Peel Region
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Assessing exposure, sensitivity, and adaptive capacity in Peel region

Update to the 2012 Report on health vulnerability to climate change

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Glossary

Adaptation: the process of enhancing, developing, or implementing strategies and measures to moderate or cope with climatic events. In public health, adaptation can be considered synonymous to prevention. Types of adaptation could include anticipatory and reactive, private and public, autonomous, and planned measures.

Adaptive capacity: the ability of individuals, communities, and institutions to prepare for, and cope with climate variability and change.

Mitigation: actions or measures (e.g., policy) to reduce greenhouse gas emissions and/or enhance the capture of greenhouse gas emissions through green space initiatives.

Resilience: ability of a natural or human system to absorb disturbances while retaining the same basic structure and function. The capacity for self-organization, and the capacity to adapt to and learn from stress and change.

Risk (i.e., climate-related risk): likelihood of exposure or the consequence(s) of exposure from the interaction of a physically defined hazard due to vulnerability. System vulnerability is a critical determinant of the risk a region or subpopulation will face when exposed to a hazard. Programs that decrease vulnerability will decrease risk.

Sensitivity: differential degree to which individuals may be affected by climate change, or the proportion of the population more vulnerable due to particular characteristics. The sensitivity of individuals and/or populations is influenced by factors such as socio-economic status, physiology, biology, genetics, access to health resources and services, gender, age, and personal health practices.

Vulnerability: the degree to which a system is susceptible to, or unable, to cope with the adverse effects of climate change. Vulnerability is influenced by a range of factors and is a function of a population's exposure to climate hazards, sensitivity to those impacts, and adaptive capacity to effectively manage climate change and reduce associated health risks.

Executive summary

Background

Canada's climate is changing, and weather patterns are exhibiting greater variability across the country. The impacts of climate change will be regionally specific and dependent on a variety of factors relating to geography and community vulnerability. Vulnerability is defined as a function of sensitivity, exposure and adaptive capacity. This report is an update to the 2012 Vulnerability Assessment, first prepared in response to the Region of Peel's 2011 Climate Change Strategy. Since then, Peel region has grown in population and the 2016 Census of Population (Canada) has been released.

The Region of Peel, led by the Office of Climate Change and Energy Management, has worked with stakeholders to develop the *Regional Climate Change Master Plan*; to provide details for decision-makers on potential solutions to achieve the Region's climate change outcomes and provide subject-matter expertise on how these actions should be implemented. The Region of Peel – Public Health has also determined "Reducing Health-Related Impacts of Climate Change" as a strategic priority to support increasing resiliency among Peel residents to adverse health outcomes and hazards associated with climate change. In addition, the Region of Peel – Public Health has developed *The Changing Landscape of Health in Peel – A Comprehensive Health Status Report* to support the design and implementation of programs to address the most significant health issues in Peel.

In Peel, there has been a slow increase in annual mean temperatures from 8.1°C in 1938 to 9.3°C in 2017 at Toronto Pearson International Airport[1]. Climate change has the potential to increase the number, intensity and duration of extreme forms of weather including severe storms accompanied by rain, hail, thunder and lightning; high wind events and tornados; and high precipitation events that lead to flooding[2,3]. In Peel, total rain has increased slightly between 1940 (665 mm) and 2010 (701 mm)[4].

Climate change holds implications for human health and well-being. Increasing temperatures are implicated in rising rates of heat related morbidity and mortality, and a host of other health-related outcomes.

Updated report

This report updates the *2012 Health Vulnerability to Climate Change Report: Assessing Exposure, Sensitivity, and Adaptive Capacity in the Region of Peel*. Several changes have taken place since the release of the 2012 report, including newly released Peel-specific climate data. The changes and availability of data have strengthened the Region's and Peel Public Health's work and leadership on climate change.

The report keeps much of the original content from 2012, as it provides background and context. Where possible, data from the 2012 report is compared to updated data. Updates to the vulnerability assessment primarily focus on the following areas:

1. Region's historical climate trends
2. Peel's future climate trends and projections
3. Expected health impacts
4. Changes in Peel region's population
5. Peel-specific data on key health vulnerability indicators and updated program information, and
6. Recommendations

The report utilizes the World Health Organization/Pan American Health Organization's methodology to identify current and future climate-related exposures, sensitivities, and adaptive capacities in Peel region. As such, this report establishes a foundation from which to guide public health adaptation to climate change in Peel based on: [1] the identification of key climate change vulnerabilities, and [2] the provision of a scoping analysis that will serve as the basis to inform future data collection and research on public health vulnerability to climate change in the Region. By taking a comprehensive approach to assessing vulnerability, this document focuses on a multitude of health issues that are specific to Peel region. More specifically, this report aims to:

1. Identify indicators of health priority areas as indicated by the peer-reviewed literature, government and non-government reports; and
2. Assess information on these indicators that are specific to the Region of Peel to determine current and future vulnerabilities to climate change.

While some of the indicators focus on individual-level vulnerability, most are community-level indicators of current and/or future vulnerability (i.e., exposure, sensitivity, and adaptive capacity) using available data for Peel region.

Report findings

Peel's changing climate has the potential to affect human health by:

1. Increasing temperature-related morbidity and mortality;
2. Exacerbating air quality and worsening respiratory and cardiovascular conditions;
3. Increasing the risk of injuries and mortality resulting from extreme weather;
4. Increasing food and water contamination with resulting increases in illness; and
5. Increasing the incidence of vector-borne illnesses associated with the spread of vectors as climates become more favourable to their survival.

Particular population sub-groups may be more vulnerable to ill-health outcomes related to climate change due to differential exposure or particular climate-related sensitivities. In Peel region, these sub-groups include:

- Seniors (total population expected to more than double by 2030);
- Children;
- Those experiencing social isolation;
- Individuals with chronic conditions, disabilities, or both; and
- Socially or economically marginalized individuals.

One of the largest concerns associated with climate change is its potential to worsen existing health inequities by increasing the health burden on already vulnerable groups, particularly among those with lower amounts of social support, education, or economic resources.

The Region of Peel's existing programs may not be able to address future climate change impacts, so engaging community partners and integrating the local knowledge of community members will be a crucial part of increasing Peel's adaptive capacity to climate change and to deal with unforeseen and emerging health impacts.

Due to the complex nature of climate change and the uncertainty around its impacts on human health, this report does not reflect all possible health impacts (e.g., skin cancer from UV exposure, mental health, food (in)security). However, as knowledge increases on the range of health impacts associated with climate change, further investigation into the less known health-related impacts of climate change will be crucial.

Recommendations

Peel Public Health should:

1. Use the report as a foundation to begin broader discussions around public health vulnerability to climate change in Peel region.
2. Share the report with key stakeholders and engage in knowledge translation activities.
3. Conduct community and stakeholder consultation to capture the social and cultural distinctions present in Peel region to further inform programming and policy.
4. Map vulnerable populations/neighbourhood characteristics.
5. Continue to gather relevant health information on an ongoing basis to improve our understanding of local climate change health impacts in Peel region.
6. Conduct further work on how mental health and health equity are impacted by climate change.
7. Develop an implementation plan to address identified vulnerabilities.

1.0 Purpose of the report

This report updates the *2012 Health Vulnerability to Climate Change Report: Assessing Exposure, Sensitivity, and Adaptive Capacity in the Region of Peel*. The report will guide Public Health's work on climate change by providing a greater understanding of the current impacts and projected risks of climate change in Peel. The updated report uses the information in the 2012 report, and provides updated data, where possible.

Climate change is a complex issue, and the vulnerability assessment is one data point to help gain a greater understanding of how to move forward on the issue. Climate change risks and impacts vary as measures are, or are not, implemented. As such, the vulnerability assessment is a living document and will be updated as necessary.

2.0 Why update the assessment now

Several changes have taken place since the release of the 2012 report. The changes and availability of data have strengthened the Region's and Peel Public Health's work and leadership on climate change. Changes and new available data include the following:

- The 2015 - 2018 Region of Peel Term of Council Priorities (TOCP) included a priority to *adapt to and mitigate the effects of climate change*. The inclusion of climate change as a TOCP elevated the Region's leadership and action on the issue. The updated 2018 – 2022 TOCP's continue to acknowledge the importance of climate change and its impacts on the community. The new priority to *build environmental resilience* will amongst other outcomes, address the health and environmental stresses that will both be amplified by the adverse impacts of climate change.
- In 2016, the *Climate Trends and Future Projections in the Region of Peel: Technical Report* was released. The report provides updated information in characterizing recent trends and future projections in climate for Peel.
- Statistics Canada released the *2016 Census of Population* data.

- The Ministry of Health and Long-Term Care released the *Ontario Climate Change and Health Toolkit* in 2016. The toolkit provides a technical document and workbook to assist local health units in undertaking vulnerability assessments. The toolkit also includes the *Ontario Climate Change and Health Modelling Study*, which assessed the potential impacts of climate change on health and forecast key health risks across Ontario; generated projection scenarios for the 2020s, 2050s and 2080s for the 36 Ontario public health units; and illustrated the spatial distribution of potential health risks.
- The new Ontario Public Health Standards were released in 2018 and have placed more emphasis on climate change. The Healthy Environments Standard and Healthy Environments and Climate Change Guideline have a much more explicit mandate for local public health units to undertake actions such as: assess the health impacts related to climate change; collaborate with municipalities under the Ontario *Planning Act*; consider the use of the Ontario Climate Change and Health Toolkit, 2016 in conducting a vulnerability assessment; and monitor the impacts of climate change.
- The 2019 *Comprehensive Health Status Report* identifies the status of health outcomes in Peel and tracks changes in health outcomes from 2008 to 2018. The report includes updated climate change data.
- The 2020 – 2029 Public Health Strategic Plan identified *Reducing Health-Related Impacts of Climate Change* as a strategic priority.

3.0 About this report

The report keeps much of the original content from 2012, as it provides background and context. Where possible, data from the 2012 report is compared to updated data. However, at times a comparison is not possible as the information was not initially included in the 2012 report, updated data is not available, and/or the way data has been updated, does not allow for a comparison. Updates to the vulnerability assessment primarily focus on the following areas:

1. Region's historical climate trends
2. Peel's future climate trends and projections
3. Expected health impacts
4. Changes in Peel region's population
5. Peel-specific data on key health vulnerability indicators and updated program information, and
6. Recommendations

The report is organized into four sections. First, background is provided. Next, the report presents the methodology used to identify relevant climate-related vulnerability indicators such as exposure, sensitivity, and and adaptive capacity in Peel region. Third, the findings from the literature review are presented which include: [A] a description of Peel's population; [B] an overview of the region's historical climate; [C] an overview of future climate trends and projections; [D] expected impacts on health from climate change; and [E] a summary of key health vulnerability indicators found in the literature with Peel-specific data. The report concludes with recommendations.

4.0 Background

Climate change is expected to affect most populations. One significant area of impact will be on human health and well-being.[5,6,7] In Canada, evidence confirms that climate change is affecting, and will continue to affect, the health of Canadians[8]. There is an urgent requirement for the public health sector to respond to climate change in a proactive manner; to adapt to its effects and address its causes before greater health consequences come to bear.[9,10,11]

The 2012 report was developed for the Region of Peel with support from Canada's Climate Change and Health Office (CCHO) and Peel Public Health (PPH). Guidelines from the World Health Organization (WHO)/Pan-American Health Organization (PAHO) 2012 document *Protecting health from climate change: Vulnerability and adaptation assessment* were used.

The vulnerability assessment describes current climate risks and identifies vulnerable populations and adaptive capacities within Peel region through a detailed review of published and grey literature. The report takes a comprehensive—but not exhaustive—approach to assessing vulnerability in that it is not focussed on any one health impact, but a multitude of issues that are specific to Peel region. This work is timely as various jurisdictions throughout the world have begun to prepare for the health effects of climate change using climate change vulnerability assessments for human health.

This report is an initial component of a multi-phase public health strategy that will be needed to address the health effects of climate change in Peel region. This report has not been vetted by stakeholders, and as such, important data and information gaps may persist. The report should be treated as background and greater stakeholder input is required to better comprehend the climate-related vulnerability and associated health risks in Peel. The findings presented are preliminary and should serve to indicate some key issues and areas of vulnerability for Peel region.

4.1 Vulnerability: Exposure, sensitivity, and adaptive capacity

According to the Intergovernmental Panel on Climate Change, vulnerability is "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes".[12] Climate change vulnerability is influenced by a range of factors that include the determinants of health as indicated by the WHO.[11] Vulnerability is dependent on a host of geographic and cultural conditions and in a given population is a function of a population's:

1. Exposure to climate hazards;
2. Sensitivity to those impacts; and
3. Adaptive capacity to effectively manage climate change and reduce associated health risks[13]

Definitions for each concept are presented in this section based on the Health Canada's *Human Health in a Changing Climate: A Canadian Assessment of Vulnerabilities and Adaptive Capacity* Report.[8]

Exposure to climate hazards is the probability of a climate-related occurrence (e.g., extreme weather event) and its impact, or effect on, natural or human systems in a geographic area during a given time period.[14] Exposure is the degree to which a person or group is in contact or proximity to a factor and the extent to which this level of exposure causes impacts to health. For example, increased temperatures may produce more favourable outdoor conditions which can inadvertently increase individual environmental exposure to climate-related hazards (e.g., extreme heat; vectors; waterborne contamination).

Exposure is often difficult to quantify, as is the exact amount of exposure to a climate-related factor required to produce a measurable effect on human health. Thus, exposures can also capture locations where exposures tend to occur or areas where exposure is greatest. Different groups may be differentially exposed to particular climate stimuli as a result of their occupation or by virtue of particular lifestyle practices. Exposures are typically documented in this report as the number of individuals affected and particular demographic groups they may belong to. Where possible, baseline records of disease and death, and numbers of cases of hospital admissions are included (see for example, McMichael and Kovats 2000).

Sensitivity is the differential degree to which individuals in a population may be affected by climate change, or the proportion of the population that is more vulnerable due to particular physiological or social characteristics. "All Canadians display sensitivity to some health impacts arising from climate change"[15], but specific populations may be at elevated risk for particular climate-related events due to a number of contextual features. Sensitivity is the degree to which a system is affected by climate-related stimuli. The sensitivity of individuals and/or populations is influenced by factors such as physiology, biology, genetic endowment, access to health resources and services, gender, age, and personal health practices.[15]

Adaptive capacity refers to the ability of a system to adjust to climate change[12] and is estimated using a range of community characteristics and factors that indicate individual and population resiliency and adaptability. At the community level, attributes of adaptive capacity include programming and policies enacted by government, the proportion of the population that are of low socioeconomic status, and community networks and infrastructure that support a community's ability to cope with the consequences of a changing climate. The effectiveness of institutions or institutional arrangements plays a critical role in increasing capacity to adapt to the health effects of climate change.[16] At an individual-level, adaptive capacity refers to an individual's ability to cope with climate change by accessing technologies or adopting behaviours to reduce exposure or sensitivity (e.g., accessing cool spaces or utilizing air conditioning during extreme temperature alerts). Adaptive capacity is directly related to reducing, limiting or mitigating climate-related exposures and associated sensitivities[15], and is dependent upon a broad range of economic and human resources including information and skills.

5.0 Methods: A review of the climate change vulnerability literature

A literature review was conducted to develop health vulnerability indicators (i.e., exposures, sensitivities, and adaptive capacities) for Peel's population in 2012. This section was not updated for the 2023 report.

A literature search was conducted using Ovid Medline. The literature search sought to: (a) identify indicators for each public health priority area targeted as indicated by the peer-review literature, government, and non-government reports, and (b) to collect information on the indicators that were specific to Peel region to assess current and future vulnerabilities to climate change. Peer-reviewed scientific literature and case studies made also available through government publications. Additional reports and resources were supplied directly from stakeholders at PPH and the CCHO.

5.1 Search for peer-reviewed literature

Search terms were identified from a review of initial documents provided by PPH and CCHO stakeholders. A search strategy was developed to identify indicators based on the climate-related priority areas identified for Peel region. A Medline search of article and report titles, abstracts and key words was conducted using twenty-five academic databases (see Annex 1) with no restrictions on the year of publication. An initial search was used to identify a broad range of vulnerability indicators, with subsequent searches targeted towards the specific climate-related priority areas, including the following: extreme temperatures, air quality, extreme weather and natural disasters/hazards, water and food contamination, and vector-borne diseases (see Annex 2 for search strategy and results).

Articles were appraised and included based on a set of inclusion criteria. An article or report was included if it: [1] was applicable to the Peel context; [2] provided measures or indicators of vulnerability and adaptive capacity for given priority areas; [3] was written in English, and [4] focused on areas other than tropical or arctic climates.

Titles and abstracts of articles or reports from the search were scanned. If a resource (article/report) met inclusion criteria, the full document was retrieved and reviewed to identify potentially relevant vulnerability indicators. If the resource did not include one or more relevant vulnerability indicators, it was considered not relevant and excluded. After removing duplicates and non-relevant articles, the initial search identified twenty-nine articles. An additional six resources met inclusion criteria but were not included as they were inaccessible online or were out of print.

Based on discussions with stakeholders at PPH and CCHO, subsequent searches for specific health issues were conducted identifying: five resources for extreme temperature (heat and cold); nine resources for air quality; six resources for extreme weather and natural disasters/hazards; one resource on food and waterborne contamination, and one resource on vector-borne disease.[i] When combined, the total number of references found using Ovid Medline was fifty-one. An additional twenty-eight hand-searched, peer-review articles were supplied directly by CCHO or stakeholders with the Region of Peel (including Peel Public Health).

5.2 Grey literature, additional documents and data collection on the Region of Peel

Employees from the CCHO, PPH, Toronto and Region Conservation Authority (TRCA), Credit Valley Conservation (CVC) and other departments within the Region of Peel contributed forty-nine resources in the form of documents, reports, policy briefs, and research notes. Information provided by sources was measured against inclusion criteria and included if they contained pertinent information on one or more public health priority areas selected. Other relevant data was obtained through census information or publicly accessible records (e.g., Environment Canada climate data). Indicators of exposure, sensitivity, and adaptive capacity specific to Peel Region were identified and included in this report. The results from the literature review are presented in the following sections.

i Numbers reported after the removal of duplicate resources identified by previous searches

6.0 Peel region in context

Population data from the 2016 Census are presented and compared to the data from the 2012 vulnerability assessment report (Table 1 and Table 2). Indicators that cross multiple health impacts of climate change are also presented.

Peel region is rapidly growing. The population in 2016 was 1,381,739 and has increased by 6.5 per cent from 2011 (1,296,809).[17] The biggest population percent change occurred in Brampton (13.3 per cent), followed by Caledon (11.8 per cent) and Mississauga (1.1 per cent).[18,19,20]

The Region is home to a relatively young (median age from 2016 census is 38.1 years, compared to 36.0 in 2006), culturally and socio-economically diverse population.[17,21] Seniors (65 years +) are the largest and fastest growing age group in the Region. Peel estimates its senior population will grow to 21 per cent of the population by the year 2041.[22] Peel region has 176,820 seniors (2016 census), an increase from 135,860 in 2011.[17,23] The population percent change from 2011 to 2016 was 44.0 per cent, which is higher than the provincial rate of 36.1 per cent.[17] The City of Brampton has the highest senior's population in Peel with the population growing 52.0 per cent from 2011.[17,23] In 2006, 15,520 Peel seniors (65+) were living alone, and increased to 24,755 seniors by 2016.[21,24] In 2016, 11.8 per cent (163,575) of Peel's population was 10 years and younger.[17]

South Asians are the largest reported racialized group in Peel, comprising 50.8 per cent of the population.[17] Peel's indigenous population represents 0.7 per cent.[17] In 2016, 10 per cent of Peel's population classified as being low income after taxes.[17] 5.7 per cent of individual's aged 25-65 had no degree, certificate, or diploma and 3.9 per cent had no knowledge of French or English, an increase from 3.7 per cent in 2006.[17,21]

Individuals who work outdoors or in environments with limited indoor ventilation are at greater risk of experiencing heat-related illness. In 2016, 44,755 individuals were employed in construction, 2,180 individuals were employed in agriculture, forestry, fishing, and hunting, and 90,485 individuals worked in manufacturing environments.[17]

There have been no significant changes in the number of hospitals, regionally operated long-term care centres, residential care facilities, shelters, and emergency housing.

