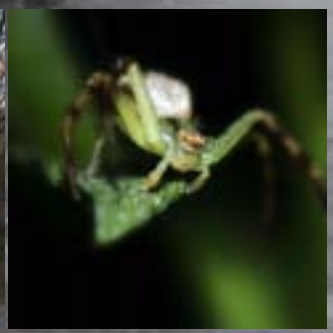
Adapting to climate change: Challenges for Niagara



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EXECUTIVE SUMMARY

Most Canadians recognize that climate change is underway, fuelled largely by human activities. The changes that have occurred are measureable and the impacts are growing.

More and more governments and other organizations have begun to commit to climate change adaptation – taking action to reduce the impacts of climate change and, where possible, taking advantage of opportunities.

This report has been written to describe how climate is changing in the Niagara region, the impacts that can be expected in the near future, protective activities that are underway in the region, and gaps that need to be addressed in order to develop and implement adaptation strategies. It also provides an Appendix with selected case studies of adaptation in other parts of Ontario, which may provide ideas and inspire action in Niagara.

1. CLIMATE CHANGE BASICS

Greenhouse gases are produced by many natural processes and are essential to life on earth. They absorb and trap in the atmosphere some of the infrared radiation produced by solar rays that reach the earth's surface. This helps warm the planet.

However, human activity is rapidly changing the concentration of greenhouse gases in the atmosphere. Since the early days of the Industrial Revolution carbon dioxide (CO_2) levels in the atmosphere have increased by about 39%. The Intergovernmental Panel on Climate Change estimates that greenhouse gas levels are now higher than they have been anytime in the last 650,000 years.

Increases of greenhouse gases in the atmosphere bring about a host of changes. The most obvious effect is global warming. In Canada, temperatures have increased by 1.3˚C on average in the last century. 2001-2010 was the hottest decade since weather records began. If emissions continue to increase, global temperatures may rise 4-7˚C in the next century.

Warmer average temperatures are not the only effect of higher concentrations of greenhouse gases. A warmer atmosphere leads to a cascade of changes that are of concern to the Niagara region.

2. CLIMATE TRENDS AND PROJECTIONS FOR NIAGARA

A number of changes in the climate of the Niagara Region have already been seen. These changes include:

- An increase in annual average temperature of about 1.3 C in the last 40 years
- A trend towards more days with temperatures over 30˚C
- More heat waves of 3 or more consecutive hot days
- Longer growing season, with May and September significantly warmer
- An increase in average number of frost-free days with 10 more per year compared to 1970
- A small increase in annual precipitation, with most of the increase coming in winter
- More rain and less snow in winter
- More summer droughts and dry spells
- Increased numbers of freeze-thaw cycles
- An increase in heavy rain events.

For the future, climate scientists are projecting:

- An increase in average annual temperatures of 3-4˚C in the Niagara region by the 2050's
- Increase in freeze-free days by as much as 30 days in the 2050's and 50 days in the 2080's
- A 20% decrease in summer rainfall by the 2050's
- A continuing increase in freeze-thaw cycles for the next few decades
- Growth in the conditions that give rise to thunderstorms with a likely increase in heavy rains, lightning strikes, high winds, hailstorms and tornadoes.

Although not a climate change in itself, scientists have also noted that water levels on Lake Erie and other Great Lakes have been on a declining trend since 1986. Because of warmer temperatures and reduced ice cover, evaporation is likely to exceed precipitation and lake levels are likely to continue declining.

3. LIKELY IMPACTS OF CLIMATE CHANGE IN NIAGARA

AGRICULTURE

Although there are likely to be both positive and negative effects of climate change on agriculture in Niagara, the negative impacts are likely to outweigh the positive. Some of the expected negative impacts are:

- Shorter season for Niagara's signature ice wine
- Reduced productivity and quality of "cool climate" grape varietals
- Increased cooling requirements and energy costs for greenhouse operators
- Increase in invasive weed species and agricultural pests
- Increasing requirements for irrigation
- Heat stress in animals
- Increased damage from freezing rain and freeze-thaw cycles
- Damage to crops from heavy downpours and strong winds
- Increased runoff and soil erosion
- Damage to greenhouses and livestock barns from big storms
- Power outages that jeopardize dairy operations.

Positive effects may include:

- "Fertilization effect" of increased carbon dioxide
- Longer and warmer growing season creates opportunities for more "hot crop" production
- Better conditions for warm climate grape varietals
- Warmer winters reduce stress for fruit trees
- Drier summers can reduce some plant diseases.

ECOSYSTEMS

Climate is a key factor in the functioning of all ecosystems, affecting the availability of food, water, shelter, and reproduction. Climate change creates additional pressure on ecosystems that are already stressed and have been fragmented or impoverished by deforestation, filling in wetlands, expanding roads and sprawl, and other pressures. Some of the impacts are:

- Increased insect and disease outbreaks in trees and other vegetation
- Increased stress for woodlands due to summer heat and reduced rainfall, making them more vulnerable to fire
- Decline in wetlands due to lower water levels, with impacts on wetland plants, marsh-nesting birds, amphibians and fish
- Threats to fish from higher water temperatures, declining water levels in rivers and lakes, reduced flows in some rivers, and reduced levels of dissolved oxygen in summer
- Expansion of some warm water fish and invasive aquatic species such as sea lamprey and zebra mussels
- More outbreaks of Type E botulism causing mass die-offs of mudpuppy salamanders and fish-eating birds in the Great Lakes
- More outbreaks of toxic blue-green algae in the Great Lakes and especially in Lake Erie

Hotter weather, intense rainfall events and windstorms will also increase the stress on urban ecosystems and make it harder to maintain or expand the tree canopy in towns and cities.

INFRASTRUCTURE

Public infrastructure provides a wide range of essential services to the people of Niagara, including: water supply; sewage treatment and stormwater management; transportation; and energy. Weather – and climate change – affects all these forms of infrastructure.

Water Supply Infrastructure

Climate change is likely to affect the quality of source water in Niagara and elsewhere. Lower water levels are likely to increase the concentration of chemical contaminants in surface waters. Higher temperatures contribute to blue-green algal blooms, which affect the taste and odour of drinking water in summer. Increased runoff and combined sewage overflows from intense rainfall will also carry more contaminants and infectious organisms into the water bodies that provide Niagara with most of its water supply. All these changes will increase the challenge and cost of water treatment in the region.

More than 75,000 people in rural Niagara get their water from private wells and cisterns. Several of these areas are already under moderate or significant groundwater stress. As climate change progresses, drier summers and more frequent droughts will reduce groundwater recharge. More precipitation will come in intense rainfall, which causes water to run off into streams and other watercourses, rather than filter through the ground. This is likely to increase the stress on those groundwater supplies. Some rural residents may experience shortages.

Stormwater Management Infrastructure

As towns and cities grow, buildings, roads, sidewalks, driveways and parking lots proliferate. Much of the rain and snow that falls on these impermeable surfaces runs off into a stormwater system that releases it into a nearby stream or lake. This water is contaminated with pollutants from roads, animal feces, lawn and garden chemicals and other substances. In hard rains or rapid snowmelt situations, stormwater overflows may carry a mix of contaminated stormwater and raw sewage into the region's lakes and rivers.

Prolonged or intense rainfall can also overwhelm sewer systems and back up sewage into basements, especially in low-lying areas. Several Niagara neighbourhoods have experienced repeated basement floods due to intense rainfall. Intense rainfall or rain-on-snow events can also overwhelm the capacity of soils, water courses and stormwater systems and cause overland floods. A growing number of Ontario towns and cities have experienced costly floods in the last decade.

Most of Niagara's municipal governments have been working on improvements to stormwater systems to reduce basement flooding and releases of contaminated stormwater and sewage to the area's rivers, streams and lakes. This work will become more urgent and challenging with the more frequent intense rainfall and rain-on-snow events expected as a result of climate change.

Electricity Demand, Supply and Distribution Infrastructure

Climate change has several impacts on energy systems. First, it shifts seasonal demand for energy. Because winter temperatures are warming, there is less need for energy for heating purposes. This reduces demand for natural gas and home heating oil.

However, as summers get hotter, more homeowners and businesses are installing and using air conditioning systems, which increases demand for electricity. Hot days and nights create peak loads that pose the potential for brownouts and blackouts.

Climate change will also affect the generation of electricity. Lower water levels in Lake Erie and the Niagara and Welland Rivers, for example, will reduce flows to the Adam Beck power stations, affecting their output.

And finally, the increase in the frequency and intensity of extreme weather will affect the transmission and distribution of electricity. High winds during thunderstorms, heavy snow and ice storms often bring down electrical lines, shutting down services to the surrounding area for a few hours or days.

Buildings

Climate change will have impacts on all kinds of buildings. Some of these impacts will result from extreme weather events and others are due to changes in average weather conditions.

The impacts of extreme weather events are likely to be the most dramatic. They include:

- Basement floods due to intense or prolonged rainfall that overwhelms stormwater systems and backs up sewage drains
- Overland floods from rivers swollen by prolonged rainfall, sudden snowmelt or ice jams, damaging buildings and other structures
- Thunderstorms such as the recent storm that took part of the roof off the Lockview Public School in St. Catharines, and damaged a number of other buildings
- Strong winds along the north shore of Lake Erie, which caused 6 metre waves and drove water and chunks of shore ice through some lakeside living room windows in a January 2008 storm
- Tornados such as the one that damaged more than 600 homes and a school in Vaughan in 2009; another that shattered Leamington greenhouses and damaged a local marina and homes in 2010; and a third that badly damaged the heritage centre of Goderich in 2011

Climate change is also expected to worsen weathering damage to buildings. An Environment Canada analysis of climate change impacts on buildings determined that:

- Increased freeze-thaw cycles will lead to premature deterioration of concrete, increased problems of roof damage due to ice dams, and moisture damage
- Higher temperatures speed up chemical reactions which increases corrosion in some building materials and accelerates the deterioration of building facades
- More intense precipitation events will speed up decay processes, and increase rain penetration and moisture absorption in buildings.

The combined effects of these weathering processes will be to reduce the lifecycle of building materials and structures, requiring earlier and costly renovation and restoration measures.

Transportation Infrastructure

Climate change will affect most forms of transportation. One of the more significant impacts in Niagara is likely to be on Great Lakes shipping. The positive effects include reduced ice cover on the lakes and connecting channels that will extend the shipping season. This change can be seen already, with the Welland Canal opening on record early dates in 2006, 2007 and 2008.

However, Great Lakes shipping will also have to contend with lower water levels in the lakes and canals, which will force most ships to lighten their loads in order to safely clear the bottom. This will increase costs and may lead to a further decline in shipping. Lower water levels will also affect port facilities, marinas, docks and boat ramps on Lakes Erie and Ontario, which may need to be renovated or rebuilt.

Climate change will also affect roads. Freeze-thaw cycles are particularly damaging, creating frost heave and potholes, accelerating the deterioration of pavements and requiring higher maintenance expenditures. Hot weather also causes pavement softening and rutting, especially on roads with heavy truck traffic such as the QEW.

Road infrastructure such as bridges, culverts and tunnels are also likely to be affected by climate change. Bridges, abutments or piers are scoured by fast flowing water and debris, especially after intense rainfalls, rain-on-snow events or quick thaws – all more likely under climate change. Increased freeze-thaw cycles also cause premature deterioration of concrete in bridges.

Culverts, and the roads above them, are at particular risk from intense rainstorms that increase flow and debris in water courses. Tunnels will also have increased susceptibility to flooding under climate change.

Road accidents due to storms are also a concern. Although climate change is likely to reduce overall snowfall, lake-effect snowstorms and intense rainfall events may increase road accidents and injuries. Strong winds can also be problematic on bridges, which will be a concern for bridges to the United States and the Garden City Skyway.

TOURISM AND RECREATION

Climate change is likely to have mainly positive effects on tourism and recreation in the Niagara region. An earlier spring, warmer summer and later fall are likely to extend the main tourist season. Outdoor activities will especially benefit, with a longer season for viewing the Falls, touring wineries, visiting beaches, parks and nature trails, water sports, fishing and golf.

However, many tourist and recreational activities take place in natural areas or involve interaction with natural systems that may be adversely affected by climate change. Declining water levels may affect use of existing docks and facilities and increase navigational hazards. Changes in the prevalence of desirable fish species could have negative effects on the sport fishing industry. Declining water quality and increased frequency of algal blooms may increase beach closures. Extreme weather events may also have adverse impacts on tourist facilities and activities in the region.

HUMAN HEALTH AND WELL-BEING

The comprehensive report Human Health in a Changing Climate recently released by Health Canada, describes a wide variety of potential health effects from climate change. These include:

- An increase in heat-related illnesses and deaths
- Worsening of respiratory ailments such as asthma, as a result of increased smog
- Increase in vector-borne diseases such as West Nile virus and Lyme disease as more insects overwinter, reproduce more quickly and expand their range
- More outbreaks of waterborne diseases
- More foodborne illnesses
- Injuries due to storms and floods
- Mental stress resulting from weather-related damage to homes and livelihoods

THE ECONOMY

The costs of extreme weather and climate change are proving to be high for communities, public institutions, businesses and households. While climate change may provide economic opportunities for some sectors, taking advantage of these opportunities will require planning with climate change in mind.

Economic costs may result from:

- Damages to homes, buildings, infrastructure, or other property from extreme weather
- Maintenance costs or premature replacement of infrastructure due to more rapid weathering
- Downtime for businesses affected by power outages, floods, and other weather-related incidents
- Increased emergency management costs (for police, fire fighters, ambulance drivers and paramedics and other emergency personnel)
- Lower productivity and lost work time as a result of weather-related illnesses or accidents
- Rising insurance premiums
- Increased health care costs.

Some of the potential local costs of climate change can be inferred from the price tag of recent changes in weather patterns and extreme weather events in one Ontario community. The 2009 tornado in Vaughan cost the municipality $730,000, not including replacement of 1600 trees that were destroyed. For the same event, insurance companies paid out damages of $88 million to households and businesses. No estimate is available for uninsured damages.

4. CLIMATE CHANGE ADAPTATION IN NIAGARA

Action is needed to reduce Niagara's vulnerability to the weather extremes that we can expect in the near- and medium-term. There are three broad categories of adaptation action:

- Building adaptive capacity
- Taking adaptive action to prevent or reduce impacts
- Responding to and recovering from climate-related emergencies and impacts

Niagara is in the early stages of developing adaptive capacity. The region has access to much of the data needed to analyze how climate is changing in the region, and to identify possible impacts. A number of local researchers are involved in projects to identify and measure impacts. A major climate change risk assessment has been done for Welland's stormwater and wastewater system, piloting a process that could be replicated in other Niagara municipalities. And several organizations have held workshops that increase engagement of stakeholders on issues of climate change impacts and adaptation.

A small number of individuals and organizations in Niagara are currently involved in assessing the risks of climate change for their sectors, and developing plans for climate change adaptation. A larger number have taken action to reduce the impacts of current weather extremes in Niagara, but have not yet started planning for future climate change.

All these activities lay the groundwork for more planned and comprehensive adaptation to climate change in the region. The rest of this section will describe some of the activities that provide the foundation for protecting the region from the impacts of climate change.

PLANNING ADAPTATION

An important first step in building adaptive capacity is making the commitment to plan with climate change in mind, and engaging stakeholders in the process. This is beginning to happen in Niagara, as shown in the following three examples.

Niagara Region

Niagara's regional government established a start-up team on climate change mitigation and adaptation planning in 2007. The team proposed a high-level Climate Change Action Work Plan in 2008, and in 2009 Niagara region joined Partners for Climate Protection (PCP), a project of the Federation of Canadian Municipalities with more than 200 municipal members that receive planning guidance for reducing greenhouse gas emissions. The Region has completed an emissions inventory as a first step in this process. In 2010, Niagara Region organized a workshop for the Niagara Climate Action Plan, focused on setting up a multi-stakeholder organization to develop the Action Plan.

Niagara Climate Change Network

Environment Canada and researchers at Brock University began work in 2009 on a collaborative project to facilitate a climate change network and action plan in the region. As part of this work, researchers from Environment Canada and Brock analyzed climate trends and projections for the region, and identified some initial impacts. The project held workshops with a broad range of Niagara stakeholders in December 2010 and 2011.

Early in 2011, the process begun at Niagara Region and the community-based process of the Niagara Climate Change Network converged and the Niagara Climate Change Network (NCCN) was formed. The NCCN is developing a Niagara Climate Change Charter and will be encouraging Niagara organizations to sign the charter and commit to mitigating and adapting to climate change.

City of St. Catharines Sustainability Strategy

In 2011 the City of St. Catharines passed a sustainability strategy, which includes climate change as one of six major challenges facing the city. The strategy includes several high-level commitments to address climate change adaptation:

- Protection of critical infrastructure from climate change
- Neighbourhood planning that considers the projected impacts of climate change
- Ensuring plans are informed by future projections about the frequency and severity of weather-related events
- Informing the community about climate change and its potential effects for St. Catharines
- Encouraging trees as part of site design shading and cooling
- Incorporating food security into adaptation planning.

TRACKING WEATHER DATA AND INVESTIGATING CLIMATE PROJECTIONS FOR THE REGION

Data on weather trends is one valuable component of adaptive capacity. It can help to increase awareness of climate change in the region, and provide information that is helpful in identifying risks and opportunities. A number of organizations currently collect weather data in Niagara, including Environment Canada, the Niagara Region itself, the Niagara Peninsula Conservation Authority, the Ontario Weather Network and Weather Innovations Incorporated (WIN).

Although a large amount of weather data is currently collected, there is not much coordination or trends analysis of this information, which could make it much more useful for understanding recent climate trends and their impacts in the region.

The region also needs more capacity to investigate and incorporate future climate projections into long-term infrastructure, land-use, natural heritage and public health planning. Some resources are available and are described below.

Environment Canada Weather Data, Trends Analysis and Climate Projections

Environment Canada has six weather stations in the Niagara region and two weather buoys in Lake Ontario and Lake Erie. Daily weather data from these stations is available on Environment Canada's on-line National Climate Data and Information Archive.

This Archive also allows viewers to download "climate normals" for 1971-2000, compare current temperatures and precipitation with past climate averages and analyze trends for a number of climate variables.

Environment Canada's on-line resource, the Canadian Climate Change Scenarios Network, can also be used to access future temperature and precipitation projections for the region.

Weather Data from Weather Innovations Incorporated

Weather Innovations Incorporated (WIN) is a private company with 26 weather stations in Niagara. WIN provides hourly and daily weather data for grape and fruit growers. The company has collected weather data since 2006, and provides charts showing how temperatures and rainfall vary in the region. This could be a useful supplement to Environment Canada data.

Niagara Region's Mesoscale Weather Monitoring Network

The Mesoscale Weather Monitoring Network for Niagara Region includes 13 precipitation stations in locations across the region and 4 full climate stations in Grimsby, Welland, Niagara Falls and Fort Erie. Some of these stations have data loggers that send data to the Niagara Peninsula Conservation Authority. These stations have been collecting weather data since 1991. They measure rainfall every 5 minutes, which provides good information on the intensity of rainfall. At present this data is not analyzed for long-term weather trends, nor is the data readily available to the public.

Precipitation and Other Water Data Collected by the Niagara Peninsula Conservation Authority

The Niagara Peninsula Conservation Authority (NPCA) collects a considerable amount of data about precipitation, water flows, and water quality in the region. This data is used to support the NPCA's mandate of managing, conserving and restoring natural resources in Niagara's complex system of watersheds, and planning to protect water quality in the region.

Recently, NPCA conducted an assessment of the vulnerability of Niagara's water systems to climate change and determined that 7 out of 13 Watershed Planning Areas in the region were highly sensitive to climate change.

Based on its analysis, NPCA recommended adding or re-activating 7 weather stations in the region to provide more comprehensive water quality and flow data from Niagara watersheds that are highly sensitive to climate change. The additional data could support hydrological modelling in Niagara to assess the impact of climate change on water resources over time.

