitoring of small drinking water systems. • Issuing boil water advisories. • Coordinating collection of private well water samples. • Investigating Adverse Water Quality Incidents.



Food safety protocols are mandated by the Ontario Public Health Standards. Regular inspections occur at the federal, provincial, and local level to assist in identifying risks of disease transmission and administering appropriate preventative protocols. Adequate consideration of the production, processing, distribution and preparation/ consumption of foods should be carefully considered in relation to the availability, accessibility and usability of food resources.(199) Public Health provides inspection oversight of small drinking water systems under Ontario Regulation 319/08. Public Health also inspects these systems every two to four years, based on risk level, to ensure compliance with the regulations and standards. Evidence is currently limited in the Canadian context for risks posed to livestock from zoonoses and/or heat stress, and new surveillance programs are emerging to provide better research.(200)





6.5.3 Actions led by community partners

There are a number of policies and infrastructure that support access to clean and reliable sources of food and water across the study area. These include, but are not limited to:

- Mandatory annual reporting on drinking water and wastewater treatment under *O. Reg 170* and *O. Reg 319*.
- The Province of Ontario revamped the Clean Drinking Water Act after the Walkerton crisis where *E. Coli* and *Campylobacter* contaminated water supplies sickening more than 2000 people and resulting in six deaths. The Ontario Clean Water Agency now assists with the operations, maintenance, and management of services for more than 450 water and wastewater treatment facilities across the province.
- Source water protection committees and risk management officials administer and enforce policies under local source water protection plans under the Clean Water Act.
- The GRCA and other conservation authorities within the study region regularly test and report on water quality for all water sources within the conservation authority boundary (e.g., lakes, rivers, streams, and recreational sites).

6.6 Conclusion

As climate change continues to alter temperature and precipitation patterns across the study area, these changes will impact the growth and survival of food- and water-borne pathogens while also impacting food and water security. However, it is difficult to determine with great certainty the impact that climate change will have on these issues in the future, and more information is required to understand future transmission pathways relative to known exposure patterns at present.

Most food- and water-borne illnesses that occur in Ontario are strongly associated with seasonality, peaking in the summer months or early fall.⁽¹⁵⁴⁾ As climate change increases the time spent outdoors, lengthens the season for outdoor events and recreational water use, and increases flood risks, it stands to reason that there may be possibilities for increased disease transmission and localized outbreaks. Private wells and small drinking water systems are likely at greatest risk to potential contamination during precipitation and flooding events under a changing climate, and changing flood patterns may also impact public drinking water treatment facilities. Data is currently limited for how climate change will impact local food and water security, leading to uncertainty in the potential magnitude of local health risks in the future.

Each Public Health Unit takes a comprehensive approach to water and food safety in line with existing provincial mandates and regulations. Increasing efforts to encourage the public to better report food and water-related illness may support more adequate accounting of population-level risks in the future. Horizon scanning activities to anticipate new and emerging threats not currently accounted for in existing surveillance, enhancing risk communication and well water testing, and integrating climate data into disease and outbreak investigation will provide additional information to enable Public Health staff to respond under future climate change.

7.0 Air Quality





7.0 Air Quality: Key Findings

Climate change projections

- Globally, concentrations of PM_{2.5} (particulate matter that is 2.5 microns or less) are expected to increase marginally by 0.43µg/m³ under RCP8.5. Similar projections forecast increases of <0.2 µg/m³ over much of North America, although these concentrations may be modified by increases in episodic wildfires.
- Ozone concentrations are expected to increase across southwestern Ontario by up to four to five parts per billion by volume by 2050 when anthropogenic emissions are kept constant.
- Warming will likely produce an increase in moderate to high-risk air quality days with smog episodes for urban areas with dense transportation networks, leading to more Special Air Quality Statements (SAQS) or Smog and Air Health Advisories (SAHA) issued by Environment and Climate Change Canada (ECCC), accompanied by increasing health impacts and rising healthcare costs.
- Warming will lead to earlier onset of the pollen season with implications for seasonal allergies, with ragweed season becoming longer.

Population-level exposure

- Outdoor workers may have greater exposure to ambient air pollution while on the job (10.8% of the Wellington-Dufferin-Guelph population and 8.0% of the Waterloo Region population work in construction and/or agricultural industries).
- Other populations that may experience greater exposure include those that commute in cars to and from the Greater Toronto Area.
- Evidence suggests that active transportation commuters may experience higher doses of pollution along busy roadways, but there appears to be limited risk for negative effects on lung function while using active transportation relative to utilizing motorized transport.

Population-level sensitivities

- Older adults (aged 65 and older) are at a higher risk of health complications resulting from poor air quality, especially if they have cardiovascular or respiratory conditions.
- Children (under the age of 15) can be negatively impacted by short-term and chronic exposure to air pollution by contributing to early onset of childhood asthma and inhibiting lung function.
- People with pre-existing respiratory conditions (e.g., chronic obstructive pulmonary disease, asthma) and cardiovascular conditions (e.g., heart disease) are more likely to have these existing conditions exacerbated by poor air quality.



Population-level adaptive capacity

- People who have low-income, are unemployed or who have precarious occupational status may have greater exposure to poor indoor and outdoor air quality, as low-income housing is often located near busy roadways or other sources of industrial emissions.

Adaptive actions

- Individuals most at risk, including those who exercise outdoors, children, and seniors, should reduce time spent outdoors during days with higher Air Quality Health Index (AQHI) values (i.e., AQHI of seven or more).
- Public Health's assessment and surveillance actions to address air quality include identifying populations at risk from poor air quality, and monitoring SAQs and SAHAs from ECCC.
- Public Health also participates in health promotion activities, including sharing information about the AQHI, participating in Official Plan and key strategic document reviews on built environment and shade policies, supporting policy development and community engagement on active transportation and vehicle electrification.
- Community actions to address air quality concerns include using tree planting and urban forest strategies to address extreme heat and air pollution, as well as working with Public Health to include air quality considerations in municipal and regional planning activities.

Baseline health impacts

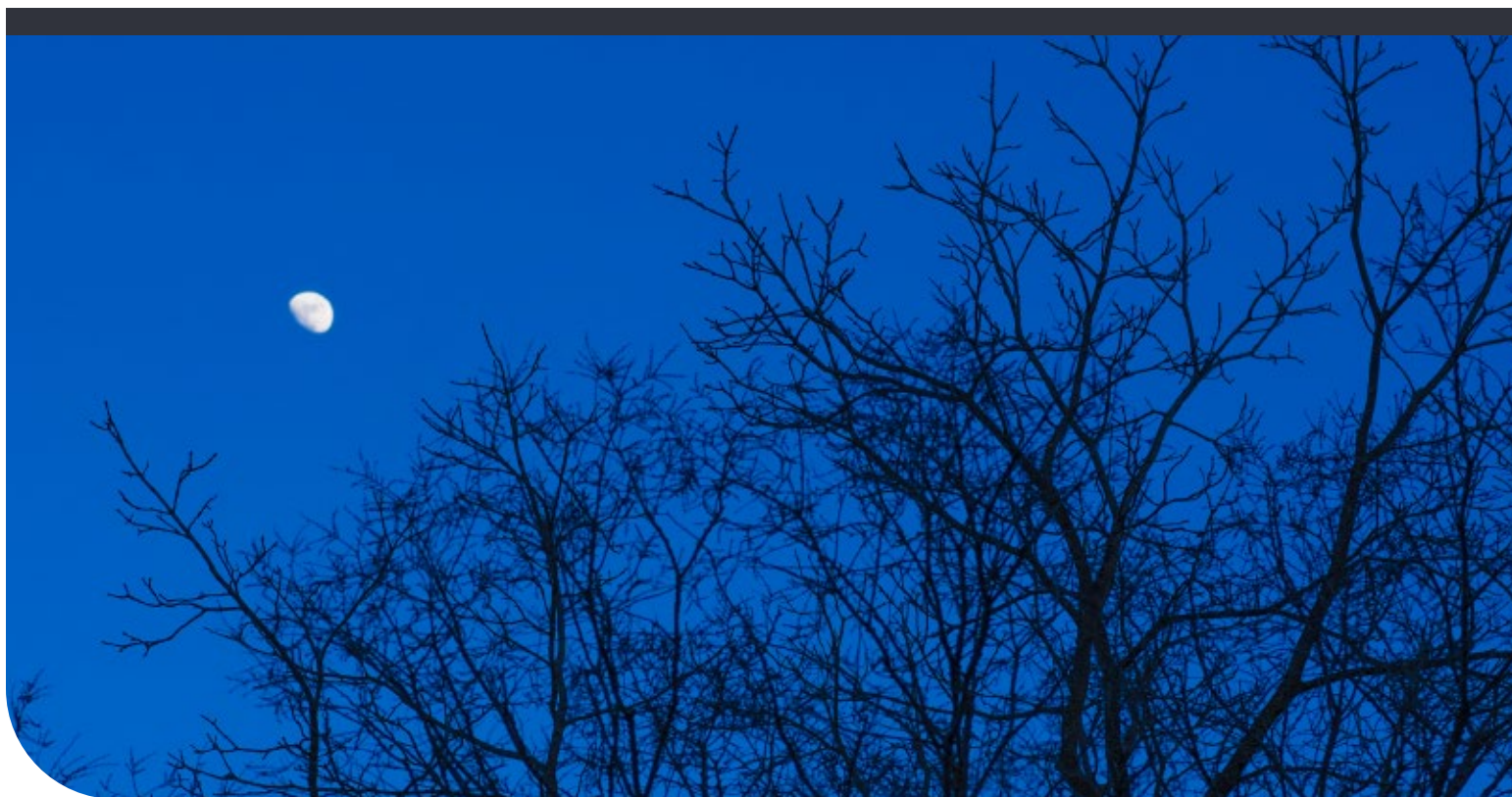
- There are many health outcomes associated with poor air quality such as lower respiratory tract infections, allergic reactions precipitating hay fever, and chronic conditions such as asthma, chronic obstructive pulmonary disorder (COPD), and/or lung cancer.
- According to Health Canada, the annual number of premature deaths associated with air pollution (PM_{2.5}, ozone and nitrogen dioxide) in 2016 was 257 in Waterloo Region and 138 in Wellington-Dufferin-Guelph.
- Emergency department visits for COPD have remained stable across the study area, however Wellington-Dufferin-Guelph has twice the rates of emergency department visits than Waterloo Region at baseline.
- Emergency department visit rates for asthma been consistently falling over the past 10 years and are generally higher for Wellington-Dufferin-Guelph relative to Waterloo Region.
- Emergency department visits due to allergy to pollen are typically less than 2 per 100,000 people per year across the study area, although since pollen is also a trigger for asthma symptoms, this figure may under-represent the true burden of illness.



7.0 Air Quality

Air pollution is a globally recognized cause of premature mortality from heart disease, stroke, and lung cancer, and represents the greatest environmental risk to health as the fifth leading mortality health risk in the world.(202,203) The government of Canada estimates that air pollution from fine particulate matter (PM), nitrogen dioxide (NO₂) and ozone (O₃) is responsible for as many as 15,300 deaths a year.(204)

Climate change is already altering human exposure to air pollution with associated impacts to respiratory health, cardiovascular health, and other adverse health conditions for Canadians.(7,205) Air pollution in the study area has a number of sources including, but not limited to: transportation, burning of fossil fuels for electricity and heating, industrial activities, and transboundary air flows (e.g., from industrialized areas of the United States Midwest and/or particulate matter from wildfires in northern Ontario). Ontario's air quality monitoring infrastructure includes 39 stationary monitoring sites—two of which are located within the study area in central Kitchener and central Guelph. Between 2007-2016, trends in ambient concentrations of climate sensitive pollutants such as nitrogen dioxide, sulfur dioxide, and PM_{2.5} (particulate matter that is 2.5 microns or less) are been decreasing, while ozone has increased approximately 1%.(206) A separate study found that between 1990-2014, emissions for sulfur dioxide and nitrogen oxides were reduced by 63% and 33% across the eastern United States and Canada, including the study area.(207)



While reductions in air pollutants are largely attributable to Ontario's air quality initiatives—including a phase out of coal-fired generating stations and requirements for air quality exceedances outlined in this chapter—the study area



still faces challenges associated with poor air quality at times, and these risks are expected to be exacerbated under a changing climate. The study area has historically experienced some of the highest levels of ground level ozone, fine particulate matter, and toxic air pollutants in all of eastern Canada, driven primarily by historical manufacturing and traffic-related air pollution, (208) although improvements to all climate-sensitive air pollutants have been seen across the study area over the past decade.(207) Notwithstanding these reductions in air pollution concentrations, air quality still poses health risks to residents located within the study area. Moreover, there is robust evidence that even at low concentrations, the air pollutants described in this chapter pose health risks, and “any incremental increase in air pollutant concentration is associated with an increased risk of adverse health outcomes.”(204)

At the time of this assessment, the study area had two stationary air quality monitors located in central Kitchener and central Guelph (a growing population where a high percentage of people commute to or from its many municipalities). Additional risks with the geography of southwestern Ontario are also present, particularly for transboundary air pollution from the northeastern United States carried by the Gulf Stream. Analysis suggests that Ontario communities can be subject to poor air quality days due to weather and geography-oriented interactions at any time of year.(209) Air quality data with high spatial resolution are important for understanding differences in local air quality to inform Public Health decisions.(210) This chapter resolves the need for greater spatial resolution and overreliance on stationary monitoring stations by providing an array of satellite data and health information to create a baseline for air quality and health across the study area, discusses the implications of future climate change, and delineates actions and activities that are both underway or which could be implemented to bolster adaptive capacity to changing air quality under future climate change.

7.1 Population Baseline Exposure to Air Pollutants

Human populations are exposed to pollutants in both indoor and outdoor air. Recent research suggests that even short-term exposure to air pollution driven by $PM_{2.5}$, nitrogen dioxide, ozone, and sulfur dioxide can increase emergency department visits for upper and lower respiratory infections, particularly among people with pre-existing respiratory conditions (e.g., asthma, chronic obstructive pulmonary disorder (COPD)), even in places with relatively low concentrations of these compounds (see below in this chapter for descriptions of each pollutant).(211) Further, Canada’s burden of disease from air pollution is a considerable concern, particularly as it relates to cardiovascular health.(204) Climate change is anticipated to increase concentration of air pollutants through several pathways, including the modification of ventilation and dilution patterns of air pollutants, photochemical reaction rates, removal processes, stratosphere-troposphere exchange of ozone, wildfires, and natural biogenic and lightning emissions. (212,213)

The two air quality monitoring stations located in the study area routinely collect information on a number of air pollutants. Environment and Climate Change Canada use local air quality concentration data to issue special air quality statements (SAQS) and smog and air health advisories (SAHA). SAQs and SAHAs replaced previous air quality alert guidelines in 2015. Alerts are now dependent on the value of the Air Quality Health Index—a scale designed to help people understand the health risks of air quality in local environments ranked on a scale of 1 to 10 or greater. SAQS are triggered when AQHI values are 7 or greater for one to two hours. SAHAs are issued at AQHI levels of 7 or greater, for persistent events lasting three or more hours in length.(214)



Table 25 indicates that the number of air quality advisories and affected days is relatively low, suggesting that these alerts are currently rare for the study area. However, SAQs and SAHAs are only issued when air quality is considered 'high-risk' and are not meant to characterize the quality of air across the study area. For example, even AQHI ratings of 4-6 are considered 'moderate risk' by Health Canada, which recommends people reduce strenuous outdoor activities, particularly for people with heart or breathing problems. However, even background exposure to low levels of air pollutants can result in poor health outcomes. Indeed, despite the relatively low occurrence of SAQs and SAHAs recorded by each monitoring station, Health Canada estimates that in 2016 across the study area there were 88,000 asthma symptom person-days (i.e., the estimated number of person-days where asthma symptoms could reasonably be expected in a given calendar year), one million acute respiratory symptom person-days, and 1,300 child acute bronchitis person-days associated with exposure to air pollution.(204) The remainder of this section describes climate sensitive air pollution pathways and baseline exposure data for a variety of air pollutants

Table 25. SAQS and SAHA advisories for Wellington-Dufferin-Guelph and Waterloo Region, 2010-2019

Year	Kitchener Station		Guelph Station	
	# of Advisories/Alerts	# of Affected Hours	# of Advisories/Alerts	# of Affected Hours
2015	0	0	1	2 hours
2016	1	6 hours	0	0
2017	0	0	0	0
2018	2	12 hours each	0	0
2019	0	0	0	0
2020	0	0	0	0

Source: Data is based on hourly AQHI readings extracted from Air Quality Ontario, Ministry of Environment, Conservation and Parks, <http://www.airqualityontario.com/aqhi/search.php>

7.1.1 Particulate matter

Particulate matter (PM) is a complex mixture of solid and liquid particles suspended in the air. The size, chemical composition, and other physical and biological properties of particles vary with location and time but are typically small enough to be breathed into human lungs.(215,216) Particulate matter can be composed of organic and inorganic matter, and can range from 0.005 to 100 microns in diameter. Particulate matter that is 2.5 microns or less in diameter is referred to as PM_{2.5}, and 10 microns or less is referred to as PM₁₀. PM_{2.5} is a regularly monitored air pollutant and is a known carcinogen that contributes to lung cancer.(217) Both short and long-term exposure to PM_{2.5}



increases the risk of respiratory and cardiovascular morbidity and mortality.(218) $PM_{2.5}$ has health impacts even at very low concentrations and no threshold has been identified below which no impact is observed.(219)

The largest sources of emissions of $PM_{2.5}$ in Ontario are dust (e.g., from road traffic), wildfires, and wood-burning stoves for heating and cooking.(220) Southwestern Ontario typically sees the highest rates of $PM_{2.5}$ in the summer.(221) In Ontario, Ambient Air Quality Criteria (AAQC)¹⁰ stipulate that $PM_{2.5}$ should not exceed $27\mu\text{g}/\text{m}^3$ in a 24-hour period, and that average annual ambient $PM_{2.5}$ concentrations should not exceed $8.8\mu\text{g}/\text{m}^3$.

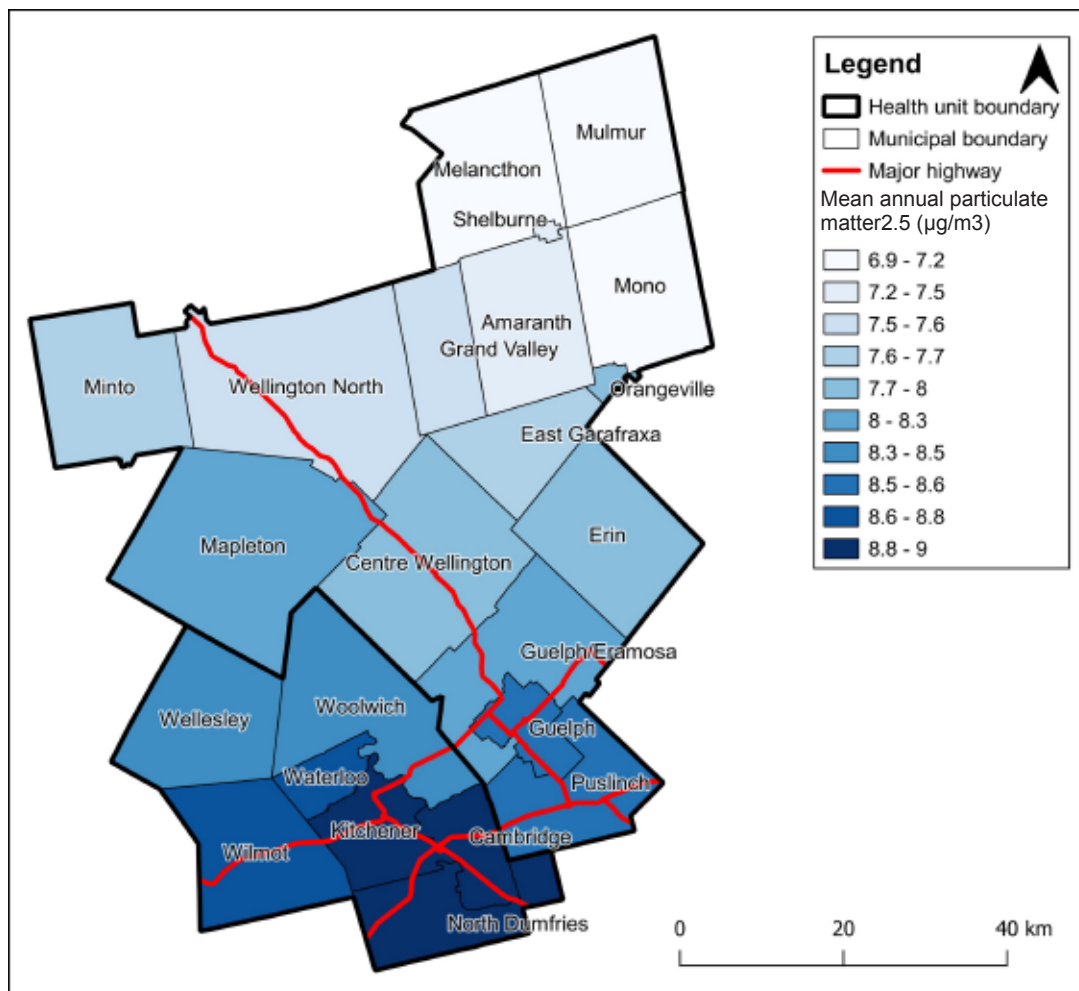
Figure 31 displays a three-year moving average for $PM_{2.5}$ levels across the census sub-divisions of the study area using satellite observations. A multi-year average is typically used to overcome challenges associated with potential outlying years of poor air quality. Average annual $PM_{2.5}$ levels are highest in the more urbanized southern municipalities of the study area. This confers with provincial evidence suggesting urban area residents are more likely to develop asthma or visit physicians or emergency departments for exposure to $PM_{2.5}$.(222)



¹⁰ All Ontario Ambient Air Quality Criteria are available: <https://www.ontario.ca/page/ontarios-ambient-air-quality-criteria>



Figure 31. Average annual $PM_{2.5}$ (3-year moving average) for Waterloo Region and Wellington-Dufferin-Guelph, 2010-2012



Source: Data extracted from: van Donkelaar, A., R. V. Martin, M. Brauer, N. C. Hsu, R. A. Kahn, R. C. Levy, A. Lyapustin, A. M. Sayer, and D. M. Winker. 2018. Global Annual $PM_{2.5}$ Grids from MODIS, MISR and SeaWiFS Aerosol Optical Depth (AOD) with GWR, 1998-2016. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). <https://doi.org/10.7927/H4ZK5DQS>.

7.1.1.1 Wildfires

Ontario averaged 855 wildfires a year over the past decade, with most fire activity taking place in the northwest and northeast regions of the province.(223) Wildfires produce a significant amount of particulate matter in the form of microscopic ash.

Southwestern Ontario is considered outside the principal fire regions of the province, and wildfire risks are generally low for the study area.(223) However, transboundary air pollution in the form of particulate ash has been observed throughout southwestern Ontario, and wildfire smoke creates seasonal respiratory risks for Canadians.(224)



For example, in July 2019, smoke from 18 wildfires burning across northern Ontario spread across the southwestern part of the province through prevailing western winds.(135) Appearing as a 'smoky haze', particulate matter exacerbates air quality posing serious health risks to vulnerable populations including children, pregnant women, the elderly, people with chronic lung or heart conditions, and people involved in strenuous outdoor activities.(225,226)

7.1.2 Ground-level ozone

Ground-level ozone (O_3) is a colorless gas that is highly irritable to respiratory tracts. It forms just above the earth's surface as nitrogen oxides and volatile organic compounds interact with sunlight and stagnant air.(227) There is strong evidence that suggests short-term exposure to ground-level ozone is linked to pre-mature mortality, increases in hospital admissions, and exacerbates asthma symptoms.(228) Speculative and early evidence suggests that long-term exposure may result in slightly elevated risk of death due to cardiovascular and respiratory causes.(229) In Ontario, annual mean ozone concentrations have remained stable across the province (2008-2017),(206,230) although southwestern Ontario consistently has among the highest levels of ground-level ozone in the country.(230)

In southwestern Ontario, ozone tends to be highest between May and September, and typically increases between mid-afternoon and early evening.(227,231) Ozone is regulated under Ontario's AAQCs which stipulate that ozone should not exceed $165 \mu\text{g}/\text{m}^3$ in a one-hour period (approximately 80 ppb), and the eight-hour average standard for ozone is 62ppb.