Table 1[ii]. Selected population indicators for Peel region (2012 Report compared to updated 2023 data) and indicators that cross multiple health impacts of climate change[17,18,19,20,21,23]

2012 Report

Indicator	Year	Brampton	Caledon	Mississauga	Peel	Ontario
Total population	2011	532,911	59,460	713,443	1,296,809[iii]	12,851,821
Population per cent change	2006-2011	n/a	n/a	n/a	11	n/a
Land area (km²)	2006	266.71	687.17	288.53	1,242.40	n/a
Population density (km²)	2006	1,626.51	83.02	2,317.09	933.2	n/a
Gender female	2006	219,375 (51%)	28,615 (50%)	341,015 (51%)	589,005 (51%)	6,229,500 (51%)
Gender male	2006	214,430 (49%)	28,435 (50%)	327,535 (49%)	570,400 (49%)	5,930,700 (49%)
Age <10 years	2006	65,335 (15%)	7,945 (14%)	83,555 (12%)	156,825 (13%)	1,392,360 (11%)
Age 10-24 years	2006	94,350 (22%)	11,975 (21%)	145,005 (22%)	251,325 (22%)	2,448,815 (20%)
Age 25-64 years	2006	240,435 (55%)	31,970 (56%)	374,290 (56%)	646,695 (56%)	6,669,925 (55%)
Age >= 65 years	2006	33,670 (8%)	5,155 (9%)	65,700 (10%)	104,530 (9%)	1,649,180 (14%)
>= 65 years population per cent change	n/a	n/a	n/a	n/a	n/a	n/a
Median age in years	2006	33.7	37.7	36.7	36.0	39.0
Living alone/ one-person household	2006	n/a	n/a	n/a	52,555 (15%)	1,104,865 (24%)
Low income status[iv] 18-64 years	2005-2006	n/a	n/a	n/a	n/a	n/a
Low income status[iv] >= 65 years	2005-2006	n/a	n/a	n/a	n/a	n/a
Low income measure, after tax (LICO-AT)[v] **-** 18-64 years	2005-2006	n/a	n/a	n/a	n/a	n/a
Low income measure, after tax (LICO-AT)[v] **-** >= 65 years	2005-2006	n/a	n/a	n/a	n/a	n/a
Socio-economic status Prevalence of low income for total persons in private households	2006	n/a	n/a	n/a	11%	n/a

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[ii] Note: Not all totals add up to 100% due to rounding

[iii] The 2011 count for this area was revised in the 2016 Census

[iv] 'Low-income status' refers to the income situation of the statistical unit in relation to a specific low income line in a reference year.

[v] The low-income cut-offs, after tax refer to income thresholds, defined using 1992 expenditure data, below which economic families or persons not in economic families would likely have devoted a larger share of their after-tax income than average to the necessities of food, shelter and clothing.

Table 2[ii]. Selected population indicators for Peel region (Updated 2023 Report compared to 2012) and indicators that cross multiple health impacts of climate change[17,18,19,20,21,23]

Updated 2023 Report

Indicator	Year	Brampton	Caledon	Mississauga	Peel	Ontario
Total population	2016	593,638	66,502	721,599	1,381,739	13,448,894
Population per cent change	2011-2016	13.3	11.8	1.1	6.5	4.6
Land area (km²)	2016	266.36	688.16	292.43	1,246.95	908,699.33
Population density (km²)	2016	2,228.7	96.6	2,467.6	1,108.81	14.8
Gender female	2016	300,105 (51%)	33,265 (50%)	369,670 (51%)	703,040 (51%)	6,889,105 (51%)
Gender male	2016	293,535 (49%)	33,235 (50%)	351,930 (49%)	678,700 (49%)	6,559,390 (49%)
Age <10 years	2016	79,205 (13%)	7,430 (11%)	76,955 (11%)	163,575 (12%)	1,453,445 (11%)
Age 10-24 years	2016	126,665 (21%)	14,260 (21%)	146,830 (20%)	287,755 (21%)	2,460,590 (18%)
Age 25-64 years	2016	321,505 (54%)	36,045 (54%)	396,045 (55%)	753,580 (55%)	7,282,810 (54%)
Age >= 65 years	2016	66,270 (11%)	8,770 (13%)	101,870 (14%)	176,820 (13%)	2,251,655 (17%)
>= 65 years population per cent change	2011-2016	52.0	37.5	39.9	44.0	36.1
Median age in years	2016	35.8	41.0	40.0	38.1	41.3
Living alone/ one-person household	2016	20,820 (12%)	2,560 (12%)	44,960 (19%)	68,345 (16%)	1,341,300 (26%)
Low income status[iv] 18-64 years	2015-2016	381,250 (65%)	42,120 (64%)	469,290 (66%)	892,655 (65%)	8,418,960 (64%)
Low income status[iv] >= 65 years	2015-2016	64,515 (11%)	8,605 (13%)	97,100 (14%)	170,220 (12%)	2,108,560 (16%)
Low income measure, after tax (LICO-AT)[v] 18-64 years	2015-2016	32,175 (61%)	1,160 (66%)	52,425 (62%)	85,760 (62%)	887,640 (68%)
Low income measure, after tax (LICO-AT)[v] >= 65 years	2015-2016	3,620 (7%)	125 (7%)	7,245 (9%)	10,990 (8%)	106,555 (8%)
Socio-economic status Prevalence of low income for total persons in private households	2016	n/a	n/a	n/a	10.1%	n/a

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[ii] Note: Not all totals add up to 100% due to rounding

[iii] The 2011 count for this area was revised in the 2016 Census

[iv] 'Low-income status' refers to the income situation of the statistical unit in relation to a specific low income line in a reference year.

[v] The low-income cut-offs, after tax refer to income thresholds, defined using 1992 expenditure data, below which economic families or persons not in economic families would likely have devoted a larger share of their after-tax income than average to the necessities of food, shelter and clothing.

2012 Report continued

Indicator	Year	Brampton	Caledon	Mississauga	Peel	Ontario
Race/ethnicity Aboriginal status	2006	n/a	n/a	n/a	5,550 (<1%)	n/a
Race/ethnicity Racialized group	2006	n/a	n/a	n/a	576,665 (50%)	n/a
Race/ethnicity #1 Reported South Asian	2006	n/a	n/a	n/a	n/a	n/a
Knowledge of official language English only	2006	388,750 (90%)	52,415 (92%)	591,205 (89%)	1,032,370 (89%)	10,335,700 (86%)
Knowledge of official language French only	2006	195 (<1%)	15 (<1%)	700 (<1%)	910 (<1%)	49,210 (<1%)
Knowledge of official language English and French	2006	24,135 (6%)	3,975 (7%)	49,495 (7%)	77,605 (7%)	1,377,330 (11%)
Knowledge of official language Neither English nor French	2006	18,495 (4%)	435 (<1%)	24,245 (4%)	43,175 (4%)	266,655 (2%)
Immigration status and period of immigration Non-Immigrants	2006	222,080 (51%)	44,830 (79%)	314,965 (47%)	581,875 (50%)	8,512,020 (71%)
Immigration status and period of immigration Immigrants	2006	206,190 (48%)	11,805 (21%)	343,250 (52%)	561,240 (49%)	3,398,725 (28%)
Immigration status and period of immigration Before 1981	2006	n/a	n/a	n/a	n/a	n/a
Immigration status and period of immigration 1981-1990	2006	n/a	n/a	n/a	n/a	n/a
Immigration status and period of immigration 1991-2000	2006	68,620 (16%)	1,505 (3%)	110,875 (17%)	181,000 (16%)	933,545 (8%)
Immigration status and period of immigration 2001-2010	2006	n/a	n/a	n/a	n/a	n/a
Immigration status and period of immigration 2011-2016	2006	n/a	n/a	n/a	n/a	n/a
Immigration status and Period of Immigration Non-permanent residents	2006	3,305 (1%)	205 (<1%)	7,440 (<1%)	10,950 (<1%)	118,150 (<1%)

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Updated 2023 Report continued

Indicator	Year	Brampton	Caledon	Mississauga	Peel	Ontario
Race/ethnicity Aboriginal status	2016	4,330 (1%)	615 (1%)	4,175 (1%)	9,120 (1%)	374,395 (3%)
Race/ethnicity Racialized group	2016	433,230 (73%)	12,410 (19%)	408,930 (57%)	854,565 (62%)	3,885,585 (29%)
Race/ethnicity #1 Reported South Asian	2016	261,705 (44%)	6,635 (53%)	165,765 (23%)	434,105 (32%)	1,150,415 (9%)
Knowledge of official language English only	2016	532,650 (90%)	60,970 (92%)	639,595 (89%)	1,233,210 (90%)	11,455,500 (86%)
Knowledge of official language French only	2016	500 (<1%)	10 (<1%)	645 (<1%)	1,155 (<1%)	40,040 (<1%)
Knowledge of official language English and French	2016	30,200 (5%)	4,265 (6%)	51,935 (7%)	86,395 (7%)	1,490,390 (11%)
Knowledge of official language Neither English nor French	2016	28,325 (5%)	1,035 (2%)	25,680 (4%)	55,040 (4%)	326,935 (2%)
Immigration status and period of immigration Non-Immigrants	2016	272,365 (46%)	49,725 (75%)	320,750 (45%)	642,835 (47%)	9,188,815 (69%)
Immigration status and period of immigration Immigrants	2016	308,790 (52%)	16,310 (25%)	381,730 (53%)	706,835 (51%)	3,852,145 (29%)
Immigration status and period of immigration Before 1981	2016	49,655 (8%)	7,480 (11%)	77,125 (11%)	134,265 (10%)	1,077,745 (8%)
Immigration status and period of immigration 1981-1990	2016	41,145 (7%)	2,465 (4%)	50,500 (7%)	94,105 (7%)	513,995 (4%)
Immigration status and period of immigration 1991-2000	2016	77,800 (13%)	3,045 (5%)	90,385 (13%)	171,230 (12%)	834,510 (6%)
Immigration status and period of immigration 2001-2010	2016	100,280 (17%)	2,540 (4%)	110,310 (15%)	213,135 (16%)	953,730 (7%)
Immigration status and period of immigration 2011-2016	2016	39,915 (7%)	780 (1%)	53,410 (7%)	94,105 (7%)	472,170 (4%)
Immigration status and period of immigration Non-permanent residents	2016	9,790 (2%)	185 (<1%)	12,990 (2%)	22,970 (2%)	201,200 (2%)

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2012 Report continued

Indicator	Year	Brampton	Caledon	Mississauga	Peel	Ontario
Education No degree, certificate or diploma ages 25-64	2006	37,685 (16%)	3,430 (11%)	38,385 (10%)	79,500 (12%)	n/a
Occupational groups Construction	2006	n/a	n/a	n/a	33,720	n/a
Occupational groups Manufacturing	2006	n/a	n/a	n/a	n/a	n/a
Occupational groups Agriculture, Forestry, Fishing & Hunting	2006	n/a	n/a	n/a	5,775[vi]	n/a
Shelter use Individuals	2010	n/a	n/a	n/a	11,920	n/a
Shelter use Dependents	2010	n/a	n/a	n/a	3,134	n/a
Shelter use Youth	2010	n/a	n/a	n/a	696	n/a
Hospitals	2012	Credit Valley Hospital, Mississauga Trillium Health Centre, Mississauga Brampton Civic Hospital, Brampton				
Regionally operated long-term care facilities	2012	Five regionally operated LTC facilities (additional offered privately or by non-for-profits. **Brampton:** Peel Manor, Tall Pines **Caledon:** Davis Centre **Mississauga:** Malton Village, Sheridan Villa				
Residential care facilities	2012	31 residential care facilities in Peel for people not able to live independently or who require on-site nursing care				
Shelters and emergency housing	2012	9 shelters and emergency housing facilities in Peel. **Brampton:** Wilkinson Road Shelter, Salvation Army Family Life Resource Centre, Our Place Peel, St. Leonard's House **Mississauga:** Interim Place I, Interim Place II, Our Place II, Region of Peel Family Shelter, Vita Manor Region of Peel Human Services Department conducts outreach activities to community agencies and shelters in the event of extreme temperature warnings.				

[vi] Was characterized as 'Agriculture and Mining' in the 2006 Census

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Indicator	Year	Brampton	Caledon	Mississauga	Peel	Ontario
Education No degree, certificate or diploma ages 25-64	2016	42,505 (13%)	3,310 (9%)	33,520 (8%)	79,325 (11%)	n/a
Occupational groups Construction	2016	17,840	4,525	22,390	44,755	n/a
Occupational groups Manufacturing	2016	45,780	4,330	40,380	90,485	n/a
Occupational groups Agriculture, Forestry, Fishing & Hunting	2016	730	565	885	2,180	n/a
Shelter use Individuals	2016	n/a	n/a	n/a	17,784	n/a
Shelter use Dependents	2016	n/a	n/a	n/a	1,889	n/a
Shelter use Youth	2016	n/a	n/a	n/a	n/a	n/a
Hospitals	2016	**Trillium Health Partners:** Credit Valley Hospital, Mississauga Mississauga Hospital, Mississauga **William Osler Health Centre:** Brampton Civic Hospital, Brampton Peel Memorial Centre for Integrated Health and Wellness, Brampton				
Regionally operated long-term care facilities	2018	No change				
Residential care facilities	2018	28 residential care facilities in Peel for people not able to live independently or who require on-site nursing care				
Shelters and emergency housing	2018	11 emergency shelters and transitional housing facilities **Brampton:** Wilkinson Road Shelter, Family Life Resource Centre, Brampton Queen Street Youth Shelter, New Leaf Program (St. Leonard's Place Peel) **Mississauga:** Cawthra Shelter, Peel Family Shelter, Interim Place South, Interim Place North, Our Place Peel, Peel Youth Village, Angela's Place No change				

7.0 Historical climate data for Peel region

The following update is taken from the 2019 *Comprehensive Health Status Report*. The report provides data on Peel's climate trends, both temperature and precipitation.

7.1 Temperatures

There has been a slow increase in annual mean temperatures from 8.1°C in 1938 to 9.3°C in 2017 at Toronto Pearson International Airport.[1] The mean seasonal temperature by season and decade, shows a warming trend over time for all seasons. However, the most significant increases have been in the summer and winter. Mean temperature in the summer has increased from 19.8°C in the 1940s to 21.2°C in 2010. The mean temperature in the winter has increased from -5.4°C in the 1930s to -3.3°C in 2010.[24] Over the years there has been limited variation in extreme maximum temperatures. The extreme maximum temperature was 36.1°C in 1938 and 36.8°C in 2012. However, there has been significant change in the extreme minimum temperature which was recorded as -27.2°C in 1938 and -16.5°C in 2012.[1]

7.2 Precipitation

Climate change has the potential to increase the number, intensity and duration of extreme forms of weather including severe storms accompanied by rain, hail, thunder and lightning; high wind events and tornados; and high precipitation events that lead to flooding.[2] In Peel, total rain has increased slightly between 1940 (665 mm) and 2010 (701 mm).[4]

On October 15, 1954, Hurricane Hazel hit Southern Ontario and brought 110 km winds and 285 millimetres of rain in 48 hours and resulted in 81 deaths across the Greater Toronto Area.[25] While more recent events in the GTHA have had smaller total rainfall amounts than Hurricane Hazel, the one-hour maximum intensities of the storm events from 2004 to 2014 have been greater than the regulatory event (which is the greater of either a 100-year return period storm or the observed rainfall from a major historic storm, such as Hurricane Hazel).[25]

8.0 Future climate forecasting for Peel region

While historical data are useful in demonstrating past changes in a region's climate, sophisticated modelling techniques and expert analysis are required to forecast future climatic changes. The following update is taken from the *Climate Trends and Future Projections in the Region of Peel: Technical Report* by RSI, the Ontario Climate Consortium and the Toronto and Region Conservation Authority. The report characterizes recent trends and future projections in climate across a range of climate indicators. Projections are provided on Peel's climate in the 2020's, 2050's and 2080's for temperature, precipitation, days above 30°C, days above 35°C and the growing season. It is important to note that the projections are based on delta models (also known as climate change factor approach) and uncertainty exists in the magnitude of changes in the future. In the *Climate Trends and Future Projections in the Region of Peel* report, the delta approach was used to obtain future estimates of climate variables for Peel region, which were taken from the full global climate model output from CMIP5. The future climate analysis compared the differences between deltas (historical and future modeled results) through a coarse projection (many models run at coarse resolution) and then applied to a spatially distributed gridded dataset of baseline climate to create a map of future climate projections.

Table 3. Future projections in climate for Peel region in the 2020's, 2050's and 2080's[26]

Climate category	2020s	2050s	2080s
Temperature	• Increase in all seasons • Greatest increase in winter and minimum temperatures • Mean annual temperatures expected to rise 1.4°C[vii]	• Very likely to continue increasing in all seasons • Greatest increases projected for winter and minimum temperatures • Mean annual temperatures expected to rise 2°C	• Increase over all seasons throughout the year • Rise by 4.9°C annually
Precipitation	• Likely to increase overall throughout the year • Greatest increase in winter and spring seasons • Extreme precipitation is likely to become more severe and frequent • 1-day and 5-day maximum precipitation amounts are expected to increase by 5% • Worst 1% of extreme precipitation events projected to increase 20% (with business-as-usual emissions continuing)	• Likely to increase overall • Most increase in the winter and spring seasons • Extreme precipitation is likely to become more severe and frequent • 1-day and 5-day maximum precipitation amountsviii expected to increase by 8% and 10% • Worst 1% and 5% of extreme precipitation events are expected to increase by 51% and 28% in magnitude	• Likely to increase overall throughout the year • Annually, 99mm more per year is expected • Frequency of rain versus snow will continue to increase Instances of extreme precipitation may become significantly more severe and frequent • 1-day and 5-day maximum precipitation amounts[viii] could increase by 22% and 17%, respectively • Worst 1% and 5% of extreme precipitation events could increase by 90% and 46% in magnitude
Days above 30°C	• Very likely to increase by 5 days per year	• Very likely to increase by 14 days per year	• Over 60 days per year
Days above 35°C	n/a	• Expected to occur twice per year	• Expected to occur 14 times per year
Growing season	• Longer growing season (up to 14 days longer)	• Much longer growing seasons (34 days longer)	• Significantly longer growing season (54 days per year)

Modelling done by the federal and provincial government mirror the work above and indicate that the forecasted trends will continue.

[vii] Assuming business as usual emissions

[viii] Historically 37mm and 59mm, respectively

9.0 Climate change and health impacts

Climate change has begun to adversely affect the health of populations around the world[27,28,29] and research from the Canadian government and local communities around the country have begun to document the health effects of climate change in the Canadian context (see Health Canada 2008). Table 4 presents climate-related health concerns in the Canadian context.

Table 4. Health impacts of climate change in Canada[30]

Health impact categories	Climate-related causes	Projected/possible health effects
Temperature extremes	• More frequent and severe heat waves • Overall warmer weather, with possible colder conditions in some locations	• Heat-related illnesses and deaths • Respiratory and cardiovascular disorders • Possible changed patterns of illness and death due to cold
Extreme weather events and natural hazards	• More frequent and violent thunderstorms, more severe hurricanes, and other types of severe weather • Heavy rains causing mudslides and floods • Rising sea levels and coastal instability • Increased drought in some areas affecting water supplies and quantity, as well as agricultural production, and contributing to wildfires • Social and economic changes	• Death, injury and illness from violent storms, floods, etc. • Psychological health effects, such as mental health and stress-related illness from loss of loved ones, property, and livelihoods • Health impacts due to food or water shortages • Illnesses related to drinking water contamination • Effects of displacement of populations and crowding in emergency shelters • Indirect health impacts from ecological changes, infrastructure damages and interruptions in health services
Air quality	• Increased air pollution: higher levels of ground-level ozone and airborne dust including smoke and particulates from wildfires • Increased production of pollens and spores by plants	• Eye, nose and throat irritation, and shortness of breath • Exacerbation of asthma symptoms • Chronic obstructive pulmonary disease and other respiratory conditions • Exacerbation of allergies • Heart attack stroke and other cardiovascular diseases • Increased risk of certain types of cancer • Adverse pregnancy outcomes • Premature death

Health impact categories	Climate-related causes	Projected/possible health effects
Contamination of food and water	• Contamination of drinking and recreational water by run-off from heavy rainfall • Changes in marine environments that result in algal blooms and higher levels of toxins in fish and shellfish • Behavioural changes due to warmer temperatures resulting in an increased risk of food- and water-borne infections (e.g., through longer BBQ and swimming seasons)	• Outbreaks of strains of micro-organisms such as *E. coli*, *Cryptosporidium*, *Giardia*, *S. typhi* (typhoid), amoebas and other water-borne pathogens • Food-borne illnesses • Other diarrhoeal and intestinal diseases • Blue-green algae outbreaks
Infectious diseases transmitted by insects, ticks, and rodents	• Changes in the biology and ecology of various disease-carrying insects, ticks and rodents (including geographical distribution) • Faster maturation for pathogens within insect and tick vectors • Longer disease transmission season	• Increased incidence of vector-borne infectious diseases native to Canada (e.g., eastern & western equine encephalitis, Rocky Mountain spotted fever) • Introduction of infectious diseases new to Canada • Possible emergence of new diseases, and of those previously eradicated in Canada
Stratospheric ozone depletion	• Depletion of stratospheric ozone by some of the same gases responsible for climate change (e.g., chloro- and fluorocarbons) • Temperature-related changes to stratospheric ozone chemistry • Increased human exposure to UV radiation owing to behavioral changes resulting from a warmer climate	• More cases of sunburns, skin cancers, cataracts, and eye damage • Various immune disorders

Warming temperatures have begun to result in an increase in the number of severe storms and floods with resultant increases in accidental injuries.[31] Warming temperatures also allow for increased risk of infection with pathogens such as the West Nile Virus (WNV)[32] and the bacteria that causes Lyme disease due to more climatically suitable environments with warmer temperatures, shorter winters, increased human exposure and faster maturation cycles for pathogens[33,35] Increases in heat-related morbidity and mortality (e.g., heatstroke[34]), and the contamination of food and water with resultant increases in the burden of diarrheal diseases are projected to increase in many Canadian communities in the absence of further adaptation.[30] Indirect effects of climate change include resource shortages (e.g., food and water production) and economic disruptions affecting human well-being. The Ministry of Health and Long-Term Care's *Ontario Climate Change and Health Modelling Study* assessed the potential impacts of climate change on health and forecast key health risks across Ontario; generated projection scenarios for the 2050s and 2080s for Ontario's public health units; and illustrated the spatial distribution of potential health risks. Data for Peel indicates the following:

Number of heat waves[ix]

- 1971-2000: 0.29 heat waves
- 2050's: 1.42 heat waves
- 2080's: 3.38 heat waves

Projected percentage increase in basel cell carcinoma in 2050's and 2080's over the baseline period of 1971-2000

- 2050's: 7.7
- 2080's: 13.0

Projected percentage increase in squamous cell carcinoma in 2050's and 2080's over the baseline period of 1971-2000

- 2050's: 14.7
- 2080's: 24.6

Changes in the number of days with ozone exceedances (>80 ppb) count for the baseline period (1971-2000) and two projection periods (2050's and 2080's)

- Days above 80 ppb (1971-2000): 5
- Days above 80 ppb (2050's): 5
- Days above 80 ppb (2080's): 5

[ix] Heat wave is identified as at least three consecutive days exceeding 32°C

10.0 Peel region's vulnerability to climate change and impacts on human health

Based on a review of key climate change and health concerns facing Canadians and consultations with public health officials from the Region of Peel and Health Canada, the issues covered in this report include:

- Extreme heat;
- Air quality;
- Extreme weather and natural disasters/hazards;
- Food and water contamination; and
- Vector-borne diseases.