RESEARCH INVESTIGATING CLIMATE CHANGE IMPACTS AND ADAPTATION OPTIONS IN THE REGION

A number of Niagara-based researchers are currently analyzing ways in which climate is changing in the region, what impacts can be expected, and what some adaptation options might look like.

Investigating Climate Change Effects and Adaptation Options in Ontario's Wine Regions

In 2011, Brock University's Cool Climate Oenology and Viticulture Institute received a grant from the Province to study how climate change impacts Ontario's grape and wine industry. The project involves 19 researchers in several projects over 5 years.

Investigating Impacts of Climate Change on Niagara Ecosystems

Brock researchers are also trying to understand the impacts of climate change in Niagara's ecosystems. Trees on the campus will be monitored over time for growth, flowering and fruiting to better understand which species can best survive in a changing climate. Some Brock undergraduate and graduate students are also studying the impact of climate-related events such as drought or heavy rain on meadow ecology and other ecosystems in the region.

Tracking the Movement of Insect Vectors into the Niagara Region as the Climate Warms

Niagara Public Health is collaborating with Brock University in the use of a Rothamsted trap to capture insects that serve as carriers of infectious disease. Researchers in Brock's Biological Sciences department are monitoring climate data and identifying and analyzing the insects, to determine which insects are migrating northwards from the US and diseases they may be carrying.

Developing and Testing Resilient and Warm-Climate Plants

The Vineland Research and Innovation Centre is involved in several agricultural research projects that may facilitate climate change adaptation in the Niagara Region. These projects include:

- ◊ Greening Ontario Highways: The project is growing and planting 14 varieties of trees along busy Ontario highways and in urban settings, to see how well they survive in these stressful environments. Some of the trees in the experiment are resilient native varieties, but others are from areas which have a climate similar to that expected in southern Ontario in the future.

- ◊ Native Plants for Green Roofs: Vineland researchers are investigating more than 20 types of native plants with potential for planting on green roofs. Green roofs aid in adaptation by cooling buildings, reducing energy use, reducing the rush of rainwater into stormwater systems and providing habitat for birds and butterflies. Few native plants have been evaluated previously for Canadian conditions.

- ◊ World Crops: This project is researching the production of warm-climate crops that are currently imported into Canada. Warmer summers and longer growing seasons provide more opportunity for growing some of these crops locally and reducing emissions from transportation. The research will provide first hand information about growing needs and conditions that will help Niagara farmers grow and market new warm-climate crops.

Monitoring the Resilience of Trees to Climate Change

The Association of Canadian Educational Resources (ACER) is collaborating with Climate Action Niagara in schoolyard tree planting in "local climate change experimental plots" in Thorold and Welland public schools. The students will collect data on the health and annual growth of the trees, as a way of exploring issues relating to climate change. ACER also manages a one-acre biodiversity observation plot in Niagara-on-the-Lake. These programs are part of a larger initiative to assess which trees can do well as climate changes.

CLIMATE CHANGE RISK ASSESSMENT

The first climate change risk assessment for infrastructure in the Niagara Region was recently completed for the City of Welland's stormwater and wastewater systems. The consultants for the study conducted a climate analysis, examining 18 climate variables for Welland, and then organized a risk assessment workshop with stormwater/wastewater managers and related specialists in the region. Participants identified how each feature of the Welland system could be impacted by the anticipated changes in climate and developed a risk score for each impact. The report makes a number of short- and longer-term recommendations to reduce these impacts.

IMPACTS AND ADAPTATION WORKSHOPS

In January 2011, Niagara's WaterSmart program and AMEC hosted a one-day workshop focused on designing water and stormwater infrastructure that is resilient to climate change. The event attracted participants from all over the region, including staff from most of the region's municipalities. The workshop heard presentations on:

- How climate change is altering the magnitude, frequency, timing, intensity and variability of precipitation and increasing extreme storms
- Assessment and mapping of future flood risks
- The need to take climate change into account when designing and building new infrastructure
- The need for more long-term rainfall data and sharing of existing data among those agencies that monitor precipitation and other weather variables.

The participants asked for a follow-up workshop to determine how weather data can be shared by Niagara agencies and to hear the results of the climate change risk assessment study for the City of Welland.

CURRENT ACTIONS LIKELY TO REDUCE CLIMATE CHANGE IMPACTS

There are a number of programs and activities underway in Niagara that provide some protection from some of the impacts of climate change. Relatively few of these activities are undertaken with the explicit goal of adapting to climate change. To be fully effective as an adaptation strategy, many of these programs will need to be ramped up.

Energy Conservation Programs that Reduce Pressure on the Grid

Energy conservation can provide some protection from the impacts of climate change. Reducing demand for electricity, for example, reduces the stress on electricity transmission and distribution systems, making them less vulnerable to brownouts and blackouts during heat waves.

A number of municipal governments, private companies and utilities in Niagara have taken action to reduce consumption of electricity and other forms of energy. These actions include:

- ◊ Utility-led energy conservation and demand management programs such as energy audits, energy retrofits, demand response programs, etc.
- ◊ Replacement of traffic and pedestrian signals with high-efficiency LED lights
- ◊ Energy conservation programs in local businesses, including Niagara's wineries
- ◊ The Quick Wins Home Energy Program led by several Niagara non-profits, which identifies drafts and seals leaks in homes, helping reduce energy use and the impacts of both hot and cold weather on homeowners.

- Actions that Reduce the Impacts of Intense or Prolonged Rainfall, or Rain-on-Snow Events

The Niagara Region and several Niagara municipalities have several programs in place to help reduce the impacts of intense or prolonged rainfall. These programs include:

Stormwater Management Master Plans

- Niagara Region's WaterSmart program is supporting the development of local watershed-based stormwater management master plans. The Town of Pelham and City of Port Colborne are currently undertaking studies to produce such plans.

Stormwater Infiltration Systems

- Many best management practices for stormwater management are outlined in the NPCA's recent Stormwater Management Guidelines. These prioritize "low impact development" or "green infrastructure" practices that increase infiltration of rainwater and reduce runoff, erosion and flooding, which will become increasingly important for reducing impacts.
- Niagara communities have so far made limited investments in infiltration systems such as green roofs or permeable pavement installations that can absorb, retain and gradually release rainwater, reducing the impact of heavy storms on infrastructure and waterways. However the region has installed a growing number of swales and wet and dry stormwater ponds to hold stormwater and reduce runoff.

Downspout Disconnection, Weeping Tile Disconnection and Rain Barrel Programs

- Several local Niagara municipalities have had downspout disconnection by-laws, public education, inspection and enforcement programs to ensure that downspouts are disconnected from sewer systems to reduce heavy flows and the potential for combined sewer overflows. Several communities also have programs to subsidize the purchase of rain barrels to encourage homeowners to capture rainwater from their roofs.
- Niagara Falls and Fort Erie both have active weeping tile disconnection programs and Niagara Falls subsidizes homeowners who disconnect. The two cities gathered flow data to evaluate the effectiveness of the program and determined that it has significantly reduced combined sewer overflows.

Backflow Prevention and Flood Alleviation Programs

- St. Catharines initiated a Backflow Prevention Program to ensure that existing commercial, institutional, industrial and multi-level residential buildings install backflow devices to prevent sewage water back-ups into basements. The City also provides grants of up to $3000 for homeowners who have suffered basement flooding, to help them install backwater valves, sump pumps, disconnect weeping tiles from the sanitary sewer and other mechanisms to reduce the incidence of future basement flooding.

Combined Sewer Separation and Treatment for Combined Sewer Overflows

- Combined sewer and stormwater pipes are a problem in older towns and several Niagara communities have been working to separate combined sewers and to implement other mechanisms to reduce combined sewer overflows during wet weather. Limited funds from the federal and provincial governments have slowed these expensive projects.

Actions that Reduce the Impacts of Hot Days and Heat Waves

The impacts of hot days and heat waves under climate change will be felt most in urban areas where vegetation has been removed and replaced by concrete and asphalt. These changes create urban heat islands which can increase temperatures up to 7˚C higher than the surrounding countryside. There are a variety of strategies to combat these effects. The main strategy used so far in Niagara is tree planting. Several organizations in the region have campaigned for and participated in tree planting and maintenance in urban areas. These include:

- Land Care's Re-Leaf Niagara program, which grows and plants native trees suitable for planting in urban settings
- NPCA's Canopies for Kids program, funded by WaterSmart, which plants trees in school playgrounds for shade and cooling
- Climate Action Niagara's "Take the Heat off Our Streets" campaign for planting more trees on boulevards and in cul-de-sac circles.

The City of St. Catharines adopted an Urban Forestry Management Plan in 2011. The plan acknowledges the importance of urban trees for climate change mitigation and adaptation. The City has committed to increasing the tree canopy from the current level of 15-17% to 30% by 2030.

Actions that Facilitate the Adaptation of Natural Systems in Niagara to Climate Change

Niagara has an abundance of organizations working to restore and enhance the natural heritage of the region. Rehabilitated and enlarged natural areas reduce the impacts of climate change by cooling the air, reducing runoff and flooding, improving the quality of the water and the health of the streams as well as aiding the continued survival of the region's trees, plants and wildlife.

Much of Niagara's tree planting has been designed to connect forest fragments, especially along streams and other natural corridors. Since 1997, NPCA has undertaken 10-15 projects annually to aid in connecting forest fragments and has planted 1.5 million trees. The Niagara Restoration Council has also overseen a three-year wildlife corridor project to connect existing forest fragments in the several critical watersheds.

NPCA and Land Care emphasize diversity in their plantings, in case changing weather conditions or unexpected new pests prove particularly damaging to some trees.

FORECASTING AND WARNING SYSTEMS TO HELP NIAGARA RESIDENTS AVOID EXTREME WEATHER AND CLIMATE CHANGE IMPACTS

An important component of adaptation is to provide forecasting and warning systems to help people avoid the impacts of climate change. The classic example of this is heat alerts.

Excessive Heat Alerts

Niagara Region Public Health (NRPH) initiates an excessive heat alert if:

- The humidex (an index that combines heat and humidity) is forecast to rise to 40 or higher
- The humidex is forecast to rise to 38 or higher, and a smog alert is also underway, or
- Environment Canada issues a humidex warning for the Niagara area

NRPH issues a media alert to warn the public to watch for the symptoms of heat stroke, to take precautions such as drinking plenty of fluids and resting in shaded areas, and to check on vulnerable neighbours. The department also alerts community agencies in the Niagara region, who in turn communicate the warning to their staff and clients.

A Real-Time Weather Monitoring System to Provide Timely Warnings of Beach Water Contamination

NRPH is also responsible for monitoring beach water quality in the region, and posting beaches with warnings when the water is contaminated, as often occurs after storms. In 2010, Niagara beaches were posted 32.5% of the time.

NRPH is testing a mini-weather station that will be moored in the water off a Niagara beach. The equipment will provide real-time information on rainfall, wind speed and other factors that contribute to contamination. This will be correlated with water sampling. If Public Health staff can correctly predict E. coli contamination as a result of weather conditions, then the Department will likely install mini-weather stations at other strategic locations.

Vector-Borne Disease Controls, Surveillance and Early Warning Program

Niagara Region Public Health plays a role in monitoring the expansion of insect vectors and vector-borne diseases such as the West Nile virus (transmitted by infected mosquitoes) and Lyme disease (spread by blacklegged ticks).

Climate change is expected to increase the transmission vector-borne diseases by speeding up the life cycle of the vectors and extending the transmission season.

Surveillance for West Nile and for other mosquito-borne diseases will be enhanced by the Rothamsted trap that NRPH and Brock scientists recently erected. If vector-borne diseases of concern are identified, NRPH notifies family physicians and emergency rooms so they are better able to identify and treat the diseases.

NRPH collaborates with Health Canada on small mammal trapping to test for blacklegged ticks, which have been increasing in Niagara in recent years. NRPH encourages doctors, veterinarians and the public to submit ticks for identification and testing. NRPH has also collaborated in "tick dragging" campaigns in the Wainfleet Bog, to capture and

identify ticks. The department provides information to the public about ways to avoid tick bites and about symptoms if they do get bitten.

RESPONDING TO AND RECOVERING FROM CLIMATE CHANGE IMPACTS

Emergency Management Planning

Several severe weather events in the last 15 years have highlighted the need for strong emergency plans and preparedness and led to strengthening emergency services in Ontario and across Canada.

Emergency managers in Niagara report that planning has changed recently because of threats that may be associated with climate change including the April 28th windstorm that struck the region in 2011, recent severe heat waves and tornadoes like the ones that recently devastated Vaughan and Goderich. Niagara Region's Hazard Identification and Risk Assessment is currently being updated and stronger working relationships formed between emergency planners and utilities in the region.

Emergency managers have recently strengthened messaging to encourage individuals and households to prepare in advance for weather-related and other emergencies.

Business continuity planning is an important aspect of emergency preparedness. Recently, more attention is being paid to internal continuity planning in the Niagara Region, to ensure that regional government departments can continue to provide services in the event of an emergency. Most large businesses have plans in place. However, smaller businesses are less likely to be prepared.

5. FILLING THE GAPS IN NIAGARA'S PREPARATION FOR CLIMATE CHANGE

Although there are many initiatives in the Niagara region that will serve to reduce the impact of climate change, much remains to be done. The following provides an outline of some of the ways in which Niagara could organize and strengthen its capacity to adapt to climate change.

LEADERSHIP IN CLIMATE CHANGE ADAPTATION PLANNING

The experience of strong regional and local initiatives in other parts of Ontario, Canada and internationally suggests that additional commitments to adaptation planning are needed in Niagara, including:

- Support by strong political or executive champions
- Establishment of a clear organizational structure for adaptation planning with clear mandates, financial support and the collaboration of key stakeholders in the region
- Allocation of dedicated staff and budget
- Active collaboration with local and regional researchers prepared to help with climate information, vulnerability and risk assessment, and identification of adaptation options
- Identification of priority sectors and projects for adaptation.

COORDINATION AND SHARING OF WEATHER DATA, ANALYSIS OF TRENDS, REGIONAL CLIMATE PROJECTIONS

Participants in the Engineering for Climate Change Workshop hosted by WaterSmart last year recommended that the weather data currently being collected in Niagara be coordinated and shared and that more analysis be done on climate trends. An analysis of climate projections that builds on Fenech and Shaw's work in 2010, and on AMEC's report for Welland would also be very useful for the region.

AWARENESS AND ENGAGEMENT ACTIVITIES

Participants in the 2011 Engineering for Climate Change Workshop also recommended a follow-up in 2011. More workshops of this kind would be very valuable in attracting and sustaining the interest and engagement of local infrastructure managers, staff and the public.

Awareness and engagement can also be increased by dedicated communications tools such as Halifax Regional Municipality's Climate SMART website, which identifies the risks of climate change for the region, consultant reports on vulnerabilities including maps, a guide for resilient development, links to related magazine articles, etc.

VULNERABILITY ASSESSMENTS

This report provides an initial look at overall vulnerabilities in Niagara and the NPCA has assessed the vulnerability of surface water and groundwater in the region. However, more specific assessments are needed for specific sectors expected to be vulnerable. There are a number of guides currently available to help in undertaking climate change vulnerability assessments.

INFRASTRUCTURE RISK ASSESSMENTS

Engineers Canada has developed a protocol for public infrastructure risk assessments. This protocol guides the use of climate trends and projections information to assess future climate risks. The protocol also recommends a scoring system that quantifies and helps prioritize different risks. AMEC used this methodology in the recent climate change risk assessment of Welland's stormwater/wastewater systems. This assessment could be replicated for other stormwater/wastewater systems in the region, and for other types of public infrastructure (buildings, transportation systems, water treatment plants, etc.).

INVENTORY OF ADAPTATION ACTIVITIES TO DATE AND GAPS ANALYSIS

This white paper has done an initial survey of programs and projects in the region that are likely to provide some protection from future climate change, even though many of these actions have not been taken with the explicit goal of adaptation. Some activities that will help the region adapt have undoubtedly been missed. It will be valuable for specific sectors to develop their own inventory of current activities that they believe will contribute to adaptation and to suggest how these activities can be augmented to provide expanded climate change protection.

6. CONCLUDING COMMENTS

Climate change is underway in Niagara, as it is in the rest of the world. This can be seen in several key features of climate, including warming temperatures, changes in precipitation patterns, shifts in the growing season and other harbingers of climate change.

Many organizations in Niagara and around the world are working to reduce greenhouse gas emissions and limit global warming so that climate change does not result in catastrophe. However, the increased concentration of greenhouse gases that has already occurred will ensure that the earth will continue to warm for several decades, even if we are able to make dramatic reductions in emissions in the near future. This warming will continue to change temperatures, rainfall, storm patterns and other important features of our weather and this will inevitably impact on our communities.

Niagara is a very special region in Ontario and Canada for many reasons. Its unique attributes need to be nurtured and protected from climate change. Many organizations and individuals in the region have already begun this task, and are increasing the capacity of Niagara to adapt. This work is still in the very early stages however.

Organizations and individuals throughout the region need to be asking the climate question: How will climate change affect me and my community? Answering this will require concerted efforts to elevate the awareness and engagement of the public and key stakeholders. It will also require more and better-coordinated climate information, a commitment to assessing impacts and to climate change adaptation planning throughout the region. Resources will have to be mobilized both for planning and for implementation of adaptation programs.

It is hoped that this report will contribute to the continuation and acceleration of this important work.

INTRODUCTION

Most Canadians recognize that climate change is underway. There is undeniable evidence that emissions from human activities have increased carbon dioxide, methane and other heat-trapping gases in the atmosphere.

As a result, worrisome changes are occurring at a global level. According to the U.S. National Aeronautics and Space Administration:

- Global average temperatures have risen by more than 0.8 degrees Centigrade since 1880. Most of this warming has occurred since the 1970's. The ten hottest years since records began have occurred in the last 12 years.
- The Greenland and Antarctic ice sheets are losing mass. Greenland lost 150-250 cubic kilometres of ice between 2002 and 2006, and Antarctica lost more than 150 cubic kilometres between 2002 and 2005.
- Arctic summer ice has been declining by 11.5% per decade in the last 30 years.
- Glaciers are retreating all over the world.
- Sea levels have risen 17 centimetres (6.7 inches) in the last century.
- Extreme weather events such as heat waves and intense rainfall are increasing.

In Canada, considerable attention has been paid to the impacts of climate change in the far north – which is warming faster than the rest of the country – and in coastal areas, where sea level rise and storm surges are a threat. However, all regions of Canada are experiencing climate change, and need to develop strategies to deal with it.

These strategies fall into two main categories: mitigation and adaptation. Mitigation is reducing greenhouse gas emissions. According to the United Nations Environment Programme, if we are able to stop emissions from rising in the next five years, and succeed in reducing emissions 48-72% by 2050, we may be able to limit global warming to 2˚C, which will help keep impacts from becoming catastrophic. To date, however, most jurisdictions have been unable or unwilling to substantially reduce emissions.

This increases the urgency of adaptation – actions to reduce the impacts of climate change and, where possible, take advantage of opportunities. Even if we were to stop emissions today, the increase in greenhouse gases in the earth's atmosphere means that some climate changes are inevitable over the next several decades.

This report has been written to describe how climate is changing in the Niagara region, what impacts are occurring or can be expected in the near future, activities that are underway in the region that will help reduce impacts, and gaps that need to be addressed in order to develop and implement adaptation strategies. It also provides an Appendix with selected case studies of adaptation in other parts of Ontario, which might provide ideas and inspire action in Niagara.

Although the focus of this document is on climate change adaptation, it is not meant to diminish the critical importance of reducing emissions. If we are unable to dramatically reduce emissions impacts will become more and more severe and adaptation will become very difficult. Mitigation and adaptation are both essential.

1. CLIMATE CHANGE BASICS

GREENHOUSE GAS EMISSIONS ARE RISING AND DRIVING CHANGES TO OUR WEATHER

1.1 GREENHOUSE GASES AND CLIMATE CHANGE

Greenhouse gases are produced by many natural processes and are essential to life on earth. They absorb and trap in the atmosphere some of the infrared radiation produced by solar rays that reach the earth's surface. This helps warm the planet.