The most recent satellite evidence (2012) for ground-level ozone suggests that census sub-divisions (i.e., municipal boundaries derived by Statistics Canada) in the north and east of the study area have the highest average annual ozone exposure. This is likely because ozone depletes as it reacts with nitrogen oxides emitted from vehicle traffic and other combustion sources, meaning ozone concentrations tend to be lower in urban areas.(206)

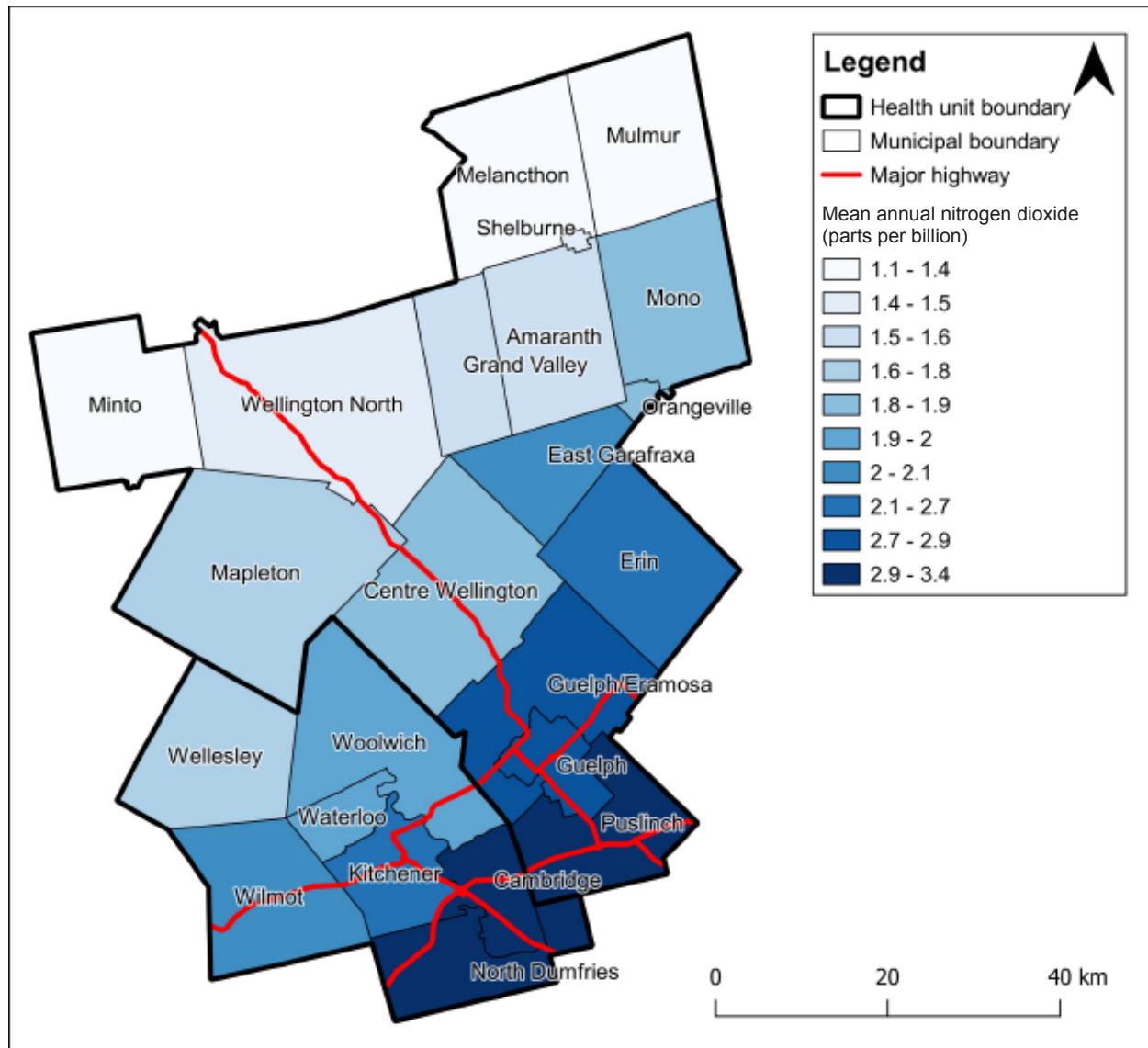
7.1.3 Nitrogen dioxide

Nitrogen dioxide (NO_2) is an air pollutant principally generated through the combustion of fossil fuels, which can interact with other air pollutants to form smog and ground-level ozone. Short-term exposure to nitrogen dioxide can cause irritation of the eyes, skin and respiratory system, aggravate existing respiratory conditions, and create difficulty breathing, and long-term exposure can result in asthma, respiratory infections, and premature mortality. (232–234)

Ontario AAQC for nitrogen dioxide is $200 \mu\text{g}/\text{m}^3$ over a 24-hour period (equivalent to 100 ppb) and $400 \mu\text{g}/\text{m}^3$ over a one-hour period (equivalent to 200 ppb). Results from remote sensing of mean annual nitrogen dioxide concentrations from 2010-2012 across the study area are presented in Figure 32, with higher concentrations occurring in the southern portion of the study area, namely North Dumfries, Cambridge, and Puslinch.



Figure 32. Annual average concentrations (3-year average) of nitrogen dioxide in Waterloo Region and Wellington-Dufferin-Guelph, 2010-2012



Source: Geddes, J.A., R.V. Martin, B.L. Boys, and A. van Donkelaar. 2017. Global 3-Year Running Mean Ground-Level Nitrogen Dioxide (NO₂) Grids from GOME, SCIAMACHY and GOME-2. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). <https://doi.org/10.7927/H4JW8BTT>.



7.1.1.2 Traffic-related air pollution (TRAP)

Traffic-related air pollution (TRAP) includes an array of fine particulate matter, but also carbon monoxide, nitrogen oxides, and volatile organic compounds. Passenger vehicles also emit carbon dioxide which is one of several greenhouse gases that contribute to atmospheric warming. Traffic is the main contributor to air pollution in Ontario, with concentrations of pollutants being higher near and on major roads and highways.(235) Major roadways include several road classes defined in the Ontario Road Network¹¹. These include arterial roads (i.e., a major thoroughfare with medium to large traffic capacity) and expressways (i.e., high-speed thoroughfares with a combination of controlled access and intersections). By contrast, highways refer to unimpeded, high-speed controlled-access thoroughfares for through traffic, typically accessed via a ramp, with typically no intersections, and which typically do not have property access or direct access. Exposure to traffic-related air pollution is typically greatest within 100 metres of a major roadway, or 500 metres of a highway.(20) In Ontario, 28% of residents, 26% of schools, and 48% of long-term care facilities are within this range.(20)



TRAP exposure is estimated to be responsible for approximately 700 premature deaths and over 2,800 annual hospitalizations due to heart and lung conditions in the Greater Toronto Area and Hamilton region per year, resulting in an economic impact of more than \$4.6 billion per year.(236)

¹¹ For more information on the Ontario Road Network and corresponding definitions, see: <https://dr6j45jk9xcmk.cloudfront.net/documents/1866/go-its-29-ontario-road-network-orn.pdf>



TRAP exposure rates for the study area were calculated at the level of census subdivisions (i.e., municipalities), and methods for calculations were derived from [Public Health Ontario's Ontario Health Profile—Technical Appendix](#). Information on the application of this methodology and its associated limitations are presented in Appendix 2. Three different TRAP groups were created by applying varying buffer sizes to each of these datasets. The three TRAP groups were: A) 50 metres from major roads and 50 metres from highways; B) 100 metres from major roads and 150 metres from highways; and C) 100 metres from major roads and 500 metres from highways. TRAP exposure rates were calculated at the census subdivision (CSD) level (which is the same as the municipal level) by dividing the number of people within each TRAP group by the total 2016 population of the CSD.

Results of the analysis are presented in Figure 33 and Table 26. The number of people exposed to TRAP was highly correlated with the population size of each municipality, with the population exposed for each of the three TRAP groups exhibiting a Pearson's correlation test statistic of 0.98. This finding suggests that a strong urban disparity exists in terms of exposure to TRAP, and that more densely populated municipalities tended to contain more major roads and highways than less-densely populated ones. This is evident in the fact that the major cities (Kitchener, Waterloo, Cambridge, Guelph) had among the highest rates of exposure. However, visual comparisons between raw values and rates revealed some outliers. Minto, Grand Valley, Shelburne, Wilmot, and Woolwich were higher than would be proportionate to their raw values, indicating a relatively large proportion of the population in these municipalities living near major roads and highways.

Table 26. Population proportions residing within TRAP buffers by census sub-division, 2016

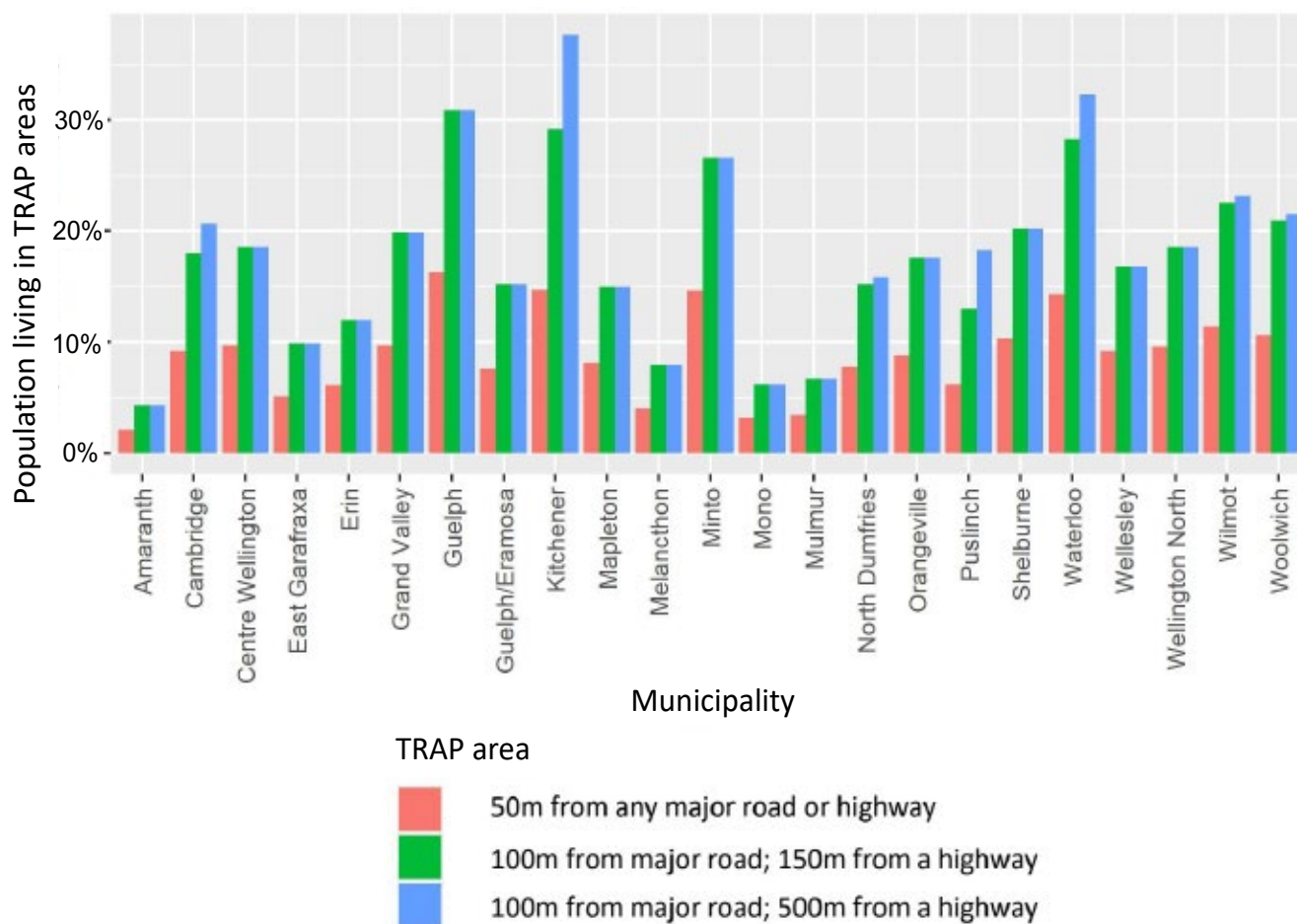
Municipality	2016 Total Population	Buffer A: % of Total Population Living Within 50m of major roads and highways	Buffer B: % of Total Population Living Within 100m of major roads and 150m of highways	Buffer C: % of Total Population Living Within 100m of major roads and 500m from highways
Amaranth	4079	2.1%	4.3%	4.3%
Cambridge	129,920	9.2%	18.0%	20.7%
Centre Wellington	28,191	9.7%	18.6%	18.6%
East Garafraxa	2,579	5.1%	9.9%	9.9%
Erin	11,439	6.1%	12.0%	12.0%
Grand Valley	2,956	9.7%	19.9%	19.9%
Guelph	131,794	16.3%	30.9%	30.9%



Municipality	2016 Total Population	Buffer A: % of Total Population Living Within 50m of major roads and highways	Buffer B: % of Total Population Living Within 100m of major roads and 150m of highways	Buffer C: % of Total Population Living Within 100m of major roads and 500m from highways
Guelph/Eramosa	12,854	7.6%	15.2%	15.2%
Kitchener	233,222	14.7%	29.2%	37.7%
Mapleton	10527	8.1%	15.0%	15.0%
Melancthon	3008	4.0%	7.9%	7.9%
Minto	8671	14.6%	26.6%	26.6%
Mono	8609	3.2%	6.2%	6.2%
Mulmur	3478	3.4%	6.7%	6.7%
North Dumfries	10215	7.8%	15.2%	15.8%
Orangeville	28900	8.8%	17.6%	17.6%
Puslinch	7336	6.2%	13.0%	18.3%
Shelburne	8126	10.3%	20.2%	20.2%
Waterloo	104986	14.3%	28.3%	32.3%
Wellesley	11260	9.2%	16.8%	16.8%
Wellington North	11914	9.6%	18.6%	18.6%
Wilmot	20545	11.4%	22.5%	23.2%
Woolwich	25006	10.6%	21.0%	21.5%



Figure 33. Proportion of Population living within three TRAP areas by municipality, 2016*



* Data sources: [1] Census subdivision boundaries - Census Subdivision Boundary File, 2019, Statistics Canada Catalogue no. 92-162-X; [2] Census dissemination block boundaries- Dissemination Block Boundary File, 2016 Census. Statistics Canada Catalogue no. 92-163-X; [3] Population estimates by dissemination block - Geographic attribute file: census year 2016. Ottawa, ON: Minister of Industry; 2016. Available from: <http://www12.statcan.gc.ca/census-recensement/2011/geo/ref/att-eng.cfm>; [4] Roads - Ontario Road Network (ORN) Segment with Address – Land Information Ontario Data Class. Government of Ontario. Accessed October 29, 2020. Available from: <https://geohub.lio.gov.on.ca/datasets/mnrf::ontario-road-network-orn-segment-with-address/about>

Among the larger cities, Guelph, Kitchener, and Waterloo all exhibited relatively similar rates, while Cambridge was noticeably lower. Municipalities with the smallest rates were Amaranth, Mono, and Mulmur. In all municipalities, there was moderate to no difference between rates among TRAP groups B and C, as compared to the much larger difference observed in rates (nearly 50%) between TRAP groups A and B. This finding suggests that many municipalities do not have major highways running through them, and those that do have relatively small populations living nearby. Additionally, this suggests that populations living along major highways tend to be located within 150 metres of them, since the expanded highway buffer size of group C (500 metres) did not increase the exposed



population by much compared to groups A and B, which had a highway buffer size of 50 metres and 150 metres, respectively. Kitchener, Puslinch, and to a lesser degree Waterloo and Cambridge, were exceptions to this trend whereby there were more people living between 150-500 metres from the highways than in other municipalities with highways. Puslinch was unique in that it was the only municipality with a small population and yet a relatively large proportion of people living between 150-500 metres from a highway.

7.1.4 Aeroallergens

Climate change will create more prolonged and intense allergy seasons for people who suffer from seasonal allergies across Canada.(7) This can lead to exacerbations of existing respiratory conditions including asthma and drive increases in hospitalizations.(237,238) Ragweed is currently responsible for approximately 75% of seasonal allergy symptoms in Canada, and its growing season has already been extended in Canadian municipalities by as many as 27 days.(239) Further, climate change and increasing temperature are linked to not only increased duration of pollen seasons, but increases in pollen production and the possibility of increase allergenicity of pollen.(240) Currently, there is limited data or information available on the proportion of population in the study area that suffers from seasonal allergies, although asthma data are described later in this report as a potential proxy measure.

7.1.5 Indoor air quality

Indoor air quality can be modified by a changing climate, where higher temperatures and precipitation can create the conditions for growth of biological contaminants that can infect respiratory health. Fungi and infectious bacteria,(241,242) and volatile organic compounds can increase the risk of asthma and allergies, even while indoors, when these compounds interact with stagnant air and direct sunlight in the production of ozone.(243) Indoor air quality can be remedied by reducing contaminants at the source, improving ventilation or utilizing air purification devices.(244) Indoor air quality is also directly related to heating and cooking fuels in households, and can create conditions for PM_{2.5} exposure.

Preliminary research suggests that using air conditioning can help to reduce indoor exposure to ozone,(245) but that it may increase asthma symptoms (246,247) and sick building syndrome (primarily in large office buildings)—a not fully understood set of acute health symptoms including irritation of the eye, nose, and throat as well as headaches and fatigue.(248)

There is currently limited information available assessing indoor air quality of Canadian municipalities, and limited evidence to suggest that climate change will alter exposure to other common indoor air pollutants such as radon or trichloroethylene, and further research is needed to establish a relational understanding between changes in moisture and resulting exposure.(249)



7.2 Future Climate Change

A full articulation of expected climate change under a variety of scenarios can be found in a supplemental report titled Climate Science Report for the Climate Change and Health Vulnerability Assessment for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph.(29) The report provides the following highlights for the study area:

- Globally, concentrations of PM_{2.5} are expected to increase marginally by 0.43µg/m³ under RCP8.5.(201) Similar projections forecast increases of <0.2 µg/m³ over much of North America, although these concentrations may be modified by increases in episodic wildfires;(7,250)
- Ozone concentrations are expected to increase across southwestern Ontario by up to four to five parts per billion by volume by 2050 when anthropogenic emissions are kept constant;(39)
- Warming will likely produce an increase in moderate to high risk air quality days (SAQs and SAHAs) with smog episodes for urban areas with dense transportation networks accompanied by increasing health impacts and rising healthcare costs;(9) and
- Warming will lead to earlier onset of the pollen season with implications for seasonal allergies, with ragweed season becoming longer (ragweed is pervasive across Canada and is responsible for approximately 75% of seasonal allergy systems).(7,239)

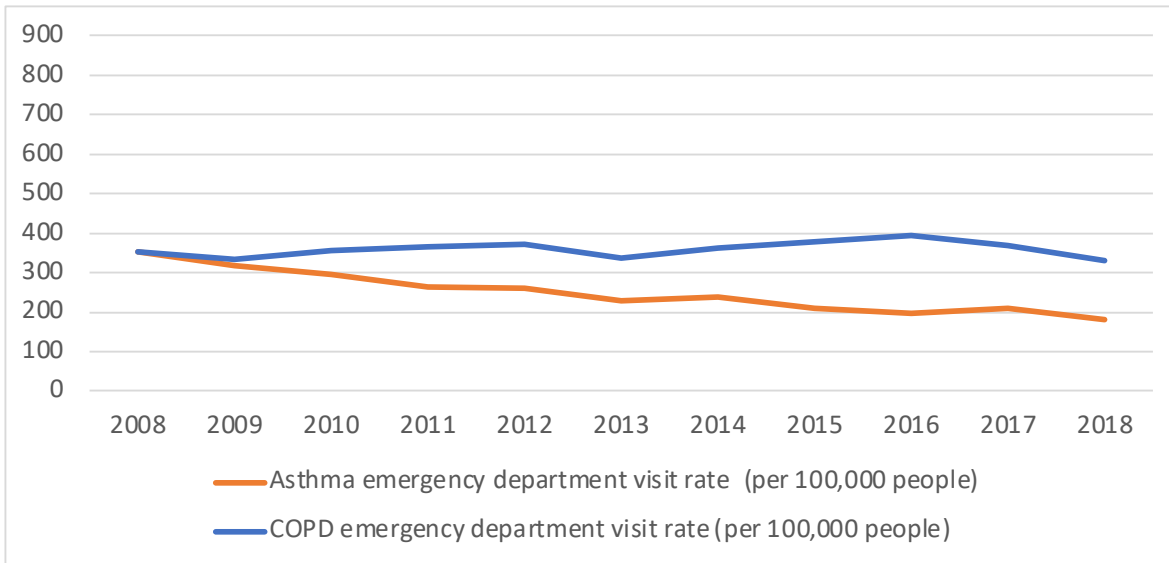
7.3 Baseline Historical Assessment of Population Sensitivity: Population Health Outcomes Related to Air Quality

Poor air quality poses a number of health risks and is one of the largest contributors to avoidable mortality around the world.(203) There are many health outcomes associated with poor air quality such as lower respiratory tract infections, allergic reactions precipitating hay fever, and chronic conditions such as asthma, chronic obstructive pulmonary disorder (COPD), and/or lung cancer. However, because lungs transfer oxygen to blood cells, air quality is also intricately tied to circulatory function of the human body. Poor air quality is also associated with various forms of cancer and vascular conditions such as hypertension, heart attack, and stroke.(251)

According to Health Canada, the annual number of premature deaths associated with air pollution (PM_{2.5}, ozone, and nitrogen dioxide) in 2016 was 257 in Waterloo Region and 138 in Wellington-Dufferin-Guelph. PM_{2.5} is responsible for the highest proportion of pre-mature deaths in Canada. Health Canada further estimated that in 2016, the census division of Waterloo had 45 pre-mature deaths per 100,000 due to air pollution.(204) Additional select health outcomes for which data are available are presented below (see Figures 34 and 35).

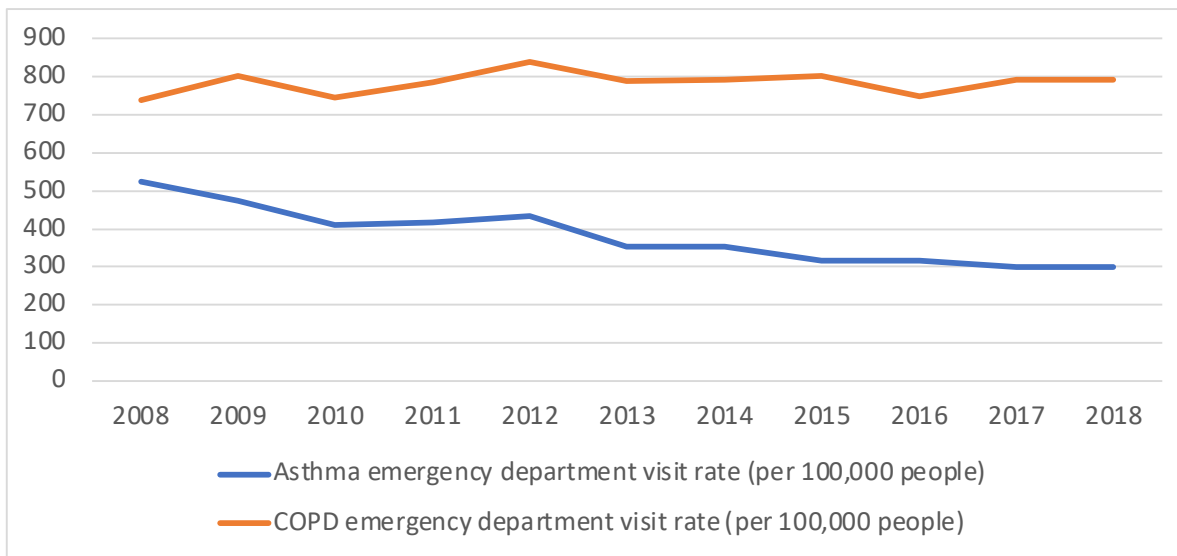


Figure 34. Crude rates for emergency department visits for select respiratory conditions (per 100,000 people), Waterloo Region, 2008-2018



Source: Asthma data from ICD 10-CA:J45; COPD data from ICD10-CA: J40-44. Data Source: NACRS and DAD, IntelliHealth, Ministry of Health, Extracted October 15, 2020, Statistics Canada Annual Population Estimates

Figure 35. Emergency department visits for select respiratory conditions, Wellington-Dufferin-Guelph, 2008-2018



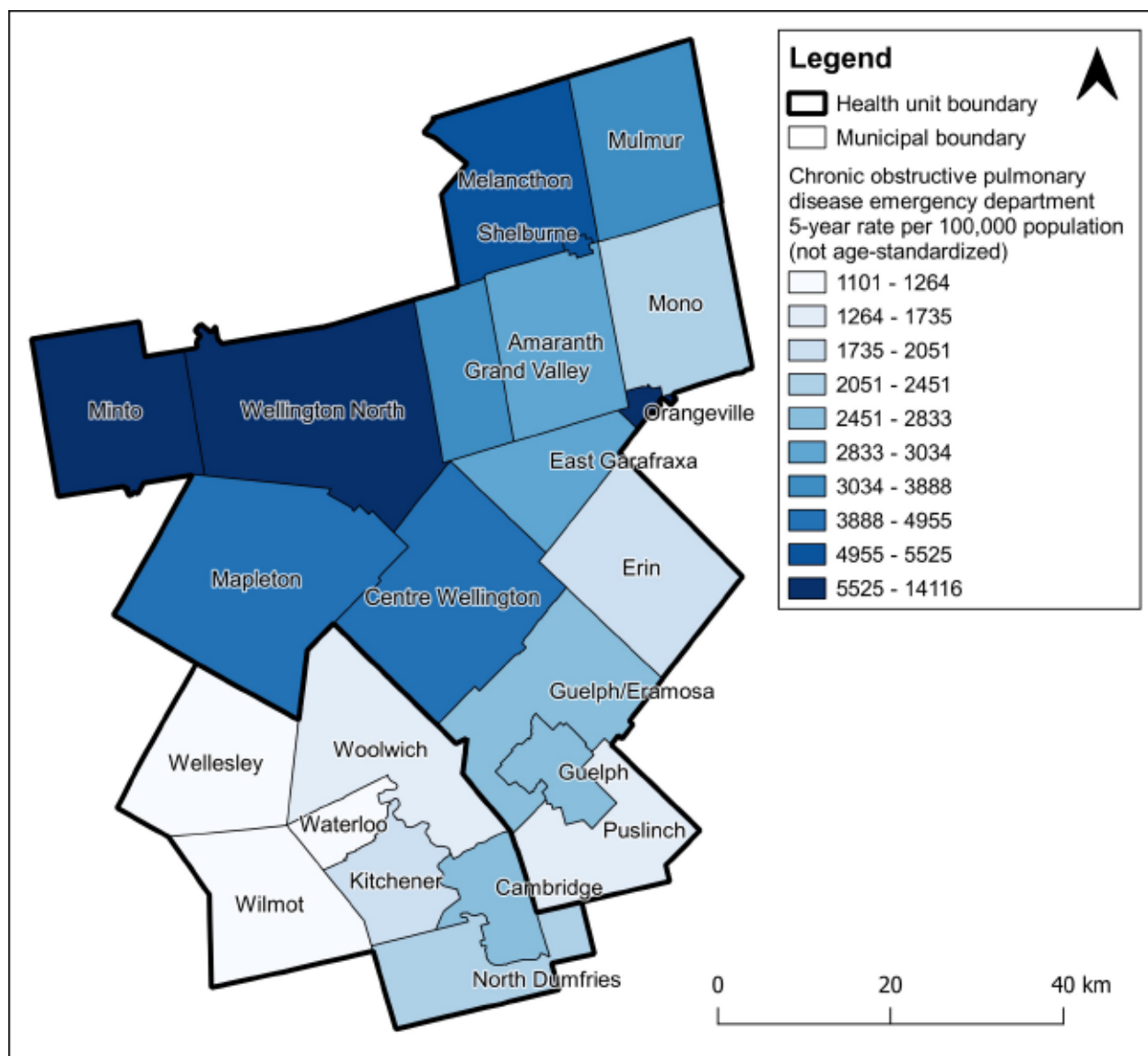
Source: Asthma data from ICD 10-CA:J45; COPD data from ICD10-CA: J40-44. Data Source: NACRS and DAD, IntelliHealth, Ministry of Health, Extracted October 15, 2020, Statistics Canada Annual Population Estimates

The data suggest that emergency department visits for COPD have remained stable across the study area, but that Wellington-Dufferin-Guelph has twice the rates of emergency department visits than Waterloo Region at baseline. A full



accounting for why these differences exist is beyond the scope of this report. Figure 36 uses the same data from the figures above but presents five-year emergency department visit rates according to each municipality within the study area. Calculations were made by adding all emergency department visit occurrences for COPD between 2014-2018 and dividing them by the 2016 population for each municipality, and then multiplying by 100,000 to calculate the rate. The figure indicates that northern municipalities located in Wellington-Dufferin-Guelph, namely Minto, Wellington North, and Orangeville have experienced the highest healthcare utilization for COPD over the past five years.