The following sections outline relevant indicators for exposures, sensitivities, and adaptive capacities as they relate to Peel's climate-related health areas. Specifically, each section highlights specific indicators and justifies inclusion based on the literature review. While some indicators focus on individual-level vulnerability, most are community-level indicators of current and/or future vulnerability (i.e., exposure, sensitivity, and adaptive capacity) available for Peel region. Data for the region is available in summary tables (see Tables 5, 7-10) and may be valuable for public health practitioners and decisionmakers in developing future programming and policies related to public health interventions and adaptation to climate change.

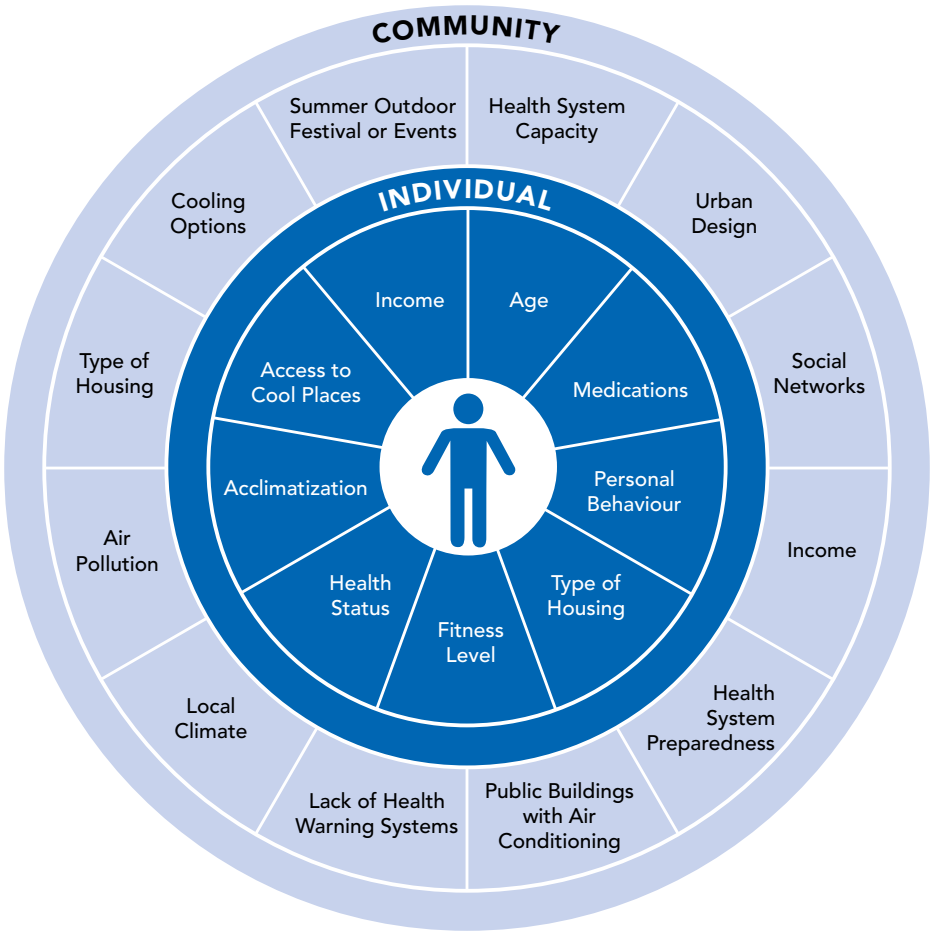
Mental health and social equity are not addressed in this vulnerability assessment. Mental health is an indirect impact of climate change. Climate change can cause psychological distress and/or amplify pre-existing conditions. Climate change and health inequities are also interconnected. Climate change disproportionately impacts the health of low-income communities, increasing exposure and vulnerability. Further work is needed to address both issues and their relationship to climate change.

10.1 Extreme temperatures

Health Canada, in collaboration with numerous stakeholders, have developed a methodology for undertaking extreme heat and health vulnerability assessments. The methodology is drawn from the same framework used to develop this report, which was created by the World Health Organization and the Pan-American Health Organization in 2012. Health Canada's (2011) *Adapting to Extreme Heat Events: Guidelines for Assessing Health Vulnerability* was also used.

Figure 1 outlines community and individual level determinants of vulnerability to extreme heat events. It presents the determinants of heat-related illness. These include income, age, medications, personal behaviours, housing type, fitness level, health status, acclimatization and access to cool places at the individual-level, and summer outdoor events, health system capacity, urban design, social networks, income, health system preparedness, public buildings with air conditioning, lack of health warning systems, local climate, air pollution, type of housing and cooling options at the community-level. The remainder of this section is largely based on the Health Canada (2011) document which represents a set of Canadian 'best practices' for assessing heat vulnerability.

Figure 1. Determinants of heat-related illness[35]



While winters are projected to become warmer with greater amounts of precipitation (i.e., rain rather than snow), extreme cold snaps can still occur and negatively impact human health in the region due to the exposure to freezing temperatures. Frostbite and cold-related mortality will pose serious public

health challenges, particularly for those who are most vulnerable (e.g., individuals with fewer material resources or those experiencing high degrees of social isolation). This may be increasingly relevant as residents in Peel region acclimatize to warmer weather.

While Canadians have a host of adaptive behaviours for cold weather given Canada's historically cooler climate, increasing temperatures will pose new challenges to the adaptive capacity of Peel region and its residents. This assessment focuses primarily on heat, as it is currently considered a higher priority health risk. However, it is important to monitor impacts associated with extreme winter weather, particularly as Canadians adjust to the warmer temperatures associated with climate change. Vulnerability to extreme heat and cold are similar.[36,37] As such, much of the data reported on extreme heat is relevant for future, more thorough vulnerability assessments of extreme cold weather.

10.1.1 Extreme heat: Exposure

Heat-related illness

As temperatures are expected to increase, maximum temperatures—particularly in the summer months—pose health risks to residents in Peel region. The human body's ability to successfully thermo-regulate and maintain a stable core temperature can be affected by exposure to very hot conditions, such as a heat warning[x] which raises body temperatures beyond optimal levels.

Heat stresses or heat-related morbidity are typified by heat stroke, heat exhaustion, fainting, edema, heat rash, and heat cramps.[35] Climate change will also increase the risk of UV caused cancers because of increased time spent outdoors.[38] Limited data is available on heat-related illness in Canada and obtaining such data is challenging[39], in part due to inadequate health surveillance and monitoring systems that may not capture heat-related health outcomes. For example, in the neighbouring City of Toronto, it is estimated that 120 deaths occurred annually from 1954 to 2000 that can be attributed to heat.[36]

In 2008, heat was estimated to increase the average annual death rate by 8 per cent and 4 per cent, for the Cities of Mississauga and Brampton respectively.[40] Updated data is not available for Peel.

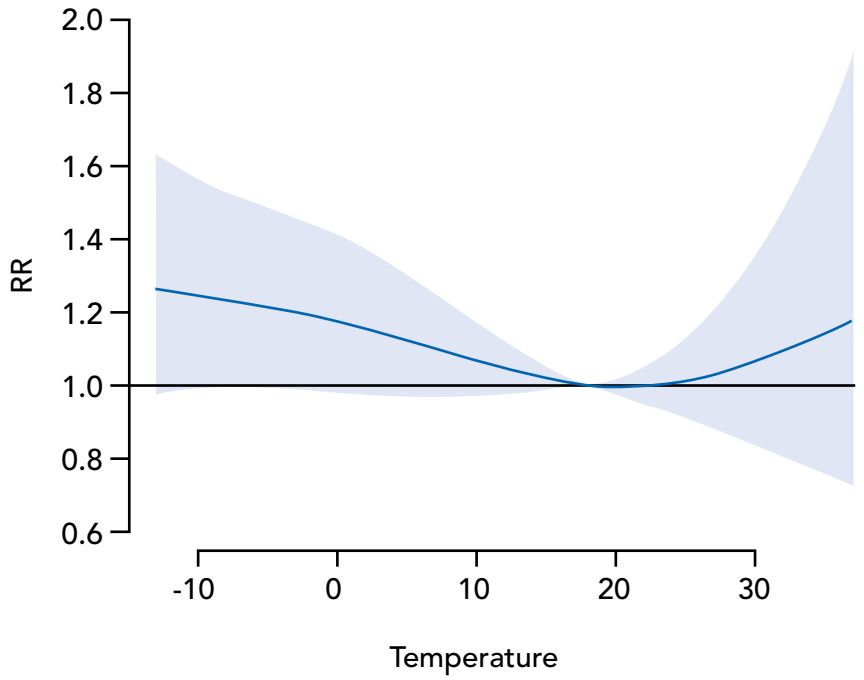
Heat mortality in Peel

Public Health Ontario (PHO) conducted a population-based study of all Ontario residents who died between Jan. 1, 1996, and Dec. 31, 2010, from any non-accidental cause. The study evaluated the extent to which cold and hot outdoor temperatures affect mortality in Ontario. PHO's results indicate that heat contributes to excess deaths in Ontario. In warm seasons, each 5°C increase in daily mean temperature was associated with a 2.5 per cent increase in non-accidental deaths on the day of exposure. Heat was also most strongly associated with increased respiratory-related deaths during admission to hospital.[41]

Figure 2 highlights Peel-specific data from PHO. The blue line indicates the relative risk estimate, comparing the risk of mortality at outdoor temperatures either below or above 20°C to the risk of mortality at 20°C. A relative risk greater than 1.0 indicates an increased risk of mortality and a relative risk less than 1.0 indicates a decreased risk of mortality. In Peel, there is an increasing risk of mortality as outdoor temperatures rise above the low twenties, compared with the risk at 20°C.

[x] Environment Canada Heat Thresholds for Peel Region

Figure 2. Relative risk of excess mortality in Peel by outdoor temperature, 1996 – 2010



A) **Heat warning:** Duration 2 days/Forecast daytime temperatures are expected to be at least 31°C and overnight temperatures are 20°C or above OR humidex is at least 40.

B) **Extreme heat warning/extended heat warning:** Duration 3+ days / Forecast daytime temperatures are expected to be at least 31°C and overnight temperatures are 20°C or above OR humidex is at least 40.

- The y-axis represents the excess mortality with respect to the 75th percentile of Peel temperature (1996-2010). The maximum likelihood estimate is shown as a smooth line and the pointwise 95 per cent confidence intervals are shown in the shaded area.
- Adjusted for: NO_2, O_3, influenza activity, statutory holidays, seasonal and long-term time trends.

Source: Data analysis by Public Health Ontario (2015)

The information above, combined with climate projections indicating an increase in day-time temperatures above 30°C and night-time temperature above 22°C will have implications for Peel residents in multi-unit residential buildings.[41] Maximum indoor temperature standards are one strategy that could be considered in multi-unit residential buildings to better protect the health of residents; for example, the City of Mississauga enacted the *Adequate Temperature By-law 0110* updated in 2018 stating that adequate and suitable cooling must be made available ensuring temperature within a resident's unit does not exceed 26°C.[44]

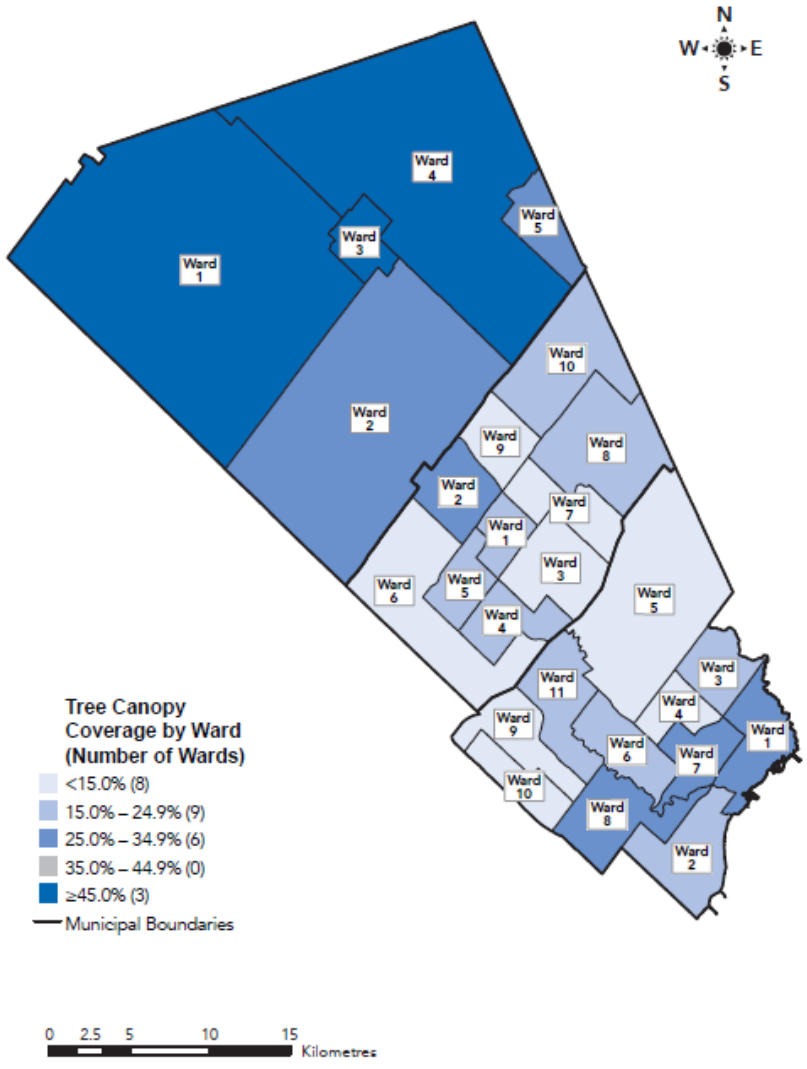
Land use and the urban heat island effect

The built environment plays an important role in exposure to extreme temperature. A variety of land uses can help mitigate the health effects of extreme heat.[42] For example, parks and tree cover are cooler than impervious surfaces often found in urban spaces.[43,44] Impervious land cover refers to urban spaces covered by cement or buildings rather than organic matter.

Urban heat islands (UHIs) occur in highly urbanized communities with large proportions of impervious land cover.[45] Average temperatures in UHIs can be up to 5 degrees warmer than surrounding areas[34], and have been widely documented in the Windsor-Toronto corridor.[46] Figure 3 shows the urban tree canopy in Peel. Due to urban development, Mississauga is particularly vulnerable to the UHI effect, as are the residential and commercial areas of Brampton. Overall, Caledon is at a lower risk of exposure due to the nature of rural, largely undeveloped land cover.

Peel region—except for rural Caledon—is a highly urbanized area with limited tree cover to mitigate the UHI effect. Tree canopy cover has increased from 11 per cent in Brampton and 15 per cent in Mississauga in 2006 to 18 per cent and 15 per cent respectively in 2017.[47] Data for Caledon cannot be compared as it was captured differently over the years.

Figure 3. Urban tree canopy, Peel, 2015



Source: Region of Peel, 2015, Peel Data Centre.

Building design

Individuals living on higher floors of high-rise buildings without adequate air circulation or air conditioning are particularly vulnerable to increased exposure to heat.[48,49,50] In 2016, 7.7 per cent (106,745) of Peel residents lived in apartments, compared to 7.6 per cent (88,040) of the population in 2006.[17] In 2016, 5.8 per cent (80,780) of individuals lived in apartments greater than 5 stories, compared to 5.7 per cent (66,025) in 2006.[20] Data on the availability of air conditioning in Peel is not available.

Evidence suggests that people living in thermally inefficient housing (e.g., those in disrepair) are more prone to heat-related illness.[6] No data on thermally inefficient housing is readily available in Peel region, nor are criteria for evaluating thermal inefficiency. As a proxy measure, 4 per cent of all dwellings in the region were identified as requiring major repairs in both the 2006 and 2016 census.[17,21]

Visitors and newcomers

In 2007, the City of Brampton tourism department estimated that Peel had over three million visitors (e.g., tourists) to the entire region.[51] Between 2001-2006, 100,000 newcomers immigrated to Peel.[21]

Visitors, newcomers, and those with low levels of education may be vulnerable to heat due to cultural differences, language barriers, or a lack of understanding of what to do in the event of an extreme heat alert (e.g., comprehending health messages and taking preventative measures). In 2016, 55,040 individuals had no knowledge of English or French, compared to 44,175 individuals in 2006.[17,21] There were 79,500 individuals in Peel, aged 25 to 64 with no degree, certificate or diploma in 2006 compared to 79,325 in 2016.[17,21]

Individuals participating in outdoor activities, events, or exercise

Individuals who participate in outdoor activities, events, or exercise are also at elevated risk of heat-related morbidity and mortality due to prolonged exposure and potentially high levels of physical exertion.[52,53] Data measuring outdoor exertion or the number of individuals exercising outdoors in Peel is not currently available.

Occupational groups

Occupational groups working in environments with a high baseline exposure to heat are at a greater risk of heat-related morbidity and mortality (e.g., bakeries, smelters).[35,54] Further, individuals working in construction, parks management, and occupations involving work outdoors may be increasingly exposed to warmer temperatures.[48] Data for these groups in Peel region is discussed in section 6.0. Additional information on other occupational groups experiencing differential exposure to heat is required.

Socioeconomic status

Individuals with low-incomes or those experiencing homelessness may be particularly vulnerable to heat.[46,55] Those with relatively lower incomes and fewer social supports—who typically experience poorer health than individuals with higher degrees of social and economic resources—may lack pertinent information or the capacity to protect themselves, cool themselves, or seek relief during extreme heat events.[56,57] These factors increase exposure to extreme heat and simultaneously reduce adaptive capacity. Data for Peel is discussed in Section 6.0.

O'Neill and Ebi reviewed the literature on vulnerability to extreme temperatures in the United States. They found that racialized communities may be particularly vulnerable to the health effects of extreme heat events, as such groups tend to experience relatively poorer health status as a result of pre-existing social and economic inequities.[57] Peel has a large population of individuals who immigrated to the region; however, the socioeconomic context of these individuals may be different than their American counterparts due to relatively higher levels of income and education.[40] More research is required to determine whether racialized communities in Peel may be differentially exposed to extreme heat. Peel-specific data is presented in section 6.0.

10.1.2 Sensitivity

Seniors

Individuals react differently to heat stress and some groups of individuals are more vulnerable to heat than others. Seniors are particularly vulnerable to extreme heat. According to the literature, seniors are at increased risk of adverse health effects of extreme heat if they live alone, have chronic health conditions, impaired cognition, or reduced mobility.[46,52,55,58,59] Seniors may be reliant on caregivers and unable to successfully engage in heat-adaptation efforts on their own. Seniors also have reduced thirst sensation, lower levels of physical activity, reduced sweating ability, increased susceptibility to chronic dehydration, and an increased reliance on medications such as diuretics.[35,54] Peel-specific data is presented in section 6.0.

Children

Children (under the age of ten) are vulnerable to extreme heat because they are often reliant on caregivers and have under-developed immune systems.[36,58] Children also perspire less and produce more body heat per body mass, while experiencing faster heat gain from the environment relative to adults.[35] Peel-specific data is presented in section 6.0.

Chronic conditions

Individuals with chronic health problems such as cerebrovascular or cardiovascular disease, mental illness, diabetes, obesity, and/or respiratory conditions are more sensitive to extreme heat as they have weakened or suppressed immune systems and may have impaired senses and increased dependency on caregivers.[56,60] Chronic conditions can be exacerbated by heat, but can also limit a person's mobility and their ability to seek out cooler locations.