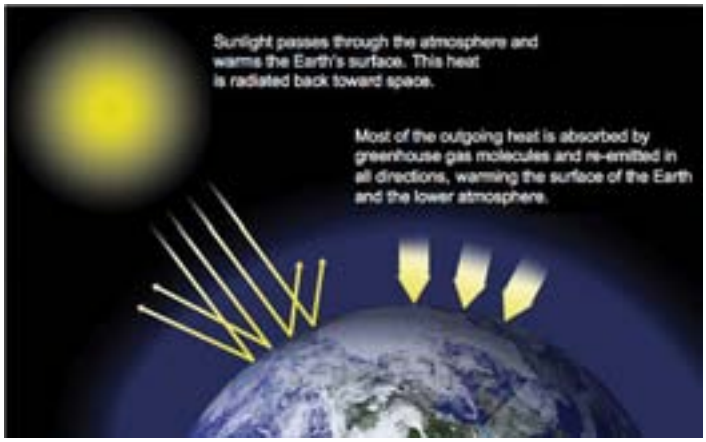


Figure 1: The Greenhouse Effect: NASA, 2011

However, human activity is rapidly changing the concentration of greenhouse gases in the atmosphere.

Carbon dioxide, methane and nitrous oxide are the main greenhouse gases produced by human activities. Large amounts of these gases are released by:

- Extraction and burning of fossil fuels – coal , oil, and natural gas
- Deforestation, which releases carbon stored in trees and soils
- Producing lime to make cement
- Livestock operations and wetland rice cultivation
- Landfills and treatment of garbage and sewage
- Manufacture and application of fertilizers
- Use of fluorocarbons and sulphur hexafluoride.

Since the early days of the Industrial Revolution carbon dioxide (CO_2) levels in the atmosphere have increased by about 39% according to the World Meteorological Organization. The Intergovernmental Panel on Climate Change estimates that greenhouse gas levels are now higher than they have been anytime in the last 650,000 years.

Despite international commitments to reduce greenhouse gas emissions, they continue to climb. The International Energy Agency recently reported that 2010 CO_2 emissions were 5% higher than in 2008, the highest in history.

1.2 GLOBAL CLIMATE CHANGE

Increases of greenhouse gases in the atmosphere bring about a host of climate changes. The most obvious effect is global warming. According to a recent report by the US National Oceanic and Atmospheric Administration global land surface temperatures have risen by 0.84˚C in the last century. 2001-2010 was the hottest decade since weather records began, and 2010 is tied with 2005 as the hottest year. 2011 was the ninth hottest year, despite it being a La Niña year, which tends to be cooler. If emissions continue to increase, global temperatures may rise 4-7˚C in the next century.

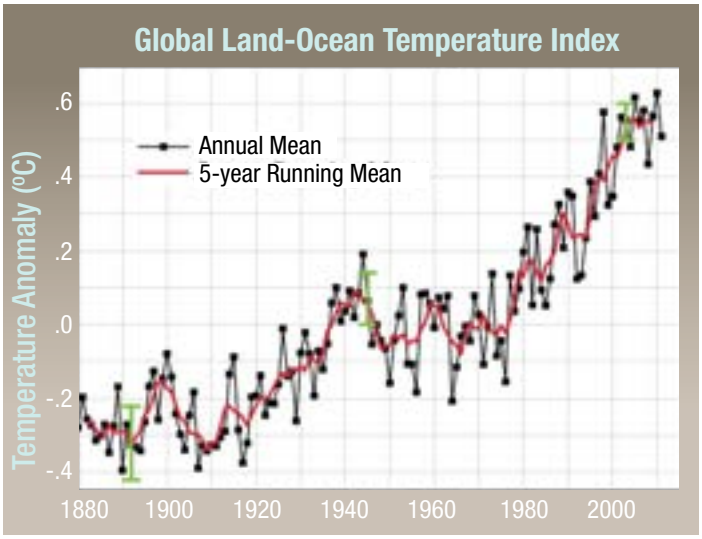


Figure 2: Global Temperature Increase 1880-2010: NASA, 2011

The significance of this temperature change cannot be overstated. Global temperatures in the last ice age were approximately 5˚C cooler than they are now. During that time, Canada was covered with an ice sheet approximately 1 mile thick. It is not easy to imagine the difference that the same degree of warming could mean for Canada or the planet as a whole, especially if it takes place over a century or less.

In Canada, average temperatures have already increased by 1.3˚C and in the North much more. This is can be seen in Figure 3, which shows mean temperatures in different regions of Canada for June, July and August of 2011, compared to the average of summer temperatures from 1971 to 2000.

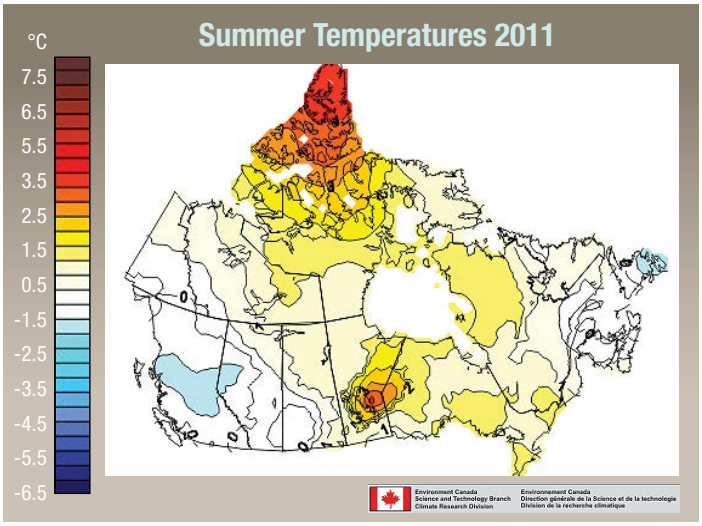


Figure 3: Summer Temperatures in 2011 Compared to 1971-2000: Environment Canada, 2011

Warmer average temperatures are not the only effect of higher concentrations of greenhouse gases. If that were the case, then we would not be so worried. But a warmer atmosphere causes many other significant changes:

- More hot days and heat waves
- Shorter winters, earlier spring, longer summers and later fall
- Increased freeze-thaw cycles and freezing rain in some regions
- Changes in precipitation patterns
- Increases in the variability and unpredictability of weather
- Increases in the frequency and/or intensity of extreme weather events such as heavy rainfall, thunderstorms and cyclonic storms
- Increased evaporation from lakes and streams
- Sea level rise and strong storm surges in coastal areas
- Shrinking of polar ice and most glaciers.

While some of these changes may provide new opportunities for some regions or sectors, they create serious risks for many more.

2. CLIMATE TRENDS AND PROJECTIONS FOR NIAGARA

CLIMATE CHANGES ARE ALREADY FELT IN NIAGARA AND WILL INTENSIFY IN THE FUTURE

This section of the report is focused on climate changes that are underway or are projected for the Niagara region. It is important to keep a watch on trends in other regions as well, especially the larger Great Lakes area, southern and southwestern Ontario as a whole, and the northern U.S. Where specific information is not available on trends and projections in Niagara, this report includes data from these regions.

2.1 WARMER TEMPERATURES, MORE HOT DAYS AND HEAT WAVES

Temperatures in the Niagara Region have increased by about 1.3˚C in the last 40 years, according to Environment Canada weather records at the Vineland weather station analyzed in Niagara Region's Changing Climate: Preliminary Results (Fenech & Shaw, 2010). Temperatures have increased more in the winter than in the summer.

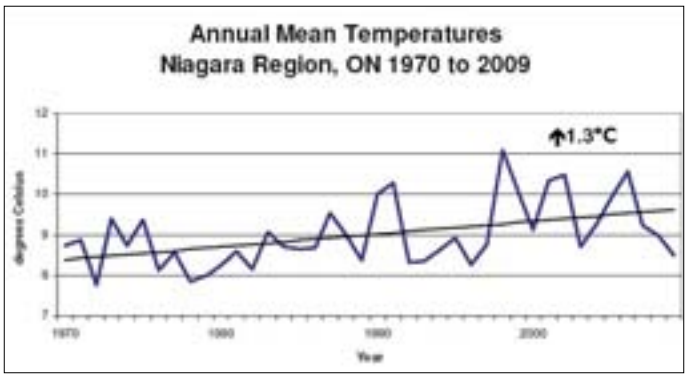


Figure 4: Temperature Trend in Niagara: Fenech and Shaw, 2010

Extreme hot days – where temperatures rise above 30˚C – are also on the increase. From 1971 to 2009 Niagara experienced an average of 8 hot days per year. However, there were 26 hot days in 1998, 39 in 2002, 37 in 2005 and 16 in 2007, reflecting an overall increase. In July 2011 temperatures in Grimsby reached 38.5˚C, during a heat wave that lasted more than a week.

Heat waves – 3 days or more with temperatures above 32˚C – are on the upswing according to a recent analysis by the consulting group AMEC for the City of Welland. During the most recent 10-year period, 5 heat waves hit the area.

Temperatures will continue to climb in the coming decades. Figure 5 shows the temperature change projected for Ontario in the 2050's as a result of high greenhouse gas emissions. Temperature is expected to increase by almost 3.0˚C from the 1961-90 average as a result of climate change, as the graph shows.

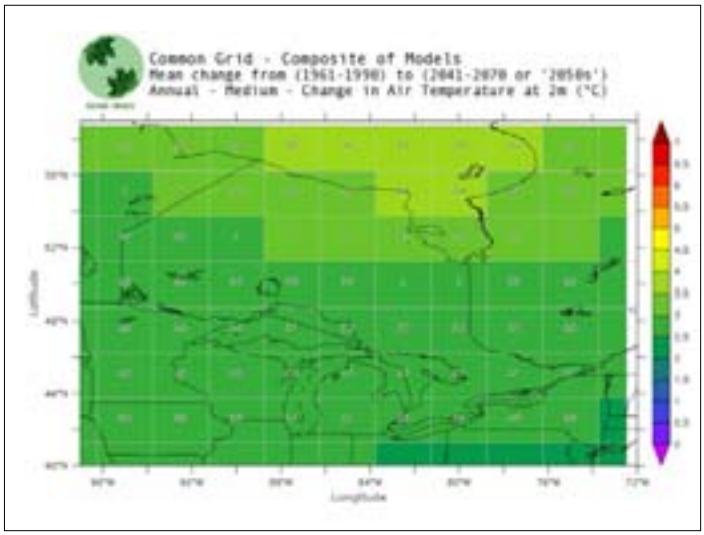


Figure 5: Temperature Increase in Southern Ontario in the 2050's: Canadian Climate Scenarios Network, 2011

2.2 SEASONAL SHIFTS

Over much of Earth's northern hemisphere, spring is coming earlier and winter is arriving later. Changes have been seen in satellite photos; leafing, flowering and fruiting records; bird migrations; length of the growing season; frost-free days and other indicators. These changes are most pronounced in

western Canada, but are also seen in the east.

In his recent presentation Climate Change in the Niagara Wine Region (2010), Brock University professor Tony Shaw reported that frost-free days in the Niagara region have increased by 10 days on average since 1970. Growing Degree Days – the number of days with temperatures at which plants can develop and mature – have also increased in this time period. May and September have both become significantly warmer, which allows many plants to mature sooner and some that require a longer growing season to reach maturity.

During 1971-2000, the St. Catharine's Power Glen weather station reported an average of 223 frost-free days. In Climate Change and the Niagara Region, What will it be like in the 2050's (2010), Environment Canada's Brad May reported that freeze-free days could increase by about 30 days in the 2050's, and 50 days in the 2080's. Similarly, Growing Degree Days are expected to increase substantially.

2.3 FEWER COLD DAYS AND COLD WAVES

With average temperatures rising, especially in winter, the current trend in the Niagara Region is for fewer cold days and especially extreme cold days with maximum temperature under -15˚C. However this situation is quite variable, as can be seen in the graph below.

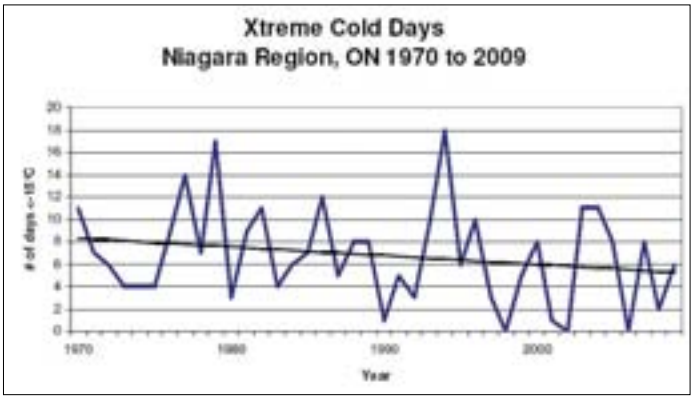


Figure 6: Cold Days Trend in Niagara: Fenech and Shaw, 2010

Scientists expect that the number of extreme cold days and "cold waves" will continue to decline as the climate warms, but periods of cold weather will still occur, especially when La Niña weather systems bring in cooler temperatures from the central and eastern Pacific.

2.4 FREEZE-THAW CYCLES

Freeze-thaw cycles occur when daily temperatures fluctuate above and below freezing (0˚C). Freeze-thaw cycles appear to be on the increase in much of Canada. As AMEC shows in Figure 7, freeze-thaw days in Welland increased substantially between 1970 and 2010, though the number of freeze-thaw cycles varies substantially from year to year.

Over the longer term, freeze-thaw cycles are likely to peak and then decline in Niagara and other parts of southern Ontario as warming continues.

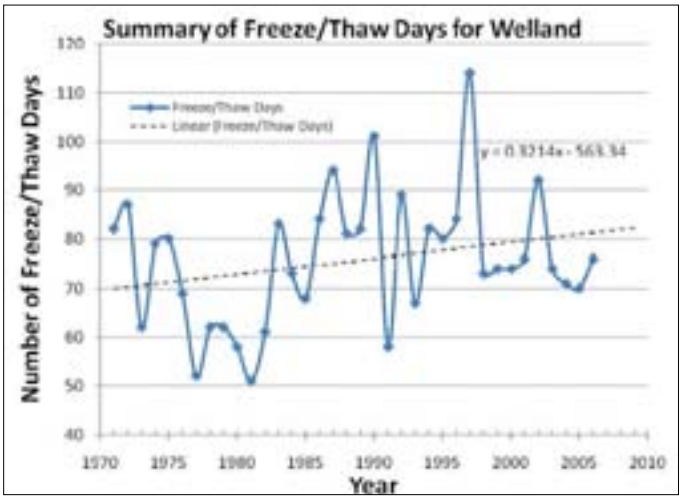


Figure 7: Freeze-Thaw Trend in Welland: AMEC, 2011

2.5 ANNUAL AND SEASONAL CHANGES IN RAIN AND SNOWFALL

Changes in rain and snowfall in Niagara over the last 40 years are not as marked as those for temperature. Annual precipitation has increased about 2% in the last 40 years, especially in winter, and in recent years appears to be slightly more variable than previously. Precipitation is occurring slightly more frequently in all seasons except the fall.

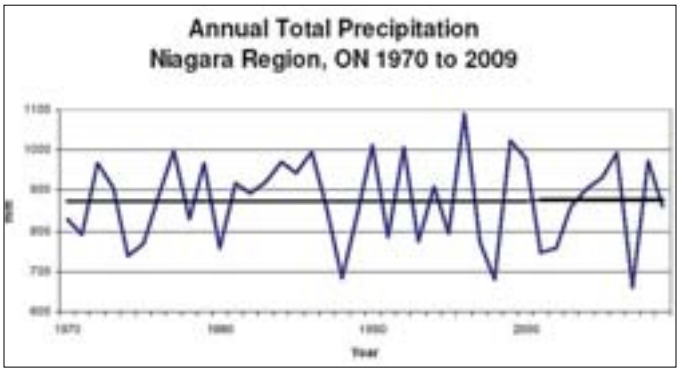


Figure 8: Precipitation in Niagara: Fenech and Shaw, 2010

Total annual precipitation is expected to continue increasing under climate change, but more of this rain is likely to fall in winter. Summers are expected to become drier.

Winter precipitation in Niagara has increased by approximately 44 mm on average in the last 40 years. However, this precipitation is falling more as rain than snow due to warmer winter temperatures. An analysis by Hamilton and Whitelaw of Climate Change Trends along the Niagara Escarpment (2001) determined that snowfall in Welland declined by 20% from 1950 to 1999. This trend may continue under climate change, although snow will continue to fall when temperatures are low enough.

Although snowfall overall will decline, Niagara communities, especially on the Lake Erie shoreline, are very likely to see more lake-effect snow storms due to warmer lake water temperatures and reduced ice cover. Snow will stay on the ground for shorter periods, however, due to warmer winter temperatures.

2.6 DROUGHTS AND DRY SPELLS

Droughts depend on a combination of factors including levels of precipitation, air temperatures and soil moisture. Niagara and southern Ontario are not drought-prone, especially when compared to the Prairies and the interior of BC. However, the region has had several droughts and dry spells in recent years, as discussed in Historical Drought-Related Events by David Phillips of Environment Canada (2011). Significant droughts occurred in southern Ontario in 1997-99, 2001, 2002, 2005 and 2007, though Phillips reported that conditions were good for tender fruit and grape production in Niagara in 2007. The summer of 2011 was also very dry, after a wet spring.

Eva Mekis and Lucie Vincent from the Meteorological Service of Canada have studied Changes in Daily and Extreme Temperature and Precipitation for the last 100 years, measured by more than 400 weather stations across the country. Their results show no significant trend in summer precipitation in Niagara over that time period, although days with a trace of rain have increased.

This situation is likely to change in the future. In Climate Change Scenario for Ontario (2010), which provided regional projections for Ontario, the Ouranos Consortium projected a 20% decrease in summer rainfall by the 2050's for the Niagara region. Scientists at the University of Quebec at Montreal and Environment Canada also concluded that the number of dry days and dry spells would increase in the 2050's and 2080's in most of southern Canada in their study Dry Spell Characteristics over Canada in a Changing Climate (2010).

2.7 FREEZING RAIN AND ICE STORMS

Freezing rain falls as a liquid but freezes on contact with roads and sidewalks, power lines and trees. Although there is no specific data for the Niagara region, Southwestern Ontario experiences an estimated 15 hours of freezing rain a year. Freezing rain is one of the most damaging and costly weather events that occur in Canada.

After an Ice Storm on the Niagara Parkway: H. Chris MacNaughton, 1983

In Possible Impacts of Climate Change on Freezing Rain (2007), Environment Canada scientist Chad Cheng and colleagues predict that freezing rain will increase about 40% in the months of December, January and February in southern Canada over the next 40 years. These scientists expect that there will be more long-duration freezing rain events (6 hours or more) in the future, leading to greater accumulations of ice and more damage. By the 2050's, however, freezing rain is expected to decrease in the months of November, March and April.

2.8 HEAVY RAIN EVENTS

Environment Canada's analysis of Heavy Rain Events in Ontario indicates that 17 such events occurred in the Niagara Region between 1979 and 2009, about one every two years. Environment Canada defines a heavy rain event as 50 mm of rain in a 12 hour period.

Two scientists from the Meteorological Service of Canada recently analyzed the Summer Severe-Rainfall Frequency Trend in Ontario from 1979 to 2002, and concluded that these events are on the rise, especially in summers with higher temperatures.

In National Climate Change, the U.S. Global Research Program also reported that very heavy precipitation events have increased by 67% over the last 50 years in the northeast of the U.S., including the state of New York, which borders the Niagara region.

Virtually all climate scientists expect heavy rainfall events to continue to increase, especially in regions near large bodies of water because warmer temperatures increase evaporation and allow the atmosphere to hold more water vapour.

In its analysis of 5-day heavy rainfall (5 days with total rainfall greater than 100 mm), AMEC predicted that precipitation increases combined with more frequent rainfall would lead to an upward trend of 5-day rainfall for the region in the future.