Figure 36. Chronic Obstructive Pulmonary Disease (COPD) emergency department visit crude rate (5-year average, 2014-2018) by municipality, per 100,000 people

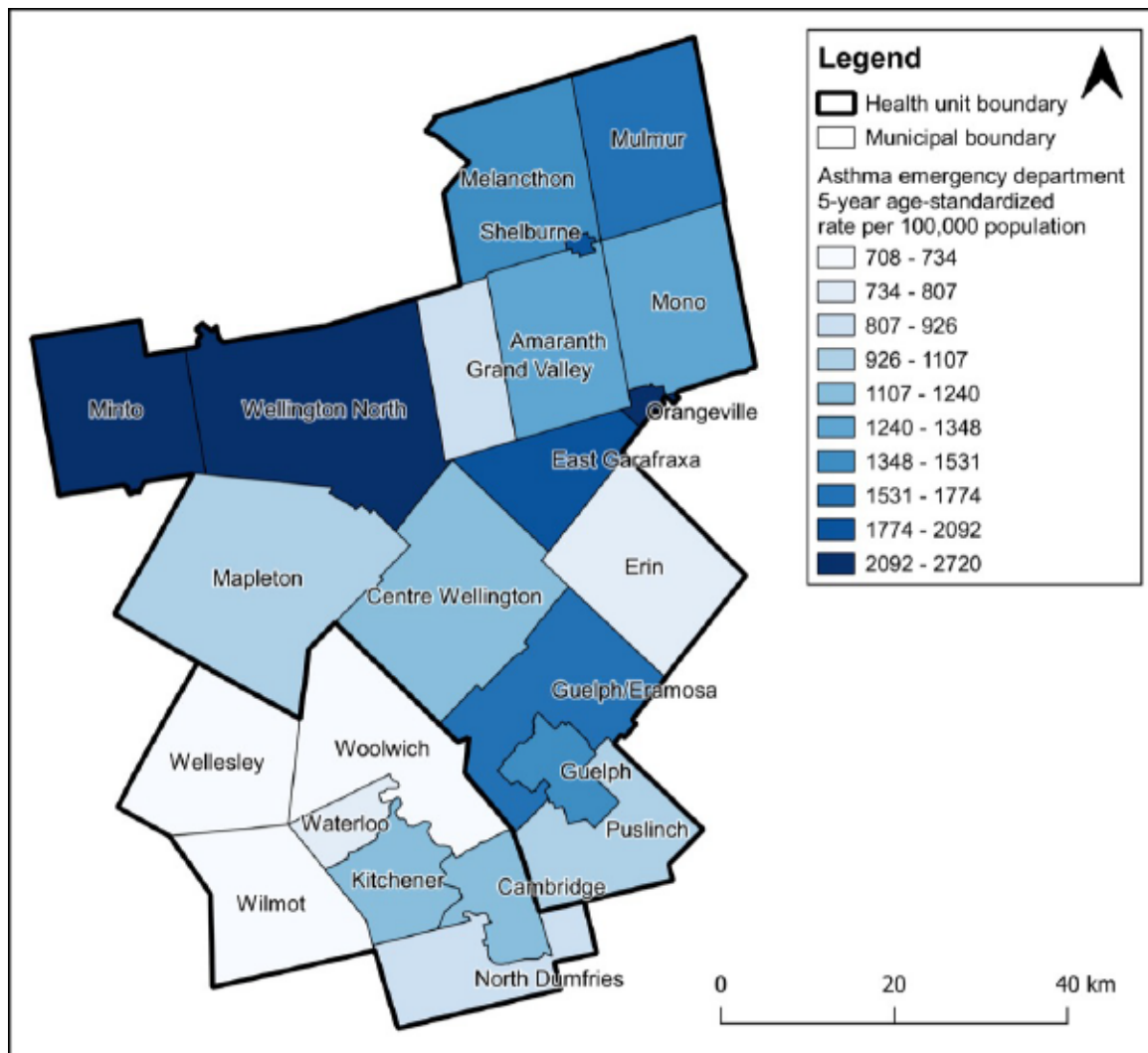


Source: COPD data from ICD10-CA: J40-44. Data Source: NACRS and DAD, IntelliHealth, Ministry of Health, Extracted October 15, 2020, Statistics Canada Annual Population Estimates



Rates of emergency department visits for asthma have been consistently falling over the past ten years and are generally higher for Wellington-Dufferin-Guelph relative to Waterloo Region. Figure 37 displays five-year average emergency department visit rates by municipality for asthma according to municipality. Findings indicate that like COPD, the communities of Minto, Wellington North, and Orangeville have higher rates of healthcare utilization for asthma relative to other communities in the study area.

Figure 37. Age-standardized asthma emergency department visit rate (5-year average, 2014-2018) by municipality, per 100,000 people

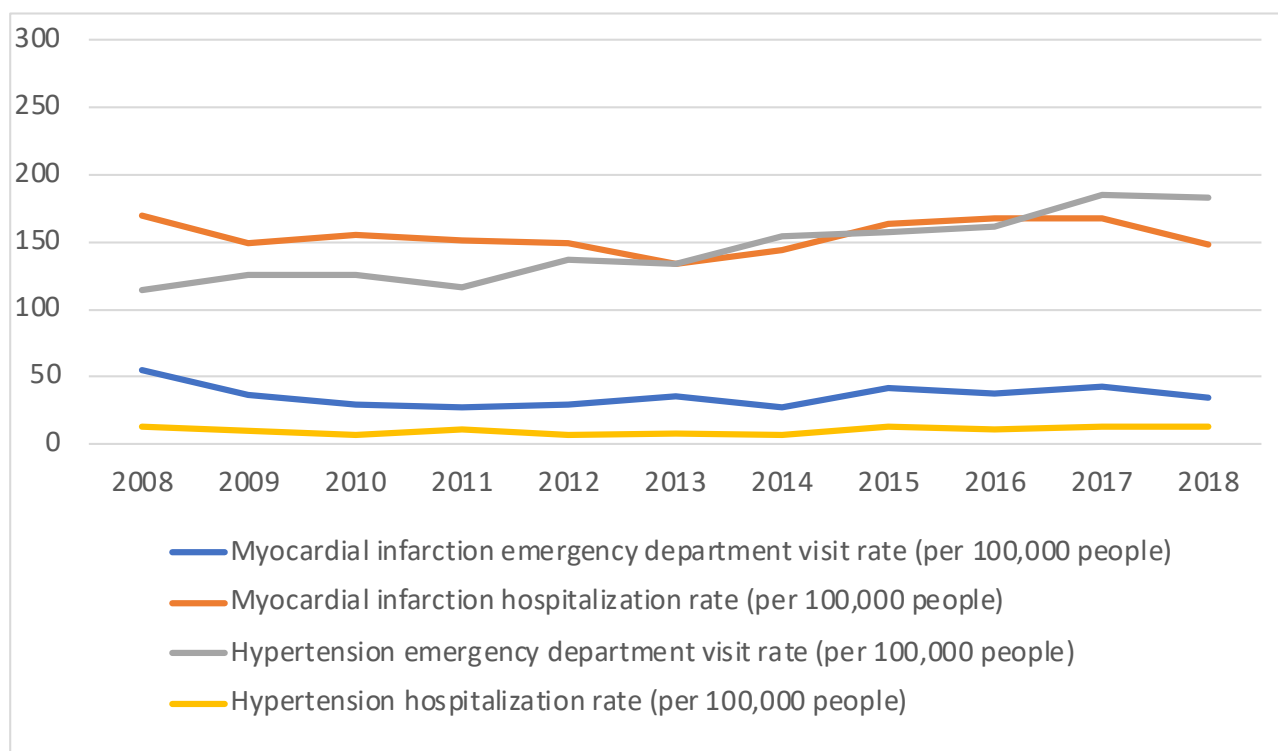


Source: Asthma data from ICD 10-CA:J45. Data Source: NACRS and DAD, IntelliHealth, Ministry of Health, Extracted October 15, 2020, Statistics Canada Annual Population Estimates



Emergency department visits due to allergy to pollen are typically less than 2 per 100,000 people per year across the study area, although since pollen is also a trigger for asthma symptoms, this figure may under-represent the true burden of illness. According to SEER*Stat data, the 10-year moving average for lung and bronchus cancer in Waterloo Region between 2007-2016 was 62.8 per 100,000, which is slightly below the provincial incidence rate of 69.6.(252) Emergency department visits data for allergy to pollen and SEER*Stat data for lung and bronchus cancer were unavailable for WDGP at the time of writing this report. The data suggest that hospitalization for hypertension has remained consistent between 2008-2018, but that emergency department visits for hypertension have increased across. Myocardial infarction emergency department visits have generally declined across both Health Unit jurisdictions, and hospitalization has remained relatively constant, although Wellington-Dufferin-Guelph has elevated numbers for all cardiovascular conditions referenced above relative to Waterloo Region (see Figures 38 and 39).

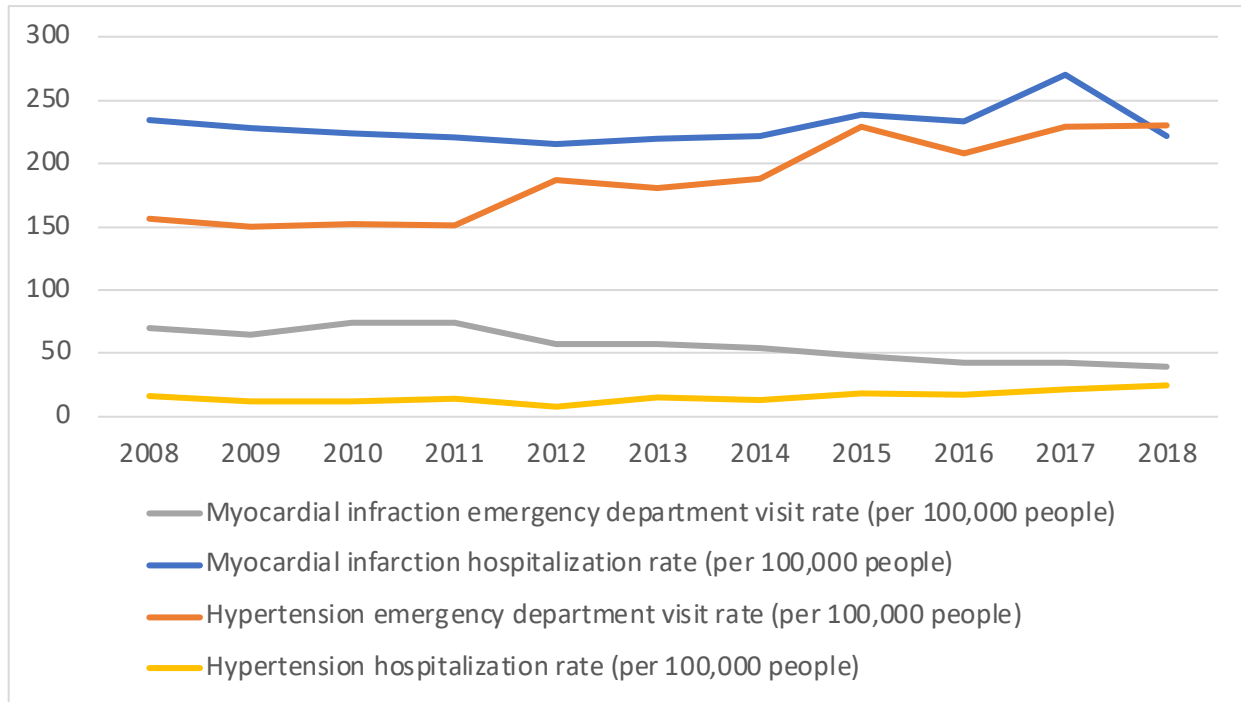
Figure 38. Crude rates for emergency department visits and hospitalizations (per 100,000 people) for select cardiovascular conditions, Waterloo Region, 2008-2018



Source: Data for Myocardial Infarction includes ICD-10-CA for I21; Data for Hypertension includes ICD-10-CA codes for I10-I13, I15. Data Source: NACRS and DAD, IntelliHealth, Ministry of Health, Extracted October 15, 2020, Statistics Canada Annual Population Estimates



Figure 39. Crude rates for emergency department visits and hospitalizations (per 100,000 people) for select cardiovascular conditions, Wellington-Dufferin-Guelph, 2008-2018



Source: Data for Myocardial Infarction includes ICD-10-CA for I21; Data for Hypertension includes ICD-10-CA codes for I10-I13, I15. Data Source: NACRS and DAD, IntelliHealth, Ministry of Health, Extracted October 15, 2020, Statistics Canada Annual Population Estimates

7.4 Populations Vulnerable to Poor Air Quality in Wellington-Dufferin-Guelph and Waterloo Region

Reviews of the evidence suggest that there are a few population sub-groups that are vulnerable to the health impacts of poor air quality, which may worsen under a warming climate. Key sub-populations and exposure pathways are characterized below, with demographics for each group displayed in Table 27.



Table 27. Key population health vulnerabilities to air pollution in Waterloo Region and Wellington-Dufferin-Guelph, 2016

	Proportion of Total Population, 2016		
	Wellington-Dufferin-Guelph	Waterloo Region	Ontario
Children aged < 15	17.7%	17.8%	16.4%
Adults aged 65+	15.8%	14.4%	16.7%
Outdoor workers (Agriculture and Construction)	10.8%	8.0%	8.3%
Unemployment rate (aged 15+)	6.3%	5.4%	6.1%
After tax low-income prevalence	9.9%	12.1%	14.4%
Active commuters (walked or cycled) aged 15+ who are actively employed	6.4%	5.5%	5.6%
Asthma prevalence [†]	8.2%	8.8%	9.0%
COPD prevalence [†]	3.2%	3.6%	4.3%
Heart disease prevalence [†]	6.3%	4.9%	6.7%
Adult current smokers [†]	11.9%	12.2%	13.6%

Source: Statistics Canada 2016 Census of the Canadian Population

[†]Canadian Community Health Survey, 2015/2016

7.4.1 Populations vulnerable to air pollution due to exposure

Outdoor workers may have greater exposure to poor air quality due to higher levels of exposure to ambient air pollution while on the job (10.8% of the Wellington-Dufferin-Guelph population, 8.0% of the Waterloo Region population). Our focus groups with community stakeholders further identified that there may be risks to populations that commute in cars to and from the Greater Toronto Area, or those using active transportation such as walking or cycling to travel locally. While evidence suggests that active transportation commuters may receive higher doses of pollution along busy roadways, there appears to be limited risk for negative effects on lung function while engaging in active transportation. (253,254) Actions such as using separate cycling infrastructure or low volume routes,



and traveling during off-peak hours are effective mechanisms for reducing exposure to point source pollution for commuters who use active transportation (e.g., walking/cycling), and are an effective means to reducing greenhouse gas emissions, especially for short trips.(255) Additional information regarding population-level exposure to traffic-related air pollution can be found in Section 7.1.1.2.

7.4.2 Populations vulnerable to air pollution due to sensitivity

Older adults (aged 65 and older) are at a higher risk of health complications resulting from poor air quality, particularly if they have co-morbid cardiovascular or respiratory conditions. This stems from the fact that the human body tends to lose lung function as it ages, and that older adults are more likely than working age populations to have chronic respiratory and cardiovascular conditions.(228)

Children (under the age of 15) can be negatively impacted by short-term and chronic exposure to air pollution by contributing to early onset of childhood asthma and inhibiting lung function.(256) This is due to children's immune mechanisms being in development, and the fact that children inhale greater air volume per body weight than adults.(257) Neonatal exposure can also lead to adverse outcomes later in life.(257) Approximately 15% of Canadian children and youth lived with asthma in 2013-2014, which is one of the leading causes of childhood hospital admissions across the country.(258) Children from the lowest income neighbourhoods in Canada are also hospitalized for asthma 1.5 times more than those from the highest income neighbourhoods.(258)

People with pre-existing respiratory conditions (e.g., chronic obstructive pulmonary disease, asthma) and cardiovascular conditions (e.g., heart disease) are more likely to have their existing conditions exacerbated by poor air quality. People who smoke and who have resultingly lower lung function are also at higher risk of adverse health outcomes due to air pollution.(259)

7.4.3 Populations vulnerable to air pollution due to adaptive capacity

People who have low-income, are unemployed or who have precarious occupational status may have greater exposure to poor indoor and outdoor air quality, as low-income housing is often located near busy roadways or sources of industrial emissions.(260) Evidence from two systematic reviews indicates that there is uncertainty (i.e., suggestive, non-statistically significant evidence) that racial/ethnic minorities, persons with low education, those in poverty and those living without central air conditioning are at greater risk to health outcomes associated with poor air quality than the average population.(225,228) However, the intersection of all these factors may compound vulnerability to air pollution. For example, a 2017 study in the City of Toronto reported that a large proportion of child-care centres, schools, long-term care facilities, and seniors' residences were more often located within proximity to high traffic corridors, and that lower socioeconomic status neighbourhoods were more likely to be within 200 metres of a highway than higher socioeconomic status neighbourhoods. Lower resourced individuals and families may also be less able to invest material resources into improving indoor air quality.(261)

7.4.4 Sex and gender-based vulnerabilities

Exposure to poor air quality can be modified by gender. Research suggests that poor air quality is linked to adverse



birth outcomes including preterm birth and infant mortality.(262) Other research has shown men to be both differentially exposed and have greater sensitivity to poor air quality due principally to having a higher prevalence of chronic conditions that can be exacerbated by poor air quality, and being more likely to work outdoors.(228,263)

7.5 Programs, Policies, and Related Actions Taken to Improve Adaptive Capacity to Air Pollution

Air quality issues can pose persistent challenges for communities in terms of health and well-being. While air quality is expected to become worse under a changing climate, there are several initiatives already underway that can bolster the ability of the study area's stakeholders and residents to protect and promote their health.



7.5.1 Individual actions

Individuals most at risk, including those who exercise heavily outdoors, children and seniors should pay close attention to AQHI values that are communicated via [Environment and Climate Change Canada](#) and [Air Quality Ontario](#). The AQHI is also circulated on popular weather forecast sites and includes public health messaging for reducing health risks at different values on the 1-10+ AQHI scale. Typically, under higher AQHI values, vulnerable populations should reduce time spent outdoors and limit physical activity. In extreme cases of air pollution, individuals may opt to use air cleaning devices or personal respiratory protection in their homes.(264)

A recent systematic review analyzing adherence to, or behavior change driven by, air quality forecasts found that actual adherence to advice ranged from 9.7% to 57% (median=31%). This is compared to adherence to a wider range of protective behaviours (e.g., medication, avoiding busy thoroughfares) ranging from 17.7% to 98.1% (median=46%). (265) Demographic factors did not predict adherence, but were determined by knowledge of where to look for air quality indices, beliefs that a person's symptoms were due to air pollution, perceived severity of air pollution, and advice from medical professionals. Not understanding AQHI, being exposed to messages that reduced concern about



air pollution or susceptibility, perception of lack of self-efficacy and reliance on sensory cues, and lack of time were consistent barriers.(265)

7.5.2 Public Health actions

Public Health staff shared that past activities that address air quality include those mandated according to the Ontario Public Health Standards, outlined in Table 28.

Table 28. Core Public Health activities related to promoting adaptive capacity to air pollution

Public Health Role	Key Actions
Population Assessment and Surveillance	<ul style="list-style-type: none"> Identify populations at risk from poor air quality Monitor Air Quality Health Index (AQHI)
Health Promotion (including policy development, advocacy and public education)	<ul style="list-style-type: none"> Share information about the Air Quality Health Index
	<ul style="list-style-type: none"> Participate in Official Plan reviews on built environment and shade policies
	<ul style="list-style-type: none"> Support policy development and community engagement related to active transportation
	<ul style="list-style-type: none"> Prepare position statements on wood smoke
Health Protection	<ul style="list-style-type: none"> Share SAQS and SAHAs on social media

7.5.3 Actions led by community partners

Municipalities across the study area are beginning to consider tree planning and urban forest strategies as means to reduce exposure to extreme heat, increase permeable surfaces to reduce flood risk, and generate opportunities for cleaner air and outdoor recreation. A recent analysis of trees in 86 Canadian cities found that urban forests were responsible for removing 16,500 tonnes of air pollution in 2010 saving an estimated \$227.2 million in health effects. (266) A recent analysis of urban forestry strategies for Guelph, London, and Waterloo compared policies related to urban forests from each municipality relative to a review of best management practices, and found that aspects of urban forest management are generally strong for these three cities.(267) Guelph is generally regarded as having a number of strengths including an aggressive tree replacement plan and a tree inventory management portal. Waterloo was identified as the city with the most room to improve (compared to Guelph and London) including invasive species management plans. In both cases, putting an economic evaluation of urban forestry activities, particularly in terms of health savings, could be an effective mechanism for promoting further dialogue and program development about this intervention.(267) Orangeville, Guelph, Cambridge, and Kitchener also have urban forestry strategies to support urban greening.



Additionally, municipalities could work with Public Health Units to make evidence-based recommendations on certain actions during high levels of acute exposure to poor air quality. Actions could include limiting outdoor activities, banning the use of specific vehicles (e.g., heavy truck traffic), stopping some outdoor construction work, closing industrial facilities that are known emitters, and banning fireworks during particularly poor air quality days. (264) Additional mechanisms to improve air quality are tied to any programming that aims to reduce emissions (such as greenhouse gas inventories and corporate activities including fleets).

7.5.3.1 Risk messaging

Environment and Climate Change Canada has provided air quality forecasts for urban centers since 2001, and since 2015, now disseminates information about the Air Quality Health Index. (268) Using data from 2003-2012, a recent analysis of cardiovascular and respiratory events associated with air quality announcements found that risk communication on days with poor air quality reduced asthma-related emergency department visits in Toronto by 4.73 cases per 1,000,000 people per day (a 25% reduction), but that air quality alerts alone are not enough to mitigate health impacts. (224)

7.6 Conclusion

Increasing temperatures and changes to precipitation patterns influence local air quality. While air quality has generally been improving across much of Ontario due to the phase out of coal-fired generating plants, climate change is expected to extend more active pollen seasons and wildfire seasons leading to higher exposure to airborne particulate matter. Higher temperatures, particularly in the TRAP zone, are expected to continue to be a challenge in the creation of and exposure to ground level ozone which is a product of volatile organic compounds, sunlight and heat leading to episodic poor air quality. Accordingly, increasing temperatures will continue to interact with tailpipe emissions to produce smog and corresponding respiratory risks under future climate change scenarios.

Given the already high rates of respiratory and cardiovascular conditions which poor air quality exposure exacerbates, population-level exposures to poor air quality are relatively high, and may worsen without further reductions in air pollutants, particularly for vulnerable populations living within 500 metres of major roadways. Nonetheless, more research is required to adequately link poor air quality to existing respiratory and circulatory health concerns that exist across the study area. Modeling is required to determine future impacts, particularly as the electrification of vehicles looks increasingly likely as a policy mechanism to meet provincial and federal climate change mitigation goals. To that end, future research that seeks to analyze climate and air quality data related to health will be essential to supporting continued surveillance and to inform appropriate interventions. There is a need for enhanced air quality monitoring across the study area to enhance the spatial depiction of air pollutants over time, identify problem areas and potential sources of pollutants, and inform adaptation strategies, many of which offer numerous co-benefits for population health.