In 2013/2014, 48 per cent of Peel's population reported having at least one chronic health condition diagnosed by a health-care professional, compared to 47 per cent in 2005.[45] The proportion of individuals who reported a two-week disability in 2008—having stayed in bed or reduced normal activities for one or more days in the previous two weeks due to illness or injury—was 5.2 per cent for males and 12.6 per cent for women. In 2013/2014, 25 per cent of Peel residents experienced activity limitation lasting or expected to last six months or more.[61]

The greatest activity limitations are among those aged 65 years or older. In Peel, 55.1 per cent of seniors (65+) reported sometimes or often experiencing activity limitation in 2013/2014, compared to 51 per cent in 2008. 2006 data also indicates that the prevalence of dementia among residents aged 65-74 is 2 per cent (compared with 0.4 per cent for the province of Ontario). Dementia is

projected to increase among residents in Peel from 8,600 cases in 2006 to over 29,000 cases by 2031.[40] Updated data from 2014 shows that the prevalence of dementia among Peel residents aged 65+ is 5.6 per cent.[24]

Individuals on particular medications or who abuse drugs or alcohol are also vulnerable to heat stress.[60,62] This is due to particular chemicals that compromise thermoregulatory systems in the body. No reliable data exists on the number of Peel residents using medications that may increase vulnerability to extreme heat. In 2013/2014, 85.9 per cent of Peel population 19+ adhered to the low risk drinking guidelines, an increase from 77 per cent reported in 2005.[24] In 2013/2014, 12 per cent of Peel residents reported binge drinking at least once per month in the past 12 months.[24] At the time of the survey, low risk drinking was defined as 14 or fewer drinks per week for males and nine or fewer drink per week for females, where neither males nor females consume more than two drinks on any single day in the previous week.

10.1.3 Adaptive capacity

To seek shelter from extreme temperature events, individuals can occupy public spaces equipped with air conditioning (or heating) such as shopping centers, movie theatres, or community centres. At the individual level, not consuming alcohol, dressing appropriately for weather, drinking adequate amounts of water, taking cool showers, avoiding strenuous activity, going to the basement, opening windows/doors or operating fans and air conditioners are key adaptive behaviours.[44,46]

Air conditioning and cooling centres

Use of air conditioning exacerbates energy insecurity and climate change by contributing to increased greenhouse gas emissions at peak use. It can also acclimatize people to a narrow range of temperatures thereby increasing their sensitivity to extreme heat.[65,66] No reliable information on air conditioner use or access (particularly for more heat sensitive populations such as the elderly) exists.

The Region of Peel and the local area municipalities have several existing adaptive strategies. Brampton has four community centres open extended hours in the event of extreme heat events and Mississauga has similar agreements with commercial centres (i.e., shopping malls). Caledon is primarily reliant on Brampton cooling facilities. Little information currently exists to identify how many individuals use cooling spaces, shelters, or social services during extreme heat events. Further, no reliable information exists on the cooling capacities of privately-run daycares and long-term care facilities, and whether such facilities are suitably protected from extreme heat.

Emergency response

Emergency response activities can help individuals better prepare for hot weather.[57] To date, a regionally coordinated emergency response to extreme heat has not been required. Some coordination has taken place across the social service sector by the Region of Peel - Human Services Department, who conduct outreach activities to community agencies and shelters in the event of extreme temperature warnings. Ensuring that vulnerable individuals have adequate access to social and health services (e.g., hospital, health clinics, shelters, emergency housing) is important, and coordination will be required between social service agencies and caregivers through outreach efforts.[29,46]

Social capital

Social networks and social capital are important elements of adaptive capacity as they provide access to resources and additional coping mechanisms. Individuals experiencing various forms of social isolation may therefore be less able to adapt to extreme heat events. The number of persons living alone increased from 4.75 per cent of Peel's population in 2006 to 6 per cent in 2016.[17,21,24]

A host of volunteer caregivers also exist in the region (168,280 individuals aged 15 or older reporting unpaid care or assistance to seniors in 2006) and engaging these caregivers will help increase adaptive capacity of particularly vulnerable groups (i.e., seniors, individuals with pre-existing chronic conditions). The continued engagement and outreach to paid caregivers working in the region's three hospitals, five regionally operated long-term care facilities, nine shelters, and numerous schools and privately-operated day cares and senior's facilities will also be an important feature of adapting to heat in the future.

Public awareness

Programs that reduce the health risks of extreme heat events such as public awareness through heat warnings and community outreach are extremely important.[43] The province of Ontario and the Ministry of Health and Long-term Care have developed a number of heat-related fact sheets to inform the public, and specific programs have been developed to provide information to seniors. For example, Tele-Health Ontario provides the general public with telephone access to nurses to ask questions about heat alerts and associated health risks.

In 2016, a Harmonized Heat Warning and Information System was introduced in Ontario to increase consistency among Public Health Units in response to heat events and to better protect residents, vulnerable community members and visitors.

A working group of Ontario public health units, including Peel, the Ontario Ministry of Health, and Long-Term Care, Public Health Ontario, Health Canada and Environment and Climate Change Canada, and the Clean Air Partnership came together to create an evidence-based harmonized system for Ontario.

Ontario's Harmonized Heat Warning Information System (HWIS) was piloted in 2015 during the Pan Am Games. In 2016, the HWIS was fully implemented across Ontario. Environment and Climate Change Canada (ECCC) monitors weather forecasts and notifies public health staff 2-4 days in advance, if their climate modelling predicts weather that meets the criteria for a health warning or an extended heat warning. Not all predictions result in a heat or extended heat warning being issued. As the heat event approaches, ECCC continues to advise public health authorities until it is confirmed that the event will meet the criteria. Notification of the public through tweets and key stakeholders (such as hospitals, community care access centres, childcare centres, long-term care facilities, municipalities, etc.) by Peel Health is done once the heat event is confirmed.

Transportation

Accessible public transit that is air conditioned has been demonstrated to be an important adaptive measure to extreme heat, particularly for low-income individuals.[60] Public transit systems are continually being developed in the region, and at present, two municipally led services operate within the three municipalities as well as the provincially run GO transit system.

Extensive regional train and bus network provides transit access to much of southwestern Ontario (e.g., GO Transit, Via Rail). However, single occupant vehicle use increased in the region from 81.5 per cent to 86.4 per cent between 1995 and 2006. More recent information on transit access and use is required, especially if public transit is to be advocated for to reduce greenhouse gas emissions through increased ridership (i.e., less cars on the road), while simultaneously operating as an adaptive measure to seek reprieve from extreme heat events.

The Region of Peel provides accessibility services including the TransHelp bus service for people with disabilities and patients needing dialysis. There was a 12.7 per cent increase in TransHelp trips from 2002 to 2010. Riders are charged a nominal fee to use the service and in 2011, 400,000 trips were estimated to be made on 56 buses. Attendants of persons with disabilities are also allowed to travel for free and on-going programs are in place to improve bus shelter accessibility.[67]

Tree cover

Increasing the percentage of land area covered by trees (including green roofs) helps reduce the urban heat island effect, as treed areas tend to be several degrees cooler than those covered by impervious surfaces.[57]

Other

Certain legislation may inhibit adaptive capacity and may need to be revised. For example, under the *Residential Tenancies Act*, the Province of Ontario requires all rental apartment buildings to be heated to a minimum of 20 degrees Celsius between September 15 and June 1 as heat is considered a 'vital service'.[68] This may be problematic as temperatures continue to increase.

To address this issue, the City of Mississauga passed an Adequate Heat By-law in 2018 which states that:

- Landlords provide adequate heat to maintain unit temperature of at least 20 degrees Celsius
- Where air-conditioning exists, landlords provide that a maximum temperature of 26 degrees Celsius is not exceeded, and
- Remove the temperature range dates (September 15 to June 1) found within the old By-law.[69]

In the City of Brampton, the Adequate Heat By-Law states that landlords are required to provide adequate and suitable heat in rental accommodations between September 15 and June 1 to a minimum of 20 degrees Celsius. However, the Director of Enforcement and By-law Services can shorten or extend the dates due to extreme variations in weather.[70]

Table 5. Climate-related vulnerability indicators for the health impacts of extreme heat in Peel region

Exposure

Indicator	2012 Report data	Updated data
Excess heat-related morbidity and mortality	**Estimated increase in yearly average death rates attributed to heat:** 8% in Mississauga; 4% in Brampton and Caledon.[71]	No changes
	By the mid-2020s, the Toronto-Niagara area could experience 144 to 447 annual heat related premature deaths among older populations.[40]	No changes
Heat projections in Peel	Data not included in 2012 Report.	See Table 3.
Tree canopy[xi]	Existing tree cover expressed as % of land cover (estimate for possible tree cover based on urban forestry strategy)[72]	Tree canopy proportion to total land size[47]
	Mississauga: 15% (~33%) **Brampton:** 11% (64%) **Caledon East:** 29% (55%)	**Mississauga:** 19% **Brampton:** 18% **Town of Caledon:** 35%
	Bolton: 17% No other data for Caledon available.	Not available
Per cent of land identified as impervious surface by land use type[73]	Rural/Estate Residential 40%	No changes
	Low Density Residential 45%	
	Medium Density Residential 55%	
	High Density Residential 67-75%	
	Institutional/school/recreational 55%	
	Commercial/Industrial 85%	
	Roadways 85%	
	Airport Lands 45%	
Per cent of land use cover classes across the Region of Peel[47]	Data not included in 2012 Report.	Buildings 7% Bare Ground 12% Impervious 15% Water 1% Road 4% Other Vegetated Areas 27%
Outdoor method of transportation	Data not included in 2012 Report.	14,215 persons walked to work, while 1,900 persons biked to work in 2016.[20]
People exercising vigorously outdoors	Not available	Not available

[xi] Data is presented in additional tables throughout the report. Indicators apply to additional health impacts such as Heat and Air Quality.

Exposure - continued

Indicator	2012 Report data	Updated data
Visitors (i.e., tourists) and newcomers	Between 2001 – 2006, 118,213 persons immigrated to Peel[74]	Between 2011 – 2016, 94,105 persons immigrated to Peel[17]
	In 2007, 3,255,000 persons visited Peel region[51]	Not available
Population living in apartments	In 2006, 88,040 persons resided in apartments (7.6% of Peel population)	In 2016, 106,745 persons resided in apartments (7.7% of Peel population)
	22,015 persons were living in apartments with <= 5 storeys (1.9% of Peel population)	25,965 persons were living in apartments with <= 5 storeys (1.9% of Peel population)
	66,025 persons were living in apartments with >5 storeys (5.7% of Peel population).[74]	80,780 persons living in apartments with > 5 storeys (5.8% of Peel population).[17]
Households without air conditioning	Not available	Not available
Proportion of dwellings requiring major repairs (i.e., potential thermally inefficient housing)	In 2006, 4% of dwellings required major repairs in Peel.[74]	In 2016, 18,140 (4%) of dwellings require major repairs in Peel.[17]

Sensitivity

Indicator	2012 Report data	Updated data
Population taking medications (e.g., diuretics)	Not available	Not available
Alcohol use	In 2005, 77% of the population adhered to low risk drinking guidelines.[40]	In 2013/2014, 85.9% of the population 19+ adhered to low risk drinking guidelines, with 12% of the current drinking population reporting binge drinking in the past 12 months.[24]
Chronic illness and disability	In 2005, 47% of Peel residents reported having at least one chronic condition.[40]	**2013/2014:** 48% of Peel residents report having at least one chronic health condition that was diagnosed by a healthcare professional[75]
	In 2008 • 23% of men and 29.4% of women in Peel sometimes or often had activity limitation. • 6.4% of men and 16% of women in Peel require assistance with activities of daily living. • 5.2% of men and 12.6% of women in Peel received two-week disability.[40]	**In 2013/2014** • 25% of the Peel population sometimes or often experienced activity limitations lasting or expected to last six months or more.[75]

Sensitivity - continued

Indicator	2012 Report data	Updated data
Chronic illness and disability (continued)	• 51% of those 65+ sometimes or often had activity limitation, the greatest proportion among all age groups. • 31.5% require assistance with activities of daily living. • 10.6% received two-week disability.[40]	**In 2013/2014:** • 55.1% of those 65+ sometimes or often had activity limitations.[75]
	In 2006 • The prevalence of dementia among residents aged 65-74 was 2%, and 35% among those aged 85+.[40] • Future vulnerability of dementia is projected to increase from 8,600 cases in 2006 to over 29,000 cases by 2031.[40]	Updated data from 2014 shows that the prevalence of dementia among Peel residents aged 65+ is 5.6%.[24]

Adaptive capacity

Indicator	2012 Report data	Updated data
Public spaces (cooling centres)	City of Brampton has four community centres with extended hours for extreme heat, as well as the Brampton City Hall Atrium. Town of Caledon primarily relies on Brampton facilities.[76]	No changes
	City of Mississauga has agreements with commercial centres (i.e., shopping malls) to remain open for extended hours for extreme heat.[77]	City of Mississauga encourages residents to visit a nearby airconditioned library or one of 11 community centres, 18 libraries, 11 indoor pools, 7 outdoor pools, and 26 spray pads.[77]

Adaptive capacity - continued

Indicator	2012 Report data	Updated data
Government policies and education	Province of Ontario and the Ministry of Health and Long-Term care have: • Extreme heat fact sheets from the Emergency Management Branch • Information and support for homecare of seniors through Senior's Care • TeleHealth Ontario service providing access to nurses • General public health information	Province of Ontario and the Ministry of Health and Long-Term Care have: • Heat and Cold Stress Policy from the Emergency Management Branch • Ministry of Labour, Extreme Heat and Safety guidelines • Information and support for homecare of seniors through Senior's Care • Standard Operating Procedure for Public Health Units • TeleHealth Ontario service providing access to nurses • General public health information
	Paramedic service operated and coordinated regionally by the Region of Peel.	No changes
Built environment including land use and access to transportation infrastructure	Peel Public Health is currently assessing the built environment in the Region of Peel through a comprehensive focus on neighbourhood walkability, land use, transportation and the links to human health.[40]	ROPA 27 came into effect September 2017. Policies related to health and the built environment; age-supportive policies are also supported.[79]

Adaptive capacity - continued

Indicator	2012 Report data	Updated data
Public transit services[11]	Transit services are provided by Mississauga Transit and Brampton Transit within the cities of Mississauga and Brampton. **Mississauga Transit:** 337 buses in total, with 45% wheelchair accessible. **Brampton Transit:** 137 buses in total, with 35% wheelchair accessible.[67]	**Mississauga Transit:** 422 buses, 92% low-floor accessible. **Brampton Transit:** 238 conventional buses, 25 rapid transit buses, 84% equipped with accessibility features.[67]
	GO transit (train travel to and from the Region) trips during the peak morning period estimated at ~28,000 in 2001.[67]	GO Transit trips grew from 29,950 riders to 32,580 between 2001 and 2006. 4.2% annual growth rate.[67]
	Accessible Transit (e.g., TransHelp) Data not included in 2012 Report	TransHelp services (accessible transit for those who are unable to use conventional transit). For those who have mobility problems that limit them to climb or descend stairs in a conventional transit.[67] 56 vehicles, ~400, 000 trips annually. 12.7% increase from 2002 and 2010.[67]
Emergency response/ public awareness and education	Emergency response can be coordinated regionally depending on scale of emergency, but municipalities operate their own emergency response systems.	No changes
Volunteer care givers (over the age of 15) reporting unpaid assistance to seniors	**2006:** • **Brampton:** 61,525 • **Mississauga:** 98,230 • **Caledon:** 8,525 • **Peel:** 168,280[81]	No changes
Social isolation	In 2006, 52,555 persons lived alone (4.5% of Peel population).[81]	In 2016, 68,345 persons lived alone (6.1% of Peel population).[17]
	In 2006, 15,520 persons aged 65+ lived alone (1.3% of Peel population).[81]	In 2016, 24,755 people or 14% of Peel seniors aged 65+ lived alone.[24]
Early notification of heat event	Not available	Peel Public Health provides early notification of a heat warning to key stakeholders.

10.2 Air quality

Climate change holds the potential to exacerbate existing air quality issues.[82] Increases in temperature contribute to the increased development of ground level ozone, and enhanced pollen production (as a result of changes in pollen season onset and duration) and the spread of particulate matter.[83,84,85] Particulate matter may also spread because of the long-range transport of smoke and ash from wildfires, which are predicted to increase with climate change. Poor air quality is linked to respiratory diseases, cardiovascular conditions, seasonal allergies, some types of cancer, and premature death.[40]

10.2.1 Exposure

Sources of pollution and resultant exposure

Air quality in Peel is improving due to decreased emissions of NO_2, SO_2, CO and $PM_{2.5}$ as a result of closing coal-fired generating stations, improved fuel and vehicle emissions standards, and tighter industrial emissions standards.[86]

Peel is unique in Ontario due to the number of highways, large arterial roads, and the Toronto Pearson International Airport. Peel also has a large goods movement industry. Every day, nearly 70,000 vehicles transport goods over Peel's roads.[87]

Transportation is a major concern because people are widely exposed to its emissions. People living near major roads and travelling in cars are exposed to higher levels of air pollution. Exposure to air pollutants from traffic emissions generally occurs within 300 to 500 metres from a highway or major road, with the highest exposure closest to the road and decreasing with distance from the road. Traffic-related emissions in the Greater Toronto-Hamilton area (GTHA) are estimated to be responsible for up to 1,000 premature deaths and 4,000 hospitalizations each year.[88]

Fifty-three per cent of Peel's population lives within 300 metres of a high-volume traffic road or highway (>25,000 vehicles per day).[88,24]

Air pollution affects everyone, but some people face a higher risk. These include people with heart disease, asthma, chronic obstructive pulmonary disease and other respiratory illnesses, obesity, diabetes, young children, the elderly, pregnant women, those with lower incomes (whose homes are often in close proximity to sources), those who work or exercise vigorously outdoors, and those who live or work in close proximity to a significant pollution source.

Exposure, excess mortality and hospital admissions

Table 6 summarizes the range of potential health effects by pollutant.

Table 6. Summary of potential acute and chronic health effects from outdoor air pollution[89,90]

Pollutant	Acute	Chronic
Ground-level ozone (O_3)	• Reduction in lung function in healthy people during periods of exercise, generally accompanied by tightness in the chest, pain and difficulty breathing, coughing and wheezing • Inflammation • Premature mortality	• All-cause mortality • Development of asthma • Lung tissue damage
Fine particulate matter ($PM_{2.5}$)	• Irritation of the eyes, nose and throat • Coughing, breathing difficulties, reduced lung function • Inflammation • Decreased lung function	• Cancer • Ischemic heart disease • Mortality (all-cause, cardiovascular, respiratory) • Low birth weight
Sulfur dioxide (SO_2)	• Irritation of the eyes, nose, throat, and airways to cause coughing, wheezing, shortness of breath • Respiratory problems in people with asthma, but at relatively high levels of exposure	• Marginally associated with all cause and cardiopulmonary mortality
Nitrogen oxides (NO_x)	• Irritation of the respiratory system/ triggers asthma • Impaired lung function	• Chronic effects on the cardiovascular system

Carbon monoxide (CO)	• Low-level, short-term exposure:
	  • Decreased athletic performance
	  • Aggravated cardiac symptoms
	• Acute exposures in the range of 70-800 ppm can cause headache, dizziness, disorientation
	• Reduces the ability to transport oxygen
	• Premature death (above 800 ppm)
		n/a

Volatile organic compounds (VOC)	• Depends on the VOC	• Some VOCs can cause cancer over long-term exposures (e.g., formaldehyde and benzene)

A key indicator of exposure to poor air quality is when the level of ozone or particulate matter exceeds government standards. Peel has two air quality monitoring stations—one in Mississauga and one in Brampton. Pearson International Airport also had an air monitoring station, but it has not been operational since 2008.

Between 2007 and 2016, monitoring data for ozone annual means in Ontario show the trend to be slowly increasing. Ozone annual means have increased by 1 per cent in Brampton and 8 per cent in Mississauga but remain below that of Ontario levels. In Newmarket (representative for Caledon), levels have decreased by 8 per cent over the past 10 years.[86]

Due to changes in how $PM_{2.5}$ was measured between 2013 and 2016, ten-year trends regarding $PM_{2.5}$ are not directly comparable; however, the Ministry of Environment, Conservation and Parks (MECP) has applied a correction factor to approximate the ten-year trend–between 2007 and 2016, there was a 12 per cent decrease in $PM_{2.5}$ annual mean concentrations and a 16 per cent reduction in $PM_{2.5}$ emissions in Ontario (Figure 7.5). $PM_{2.5}$ emissions from electric utilities and industrial processes decreased by approximately 33 per cent in Ontario between 2007 and 2016.[86] Emissions from the transportation sector decreased by 48 per cent during the same period due to the phase-in of new vehicles/engines with stricter emission standards.[86,91]

To assess and manage regional air quality, the MECP developed Ambient Air Quality Criteria (AAQC). AAQCs refer to a desirable concentration of an air pollutant not to be exceeded over defined averaging times – generally over one-hour, eight-hours, 24-hours and/or annually, based on human health and environmental effects. The averaging times are designed to protect against both acute and chronic health effects.[86] There were no exceedances of AAQC recorded in Peel stations for 2016. The station in Newmarket (representative of Caledon) recorded seven hours above the one-hour ozone AAQC in 2016.[86]

In 2011, the Canadian Medical Association (CMA) "Illness Cost of Air Pollution" model estimated that excess mortality due to particulate matter under current conditions (i.e., not accounting for climate change) is about 300 per year per 100,000 for Peel region. Poor air quality is also estimated to produce an increase in excess hospital admissions from those experiencing symptoms of asthma, COPD, and cardiovascular disease.