2.9 THUNDERSTORMS, LIGHTNING, HAIL AND TORNADOES

Southwestern Ontario and the north shore of Lake Ontario get more thunderstorms each year than other parts of the province. During 1971-2000, Niagara averaged 30 thunderstorms a year, according to Environment Canada. In addition to lightning, these storms often bring heavy rain and high winds, and on occasion hail or tornadoes. During thunderstorms, winds may gust to 140 kilometres per hour or more.

Lake Erie Thunderstorm: Jim Thibert, 2012

It is difficult to identify recent trends in these events, partly because they are so localized. Government weather stations that monitor and report on storms are relatively far apart so many incidents are not recorded.

Thunderstorms occur when an air mass is unstable, and air near the ground is warm and humid but cold and dry further up. Vertical wind movement (created by a weather front, for example) can cause pockets of the warm, humid air to rise and cool, forming towering clouds, ice crystals, snow and sometimes hail.

As climate changes, the conditions that give rise to thunderstorms are expected to increase in the Great Lakes and some other regions, according to the report Changes in Severe Thunderstorm Environment Frequency (2007) by scientists at Purdue University's Climate and Extreme Weather Initiative. This could result in increases in thunderstorms, lightning strikes, high winds, hailstorms and tornadoes in the region.

2.10 WATER LEVELS

Water levels in the Great Lakes have fluctuated as much as 2 metres in the last century. Water levels fluctuate seasonally, with levels lowest in the late fall and early winter, and highest in summer. However, water levels can also fluctuate over several years, depending on patterns of precipitation, runoff, inflow from rivers and streams, air temperature, ice cover and evaporation.

According to Water Levels of the Great Lakes, by the Great Lakes Environmental Research Laboratory, water levels have generally been in decline since 1986. Water levels in Lakes Superior, Huron and Erie dropped sharply in 1997-1999, increased slightly in 2008 and 2009, and then dropped again. (Water levels in Lake Ontario are tightly regulated by dams on the St. Lawrence, and as a result water levels do not fluctuate as much.)

Climate change models project changes in precipitation and temperature that are expected to affect lake levels. While overall increases in annual precipitation will tend to raise water levels, higher temperature and declining ice cover will increase evaporation from the lakes. Most reports indicate that increased evaporation is likely to exceed precipitation, and that lake levels will continue to decline.

Just how much lake levels will decline is not certain. Environment Canada scientists David Fay and Yin Fan analyzed 4 different climate models for projected changes that would affect water levels, and calculated that Lake Ontario water levels could decrease 5-25% or 0.08-0.47 metres by the 2050's.

Lake Erie levels could drop by 5-26% or 0.15-0.81 metres. Water levels in the connecting channels would also be lower. Because of its flat topography, lower Lake Erie water levels could cause the shoreline to move lakeward by hundreds of metres.

Summary

Climate is already changing in the Niagara Region, in ways that are projected to increase in the future. These changes include:

- Higher average temperatures and more hot days
- An increase in frost-free days and longer growing season
- Fewer cold days, but more freeze-thaw cycles
- A likely increase in freezing rain in the next few decades
- A slight increase in annual and winter precipitation and decrease in snowfall
- More dry spells, especially in summer
- An increase in heavy rainfall events
- More thunderstorms, lightning and high winds
- Potentially more tornadoes
- Lower water levels in Lakes Erie and Ontario.

These changes will result in a number of impacts that the region needs to consider and plan for. Likely impacts are discussed in the next section of this report.

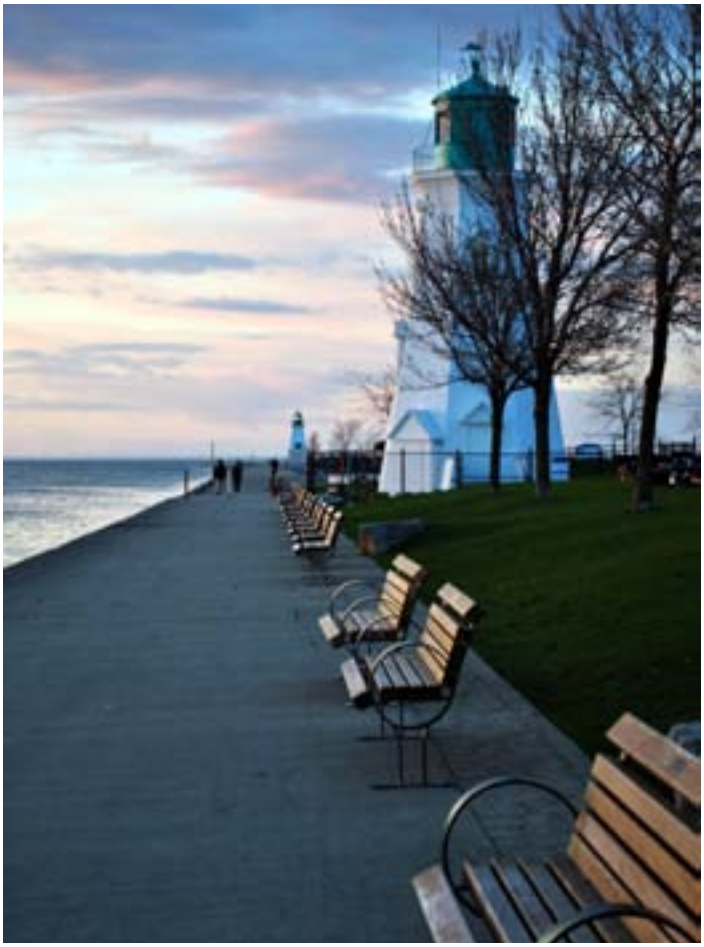
3. LIKELY IMPACTS OF CLIMATE CHANGE IN NIAGARA

CLIMATE CHANGE WILL AFFECT ALMOST ALL SECTORS AND SERVICES IN THE REGION

Weather and climate affect almost all aspects of our lives. Climate change alters:

- The range of weather we experience day-to-day and year-to-year
- The frequency and intensity of different kinds of storms
- Levels of water in our lakes, streams and underground aquifers
- The habitat, health and reproductive capacity of plants and animals
- Many other aspects of our environment and our lives.

This section of the report will explore how the climate changes that are underway are likely to affect different sectors and services in the Niagara region.



A Year of Extreme Weather

2011 has been a year of extremes for the Niagara Region according to David Phillips, a senior climatologist from Environment Canada. In the early winter months of 2011, Brock University experienced 160 cm of snow, 30% more than usual. After April, every month of 2011 was warmer than normal. The region experienced the wettest spring on record, followed by drought from late June to August, an extended heatwave in July, tornado warnings and several intense lightning storms. July was the warmest month recorded in Niagara thus far. December was 3.5˚C warmer than usual and very dry. These kinds of weather conditions create challenges for many aspects of life in Niagara.

Niagara has not been alone in experiencing extreme weather. The U.S. National Oceanic and Atmospheric Administration referred to 2011 as “a year for the record books”, citing a record 14 weather disasters in that country, each costing more than $1 billion in damages. The events included a major blizzard, multiple tornadoes, drought and heatwaves, floods, hurricanes and tropical storms and wildfires. More than 500 people were killed in tornadoes.

3.1 AGRICULTURE

In 2010, the Niagara Peninsula had more than 2,200 farms which contributed approximately $2.8 billion to the economy. Agriculture takes up approximately half the land in the region and is strongly connected to other key industries including wine production and tourism. Climate change impacts on agriculture may have consequences not only for the sector itself, but also for the economic health of the region.

Of the different types of farms in Niagara, greenhouses bring in the largest income, with 43% of gross farm receipts, followed by fruit (17.4%), poultry and egg production (14.6%), nursery products and sod (7.3%) and grain and oilseeds (4.7%).

Researchers at the Ontario Ministry of Agriculture and Rural Affairs, Natural Resources Canada, and several universities have been investigating how climate change is likely to affect agriculture in Canada, and have produced a number of studies that are relevant to Niagara. Researchers at Brock University have been looking at ways in which grape and wine production in the region will be affected by climate change. Table 1 summarizes some of this research.

Although there are likely to be both positive and negative effects of climate change on agriculture in Niagara, the negative impacts are likely to outweigh the positive. Some responses to these impacts are described in Section 4 of this report.

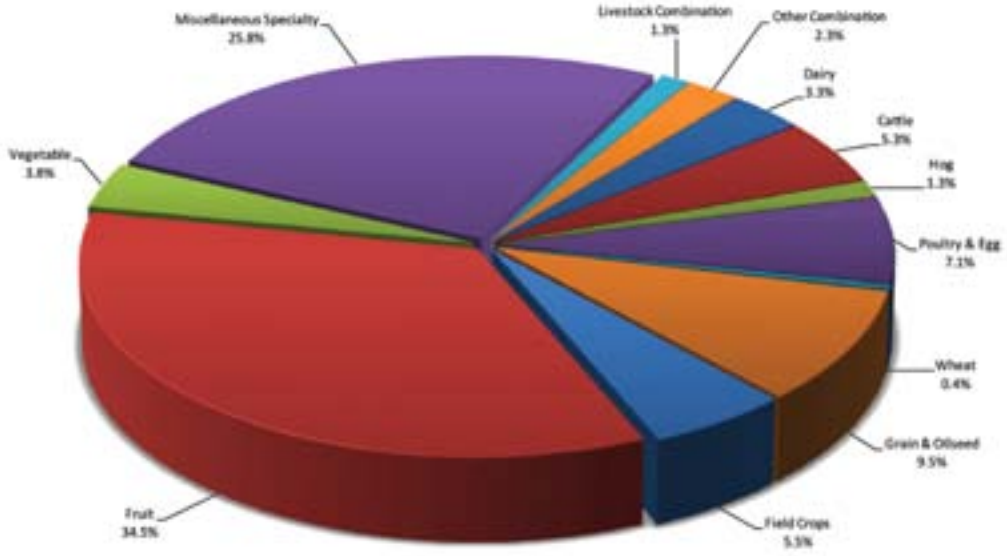


Figure 9: Percentage of Farms by Farm Type, 2006: Regional Economic Impact Study, 2010

TABLE 1: SUMMARY OF CLIMATE CHANGE IMPACTS AND OPPORTUNITIES FOR AGRICULTURE IN NIAGARA

CLIMATE-RELATED CHANGES	IMPACTS AND OPPORTUNITIES
Increased CO2 levels	**Positive Impacts and Opportunities** • Carbon dioxide "fertilization effect" helps plants grow faster and can increase productivity in many crops, given good temperature, water, light and root space conditions • Higher levels of CO_2 can also reduce water vapour loss and water use by plants **Negative Impacts and Risks** • Increased levels of carbon dioxide may decrease the protein content of many plant species including wheat and clover
Longer growing season	**Positive Impacts and Opportunities** • Longer and warmer growing season improves conditions for field production of "hot crops" such as tomatoes, peppers and melons, and allows for diversification into new crops that require more warmth and time to mature • Better conditions for warm climate grape varietals such as Merlot, Syrah, Cabernet Franc and Cabernet Sauvignon
Hot spells and heat waves	**Negative Impacts and Risks** • Hot days reduce photosynthesis and create moisture stress in grapes and other crops • Extremely high temperatures can decrease yields in annual field crops such as wheat and damage tree fruit such as apples • Heat stress in animals reduces appetite and weight gain, and adversely affects milk production • Heat waves can produce large numbers of poultry deaths
Freezing rain and freeze-thaw events	**Negative Impacts and Risks** • Freezing rain coats tree limbs, making them brittle and vulnerable to breaking • Mild winters and warm springs can induce early plant development and flowering, making plants more vulnerable when freezing conditions occur
Changes in precipitation patterns, especially decreased summer precipitation	**Positive Impacts and Opportunities** • Drier summer conditions will reduce the incidence of plant diseases that proliferate in humid weather **Negative Impacts and Risks** • Precipitation in winter will fall increasingly as rain, decreasing the insulation of soils by snow, and increasing run-off and soil erosion • Increased summer demand for water to irrigate tender fruit and grapes and competition for other water uses in the region • Reduced water availability and reduced yields for field crops such as grains and pulses

CLIMATE-RELATED CHANGES	IMPACTS AND OPPORTUNITIES
Warmer average temperatures in winter and other seasons	**Positive Impacts and Opportunities** • Warmer winters reduce cold stress for fruit trees • Warmer winters lower feed requirements, increase survival of young animals, and reduce energy costs for livestock producers **Negative Impacts and Risks** • Shorter growing season for cool-weather crops such as lettuce, spinach, potatoes or broccoli • Delayed and reduced season for ice wine production and crop losses due to delayed harvests • Reduced productivity and quality of "cool" grape varietals such as Riesling, Sauvignon Blanc and Pinot Noir • Warmer temperatures shorten the grain-filling period of some grains and may decrease yields • Increased cooling requirements and energy costs for greenhouse operations in summer • Warmer fall temperatures can decrease fall "hardening" of fruit trees and reduce cold hardiness over winter • Increase of weed species such as the extremely invasive kudzu vine, which recently appeared in southwestern Ontario and carries the soybean rust fungal disease • Expansion in agricultural crop pests such as corn ear-worms and bean leaf-beetles, which are more likely to survive winter and reproduce earlier and more often during the growing season • Increase in the overwinter survival rate of fungi, viruses, and bacteria that cause plant disease, increasing the severity and number of plant diseases • Reduced efficacy of some pesticides (such as pyrethroids) and an increase in pest species may result in higher rates of pesticide use • Higher rates of evaporation for soils and crops, requiring increased irrigation • Altered migration patterns of wild bird populations may transmit new strains of diseases (such as influenza) to livestock
Increase in storms and extreme weather	**Negative Impacts and Risks** • Excessive rainfall in the spring can delay spring planting • Flooding as a result of excessive rainfall can reduce oxygen levels in the soil, cause root rot, and increase soil compaction by machinery • Intense rainfall causes soil erosion • Hail, strong winds, and heavy downpours can damage crops and decrease yields • Severe weather events can damage buildings such as greenhouses and livestock barns • Storms may cause power outages that can jeopardize daily operations, revenues, and animal health

Impacts of Climate Change on Niagara Grape and Wine Production

All crops need favourable climates, but wine grapes are especially vulnerable to temperature and other extremes. Niagara is uniquely situated for grape and tender fruit production because of its location between two Great Lakes, which moderates temperatures and reduces winter injury. The majority of grapes currently grown in the region are cool-climate varietals, which are well adapted to historic temperatures. These include Riesling, Chardonnay, Sauvignon Blanc, Gewürztraminer, Gamay Noir, Pinot Noir and Cabernet Franc. More intense, aromatic wines are produced in moderate climates. Niagara is also uniquely positioned for the production of ice wine, and is the largest producer and exporter of ice wines in the world.

Grape and wine production is an important sector of the regional economy. Niagara is home to approximately 90 wineries, and almost 400 grape growers. A recent KPMG study estimated that Ontario's VQA wine industry contributed $191 M to the economy and $10 M to tourism receipts in 2010, and created an additional 1300 jobs between 2007 and 2011.

Climate change is expected to have positive and negative impacts on the industry. On the plus side, the increase in minimum winter temperatures and frost-free days is allowing the cultivation of popular warmer-climate varieties such as Merlot, Syrah/Shiraz, Cabernet Sauvignon and Viognier that are more vulnerable to winter cold and spring frosts and require a longer growing season to mature. In the longer term, Niagara could also benefit from reduced competition with hotter regions. For instance, Stanford scientists predict that rising temperatures could shrink northern California's prime vineyards by half in the next 30 years. (Temperatures above 30˚C halt photosynthesis and contribute to moisture stress in the vine.)

On the minus side, a number of features of climate change present growing challenges for grape growers and wine producers in the region. For example, climate change appears to be bringing greater weather volatility according to Dr. Tony Shaw at Brock University. Although winters are becoming warmer, an increase in freeze-thaw cycles can damage rootstock.

More extreme weather events including intense precipitation, high winds or hail can also damage the vines and fruit. Warmer winters contribute to the expanding range of insect pests, such as the multi-coloured Asian lady beetle, which worked its way up to Niagara from the southern US in 2001. The beetle taints wine if it is crushed with the fruit.

Hotter and dryer summers are likely to require increased irrigation in vineyards.

Much more may be known soon about the impacts of climate change on Niagara grapes and wine production. The province has provided $2.86 million to researchers at Brock University's Cool Climate Oenology and Viticulture Institute to study ways in which climate change impacts the industry.

3.2 ECOSYSTEMS

The Niagara region is home to many unique ecosystems where living things interact with each other and with the physical and human environment in complex life cycles. Niagara is part of the Carolinian ecosystem, which extends all along the north shore of Lake Erie and around the western edge of Lake Ontario. This region is less than 1% of the land area of Canada, but hosts more plant and animal species than any other Canadian ecosystem. A number of smaller ecosystems are found within the Carolinian system in Niagara:

- Carolinian woodlands with an estimated 2200 species of trees, shrubs and flowering plants, birds, mammals, reptiles and amphibians, many of which are rare in other parts of Canada
- Slopes and cliffs on the Niagara escarpment with its communities of ferns and orchids, mosses and lichens, and tiny Eastern white cedar trees
- Niagara's many creek and river ecosystems which are home to fish and shellfish, worms and leeches, insects, and aquatic and shoreline plants
- Lake Ontario and Lake Erie ecosystems, including shoreline ecosystems and habitat, with many species of fish, molluscs, insects, waterfowl and other birds
- Wetlands including swamps, marshes, and bogs, each with unique communities of sedges, rushes, reeds, cattails and pondweeds, fish, amphibians, turtles, snakes and birds.

Carolinian Woodland: Jane Bowles

Most Canadians appreciate and value nature for itself. However, our ecosystems also provide many important goods and services that contribute to our well-being. These include: storm protection; storage and retention of water; flood control; erosion control and sediment retention; cycling of nutrients such as nitrogen; absorption and breakdown of wastes and pollutants; pollination; ornamental plants; recreational activities; tourism; and beauty among other contributions.

Climate is a key factor in the functioning of all ecosystems, affecting the availability of food, water, shelter, and reproduction. Some species can tolerate a fairly wide range of climatic conditions, or are mobile enough to move to new areas as their environment changes. But a number of niche species have quite specific habitat requirements, and are at greater risk for decline or extinction as climate changes. (*See The Known and Potential Effects of Climate Change on Biodiversity in Ontario's Terrestrial Ecosystems.*)

Climate change creates additional pressure on ecosystems that are already stressed and have been fragmented or impoverished by deforestation, expanding roads and suburbs, diversion or drainage of water, pollution, invasive species and other challenges.

Some of the climate change impacts that have already been seen or are predicted for Niagara's ecosystems include:

- Increased insect and disease outbreaks in trees and other vegetation, as warmer winters and longer growing seasons allow pests to survive the winter and to reproduce more rapidly (*See Threats and Impacts of Exotic Pests under Climate Change*.) The Emerald Ash Borer is one such pest, currently threatening an estimated 500 million ash trees in the Niagara Peninsula according to Paul Robertson of the Niagara Woodlot Association.