8.0 Vector-borne and Zoonotic Diseases





8.0 Vector-borne and Zoonotic Diseases: Key Findings

Climate change projections

- In general, temperature is expected to increase, resulting in warmer winters that may allow for certain vectors to withstand harsh conditions and have prolonged development cycles.
- Precipitation is expected to increase in the spring and the fall, and extreme rainfall events may pose risks for growth of mosquito populations in the summer months if stagnant water is allowed to accumulate following extreme rainfall.
- Climate change increases the climatic suitability for the survival of disease vectors and is expected to increase their range across southwestern Ontario.

Population-level exposure

- West Nile virus is typically present in the summer and fall across most of Ontario, including southwestern Ontario and the study area. Human case counts for the study area appear generally low, however ROWPH experienced a significant spike in cases in 2018.
- Passive surveillance of tick populations in Canada revealed a tenfold increase in ticks infected with *Borrelia burgdorferi* when comparing 1990-2003 with submissions from 2004-2012. The study area borders regions of southwestern Ontario where black-legged ticks are now endemic.
- Comparisons of 2016 and 2020 Lyme disease estimated risk areas in Ontario reveal that risk areas are growing quickly and moving into the southern portion of the study area.
- People who spend greater amounts of time outdoors for recreational or work purposes may also be differentially exposed.

Population-level sensitivities

- Older adults (aged 65 and older) are at high risk of health complications due to the diminished functionality of immune response, and the fact that older populations are more likely to have chronic conditions.
- Children under the age of 15 are susceptible to vector-borne and zoonotic diseases as they have developing immune systems and may be more reliant on caregivers to translate risk messaging and engage in adaptive behaviours such as wearing insect repellent.



Population-level adaptive capacity

- There is currently limited evidence that people with low adaptive capacity to other climate-related health issues (e.g., those experiencing poverty) are at greater risk of vector-borne disease transmission.

Adaptive actions

- Individuals can take a variety of precautions to protect themselves from the spread of vector-borne diseases, including using protective clothing or equipment when outside, using window and door screens to keep out mosquitos, and avoiding areas with known harmful species.
- Public Health activities include public education and outreach, human case and vector surveillance programs, and biological treatments (e.g., larvicide) on both known and possible reservoirs of mosquito vectors.
- Public Health conducts passive tick surveillance to identify black-legged ticks before they are sent to lab testing for *Borrelia burgdorferi*.
- Each municipality within the study area can play a role in reducing the impact of vectors and zoonoses through official planning processes to reduce standing water and/or expanding urban greening strategies.

Baseline health impacts

- Symptoms of Lyme disease typically include fever, headache, chills, muscle and joint pain, swollen lymph nodes, and sometimes a 'bull's eye' rash around the bite. If left untreated, long-term symptoms such as skin rashes, heart palpitations, arthritic symptoms, extreme fatigue, and central and peripheral nervous system disorders could present themselves.
- Between 2008-2018, ROWPH had a cumulative 47 cases of Lyme disease, the most of which were recorded in 2018. WDGPH had 33 identified cases of Lyme disease in the same period, with 2017 and 2018 having among their highest incidence rates. Current data collection may not accurately reflect where cases were exposed to the vector and exposure may have occurred outside of the study area.
- Symptoms of West Nile virus (WNV) are typically mild and flu-like, although a small percentage (less than 1%) of infected persons develop encephalitis or paralysis.
- Case counts of WNV were low in both the ROWPH and WDGPH for the period of 2008-2018 with 14 and 7 cases, respectively.



8.0 Vector-borne and Zoonotic Diseases

Climate change is already altering human exposure to vectors capable of transmitting infectious disease to humans across Canada.(7,269) Zoonotic disease refers to infectious diseases that are transmitted from animals to humans. Vector-borne diseases are zoonoses that are transmitted by arthropod vectors (for example, ticks and mosquitoes) that can transmit infectious pathogens between hosts (e.g., a mosquito can transmit West Nile virus from a bird to a human). This chapter focuses primarily on vector-borne zoonotic diseases.

The distribution and abundance of vector-borne and zoonotic diseases will be altered by climate change through several mechanisms. As the climate warms, ecosystem conditions change, creating opportunities for vectors to inhabit regions where those vectors did not previously exist. Additionally, changing ecosystem conditions may increase the number of pathogens or vectors that are already present in a region. Changes in human activities (e.g., spending more time outdoors due to increasing temperatures, new residential developments adjacent to vector-friendly ecosystems) may modify existing interaction with vectors. Finally, changes in evolutionary pressures on pathogens that affect their degree of transmissibility are also possible under most warming scenarios.(7,156,270) One example of how changing climate conditions have altered the distribution of vector-borne diseases is the spread of the blacklegged ticks (Lyme disease vector) from the northeastern United States into southwestern Ontario.(271)

In southwestern Ontario—and more specifically, the study area—the principal climate-related vector-borne diseases of concern are West Nile virus (WNV), Eastern equine encephalitis (EEE), and Lyme disease.(272,273) However, climate change is also changing the distribution of, and exposure, to other vectors worldwide, which may pose risks to residents of the study area due to a combination of international travel patterns and changing climate conditions that increase the risk of transmission of certain diseases.(272) This chapter provides an overview of exposure pathways for vector-borne and zoonotic diseases that are already endemic to the study area, and those which may modify their range under a changing climate. The impacts that climate change may have on exotic infectious diseases typically acquired from international travel are also discussed. Historical population health data are then displayed and discussed before tying climate-sensitive vector-borne diseases to known vulnerabilities from the evidence-base. The chapter ends with a discussion of on-going adaptive activities being undertaken across the study area, with a particular focus on Public Health actions.

8.1 Population Baseline Exposure to Vector-borne and Zoonotic Diseases and Associated Health Surveillance Data

This section describes key climate-related vector-borne diseases with relevance to Ontario under future climate change scenarios.(273) Transmission pathways, symptoms, and disease/vector range are discussed before providing baseline health outcome information (e.g., human cases) for each Health Unit within the study area. However, it is important to note that the surveillance of vectors of specific diseases (e.g., mosquito populations of interest) are distinct from data monitoring of human cases (e.g., West Nile virus). The difference between these data is that the former reflects possible patterns of risk that may emerge season-by-season, which may or may not translate into an increase in the incidence of a particular disease in human populations. The latter (i.e., human cases) reflects the historical incidence rate for particular diseases.



8.1.1 West Nile virus

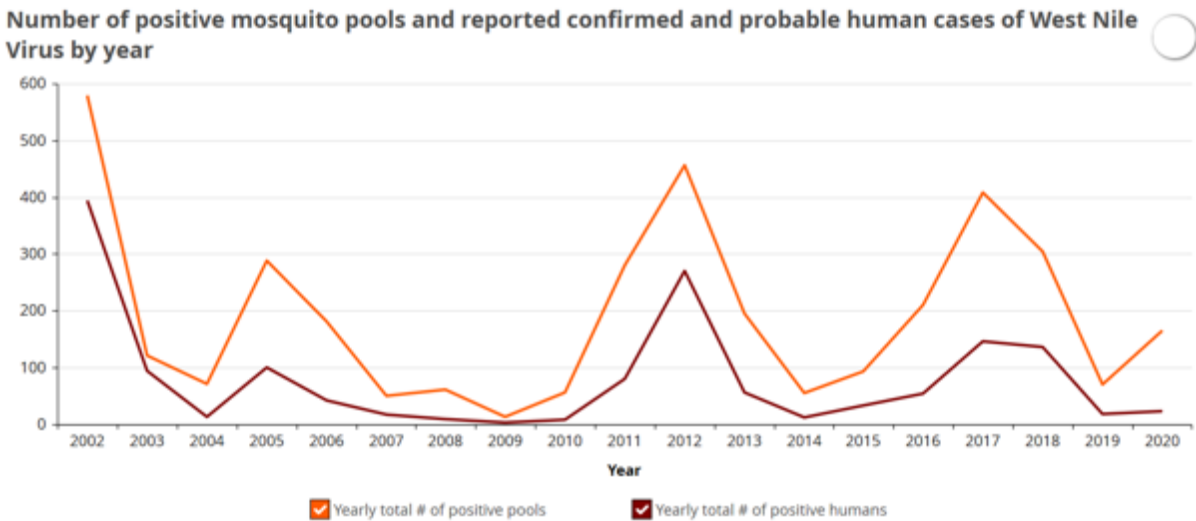
West Nile virus (WNV) is a mosquito-borne illness spread by the *Culex* group of mosquitoes (*Culex pipiens* and *Culex restuans*), although there are multiple other species that can act as bridge vectors. The virus is found in birds (namely crows, ravens, and jays) and carried by infected mosquitoes. People can become infected when bitten by a WNV infected mosquito, or if they receive a blood transplant from an infected person. Symptoms are typically mild and flu-like, although a small percentage (less than 1%) of infected persons develop encephalitis or paralysis.(274)

WNV is typically present in the summer and fall across most of Ontario, including southwestern Ontario and the study area. The mosquito species that carry WNV only grow into adult stage over a specific number of accumulated degree days. A degree day is a measure of temperature that reflects the amount of heat required for an organism to advance between life stages. In the context of WNV, a degree day is one 24-hour cycle where the temperature is above or below a fixed reference temperature of 18.3 degrees Celsius. For example, if the temperature remained at 18.3 degrees Celsius for 24 hours, one-degree day would be accumulated. In the study area, the majority of the WDGP area can expect to accumulate 0-10 degree days, and the ROWPH area can expect 10-30 degree days, depending on location.(275) Changes in degree days (e.g., increases) can be utilized to project possible growth rates in vectors.

WNV is tracked by testing mosquito pools for positive cases of mosquitoes with WNV—which typically reflects the incidence of WNV in human populations(276)—and by tracking case counts of WNV in the human population recorded through laboratory-confirmed WNV in the human population. In 2019, Ontario had a WNV incidence rate of 0.16 per 100,000 people, and between 2015-2019, Ontario had a five-year average incidence rate of 0.58 per 100,000 people (see Figure 40).(1)



Figure 40. Number of positive mosquito pools and reported confirmed and probable human cases of West Nile virus by year, Ontario, 2002-2020



Source: West Nile Virus Surveillance [Internet]. Public Health Ontario. [cited 2020 Oct 22]. Available from: [https://www.publichealthontario.ca/en/Data and Analysis/Infectious Disease/West Nile Virus](https://www.publichealthontario.ca/en/Data%20and%20Analysis/Infectious%20Disease/West%20Nile%20Virus)

In the study area, human cases of WNV are low for both health authorities (see Table 29 and 30). ROWPH surveillance indicates a cumulative case count of WNV of 49 from 2008-2018, with 12 of those cases appearing in 2018 resulting in an age-standardized incidence rate of 2.12 cases per 100,000 people. WDGPH had a cumulative case count of 14 cases between 2008-2018, with five cases occurring in 2018 resulting in an age-standardized incidence rate of 0.93 per 100,000 people.





Table 29. West Nile virus human cases and mosquito pool testing, Waterloo Region, 2008-2018

Year	Case Count	Age-standardized Rate (per 100,000)	# of Positive Pools
2008	3	0.68	0
2009	1	0.18	0
2010	0	0	0
2011	4	0.72	3
2012	3	0.61	2
2013	3	0.58	4
2014	1	0.19	2
2015	10	1.88	1
2016	4	0.71	1
2017	8	1.42	2
2018	12	2.12	9

Source: Statistics Canada 2019 iPHIS Annual Population Estimates, West Nile Virus

Table 30. West Nile virus human cases and mosquito pool testing, Wellington-Dufferin-Guelph, 2008-2018

Year	Case Count	Age-standardized Rate (per 100,000)	# of Positive Pools
2008	0	0.00	0
2009	0	0.00	0
2010	0	0.00	0
2011	2	0.37	3



Year	Case Count	Age-standardized Rate (per 100,000)	# of Positive Pools
2012	3	0.58	2
2013	0	0.00	4
2014	0	0.00	2
2015	1	0.19	1
2016	0	0.00	1
2017	3	0.59	2
2018	5	0.93	9

Source: Statistics Canada 2019 iPHIS Annual Population Estimates, West Nile Virus

8.1.2 Eastern equine encephalitis

Eastern equine encephalitis (EEE) is a mosquito-borne illness transmitted principally through the *Culiseta melanura* group of mosquitoes, although mosquito surveillance suggests *Culex erraticus* is also a possible carrier in Ontario. EEE is typically found in passerine birds as the primary hosts or reservoirs. Mosquitos can then become infected from feeding on these birds, and pass the infection to dead-end hosts including horses, other birds, and humans. Dead-end hosts refer to specific species, that when infected with a virus, are not able to spread the species. EEE activity is typically highest in late summer and early fall across North America.

EEE virus causes encephalitis (i.e., brain swelling) and is fatal approximately 30-70% of the time in equine (horse) populations. EEE in humans typically manifests 4-10 days after being bitten by an infected mosquito with symptoms largely dictated by the age of the person infected (i.e., children under the age of 15, and adults over the age of 50). Severe case symptoms include fever, headache, and chills, and may progress to encephalitis, seizures, and coma. Approximately one third of patients who develop EEE die, and many who survive have mild to severe brain damage as a result of brain swelling, but the majority of virus cases are asymptomatic and self-limiting.(278)

There are no recorded human cases of EEE in Canada, but equine and mosquito infection dates back as early as the 1930s across eastern North America.(279) In Ontario, 14 equine cases were reported in six Public Health Unit jurisdictions (two of which border the study area, Grey Bruce Health Unit and Simcoe Muskoka District Health Unit) during a three-year enhanced surveillance program run by Public Health Ontario between 2012-2014.(280)

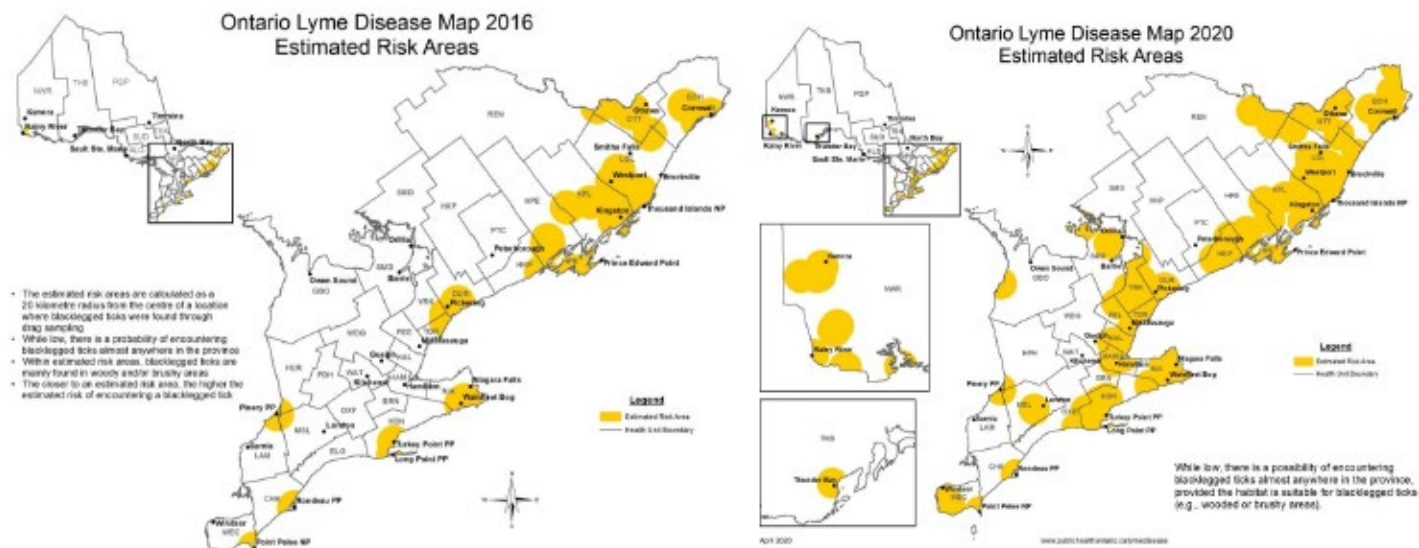


8.1.3 Lyme disease

Lyme disease is spread through the bite of a blacklegged tick (i.e., deer tick) infected with a bacterium known as *Borrelia burgdorferi*. Not all ticks are infected with the bacteria, and a bite from an infected tick is not guaranteed to transmit the bacteria to humans.(281) An infected tick must be attached to human skin for 24-36 hours in order for the bacterium to be transmitted.(282) Symptoms typically include fever, headache, chills, muscle and joint pain, swollen lymph nodes, and in some cases, a characteristic ‘bull’s eye’ rash around the bite. If left untreated, more severe symptoms can emerge that last from months to years, and may include skin rashes, heart palpitations, arthritic symptoms, extreme fatigue, and central and peripheral nervous system disorders.(282)

Ticks cannot fly or jump so they wait on low vegetation and attach to a host that passes by. Although most of the study area is not currently in a Lyme disease estimated risk area as determined by Public Health Ontario (see Figure 41), the two maps below reveal that the estimated risk areas are growing quickly and moving into the southern portion of the study area. Because ticks can travel on animals and birds, there is the possibility of encountering blacklegged ticks anywhere in the province.

Figure 41. Lyme disease estimated risk areas in Ontario, 2016 compared to 2020



Source: Public Health Ontario. Ontario Lyme Disease Map 2020 [Internet]. Toronto, ON: Queen’s Printer of Ontario; 2020 [cited 2020 Jun 1]. Available from: <https://www.publichealthontario.ca/-/media/documents/l/2020/lyme-disease-risk-area-map-2020.pdf>

Rates of Lyme disease in humans are relatively low in Ontario when compared to other parts of the world where Lyme has been historically endemic.(283) Prior to COVID-19, both Health Units in the study area have accepted ticks found on a person for identification and testing. Currently, ROWPH refers inquiries about collected ticks to etick.ca. Approximately 25% of ticks submitted to ROWPH between 2012-2018 were blacklegged ticks. Of those blacklegged ticks submitted, 25 were carriers of *Borrelia burgdorferi*, although most of those ticks were not locally acquired (see Tables 31-32).



Table 31. Case counts of Lyme disease in humans and tick submission records, Region of Waterloo Public Health, 2008-2018

Year	Case Count	Age-standardized rate (per 100,000)	# Ticks Submitted	# Black Legged Ticks (BLT)	# BLT with <i>Borrelia burgdorferi</i>
2008	3	0.68	No Data	No Data	No Data
2009	1	0.18	No Data	No Data	No Data
2010	0	0	No Data	No Data	No Data
2011	4	0.72	No Data	No Data	No Data
2012	3	0.61	48	5	1
2013	3	0.58	53	8	0
2014	1	0.19	47	15	4
2015	10	1.88	99	19	5
2016	4	0.71	85	7	1
2017	8	1.42	112	46	7
2018	12	2.12	203	59	7**

**Ticks not acquired locally

Source: Statistics Canada iPHIS Annual Population Estimates and ROWPH tracking system



Table 32. Case counts of Lyme disease in humans and tick submission records, Wellington-Dufferin-Guelph Public Health, 2008-2018

Year	Case Counts	Age-standardized rate (per 100,000)	# Ticks Submitted	# Blacklegged ticks (BLT)	# BLT with <i>Borrelia burgdorferi</i> and acquired locally
2008	0	0	No Data	No Data	No Data
2009	0	0	No Data	No Data	No Data
2010	1	0.3	11	3	0
2011	3	1.6	7	3	0
2012	1	0.4	13	8	0
2013	3	1	16	14	1
2014	2	0.7	85	28	0
2015	1	0.3	72	26	2
2016	5	1.7	234	94	3
2017	9	3	192	82	1
2018	8	2.3	371	197	3

Source: Statistics Canada iPHIS Annual Population Estimates

Historically to the present, there has been a low incidence rate of Lyme disease in the study area. However, these rates are changing as the climate changes and blacklegged ticks become more prevalent in the study area and other areas of Ontario nearby.(284):

- In 2019, Ontario had a Lyme disease incidence rate of 7.74 per 100,000, and a five-year (2015-2019) average incidence rate of 3.96 per 100,000.
- Between 2008-2018, ROWPH had a cumulative 49 cases of Lyme disease, and the highest incidence rate of 2.3 age-standardized cases per 100,000 people occurred in 2018 (see Table 31).



- Between 2008-2018, WDGP had 33 identified cases, with 2017 and 2018 having among their highest incidence rates at 3.0 and 2.3 per 100,000 people, respectively (see Table 32).

Passive surveillance of tick populations in Canada revealed a tenfold increase in the percentage of ticks infected with *Borrelia burgdorferi* when comparing 1990-2003 with submissions from 2004-2012, suggesting a more established range for blacklegged ticks and the possibility of Lyme transmission beyond known Lyme disease-endemic areas. (285) Precaution around Lyme disease transmission is warranted, especially given the study area borders regions of southwestern Ontario where infected blacklegged ticks are now endemic. (286)

8.1.4 Exotic zoonosis and other climate-sensitive vector-borne diseases

A number of studies have assessed Canadian vulnerability to exotic diseases not established in Canada and which are often found in tropical locations. (269,287) Examples include malaria, Rift Valley fever, dengue, chikungunya, and Japanese encephalitis. At present, disease occurrence of exotic diseases in areas where it is not currently endemic primarily stems from migration, and manifests in communities that contain high proportions of people who have recently travelled from areas where these diseases are endemic. (288) Risks of human-to-human transmission for these diseases remain low. However, climate change and economic and disaster-driven migration is expected to increase changing distributions of vectors, especially in developing countries. (289) This can create opportunities for human to vector to human transmission, even in areas where exotic vector-borne diseases are not endemic.

Of the more than 3,500 mosquito species that exist around the world, only a small portion have the potential to transmit mosquito-borne diseases, with the most common exotic mosquito-borne illnesses being malaria and dengue, neither of which are currently established in Canada. (290) Mosquitoes native to Canada may become infected with new pathogens when Canada's climate becomes more accommodating, however, it is also possible that new species will start to occupy previously inhospitable ecosystems and climate regions. (290) Indeed, southern Canada, including the study area, already has competent malaria vectors which are in geographical range of several major urban areas, and historical climate conditions have supported local malaria transmission in the past. (287) Rising temperatures may increase incidence in Canada and permit local mosquito transmission should malaria be introduced locally. (269,287) Similarly, other exotic mosquito-borne illnesses, such as Zika virus, while not currently a risk in Canada, could become established across the study area as the climate warms, and the mosquito vector for Zika virus has already been found in southern Ontario. (291)

Other vector-borne diseases may also increase under future climate scenarios. A recent multi-criteria decision analysis framework was applied to endemic and non-endemic diseases in Canada that could be impacted by climate change. Endemic diseases ranked from highest to lowest priority for Canada included Cache Valley virus, Lyme disease, WNV, Babesiosis, and human granulocytic anaplasmosis; and non-endemic diseases ranked from highest to lowest priority included EEE, Powassan virus, La Cross encephalitis, Rocky Mountain spotted fever, plague, Chikungunya virus, and St. Louis encephalitis. (292) Lone star ticks are competent vectors for human ehrlichiosis, southern tick associated rash illness, Heartland virus, Bourbon virus, Rocky Mountain spotted fever, and alpha-gal syndrome. (293) While the risks of these diseases are currently low in Canada, modeling suggests that their presence



is likely underestimated throughout the northeastern United States and Midwest, and range is likely to increase under climate change.(293)

For Ontario, the evidence for climate-related changes on distribution of vector-borne disease is strongest for Lyme disease, EEE, WNV, and the California serogroup of viruses (e.g., Jamestown Canyon virus and snowshoe hare virus). (273,294) Diseases of the California serogroup of viruses are currently rare in Canada, but have the potential to increase under climate change. Utilizing existing disease surveillance for tracking cases of encephalitis and other emerging vector-borne diseases may be a suitable early warning system for mobilizing resources towards enhanced vector and disease surveillance.(295,296)

8.2 Future Climate Change

A full overview of expected climate change under a variety of scenarios can be found in a supplemental report titled *Climate Science Report for the Climate Change and Health Vulnerability Assessment for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph*.(4) The report provides the following highlights for the study area in relation to vector-borne diseases:

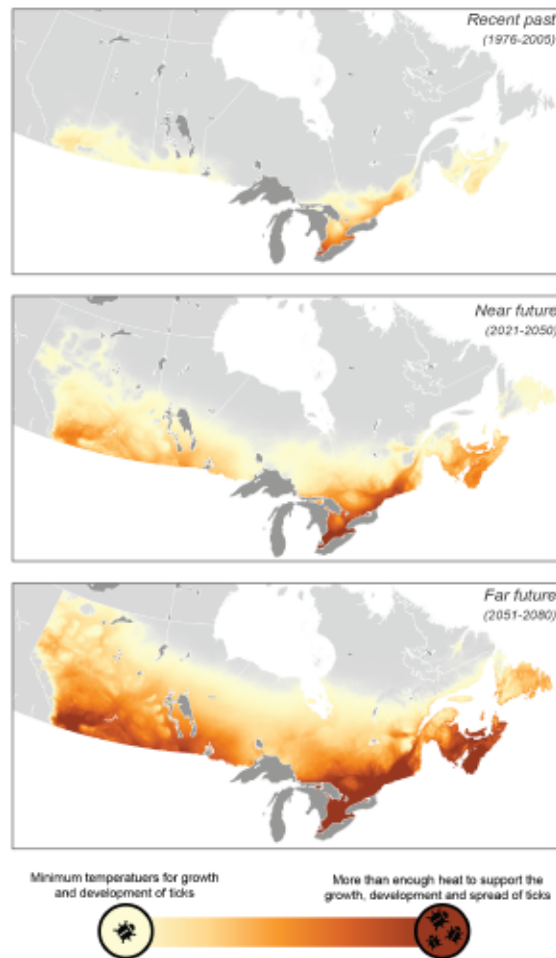
- In general, temperature is expected to increase, resulting in warmer winters that may allow for certain vectors to withstand harsh conditions and continue seasonal development cycles (i.e., overwinter) which could propagate certain drivers of illness.
- Precipitation is expected to increase in the spring and the fall, and extreme rainfall events may pose risks for growth of mosquito populations in the summer months if stagnant water is allowed to accumulate following extreme rainfall(297). Extreme rainfall events are projected to increase across the study area through the spring, summer, and fall.
- *Culex pipiens* mosquitoes, blacklegged ticks (see Figure 42), and *Culiseta melanura* mosquitoes are all expected to increase their range across southwestern Ontario and further north across the province under all future climate change scenarios as climate change increases the climatic suitability for the survival of these vectors. (283,285,297–300) A 2013 Canadian study modelled three scenarios between 2010-2039 and found that WNV infection rates could increase by between 24%-232% each month.(301)



Figure 42. Climate change, historical and future blacklegged tick range, and Lyme disease risk across Canada

Climate Change, Ticks, and Lyme Disease Risk in Canada

These maps show where temperatures are suitable for the growth and development of blacklegged ticks in future climates if we continue to increase our emissions. Blacklegged ticks can carry Lyme disease. These ticks live in wooded areas, so if you live, work, or play in wooded areas with suitable temperatures, you may be at risk of encountering a tick carrying Lyme disease.