There are an estimated 290 to 900 new cancer cases in Ontario annually from exposure to fine particles in outdoor air. The estimated number of lung cancer cases attributable to diesel particulate matter exposure is 100 per year.[92]

Based on the updated Air Quality Benefit Assessment Tool model, it is estimated that 0.9 per cent (95 per cent confidence interval [CI]: 0.3 per cent-1.5 per cent) of non-accidental mortality in Peel can be attributed to acute exposure of the Peel population to anthropogenic emissions (caused by human activities) of NO_2. This represents 45 deaths per year.[93]

Acute exposure to ozone in Peel from 2007 to 2009 was associated with 1.3 per cent (95 per cent CI 0.9 per cent-1.7 per cent) of non-accidental mortality (60 deaths per year), whereas chronic exposure to ozone in Peel was linked to 8.1 per cent of respiratory-related mortalities (95 per cent CI: 2.8 per cent-13.1 per cent), equivalent to 31 respiratory mortalities per year.[93]

In Peel, there was a 2.7 μg/m^3 decrease in $PM_{2.5}$ from 2000 to 2011, representing a 24.2 per cent decrease in anthropogenic attributable $PM_{2.5}$ emissions. This decrease was associated with a gain in life expectancy of 0.22 years and a reduction in the number of people experiencing air pollution related health impacts such as respiratory and cardiac hospital admissions.[93]

With an increasing population and hotter days, the risk of smog is predicted to increase in Peel region. In 2011, the annual smog-related deaths in Peel region were estimated to be approximately 50.[71] Under current conditions, the total number of smog-related deaths could increase to 90 by 2031;[71] however, these data do not account for climate change and there is a demonstrated need for a more sophisticated analysis of how climate change will impact concentrations of particulate matter, ozone and smog in the future under warmer temperatures.

Socioeconomic status

The relationship between socio-economic status and air quality in Peel is unknown. However, persons of low socioeconomic status may experience differential exposure to air pollution, particularly if they are homeless. McMichael, Woodruff and Hales indicate that poorly ventilated housing is a key air quality vulnerability indicator (estimated at 4 per cent of total dwellings in Peel region when using census data indicating the proportion of dwellings requiring major repairs).[6,82] Housing is directly related to the relative economic (dis)advantage of particular groups[3], and individuals with higher incomes tend to have fewer chronic conditions and lower exposure to air pollution.[85,94] For example, in Hamilton, Ontario study results show that neighbourhoods with lower incomes, higher rates of unemployment and higher proportions of immigrant populations are associated with higher particle concentrations for air pollutants.[95,96] Individuals with low levels of education may also lack an understanding of the risks associated with poor air quality, particularly on poor air quality days. Information on education, income and shelter use are presented in section 6.0.

10.2.2 Sensitivity

Children and the elderly

Children and the elderly are most at risk of adverse health effects of poor air quality under climate change. As indicated above, children typically spend more time outdoors, particularly in the summer months, and physical exertion typically leads to a higher cumulative dose of air pollution to the lungs.[82] The elderly may have numerous pre-existing health conditions that are likely to be exacerbated by poor air quality.[97] It is estimated that between 2008 and 2031, 80 per cent of smog-related deaths will occur among the elderly, and smog-related emergency room visits will increase by 60 per cent.

Chronic conditions

Individuals with pre-existing health conditions also face increased risk, but especially those with lung diseases, cardiovascular disease, or other kinds of respiratory conditions.[9,10,97] Asthma is exacerbated by exposure to ozone, particulate matter, and aeroallergens,[85] and 8 per cent of the Peel population displayed asthma symptoms in 2005 resulting in 52 hospitalizations and an estimated 136,000 'asthma symptom days'.[71] There were 634 hospitalizations for asthma in 2016.[24] In 2013/2014, 6.2 per cent of Peel's population were diagnosed with asthma.[98]

Smokers are at elevated risk of contracting a host of chronic respiratory conditions and are more vulnerable to the health effects of poor air quality.[85,99] In 2013/2014, 11 per cent of the Peel population were smokers. This is significantly lower compared to Ontario (17 per cent). The proportion of the population in Peel of current smokers declined significantly between 2000/2001 (20 per cent) and 2013/2014 (11 per cent). In Peel, the proportion of males who were current smokers was significantly higher, compared to females across all years between 2000/2001 and 2013/2014.

In 2015, 53,266 people had Chronic Obstruction Pulmonary Disease (COPD) in Peel.100 In 2016, Peel had 1,235 hospitalizations for COPD.[71,24]

People chronically exposed to air pollution are also most likely to be overweight/obese, diabetic, and prone to a number of related chronic conditions.[99] Residents of Peel who are overweight/obese (BMI>25.0) may have difficulty breathing due to their weight. In 2013/2014, 62.6 per cent (18+) of Peel's population were overweight/obese.[101]

10.2.3 Adaptive capacity

Reducing health risks of poor air quality that may worsen with climate change involves a combination of greenhouse gas and air quality mitigation (e.g., increasing green spaces, strategies to reduce fossil fuel emissions) and adaptation measures. Adaptive measures include the ongoing surveillance of the health effects of air pollution and enhancing the quality of health care services and public health infrastructure. Doing so will increase public health capacity to respond to increased burden of disease associated with changing air quality due to climate change.[9,10] Blashki et al. indicate that the coordination of regular communication to the public and the provision of early warning systems are key components of climate-related responses to poor air quality that can aid in reducing or limiting emissions on poor air quality days.[102] Reassessing and/or strengthening the enforcement of local, regional or national air quality regulations and the provision of incentives to increase energy efficiency are important strategies to minimize the health risks associated with poor air quality.[3]

Increased emissions controls are identified in the literature as a valuable intervention to reduce exposure,[82,103] but an overall reduction in emissions may still lead to the differential exposure to poor air quality among socially and economically vulnerable groups. A range of strategies that focus on human interaction with features of the built environment has been offered as strategies to reduce differential exposure and improve air quality.[43] For example, the effective management of allergenic plant species in a given region is important in reducing exposure to aeroallergens.[102] Increasing the green space (e.g., tree cover, parks, vegetation cover) in an urban area can also improve air quality as plants capture pollutants (e.g., carbon dioxide) and convert it to oxygen.[85,104] The Region of Peel partnered with Conservation Authorities, Health Canada, York University, and other municipalities in the development of Peel's Urban Forestry Strategy. In 2012, the percentage of tree canopy in each municipality of Peel was 11 per cent in Brampton, 15 per cent in Mississauga and 29 per cent in Caledon East.[2] In 2017, there was 18 per cent in Brampton, 19 per cent in Brampton and 35 per cent for the Town of Caledon.[47]

A host of emissions reduction programs exist at the national, provincial, local and corporate level for the Region of Peel, and staff from the region are engaged in numerous programs to better address air quality (see Table 7). Government regulations have been developed to improve the air quality in Canada. New Canadian-wide standards were introduced in 2012 and aimed at reducing the health and environmental risks of fine particle matter and ozone. Updated sulphur regulations and Canadian Alternative Fuels Act for the reduction of emissions of carbon dioxide and greenhouse gases have also been developed.

Provincially, the Ministry of Environment, Parks and Conservation began issuing Special Air Quality Statement (SAQS) and the Smog and Air Health Advisories (SAHA) in 2015 for the Pan Am Games.[29] Special Air Quality Statements and Smog and Air Health Advisories are issued based on the Air Quality Health Index whereas smog advisories were issued based on the old Air Quality Index. Due to the differences, the Special Air Quality Statements and Smog and Air Health Advisories should not be compared with the past smog advisories.

Peel Public Health's comprehensive focus on the built environment and active transportation will continue to contribute to the improvement of air quality and health under climate change. Encouraging individuals to utilize public transit through infrastructure upgrades, improvements, and service expansion can reduce transportation emissions and the differential exposure of individuals living near major roadways.[3,85] More information and up to date data will be required to better understand how public transit can offer useful adaptive mechanisms to improving health, while also serving to mitigate climate change in the attempt to increase transit ridership and reduce the amount of vehicle traffic in the region.

Peel staff utilize the data from two Ministry of Environment air quality monitoring stations that operate year-round to better monitor pollution levels at the local level. Regional Council also approved the implementation of an air modelling program for common air pollutants (PM, NO_x, NO_2, O_3, CO, SO_2 and VOCs) across the region. The Region of Peel also implements initiatives to reduce their carbon footprint - the Smart Commute program, anti-idling polices and active transportation policies. In addition, in 2013 the Region of Peel adopted the Energy and Environment Sustainability Strategy (EESS) to ensure compliance with energy regulations as well as developed the *Regional Climate Change Master Plan* in 2019 as a guide to delivering critical services aimed at reducing emissions and increasing Regional preparedness to mitigate and adapt to the effects of climate change.

Table 7. Climate-Related vulnerability indicators for the health impacts of poor air quality in Peel region

Exposure

Indicator	Data from 2012 report	Updated data
Number & duration of smog advisories	Varies yearly and is driven by weather patterns.[71]	SAQS and SAHA's were introduced in 2015, therefore, data was not available for the 2012 Report. Data can not be compared.[xii]
Number of Special Air Quality Statements (SAQS) and Smog and Air Health Advisories (SAHA) issued by the MECP	Not available	Halton-Peel Special Air Quality Statements Issued: 2015 - 1 2016 - 1 2017 - 1 Smog and Air Health Advisories - 0 from 2015 - 2018 **http://www.airqualityontario.com/aqhi/advisories_stats.php?t=1**
Air quality exceedances	**Ozone (1-hour) exceedances**[71] In 2010, Mississauga recorded 3 ozone exceedances. **Particulate Matter ($PM_{2.5}$) (24-hour) exceedances**[71] There were no exceedances recorded in Brampton or Mississauga.	• No exceedances of AAQCs recorded in Peel stations for 2016 • The Newmarket station (representative of Caledon) recorded seven hours above the one-hour ozone AAQC in 2016.[86]
Industrial sector air pollution (Industrial facilities in Peel)	Between 1993 and 2010 there were 231 large emitters in Peel: • Brampton – 87 • Caledon – 9 • Mississauga – 134[71]	**In 2016** • 111 industries reported releases to air to the National Pollutant Release Inventory (NPRI)[xiii] • A total of 19,075 tonnes of pollutants were released to the air, covering 12 different groups of substances[24]
Transportation air pollution (highways and major arterial roads)	• Seven 400-series highways, most frequented in AM and PM rush hour • Trip length and number of trips remain steady, but number of households increasing greatly • 3% of Peel residents walk or bike to work[71]	• Increase of trucks (goods movement) within the Region of Peel. 46.7% of truck trips (highest since 2004) were heavy trucks, 34.8% lights trucks, and 18.5% medium trucks • Approximately 70,000 vehicles transport goods over Peel's roads[87]

[xii] The Ministry of Environment, Parks and Conservation stopped issuing smog advisories in 2015. Environment Canada and the Ontario Ministry of the Environment, Conservation and Parks issue Special Air Quality Statements (SAQS) and Smog and Air Health Advisories (SAHA) as of 2015. If a high-risk Air Quality Health Index value is forecast to last for 1 to 2 hours, then a SAQS will be issued. If the high-risk Air Quality Health Index is forecast to be persistent, a duration of at least 3 hours, then a SAHA will be issued.

[xiii] The National Pollutant Release Inventory (NPRI) collects information from Canadian industrial, commercial and institutional facilities on their releases, disposals and transfers of pollutants and other substances of concern annually. Facilities that manufactured, processed or otherwise used one or more NPRI substances during the year and had more than approximately 10 full-time employees are legally required to report to the NPRI. Waste or sewage sludge incineration, wood preservation, fuel terminal operations, municipal wastewater collection or treatment, or pit and quarry operations or operating stationary combustion equipment (if release thresholds are met), must report to the NPRI, regardless of employee thresholds.

Exposure - continued

Indicator	Data from 2012 report	Updated data
Traffic-related emissions and pre-mature death and hospitalizations	Data not included in 2012 Report.	Traffic-related emissions in the Greater Toronto-Hamilton area (GTHA) are estimated to be responsible for: Up to 1,000 premature deaths and 4,000 hospitalizations each year.[88]
Population/sites within 300 metres of high traffic volume on roads	It is estimated that 115,900 residents & 10 schools are located within 300m of 400 series highways.[71]	Fifty per cent of Peel's population lives within 300 metres of a high-volume traffic road or highway (>25,000 vehicles per day).[88] For a breakdown, please refer to Table 7A.
Other significant sources of air pollution in Peel	Toronto Pearson International Airport, energy use (corporate, residential); transboundary air pollution (e.g., Sarnia, Hamilton, USA); Toronto Pearson International Airport air monitoring has not occurred since 2008 due to upgrades.[71]	A recently completed Air Quality and Human Health Risk Assessment for Toronto Pearson International Airport found that the traffic on major highways around the airport contributes more to poor air quality than the airport itself.[106] Airport operations directly contribute an estimated 8% of air pollutants within 7.5 km of the airport.
Estimated number of attributable morbidity and mortality associated with air pollutants	**Between 1999 and 2009,** • Approximately 15% of Peel residents were estimated to have been hospitalized at least once or saw their doctor at least twice within a two-year period for asthma.[71] **In 2008,** • The number of asthma hospitalizations per 100,000 population < 18 years in Peel was equivalent to 177.9, compared to 26.4 for those aged 18 years +.[71] • It is estimated that acute exposure to air pollution in Peel causes approximately 8 hospitalizations for asthmatic children and 4 for asthmatic adults each year in Peel.[71] **In 2011,** • Long-term exposure to air pollution estimated to result in approximately 93 deaths, 395 hospital admissions and 3,396 emergency room visits.[71]	**As recent as 2017,** • Data shows a 2.7 μg/m^3 decrease in $PM_{2.5}$ between 2000-2011, representing a 24.2% decrease in anthropogenic $PM_{2.5}$ emissions, associated with a life expectancy gain of 0.22 years. This gain also reduced the number of people experiencing respiratory and cardiac hospital admissions.[24] • 0.9% of non-accidental mortality in Peel can be attributed to acute exposure to anthropogenic emissions of NO_2, representing 45 deaths per year.[24] • Acute exposure to anthropogenic emissions of ozone in Peel was associated was 1.3% of nonaccidental deaths, or 60 deaths per year. Whereas chronic exposures were linked to 8.1% of respiratory-related mortalities, or 31 respiratory deaths per year.[24]

Sensitivity

Indicator	Data from 2012 report	Updated data
Population with pre-existing health conditions	**In 2005,** • 8% of the population had asthma, leading to 52 hospitalizations • Totalling an estimated 136,000 'asthma symptom days'[71]	**In 2011,** • 42 hospitalizations reported for asthma each year in Peel based on 2011 population estimates. **In 2012,** • Approximately 35 hospitalizations for childhood asthma per day. **In 2013/2014,** • 6.2% of Peel population was diagnosed with asthma. **In 2016,** • There were 634 hospitalizations due to asthma.[71,98,24]
	In 2006, • Approximately 2% of Peel residents were treated for COPD.[71]	**In 2015,** • There were 53,266 people with Chronic Obstructive Pulmonary Disease (COPD)[71,100,24] **In 2016,** • 1,235 hospitalizations for COPD among residents in Peel.
	In 2004, • Incidence of lung cancer among men was approximately 60/100,000 for men, and 50/100,00 for women.[71]	**In 2012,** • The number of lung cancer cases among men was 309 and 253 for women.[107]
	In 2006, • 50.2% of the population aged 18+ had a BMI over 25.0, equal to the overweight/obesity category.[71]	**In 2013/2014,** • 62.6% of the population aged 18+ had a BMI over 25.0, equal to the overweight/obesity category.[101]
Smoking status	**In 2010,** • Among women, 10.5% are smokers. • Among men, 19.5% are smokers.[108]	**In 2011/2012,** • 12.1% of the population are daily smokers[xiv] • 7.9% among women; 16.4% among men[63]

[xiv] A daily smoker is one who currently smokes and has smoked at least 100 cigarettes in their lifetime

Adaptive capacity

Indicator	Data from 2012 report	Updated data
Air quality monitoring capabilities	The Ontario Ministry of Environment has two monitoring stations in Peel, one in Brampton and one in Mississauga.[71]	No changes
	Additional monitoring stations include: • National-run monitoring station in Brampton "NAPS" • Industry-run monitoring station in Mississauga "CASIA" • Neighbouring Halton Region has an extensive modelling and monitoring program.[71]	No changes
	A combined air quality modelling program from Peel Region was implemented by Peel Public Health based on 2010 emissions and 2012 meteorological data.	The combined air quality model was updated with 2015 emissions and meteorological data.
Outreach and awareness	Poor air quality days announced to the public through media releases.	Poor air quality days announced to the public through twitter.
Built environment	Peel Public Health has established a comprehensive focus on the built environment and is currently assessing neighbourhood walkability, land use, transportation, and the resulting links to human health.	In September 2017, the Region of Peel Official Plan Amendment 27 came into effect, supporting policies related to health and the built environment.
Tree canopy[xv]	Existing tree cover expressed as per cent of land cover (estimate for possible tree cover based on urban forestry strategy)[72]	Tree canopy proportion to total land size[47]
	Mississauga: 15% (~33%)	**Mississauga:** 19%
	Brampton: 11% (64%)	**Brampton:** 18%
	Caledon East: 29% (55%)	**Town of Caledon:** 35%
	Bolton: 17% No other data for Caledon available.	Peel region has a total of 34% tree canopy versus other land classifications (e.g., building, water, and road)[47] There is a total of 40,528 hectares of tree canopy in Peel, with Caledon having the highest proportion of tree canopy at 31,480 ha, followed by Mississauga at 4,534 ha, and Brampton at 4,513 ha.[24]

[xv] Data is presented in additional tables throughout the report. Indicators apply to additional health impacts such as Heat and Air Quality.

Adaptive capacity - continued

Indicator	Data from 2012 report	Updated data
Public transit services	Transit services are provided by Mississauga Transit and Brampton Transit within the cities of Mississauga and Brampton. **Mississauga Transit:** 337 buses in total, with 45% wheelchair accessible. **Brampton Transit:** 137 buses in total, with 35% wheelchair accessible.[67]	**Mississauga Transit:** 422 buses, 92% low-floor accessible. **Brampton Transit:** 238 conventional buses, 25 rapid transit buses, 84% equipped with accessibility features.[67]
	GO transit (train travel to and from the Region) trips during the peak morning period estimated at ~28,000 in 2001.[67]	GO Transit trips grew from 29,950 riders to 32,580 between 2001 and 2006. 4.2% annual growth rate.[67]
Automobile use	Peel region continues to see an increase in individual automobile use (35% increase between 1991 and 2001) and the proportion of single occupant vehicles crossing Peel boundaries increased from 81.5% to 86.4% between 1995 and 2006.[109]	Peel region continues to see auto as a preferred method with 75% use versus any other method of transportation. The proportion of single occupant vehicles crossing Peel boundaries increased from 86.4% to 89% between 2006 and 2014.
Federal government regulations aimed at improving air quality	Canada wide standards aimed at reducing health and environmental risks within a given timeframe: • Ozone – 65ppb over 8 hours • $PM_{2.5}$ – 30ug/meter cubed over 24 hours.[110]	Canada wide standards aimed to reducing health and environmental risks within a given timeframe were updated. For the first time in Canada, standards also include long-term (annual) targets for fine particle matter. **In 2015,** • Ozone – 63 ppb over 8 hours • $PM_{2.5}$ – 28 µg/m³ over 24 hours • $PM_{2.5}$ – Annual 10 µg/m³ **In 2020,** • Ozone – 62 ppb over 8 hours • $PM_{2.5}$ – 27 µg/m³ over 25 hours • $PM_{2.5}$ – Annual 8.8 µg/m³
	In 2005, all gasoline in Canada must have low sulphur content.[110]	In 2017, regulations limit the sulphur content of gasoline to 14 mg/kg as of January 1, 2017, with the limit reducing to 12 mg/kg on January 1, 2020.
	In 2005, Canadian Alternative Fuels Act developed to accelerate use of alternative fuels.[110]	No changes

Adaptive capacity - continued

Indicator	Data from 2012 report	Updated data
Provincial government regulations aimed at improving air quality	The Province of Ontario funds the development of monitoring infrastructure and emissions testing while also playing a role in establishing land use policies to reduce urban sprawl.[109]	No changes
	The Ministry of the Environment is responsible for all air quality monitoring in the province, sets standards for toxins and deals with individual industrial emitters on a facility-by-facility basis.[110]	Repeal of the Toxic Reduction Use Act under Bill 66.
	Ontario Smog Strategy (1999) Plan to reduce emissions or smog-causing pollutants by 2015.[110]	Ministry of the Environment, Conservation and Parks provides an email air quality alert regarding a warming of Special Air Quality Statement (SAQS) or Smog and Air Health Advisory (SAHA).
	Drive Clean program (1998) enacts strict emissions controls on automobiles.[110]	As of April 1, 2019, the Ministry of the Environment, Conservation and Parks (MECP) is ending the requirement for light duty vehicle owners to obtain an emissions test prior to vehicle registration renewal. The Province is proposing changes to heavy duty vehicle testing to target heavy duty diesel vehicles such as commercial transport trucks
	Ontario's Action Plan on Climate Change includes greenhouse gas reduction targets: • 6% below 1990 levels by 2014 • 15% below 1990 levels by 2020 • 80% below 1990 levels by 2050.[110]	The goal of 6% below 1990 levels by 2014 was successful through initiatives (i.e., closing all of Ontario's coal-fired electricity generating stations).
	Not available	The Cap-and-Trade program was cancelled in 2018.
Local government regulations aimed at improving air quality	The Region of Peel has developed a Clean Air Strategy (2007) to build awareness and support for air quality through the improvement in monitoring and emissions reduction with an associated reduction in morbidity and premature mortality.[110]	No changes
Corporate regulations aimed at improving air quality	**Corporate programs include:** • Smart Commute - employee trip reduction program for Region of Peel employees. • Corporate greenhouse gas inventories. • Anti-idling policy for fleet vehicles. • Active transportation initiatives.[110]	Corporate programs listed in 2012 are still on-going. 2013 Adoption of the Energy and Environment Sustainability Strategy (EESS) to ensure compliance with energy regulations.[111]

Table 7A. Population/sites within 300 metres of high traffic volume on roads

Population / site	Total Number	Number within 300 meters of high traffic volume roads	Per cent within 300 meters of high traffic volume roads
Population, all ages	1,296,815	690,960	53.3
All recreational centres	1,541	439	28.5
Outdoor sports fields	1,439	403	28.0
Licensed daycares	544	175	32.2
Parks and playgrounds	643	163	25.3
Schools	391	103	26.3
Long-term care facilities	26	18	69.2

10.3 Extreme weather and natural disasters/ hazards

Climate change is expected to increase the number of violent and extreme forms of weather including severe storms accompanied by rain, hail, thunder and lightning; high wind events and tornados; and high precipitation events that lead to flooding.[3] While extreme weather is linked to a number of health concerns, this section focuses on important direct and indirect health outcomes that may result from extreme weather events such as storms, high winds, and flooding. The increased risk of vector-borne disease transmission and food and water contamination resulting from floods are covered in subsequent sections of this report.