Emerald Ash Borer: David Cappaert, Michigan State University

- Increased stress for trees and woodlands due to summer heat and reduced rainfall, potentially making them more vulnerable to fire (*See Ontario's Forests and Forestry in a Changing Climate*.)
- Increase in some undesirable plant species, such as poison ivy, which appears to thrive at higher levels of atmospheric CO_2
- Decline in wetlands due to lower water levels, with impacts on wetland plants, marsh-nesting birds, and fish that spawn or live lifelong in vegetated wetland environments. (*See Great Lakes Coastal Wetlands Communities: Vulnerabilities to Climate Change*.) Amphibians such as frogs, toads and salamanders – already at risk in the Niagara region – are particularly vulnerable.
- Threats to fish from higher water temperatures; declining water levels in rivers and lakes; reduced or intermittent flows in some rivers; reduced levels of dissolved oxygen in summer; and increased nutrients and siltation from storms. Species that appear to be most vulnerable include:
  - ◊ Cold-water species such as lake trout, steelhead (rainbow trout), salmon and smelt
  - ◊ Some cool-water species such as musky (muskellunge), yellow perch, northern pike and black crappie
  - ◊ Warm-water species already at risk in the Great Lakes, including the pugnose minnow, warmouth (a type of sunfish), lake chubsucker, and others that depend on abundant aquatic plant cover
- Expansion of some aquatic species, including:
  - ◊ Warm-water fish such as smallmouth bass
  - ◊ A number of invasive aquatic species such as the sea lamprey, round goby, carp and zebra mussels
- More outbreaks of Type E botulism, which since the late 1990's has caused mass die-offs of mudpuppy salamanders on the shores of Lake Erie, as well as thousands of fish-eating birds including gulls, terns, diving ducks, mergansers, grebes and loons that wash up on the shores of Lakes Erie and Ontario (S*ee Type E Botulism in Birds*.) Type E botulism is linked to the presence of zebra mussels and round gobies as well as climate–related factors such as warm water temperatures, low water levels and low levels of dissolved oxygen.
- More outbreaks of toxic blue-green algae blooms as a result of warmer water temperatures, stagnant and drought conditions, and phosphorus from agricultural run-off and sewage treatment plants washed into water bodies during intense rainfalls events (*See Lake Erie Nutrient Loading and Harmful Algal Blooms*.)

Urban ecosystems also deserve some attention. Urban ecosystems in Niagara and elsewhere are managed landscapes, with fewer and different trees, plants and animals than are found in natural settings. In many private and public gardens trees and plants, birds and butterflies

Birds Killed by Type E Botulism: Benjamin Ricetto, The Canadian Press, 2011

are carefully nurtured. More and more of these gardens are naturalized, with plants selected from species native to the local area. Trees, shrubs, flowering plants and groundcovers, birds, squirrels and beneficial insects are desirable features of urban landscapes. Among other benefits, trees and other vegetation can help reduce the impacts of climate change by cooling nearby areas and absorbing rainwater to prevent excessive runoff, flooding and pollution of our waterways and drinking water.

Nevertheless, plants and trees found in urban settings are surrounded by asphalt and concrete and are often very stressed by foot and automobile traffic, road salts, compacted and degraded soils, limited space for root growth, inadequate light, and the urban heat island effect. Hotter weather, intense rainfall events and windstorms will increase the stress on urban ecosystems. Insect pests that more easily survive warmer winters are likely to proliferate and damage trees and other plants.

3.3 INFRASTRUCTURE

Public infrastructure provides a wide range of essential services to the people of Niagara, including: water supply; sewage treatment and stormwater management; road transportation, canals and shipping; and energy generation and distribution. Weather – and climate change – affects all these forms of infrastructure.

3.3.1 Water Supply

More than 80% of Niagara's population is supplied with water drawn by six treatment plants from Lake Ontario, Lake Erie, the Welland Canal and the Niagara River. Though lower lake levels are expected due to higher temperatures and increased evaporation, and water demand is likely to increase, water should remain plentiful for areas serviced by these treatment plants.

However, lower water levels and higher water temperatures are expected to have impacts on water quality. The Ontario Ministry of Environment and Conservation Ontario recently assessed the vulnerability of 31 watersheds in Southern Ontario to climate change and gave three of Niagara's watersheds a "high sensitivity" rating, meaning that these watersheds are highly vulnerable to climate change. (*See Climate Change Monitoring Review Project*.)

The quality of source water in the region is already problematic. According to a recent assessment of the *Niagara Peninsula Source (Water) Protection Areas*, 70% of Niagara's 69 surface water quality stations have poor or impaired water quality, 25% have marginal or fair water quality, and only 5% have good or unimpaired water quality. The main causes of impairment are phosphorus; E. coli bacteria; sediment and chloride from agricultural runoff; septic systems; manure storage and urban stormwater.

This situation is likely to be worsened by climate change. Lower water levels are likely to increase the concentration of chemical contaminants. Higher temperatures contribute to blue-green algal blooms, which affect the taste and odour of drinking water in summer. Increased runoff and combined sewage system overflows from intense rainfall will also carry more contaminants and infectious organisms into the water bodies that provide Niagara with most of its water supply. All these changes will increase the challenge and cost of water treatment in the region. (*See Climate Change and Water Quality in the Great Lakes Basin*.)

Algae and sediment in Lake Erie: NASA Earth Observatory, March 2012

More than 75,000 people in rural Niagara areas get their water from a mix of private wells and cisterns. The Niagara Peninsula Source Water assessment determined that groundwater supply is adequate to meet current demand in most of the region's watershed protection areas. However, the Lake Erie North Shore area has significant groundwater stress and the Fort Erie Creeks and Fifteen, Sixteen and Eighteen Mile Creek watersheds have moderate groundwater stress levels.

Water is replenished in these aquifers by rain filtering through the soils and cracks in bedrock. As climate change progresses, drier summers and more frequent droughts will occur, reducing groundwater recharge, especially in shallower aquifers. More precipitation will come in intense rainfall, which causes water to run off into streams and other watercourses, rather than filter back through the ground. This is likely to increase the stress on groundwater supplies that are already moderately or significantly stressed, and may increase stress on aquifers which are currently in good shape. Some rural residents may experience shortages, and may have to deepen their wells.

Climate change may also affect the quality of groundwater. This is already a major issue in the Wainfleet Lakeshore area, where a boil-water advisory has been in effect since April 2006. Dangerous levels of bacteria and nitrates, mainly from septic systems, have contaminated water in more than half of tested private and communal wells. Thin soils and fractured bedrock make this area particularly susceptible to contamination, especially if heavy rains saturate the septic leach fields, causing a flow of contaminated water into groundwater and likely into Lake Erie as well.

3.3.2 Stormwater Management

Natural areas with trees and other vegetation absorb most rainfall or melting snow, allowing it to gradually infiltrate soils and recharge the water table below. As towns and cities grow, buildings, roads, sidewalks, driveways and parking lots proliferate. Much of the rain and snow that falls on these impermeable surfaces runs off into a stormwater system that dumps it into a nearby stream or lake. This water is usually contaminated with pollutants from road surfaces, animal feces, chemicals used in lawns and gardens and other substances. In hard rains or rapid snowmelt situations, stormwater in combined sewer systems will often overwhelm the system and carry a mix of stormwater and raw sewage into the receiving waters.

Prolonged or intense rainfall can overwhelm sewer systems and back up sewage into basements, especially in low-lying areas. This occurs more frequently in combined sewer-stormwater systems, but can also occur in separated systems as water enters sewer pipes through cracks and breaks and maintenance holes. Several Niagara neighbourhoods have experienced repeated basement floods due to intense rainfall.

Flooded Basement: Institute for Catastrophic Loss Reduction

Of course intense rainfall or rain-on-snow events can also overwhelm the capacity of soils, water courses and stormwater systems and cause overland floods from swollen rivers, creeks or ponds. A growing number of Ontario towns and cities have experienced costly floods in the last decade.

Most of Niagara's municipal governments have been working on improvements to stormwater systems to reduce basement and overland floods and releases of contaminated stormwater and sewage to the area's rivers, streams and lakes. This work will become more urgent and challenging with the more frequent intense rainfall and rain-on-snow events expected as a result of climate change.

3.3.3 Electricity Demand, Supply and Distribution

Climate change has several impacts on energy systems. First, it shifts seasonal demand for energy. Because winter temperatures are warming, there is less need for energy for heating purposes. This reduces demand for natural gas and home heating oil.

However, as summers get hotter, more and more homeowners and businesses are installing and using air conditioning systems, which in turn increases demand for electricity. Hot days and nights create peak loads that are hard for electricity generating plants and transmission systems to supply. Although Ontario has made changes to strengthen the grid since the August 2003 blackout that paralyzed almost all of Ontario and the US Northeast, peak demand on very hot days still poses the potential for brownouts and blackouts.

Another impact of hot weather is that peak demand in Ontario is typically met by importing electricity from coal-fired generating stations in the Ohio Valley, which increases air pollution and smog carried into southern Ontario on the prevailing winds from the southwest.

Climate change will also affect the generation of electricity. While water levels will continue to fluctuate from season to season and year to year, it is expected that increased evaporation due to warmer temperatures will lead to lower levels in the Great Lakes and connecting channels. *From Impacts to Adaptation: Canada in a Changing Climate* reports that flows on the Niagara River have already decreased by an average of 7% between 1970 and 2000. Lower water levels in Lake Erie and the Niagara and Welland Rivers will reduce flows to the Adam Beck power stations and other generating stations, affecting their output.

And finally, the increase in the frequency and intensity of extreme weather will affect the transmission and distribution of electricity. High winds during thunderstorms, heavy snow and ice storms often bring down tree limbs or even uproot whole trees, some of which fall on electrical lines, shutting down services to the surrounding area for a few hours or even days.

A storm in the Niagara region on April 28, 2011 demonstrated the potential for this kind of damage. Wind gusts between 90-100 km/h whipped through the area, resulting in power outages and accidents as trees and branches were knocked

to the ground. Power lines were brought down in Niagara Falls, St. Catharines, Grimsby and elsewhere. 30,000 customers were without power in St. Catharines alone.

Aftermath of April 28, 2011 Storm in St. Catharines: Courtesy of Niagara This Week

Another example of how changes in weather patterns can affect power lines occurred in October 13, 2006 when a lake-effect snowstorm hit Fort Erie and Port Colborne. This was the earliest that the two communities had every experienced such a storm. The heavy snow and strong winds snapped tree branches and left more than 155,000 households and offices without electricity. In some areas it took up to five days to restore service.

3.3.4 Buildings

Climate change will have impacts on all kinds of buildings: homes and apartment buildings; office, commercial and industrial buildings; schools; hospitals and nursing homes; police and fire stations; farm buildings including greenhouses; and buildings that house infrastructure services including water and sewage treatment, electricity generation, seaway control and other facilities.

Extreme weather events are likely to create the most dramatic impacts. Some of these have already been seen recently in Niagara and other parts of southern Ontario. They include:

- Basement floods due to intense or prolonged rainfall that overwhelms stormwater systems and backs up sewage drains, damaging floors, walls, appliances, furniture and stored goods, and creating the potential for mould and other problems
- Overland floods from rivers swollen by prolonged rainfall, sudden snowmelt or ice jams (Although major overland floods have not occurred recently in the Niagara region, the last decade has seen such floods in Hamilton, Peterborough, Stratford, London, Kitchener-Waterloo, Toronto, Barrie, Belleville, and other Ontario communities.)
- Thunderstorms such as the April 28, 2011 storm with strong winds that took part of the roof off the Lockview Public School in St. Catharines when the school was in session; the same windstorm damaged a number of other buildings in the region and caused power outages for thousands
- Strong winds along the north shore of Lake Erie in January 2008, which caused 6 metre waves and drove water and chunks of shore ice through some lakeside living room windows
- Tornados such as the one that damaged more than 600 homes and a school in Vaughan in 2009; another that shattered several Leamington greenhouses and badly damaged the Leamington Marina and 12 homes in 2010; and a third that destroyed or damaged heritage buildings, homes and a church in the downtown area of Goderich in 2011.

Extreme weather is not the only way in which climate change is expected to damage buildings. In the report *Weathering of Building Infrastructure and the Changing Climate*, Environment Canada scientists Auld, Klaassen and Comer examined the slower weathering effect of climate change on buildings. Their findings are summarized in Table 2, adapted from their report.

Table 2: Climate Change-Enhanced Weathering Processes and Potential Impacts on Building Infrastructure

WEATHERING PROCESSES LIKELY TO BE ALTERED BY CLIMATE CHANGE	POTENTIAL BUILDING INFRASTRUCTURE IMPACTS
Increased freeze-thaw cycles	• Premature deterioration of concrete, pavement • Roof ice damming • Moisture damage
Higher temperatures, increased chemical reactions More freeze-thaw cycles in cold winter climates	• Increased corrosion (above some thresholds, decreased corrosion rates) • Accelerated deterioration of building facades • Premature weathering • Fractures and spalling
More intense precipitation events Changes in timing of seasonal precipitation, rainfall, length of season for wetting of surfaces	• Increased decay processes (e.g. in wood) • Increased rain penetration (wind-driven rain) and moisture absorption • Decreased durability of materials • Efflorescence and surface leaching • Damaged or flooded structures

The combined effects of these weathering processes will be to reduce the lifecycle of building materials and structures, requiring earlier and costly renovation and restoration measures.

In addition to damage from storms and weathering processes, warmer temperatures and heat waves will result in increased energy and water demands and costs for building owners.

3.3.5 Transportation

Climate change will affect most forms of transportation in Niagara and other regions. One of the more significant impacts is likely to be on Great Lakes shipping, much of which currently passes through the Welland Canal. Frank Millerd at Wilfrid Laurier University has analyzed the likely effects of climate change on Great Lakes Shipping. His recent study *Global Climate Change and Great Lakes International Shipping* (2007) explains that there are likely to be both positive and negative effects. The positive effects include reduced ice cover on the lakes and connecting channels that will extend the shipping season. This change can be seen already, with record early opening dates of the Welland Canal on March 21st in 2006 and March 20th in 2007 and 2008.

However, Great Lakes shipping will also have to contend with lower water levels in the lakes and canals, which will slow shipping and force most lake vessels and many of the ocean going vessels that traverse the lakes to lighten their loads in order to safely clear the bottom. In 2000 and 2001, water levels were at their lowest in 35 years on the Great Lakes – St. Lawrence Seaway, which reduced vessel carrying capacity to about 90% of previous averages according to the US Department of Transportation.

Currently, Great Lakes shipping is the lowest cost transportation choice for commodities such as grain and iron ore. It also produces the fewest greenhouse gases. If costs go up sufficiently, other transportation options are likely to become more cost-competitive, which may lead to a further decline in shipping. Millerd estimated that by 2050, costs could increase by 13-29% as a result of climate change, depending on the commodity shipped.

Canadian Olympic in the Welland Canal: Brian Switzer, 2006

Natural Resources Canada also points out that lower water levels in the Great Lakes and connecting passages could increase the risk of ships being grounded. Currently 10 to 12 ships run aground in the Great Lakes St. Lawrence Seaway each year according to a CBC news report.

Lower water levels will also affect port facilities, marinas, private docks and boat ramps on Lakes Erie and Ontario, which may need to be renovated or rebuilt to be functional at lower water levels.

Climate change will also affect roads. The 1992 Royal Commission on National Passenger Transportation estimated that environmental factors account for up to 50% of the deterioration on high-volume roads and as much as 80% on low-volume roads. Freeze-thaw cycles are particularly damaging, creating frost heave and potholes, accelerating the general deterioration of pavements and requiring higher maintenance expenditures.

Hot weather also damages roads, causing pavement softening and rutting. This can be a serious problem in extended periods of hot weather, especially on roads with heavy truck traffic such as the QEW. Hot weather can also cause the migration of liquid asphalt to the surface in older pavements according to Natural Resources Canada.
(*See Impacts on Transportation Infrastructure.*)

Besides pavement, road infrastructure such as bridges, culverts and tunnels are also likely to be affected by climate change. Bridges are subject to scour around their abutments or piers from fast flowing water and debris. (The US Geological Survey estimates that more than 60% of bridge failures are due to scour.) This increases during and after intense rainfalls, rain-on-snow events or quick thaws – all more likely under climate change. Increased freeze-thaw cycles also cause premature deterioration of concrete in bridges.

Culvert on Toronto's Finch Avenue at Black Creek Destroyed by August 19, 2005 Storm

Culverts, and the roads above them, are at particular risk from intense rainstorms that increase flow and debris in water courses. A recent study in Keene, New Hampshire, estimated that 30-80% of culverts are likely to fail under the combined effects of climate change and development. The City of Toronto is currently involved in a study of several culverts that they suspect to be at risk of failure due to climate change, after the disastrous breach of Finch Avenue by Black Creek in a storm in August 2005, when the culvert failed.

Tunnels will also have increased susceptibility to flooding under climate change. Excessive rainfall during a winter thaw caused a major flood in the Townline Tunnel under the Welland Canal in the 80's. Flooding also caused the erosion of concrete pipes that threatened to turn into a major sinkhole, and caused closure of the same tunnel for a month in 2010. Similar events could occur more frequently as climate change progresses.

Road accidents due to changing climate conditions are also of concern. Currently, precipitation events increase road accidents by about 45%. Both snowfall and rainfall cause similar increases in the numbers of accidents. Although climate change is likely to reduce overall snowfall, lake-effect snowstorms and intense rainfall events may increase road accidents and injuries. Strong winds can also be problematic on bridges, as evidenced by the April 28, 2011 storm that flipped over a tractor trailer on the Garden City Skyway, resulting in closure of the bridge for several hours.

3.4 TOURISM AND RECREATION

Tourism is a key feature of Niagara's economy, second only to manufacturing. An estimated 20 million people visit the Niagara region each year. Visitors are drawn by Niagara Falls and related attractions; cultural offerings such as the Shaw Festival; historic sites; wineries; gaming and casinos; outdoor activities including hiking, cycling, beach play, fishing, golf and water sports; as well as festivals and events.

Climate change is likely to have mainly positive effects on tourism and recreation in the Niagara region – unlike tourist areas more dependent on winter sports. An earlier spring, warmer summer and later fall are likely to extend the main tourist season, which currently peaks in the months of June, July and August. Outdoor activities will especially benefit, with a longer season for viewing the Falls, touring wineries, visiting beaches, parks and nature trails, water sports, fishing and golf.

As an example, Fenech and Shaw (2011) took a look at what climate change might mean for golfing in the Niagara region. Niagara has more than 40 public golf courses, which attract people from within the region, and many visitors as well. Fenech and Shaw estimated that annual premium golf days have increased by 13 days in the last 40 years due to warmer temperatures and reduced precipitation. Future projections suggest that premium golf days will continue to increase.

Cycling is also growing in popularity in the region, and warmer temperatures and decreased summer precipitation are likely to contribute to this growth according to Niagara Tourism. Similarly, the season for camping, hiking, water sports and outdoor festivals and events is likely to be extended.

However, many tourist and recreational activities take place in natural areas or involve interaction with natural systems that may be adversely affected by climate change. Declining water levels may reduce boat access to existing docks and facilities and increase navigational hazards, for example. Changes in the prevalence of desirable fish species may have negative effects on the sport fishing industry. Declining water quality from stormwater runoff, and increased frequency of algal blooms may increase beach closures. Extreme weather events that damage conservation and recreation areas may also have adverse impacts on tourism and leisure in the region.

3.5 HUMAN HEALTH AND WELL-BEING

A growing number of reports that have assessed the likely impacts of climate change on human health have become available recently. The comprehensive report *Human Health in a Changing Climate* recently released by Health Canada, is particularly valuable. The report covers a wide variety of potential climate-related health impacts from exposure to natural hazards and extreme weather; air pollution; and infectious diseases. Table 3 summarizes the potential health impacts of climate change that are described in more detail in the Health Canada report.

Table 3: Key Weather-Related Hazards in Canada and their Associated Health Impacts

EXTREME WEATHER	HEALTH IMPACT PATHWAYS	POTENTIAL HEALTH EFFECTS	POPULATIONS AT HIGHER RISK
Hotter weather and heat waves	• Body temperatures are elevated beyond normal range • Increased growth and abundance of disease-causing organisms or vectors • Air quality is negatively affected	• Dehydration • Heat-related illnesses (heat stroke, fainting, heat cramps, heat rash) • Worsening of existing medical problems such as asthma and allergies • Physical and mental stress • Respiratory and cardiovascular disorders • Food-borne diseases • Vector-borne infectious diseases	• Young children • Seniors, especially those unable to care for themselves or socially isolated • Chronically ill individuals • People with compromised health • People living in areas with poor air quality • People working or exercising outdoors • People without access to air conditioning • People on certain medications
Extreme rain or snowfall	• Flooding and its after-effects (e.g. poor air quality from growth of moulds) • Increase in mosquitoes and other disease carriers • Contamination of drinking water by chemicals or wastes in surface runoff • Failure of infrastructure (e.g. sewers, culverts) • Algal blooms	• Physical injury, shock and trauma • Death by drowning • Respiratory illnesses • Outbreaks of vector-borne diseases • Outbreaks of cryptosporidiosis, giardiasis, amoebiasis, typhoid and other water-borne infections	• Children • Seniors • People living along coasts or waterways • People with chronic illnesses • People with compromised health status • People with impaired immune systems • People with inadequate or no housing
Severe Storms	• High winds • High waves and storm surges • Flooding • Property damage • Damage to essential infrastructure (e.g. power lines, roads, hospitals) • Increased risk of automobile and other accidents	• Injuries or death from falls, collapsing buildings, windblown debris, fires, auto accidents, etc. • Hypothermia • Electrocution • Food-borne disease • Drowning • Stress disorders	• People living in storm-prone areas • People living in low-lying coastal areas or flood-prone areas • People living in areas where environmental degradation has created hazardous conditions

HOW MIGHT THESE HEALTH EFFECTS PLAY OUT IN NIAGARA?