Temperatures sufficient for the growth and development of blacklegged ticks are at least 2860 degree days (the total of all daily temperatures above 0 °C in a year). The colour scale shows 2860 degree days (yellow) to 4000 degree days (red). This map does not apply to the species of Lyme-carrying ticks that live west of the Rocky Mountains. The climate projections on these maps were made using 24 climate models running the "high carbon" emissions scenario (RCP8.5). Climate model data was downscaled and made available by the Pacific Climate Impacts Consortium (PCIC).

Source: Lyme Disease Under Climate Change | Climate Atlas of Canada [Internet]. [cited 2020 Oct 22]. Available from: <https://climateatlas.ca/lyme-disease-under-climate-change>

8.3 Populations Vulnerable to Vector-borne and Zoonotic Diseases

Reviews of the evidence suggest that there are a few population sub-groups that are vulnerable to vector-borne and zoonotic diseases, which may worsen under a warming climate. Key sub-populations are characterized by exposure and sensitivity with demographics for each group articulated in Table 33. Notably, there is currently limited Canadian



evidence that people with limited adaptive capacity to other climate-related health issues (e.g., those experiencing poverty) are at greater risk of vector-borne disease transmission in Ontario, and thus there is no stand-alone section describing population level vulnerabilities according to adaptive capacity, as per other chapters comprising this assessment. A description of adaptive actions being undertaken across the study area is provided in the final section of this chapter.

Table 33. Key population health vulnerabilities to vector-borne disease in Waterloo Region and Wellington-Dufferin-Guelph, 2016

	Proportion of Total Population, 2016		
	Wellington-Dufferin-Guelph	Waterloo Region	Ontario
Children aged < 15	17.7%	17.8%	16.4%
Adults aged 65+	15.8%	14.4%	16.7%
Outdoor workers (Agriculture and Construction)	10.8%	8.0%	8.3%
Active commuters (walked or cycled) aged 15+ who are actively employed	6.4%	5.5%	5.6%

Source: Statistics Canada 2016 Census of Canadian Population

8.3.1 Populations vulnerable to vector-borne and zoonotic diseases due to exposure

People who spend greater amounts of time outdoors for recreational purposes may be differentially exposed. While there is currently no reliable estimation of average time spent outdoors, we have included a proxy measure of the proportion of active commuters (walked or cycled) for the study area in Table 33. Additionally, outdoor workers, such as those working in agriculture, on road repair, and those employed in the conservation of rural areas, may experience greater exposure to vectors that pose risks to human health. (302,303)

8.3.2 Populations vulnerable to vector-borne and zoonotic diseases due to sensitivity

Older adults (aged 65 and older) are at high risk of health complications due to a diminished functionality of immune response, and the fact that older populations are more likely to have chronic conditions.(156,299)

Children under the age of 15 are also susceptible to vector-borne and zoonotic diseases(304) as they have developing immune systems and may be more reliant on caregivers to translate risk messaging and engage in adaptive behaviours such as wearing insect repellent.



Finally, people with compromised immune systems (e.g., cancer patients or transplant recipients people taking immunosuppressive drugs) are more susceptible to serious illness due to suppressed immune response.(299) However, data on people with a suppressed immune response is not publicly reported for the study area.

8.3.3 Sex and gender-based vulnerabilities

There is a higher proportion of men than women working in outdoor occupations across both Health Units, despite there being slightly more women than men residing within the study area (50.8% in Waterloo Region and 50.6% in Wellington-Dufferin-Guelph). There are seven times more men in construction jobs than women across the study area, and more than double the number of men in agricultural jobs than women.

8.4 Programs, Policies, and Related Actions Taken to Improve Adaptive Capacity to Vector-borne and Zoonotic Diseases

While several vector-borne and zoonotic diseases are already established across the study area, the health risks are expected to become greater the warmer and wetter the study area becomes. Fortunately, there are a number of initiatives already underway that can bolster the ability of the study area's stakeholders and residents to protect and promote their health.

8.4.1 Individual actions

Individuals can take precautions to protect themselves from the spread of climate-sensitive vectors described in this chapter. These include:

- Protecting oneself from bug bites when outdoors by wearing light-colored clothing, long sleeves, pants, a hat, and socks and closed-toed shoes, and using an insect repellent containing DEET or Icaridin.
- Using window and door screens to keep mosquitoes outside.
- Avoiding areas with known harmful species (e.g., blacklegged ticks, Culex mosquitos).
- Cleaning up any standing water outside of the home to limit mosquito larvae and cutting or avoiding long grasses on your property.
- Checking yourself, family members and pets for ticks after returning from the outdoors and promptly removing any found ticks.
- Submitting captured ticks to local Public Health staff for identification.
- Prior to international travel, research possible vectors of diseases which may be endemic to other parts of the world and following medical advice on how best to reduce health risks.

8.4.2 Public Health actions

Existing Public Health activities that bolster adaptive capacity to vector-borne and zoonotic diseases under a



changing climate include public education and outreach, disease and vector surveillance programs, and biological treatments (e.g., larviciding) on both known and possible reservoirs of mosquito vectors (e.g., catch basins, roadside ditches, stagnant pools of water). A list of core Public Health activities in relation to programming mandated by the Ontario Public Health Standards is provided in Table 34.

Table 34. Public Health adaptive capacity to vector-borne disease in Waterloo Region and Wellington-Dufferin-Guelph

Public Health Standard	Existing Activities
Population Health Assessment and Surveillance	<ul style="list-style-type: none"> • Identification of populations at greatest risk to vector-borne disease • Case investigation of reported cases of vector-borne disease • Monitoring of incidence of vector-borne disease • Adult mosquito and larval monitoring (species and abundance). Viral testing of adult mosquito pools • Passive and active tick surveillance (e.g., tick dragging) (currently, WDGPH only)
Health Promotion (including policy contributions, education and advocacy)	<ul style="list-style-type: none"> • Public education regarding prevention and personal protection through websites, social media, and media briefings • Policy development related to standing water by-laws and stormwater infrastructure (e.g., cleaning schedules)
Health Protection	<ul style="list-style-type: none"> • Risk assessment process to determine larvicide locations • Provide recommendations to limit exposure for outdoor workers • Support Ministry of Health in assessment of risk for adulticiding

Surveillance consists primarily of collecting pooled groups (e.g., of the same species) of captured mosquitos, and submitting them to partner agencies for testing. For example, WDGPH tested 140 mosquito pools in 2017, and only three (all from Guelph) tested positive for WNV.(305) In that same year, approximately 1.64% of all captured mosquitos were suitable WNV vector species.

Weather-based forecasting of mosquito-borne disease outbreaks in Canada is an emerging field of study that requires further validation.(306) Collaborations with weather-based disease modellers could assist in identifying suitable weather patterns for predicting future outbreaks. As mentioned above, modeling changes in accumulated degree days, incidence, distribution of vectors, and resulting implications for human transmission could be a potentially informative future direction for researching the prevalence of both tick- and mosquito-borne



diseases. Additionally, existing mosquito-borne disease surveillance can be applied to surveillance of emerging mosquito-borne illnesses that are not yet endemic to Canada, although existing surveillance practices are likely to underestimate true risks requiring consistent and representative testing data.(307)

Climate change will impact the distribution of these disease vectors into the future. Significant funding and research is required to address existing and emerging diseases in light of the globalized spread and severity of human diseases that result from the mobility of people, animals and trade; increasing patterns of drug and insecticide resistance; and availability of effective treatments and quality Public Health service.(308)

8.4.2.3 Biological treatments

Across the study area, larvicide is used to control larval mosquito populations. Each Health Unit works with expert consultants to apply larvicide to catch basins and pools of standing water including storm drains, storm water management ponds, and standing water in natural and urbanized areas.

Adulticiding is not currently conducted by either Health Unit, and refers to ultra-low volume liquid sprays that kill adult mosquitos on contact. The Ministry of Health is responsible for adulticiding programs based on established thresholds and parameters when mosquito season begins. Risk assessments must weigh the level of WNV risk to public health based on current evidence, and in relation to the expected benefits and risks of pesticide use in impacted areas. Risk assessments are supported as necessary by both Health Units.(309)

8.4.3 Actions led by community partners

Reducing the risks of vector-borne and zoonotic diseases is supported by programming at each Health Unit within the study area. However, other community partners and collaborators can also play active roles. Local employers with outdoor workers can support staff members with appropriate risk messaging and resources to reduce occupational exposures.

Further, each municipality within the study area can play a role in reducing the impact of vectors and zoonoses on their residents through official planning processes. Suitable planning for tick and mosquito-borne illnesses in urban and suburban design has proven to moderate risks, where heavy rainfall is more likely to lead to possible mosquito breeding in suburban areas, where even drought allows for successful breeding grounds for mosquitos in drains and sewers.(310) Consideration for reducing tick and mosquito habitats should therefore be incorporated into other climate change actions that have co-benefits for human health—such as urban greening (e.g., gardens) and urban forestry strategies that increase green space.(310) Municipal staff also play a key role in responding to standing water complaints through municipal by-law enforcement and property standards departments, and can design policies to direct enforcement for elimination of standing water, such as the City of Guelph's standing water by-law.



8.5 Conclusion

Climate change is altering the ability of certain vectors to establish themselves across the study area due to warmer overall temperatures, milder winters that allows species survival, and changes in precipitation patterns. As temperatures warm, the range of certain vectors is spreading north, and may lead to increasing risk of disease transmission.

Lyme disease activity is increasing across southwestern Ontario, and blacklegged tick populations are expected to increase across the study area in the future. Possible exposures to West Nile virus are also present, and EEE continues to be a vector-borne disease of interest given growing rates in the northeast region of the United States, but no confirmed human cases have been detected in Canada. Currently, vector-borne diseases such as Lyme disease and West Nile virus are estimated increase in the study area.

As the climate continues to warm, it is expected that population exposures to these vectors will increase, as will the potential for the emergence of new vector-borne diseases which have previously not been endemic to the study area (e.g., snowshoe hare virus, babesiosis, malaria). Growth in vectors may also be supported by the high prevalence of woodland and agricultural areas across the study area. Each Health Unit monitors both vector and human populations which will enhance their responsiveness in the event of growing incidence rates.



9.0 Mental Health





9.0 Mental Health: Key Findings

Climate change projections

- Climate change projections show a general warming trend for the study area, an increase in the frequency and severity of extreme weather events, warmer winters, and wetter spring and summer periods. Changing climatic conditions may exacerbate mental health conditions into the future.

Population-level exposure

- Outdoor labourers, particularly farmers, who have strong and regular connections to the land and climate conditions, and where anxiety and fear over crop or livestock loss can negatively impact their financial livelihoods, are differentially exposed to mental health impacts relative to the population at large.

Population-level sensitivities

- Children, particularly those with pre-existing depression and anxiety, are at risk of worsening mental health symptoms under climate change.
- Older adults (e.g., aged 65 and older) are more likely to have existing cognitive challenges which naturally present with age, and may be more reliant on caregivers to seek adequate treatment options.
- Populations with pre-existing addictions or mental health conditions may be exacerbated by acute and indirect impacts of climate change, and may drive increases in violence, crime, and substance misuse.

Population-level adaptive capacity

- Factors such as: social capital, sense of community, government assistance, access to resources, community preparedness, intersectoral/transdisciplinary collaboration among stakeholders, vulnerability and adaptation assessments, communication and outreach, mental health literacy, and culturally relevant resources may increase adaptive capacity.
- Some populations may have less ability to adapt to the mental health impacts of climate change relative to others, these include people who have low-income, people with low social connectedness, and Indigenous Peoples, who may experience a sense of cultural loss associated with changes to land and associated cultural practices.
- Urban areas in the study area tended to have higher rates of people experiencing both homelessness and complex mental health-related disorders than rural parts of the study area.



Adaptive actions

- WDGPH has developed an opioid tracking system (Flexible, Accessible, Scalable, and Timely (FAST) Overdose Alert Platform) that works to quickly identify overdose patterns in the community and enhance response time.
- ROWPH participates as a member of the Waterloo Region Integrated Drugs Strategy to prevent, reduce, or eliminate problematic substance use and its consequences with an emphasis on prevention and harm reduction.
- The Waterloo Region Suicide Prevention council implemented two mental health strategies across the region that seek to connect community partners, raise awareness, and coordinate efforts to deliver programs that are well-received by clients.
- The establishment of the Crime Prevention Council in Waterloo Region, the Well-being Waterloo Region initiative, and Children's Needs Planning Tables are other examples of allied initiatives that support service delivery across the region.

Baseline health impacts

- Rates of emergency department visits for posttraumatic stress disorder (PTSD)—which could be exacerbated under a changing climate—have remained stable, with incidence rates consistently below 50 per 100,000 people across the study area from 2008-2018.
- Emergency department visits for both depression and suicide/self-harm have increased in Waterloo Region since 2013, whereas Wellington-Dufferin-Guelph has seen increases since 2011.





9.0 Mental Health

Mental health encompasses emotional, psychological, behavioural, and social well-being, and determines people's ability to cope with life stress and function in their community. Climate change can have immediate, gradual, and indirect impacts on mental health and well-being.(311–313) This chapter briefly describes the relationship between climate change and mental health across the study area—including a description of the mental health impacts of climate change, the historical burden of disease for select mental health outcomes, present population vulnerabilities, and existing adaptive capacity among Health Units and community partners.

9.1 Climate Change and its Relationship to Mental Health

Mental health is complexly related to a number of pressures that are directly and indirectly associated with climate change, including compounding existing life stressors. These include: loss of personal resources; pressure on, or disruption to, societal and community functioning; pressure on, or disruption to, public resources (including public health function); widespread destruction or social upheaval; and aggravation of root causes of mental illness. (314) Mental health impacts of climate change can manifest directly from acute events, such as in the aftermath of natural disasters, and indirectly from slow changes to local environments. Following extreme weather events (e.g., violent storms), adults may experience a number of mental health outcomes including post-traumatic stress disorder (PTSD), depression, increases in suicidal ideation and suicide, anxiety and/or substance abuse; and children may exemplify aggression, anxiety and related behaviour problems which can last for months or even years.(130,315–318) Recent analysis of the flooding events that impacted much of High River, Alberta found similar results following extreme precipitation and flooding.(319)

A recent analysis of the direct health impacts of extreme heat events in a mid-sized Australian city found that, compared with non-heat wave periods, mental health-related hospital admissions increased by 7.3% during heat waves. Mental health outcomes registered at time of hospitalization included mental disorders; dementia; mood (affective) disorders; neurotic, stress-related and somatoform disorders (mental disorders that manifest as physical symptoms), senility; and disorders of psychological development.(320) Further, mortality attributable to the disorders listed above increased during heat waves for people aged 65-74, and people aged 65 and older who also had dementia saw increases in mortality rates.(320,321) Even the anticipation of exposure to extreme weather and the potential for loss of resources and loss of life can negatively impact mental health.(322)

A 2002-2012 study of two million randomly sampled US residents compared climate conditions with mental health impacts finding that when temperature increased to hotter than 30 degrees Celsius (relative to 25-29.9 degrees Celsius), there was a 0.5% increase in the probability of mental health difficulties.(323) Further, a one degree temperature increase over five years was associated with a 2% increase in mental illness prevalence.(323) Increases in ambient temperatures are also correlated with increases in aggressive criminal behaviours such as assaults and homicides,(324–326) and have also been known to increase suicide risk for men and older adults.(327,328)

Climate change can also indirectly impact mental health through a variety of pathways that are not driven by a single event.(329) For example, a review (330) of emerging 'psychoterratic syndromes' (i.e. non-diagnosable mental health



conditions that arise from negative feelings of environmental change) surfaced the following conditions:

- **Ecoanxiety:** “anxiety related to a changing and uncertain environment.” (p.49).
- **Ecoparalysis:** “the inability to meaningfully respond to the climatic and ecological challenges that face us [which are] not always an expression of apathy.” (p.50).
- **Solastalgia:** “lived experience of negatively perceived change to a home environment.” (p.51).
- **Econostalgia:** “a yearning to return to a past time and its corresponding place where things are perceived to be better than they are in the present.” (p.54).

Terms related to those defined above which are often used interchangeably include: ecoguilt, ecological grief, and biospheric concern.(331) The core theme that underlies these emerging ecological mental health concerns is a recognition of limited control, and feeling grief or sorrow over the loss of some previous physical state of the environment.

9.2 Future Climate Change

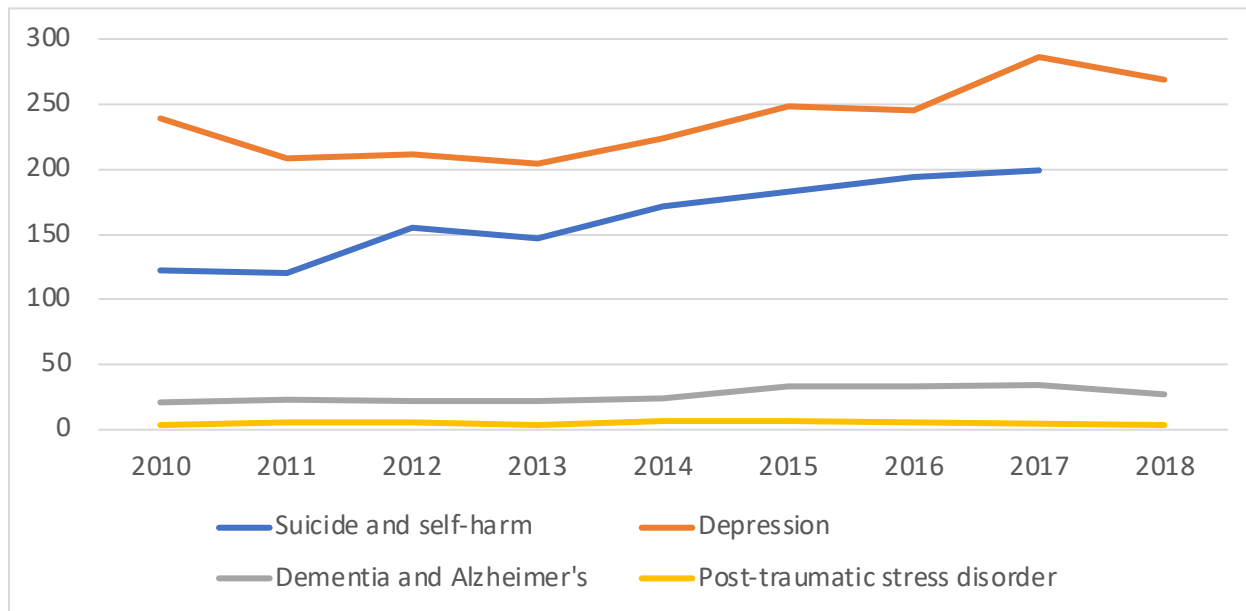
A full range of climate scenarios for the study area has been made in a separate supplemental report titled *Climate Science Report for the Climate Change and Health Vulnerability Assessment for Waterloo Region, Wellington County, Dufferin County, and the City of Guelph*.(4) Highlights from this report include a general warming trend for the study area, an increase in the frequency and severity of extreme weather events, warmer winters, and wetter spring and summer periods, all of which are likely to exacerbate existing and climate-related mental health conditions into the future.(332)

9.3 Baseline Mental Health Conditions

The links between climate change and diagnosable mental health conditions represent an emerging evidence base and further research is needed to establish causal connections and clear trends. As such, the causal mechanisms are not always clear as to whether and how climate change may exacerbate or (in)directly cause mental health. To establish a historical baseline, select mental health outcomes for which data are available for the study area are presented in Figures 43 and 44, below. Rates of emergency department visits for dementia, Alzheimer’s disease, and PTSD—which can both be exacerbated and characterize vulnerable populations under a changing climate—have remained stable, with incidence rates consistently below 50 per 100,000 people across the study area from 2008-2018. Emergency department visits for both depression and suicide and self-harm have increased in Waterloo Region since 2013, whereas Wellington-Dufferin-Guelph has seen increases for these health issues since 2011.

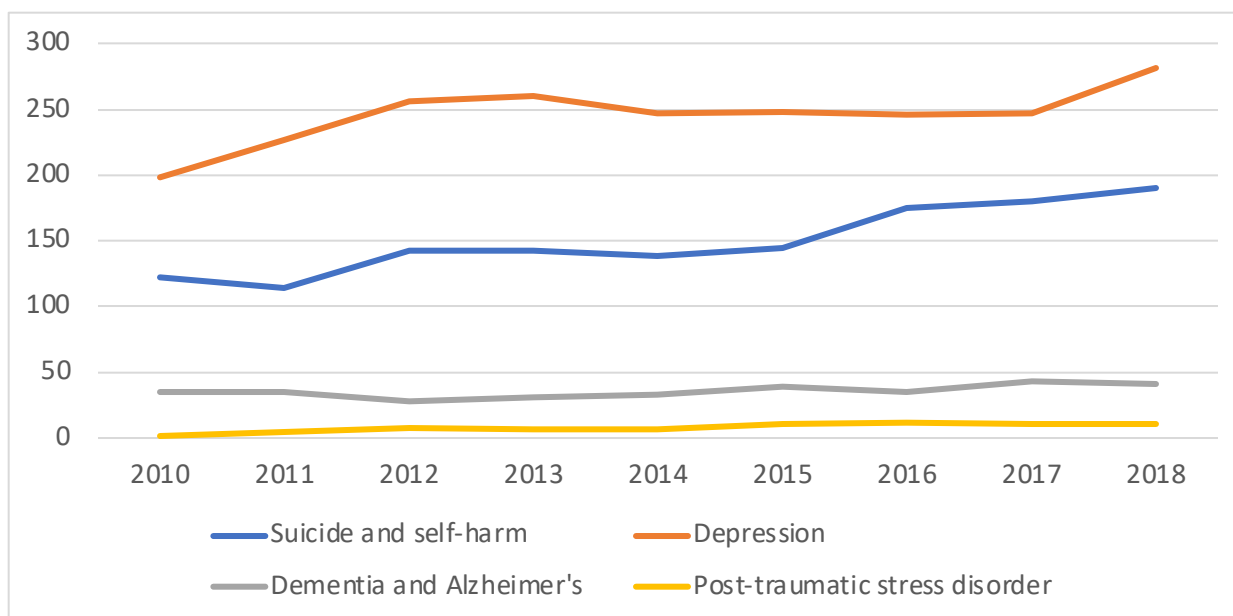


Figure 43. Age-standardized emergency department visit rate (per 100,000 people) for select mental health conditions, Waterloo Region, 2010-2018



Source: Dementia and Alzheimers (Includes ICD-10-CA codes F00, F01, F03, G30); Depression (Includes ICD-10-CA codes F32, F33, F34.1, F38.1); Suicide and self-harm (Includes ICD-10-CA codes X60-X84 and Y87.0); Post-traumatic Stress Disorder (PTSD) (ICD-10-CA code F43.1). NACRS & DAD, IntelliHealth, Ministry of Health, extracted 2019-10-10 & 2019-10-16; Population: Annual Population Estimates, Statistics Canada, extracted 2019-08-23.

Figure 44. Age-standardized emergency department visit rate (per 100,000 people) for select mental health conditions, Wellington-Dufferin-Guelph, 2010-2018





Source: Dementia and Alzheimers (Includes ICD-10-CA codes F00, F01, F03, G30); Depression (Includes ICD-10-CA codes F32, F33, F34.1, F38.1); Suicide and self-harm (Includes ICD-10-CA codes X60-X84 and Y87.0); Post-traumatic Stress Disorder (PTSD) (ICD-10-CA code F43.1). NACRS & DAD, IntelliHealth, Ministry of Health, extracted 2019-10-10 & 2019-10-16; Population: Annual Population Estimates, Statistics Canada, extracted 2019-08-23.

These findings suggest that the burden of mental illness is similar for each Health Unit in the study area. However, there is currently limited local data that enable a comparison of emergency department visits immediately following periods of extreme weather (e.g., heat warnings, thunderstorm events with significant precipitation and/or localized flooding) to enable an analysis of how these events impact health service utilization.