10.3.1 Exposure

Indirect and direct health impacts of extreme weather events may include: an increase in accidental morbidity/mortality, the worsening of chronic conditions, the loss of shelter, and the loss of or damage to health care systems.[112,113] Monitoring baseline levels of morbidity and mortality are important in assessing exposure to extreme weather and disasters, and the active surveillance of hospital admissions during and after extreme climate events are telling of the impacts on human health.[29]

Extreme weather and flooding

In 1954, the Greater Toronto Area experienced the worst flood on history resulting from Hurricane Hazel where 210 mm of rain fell in under 12 hours. The rain overwhelmed infrastructure causing widespread flooding and 81 deaths. In August of 2005, the Greater Toronto Area saw another flood event that caused storm water to flow into the streets and flood the basements of homes.

Three extreme weather events have occurred in Peel within the last ten years. A summer rainstorm occurred in July 2013 when a severe flash flood resulted in 127mm of rain falling over five hours. This flooding caused approximately 450,000 people to be without power.[25] Fortunately, no human deaths occurred. In December 2013, Peel region experienced a severe ice storm that damaged trees and caused power outages, leaving approximately 250,000 residents without power.[25] The windstorm in May 2018 also caused significant damage. The Insurance Board of Canada stated that the storm caused $410 million in insured damages to both Ontario and Quebec, with $380 million of the damage recorded in Ontario.[114]

Within Peel, there are clusters of buildings that are vulnerable to flooding. In Mississauga's Cooksville Creek watershed, there are approximately 300 buildings in the middle and lower part of the watershed that would be inundated in a regulatory flood, and approximately 120 buildings would be inundated for the 100-year flood.[115] In Brampton, the Toronto and Region Conservation Authority has reported 23 flood vulnerable areas and 41 flood vulnerable roads within the Etobicoke-Mimico watersheds. There are an additional 27 flood vulnerable areas and roads within the West Humber watershed in Brampton. There are currently 443 roads in Peel that are at least partially within the Regional Floodplain Boundary.[116] Within the Humber River, Etobicoke Creek and Mimico Creek watersheds, the TRCA estimates that 944 people live within 50-year flood lines, 1096 live within 100-year flood lines, and 3272 people are vulnerable to flooding as a result of the regional storm (i.e., Hurricane Hazel which occurs once every 200 years or more) (see Figure 9).

Tall apartment and condominium buildings are particularly susceptible to damage during high wind events or violent storms and may increase accidental injury or mortality. Those living in sub-adequate housing are also vulnerable to the health impacts of extreme weather and flooding. In 2016, 7.7 per cent (106,745) of Peel residents lived in apartments, compared to 7.6 per cent (88,040) of the population in 2006. In 2016, 5.8 per cent (80,780) of individuals lived in apartments greater than 5 stories, compared to 5.7 per cent (66,025) in 2006.[17] According to the 2006 census, 4 per cent of all dwellings in the region require major repairs. There was no change in the 2016 data.

Impervious surfaces (e.g., buildings, roadways, and commercial land) associated with urban infrastructure also increase the risk of flooding due to the risk of overwhelming storm water infrastructure in the event of extreme precipitation events.

Socioeconomic status

Socioeconomic status has been demonstrated to play little role in the differential risk of living near flood plains in some countries.[84] Careful consideration of existing social and economic disparities does warrant attention, as disasters and extreme weather will have greater impacts on vulnerable populations through a variety of mechanisms. First, individuals with low incomes or those experiencing homelessness already share a disproportionate burden of disease which may be exacerbated in the event of a disaster. Further, they may be less able to recuperate from indirect effects of storms or disasters such as property damage.[117] This point is particularly salient given that individuals with lower incomes may lack quality shelter, thereby increasing the level of exposure to violent weather.[6,118] As indicated in previous sections, income and education also play key roles in accessing or utilizing adaptive behaviours in the event of a natural disaster, and understanding the inherent health risks associated with extreme weather. Ten percent of the population are classified as being low income in 2016, which was similar to 11 per cent in 2006.[17,81]

Figure 4. Credit River watershed[119]

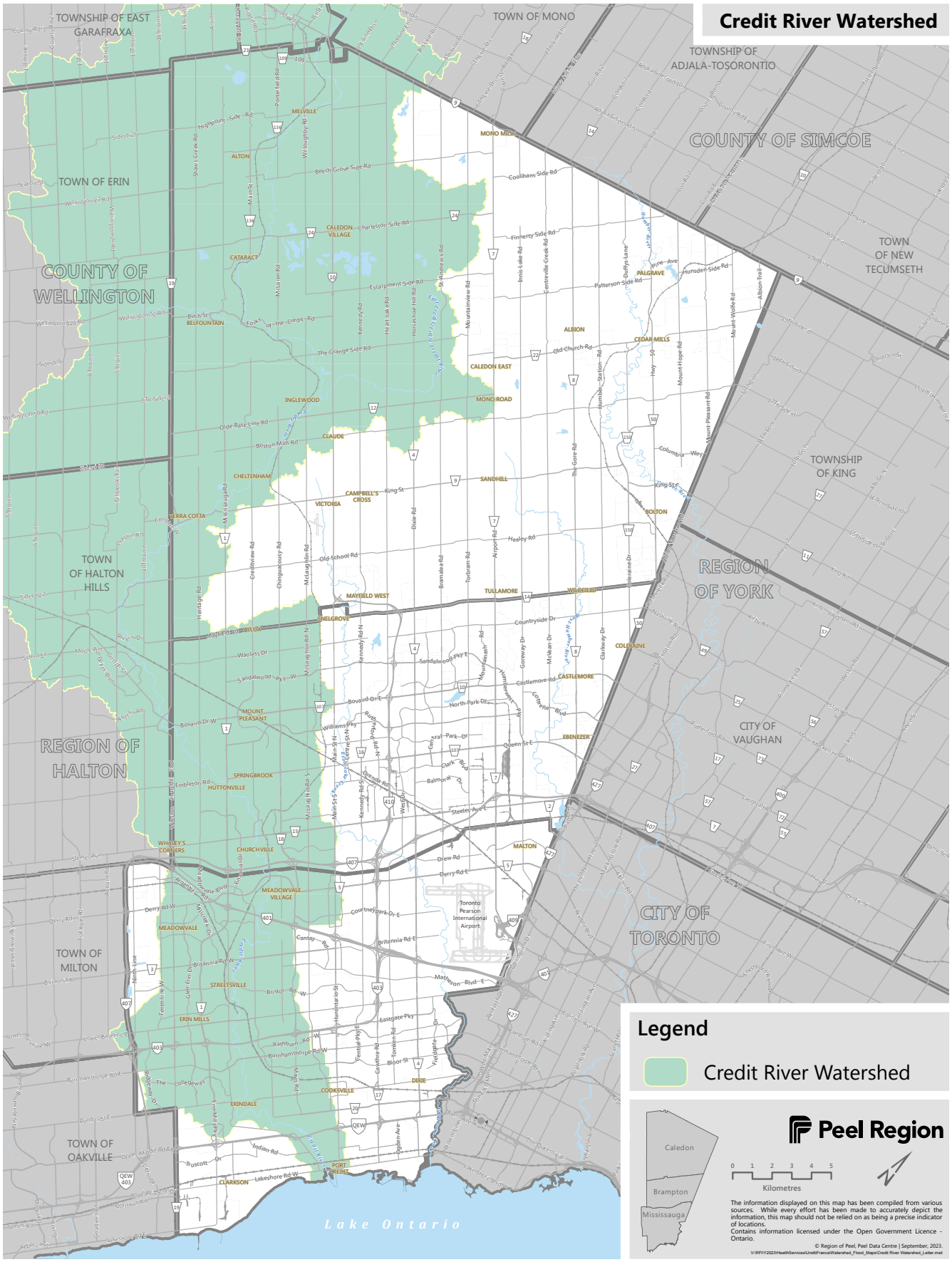
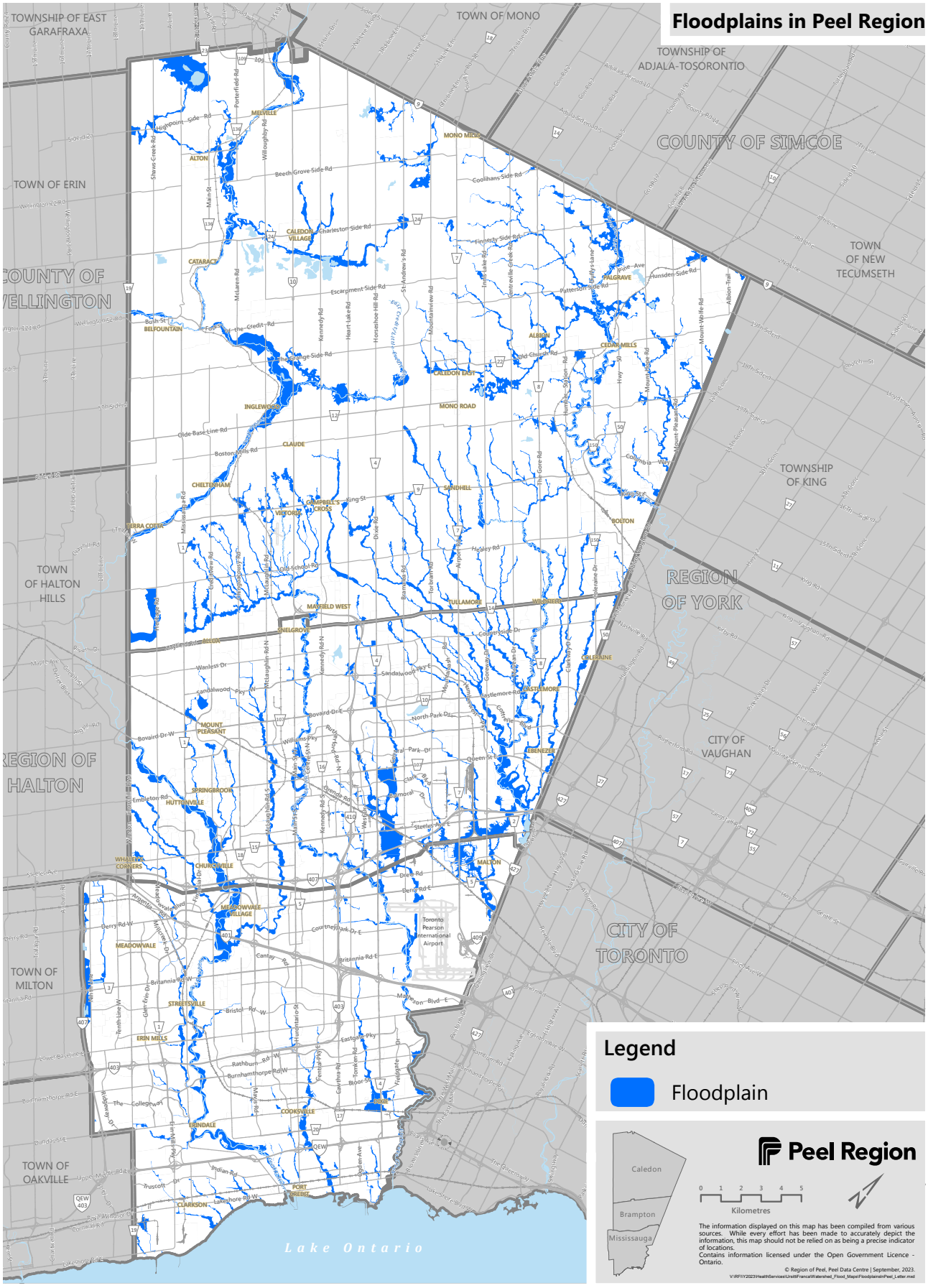


Figure 5. Floodplain map for Peel region



10.3.2 Sensitivity

English et al. identify numerous populations vulnerable to extreme weather events and climate-related natural disasters.[113] Similar to other priority areas identified in this report, the elderly and young children/infants may be more reliant on caregivers in order to seek adequate shelter from extreme weather events or disasters.

Individuals living with chronic conditions or disabilities that affect their mobility are also particularly vulnerable, as are those with cognitive restraints such as dementia.[52] Individuals with chronic conditions may also experience reduced mobility and may face difficulties in mobilizing to relocate themselves quickly enough to avoid health outcomes from being trapped or restricted in affected areas.[113,117] Residents of Peel who have a chronic illness and/or disability face an increased sensitivity to adapting to natural disasters and extreme weather events. Mobility and cognitive restraints can make individuals more vulnerable to the changing climate. In 2016, 48 per cent residents had at least one chronic disease.[75] According to 2013/2014 data, 55.1 per cent of seniors often or sometimes experience activity limitations. In 2014, prevalence of dementia for people ages 65+ was 5.6 per cent.[24]

10.3.3 Adaptive capacity

Ebi and Semenza present information on the level of resilience in communities to minimize the health effects of extreme weather and climate-related natural disasters. Their findings show that indicators of social capital such as the level of community engagement (e.g., volunteerism), cooperation, participation and intersectoral action are all determinants of how well a community can respond to a natural or climate-related disaster.[66]

Social isolation is a particularly important indicator of vulnerability because it may result in a lack of awareness and a lack of social support to effectively adapt in the event of a natural disaster.[29] Similarly, Keim (2008) highlights that social support is a key indicator of adaptive capacity, and lone-parent families are at elevated risk from extreme weather events.[117] Keim further identifies that efforts to reduce poverty may be the most effective adaptive strategy to reduce vulnerability to climate-related disasters and extreme weather.[117] In 2016, 6.1 per cent (68,345) of Peel's population lived alone and 4.8 per cent (65,665) were lone-parent households.[17] This is an increase from 4.5 per cent (52,555) and 4.3 per cent (49,600) in 2006.[81] There are a growing number of Peel residents that are currently living alone, potentially decreasing the ability to respond to extreme weather or natural disasters.

Developing effective early warning systems, emergency response plans that focus on response and recovery, and fostering a culture of public health preparedness are important adaptive measures that will increase the capacity of communities to reduce health risks associated with extreme weather events and natural disasters associated with climate change.[6,117,118]

Education campaigns and fostering strong links between community and government organizations will aid in developing suitable disaster preparedness and response.[66,112] While the housing stock in Peel is relatively new, current building codes may or may not be robust enough to account for an increase in frequency and severity of extreme weather events. The TRCA and CVC currently operate flood monitoring programs for Peel watersheds. Effective training of staff is also essential to emergency response, and considerations should account for seasonal variations in staff availability (i.e., summer months and the winter holiday season).

Peel Public Health's emergency response plan is mandated under the *Ontario Health Protection and Promotion Act*, which lays out protocol and prescriptive requirements for emergency preparedness protocol. The Region also has the Peel Regional Emergency Program (PREP) that deals with issues broader than public health. Each municipality also has the authority to declare an emergency, and if necessary, the Region of Peel can coordinate resources and emergency response activities across municipalities. Considering improvements in climate forecasting for the region, the emergency preparedness plan should be reassessed using a climate change lens.

Table 8. Climate-related vulnerability indicators for the health impacts of extreme weather and natural disasters/hazards in Peel region

Exposure

Indicator	Data from 2012 report	Updated data
Total precipitation projections in Peel[26]	Data not included in 2012 report	**By 2020's:** • Total precipitation likely to increase throughout the year • Winter and spring will have greatest increase in precipitation • Summer and autumn precipitation is projected to remain steady or slightly decrease • Extreme precipitation events are likely to become more severe and frequent • 1-day and 5-day maximum precipitation amounts (historically 37 mm and 59 mm, respectively) are expected to increase by 5% in the 2020s • The worst 1% of extreme precipitation events (similar to July 8th, 2013, for example) are projected to increase by 20% in magnitude should business-as-usual emissions continue. **By 2050's:** • Total precipitation likely to increase overall • The most increase in precipitation in the winter and spring • Summer and autumn precipitation are projected to remain steady or slightly decrease • Annually, 74 mm more per year is expected in the medium term, most of which will be delivered in the winter and spring months • Northwestern Peel is typically the wettest area within Peel region while the southern portion receives the least precipitation. Into the future, the north-south gradient is likely to increase due to an increase in lakeeffect precipitation with increasing ice-free conditions over Lake Huron to the northwest. • Instances of extreme precipitation are likely to become more severe and frequent • 1-day and 5-day maximum precipitation amounts are expected to increase by 8% and 10%, respectively in the 2050s. • The worst 1% and 5% of extreme precipitation events are expected to increase by 51% and 28% in magnitude, respectively, with business-as-usual emissions.