Some recent events may provide clues:

- During the April 28, 2011 windstorm that swept northwards from the southern United States and hit the Niagara Region hard, many trees were felled on power lines, autos were crushed, and roofs lifted off schools and other buildings. Fortunately, few injuries were reported. However, two men were killed as a result of the storm. A Grimsby man was killed when he was hit by a metal garage door swept up by winds and another man died from his injuries after a tree fell on his car in St. Catharines.

- On July 15th, 2011, Niagara Region Public Health called an excessive heat alert, warning the public to take precautions and providing warning signs for heat stroke. The alert was not called off until 10 days later. In the meantime, temperatures reached 37˚C for several days in much of the Peninsula and the Humidex sat well above 40. On July 21st Grimsby temperatures reached 38.5˚C. The hot weather was linked to an extended heatwave and drought in southwest and central US, which caused at least 13 heat-related deaths. While no deaths in Niagara were attributed directly to the heat wave, at least two medical emergency calls resulted from the excessive heat and humidity. It is not known how many people suffered from illnesses caused or worsened by the heat wave because these are typically not reported.

- West Nile virus showed up in 11 mosquito pools across the Niagara Peninsula during the summer of 2011. A Niagara-on-the-Lake resident was diagnosed with the disease in September. Weather conditions – a very wet spring followed by several hot, dry weeks – were considered ideal for breeding the mosquitoes that carry the virus. Climate change is expected to increase the incidence of West Nile in much of Canada.

- In 2009, Ministry of Natural Resources staff caught 50 ticks in the Wainfleet Bog, 26 of which tested positive for Lyme disease, which can cause long-term disorders of the joints, heart and nervous system if untreated. Higher temperatures are expected to improve conditions for the survival and reproduction of the black-legged tick that carries the disease. Recent anecdotal reports have been made about Niagara residents who contracted the disease, and the Town of Niagara-on-the-Lake recently passed a resolution asking Ontario's Ministry of Health to increase public education about the spread of the tick-borne illness and to develop diagnostic and treatment protocols.

Tick dragging, courtesy of Robbin Lindsay

- Niagara Region Public Health monitors local beaches each year for E. coli and other contaminants, which appear to be on the rise. The Living in Niagara Report recently summarized data on beach postings in the region for 2003 to 2010. In 2004, beaches were posted 12.57% of the time. By 2009-2010, 32% of swimming days were considered lost as a result of contamination and beach postings. Beach sites in Port Colborne and St. Catharines had the highest number of days lost. Beaches are most likely to be affected after rainstorms that wash contaminants off the land into the water, or overwhelm sewage treatment plants, resulting in the release of untreated sewage. High E. coli levels in water can cause skin irritation, ear infections, and gastrointestinal illness.

3.6 THE ECONOMY

The costs of extreme weather and climate change are proving to be quite high for communities, public institutions, businesses and households. While climate change may provide economic opportunities for some sectors such as tourism or the production of warm climate wines, taking advantage of these opportunities will require planning with climate change in mind, something that is happening very little at present.

The international insurance industry has been keeping tabs on the rapidly rising costs of natural disasters. Early in 2011, for example, Munich Reinsurance issued an analysis of natural disasters worldwide in the previous year, identifying 950 disasters, nine-tenths of which were weather-related events such as storms, floods or heatwaves. More than 295,000 people died (many of them in earthquakes) and overall losses reached $130 billion in US dollars, of which just $37 billion was insured. The cost of weather-related disasters has increased substantially over the last 50 years, partly due to increased frequency and also because of the growing value of the assets that are affected. Canada's Institute for Catastrophic Loss Reduction recently published a chart showing how these costs have grown.

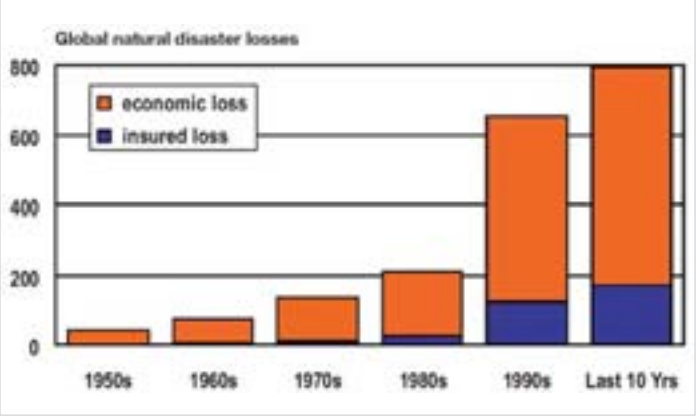


Figure 10: Institute for Catastrophic Loss Reduction (2008), based on data from Munich Reinsurance: Losses are in billions of US dollars)

Relatively little work has been done in Ontario to assess the costs to the economy of climate change. However, in 2011 the National Roundtable on the Environment and the Economy published the report *Paying the Price: The Economic Impacts of Climate Change for Canada*. The report estimated overall costs of climate changes for Canada at $5 billion in 2020, and between $21 and $43 billion by the 2050's if global temperatures rise by 2˚C. The more that temperatures rise, the greater the impacts and the higher the costs will be.

Economic costs may result from:

- Damage to homes, buildings, infrastructure, or other property from extreme weather
- Maintenance costs or premature replacement of infrastructure due to more rapid weathering
- Downtime for businesses affected by power outages, floods, and other weather-related incidents
- Increased costs for electricity
- Increased emergency management costs (for police, fire fighters, ambulance drivers and paramedics and other emergency personnel)
- Lower productivity and lost work time as a result of weather-related illnesses
- Rising insurance premiums
- Increased health care costs.

Some of the potential local costs of climate change can be inferred from the price tag of recent changes in weather patterns and extreme weather events in Ontario communities. For example, the 2009 tornado cost the City of Vaughan $730,000 to clean up and repair damages, not including replacement of 1600 trees that were destroyed. For the same event, insurance companies paid out damages of $88 million according to the Insurance Bureau of Canada. No estimate is available for uninsured damages.

The most expensive extreme weather event ever to occur in Ontario was the August 19, 2005 storm that passed through the Niagara Peninsula, and dumped more than 100 mm of rain in one hour on north Toronto. The downpour turned Black Creek into a raging torrent that destroyed a section of Finch Avenue, taking out the culvert, road, water and gas mains, power and communications cables, and then plunging southwards to scour a major park and ravine system. The storm also flooded basements in 4500 buildings, including commercial establishments with goods stored downstairs. More than half a billion dollars was paid out by insurers and the City paid an additional $44 million to replace damaged infrastructure.

During the 2003 blackout, approximately 11% of employees in Ontario put in a total of 7.5 million overtime hours. Many of these employees were emergency personnel involved in directing traffic, patrolling streets without lights, or restoring power.

A 2002 flood in Stratford, Ontario overwhelmed sewage and stormwater systems. The City paid out $1.3 million in emergency compensation to affected homeowners. This was not enough to cover all the damage and so almost 800 homeowners launched a lawsuit against the City for failing to take preventive action despite prior flooding and known weaknesses in the stormwater system. In a mediated settlement concluded in March of 2010, the City agreed to pay out an additional $7.7 million. The City was also forced to upgrade its sewage system, at a cost of $50 million.

4. CLIMATE CHANGE ADAPTATION IN NIAGARA

SOME ORGANIZATIONS IN THE REGION ARE ALREADY ACTING TO UNDERSTAND THEIR VULNERABILITIES AND REDUCE THE IMPACTS OF CLIMATE CHANGE

Our past greenhouse gas emissions have already set in motion changes in climate that are unavoidable over the next several decades. We are on course for a 3-4˚C increase in temperature by the 2050's and the related weather changes that warming will bring. If we are successful in massively reducing greenhouse gas emissions, we will prevent much larger impacts from occurring later this century, but we still need to take action to reduce our vulnerability to the weather extremes that we can expect in the near- and medium-term. Adaptive action can be described in three broad categories.

Climate Change Adaptation: Three Broad Categories

1. BUILDING ADAPTIVE CAPACITY – GETTING READY FOR ADAPTATION

- Tracking and analysis of weather trends
- Developing and using projections for future climate in the region
- Analyzing the impacts of recent weather-related events and assessing local vulnerabilities
- Undertaking quantitative risk assessments that prioritize areas for action
- Outreach and education for the public and stakeholders about risks and ways to respond
- Creating and supporting organizational structures that support adaptation
- Identifying and assessing adaptation actions for specific sectors
- Providing formal guidance for adaptive action

2. TAKING ACTION TO PREVENT OR REDUCE IMPACTS

- Interventions to reduce existing stresses on systems or sectors that are vulnerable to climate change (e.g. energy conservation to reduce electricity demand and the chance of brownouts and blackouts during hot weather)
- Action to increase resilience of systems in the face of extreme weather or climate change (e.g. planting diverse tree species to avoid huge loss of canopy if one species becomes susceptible to pests moving northward)
- Creation of buffer zones for vulnerable areas or relocation of vulnerable structures
- Taking action to fortify vulnerable systems and structures to withstand storms or other effects of climate change (e.g. using inexpensive hurricane straps to secure roofs on buildings)
- Forecasting and early warning systems to help people avoid impacts of extreme weather or disease-bearing insects

3. RESPONDING TO AND RECOVERING FROM IMPACTS

- Emergency response systems that take climate change into account when planning for extreme weather and related events
- Programs to aid recovery from extreme weather events

At this time, Niagara is mainly at the stage of developing adaptive capacity. The region is collecting or has access to data needed to assess how climate is changing in the region. A number of researchers are involved in projects to identify and measure impacts. A major climate change risk assessment has been done for one stormwater and wastewater infrastructure system in the region, piloting a process that could be replicated in other Niagara municipalities. Several organizations have held workshops that increase awareness and engagement of stakeholders on issues of climate change impacts and adaptation.

A small number of individuals and organizations in Niagara are currently involved in assessing the risks of climate change for their sectors, and are developing plans for climate change adaptation.

Some organizations have taken action to reduce the impacts of current weather extremes in Niagara, but have not yet considered the frequency or intensity of these events in future. Sometimes adaptive actions are taken for reasons other than climate change, but will nevertheless protect the region from the impacts of climate change.

All these activities lay the groundwork for more planned and comprehensive adaptation in the region. The rest of this section will describe some of these activities.

4.1 BUILDING ADAPTIVE CAPACITY IN NIAGARA

4.1.1 Climate Change Adaptation Commitments and Planning Initiatives

An important first step in building adaptive capacity is making the commitment to plan with climate change in mind, and engaging stakeholders in the process. Three examples of this are included below:

Niagara Region

In October 2008, Niagara Region's start-up team on climate change mitigation and adaptation planning proposed a Climate Change Action Work Plan including:

- Joining Partners for Climate Protection to work on greenhouse gas emissions reduction
- Organizing an assessment of the vulnerability of the Region to climate change
- Developing an "in-reach" program to increase awareness and engagement of the Region's Councillors and staff
- Developing broad partnership opportunities for mitigation and adaptation work.

In February 2009, Niagara Region joined Partners for Climate Protection (PCP), a project of the Federation of Canadian Municipalities with more than 200 municipal members. The Region has completed greenhouse gas emissions inventories as the first milestone in the PCP process.

In December 2010, Niagara Region organized a kick-off workshop for the Niagara Climate Action Plan. Most of the discussion at this meeting focused on setting up a multi-stakeholder organization to develop the Action Plan and on reducing emissions.

The Niagara Climate Change Network

Environment Canada and researchers at Brock University began work in 2009 on a collaborative project to facilitate the development of a climate change network and action plan in the region. As part of this work, researchers from Environment Canada and Brock conducted an analysis of climate trends and projections for the region, and identified some initial impacts.

The project held workshops with a broad range of Niagara stakeholders in December 2010 and in 2011. Participants agreed with the value of establishing what a network to collaborate on climate change work in the region.

Early in 2011, the process begun at Niagara Region and the community-based process of the Niagara Climate Change Network converged and the Niagara Climate Change Network was formed. The NCCN is developing a Niagara Climate Change Charter and will be encouraging Niagara organizations to sign the charter and commit to mitigating and adapting to climate change.

City of St. Catharines Sustainability Strategy

In 2011 the City of St. Catharines passed a new sustainability strategy, which includes climate change as one of six major challenges facing the city. The strategy includes several high-level commitments to address climate change adaptation:

- The protection of critical infrastructure from climate change
- Neighbourhood planning that considers the projected impacts of climate change
- Ensuring plans are informed by future projections about the frequency and severity of weather-related events
- Informing the community about climate change and its potential effects for St. Catharines
- Encouraging trees as part of site design shading and cooling
- Incorporating food security into adaptation planning.

4.1.2 Tracking Weather Data and Trends and Investigating Climate Projections for the Region

Data on weather trends is one valuable component of adaptive capacity. It can help to increase awareness of climate change in the region, and provide information that is helpful in identifying risks and opportunities. A number of organizations currently collect weather data in Niagara, including Environment Canada, the Niagara Region itself, the Niagara Peninsula Conservation Authority, and Weather Innovations Incorporated (WIN).

Although a large amount of weather data is currently collected, there is not much coordination or trends analysis of this information, which could make it much more useful for understanding recent climate trends and their impacts in the region.

The region also needs more capacity to investigate and incorporate future climate projections into long-term infrastructure, land-use, natural heritage and public health planning. Some resources are available and are described below.

Environment Canada Weather Data, Trends Analysis and Climate Projections

Environment Canada has six weather stations in the Niagara region and two weather buoys in Lake Ontario and Lake Erie. Daily weather data from these stations can be accessed using Environment Canada's on-line National Climate Data and Information Archive.

Viewers can also download “climate normals” or averages for 1971-2000 for Environment Canada weather stations. This allows viewers to compare current temperatures or precipitation with past climate averages and to analyze trends in a number of climate variables.

Environment Canada’s on-line resource, the Canadian Climate Change Scenarios Network, can also be used to access future temperature and precipitation projections for the region.

Climate Change Projections and Maps by the Ministry of Natural Resources

The Ontario Ministry of Natural Resources (MNR) recently established a Climate Change in Ontario website with two interactive mapping tools. The Climate Change Mapping Tool allows users to select a region or district of the province and view maps that show 1971-2000 average summer temperatures, average winter temperatures, warm-season precipitation or cold-season precipitation for the area. (For the map that covers the Niagara region, the user selects the Guelph district.) This tool also allows the user to view maps that show changes expected in average temperature and precipitation for 2011-2040; 2041-2070; and 2071-2100.

The map that follows was taken from the MNR website, and shows the average annual increase in temperature that the MNR projects for the 2041-2070 period.

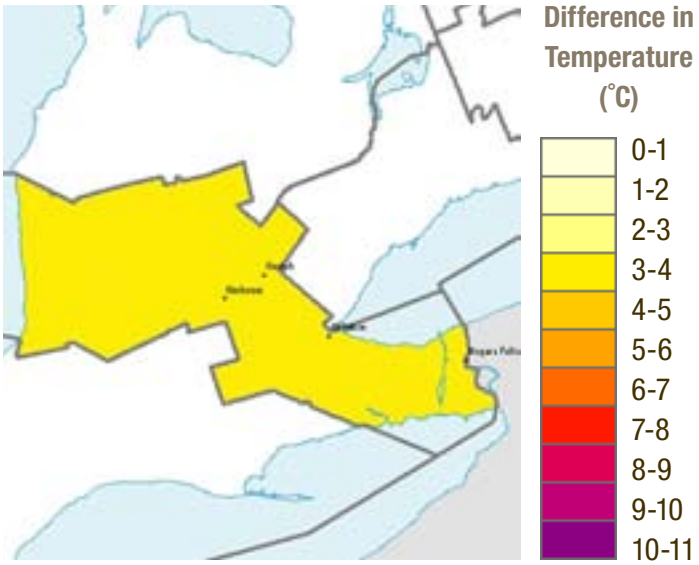


Figure 11: Average Winter Temperature Difference 1971-2000 to 2041-2070 in Guelph District (High Emissions Scenario): Ministry of Natural Resources

Weather Data from Weather Innovations Incorporated

Weather Innovations Incorporated (WIN) is a private company with 26 weather stations in the north of the Niagara region. WIN provides 15-minute, hourly and daily weather data for grape and fruit growers in the area. The company has collected weather data in the Niagara Region since 2003, and has detailed information on how temperatures and rainfall vary across the northern part of the region. This could be a useful supplement to Environment Canada data.

The graph below, accessed from WIN’s 2011 Growing Season Summary, shows variability in 2010 and 2011 hot days across Niagara West, and also compares these temperatures to the climate normal for 1971-2000.

WIN provides data summaries that could be very useful for assessing weather conditions and trends across the north of Niagara region.

Niagara Region’s Mesoscale Weather Monitoring Network

Niagara Region also collects a growing array of weather data. The Mesoscale Weather Monitoring Network for Niagara Region includes 13 precipitation stations in locations across

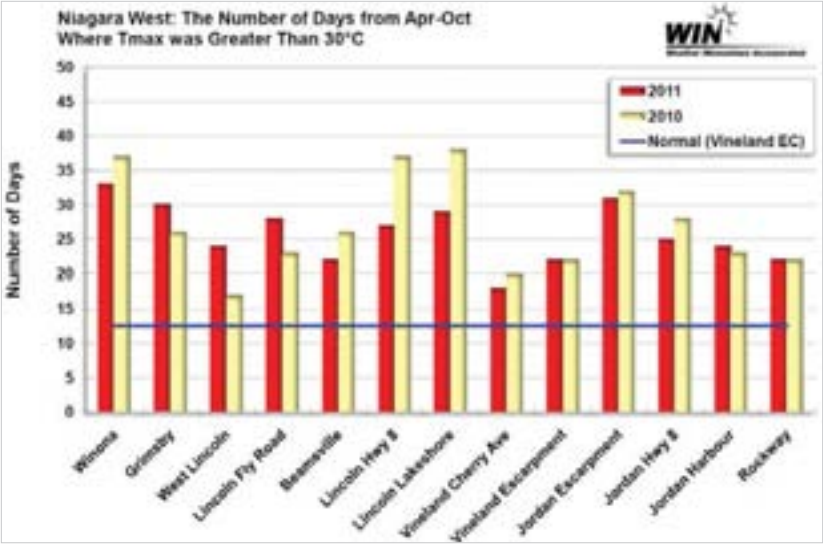


Figure 12: Hot Days in the Northwest of Niagara, 2010 and 2011: Weather Innovations Incorporated

the region and 4 full climate stations in Grimsby, Welland, Niagara Falls and Fort Erie. Some of these stations have data loggers that send data to the Niagara Peninsula Conservation Authority.

These stations have been collecting weather data since 1991. The stations measure rainfall every 5 minutes, which provides useful information on precipitation intensity. The data is used currently for capital planning for sewers and stormwater systems, and for assessing pump station performance. At present, it is not analyzed for long-term weather trends, nor is the data readily available to the public. (Niagara organizations can ask the Region to provide specific data, but a special report would have to be created.)