9.4 Populations Vulnerable to Mental Health Impacts of Climate Change in Wellington-Dufferin-Guelph and Waterloo Region

Climate change is already impacting social, economic and environmental determinants of mental health, and these impacts are differentially experienced by disadvantaged communities.(333) Risk factors for developing mental illness in the aftermath of acute events include the degree of magnitude of the event, exposure to injury or death of family and/or friends, female gender, younger age, lower socioeconomic status, less education, minority or ethnic status, psychiatric history, family instability, and inadequate social supports.(318)

Populations vulnerable to the mental health impacts of climate change are impacted through pathways of exposure, sensitivity, and a lack of adaptive capacity. Available data for the population groups categorized according to exposure, sensitivity, and adaptive capacity across the study area is presented in Table 35. Data suggest that Wellington-Dufferin-Guelph has a higher than provincial average of residents who are employed in agriculture and both Health Units have elevated rates of self-reported mood disorders as compared to the Ontario provincial average. Residents of each Health Unit's jurisdiction have strong degrees of social connectedness which is an important aspect of adaptive capacity to the mental health impacts of climate change.

Table 35. Key mental health vulnerabilities related to climate change in Wellington-Dufferin-Guelph and Waterloo Region, 2016

	Proportion of Total Population, 2016		
	Wellington-Dufferin-Guelph	Waterloo Region	Ontario
Children aged < 15	17.7%	17.8%	16.4%
Adults aged 65+	15.8%	14.4%	16.7%
Workforce employed in agriculture	3.4%	1.4%	1.5%
Indigenous identity	1.6%	1.7%	2.8%



	Proportion of Total Population, 2016		
	Wellington-Dufferin-Guelph	Waterloo Region	Ontario
% of residents who rated their mental health as good, very good or excellent ²	88.9%	90.0%	89.2%
% of residents who rated their mental health as poor or fair	11.1%	10.0%	10.8%
% of residents who rated sense of community belonging as strong or somewhat strong ²	68.8%	68.2%	69.2%
% of residents who rated sense of community belonging as weak or somewhat weak ²	31.2%	31.8%	30.8%
% of individuals aged 12+ with self-reported mood disorder ²	10.7%	12.2%	8.7%
% of individuals aged 12+ with self-reported anxiety disorder ²	8.5% ³	8.4%	8.6%
After tax low-income prevalence	9.9%	12.1%	14.4%
Chronic homelessness ⁴	134	228	n.d.

Source: Statistics Canada 2016 Census of Canadian Population

²Canadian Community Health Survey, 2015/2016, Share File, Ontario MOHLTC

³This value has a high degree of sampling variability. Interpretations should be made with caution.

⁴ Built for Zero Canada point-in-time estimate for October 2019. Chronic homelessness refers to individuals who are currently experiencing homelessness AND who meet at least one of the following criteria: 1) they have a total of at least six months (180 days) of homelessness over the past year, or 2) they have recurrent experiences of homelessness over the past three years, with a cumulative duration of at least 18 months (546 days) <https://bfzcanada.ca/wp-content/uploads/BFZ-C-Data-Dashboards.pdf>

9.4.1 Populations vulnerable to the mental health impacts of climate change due to exposure

Outdoor labourers, particularly farmers, who have strong and regular connections to the land and climate conditions, and where anxiety and fear over crop or livestock loss can negatively impact their financial livelihoods, are differentially exposed to mental health impacts relative to the population at large.(312,316) The study area is located



in a fertile agricultural area, and 3.4% of Wellington-Dufferin-Guelph's population and 1.4% of Waterloo Region's population are employed in agriculture, forestry, fishing, or hunting.

9.4.2 Populations vulnerable to the mental health impacts of climate change due to sensitivity

Children, particularly those with pre-existing depression and anxiety, are at risk of worsening mental health symptoms under climate change.(334) Older adults (aged 65 and older) are more likely to have existing cognitive challenges which naturally present with age, and may be more reliant on caregivers to seek adequate treatment options.(311,315,321,328,335) Key population statistics for the study area for these groups can be found in Chapter 1, Table 1.

Further, populations with pre-existing addictions or mental health conditions may be exacerbated by acute and indirect impacts of climate change,(311,321,335) which is a notable concern given Canada's ongoing opioid epidemic which has negatively impacted the health of residents in the study area. There is currently limited data on the number of people who suffer from addictions, but according to data from the Canadian Community Health Survey 11.1% of the population in WDGP and 10% in ROWPH jurisdictions identify as having poor or very poor mental health.

9.4.3 Populations vulnerable to the mental health impacts of climate change due to adaptive capacity

A recent review identified 11 factors that influence the capacity to adapt to mental health impacts of climate change at the level of individuals and communities: social capital, sense of community, government assistance, access to resources, community preparedness, intersectoral/transdisciplinary collaboration among stakeholders, vulnerability and adaptation assessments, communication and outreach, mental health literacy, and culturally relevant resources. (336) Such strategies require a comprehensive process for engaging community stakeholders (including civil society and care providers), mental healthcare clients, and health administrators.

Based on this review, some populations may have less ability to adapt to the mental health impacts of climate change relative to others. These include:

- People who have low-income, experiencing homelessness and/or housing insecurity who may face complex and interconnected challenges of poverty, substance use, and pre-existing mental health conditions, all of which can be exacerbated by climate change.(78,337)
- People with low social connectedness to their community who may experience increased feelings of hopelessness, anxiety and despair, while community connectedness can enhance mental health and build adaptive capacity for individuals and communities alike.(332)
- Indigenous Peoples may experience a sense of cultural loss associated with changes to land and associated cultural practices.(312)



Focus groups with study area stakeholders provided additional context for this assessment, and for taking future actions on the mental health impacts of climate change. For example, stakeholders pointed to a multi-year history of mental health assessment across the study area that suggests that the urban areas of Guelph, Kitchener, and Cambridge tend to have higher rates of people experiencing both homelessness and complex mental health-related disorders than rural parts of the study area. The concentration of social and health services in urban areas may result in inequalities in access to services for rural areas.

Focus group participants also identified that:

- Mennonite communities may experience differential mental health outcomes given strong cultural connections to the land and understanding of local climate conditions.
- Suicidal ideation and self-harm among post-secondary students, but particularly females, may be elevated by high levels of life stress.(338)
- Middle-aged men, Indigenous Peoples and people who identify as 2SLGBTQIA have elevated risks of suicide and self-harm across the study area.(339)
- People living in floodplains were identified as a possible population at risk of solastalgia, given the loss of property may immediately impact people in flood-prone areas.(340)
- New immigrants who are climate refugees, or people who were temporarily displaced from their homes and residing in evacuation centres in the study area, may also experience mental health impacts more immediately than residents. According to the Intergovernmental Panel on Climate Change, climate-related migration will be a significant and on-going challenge into the future. This is because migration is an effective adaptation strategy for people who face the most extreme impacts of climate change, but that there is currently low confidence in quantitative projections of changes to mobility driven by climate change because of its multi-causal nature.(8) Climate-related displacement and migration is also known to have health impacts for impacted individuals.(341) No data on the mental health of these populations currently exists for the study area.





9.4.4 Sex and gender-based vulnerabilities

Men and women experience differently the mental health impacts of climate change. A recent review of the literature indicates that women may be more predisposed to ecological mental health outcomes (e.g., solastalgia, ecological grief) than men.(318) This may be related to additional burdens and stresses on persons with traditional gender roles in a household. Women are also more likely to self-report mental distress than men and seek mental health supports. In Wellington-Dufferin-Guelph, women tended to experience poorer mental health outcomes, particularly among grade 10 girls.(342) Men are, nonetheless, more likely than women to have suicidal ideation or complete suicide than women.(315,327) Analysis from other chapters (see Chapter 3: Extreme Temperature) of this report indicates that men are more likely than women to be employed in outdoor occupations across the study area, and therefore may be at greater risk than women in dealing with the mental health impacts associated with loss of livelihoods tied to changing land use dynamics.

9.5 Programs, Policies, and Related Actions Taken to Improve Adaptive Capacity to Mental Health Impacts of Climate Change

There are several opportunities and existing initiatives that may help to bolster resilience of population mental health to the impacts of climate change. Recent evidence has provided a list of priorities in terms of concrete actions to promote mental health and well-being under a changing climate.(337) These include:

- Policies that improve access and funding for mental health care.
- Epidemiological surveillance and monitoring during and after extreme events, including the monitoring of emergency department visits.
- Following mental health best practices that supports different interventions depending on the timing and level of distress of a disaster.(343)
- Adaptation planning within the mental health system and community-based planning or interventions that are forged upon concepts of hope and resilience rather than maladaptation and despair.
- Special training for first responders in psychological first aid.
- Encouraging people to engage in biological restoration (e.g., planting trees, gardening) and stewardship to overcome feelings of ecoparalysis.(344)

A recent review (345) compliments this list, where in addition to the criteria above, the authors argue for:

- Robust training on climate change and mental health for all health professionals to establish a community of practice that supports care providers who deal with anticipated changes to mental health status.
- For those working in care and service delivery, enhanced clinical assessments of mental health impacts associated with climate change and support are required, where emotions of anxiety and grief might assist people in making positive changes in their lives and support the implementation of climate solutions.



- Proven individual and group therapy strategies need to be scaled-up for vulnerable populations in cases where loneliness, isolation and shame can be countered by interpersonal strategies of bringing people together to build social capital through shared experiences.
- Social prescribing tactics of mental health care providers and doctors can be leveraged to enhance connection to nature while promoting physical and mental health. Activities such as active transportation and spending time outdoors have significant mental health benefits, as does engaging in climate solutions work such as advocating for active transportation, urban green space, and reducing air pollution through clean energy initiatives.(346)
- Family-oriented strategies (i.e., acknowledging climate challenge as a shared threat, providing empathic communication, validating feelings of fear, and jointly directing goal-oriented activities that can mobilize hope) can provide opportunities for shared responses to external threats between parents and their children and youth.
- Culturally responsible and equitably delivered systems of care that redress underlying determinants and disparities in mental health status.

Strategies such as advocating for more urban green space and creating supportive opportunities for community connection can bolster social capital, and connections to both place and neighbours while also enhancing opportunities for physical recreation.(332,346,347)

These strategies have shown success in other jurisdictions. For example, Australia implemented a large funding package in response to recent forest fires that included free trauma-informed and developmentally appropriate counselling services for front line workers and individuals impacted by fires, telehealth services for rural and remote communities to improve access, care coordination and community grants to rebuild fire affected areas, and building partnerships with allied organizations such as schools, community groups and sports clubs to reduce stigma and the potential for discrimination.(348)

9.5.1 Existing Public Health and community adaptation strategies

Each Health Unit regularly collects surveillance data on mental health outcomes of concern and reports regularly on those outcomes. Both Health Units also produce mental health resources that speak to the evolving mental health status of resident populations. General findings from this work indicate that mental health across the study area is similar to Ontario overall, that physical and mental health are strongly related, and that social disadvantage is associated with poorer mental health.(57,342) As an additional example, Public Health staff at WDGPH developed an opioid tracking system (Flexible, Scalable, Accessible and Timely (FAST) Overdose Alert Platform) that works to quickly identify overdose patterns in the community and enhance response time.(349) Staff from ROWPH participate as members of the Waterloo Region Integrated Drugs Strategy to prevent, reduce or eliminate problematic substance use and its consequences with an emphasis on prevention and harm reduction. Each Health Unit also works collaboratively with community partners to conduct research and support allied organizations in understanding the nature of changes to mental health status across the study area and devise strategies and programs to intervene on a range of issues related to mental health including, but not limited to: urban and transportation planning, health service delivery, affordable housing, built environment, and homelessness initiatives.



Examples of these initiatives across the study area include:

- A 2018-2019 initiative led by the Rotary Club, Guelph YMCA, and Public Health staff which created an “Integrated Services Model for Youth” that speaks to challenges (e.g., transportation) for service access, and seeks to establish hubs of services across the community.
- The Waterloo Region Suicide Prevention Council’s implementation of two mental health strategies across the region that seek to connect community partners, raise awareness, and coordinate efforts to deliver programs that are well-received by clients.
- The establishment of the Waterloo Region Crime Prevention Council, the Well-being Waterloo Region initiative, and Children and Youth Planning Table of Waterloo Region are examples of allied initiatives that support service delivery across the region.

9.5.2 Possible community adaptation strategies identified by focus group participants

Several indicators and measurement tools to monitor the mental health impacts of climate change have been recommended based on their application in previous assessments. Examples of these include: investigating police records following extreme heat events for elevated incidence of violence or aggression, surveys of self-reported mental health following extreme events, interviews with care providers, and broader considerations of community mental health through adapted surveys (such as the [Generalized Anxiety Disorder Scale](#)).⁽³⁵⁰⁾ Incorporating climate change considerations and evidence into mental health program planning is also a key adaptive measure for Public Health and community partners.

Our focus groups revealed a feeling that all support services are constantly trying to “do more with less” which puts strain on resources and amplifies opportunities for staff burnout in program and service delivery. This can compound waitlists for essential mental health services and limit ability of individuals to access services. Community partners are exploring comprehensive “wrap around” services to support residents in accessing a multitude of local and provincially offered services, although it was noted that these are often not framed within the context of climate change. These include:

- Emphasizing positive and effective responses to mental health challenges in the region, including following Public Health Agency of Canada guidelines for positive mental health surveillance.
- Partnering with outdoor education and activities groups (e.g., conservation authorities, Boys and Girls clubs, sport, and recreation leagues, etc.) who use trails and waterways and providing education on the positive mental health outcomes associated with outdoor activities.
- Taking an intersectional approach to mental health that does not aim to pinpoint a single cause, but rather identify myriad life circumstances, neighbourhood contexts and factors that may play a role in individual suicidal ideation.
- Supporting social and mental health service providers with evidence and resources.



9.6 Conclusion

There is growing evidence that climate change is impacting the mental health of Canadians. However, beyond post-traumatic stress disorder following extreme weather, existing diagnostic and surveillance data may not be adequate to attribute the impacts of climate change to other 'psychoterratic syndromes' such as ecoanxiety, climate anxiety, solastalgia, or climate grief. Research suggests that populations with pre-existing mental health conditions may be at greater risk, but that climate impacts may have the potential to create conditions for broad population-level mental health impacts. Improving the monitoring and surveillance of climate-related mental health through concerted collaboration with community partners and social service agencies would help to build the evidence base and understanding of these impacts locally, and to identify interventions that would better support identified vulnerable populations.



10.0 Rapid Risk Assessment of Climate Change and Health Risks : Key Findings

Background

- This chapter describes the development and implementation of Rapid Risk Assessment tool used to rank climate-related impacts and Public Health risks identified in previous chapters.
- Climate events considered in the Rapid Risk Assessment include: extreme heat and cold; air quality; ultraviolet radiation; severe thunderstorms and winter storms; flooding; food- and water-borne illnesses; vector-borne diseases; and harmful algal blooms.
- The results of the Rapid Risk Assessment provide a comparison of the relative risks between key climate-related health impacts the study area is currently facing and can expect in the future; and will support prioritization of adaptation strategies.

Methodology

- The Rapid Risk Assessment tool was developed using best practice approaches outlined by the WHO, Health Canada, and Emergency Management Ontario.
- A 5-point Likert scale was used to rank the likelihood and consequence of climate-related exposures at present and into the future.
- The Rapid Risk Assessment tool was developed to measure the likelihood and consequences of climate-related health risks. Rankings examined both present and future risks to public health.
- The likelihood of climate-related exposures was evaluated using data on:
 1. The frequency of climate events, and
 2. The likelihood (or degree) of population exposure.
- Consequences of climate events were also evaluated using two measures:
 1. Health outcomes associated with exposure, and
 2. Impact on vulnerable populations.



- A novel scoring approach was developed and used to assess risk. A separate set of scoring criteria was used to assess present risks and future risks.
- Risks were scored independently by each member of ROWPH, WDGPH, and the ICLEI project team before employing a consensus-based decision-making approach to build agreement where scores were different across teams.
- Risks were plotted to illustrate the threat of climate impacts on health locally.

Results

- The results of the Rapid Risk Assessment identified extreme heat and poor air quality as the most impactful climate-related health risks now and into the future. Increased summer temperatures, as well as longer and hotter heatwaves, have the potential to increase burden of health outcomes related to extreme heat exposure. Additionally, adverse impacts to air quality are expected to become more frequent as ground-level ozone (the main component of smog) becomes more prevalent on hot, sunny days.
- Flooding will pose an increased risk to health into the future due to an increased likelihood of extreme precipitation and annual increases in precipitation (particularly in spring and autumn).
- Vector-borne disease is projected to become an increasing risk in the future as increased annual temperatures make the study area more hospitable to disease-carrying vectors.
- Extreme cold was the only risk assessed that is projected to decrease in both likelihood and consequences, as winter temperatures are projected to rise in the future.
- Risks to monitor that were outside of the scope of the Rapid Risk Assessment include cascading climate events, food and water security, and the mental health impacts of climate change.



10.1 Background

The Climate Change and Health Vulnerability Assessment contains key information about health-related climate exposures, sensitivities, and adaptive capacity under a changing climate. Following guidance from the WHO,(351) Health Canada,(352) and Emergency Management Ontario,(353) this chapter outlines the process for implementing a Rapid Risk Assessment drawing from best practices in risk assessment and the aforementioned vulnerability assessment. The purpose of this chapter is to use information on the likelihood and consequence of climate impacts to prioritize health risks and related adaptive actions in the near term (i.e., the next five years) and in the future (i.e., by 2050).

10.1.1 Overview of Rapid Risk Assessment

A health “risk assessment is a systematic process for gathering, assessing, and documenting a level of risk”(351), where risk is typically expressed as a function of:

1. The likelihood of an event or exposure occurring, and
2. The consequence, or impact of that event or exposure, on a population’s health.(351)

Accordingly, health risk assessments are oriented towards understanding the likelihood of an exposure to a particular hazard if no action is taken, and the magnitude or severity of consequences of that hazard to public health if the hazard were to occur and created potential for exposure to harm. Health risk assessments are used to rank particular health hazards to help prioritize future actions for risk mitigation or adaptation, where high likelihood / high consequence events may require more resources than those characterized as low likelihood / low consequence events.

Results of the Rapid Risk Assessment as related to the health impacts of climate change will provide guidance to the Health Units on present and future health risks the study area is facing, and will support the prioritization of actions to reduce risks now and into the future. Risks that were outside of the scope of the Rapid Risk Assessment due to lack of available attributive data have been identified as risks to explore in the future.

10.2 Risk assessment methodology

10.2.1 Process

The project team led by ICLEI, WDGPH, and ROWPH conducted Rapid Risk Assessments for the health impacts of climate change using criteria for both the present (assessing the consequences of events happening today) and the future (based on best evidence of 2050 climate risk). The Rapid Risk Assessment used both quantitative and qualitative data in the assessment. Quantitative data included baseline climate data, future climate projections, available public health information on burden of disease, and demographic data on known vulnerable populations. Qualitative data was developed based on the extrapolation of population exposure to future projected climate risk, and used to reconcile scoring in the case of disagreement between multiple analysts.

The project team began by scoping which climate risks would be included based on attributive data available in the



vulnerability assessment. A scoring framework for characterizing both likelihood and consequence at present and in the future (i.e., 2050) was developed by the project team and is described in this chapter. The approach to scoring was applied to present and future risk assessments as outlined in Tables 36 through 39, drawing from data from the Climate Science Report(4) and Chapters 3 through 9. Each team member independently assessed and scored climate risks to human health according to the scoring criteria. Team members from the three respective organizations met to employ a consensus-based decision-making approach to build agreement where scores were different across independent reviewers. Finally, all team members from all three organizations met for consensus-based decision-making to build agreement across teams where organizations had different risk rating scores.





10.2.2 Assessing likelihood of climate events

Likelihood was scored on a 5-point Likert scale where a score of one represents low likelihood, and five represents high likelihood. Key criteria used to assist with scoring were developed for both present and future risk. Table 36 outlines the approach to scoring present risk. Note that likelihood at present is defined as a function of both the likelihood of a climate event occurring, as well as the degree of population-level exposure to the climate risk. Each climate risk was scored on a scale of one to five, with the final likelihood score being an average of the two values.

Table 36. Present climate change likelihood scoring criteria

Likelihood Ranking	Frequency of Climate Event	Degree of Population-level Exposure to Climate Risk
Highly Likely (5)	Already occurs several times per year; acute events more likely than not (>50%)	Broad or widespread population exposure is highly likely (>50% of population)
Likely (4)	Occurs about once per year; acute events have a 50/50 chance of occurrence	Broad or widespread population exposure is likely (about half of population)
Neither Likely nor Unlikely (3)	Occurs less than once per year on average, but may occur multiple times every five years; probability of single events less than 50% but still quite high	Broad or widespread population exposure is moderately likely (<50% of population, but still quite high)
Unlikely (2)	Occurs much less than once per year on average, but may occur multiple times every 5-25 years; probability of acute events is low but noticeably greater than zero	Broad or widespread population exposure is unlikely (but noticeably greater than 0% of population)
Highly Unlikely (1)	Almost never occurs once per year on average, and unlikely to occur even once every 25 years; probability of acute events is very small and closer to zero	Broad or widespread population exposure is highly unlikely (very small % of population or closer to zero)



Table 37 outlines the scoring criteria used to assess the likelihood that exposure to climate risks will increase or decrease in the future. In order to capture the dimension of time, a different scoring system was used for future risks and accounts for the expected change in exposures as a result of climate projections under RCP8.5 in 2050. Given that the future scoring criteria only has one scoring component, no averaging of multiple dimensions of likelihood was required to calculate future likelihood scores. Thus, the present and future risk plots depicted in the results cannot be directly compared, but rather, the comparative dimension is 'built into' the scoring criteria for future risk.

Table 37. Future climate change likelihood scoring criteria

Likelihood Ranking	Frequency of Climate Event
Highly Likely (5)	Climate phenomenon has or is expected to significantly increase health exposure relative to the present
Likely (4)	Climate phenomenon has or is expected to moderately increase health exposure relative to the present
Neither Likely nor Unlikely (3)	Climate phenomenon did not or is not expected to change degree of health exposure relative to the present
Unlikely (2)	Climate phenomenon has or is expected to somewhat reduce degree of health exposure relative to the present
Highly Unlikely (1)	Climate phenomenon has or is expected to significantly reduce degree of health exposure relative to the present

10.2.3 Assessing consequence of climate-related health impacts

Consequence ratings considered two factors: 1) health impacts linked to each climate change risk; and 2) impacts to vulnerable populations identified as being at higher risk to a given climate change risk. Each component was scored on a five-point Likert scale, using the information for each health risk outlined in the Climate Change and Health Vulnerability Assessment. The final consequence score is computed as an average of each of these two component scores. Table 38 describes the scoring criteria for present risk.



Table 38. Present health consequence scoring criteria

		Rationale
Consequence Rating	Health Impacts	Effects/Consequences on Vulnerable Populations
Very High Impact (5)	Large number of fatalities, serious injuries or illnesses, broad population impacts	Highest proportion of vulnerable populations; evidence suggests climate risk is seriously and differentially impacting vulnerable populations
High Impact (4)	Some fatalities, serious injuries or illnesses, moderate population-wide impacts	High proportion of vulnerable populations; evidence suggests climate-risk is differentially impacting vulnerable populations
Moderate Impact (3)	No fatalities, but a moderate number of injuries or cases of illness	Moderate proportion of vulnerable populations; evidence suggests climate-risk has moderately impacted vulnerable populations
Low Impact (2)	Near misses or minor injuries / low burden of health outcomes	Low proportion of vulnerable populations; evidence suggests climate risk is equally likely to impact vulnerable/non-vulnerable populations
Very Low Impact (1)	Appearance of threat, but no actual harms to population health	Lowest proportion of vulnerable populations to climate risk; evidence suggests climate risk does not differentially impact vulnerable populations

A five-point Likert scale was again employed for future risk. The scoring criteria for consequence ratings accounted for increases in the frequency and impacts associated with climate projections into 2050. This framework allowed for the present exposure to climate events and burden of health outcomes to be considered against a future projected burden of health outcomes to better prioritize action and adaptation measures to mitigate future risks. Consequence ratings considered both the burden of health outcomes and effects on vulnerable populations relative to the present. Low scores are assigned to events that are expected to decrease burden of health outcomes and effects on vulnerable populations. These scores were averaged to provide overall consequence ratings for future risk. Table 39 outlines the scoring criteria for future consequence.



Table 39. Future health consequence scoring criteria

Consequence Rating	Rationale	
	Health Impacts	Effects/Consequences on Vulnerable Populations
Very High Impact (5)	Significantly more deaths and illnesses relative to present	Evidence suggests climate risk will seriously and differentially impact vulnerable people/communities in the future
High Impact (4)	Moderate increases to deaths and illnesses relative to present	Evidence suggests climate risk will moderately increase impacts to vulnerable people/communities in the future
Moderate Impact (3)	No changes to health impacts relative to the present	Evidence suggests impacts on vulnerable populations are not expected to change relative to the present
Low Impact (2)	Slight decreases to deaths and illnesses relative to present	Evidence suggests vulnerable populations will be less impacted in the future
Very Low Impact (1)	Significant reduction in deaths and illnesses relative to the present	Evidence suggests vulnerable populations will not be impacted in the future

10.2.4 Creation of risk plots

Risk scores were plotted in charts where the y-axis represents the likelihood rating, and the x-axis represents the consequence rating.⁽³⁵⁴⁾ These risk plots present the distribution of scores for each climate risk in relation to others.

10.2.5 Limitations

A different approach to scoring criteria was used for future risk to allow for a clearer differentiation of present and future risk. Accordingly, the direct comparison of risk plots for present and future risks is not possible, as each risk plot conveys different information.