Exposure - continued

Indicator	Data from 2012 report	Updated data
Total precipitation projections in Peel[26] **(continued)**	Data not included in 2012 report	**By 2080's:** • Total precipitation is likely to increase • Greatest increase in precipitation in the winter and spring seasons • Summer and autumn precipitation are projected to remain steady or slightly decrease • Annually, 99 mm more per year is expected • The north-south gradient in precipitation patterns in Peel region is likely to increase due to an increase in lake-effect precipitation to the north • Frequency of rain versus snow will continue to increase • Instances of extreme precipitation may become significantly more severe and frequent on a regional scale • 1-day and 5-day maximum precipitation amounts could increase by 22% and 17%, respectively in the 2080s. • The worst 1% and 5% of extreme precipitation events could increase by 90% and 46% in magnitude, respectively, should business-as-usual emissions continue.
Flooding[51]	No flooding causing human death in Peel region since 1948 Etobicoke Creek flooding	No changes
Other natural disasters[120]	No natural disasters due to extreme weather listed in Canadian Disaster Database	No changes
Flood vulnerable structures by municipality for Credit River[121]	• Brampton – 48 • Caledon – 26 • Mississauga – 14	No changes
Flood vulnerable structures in the Mississauga's Cooksville Creek watershed[115]	Data not included in 2012 report	• Approximately 300 buildings in the middle and lower part of the watershed that would be inundated in a regulatory flood • Approximately 120 buildings would be inundated for the 100-year flood
Flood vulnerable structures in the Etobicoke-Mimico watershed[116]	Data not included in 2012 report	• 23 flood vulnerable areas • 41 flood vulnerable roads

Exposure - continued

Indicator	Data from 2012 report	Updated data
Flood vulnerable areas and roads within the West Humber watershed	Data not included in 2012 report	27 flood vulnerable areas and roads[116]
Flood vulnerable roads in Peel	Data not included in 2012 report	443 roads in Peel are at least partially within the Regional Floodplain Boundary[116]
Lake Ontario tributaries located in the City of Mississauga[73]	Data not included in 2012 report	For a breakdown, please refer to Table 8A.
Flood vulnerable persons by municipality for Etobicoke Creek, Mimico Creek, and Humber River	Data for Regional storm+/100-year storm/50-year storm • Brampton – 716/52/48 • Caledon – 796/284/248 • Mississauga – 1760/780/648	No changes
Per cent of land use cover classes across Peel region[47]	Data not included in 2012 Report.	Buildings 7% Bare ground 12% Impervious 15% Water 1% Road 4% Other vegetated areas 27%
Population living in apartments	In 2006, 88,040 persons resided in apartments (7.6% of Peel population)	In 2016, 106,745 persons resided in apartments (7.7% of Peel population)
	22,015 persons were living in apartments with <= 5 storeys (1.9% of Peel population)	25,965 persons were living in apartments with <= 5 storeys (1.9% of Peel population)
	66,025 persons were living in apartments with >5 storeys (5.7% of Peel population).[74]	80,780 persons living in apartments with > 5 storeys (5.8% of Peel population).[17]
Proportion of dwellings requiring major repairs	In 2006, 4% of dwellings required major repairs in Peel.[74]	In 2016, 18,140 (4%) of dwellings require major repairs in Peel.[17]

Sensitivity - See Table 1 and Table 2

Adaptive capacity

Indicator	Data from 2012 report	Updated data
Government regulations and programs	Emergency response mandated under the *Health Protection and Promotion Act of Ontario* (1990) lays out protocol and prescriptive requirements for infectious disease control and public health emergency preparedness protocol.[78]	No changes
	Building codes are administered by the Building and Development Branch of the Ministry of Municipal Affairs and Housing under the *Building Code Act* (1992).[78]	No changes
Social isolation	In 2006, 52,555 persons lived alone (4.5% of Peel population).[81]	In 2016, 68,345 persons lived alone (6.1% of Peel population).[17]
	In 2006, 15,520 persons aged 65+ lived alone (1.3% of Peel population).[81]	In 2016, 24,755 people or 14% of Peel seniors aged 65+ lived alone.[24]
	In 2006, 52,555 persons lived alone (4.5% of Peel population).[81]	In 2016, 68,345 persons lived alone (6.1% of Peel population).[17]
Emergency Response and public awareness/ education	Emergency response typically operationalized by municipalities, but response can be coordinated by the Region of Peel depending on scope and scale of disaster or hazard. Two overlapping emergency response units in the Region of Peel. 1. PREP – Peel's Regional Emergency Program 2. Health Emergency Planning (primarily related to epidemics/pandemics) but includes: a. Long-Term Care (5 facilities in three municipalities each with its own emergency plan for the facility and continuity of operations plan) b. Paramedics (entire region, standards met under Ministry of Health and Long-Term care and the *Ambulance Act* which develops emergency plan, plans for escalation and mutual assistance with other municipalities) c. Public Health (entire region, plays largely a coordinating role with PREP, facilities and paramedics)	Credit Valley Conservation is developing a Risk Tool for Flooding.
	Last full assessment of the Region of Peel's emergency response plan was in 2004. Each municipality required to conduct a Hazard Identification Risk Assessment every year.	Last full assessment of the Region of Peel's emergency response plan was in 2015.
	Emergency information and planning for individuals/households available on Peel Public Health website.[122]	No changes

Table 8A. Lake Ontario tributaries located in the City of Mississauga[73]

Tributary	Structures in Floodplan
Cooksville Creek	309
Serson Creek	154
Cawthra Creek	3
Applewood Creek	20
Lornewood Creek	11
Avonhead Creek	11
Sheridan Creek	8
Birchwood Creek	5
Turtle Creek	79
Tecumseh Creek	2
Lakeside Creek	0
Clearview Creek	1
Total	**603**

10.4 Contamination of food and water

Water and foodborne illness pose serious public health risks which are expected to increase with climate change. Water and food quality can be affected by several sources and mechanisms. For example, heavy rainfall and flooding can lead to the contamination of recreational and drinking water quality. Harmful algal blooms have increased in number due to warmer water temperatures and increased nitrification of water bodies which affects drinking and recreational water supplies.[113] Further, increasing temperatures will increase the survival and replication rates of disease vectors and pathogens.

The periodic contamination of water and food sources occurs in regions throughout the world, including Peel. In theory, existing surveillance programs should be able to capture baseline estimates for particular diseases and increases in particular adverse health outcomes (e.g., cases of diarrheal disease). It will be important to monitor the effectiveness of these systems in the future—particularly under a changing climate—to ensure that water and food-related illnesses are not missed or go unreported.[117] For example, in 2000, the Ontario municipality of Walkerton experienced an *E. coli* outbreak in its water supply, producing over 2,000 cases of illness. Important lessons were learned from this experience resulting in the enactment of the *Ontario Clean Water Act*.

10.4.1 Exposure

Contamination of water

Extreme temperatures, extreme weather, and rising water temperature contribute to water scarcity and the increased chemical and biological contamination of water.[123] Areas with higher population density and population growth are at elevated risk of food and waterborne contamination because a greater number of people will be exposed, and therefore at elevated risk of developing adverse health effects.[27]

The majority of Peel's population (approximately 1,300,000) gets its water from Lake Ontario. The water from the lake is treated at two treatment facilities: the Lorne Park Water Treatment Facility and the Lakeview Water Treatment Facility. Caledon is the only community in Peel to get a significant amount of its water from both communal and private wells fed by ground water. The number of people in living Caledon getting water from local sources other than Lake Ontario is 16,606.[124]

Casman et al. conducted a qualitative review of the literature assessing the public health risks associated with cryptosporidiosis due to climate change. Results from this review indicate that climate change will have little effect on cryptosporidiosis incidence in the United States, as long as adequate levels of wealth and a strong commitment to public health are maintained.[125] Peel region does not have a history of waterborne contamination, but watersheds throughout the region exhibit seasonal flooding during spring due to ice-melt, and flooding can be exacerbated during late winter due to rain on snow conditions. Moreover, rural residents serviced by private wells may be at increased risk because private water wells are not regularly monitored by municipal authorities.

McMichael and Kovats note that no sanitation system is completely protected from contamination, particularly when covered by flood waters.[29] Another risk from flooding includes the formation of mould (particularly in basements after a flood event) and more information on this topic is required to assess vulnerability for Peel region.

Warming temperatures are associated with increases in harmful algal blooms in water supplies around the world.[113] Peel region does not have a record of harmful algal blooms in any of its water sources, but non-harmful algal blooms typically occur on Lake Ontario between May and July causing an unpleasant odor.

Water contamination can also occur as a result of extreme weather events that increase turbidity of recreational water sources which have been known to cause *E. coli* outbreaks that affect recreational swimmers (Peel has five existing recreational swimming facilities open during the summer months). A study conducted in the Netherlands found a positive correlation between waterborne outbreaks among persons bathing in untreated recreational water use and days with temperatures greater than 25 degrees Celsius.[126] Evidence suggests that beaches near urban areas are at elevated risk of contamination due to an increased chance of ground water run-off being contaminated with chemicals and bacteria.[127,128] A study of Great Lakes beaches found that fine sand beaches with high soil moisture and a shallow water table (i.e., level, groomed beaches) with lots of vegetation are more prone to *E. coli* contamination which can concurrently spread into and contaminate the immediate swimming area.[129] This may be important if people spend more time outdoors due to warming temperatures. Health impacts associated with *E. coli* include skin or eye infections and/or lead to intestinal illnesses through the consumption of contaminated water.

Foodborne contamination

Climate change is forecasted to increase the exposure to harmful pathogens in food.[130] Home food safety is also of particular concern considering warming temperatures may increase the risk of foodborne contamination due to unsafe food storage and handling with increased temperatures, as well as the increased opportunity for specific pathogens to thrive in warmer temperatures (e.g., Salmonellosis and Campylobacteriosis). In addition, as temperatures increase, food preparation and cooking outdoors also increases, emphasizing the risks associated with improper food storage with increased temperatures. While it is difficult to quantify or monitor food contamination in individual

residences, it is estimated that foodborne disease from foods consumed in private dwellings is three times more frequent than illness developed as a result of food consumed from restaurants, cafeterias, bars, or other commercial establishments.[131]

Foodborne illnesses are often underreported. The two most common reportable foodborne illnesses in 2016 were Campylobacteriosis (21.8/100,000) (~327 cases per year) and non-typhoidal salmonellosis (20.7/100,000) (~288 cases per year).[132] There is limited data on the number of diseases related to pathogens in food in Peel. However, most of Peel's foodborne illness cases occurred through travel outside Ontario.

Many of the reported ill-health events in Peel region are due to unsanitary cooking practices (e.g., not washing counters, hands, or food). Rising temperatures are also associated with increases in foodborne outbreaks from microbiological agents.[133] For example, an Australian study of five metropolitan areas found a positive association between increasing temperatures and the number of monthly salmonellosis reports.[134] Longer summers and hotter weather produce increased risk that food will become contaminated if people are not handling, storing and/or preparing food safely. During periods of warm weather, more people are outside at events which often involve food being served (e.g., farmer's markets, barbeques, festivals). More detailed information regarding exposure to foodborne illness during such events or activities may be required in the future.

Socioeconomic status

Socio-economically vulnerable individuals may not have adequate information or resources on hand to handle, prepare, or store food safely. Socioeconomic vulnerability may also play a role in differential exposure to contaminated water when considering settlement patterns and access to particular water-related resources such as drinking water and recreational beaches.[123] Thus, individuals with low-income may be differentially exposed to contaminated water sources, and those with low levels of education may not be aware of the risks associated with drinking contaminated water.

Box 1. Climate change and food (in)security

The droughts and resource shortages associated with climate change will pose challenges to the procurement of nutritious food and its 'just-in-time' delivery to local supermarkets. The industrial agro-food system is heavily dependent on the continued use of fossil fuels for fertilizers and shipping and is a significant source of greenhouse gas emissions which contribute to climate change.[121] Reducing the reliance on internationally shipped foods and building the resilience in local food supplies are key adaptive measures to limiting exposure to food security issues related to climate change. Moreover, an emphasis deserves to be placed on eliminating hunger in Canadian communities. In the Region of Peel, 30 emergency food service locations exist: 9 in Brampton, 2 in Caledon, and 19 in Mississauga, however, estimating hunger amongst the broader population is difficult. Learning lessons from food insecure populations may help to inform strategic and adaptive responses to food insecurity in a changing climate. Developing further relationships with social service agencies can help to inform and prepare organizations for potential increases in clients in the future.

10.4.2 Sensitivity

Casman et al. and Balbus and Melina identify that vulnerable populations such as children, the elderly, and immuno-compromised individuals (e.g., transplant recipients or individuals living with HIV/AIDS) are more sensitive to food and waterborne contamination, for the reasons discussed in previous sections of this report.[52,125]

10.4.3 Adaptive capacity

Effective strategies for monitoring and testing water and food quality already exist in most urban areas in the developed world; however, such systems may need to be re-evaluated for effectiveness in tracking all cases of water and foodborne contamination. Current adaptive capacity to manage water and foodborne contamination is dependent upon several factors that include: regulations outlining safe food handling practices and water safety guidelines; adequate public preparedness through public awareness campaigns; effective emergency response plans (e.g., boil water notices); and the effective collaboration with stakeholders (e.g., conservation authorities, environmental groups, and local, regional and national governmental organizations).[27,28,125,130] Indeed, the Economic Commission for Europe notes that adaptation, especially in the context of local and trans-boundary water supplies, will require intersectoral collaboration between various government agencies and non-governmental actors.[123]

Reducing exposure to water contamination requires adequate watershed protection through conservation efforts and controlled urban development, water quality laws, and regular surveillance of pathogens through rapid testing.[3] The regular maintenance of infrastructure and adoption of new and efficient technologies may also improve public health actors' ability to respond to food and water borne contamination.[125] In order to prevent or reduce the risk of *E. coli* contamination at Ontario beaches, Crowe recommends planting beach grasses, building and rehabilitating sand dunes, and limiting the growth of grass lawns on the borders of beaches to ensure that grass does not spread to the beach and encourage waterfowl feeding and defecation that may facilitate *E. coli* growth.[129] Beach testing is undertaken every week in Peel region between June 4 and August 31, and results are posted on whether beaches exceed the federal standard for *E. coli* levels.

Local boards of health are required to regularly monitor small drinking water systems as specified by the *Ontario Health Protection and Promotion Act O.Reg 319/08*. Under *O.Reg 170/03* and *248/03* private drinking water systems are required to meet provincial requirements for sanitary conditions, but it is up to owners and operators of those systems to have the water tested.

Several public education and information campaigns exist to educate Peel residents about the dangers of water and foodborne illness. The *Health Protection and Promotion Act* requires reporting of food-borne illnesses which are reported throughout the provincial integrated Public Health Information System (iPHIS). For education relating to food and water contamination (i.e., during a flood) Peel residents can go to the Peel Public Health website.

Table 9. Climate-related vulnerability indicators for the health impacts of water and food contamination in the Peel region

Exposure

Indicator	Data from 2012 report	Updated data
Flooding and food/water contamination	No history of waterborne contamination in Peel region[135]	No changes
	No reported foodborne or waterborne disasters in Peel region in the Canadian Disaster Database[120]	No changes
	No floods causing human death in Peel since 1948 Etobicoke Creek flooding; Peel watersheds exhibit seasonal flooding during spring due to ice melt and flooding can occur during rain on snow conditions.	No changes
Number of human cases of disease related to pathogens in food or water	**In 2002, pathogens in Peel not related to ingestion of uncooked foods may include:** • Hepatitis A (21 cases per 100,000) • *E. coli* (2.2 cases per 100,000) • Amebiasis (11.2 cases per 100,000) • Listeriosis (0 cases per 100,000) • Cryptosporidium (0 cases per 100,000)[40]	In 2016, *Camplyobacteriosis* (21.8/100,000) and *non-typhoidal salmonellosis* (20.7/100,000) are the two most common reportable enteric diseases. Majority of human cases occurred due to travel outside Ontario.[132] Over 60% of enteric diseases are domestically-acquired through foodborne sources.[132]
Algal blooms	Harmful algal blooms are not present in Peel region. Non-harmful algal blooms typically occur between May and July on Lake Ontario.	No changes
Recreational swimming sites[136]	**5 beaches in Peel region** • 1 in Brampton (Professor's Lake Recreation Centre) • 1 in Caledon (Caledon Teen Ranch) • 3 in Mississauga (Jack Darling Park; Richard's Memorial Park; Lakefront Promenade Park)	No changes

Exposure - continued

Indicator	Data from 2012 report	Updated data
Closures of recreational swimming sites: *E. coli* levels above 200 cfu per 100 ml and/or heavy rainfall[137]	Data not included in 2012 report	**In 2017,** • Of the 45 water sampling days at Professor's Lake, 42% exceeded the *E. coli* threshold. • Of the 54 water sampling days at Richard's Memorial beach, 20% exceeded the *E. coli* threshold. • Of the 53 water sampling days at Lakefront Promenade Park beach, 13% exceeded the *E. coli* threshold. • Of the 47 water sampling days at Jack Darling beach, 11% exceeded the *E. coli* threshold.
Pools, wading pools, and splash pads inspected by Peel Public Health	360 pools (both public and private); 25 wading pools and 15 splash pads	**In 2017,** • 380 pools; 151 spas; 35 splash pads and 18 wading pools[138]
Water treatment	**In 2011, there were two water treatment facilities:** • Lorne Park Water Treatment Facility • Lakeview Water Treatment Facility[139]	No changes Caledon operates on a municipal well-based system as well as private wells. The Region of Peel owns and operates wells in the following areas in Caledon: Alton, Palgrave, Caledon East, Caledon Village, Cheltenham Village, and Inglewood.[140] 14 municipal wells treated at one of five small-scale water treatment plants in Caledon.[140]
Source of water supply	The majority of Peel's population get its water from Lake Ontario. The number of people getting water in Caledon from local sources other than Lake Ontario is 16,606. Other residents of Caledon receive water from municipal wells.[124]	Approximately 99% of Peel residents are serviced by a municipal water supply, and about 1% are on a private well water supply (mostly in Caledon).[124] The number of people receiving water in Caledon from local sources other than Lake Ontario is 19,858.[124]
	Between 2006-2011 there was a 11% population growth[17]	Between 2011-2016 there was a 11.8% population growth[17]
Farms, farmer's markets and community gardens[141]	• 28 farms located in Peel region • 5 weekly farmer's markets • Community gardens not included in 2012 report	• 20 farms located in Peel region • 10 farmer's markets • Community Gardens[xvi] in Peel: a. Mississauga 11 b. Brampton 7 c. Caledon 1

[xvi] Community gardens are defined as those that contain allotment plots for use by the general community. There may be additional private community gardens for specific populations (e.g., church groups) that are not included. Please note, these community gardens are subject to change throughout any given period depending on operational need, climate, and resources.

Sensitivity - See Table 1 and Table 2

Adaptive Capacity

Indicator	Data from 2012 report	Updated data
Government regulations[142]	Ontario *Health Protection and Promotion Act:* O. Reg. 318/08 and 319/08 – Small drinking water systems inspected by local boards of health. As per Ontario Regulation 242/05, non-municipal year-round residential and designated facility inspections run on a 1 in 4-year cycle if there are no problems (if a problem is identified, follow-up inspection can occur yearly). *Safe Drinking Water Act:* O.Reg. 170/03 and 248/03 address drinking water systems regulation and drinking water testing services, but it is up to owners and operators of municipal residential systems (i.e., private wells) to ensure they meet provincial requirements.	• In Ontario, all drinking water systems that serve the public are regulated by a series of regulations under several different laws (Regulation 170/03: Ontario Drinking Water Systems under the *Safe Drinking Water Act*, 2002, Regulation 319/08. • Small Drinking Water Systems under the Health Protection and Promotion Act, and Regulation 169/03: Ontario Drinking Water Quality Standards). • Annual reports for all Peel's drinking water systems are available to the public at: **http://www.peelregion.ca/pw/water/quality/reports/**. • *Safe Drinking Water Act* were updated in 2015.
	Food-borne illness monitored through the Reportable Diseases Information System in Ontario under the *Health Protection and Promotion Act* – known to be underreported.[131]	No changes
Public education regarding food and water contamination during flooding	Guidelines for food safety during floods posted on Peel Public Health website.[143]	No changes
	Restaurant inspection results posted publicly	No changes
Beach testing	Samples are taken and inspected weekly from beaches in Peel region between June 4 and August 31; results are posted on whether beaches passed or did not pass inspection.[136]	Inspection results posted online

10.5 Vector-borne diseases

Changing temperatures shift the geographical distribution of vectors such as ticks, mosquitos and rodents, allowing them to occupy previously inhospitable climate regions. Sutherst notes that rising temperatures, precipitation, rates of urbanization (and loss of natural land cover), declines in biodiversity, and trade and travel all affect the distribution of insect and animal vectors and may increase human exposure to a range of vector-borne diseases.[144] In Peel region, the vectors of primary concern include mosquitos carrying the West Nile Virus (WNV) and Eastern Equine Encephalitis (EEE); and black-legged ticks carrying Lyme disease. WNV and EEE are both serious viral illnesses which can cause death in extreme cases.

Figure 6. Wood tick and Deer tick comparison

L-R: Two female Wood (or Dog) Ticks, Female and Male Deer (or Black-legged) Ticks Top: Male Wood Tick. Deer ticks are much smaller and have mouthparts made to hold on stronger.

Figure 7. *Culex pipiens* – a known carrier of the West Nile Virus

10.5.1 Exposure

Mosquito-borne disease

Several mosquito vector species in Peel region are known carriers of WNV (e.g., *Culex pipiens* pictured above, and *Culex restuans*, among others) and EEE (*Culiseta melanura*), respectively (Region of Peel 2011d). Researchers found that the presence of WNV vector species (*Culex pipiens* and *Culex restuans*) in Peel region can be predicted based on relationships with temperatures of greater than 9 degrees Celsius over the preceding 11 days, and where precipitation was present in the previous 35 days.[104] In 2021, 23 mosquito batches tested positive for WNV, an 80 per cent reduction from 2017, where 114 mosquito batches tested positive.[147,24] Human cases of WNV in Peel have also decreased from 2017, with one confirmed and one probable case in Peel, compared to 11 confirmed in 2017.[147,24] In 2021, there were no *Culiseta melanura* mosquitoes found, however, 68 pools of other common EEE vectors, including *Coquillettidia perturbans*, *Aedes vexans*, and *Ochlerotatus japonicus* were found in Peel. None tested positive for EEE, and no human cases of EEE have been reported in Peel.[24]

The clear association between weather and mosquito abundance yields implications for exposure reduction strategies. Increased rainfall also increases the accumulation of stagnant water which supports mosquito breeding. Sites such as abandoned swimming pools, roadside ditches, and woodland pools are ideal habitats for mosquito replication. The location of sites that support mosquito breeding are collected by the Region of Peel every year (see Table 10).

In Ontario, WNV is most commonly found in urban areas as the key vectors *Culex pipiens/restuans* prefer to develop in standing water, often in catch basins or small containers such as bird baths, barrels, used tires, or tin cans around urban and suburban homes. Users of outdoor recreational facilities, persons who exercise outdoors, and outdoor workers are also at elevated risk of exposure.[90] More reliable information for users of outdoor recreational facilities, those who exercise outdoors, and outdoor workers will be required to better assess the differential exposure to vector-borne disease in Peel region as the climate changes.

Tick-borne illness

Lyme disease is a bacterial infection caused by the bite of black-legged ticks which can produce flu-like symptoms, paralysis and heart problems. Black-legged ticks are often carried by birds which affects their regional migration. Exposure to ticks increases with warmer temperatures and decreased rainfall (i.e., summer and autumn).