Precipitation, Water Quantity and Quality Data Collected by the Niagara Peninsula Conservation Authority

The Niagara Peninsula Conservation Authority (NPCA) collects a considerable amount of data about precipitation, water flows, and water quality in the region. For example, NPCA:

- Collects and analyzes precipitation data from various stations throughout the region
- Monitors water level and/or streamflow at 14 locations
- Tests surface water quality at over 50 stations each year
- Collects and analyzes water samples twice annually from 13 groundwater wells
- Monitors groundwater levels at 15 monitoring wells
- Collects samples of aquatic insects and molluscs (benthic macroinvertebrates) to determine water body health at 20-30 water quality stations each year
- Provides publically-accessible Water Quantity and Water Quality Observations on the NPCA website.

NPCA recently used this data to assess the vulnerability of the region's watersheds to climate change. (See: COA Climate Change Monitoring Networks Review Project, available on request from the NPCA.) In this assessment, NPCA determined that 7 out of 13 Watershed Planning Areas in the region were highly sensitive to climate change, as shown in Figure 13.

Based on its analysis, NPCA recommended adding or re-activating 7 weather stations in the region to provide more comprehensive water quality and flow data from Niagara watersheds that are highly sensitive to climate change. The additional data could support hydrological modelling in Niagara to assess the impact of climate change on water resources over time.

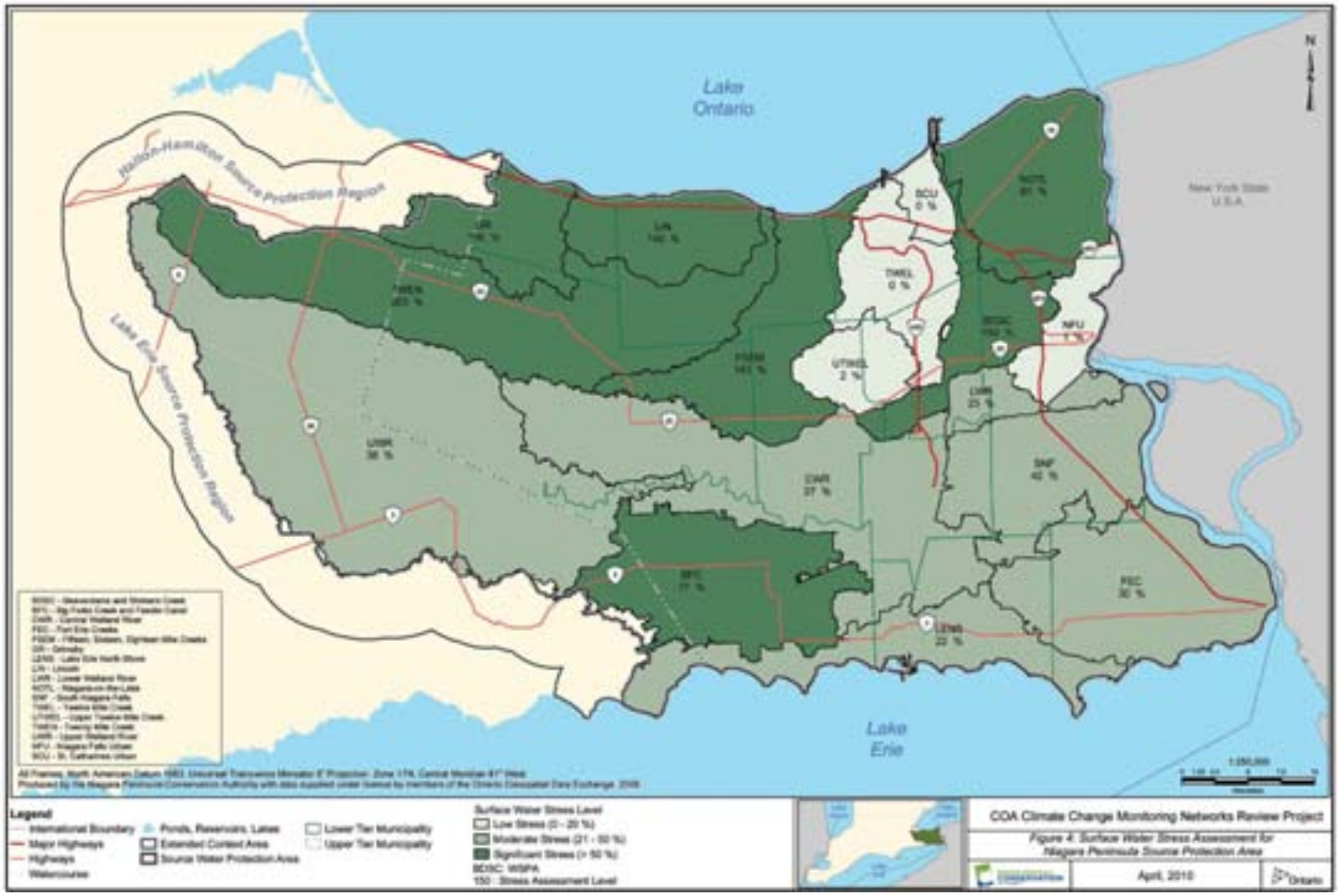


Figure 13: NPCA Surface Water Stress Assessment for Niagara

4.1.3 Research Investigating Climate Change Impacts and Adaptation Options in the Region

A number of Niagara-based researchers are currently analyzing ways in which climate is changing in the region, what impacts can be expected, and what some adaptation options might look like.

Investigating Climate Change Effects and Adaptation Options in Ontario's Wine Regions

In July 2011, Brock University's Cool Climate Oenology and Viticulture Institute (CCOVI) received a large grant to study how climate change impacts Ontario's grape and wine industry. The project involves 19 researchers in several projects over 5 years.

Investigating Impacts of Climate Change on Niagara Ecosystems

Brock researchers are also trying to understand the impacts of climate change in Niagara's ecosystems. Trees in a dispersed arboretum on the Brock campus will be monitored over time for growth, flowering and fruiting to better understand which species can best survive in a changing climate.

Some Brock undergraduate and graduate students are also studying the impact of climate-related events such as drought or heavy rain on meadow ecology and other ecosystems in the region.

Tracking the Movement of Insect Vectors into the Niagara Region as the Climate Warms

Niagara Public Health is collaborating with Brock University in the use of a Rothamsted trap to capture insects that serve as carriers of infectious disease. Researchers in Brock's Biological Sciences department are monitoring climate data and identifying and analyzing the insects, to determine which insects are migrating northwards from the US and diseases they may be carrying. (Niagara is considered a "gateway" for vector-borne disease entering Canada.)

Rothamsted Trap, DeCew Falls Treatment Plant: Niagara Region Public Health

Developing and Testing Resilient and Warm-Climate Plants

The Vineland Research and Innovation Centre is involved in several agricultural research projects that may facilitate climate change adaptation in the Niagara Region. These projects include:

- Greening Ontario Highways: The project is growing and planting 14 varieties of trees along busy Ontario highways and in urban settings, to see how well they survive in these stressful environments. Some of the trees in the experiment are resilient native varieties, but others thrive in areas to the south which have a similar climate to that expected in southern Ontario in the future.
- Native Plants for Green Roofs: Vineland researchers are investigating more than 20 types of native plants that show good potential for planting on green roofs. Green roofs aid in adaptation by cooling buildings, reducing energy use, and reducing the rush of rainwater into stormwater systems. Green roofs – especially those made up of native plants – can also provide habitat for birds, butterflies and other beneficial insects. Few native plants have been evaluated previously for Canadian conditions.
- World Crops: This project is researching the production of warm-climate crops that are currently imported into Canada. Warmer summers and longer growing seasons provide more opportunity for growing some of these crops locally and reducing emissions from transportation. The research will provide first hand information about growing needs and conditions that will help Niagara farmers grow and market new warm-climate crops.

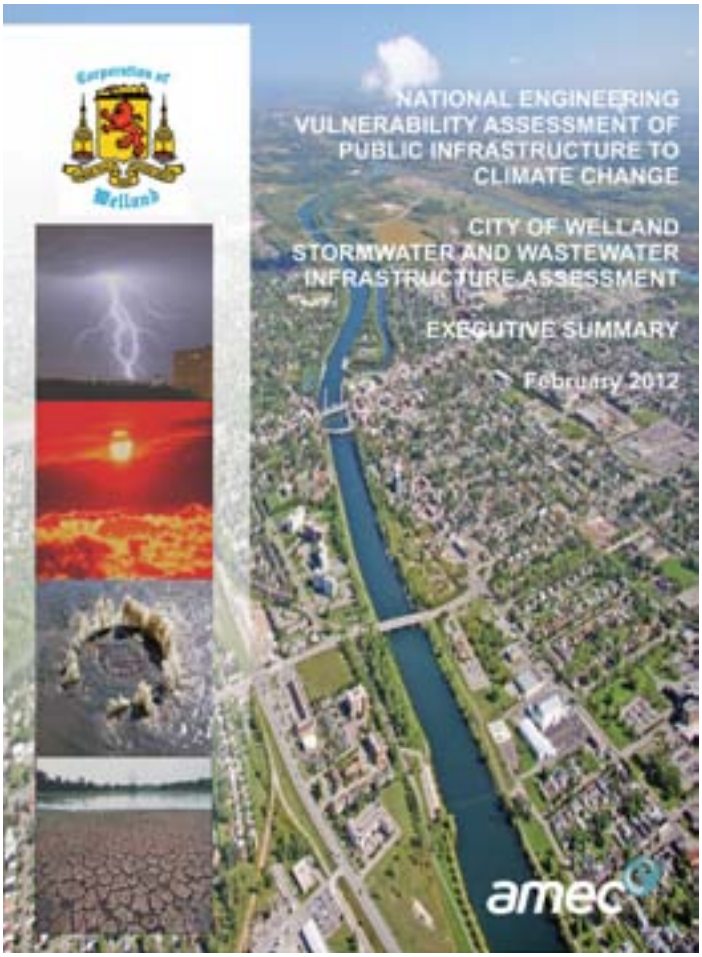
Monitoring the Resilience of Trees to Climate Change

The Planting for Change program by the Association of Canadian Educational Resources (ACER), in collaboration with Climate Action Niagara, has involved students in planting trees in public schools in Thorold and Welland in "local climate change experimental plots." The students will collect data on the health and annual growth of the trees, as a way of exploring issues relating to climate change. ACER also manages a one-acre biodiversity observation plot in Niagara-on-the-Lake. These programs are part of a larger ACER initiative to assess which trees can prosper best as climate changes in the region.

4.1.4 Climate Change Risk Assessment of Welland's Wastewater and Stormwater Management Systems

The first climate change risk assessment for infrastructure in the Niagara Region was recently completed for the City of Welland's stormwater and wastewater systems. The City is currently separating sewer and stormwater systems to reduce combined sewer overflows and basement flooding. The new sewage and stormwater systems are very expensive and expected to last 80 years. The City wants to design this infrastructure so that it will not be overwhelmed by heavier rains in the future.

The consultants for the study conducted a climate analysis, examining 18 climate variables for Welland. Then consultants organized a risk assessment workshop with stormwater/wastewater managers and related specialists in the region. Participants identified how each feature of the Welland system could be impacted by the anticipated changes in climate and developed a risk score for each impact. The final report makes a number of short- and longer-term recommendations to further analyze and reduce these impacts.



This kind of risk assessment could fairly easily be replicated in Niagara both for stormwater/wastewater systems in other municipalities and for other kinds of infrastructure, and provide the region with a much better understanding of its vulnerability to climate change as well as some of the actions that could reduce this vulnerability.

4.1.5 WaterSmart's "Engineering for Climate Change Adaptation" Workshop

In January 2011, Niagara's WaterSmart program and AMEC hosted a one-day workshop focused on designing water and stormwater infrastructure that is resilient to climate change. The event attracted participants from all over the region, including staff from most of the region's municipalities. The workshop heard presentations on:

- Assessment and mapping of future flood risks
- How climate change is altering the magnitude, frequency, timing, intensity and variability of precipitation and increasing extreme storms
- The need to take climate changes into account when designing and building new infrastructure
- The need for more long-term rainfall data and sharing of existing data among those agencies that monitor precipitation and other weather variables.

Workshop participants agreed on the need for more rainfall data, and to better share existing data in the Niagara region. The participants also asked for a follow-up workshop to determine how weather data can be shared by Niagara agencies and to hear the results of the climate change risk assessment study for the City of Welland. This workshop – and more like it – would clearly benefit the region and increase engagement of stakeholders in climate change adaptation.

4.2 CURRENT ACTIONS LIKELY TO REDUCE IMPACTS IN NIAGARA

There are a number of programs and activities underway in Niagara that provide some protection from some of the impacts of climate change. Relatively few of these activities are undertaken with the explicit goal of adapting to climate change. To be fully effective as an adaptation strategy, many of these programs will need to be ramped up.

4.2.1 Energy Conservation Programs that Reduce Pressure on the Grid and the Potential for Brownouts and Blackouts

In addition to reducing greenhouse gas emissions and energy costs, energy conservation can provide some protection from the impacts of climate change. Reducing demand for electricity, for example, reduces the stress on electricity transmission and distribution systems, which makes them less vulnerable to brownouts and blackouts during heat waves.

A number of municipal governments, private companies and utilities in Niagara have taken action to reduce consumption of electricity and other forms of energy. Some of these projects are driven by a desire to reduce energy costs, as well as to reduce emissions. These actions include:

- Participation by Niagara's local utilities in energy conservation and demand management programs such as energy audits, energy retrofits, demand response programs, etc.
- Replacement of traffic and pedestrian signals with high-efficiency LED lights
- Energy conservation programs in local businesses, including Niagara's wineries
- The Quick Wins Home Energy Program by a collaborative of Niagara non-profits, which identifies drafts and seals the leaks in individual homes, helping to reduce energy use and reducing the impacts of both hot and cold weather on homeowners.

4.2.2 Actions that Reduce the Impacts of Intense or Prolonged Rainfall, or Rain-on-Snow Events

The Niagara Region and several Niagara municipalities have programs that help reduce the impacts of intense or prolonged rainfall. These programs include:

Stormwater Management Master Plans and Best Practices

Niagara Region's WaterSmart program is supporting the development of local watershed-based stormwater management master plans. The Town of Pelham and City of Port Colborne are currently undertaking studies to produce such plans. Many best management practices for stormwater management are outlined in the NPCA's recent Stormwater Management Guidelines. These prioritize what is called "low impact development" or "green infrastructure" practices that increase infiltration of rainwater and reduce runoff, erosion and flooding, which will become increasingly important for reducing impacts.

Stormwater Infiltration Systems

So far, Niagara communities have made limited investments in infiltration systems that can absorb, retain and gradually release rainwater, reducing the impact of heavy storms on infrastructure and waterways. However, these systems can contribute to controlling stormwater and to heat in the region's towns and cities, as well as improving habitat and making local environments more attractive. Existing infiltration systems that point the way to the future include:

Green Roof: St. Catharines Museum

- Green roofs: A small number of green roofs have been created recently in the Niagara area at Flat Rock Cellars, St. Catharines Museum and the Vineland Research and Innovation Centre.
- Permeable pavement: St. Catharines recently installed a permeable pavement parking lot at their Lake Street Service Centre. The pavement is being tested to see how well it stands up to winter weather and snowplows.
- Swales: Constructed swales are used along the edge of roads and backyards in the Niagara region to aid in drainage, though some swales have been filled in, creating flooding problems. The NPCA has integrated swale restoration into watershed planning for Fort Erie Creek.
- Stormwater ponds: Wet and dry stormwater ponds are becoming more common in new developments in the region to manage runoff from new roads, parking lots and other impermeable surfaces. Some wetlands are constructed to filter and clean stormwater before it can reach natural water bodies.

Downspout Disconnection, Weeping Tile Disconnection and Rain Barrel Programs

Several local Niagara municipalities have had downspout disconnection by-laws, public education, inspection and enforcement programs to ensure that downspouts are disconnected from sewer systems to reduce heavy flows and the potential for combined sewer overflows. Several communities also have programs to subsidize the purchase of rain barrels to encourage homeowners to capture rainwater from their roofs.

Niagara Falls and Fort Erie both have active weeping tile disconnection programs and Niagara Falls subsidizes homeowners who disconnect. The two cities gathered flow data to evaluate the effectiveness of the program and determined that it has significantly reduced combined sewer overflows.

Backflow Prevention and Flood Alleviation Programs

St. Catharines initiated a Backflow Prevention Program to ensure that existing commercial, institutional, industrial and multi-level residential buildings install backflow devices to prevent sewage water back-ups into basements. The City also provides grants of up to $3000 for homeowners who have suffered basement flooding, to help them install backwater valves, sump pumps, disconnect weeping tiles from the sanitary sewer and other mechanisms to reduce the incidence of future flooding.

Combined Sewer Separation and Treatment for Combined Sewer Overflows

Combined sewer and stormwater pipes are a problem in older towns and several Niagara communities have been working to separate combined sewers and to implement other mechanisms to reduce combined sewer overflows during wet weather. Limited funds from the federal and provincial governments have slowed these expensive projects.

4.2.3 Actions that Reduce the Impacts of Hot Days and Heat Waves

The impacts of increases in hot days and heat waves under climate change will be felt most in urban areas where vegetation has been removed and replaced by concrete and asphalt. These changes create urban heat islands which can increase temperatures up to 7˚C higher than the surrounding countryside. The red areas in Figure 14 were the hottest areas in the northern part of the Niagara Peninsula near Lake Ontario, during the hot summer of 2005.

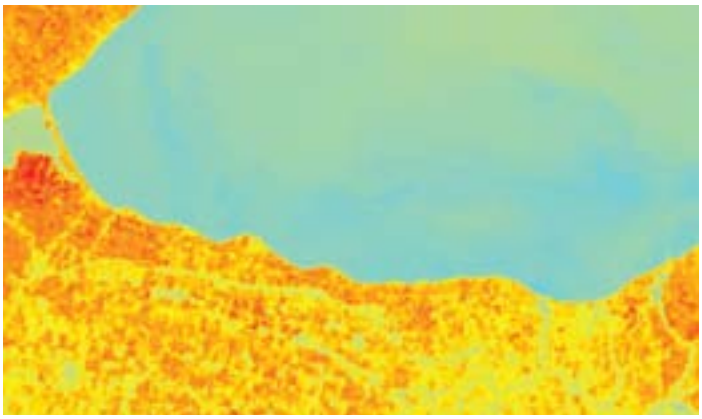


Figure 14: Hot Spots on the Lake Ontario's north shore: Natural Resources Canada 10 a.m., June 3, 2005

There are a variety of strategies to reduce heat in urban areas. The report Mitigating Urban Heat in Canada describes a number of these, including:

- Planting and protection of trees and vegetation for shade and to increase cooling through evapotranspiration
- Green roofs and walls and permeable pavements which capture rainwater and release it slowly to cool the surrounding environment
- The use of cool roofing and paving materials that reflect solar radiation
- Decreasing heat emitted to the urban environment by increasing energy efficiency of buildings, and strategies to reduce use of cars and trucks (which emit substantial heat to the urban environment

Re-Leaf Niagara Tag on newly planted maple: Land Care Niagara

The main strategy used so far in Niagara is tree planting. Several organizations in the region have campaigned for and participated in tree planting and tree maintenance in urban areas. These include:

- Land Care's Re-Leaf Niagara program, which grows and plants native trees suitable for planting in urban settings
- NPCA's Canopies for Kids program, funded by WaterSmart, which plants trees in school playgrounds for shade and cooling
- Climate Action Niagara's Take the Heat Off Our Streets campaign for planting more trees on boulevards and in cul-de-sac circles. CAN is also involved in school yard tree planting.

The City of St. Catharines was the first Niagara community to adopt an Urban Forestry Management Plan in 2011. The plan acknowledges the importance of urban trees for climate change mitigation and adaptation. The City has committed to increasing the tree canopy from the current level of 15-17% to 30% by 2030.

4.2.4 Actions that Facilitate the Adaptation of Natural Systems in Niagara to Climate Change

Niagara has an abundance of organizations working to restore and enhance the natural heritage of the region. This work is being done to safeguard unique habitats, protect endangered species, and repair degraded natural environments in the area. However, rehabilitated and enlarged natural areas also reduce the impacts of climate change by cooling the air, reducing runoff and flooding, improving the quality of the water and the health of the streams.