Further, while multiple experts from three teams were involved in risk scoring to create the comparative analysis results presented below, this is still a relatively small cohort of risk assessors, and due to timing and resources, this analysis did not engage a larger group of experts to conduct the risk assessment.

Due to a lack of sufficient data, and challenges related to predicting the cascading effects of climate change on particular public health outcomes, several climate risks were not ranked in this exercise. These risks have been identified as areas with local data gaps that may require future exploration and study and are described in the following paragraphs.

The impacts from cascading risk events (i.e., public health outcomes resulting from simultaneous climate events such as extreme heat and poor air quality) were not considered as part of the risk assessment due to a lack of sufficient local data. It is understood that these climate risks in isolation institute a public health risk that will likely be exacerbated by the presence of multiple climate related risks. In the future, more sophisticated risk assessment templates may be necessary to adequately account for overlapping and cumulative events, and their impacts on overlapping population groups (see Simpson et al. 2021 for an example risk assessment framework that considers climate change complexities such as cascading risk events).(355)

Mental health impacts can result from a variety of climate-related risks including post-traumatic stress disorder (PTSD) due to extreme weather events such as heat waves or flooding, and eco-anxiety caused by the “deep fear of environmental doom and human catastrophe.”(356) To date, there is little data to support a risk assessment of the effects of climate change on mental health due to a lack of data that causally links mental health conditions to climate change locally.

Food and water security were not considered in the risk assessment for several reasons. Food security in Ontario is linked to a global system of maritime, coastal, and inland networks to move both food and fertilizers.(357) As the climate continues to warm and seasonal precipitation becomes less predictable, there are both opportunities and risks to global and local food production that are difficult to estimate or quantify. Water security in Ontario has the potential to be affected by changing lake water levels and increases in summertime and annual temperature. Assessing impacts to water security requires complex hydrogeological study and was beyond the scope of this project.

10.3 Results

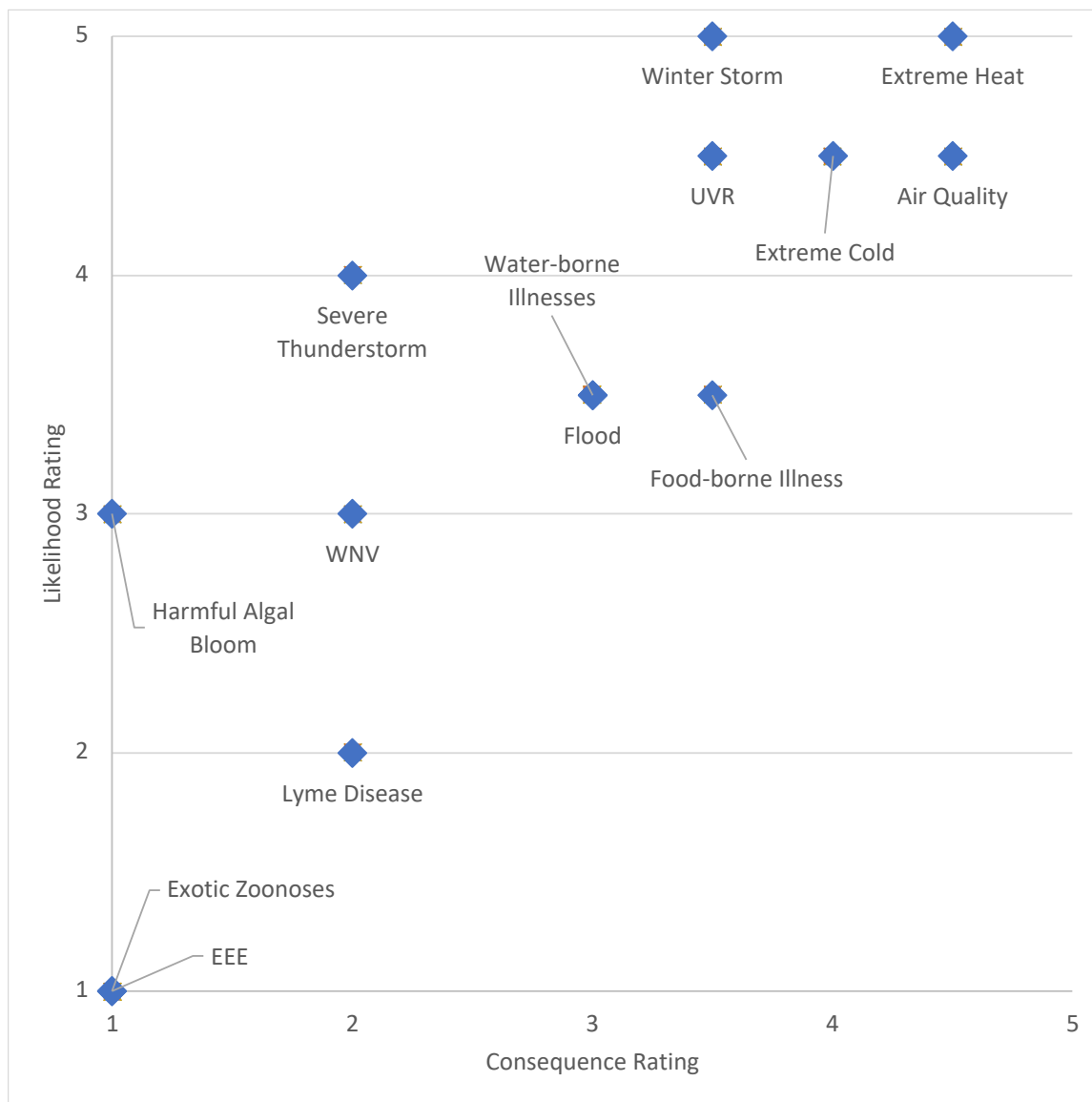
Overall, there was broad agreement between the multiple teams scoring each component of risk. Of the 168 independent scores assigned, the teams had a 93% inter-coder reliability score. For the remaining nine scores (7% of all assigned scores), the consensus-based process described above was used to finalize risk scoring and the results are presented below.

10.3.1 Present risk

The results for the assessment of present risk are displayed in Figure 45. Results indicate that extreme heat and air quality are ranked as higher health risks at present, followed by extreme cold, severe winter storms, and ultraviolet radiation. Exotic zoonoses, eastern equine encephalitis (EEE), harmful algal blooms and West Nile virus were ranked as lower health risks at present.



Figure 45. Risk plots for present climate change and health risks



When compared with stakeholder perceptions of risks collected from a survey conducted in late 2019 (see both Chapter 3 of this report for further information on the survey methods and Appendix 2, the results suggest agreement with the pre-existing perceptions, although the scoring criteria here suggest a greater potential risk overall than what was perceived by community stakeholders. Also, the results presented here do not include mental health considerations which were ranked among the highest risks perceived at present by community stakeholders. Stakeholders ranked heat-related illnesses, cold-related illnesses, UVR, injuries from extreme weather, and air quality concerns as the highest priority concerns for the study area.



The results of the Rapid Risk Assessment therefore have a high degree of alignment with existing local perceptions of climate-related health risks at present. Thus, actions that reduce vulnerability to extreme heat, poor air quality, extreme cold, winter storms, and UVR should be prioritized in the near term.

10.3.2 Future risk

The results for the assessment of future risk (i.e., in 2050) are displayed in Figure 46. It should be reiterated that due to the different approach to scoring, the two plots are not comparable, as the dimension of comparability between present and future risks is a component of the scoring process for future risk. Results indicate that extreme heat will continue to be the highest priority climate change and health risk into the future, followed by health risks posed by poor air quality, and flooding linked to extreme precipitation events. The Rapid Risk Assessment further projects that water-borne illnesses, Lyme disease, exotic zoonoses, and West Nile virus are likely to be of greater severity and likelihood in the future, while harmful algal blooms, severe thunderstorms, and winter storms may increase in likelihood, but that the consequences will present as similar to the present. UVR is anticipated to be largely unchanged in terms of likelihood and consequence, EEE is projected to potentially increase in burden of health outcomes, and extreme cold is projected to decrease in terms of both likelihood and consequence.

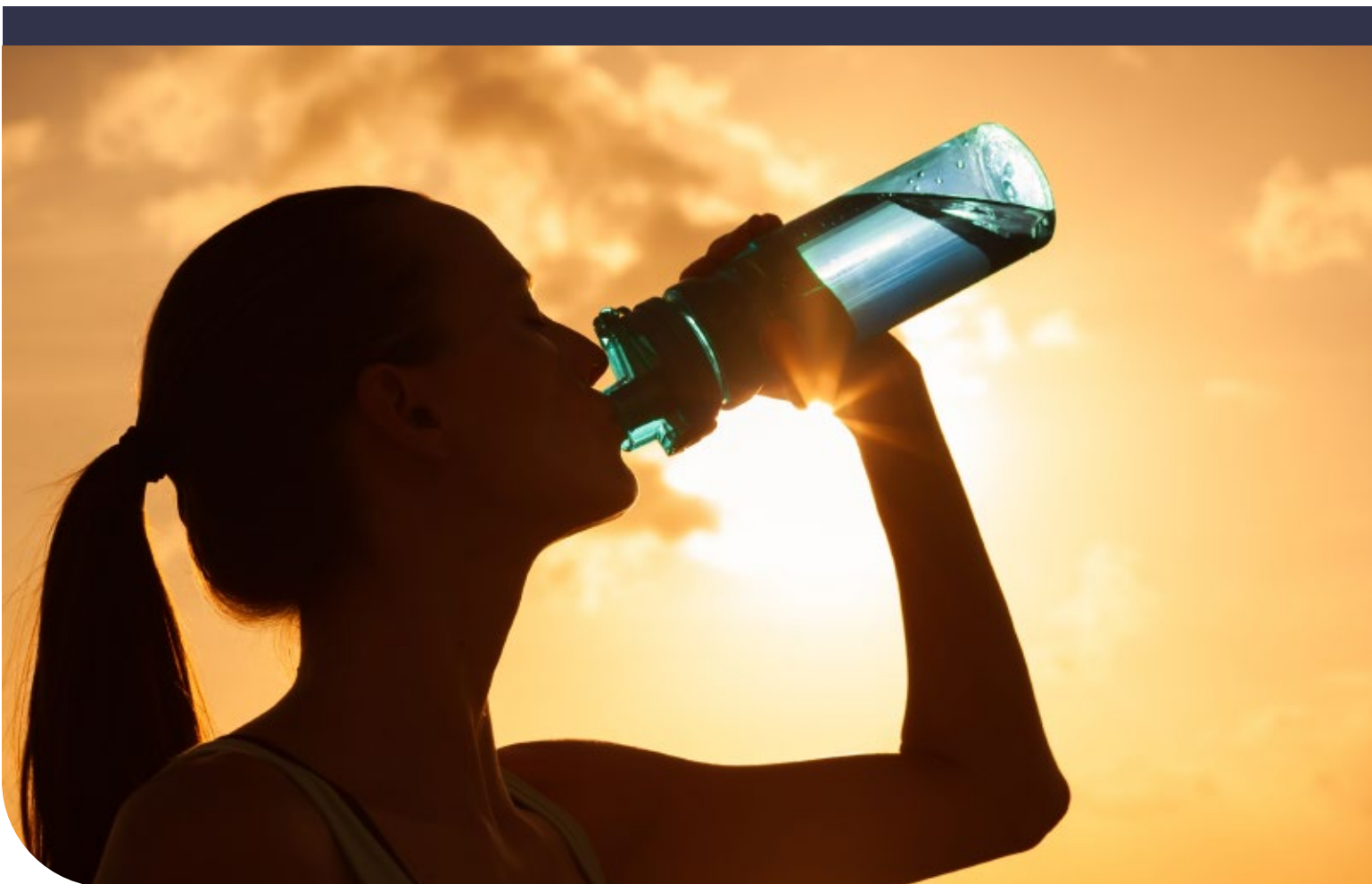
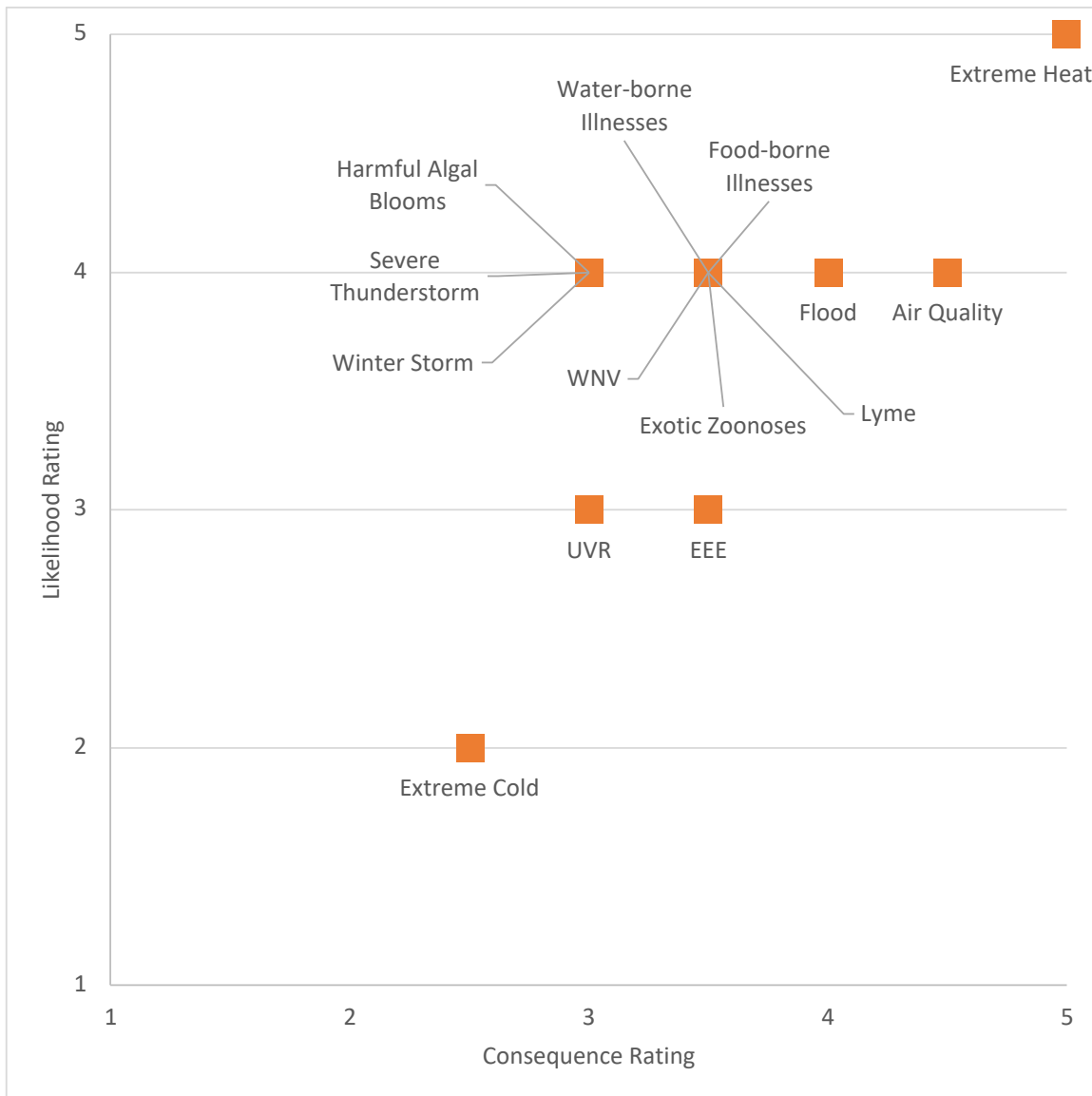




Figure 46. Risk plot for future climate change and health risks



The results of the future assessment are unable to be directly compared to the results of the stakeholder survey that assessed perceived health risks because of the difference in approach to scoring. However, it is notable that there is some agreement that heat-related illnesses and health impacts related to air quality were identified as high-risk future events by stakeholders. Future engagement with community stakeholders to replicate the above process could enable Public Health staff to better understand additional elements of perceived future climate risks, which can be cross-referenced with both the Climate Science Report and the broader findings of this vulnerability assessment.



10.4 Conclusion

The results of the Rapid Risk Assessment may help each Public Health Unit focus its efforts to achieve the greatest gains in population health from both health protection and promotion activities. The results indicate that now and into the future extreme heat and poor air quality are key issues of concern with high likelihoods of worsening over time, have broad population exposure, and are more likely to affect vulnerable populations. These aspects of climate change should be prioritized in terms of surveillance and reporting. Additional research is required to establish attributive and causal links between local acute climate events and impacts to population health.

Considering existing health promotion and protection activities through the lens of climate change, and using key data and information provided in this Climate Change and Health Vulnerability Assessment report, can enable local decision makers and staff involved in programming to review and adapt programs and interventions to address health risks anticipated to worsen into the future. This process of assessing health risks (as higher or lower risk) can also be used to identify and prioritize additional adaptive actions outlined in the adaptation assessment component of this project.





11.0 Adaptive Actions and Next Steps

Climate change is already impacting the health of people who live, work, and play across Waterloo Region, Wellington County, Dufferin County, and the City of Guelph. This assessment describes known vulnerabilities and establishes historical baselines for climate-sensitive diseases to better understand changes to health status in the future. A key goal of this assessment is to support the identification of present and future adaptation options that can enhance community resilience and reduce the health burden of both acute climate events and changes to the distribution of climate-sensitive health risks over time. Importantly, Public Health authorities, in partnership with municipal, regional, provincial, and other community partners, will be required to both mitigate and adapt to climate change to reduce current and future impacts on individuals and communities, and the costs associated with these impacts will increase without appropriate actions.

To that end, each Public Health Unit has already begun identifying possible adaptation options through literature reviews and engagement with community stakeholders. However, further work with community partners will be required to prioritize actions, consider cost-effective solutions, and meet the challenges of improving population health while also protecting those who are most vulnerable to the ill-health effects of climate change. The following sections share a sample of these results.

11.1 Evidence review of adaptive actions

The evidence of effectiveness for particular interventions that enhance population health outcomes related to climate change is a rapidly growing field, relying mostly on case studies and pilot projects. Drawing from key systematic reviews of the evidence—and conducting key searches for literature from 2017-2021 for each identified climate health risk—found that there is a patchwork of practices that may be effective at reducing health risks, but that more research, evaluation, and participation in knowledge networks to learn about programming in other contexts will be necessary to tailor particular approaches to local contexts.

The review is available upon request and identified a number of detailed adaptation options that range from the personal to the community level, and some of the actions identified may already be incorporated into local plans and programming, and local stakeholders revisiting or initiating local adaptation planning processes. However, further collaborative engagement on adaptation options will be required to assess feasibility for local implementation.

11.2 Existing initiatives supporting climate change and health locally

There are a number of adaptation actions and initiatives already underway across the study area. This assessment can be used to further support the efforts of local partners in the design and implementation of programs that both mitigate climate change and build adaptive capacity to climate change locally by illustrating the health impacts to climate change and importance of addressing these for the health of the community now and into the future. It is especially important to consider opportunities for co-benefits for health when decision-makers in other sectors (such as water, transportation, energy, housing, built environment, agriculture, waste management, and conservation) can promote health and health equity by adapting to and mitigating climate change. This presents considerable



opportunities for Public Health staff to partner with local initiatives and bring a 'health lens' to planning activities.

11.2.1 Municipal Climate Change Action Plans

A number of municipalities throughout the study area have completed, or are in the process of completing, climate change action plans to help maintain community health and address climate change from a municipal perspective. The action plans cover mitigation and/or adaptation, and consider actions at the corporate and/or community levels. The following list shares some examples of local climate adaptation planning activities in the study area at the municipal level.

- **Community Climate Adaptation Plan for Waterloo Region:** The development of the Community Climate Adaptation Plan for Waterloo Region was undertaken as a community-wide effort facilitated by the Region of Waterloo and supported by municipalities, organizations, and community members from across the region. The Community Climate Adaptation Plan for Waterloo Region identifies how climate change will affect the community and includes 36 actions to inspire and involve community members in preparing for local impacts of climate change. These actions are divided across four themes including: health and community, the built environment, the natural environment and water, and energy and the economy.
- **City of Waterloo Corporate Climate Change Adaptation Plan:** The purpose of the Corporate Climate Change Adaptation Plan is to increase the adaptive capacity and resiliency of the City of Waterloo's assets and services to future climate impacts, and to integrate climate change adaptation into day-to-day operations corporately.
- **City of Kitchener Corporate Climate Action Plan:** The City of Kitchener's Changing for Good plan responds to both climate mitigation and adaptation by setting targets to reduce greenhouse gas emissions, increase resilience to address current and future vulnerability, and integrate climate change into decision-making. Corporate adaptation actions include the Alert Waterloo Region program to distribute important public safety messages during extreme weather events, and the implementation of operating practices and training related to heat stress and reduced air quality on corporate staff.
- **City of Cambridge Climate Adaptation Plan:** The City of Cambridge Climate Adaptation Plan was prepared to address the potential impacts of climate change. The purpose of their climate adaptation planning is to identify where existing and planned buildings, infrastructure, programs, and services could be vulnerable to climate change impacts. The plan is based on the principles of a) public and staff safety, b) property protection, and c) service delivery to the community. Through assessing the City of Cambridge's risks and vulnerabilities, the City of Cambridge has laid the foundation for making more informed decisions into the future.
- **TransformWR Community Climate Action Strategy:** TransformWR is a strategy that will guide Waterloo Region's transition to an equitable, prosperous, resilient low-carbon community by 2050. The strategy was designed through the ClimateActionWR collaborative of municipalities and non-profit organizations with considerable public engagement, and was endorsed by all municipal councils in Waterloo Region in June 2021, including the Townships of North Dumfries, Wellesley, Wilmot, and Woolwich, the Cities of Cambridge, Kitchener, and Waterloo, and the Region of Waterloo. The strategy focuses on achieving Waterloo Region's clean energy transition by



transforming the ways we: move; operate and build spaces; produce, consume, and waste; and relate. While the focus of the strategy is on climate change mitigation, it takes a holistic approach and aims to use the energy transition to increase resilience and equity.

- **Wellington County Climate Change Mitigation Plan**: The County of Wellington’s Future Focused plan identifies strategies to reduce greenhouse gas emissions across sectors while integrating climate change into corporate decision-making and service delivery. Following guidance of the County’s Strategic Action Plan, Future Focused prioritizes four main goals: health and wellness, affordability and accessibility, economic development, and the local environment. Future Focused draws a direct link between mitigating greenhouse gas emissions and benefits to community health in regards to air quality impacts, extreme heat days, and the associated negative health outcomes experienced by vulnerable populations.
- **Dufferin County Climate Action Plan**: The Dufferin Climate Action Plan is a strategy for Dufferin County, local municipalities within Dufferin County, and community members to reduce greenhouse gas emissions and build climate resiliency through to 2050. The Dufferin Climate Action Plan was created through broad research and community engagement, as well as input from the public and the Dufferin County Climate Change Collaborative. This plan helped to shape the vision statement for Dufferin County’s climate future: “enhancing the health and well-being of community members; building equitable and vibrant neighbourhoods; preserving and enhancing local biodiversity and natural systems; and fostering a prosperous and innovative local economy.”
- **City of Guelph Strategic Plan**: The City of Guelph’s Strategic Plan identifies an action to create and execute “an ambitious and achievable” climate adaptation plan that includes a) investing in “green” infrastructure to prepare Guelph for the effects of climate change, and b) increasing Guelph’s tree canopy. To move forward with these actions, the City of Guelph is currently developing a Community Climate Adaptation Plan. This plan will outline how the City of Guelph will adapt its policies, plans, assets, operations, and services to the impacts of climate change. The City of Guelph Community Climate Adaptation Plan will serve as a comprehensive document, outlining all existing and planned adaptation actions across the organization. While their plan will focus primarily on corporate-led adaptation actions, it will also encourage community-led actions as well.
- **Town of Orangeville Climate Change Adaptation Plan**: The Town of Orangeville has established a commitment to advancing climate change adaptation efforts across the corporation to manage, minimize, or eliminate the local risks and impacts associated with climate change. As part of this commitment, the Town of Orangeville is in the process of developing a Climate Change Adaptation Plan. This plan aims to increase the Town of Orangeville’s capacity to cope with the risks of climate change. The plan will outline how the Town of Orangeville will adapt its assets, operations, and services related to climate change impacts.



11.3 Looking to the future: Possible adaptive actions that can reduce health risks of climate change

The recent Health of Canadians in a Changing Climate report(358) outlines some additional ways in which health sector partners can build resilience into near and long-term planning. In particular, it highlights how the health system's capacity for adaptation is influenced by:

- Having appropriate leadership and governance structures that elevate climate change as a priority health risk and develop accountability structures to advance mitigation and adaptation;
- Ensuring the workforce is knowledgeable about the health impacts of climate change and is equipped to respond;
- Building health information systems that incorporate the best available research evidence so that information on vulnerabilities can be shared across organizations and sectors to take proactive action, and that early warning systems are in place to support community preparedness;
- Bringing a climate lens to existing service delivery to build climate-informed health programs that are attentive to the environmental determinants of health while also providing robust emergency response;
- Using sustainable technologies and infrastructure to reduce health sector emissions; and
- Ensuring the climate and health portfolio is well-financed.