In previous years, passive tick surveillance allowed for identification and testing of tick samples to confirm possibility of Lyme disease, however, in 2020, this practice was suspended. An alternative was provided to the public, encouraging the use of a free online tick identification service, allowing the public to upload a photo of the tick and receive information of the species and associated public health guidance within 48 hours. In 2021, 18 per cent of submitted samples in Peel were identified as black-legged ticks.[24] Comparison to previous years is not possible as the free online service resulted in a significant increase in volume of submissions compared to previous years, and not necessarily an increase in the number of ticks.

In 2021, 13 cases of Lyme disease were confirmed, similar to the 14 cases confirmed in 2017.[24]

Each year Public Health Ontario updates the Lyme disease estimated risk areas map for the province. Estimated risk areas are locations where black-legged ticks have been identified, or are known to occur, and where humans have the potential to encounter infected ticks. Estimated risk areas identify a 20 km radius from where black-legged tick activity was found through drag sampling.

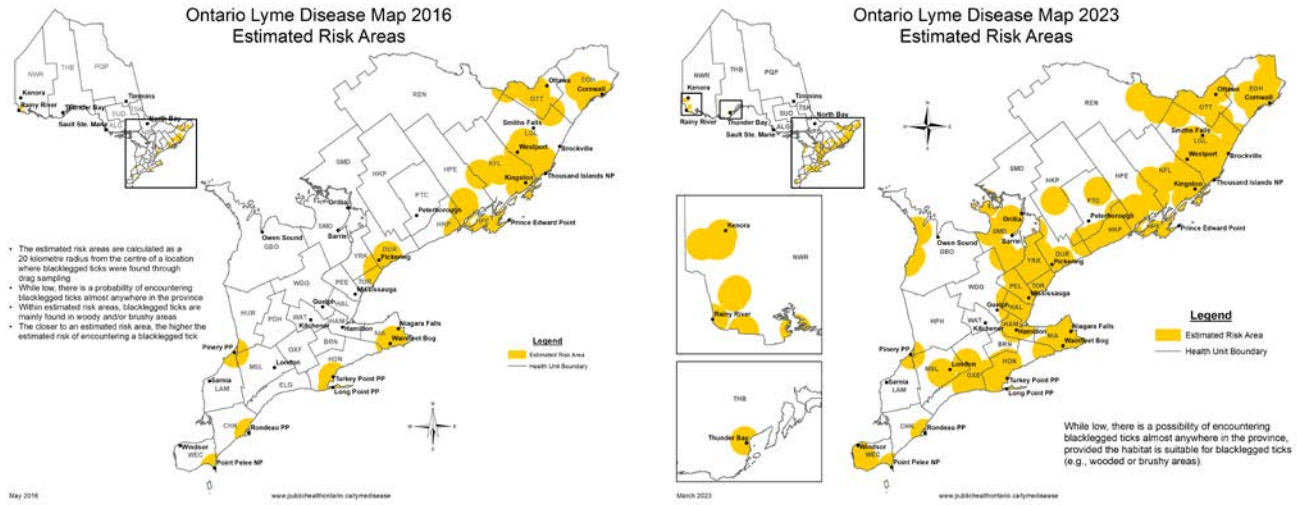
Prior to 2018, Peel region did not have a designated risk area, however, based on tick drag sampling activities in the spring and fall of 2018, the City of Mississauga, City of Brampton and majority of the Town of Caledon were identified as Lyme disease risk areas by Public Health Ontario.[147] Risk areas are identified through robust active surveillance activities, and in 2021, this practice was discontinued as Public Health Ontario identified two large risk areas for Lyme disease covering the majority of Peel region.[24]

As our climate continues changing, through warmer seasons and impacts to bird migration, there are concerns that the increasing size of Lyme disease risk areas will continue to trend upwards, impacting many parts of the province.[24]

Box 2. International travel and vulnerability to climate-related morbidity and mortality

Travel is an important vulnerability indicator not only for vector-borne disease, but for all the climate-related priority areas identified in this report. Not only will residents in the Region of Peel continue to be exposed to a range of climate-related conditions that present increases in particular forms of health outcomes; but the ability to travel internationally holds the potential to increase exposure including the transfer particular types of disease for long distances and across borders. Little information currently exists demonstrating the risk of person-to-person contact for a range of vector-borne diseases that can occur worldwide. However, if the number of cases of various diseases continues to increase as a result of climate change, diseases contracted in other areas of the world may potentially be carried and transmitted among distant populations. Travel physicians and public health units have a responsibility to inform travellers of the climate and health risks associated with particular regions of the world, as well as those risks present domestically.[148]

Figure 8. Expansion of Lyme Disease Risk Area in Ontario, 2016 and 2023



Source: Public Health Ontario

Increased Exposure

Individuals who engage in outdoor recreation (no data available) and outdoor workers are at an increased risk of WNV, EEE and Lyme disease. Individuals who travel outside of Ontario and return to Peel can introduce new infectious diseases.[1] In 2017, approximately 40 million passengers travelled through Toronto Pearson International Airport; an increase from 6.1 per cent in 2016.[83]

10.5.2 Sensitivity

Individuals with supressed or developing immune systems are more sensitive to vector-borne illnesses. Specifically, children aged 14 and younger have developing immune systems which pose health risks when infected by a vector-borne disease. In addition, seniors who have suppressed immune systems have difficulty in fighting against infectious diseases.[2] As Peel's senior population increases to 21 per cent by 2041, this population will have a greater sensitivity to vector-borne diseases.

10.5.3 Adaptive capacity

At the individual level, a range of adaptive behaviours including the application of insect repellent, avoiding the outdoors between dusk and dawn, and wearing long sleeve shirts and pants can all reduce the risk of exposure to disease carrying vectors. At the community and regional level, monitoring vectors and on-going surveillance of population health indicators are important to assess potential increases in incidence of vector-borne disease.[66] Larviciding and, in certain places outside Ontario, adulticiding through the use of chemical sprays is an often employed method of mosquito control in urban areas.[149] Perhaps most important is the provision of information to residents regarding increases in risk and what to do to limit exposure.[62] The development of early warning systems, vaccines, rapid diagnostic tests and measures to improve infrastructure by way of reducing stagnant water are also important adaptive practices.[3]

Peel Public Health has developed a comprehensive plan to address vector-borne disease in the region through a host of surveillance, monitoring, and pest management activities. The continued education and awareness building conducted by authorities in the Region of Peel will continue to improve the region's ability to adapt to emerging vector-borne diseases. Activities aimed at reducing the spread of WNV and Lyme disease comply with Ontario Regulations 558/91 and 559/91 which makes the diseases reportable under the *Ontario Health Protection and Promotion Act*. EEE is not a reportable disease under Ontario Regulations 558/91 specifically but would be captured under the general heading of viral encephalitis.[151]

The Region of Peel had 31 mosquito traps at fixed locations throughout the region to monitor mosquito populations for the presence of the virus in 2011. In 2018, the region had 33 traps, which are in place from mid-June to late September. Larval surveillance in Peel continues to show that WNV is endemic in Peel as well as across Ontario, highlighting the need for ongoing surveillance and public education.[147]

Information mail-outs regarding vector-borne disease are produced and sent to day cares, garden centres, golf courses, horticultural associations, long-term care facilities/senior's residences and hospitals, and multicultural community organizations.[147]

Table 10. Climate-related vulnerability indicators for health impacts of vector-borne disease in Peel region

Exposure

Indicator	Data from 2012 Report	Updated Data
Presence of *Culex pipiens* and *Culex restuans* (West Nile Virus (WNV) vector in Peel)	**In 2010,** • 14 mosquito batches test positive for WNV[151] **In 2011,** • 61 mosquito batches test positive for WNV[151]	**In 2018,** • 69 positive mosquito batches tested positive for WNV (season-dependent – was a relatively drier summer).[147] **In 2021,** • 23 positive mosquito batches tested positive for WNV[24]
Human cases of WNV	Between 2008-2010 there were 0 cases of WNV[151] In 2011, 3 human cases were reported.[151]	**In 2018,** • 6 Peel human cases (5 confirmed, 1 probable)[147] **In 2021,** • 2 Peel human cases (1 confirmed, 1 probable)[24]
Presence of *Culiseta melanura* (Eastern Equine Encephalitis (EEE) vector in Peel)	**In 2010,** • 2 *Culiseta melanura* collected in Peel mosquito traps and both tested negative for EEE (no human cases reported in the province of Ontario).[151] **In 2011,** • 1 *Culiseta melanura* collected in Peel mosquito traps. One in resting box study. Both tested negative for EEE.[151]	**In 2018,** • 0 *Culiseta melanura* collected[147] **In 2021,** • 0 *Culiseta melanura* collected.[24]
Human cases of EEE	No recorded human cases of EEE reported in Peel region[151]	No recorded human cases of EEE reported in Peel region.[151,24]
Presence of black-legged (deer) ticks	No established black-legged tick population in Peel region.[151]	**In 2017,** • 2 Peel ticks tested positive for *Borrelia burgdorferi* (1 Caledon, 1 Mississauga)[147] **In 2021,** • Changes to tick sampling prevent direct comparison of ticks in Peel testing positive for *Borrelia burgdorferi*, however, of 452 ticks submitted to the online tick identification service, 18% were identified as black-legged ticks, and could potentially be carrying *B. burgdorferi*.[24]

Exposure - continued

Indicator	Data from 2012 Report	Updated Data
Human cases of Lyme disease	**In 2010,** • 2 cases reported to Peel Public Health (not locally acquired).[151]	**In 2017,** • 14 confirmed cases reported to Peel Public Health. **In 2021,** • 13 confirmed cases reported to Peel Public Health, six acquired in Peel Region, seven acquired elsewhere in Ontario.[24]
Users of outdoor recreation areas	No data available	No data available
Travel	**In 2010,** • 31.8 million passengers travelled through Toronto Pearson International Airport[152]	**In 2017,** • 39.8 million passengers travelled through Toronto Pearson International Airport[152]

Sensitivity - See Table 1 and Table 2

Adaptive capacity

Indicator	Data from 2012 Report	Updated Data
Government regulation	WNV activities comply with Ontario Regulation 199/03 "Control of the WNV".[151]	Not available
	Lyme disease and WNV are both included in Ontario Regulations 558/91 and 559/91 making them reportable and communicable diseases under the *Ontario Health Protection and Promotion Act*.[151] EEE is not a reportable disease under O. Reg. 558/91 specifically, but would be captured under a general heading, primarily *viral Encephalitis*.[151]	While not specifically listed as a reportable disease in Ontario, EEE falls under the broader category of Encephalitis, including primary viral, a reportable disease under Ontario Regulation 135/18 Designation of Diseases.[147]
Integrated mosquito management activities	31 mosquito traps at fixed locations from mid-June to late September (9 in Brampton, 5 in Caledon and 17 in Mississauga).[151]	From June 20 to September 25, 2021, Public Health monitored WNV activity in the local adult mosquito population using 33 fixed CDC light traps, developed by the U.S. Centre for Disease Control. The traps were located across the Peel region: 17 in the City of Mississauga, 11 in the City of Brampton and five in the Town of Caledon.[24]
	Larval surveillance undertaken at known and suspected breeding sites.[151]	No changes

Adaptive capacity - continued

Indicator	Data from 2012 Report	Updated Data
Tick surveillance	Data not included in 2012 Report.	In 2021, passive and active tick surveillance were suspended in Peel region, due to: • Changes to Ontario's surveillance system for tick identification, as the system was designed to identify Lyme risk areas, where many areas across the Province are now confirmed risk areas by PHO. • PHO identified the majority of Peel region as an estimate risk area for Lyme disease.[24]
Larviciding strategy	Use of BS, BTI and Altosid (all chemical agents approved by the Pest Management Regulatory Agency to control mosquito larvae in Canada).[151]	No changes
	Yearly application of Altosid to ~92,000 roadside and non-roadside catch basins in Peel region four times per season.[151]	Yearly application of Altosid to ~103,500 roadside and non-roadside catch basins in Peel region three times per season.[147]
	Adulticiding only conducted if WNV or EEE pose serious threats to the population (i.e., increased incidence of WNV or EEE).[151] The risk level has never been high enough to require adulticiding in Peel region.	No changes
Outreach and education	**In 2011, resources were sent to:** • Day cares (262) • Garden centres (28) • Golf courses (17) • Horticultural associations (8) • Long-Term Care facilities/Seniors Residences and Hospitals (54) • Multicultural community organizations (21).[151]	**In 2017, resources were sent to:** • Childcare centres (238) • Garden centres (40) • Golf courses (26) • Horticultural associations (11) • Long-Term Care facilities/Seniors Residences and Hospitals (126) • Community agencies (80).[147]

11.0 Conclusion

This updated report summarizes key vulnerability indicators for health outcomes associated with Peel's changing climate. The report addresses the priority areas of extreme temperatures (heat), air quality, extreme weather and natural disasters/hazards, food and water contamination, and vector-borne diseases.

The literature review and summary tables provide insight into populations that will be most vulnerable under a changing climate. However, it is important to note that any one of these indicators used alone, may not be useful in identifying vulnerability to climate change. The indirect and direct pathways between climate change and human health in Peel region are complex, and multiple exposures and sensitivities yield some uncertainty in definitively assessing vulnerability. However, the indicators presented identify priority populations that may be at elevated health risk for the health issues outlined in this report.

Children and the elderly are particularly vulnerable, due to their unique social context. This is also true for individuals experiencing relatively poor health status in combination with other forms of socioeconomic vulnerability. As many of the findings from the literature review demonstrate, one of the largest concerns associated with climate change is its potential to exacerbate existing health inequities.

This report is useful in developing future public health planning, programming and policy making for decision-makers at the Region of Peel. In demonstrating some of the existing adaptive capacities that exist in the region, this report highlights the vast amount of readily available data, government regulations, and individual adaptation already occurring at the local and regional level. Building on existing public health priority areas and viewing them from a climate change lens will further benefit the Region of Peel's public health preparedness, emergency response, and the health of Peel residents more broadly.

While this report attempts to highlight existing health vulnerabilities from available data, extensive community and stakeholder consultation will be required to continually refine the reported indicators,[58] which are not meant to represent an exhaustive list. Utilizing local sources of knowledge will capture the social and cultural nuance that is present in Peel region. Peel's diverse population, culture, economy, and environment are all important pieces of adapting to and mitigating climate change. Through better understanding individual perceptions of climate change in relation to the priority areas highlighted in this report and their relevant vulnerability indicators, public health can best contribute to a representative solution to climate change adaptation that captures the concerns of the public. Developing a stakeholder consultation and engagement plan will be essential to further identify vulnerable groups of individuals which will aid in the development of a comprehensive vulnerability assessment. Allowing community stakeholders to provide information, feedback, and the ability to contribute to the design of various interventions may be useful to this effect.

There is still a great deal of uncertainty pertaining to climate change impacts in Peel. Further, the health exposures and sensitivities selected for this report does not reflect all possible health impacts (e.g., mental health, food (in)security). The Intergovernmental Panel on Climate Change continues to observe rising concentrations of greenhouse gases, glacial snow melt, sea level rise, sea temperature rise, an increase in the severity of storms, and declining biodiversity worldwide,[154] and our knowledge of the 'tipping points' at which these environmental declines may trigger what is often described as 'catastrophic climate change' is not well understood. However, as the climate continues to change, Peel region will undoubtedly continue to experience record heat waves, unseasonable and increasingly violent weather.

Recommendations:

1. Use the report as a foundation to begin broader discussions around public health vulnerability to climate change in Peel region.
2. Share the report with key stakeholders and engage in knowledge translation activities.
3. Conduct community and stakeholder consultation to capture the social and cultural distinctions present in Peel region to further inform programming and policy.
4. Map vulnerable populations/neighbourhood characteristics.
5. Continue to gather relevant health information on an ongoing basis to improve our understanding of local climate change health impacts in Peel region.
6. Conduct further work on how mental health and health equity are impacted by climate change.
7. Develop an implementation plan to address identified vulnerabilities.

ANNEX 1. List of databases (N=25) included in initial Medline Search

Ovid MEDLINE (1946 to February Week 4 2012)

Ovid OLDMEDLINE (1946 to 1965)

Ovid MEDLINE in-process and other non-indexed citations (February 27, 2012)

Ovid Healthstar (1966 to January 2012)

PsycINFO (1806 to February Week 4 2012)

Mental Measurements Yearbook (1st to 19th yearbooks January 2012)

Embase (1974 to 2012 February 27)

Embase Classic+Embase (1947 to 2012 Week 09)

AMED (Allied and complementary medicine) (1985 to February 2012)

A-V Online (1900 to December 2011)

Books @ Ovid (February 27, 2012)

CAB Abstracts (1973 to 2012 week 08)

List of Periodicals Indexed

FIAF Affiliates Publications (1966 to 2010)

International index to film periodicals (1972 to December 2011)

International index to TV periodicals (1979 to 2006)

Treasures from the Film Archives

Film/TV Documentation Collections

Health and Psychosocial Instruments (1985 to January 2012)

Index to Foreign Legal Periodicals (1985 to February 2012)

International Political Science Abstract (1989 to February 2012)

Journals @ Ovid Full Text (February 27, 2012)

NASW Clinical Registrar (14th edition)

Social Work Abstracts (1968 to January 2012)

Transport Database (pre-1987 to 3rd quarter 2011)

ANNEX 2. Search strategy and results from Medline Search

Inclusion criteria:

1. Had applicability to Peel context;
2. Measures or indicators of vulnerability of adaptive capacity clearly outlined for a given priority area (e.g. temperature, air quality, etc.)
3. Written in English

Exclusion criteria:

1. Do not address indicators of vulnerability or adaptive capacity;
2. Focus on tropical climates or arctic climates
3. Focus is on health outcomes not relevant to the Region of Peel (i.e. developing world health indicators)
4. Written in a language other than English

Initial search

Search: (climate change AND (vulnerab$ AND adapt$) AND health AND (measur$ OR indicat$ or determin$ or risk$)).ab

=103 results after removing duplicates in OVID
-12 duplicates further identified in refworks
-33 not relevant based on titles
-14 not relevant based on abstract
-6 inaccessible via web
= 38 for review
-9 not relevant based on article reviews
=29 resources

List = [Conlon et al. 2011; Costello et al. 2009; Ebi 2009; Ebi 2011; Ebi and Semenza 2008; English et al. 2009; Estrada-Pena and Venzal 2007; Haines et al. 2006a; Haines et al. 2006b; Hambling et al. 2011; Jendritzky and Tinz 2009; Keim 2011; Kjellstrom et al. 2009; Leichenko 2011; Maller et al. 2011; Martinez et al. 2011; McMichael 2009; McMichael and Kovats 2000; O'Neill et al. 2009; Rosenweig et al. 2011; Smoyer et al. 2000; Spickett et al. 2011; Strand et al. 2010; Sutherst 2004; Tomlinson et al. 2011; UNEFC 2009; Vescovi et al. 2009; White-Newsome et al. 2011; Younger et al. 2008

Air quality

Search: (climate change and (vulner$ OR adapt$) and health and air quality and (measur$ OR indicat$ or determin$ or risk$)).ab

=53
=17 after removing duplicates from Ovid
=14 after removing duplicates from search (1)
-4 not relevant based on abstract reviews
=10 for review
-1 not relevant based on article review
=9 resources

List = [Blashki et al. 2011; Bowler et al. 2008; Casmiro et al 2006; Ebi and Macgregor 2008; Kinney 2008; Knowlton et al. 2004; Kovats, Wilkinson and Menne 2010; Sheffield and Galvez 2009; WHO 2009]

Temperature

Search: (climate change and (vulner$ or adapt$) and health and (extreme heat or extreme temperature$ or extreme cold) and (measur$ or indicat$ or determin$ or risk$)).ab

=29
=9 after removing duplicates from Ovid
=6 after removing duplicates from search (1 and 2)
-1 article not relevant based on article review
=5 resources

List = [Cheng and Su 2010; Ebi et al. 2006; Luber and McGeehin 2008; O'Neill et al. 2005; Stone, Hess and Frumkin (2010)]

Extreme weather and natural disasters/hazards

Search: (climate change and (vulner$ or adapt$) and health and (extreme weather or natural hazard$ or natural disaster$) and (measur$ or indicat$ or determin$ or risk$)).ab

=141 references
=48 after removing duplicates from Ovid
-22 duplicates from search 1, 2 and 3
-13 articles not relevant based on abstract review
-4 articles inaccessible
=9 for review
-3 articles not relevant after article review
=6 resources

List = [Balbus and Malina 2009; Diaz 2006; Greenough et al. 2001; McMichael et al. 2006; O'Neil and Ebi 2009; Patz et al. (2000)]

Vector-borne disease

Search: (climate change and (vulner$ or adapt$) and health and (vector$ or zoono$ or infectious) and (measur$ or indicat$ or determin$ or risk$)).ab

=9 references
=5 after removing duplicates
=2 after removing non-relevant titles
=1 after removing non-relevant article based on review

List = [Patz et al. 2005]

Food and water contamination

Search: (climate change and (vulner$ or adapt$) and health and (food or water) and (measur$ or indicat$ or determin$ or risk$)).ab.

=9 references
=1 reference after deleting duplicates (8)

List=[Casman et al. 2000]

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