The Canadian Institute for Climate Choices The Health Costs of Climate Change report(359) assesses the many ways in which climate change is affecting human health and how that will intensify in the future. The report identifies air quality, extreme heat and heatwaves, Lyme disease, mental health, and strain on health systems as some of the most complex and costly impacts of climate change all levels of government must face. The report also underscores that health impacts and equity are fundamentally linked, and only by addressing factors like poverty and racism can adaptation measures be successful. Thus, building resilience and adaptive capacity to reduce health risks is not just the responsibility of the health sector. The report advocates that:

1. All orders of government should implement health adaptation policies to address both the symptoms and root causes of climate-related health threats;
2. Canada's emerging national adaptation strategy should map all key adaptation policy levers across government departments and orders of government against top climate health impact areas;
3. Central agencies in federal, provincial, and territorial governments should explicitly incorporate health resilience in climate lenses to inform cost-benefit analyses and policy decisions; and
4. Government should invest in research on emerging, unknown, and local climate change health impacts.

In addition to these activities, at a stakeholder engagement session in December 2021, Expert Task Force members were asked to identify possible interventions or initiatives to help improve adaptive capacity related to the top three risks identified by the Rapid Risk Assessment outlined in Chapter 10: extreme temperatures, extreme weather, and



air quality. The following is a sample of the ideas generated at this event that may be considered by community stakeholders or Public Health authorities in the future.

Extreme Temperatures

- Identify areas with free public access to water.
- Provide free transit on days with Heat Warnings or Extreme Cold Warnings.
- Provide educational programs at schools and universities related to extreme temperatures.
- Coordinate communications to target messaging for populations in long-term care.
- Build on partnerships built during COVID-19 vaccine roll-out to reach additional partners.
- Monitor and report on health-service utilization during and following extreme temperature events.
- Provide subsidies for air-conditioner rentals for low-income households and other vulnerable populations or locations (e.g., long-term care facilities).
- Incorporate climate change messaging with other seasonal preparedness messaging.

Extreme Weather

- Identify critical and vulnerable infrastructure, and develop legislation and source funding for back-up power at critical sites during acute emergencies.
- Focus on energy efficiency strategies and energy transition for public and private buildings (to increase resilience to extreme weather-related power outages and reduce energy consumption thereby mitigating future climate change).
- Encourage the development of evacuation plans that address the needs of vulnerable populations, particularly individuals without access to vehicles and those living alone.
- Further investigate food access and food security during and following extreme weather events.
- Share existing information and best practices to keep local workers (particularly outdoor workers) safe in extreme temperatures and weather.

Air Quality

- Identify targeted actions to support low-income communities to help protect populations at higher risk.
- Establish a research collaborative with local universities on air quality and health-related outcomes.
- Incorporate cost and benefit information on green infrastructure (particularly trees) that can support project planning and assist decision-makers in prioritizing tree planting on public and private property.



- Support community climate mitigation plans and initiatives through data provision on health outcomes related to reduced air quality.

Future stakeholder engagement activities could focus on brainstorming similar adaptation activities for the remaining climate change and health risks identified in this report (i.e., UVR, vector-borne and zoonotic diseases, food- and water-borne illnesses, and mental health). In addition, more research is needed to support decision making related to adaptation planning and the specific ideas listed here. Further research and literature reviews could support evidence-informed decision making related to adaptation planning locally. Finally, since climate change mitigation efforts are increasing across all levels of government and in the community, they offer a critical opportunity to advance adaptation work simultaneously with energy changes that are being made to systems, infrastructure, and buildings.

11.4 Final Thoughts and Next Steps

The purpose of this assessment was to evaluate the climate-related health risks to residents in the jurisdictions of Wellington-Dufferin-Guelph Public Health and Region of Waterloo Public Health. The vulnerability assessment focused on addressing rising temperatures, extreme weather, as well as impacts to air pollution, ultraviolet radiation, vector-borne disease, food-borne illness, water-borne illness, and mental health resulting from climate change locally.

The key goals of this work are to: increase public and stakeholder awareness of the health impacts of climate change in our community; provide recommendations, based on local evidence, on priority areas to focus adaptive measures for decision makers and stakeholders to strengthen overall resilience of local health systems to respond to the impacts of climate change; and collect and share local information that supports creating and strengthening policy and programming that reduces health risks and builds resiliency to current climate variability and future climate change in our community.

The report provides a comprehensive overview of vulnerable populations and an understanding of patterns of climate-related vulnerability now and into the future. In addition, it provides baseline health information and outlines existing adaptive capacity within the Public Health Units and through community partners and organizations. Finally, the report includes a health risk assessment that considered the likelihood of an exposure to a particular hazard if no action is taken, and the magnitude or severity of consequences of that hazard to public health if the exposure were to occur.

Strengths of this Climate Change and Health Vulnerability Assessment include:

- Implementing numerous research methods, including literature reviews surveys, focus groups, and analyses of both environmental and health outcome data to assess and present a depth of findings related to the health risks of climate change. This information can be used to support future advocacy and adaptation planning processes to mitigate future health risks due to climate change locally.
- Reviewing the latest research and data to understand climate related impacts to health in the study area, and in particular, highlighting vulnerable populations to which programs can be targeted towards minimizing risks



created by population-level climate exposures (e.g., acute events, but also long-term shifts in climate that may lead to increases in ill-health outcomes and health service utilization).

- Highlighting adaptive actions that already exist in the study area that support addressing climate-related health impacts.

11.4.1 Next Steps

The information presented in this report provides a baseline collection of data, climate projections, and information related to vulnerable populations locally. It is hoped that this information will be used to inform climate change adaptation initiatives that are underway or under development throughout the study area; inform policy development; prioritize programming; and stimulate new research questions related to climate change and health for Waterloo Region and Wellington-Dufferin-Guelph. It is also hoped that the findings will facilitate incorporating a health lens when considering climate change locally, as well as support the coordination and collaboration with other sectors to promote climate-resilience that reduces health-related impacts of climate change.

While this assessment presents a range of baseline data and evidence to assess local vulnerabilities to climate change, additional work is required to address some of the gaps identified as well as to assess and prioritize appropriate interventions to address future impacts from climate change and increase resilience. Key aspects of this work could include working with community stakeholders to prioritize adaptive actions based on the projected future burden of disease, its impact on vulnerable populations, the strength of the evidence of a given intervention, and the costs and benefits of its implementation. Additional information is also needed to better understand the needs, barriers, and opportunities that specific communities and sub-populations have for improving adaptation and resilience.

11.4.2 Future Adaptation Planning

As described in the methodology section in Chapter 2, this Climate Change and Health Vulnerability Assessment provides a first step in assessing climate change health impacts and existing adaptive capacity within Waterloo Region and Wellington-Dufferin-Guelph. Next steps involve further adaptation assessment and adaptation planning to identify and prioritize adaptation measures suitable for Waterloo Region and Wellington-Dufferin-Guelph. In addition, further planning could be done to develop an iterative process for monitoring and managing health risks related to climate change over time.

Opportunities for adaptation measures that could be explored include:

- Filling knowledge gaps identified in the assessment and continuing research to provide longitudinal analysis of existing health data to monitor changes locally and inform future surveillance, planning, and programming.
- Further research to better understand community needs specific to vulnerable populations, as well as barriers and opportunities for adaptation.
- Further analyzing the data collected related to current adaptation initiatives, including evaluation of current initiatives and prioritization based on available evidence.



- Additional research into new and existing government agency reports related to climate change adaptation and the effectiveness of climate change and health interventions, such as systematic reviews of interventions, the United States CDC Climate and Health Intervention Assessment,⁽³⁶⁰⁾ and the newly released Health of Canadians in a Changing Climate report.⁽³⁵⁸⁾
- Establishing surveillance systems that monitor data from a climate change and health perspective – that link real-time hospital data to acute climate events, and connect the various health risks identified to the overarching concept of climate change (i.e., enhanced use of the Acute Care Enhance Surveillance [ACES] system). Having the ability to stratify key climate-sensitive health outcomes by population vulnerabilities would significantly enhance the predictive capacity of Public Health to support effective planning with and for vulnerable populations.
- Health promotion and risk communication initiatives focused on climate change and health impacts and adaptation measures to share health risk information and proactive actions that individuals and communities can take to prevent negative health outcomes.
- Coordinating programming within Public Health Units and collaborating with stakeholders across sectors to consider climate change and health impacts; and, connecting the various topic areas and fields to clearly identify the connections related to climate change and health.
- Integrating climate change considerations into existing Public Health programs, initiatives, and communications.
- Advocating for and developing policies and measures that support climate change adaptation to enhance health systems and community resilience to climate change.
- After determining suitable climate change adaptation options, cost-benefit analysis or multi-criteria analysis should be considered.

Wellington-Dufferin-Guelph Public Health and Region of Waterloo Public Health are well-positioned to support their local partners in addressing the multiple health impacts of climate change with opportunities to align Public Health adaptation planning with existing initiatives occurring across the study area. The evidence collected, analyzed, and presented in this assessment lays a foundation for building resilience in the health system to both acute and long-term climate-related impacts locally.

The health risks associated with climate change highlight the growing need for effective action on climate change adaptation across Canada. Adaptation can help to protect against these risks through informed action and decision-making that builds climate resilience, or the ability to thrive under new climate conditions. Climate change adaptation is a shared responsibility, and involvement by all levels of government, Indigenous Peoples, non-governmental organizations, the private sector, and individuals, is crucial. Community stakeholders must continue efforts to address the future health impacts of climate change and support creating more resilient communities.

“

The global climate crisis requires urgent, society-wide mobilization to provide children born today with the livable environment and functioning health systems they need to thrive in a climate changed world.

”

Lancet Countdown on Health and Climate Change



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Appendix 1. Glossary of Terms

Adaptation: The process of enhancing, developing, or implementing strategies and measures to moderate or cope with the consequences of probable climatic changes. In Public Health, adaptation can be synonymous with prevention of the health impacts of climate change.

Adaptive capacity: The ability of individuals, communities, and institutions to prepare for and cope with the consequences of climate variability and change.

Climate: 'Average weather' in a particular place over a particular time period; typically refers to statistically 'average' variability of weather variables (i.e., temperature, precipitation) over a pre-defined time period.

Climate change: Statistically significant variation of observed climate behaviour in either the mean state of the climate or in its variability. Climate change results from natural processes and persistent anthropogenic (i.e., human induced) changes to the composition of the planet's atmosphere with resulting shifts in regional weather patterns.

Exposure (to climate-related hazards): The differential degree to which a person or group is in contact with a factor, and the extent to which this level of exposure causes impacts to health; can also capture locations where exposure tends to occur or areas where exposure is greatest.

Fifth Assessment Report: The 2014 Synthesis Report (SYR) of the IPCC Fifth Assessment Report (AR5) provides an overview of the state of knowledge concerning the science of climate change, emphasizing new results since the publication of the IPCC Fourth Assessment Report (AR4) in 2007.

Greenhouse effect: A natural earth system process by which the sun's energy is reflected from the earth's surface, with some energy being absorbed and re-radiated by greenhouse gases. Absorbed and re-radiated energy are responsible for warming both the atmosphere and the surface of the earth.

Greenhouse gases (GHGs): Any gas in the atmosphere that absorbs and emits thermal infrared radiation which is the fundamental process involved in the greenhouse effect. Notable gases include carbon dioxide, water vapour, ozone, and methane.

Health: The complete state of physical, mental, and social well-being, and not merely the absence of disease or infirmity which can be expressed at both the individual and population level.

Health equity: Health equity is when all people (individuals, groups and communities) have a fair chance at reaching their full health potential and are not disadvantaged by social, economic and environmental conditions.

Health inequity: The unfair and avoidable differences in health status between population groups. Health inequities stem from unfair or unjust life circumstances and manifest in the form of inequalities in health status.

Intergovernmental Panel on Climate Change (IPCC): An intergovernmental body of scientists established by the United Nations, the World Meteorological Organization, and the United Nations Environment Programme to provide scientific assessments on the worldwide risk of global climate change and associated implications for humans and natural environments.

Mitigation: Efforts that reduce or prevent the emission of greenhouse gases into the atmosphere.

Population health: Population health describes an approach to health promotion that aims to improve the health status of an entire population and to reduce health inequity/inequality among and between population groups. A population health perspective considers a broad range of social, environmental, economic, and biological factors and conditions that influence human health and wellness.

Public Health: Public Health entities promote the health of populations by preventing morbidity and mortality through a broad range of research, programming, and policy activities.

Sensitivity: Refers to how individuals and/or populations are influenced by factors such as physiology, biology, genetic endowment, gender, or age in ways that make them more susceptible to the health impacts of climate change.

Social determinants of health: The non-medical factors that determine or shape health, such as the conditions under which people live, work, and play. These factors include economic policy, social norms, and political systems.

Representative Concentration Pathway (RCP): Representative Concentration Pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its fifth Assessment Report (AR5) in 2014. It supersedes the Special Report on Emissions Scenarios (SRES) projections published in 2000. RCPs usually refer to the portion of the concentration pathway extending up to 2100.

RCP2.6: Lowest projected GHG concentrations, resulting from dramatic climate change mitigation measures implemented globally. It represents an increase of 2.6 W/m² (watts of solar energy per square meter) in radiative forcing to the climate system.

RCP4.5: Moderate projected GHG concentrations, resulting from some climate change mitigation measures. It represents an increase of 4.5 W/m² in radiative forcing to the climate system.

RCP8.5: Highest projected GHG concentrations, resulting from business-as-usual emissions. It represents an increase of 8.5 W/m² in radiative forcing to the climate system.

Vulnerability: The degree to which a system is susceptible to or unable to cope with the adverse effects of climate change. Vulnerability is a function of a population's exposure to climate hazards, sensitivity to those impacts, and adaptive capacity.

Appendix 2 : Community Stakeholder Survey Results

In fall 2019, an online survey was distributed to community stakeholders in the study area to gather perspectives on present and future health risks and impacts due to climate change. Additionally, the survey provided an opportunity to collect information about existing programming across the study area that might support climate change adaptation. A total of 85 respondents participated in the survey. Most respondents worked in Social Services (25.4%), Public Health (16.9%), or Municipal or Regional Planning (16.9%). Other sectors represented included health care delivery, allied health services, civil engineering/public works, emergency response, climate change, civil society organizations and governance/decision-making. Approximately 38.8% of respondents identified as working within Waterloo Region, 22.4% from Wellington County, 22.4% from Dufferin County, and 15.3% from the City of Guelph, and most respondents (52.1%) identified themselves as “Decision-makers” when asked about their role. An additional 18.3% identified as being front-line staff, and 16.9% identified various other roles. This appendix presents a summary of selected results on vulnerable populations of concern and perceived present and future health risks due to climate change. Results shared about policies and programs that focus on climate change and health in the study area are summarized in Chapter 11 of this report. Full survey results are available upon request.

Vulnerable Populations of Concern

Community stakeholders were asked about population groups that they work with who may be vulnerable (either differentially exposed, physiologically sensitive, or who have low adaptive capacity) to the health impacts of climate change. Respondents reported an array of vulnerable populations that they engaged with through their work which are represented in Table A-1.

Table A-1. Vulnerable population subgroups that survey respondents’ organizations serve, N=85, 2019

Vulnerable Population(s)	%	Count
Infants and young children	11.43%	36
Pregnant women	9.52%	30
Older adults	10.48%	33
Indigenous peoples/First Nations	9.52%	30
People experiencing homelessness	12.38%	39
Outdoor workers	6.98%	22
People experiencing social isolation	10.16%	32

Vulnerable Population(s)	%	Count
People with pre-existing health conditions	9.21%	29
Newcomers	10.48%	33
People whose livelihood is tied to the land (e.g. farmers)	6.67%	21
Other (please explain)	3.17%	10
Total	100%	315

Risk matrices for present versus future climate change and health priorities across the study area

Survey respondents were asked a series of questions regarding climate change and health risks across the study area that were identified by the scholarly literature review. While ‘risk’ can be understood as the possibility of something bad happening, it is also conceptualized as a function of the severity of impact and likelihood of impact.

Respondents were asked to estimate on a four-point scale (where 1 was the low likelihood and 4 was high likelihood) the current likelihood of specific health impacts associated with climate change, and the current severity of specific health impacts (where 1 is low impact and 4 is high impact), and 58 completed responses were received. Respondents were also asked about future likelihood and severity of climate and health risks 25 years into the future. The results of this exercise produced two risk matrices—one for the present, and one for the future—where risk is a function of the likelihood and severity of a specific climate event (see Figures A-1 and A-2).

Results suggest that at present, injuries from extreme weather, mental health, UV radiation, and temperature related illness were perceived as the highest risk. Food- and water-borne illnesses, vector-borne diseases, damage to infrastructure, and air quality were identified as medium risk. Invasive species and wildfires were identified as lower risks locally from climate change. Cold-related illness was perceived to be the most likely of identified health risks at present, while mental health is perceived as having the greatest current impact.

When asked about the future (i.e., 25 years from now), temperature-related illness, mental health, UV radiation, air quality, and injuries from extreme weather were identified as the greatest health risks perceived from climate change. Food- and water-borne illnesses, vector-borne disease, and damages to infrastructure were identified as medium risk, and wildfires and invasive species were identified as lower risks. Heat-related illness was perceived to be the most likely and as having the greatest impact.

Importantly, all the values that reflect mean perceived risks increased for each health risk when comparing present perception to future perception. This indicates that most respondents consider climate change to have greater risks in the future relative to the present.

Figure A-1. Perceived current climate change-related health risks (N=58)

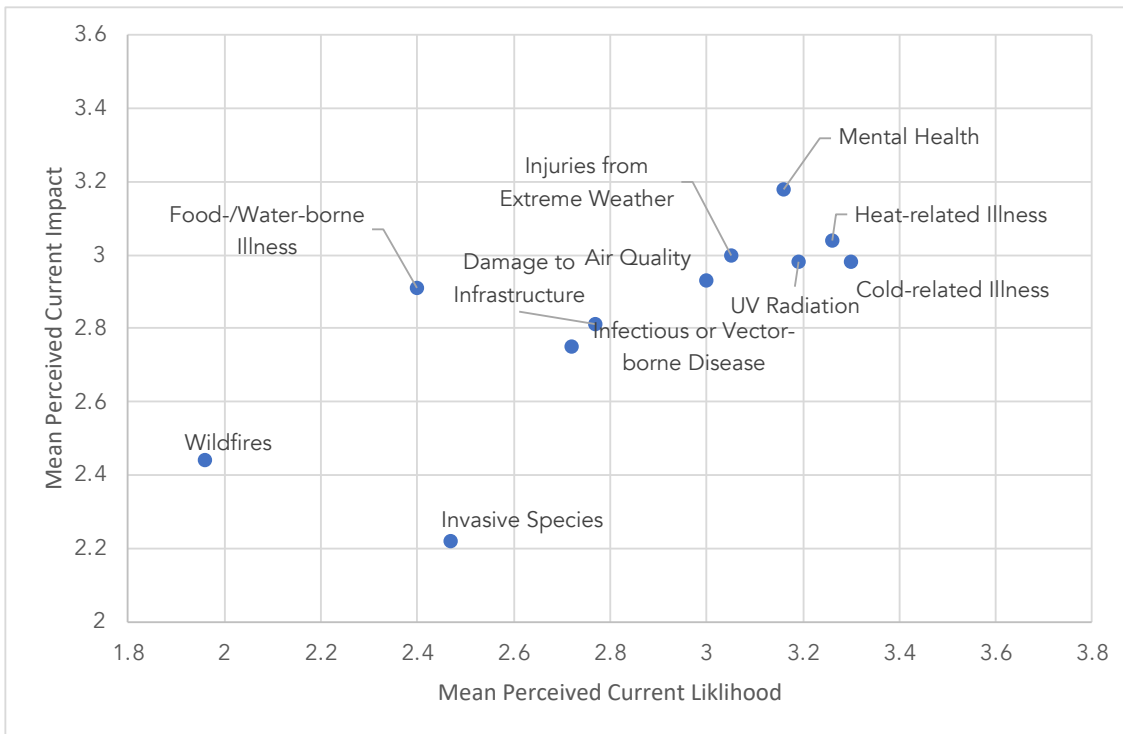
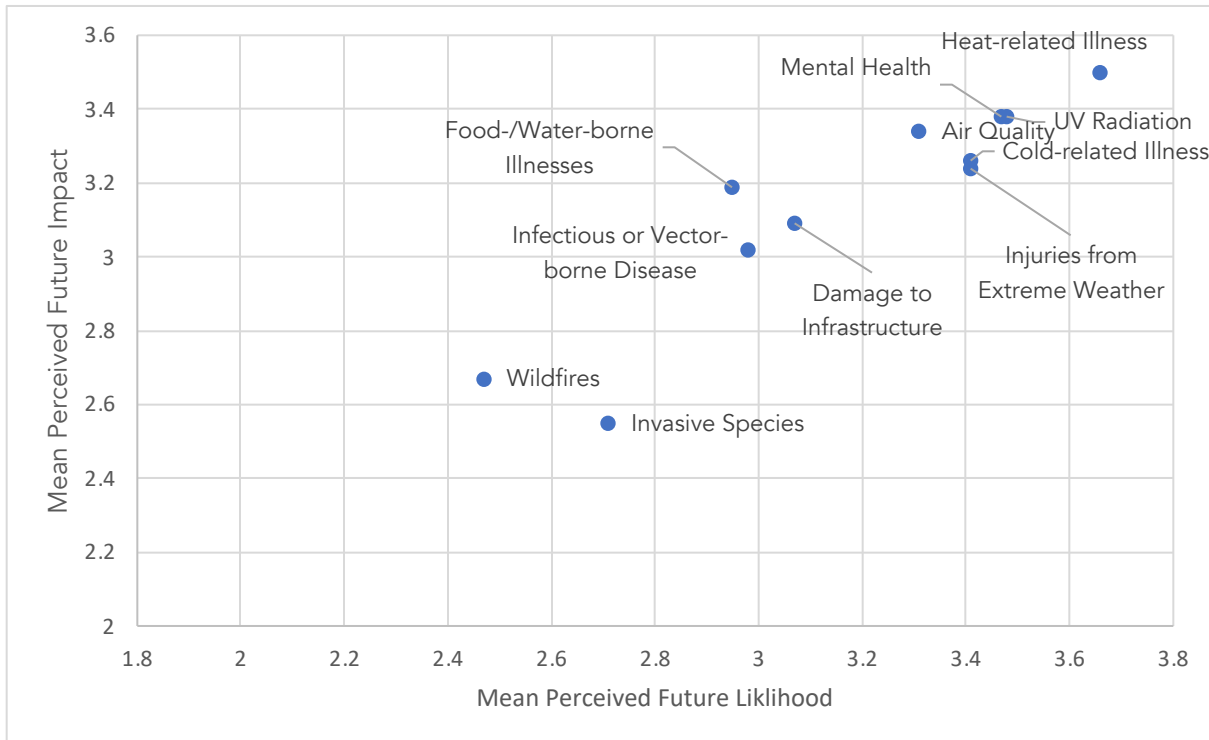


Figure A-2. Perceived future (i.e., 25 years from now) climate change-related health risks (N=58)



Appendix 3. Methodology for Calculating Population Exposure to Traffic-related Air Pollution

TRAP exposure rates for the study area were calculated at the level of census subdivisions (i.e., municipalities), and methods for calculations were derived from [Public Health Ontario's Ontario Health Profile—Technical Appendix](#). All mapping was conducted in QGIS Version 3.10.9 and data was re-projected to the NAD83 / UTM zone 17N projection. All data processing and charts were generated in R Studio Version 1.3.959.

Major roads and highways were filtered out of the road's dataset using classification terms specified in the PHO Technical Appendix, according to Ontario Road Network definitions. Three different TRAP areas were then created to extend from either side of a road feature by applying three distinct buffer sizes to each of these datasets. The three TRAP areas were: A) 50 metres from major roads and 50 metres from highways; B) 100 metres from major roads and 150 metres from highways; and C) 100 metres from major roads and 500 metres from highways. The population of each of the three TRAP areas was estimated by: 1) calculating a ratio by dividing the area of the TRAP buffer within a dissemination block by the total area of the dissemination block, 2) multiplying that ratio by the total population of the dissemination block. Values were then summed at the census subdivision level across the three TRAP groups.



TRAP exposure rates were calculated at the census subdivision (CSD) (i.e., the municipal level) by dividing the number of people within each TRAP group by the total 2016 population of the CSD, utilizing the following datasets:

- Census subdivision boundaries - Census Subdivision Boundary File, 2019, Statistics Canada Catalogue no. 92-162-X.
- Census dissemination block boundaries - Dissemination Block Boundary File, 2016 Census. Statistics Canada Catalogue no. 92-163-X.
- Population estimates by dissemination block - Geographic attribute file: census year 2016. Ottawa, ON: Minister of Industry; 2016. Available from: <http://www12.statcan.gc.ca/census-recensement/2011/geo/ref/att-eng.cfm>
- Roads - Ontario Road Network (ORN) Segment with Address - Land Information Ontario Data Class. Government of Ontario. Accessed October 29, 2020. Available from: <https://geohub.lio.gov.on.ca/datasets/mnrf::ontario-road-network-orn-segment-with-address/about>

There are several limitations associated with the PHO TRAP methodology. First, population data is from 2016 and so may not reflect current population estimates. Second, populations were assumed to be homogeneously distributed across each dissemination block for population calculations when this is likely not always the case, and in fact, may underestimate actual exposure in denser urban areas where high rises are purposefully built to promote accessibility to major roadways. Third, the roads dataset may have led to some misclassification of TRAP exposure when actual traffic volume is markedly more or less than other roads of the same classification type. Relatedly, some connectors between highways (for example, between Hwy 8 and Hwy 401 in Kitchener/Cambridge), despite being numbered highways themselves, are not classified as a highway but as a major roadway by the definitions used in the PHO methods, and so are not classified as such in this analysis. Such limitations could be mitigated through careful review of the road data by a GIS analyst. Even so, the PHO Technical Appendix suggests the Ontario Road Network classifications does serve as a reasonable proxy for traffic volume.

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