Wooded areas account for less than 18% of the land area in Niagara and are heavily fragmented. The NPCA estimates that the region needs close to 30% forest cover to improve water quality and provide healthy habitats for the region's plants and wildlife. NPCA has planted 1.5 million trees in the region since 1997 in an effort to meet this target.

Much of Niagara's tree planting has been designed to connect forest fragments, especially along streams and other natural corridors. Since 1997, NPCA has undertaken 10-15 projects annually to aid in connecting forest fragments. The Niagara Restoration Council has also overseen a three-year wildlife corridor project to connect existing forest fragments in the Fifteen, Sixteen and Eighteen Mile Creek and adjacent watersheds. Recently, the Council planted more than 50,000 trees as well as shrubs and grasses in the Thorold-Lake Gibson Corridor Naturalization Project. Currently, it is not certain which trees are likely to be most resilient in the future, and so Niagara organizations such as NPCA and Land Care emphasize diversity in their plantings, in case changing weather conditions or unexpected new pests are particularly damaging to some trees.

NPCA has also led a project called Nature for Niagara's Future. The project is identifying and evaluating natural heritage core areas and potential corridors that could support the survival and migration of trees, plants and wildlife. The project has not made a final report at this time, but the Scenario Development Team will present some options in the near future.

In the meantime, the Carolinian Canada Coalition developed the map below, which shows how natural heritage corridors might link existing natural areas in the region to create a more complete natural heritage system. Potential habitat corridors are outlined in light green.

Figure 15: Carolinian Canada Coalition's "Big Picture" of Habitat Corridors for Niagara

4.2.5 Forecasting and Warning Systems to Help Niagara Residents Avoid Extreme Weather and Climate Change Impacts

An important component of adaptation is to provide forecasting and warning systems to help people avoid the impacts of climate change. The classic example of this is the heat alert and response systems that have been put in place in many Ontario municipalities.

Excessive Heat Alerts

Niagara Region Public Health (NRPH) initiates an excessive heat alert if:

- The humidex (an index that combines heat and humidity) is forecast to rise to 40 or higher
- The humidex is forecast to rise to 38 or higher, and a smog alert is also underway
- Environment Canada issues a humidex warning for the Niagara area.

NRPH issues a media alert to warn the public to watch for the symptoms of heat stroke, to take precautions such as drinking plenty of fluids and resting in shaded areas, and to check on vulnerable neighbours. The department also alerts 35 community agencies in the Niagara region, who in turn communicate the warning to their staff and clients. Many local municipalities assist by extending hours of operation at their recreation centres and swimming pools.

A Real-Time Weather Monitoring System to Provide Timely Warnings of Beach Water Contamination

NRPH is also responsible for monitoring beach water quality in the region, and posting beaches with warnings when the water is contaminated with E. coli, as often occurs after storms. Such storms are expected to increase as a result of climate change and NRPH anticipates that beaches will be more widely used as summers warm.

Water at Niagara beaches is currently tested once a week during swimming season as recommended by the Ministry of Health protocol. These samples take 36-48 hours to analyze. As a consequence, beaches are sometimes open when the water is contaminated and closures can take place after the problem has disappeared. In 2010, Niagara beaches were posted 32.5% of the time.

NRPH recognized that a better system was needed. As a result, they are testing a buoy equipped with a mini-weather station that will be moored in the water off a Niagara beach. The equipment will provide real-time information on rainfall, wind speed and other factors that contribute to contamination. This will be correlated with water sampling. If Public Health staff can correctly predict E. coli contamination as a result of weather conditions, then the Department will likely install mini-weather stations at other strategic locations.

Warning of Water Contamination on a Niagara Beach: Niagara Region Public Health

Vector-Borne Disease Controls, Surveillance and Early Warning Program

Niagara Region Public Health plays a key role in monitoring the expansion of insect vectors and vector-borne diseases. NRPH has monitoring programs in place for West Nile virus (transmitted by infected mosquitoes) and Lyme disease (spread by blacklegged ticks).

Black-legged Tick: Robbin Lindsay, Public Health Agency of Canada

Climate change is expected to increase the transmission of West Nile by speeding up the life cycle of mosquitoes and extending the transmission season. Niagara Region has stepped up programs to apply larvacide to drains and other pools of stagnant water after heavy rains in order to kill mosquito larvae.

Like other public health units, NRPH reports on cases of West Nile. (See Historical Data for West Nile Virus in Niagara Region.) Surveillance for West Nile and for other mosquito-borne diseases will be enhanced by the Rothamsted trap that NRPH and Brock scientists recently erected. If vector-borne diseases of concern are identified, NRPH notifies family physicians and emergency rooms so they are better able to identify and treat the diseases.

Lyme disease is a bacterial infection transmitted by blacklegged or deer ticks. Warmer temperatures are expected to increase tick overwintering as well as shortening the life cycle so that ticks reproduce more quickly. Blacklegged ticks have increased in the Niagara area in recent years. NRPH provides information to the public about ways to avoid tick bites and about symptoms if they do get bitten. NRPH also collaborates with Health Canada on small mammal trapping to test for blacklegged ticks, and encourages doctors, veterinarians and the public to submit ticks for identification and testing. The department has also collaborated in "tick dragging" campaigns in the Wainfleet Bog, to capture and identify ticks.

4.3 RESPONDING TO AND RECOVERING FROM CLIMATE CHANGE IMPACTS

4.3.1 Emergency Management Planning

Several events in the last 15 years have led to strengthening emergency services in Ontario and across Canada. These include the Ice Storm of 1998; 9/11 in the US; the 2003 blackout across Ontario, Quebec and the US northeast; the 2003 heat wave that killed more than 15,000 people in France; and Hurricane Katrina in New Orleans. All of these events highlighted the need for strong emergency plans and preparedness.

Emergencies in Niagara most often result from extreme weather. Managers report that planning has changed recently because of threats that may be associated with climate change including the April 28th windstorm that struck the region in 2011, recent severe heat waves and tornadoes like the ones that recently devastated Vaughan and Goderich. Emergency Planning staff are currently updating Niagara Region's Hazard Identification and Risk Assessment.

Changes in emergency operations often occur as a result of evaluating the experience of actual events. The April 28th event, which left more than 30,000 households without power in St. Catharines, for example, has resulted in a stronger working relationship between emergency planners and utilities in the region.

Emergency managers have recently strengthened messaging to encourage individuals and households to prepare in advance for weather-related and other emergencies. After the April 28th windstorm, they hosted an "emergency preparedness market" in St. Catharines and have been holding numerous education sessions with community organizations and schools.

Business continuity planning is an important aspect of emergency preparedness. Recently, more attention is being paid to internal continuity planning in the Niagara Region, to ensure that regional government departments can continue to provide services in the event of an emergency. Most large businesses have plans in place. However, smaller businesses are less likely to be prepared.

5. FILLING THE GAPS

STRENGTHENING NIAGARA'S PREPARATION FOR CLIMATE CHANGE

Although there are many initiatives in the Niagara region that will serve to reduce the impact of climate change, much remains to be done. The following provides a brief outline of some of the ways in which Niagara could strengthen its capacity to adapt to climate change.

5.1 LEADERSHIP IN CLIMATE CHANGE ADAPTATION PLANNING

The Niagara Region and some local municipalities have made commitments to planning for adaptation. The Region established an internal committee to work on adaptation, and then joined the community-based Niagara Climate Change Network to collaboratively plan. Those are important first steps.

The experience of strong regional and local initiatives in other parts of Ontario, Canada and internationally suggests that additional commitments are needed. These include:

- Ensuring that local governments and key business organizations in the region make a commitment to do their part to reduce the impacts of climate change
- Support by strong political or executive champions
- Establishment of a clear organizational structure for adaptation planning with a clear mandate, financial support and the collaboration of key stakeholders in the region
- Allocation of dedicated staff and budget – rather than simply adding adaptation to the responsibilities of already busy staff or volunteers with few financial resources
- Active collaboration with local and regional researchers prepared to help with climate information, vulnerability and risk assessment, and identification of adaptation options
- Identification of priority sectors and projects for adaptation, either by targeting areas where impacts are likely to be greatest, where opportunities are present (e.g. at the beginning of major infrastructure projects) or where adaptation options meet multiple goals.

(See Cities Preparing for Climate Change, for more detail.)

5.2 COORDINATION AND SHARING OF EXISTING WEATHER DATA, ANALYSIS OF TRENDS, REGIONAL CLIMATE PROJECTIONS

Participants in the Engineering for Climate Change Workshop hosted by WaterSmart last year recommended that the weather data currently being collected in Niagara be coordinated and shared and that more analysis be done on climate trends. An analysis of climate projections that builds on Fenech and Shaw's work in 2010, and on AMEC's report for Welland would also be very useful for the region.

5.3 AWARENESS AND ENGAGEMENT ACTIVITIES

Participants in the 2011 WaterSmart Climate Change and Engineering Workshop recommended a follow-up workshop. The AMEC report for Welland is due to be released soon, and would be a good opportunity for holding this second workshop. More workshops of this kind would be very valuable in piquing and sustaining the interest and engagement of local infrastructure managers, staff and the public.

Awareness and engagement can also be increased by dedicated communications tools such as Halifax Regional Municipality's Climate SMART website, which identifies the risks of climate change for the region, consultant reports on vulnerabilities including maps, a guide for resilient development, links to related magazine articles, etc.

5.4 VULNERABILITY ASSESSMENTS

This report provides an initial look at overall vulnerabilities in Niagara. The NPCA has made a more specific and detailed

assessment of the vulnerability of surface water and groundwater in the region. More assessments of this kind are needed from sector specialists.

Vulnerability assessments usually look at how specific geographical areas or sectors fare when confronted with recent weather extremes, such as storms, dry spells or heat waves. Vulnerability assessments usually don't depend on climate projections. Some are quite simple.

For example, the UK Climate Impacts Program developed a simple system they call a Local Climate Impacts Profile or LCLIP, which more than 100 British towns and cities have used to do a local vulnerability assessment, helping them identify and prioritize climate hazards. Step-by-step guidance is provided on the UKCIP website.

A valuable, though more time-consuming approach for assessing vulnerability in specific sectors (and for climate change adaptation planning as a whole) is recommended in the Climate Change Adaptation Framework Manual developed by Deloitte for the Alberta government. The manual also provides a step-by-step approach that users can adapt to their own circumstances.

5.5 INFRASTRUCTURE RISK ASSESSMENTS

Engineers Canada has developed a protocol for public infrastructure risk assessments. This protocol guides the use of climate trends and projections information, as well as an assessment of local conditions to help identify future climate risks. The protocol also recommends a scoring system that quantifies and helps prioritize different risks. The City of Welland has used this PIEVC methodology in its risk assessment its stormwater/wastewater systems. This assessment could be replicated for other stormwater/wastewater systems in the region that are currently vulnerable to storms, and also for other types of public infrastructure (buildings, transportation systems, water treatment plants, etc.).

5.6 INVENTORY OF EXISTING ADAPTATION ACTIVITIES AND GAPS ANALYSIS

This report has done an initial survey of programs and projects in the region that are likely to provide some protection from future climate change, even though many of these actions have not been taken with the explicit goal of adaptation. Many activities that will help the region adapt have undoubtedly been missed. It will be valuable for individuals or organizations working in specific sectors to do their own inventory of current activities that they believe will contribute to adaptation and to suggest how these activities can be augmented to provide expanded climate change protection.

An inventory of adaptive actions may also reveal some clear gaps. See the 2010 Adaptation Background Report for Peel Region for a gap analysis that is helping the region do more complete adaptation planning and implementation.

5.7 IMPLEMENTING ADAPTATION

For the most part, adaptation doesn't involve the creation of new projects and programs, but the integration of climate change considerations into planning and implementation of activities. Adaptation advocates call this "asking the climate question" or "mainstreaming adaptation".

Asking the climate question is particularly important for sectors such as agriculture, ecosystems and stormwater infrastructure that are strongly affected by changes in weather patterns and by extreme weather. It is also very important for long-term land-use and infrastructure planning.

The previous section and Appendix A of this report show how a number of organizations are implementing adaptation.

They are doing this by:

- Sectoral partnerships to collaboratively plan for and implement adaptation strategies, e.g.:
  - ◊ The WeatherWise Partnership's electrical sector risk assessment and adaptation project
- Pilot and demonstration projects that allow organizations to showcase adaptation alternatives and assess the costs, benefits and effectiveness of adaptation options, e.g.:
  - ◊ The model resilient homes (Institute for Catastrophic Loss Reduction)
  - ◊ Low impact development demonstration projects (Credit Valley Conservation Authority)
- Incorporating climate change considerations into municipal and regional facilities and infrastructure to increase resilience and safeguard government and private sector investments, e.g.:
  - ◊ Pioneer Park Stormwater Management Facility (Town of Richmond Hill)
  - ◊ Enlarging culvert capacity in vulnerable locations (City of Toronto)
  - ◊ Changes in asphalt mix so roads can better withstand heat waves and freeze-thaw cycles (City of Toronto)
- Incorporating climate change considerations into ecosystem protection, e.g.:
  - ◊ Expanding core forests, connecting forest fragments and planting a diverse selection of trees to increase woodland resilience today and in the future (Niagara Peninsula Conservation Authority, Land Care Niagara and others)
- Incorporating climate change considerations into community services to reduce the impacts of climate change on vulnerable populations, e.g.:
  - ◊ Strengthening monitoring, warning, and control systems for vector-borne and other illnesses likely to be increased by climate change (Niagara Region Public Health)
  - ◊ Enhancing the capacity of emergency management to respond to severe weather (York Region and Peel Region)
- Using economic instruments to encourage adaptive behaviour by businesses and households, e.g.:
  - ◊ Rebates for water efficient toilets and washing machines, grey water reuse and rainwater harvesting systems (City of Guelph)
  - ◊ Subsidies for backflow valves (City of St. Catharines and others)
- Voluntary guidelines that encourage resilient /adaptive action by the private sector and/or local governments, e.g.
  - ◊ Home Builders' Guide (Institute for Catastrophic Loss Reduction)
  - ◊ Designers Guide for Low Impact Development Construction (Credit Valley Conservation Authority)
- Regulations and standards to ensure the implementation of adaption, e.g.
  - ◊ Efforts to ensure that the Ontario Building Code incorporates requirements that will increase the resilience of buildings in the face of climate change (Institute for Catastrophic Loss Reduction and others).

Robust adaptation to climate change will require a mix of these activities and more, depending on the location and sector of concern.

5.8 MONITORING IMPACTS AND ADAPTATION

In addition to monitoring climate trends and climate projections for the region, it will be important to monitor and evaluate adaptation actions to ensure that these have the desired effect. ACER and CAN, for example, are planting trees in schoolyards and elsewhere in Niagara, and are monitoring the growth of different species to determine how climate change is affecting them and determine which are most resilient.

The Clean Air Partnership's training manual Protecting your Community from Climate Change provides examples of a number of indicators that could be used to monitor adaptation processes and outcomes. A sampling of these indicators can be found in Table 4.

Table 4: Sample Climate Change Adaptation Indicators

SECTOR	SAMPLE PROCESS INDICATORS	SAMPLE OUTCOME INDICATORS
Stormwater Management	• Intensity, Duration and Frequency Curves have been updated to reflect changing risks • Programs are in place to expand low impact development	• Sewer backup and basement flooding events/complaints • Overland flood incidents & extent • Infrastructure damage and costs from intense storms
Public Health	• Heat alert and response systems are in place • Monitoring and warning systems established for vector-borne and other climate-related illnesses	• Illnesses and deaths from extreme heat and heat waves • Illnesses and deaths from climate-related diseases
Trees & Forests	• Number of trees planted (urban or rural) • Implementation of new tree planting techniques to aid tree survival	• Tree canopy coverage • Damage to trees from storms or insect pests

6. SOME CONCLUDING COMMENTS

Climate change is underway in Niagara, as it is in the rest of the world. This can be seen in several key features of climate, including warming temperatures, changes in precipitation patterns, shifts in the growing season and other harbingers of climate change.

Many organizations in Niagara and around the world are working to reduce greenhouse gas emissions and limit global warming so that climate change does not result in catastrophe. However, the increased concentration of greenhouse gases that has already occurred will ensure that the earth will continue to warm for several decades, even if we are able to make dramatic reductions in emissions in the near future. This warming will continue to change temperatures, rainfall, storm patterns and other important features of our weather and this will inevitably impact on our communities.

Niagara is a very special region in Ontario and Canada for many reasons. Its unique attributes need to be nurtured and protected from climate change. Many organizations and individuals in the region have already begun this task, and are increasing the capacity of Niagara to adapt. This work is still in the very early stages however.

Organizations and individuals throughout the region need to be asking the climate question: How will climate change affect me and my community? Answering this will require concerted efforts to elevate the awareness and engagement of the public and key stakeholders. It will also require more and better-coordinated climate information, a commitment to assessing impacts and to climate change adaptation planning throughout the region. Resources will have to be mobilized both for planning and for implementation of adaptation programs.

It is hoped that this report will contribute to the continuation and acceleration of this important work.

APPENDIX A

CASE STUDIES OF OTHER REGIONS AND COMMUNITIES ACTING TO REDUCE THE IMPACTS OF CLIMATE CHANGE

A number of communities in Ontario and other parts of Canada have begun planning and implementing programs and projects to adapt to climate change. Many of these have been led by local and regional governments, though a number have been initiated by non-governmental organizations, university-based researchers and/or conservation authorities.

This appendix includes brief descriptions of several innovative adaptation initiatives in Ontario communities that might serve as inspiration for Niagara. A number of additional adaptation initiatives have been described in other case studies. Links to these publications are provided at the end of this appendix.

ADAPTATION PLANNING

Several communities have recently launched formal adaptation planning processes. Some of these have focused on adaptation alone; others have combined mitigation and adaptation strategy development. The Region of Peel has undertaken a unique and ambitious adaptation planning process, which is described in more detail below. Adaptation plans have also been drawn up by or are under development in Toronto, Oakville, London, Ottawa, Sudbury, Richmond Hill, Ajax, Windsor, York Region, and Durham Region among others.

Most of these plans have been led by local or regional municipalities. However, it is important to note community-based planning has also occurred in some other parts of Canada, especially B.C. and Yukon. Though local governments have not always been leaders in these processes, they are always involved. In community-based adaptation processes, planning has usually been initiated by a regional non-governmental organization. The Columbia Basin Trust has been a leader in B.C., for example, and Northern Climate Exchange has galvanized adaptation planning in Yukon.

PEEL REGION'S CLIMATE CHANGE PLANNING PROCESS

In early 2009, Peel Region brought together the municipalities of Mississauga, Brampton and Caledon, the Credit Valley Conservation Authority and the Toronto and Region Conservation Authority to develop a combined climate change mitigation and adaptation strategy for the region as a whole.

The partners set up a Steering Committee of senior managers to oversee the project, a staff Project Team to work on details and a Communications Working Group. They also hired a consulting team that worked closely with the Project Team, organized workshops and drafted background reports and strategies.

1. BACKGROUND RESEARCH

In consultation with the Steering Committee and Project Team, consultants prepared an Adaptation Background Report, and a separate Mitigation Strategies Report. The adaptation report included:

- A review of climate change projections for Ontario and a listing of possible impacts from the climate change literature
- An inventory of climate change activities by partner and by sector
- A gap analysis of these activities
- Separate consideration of natural heritage challenges and strategies.

2. STAKEHOLDER WORKSHOPS TO DISCUSS AND COMMENT ON THE BACKGROUND REPORTS

Two major workshops were held with an array of stakeholders to get initial input into the development of the background reports.

3. PREPARATION AND REVIEW OF A DRAFT CLIMATE CHANGE STRATEGY

A combined draft climate change mitigation and adaptation strategy was prepared in consultation with the Project Team and Steering Committee.

Workshops were held with stakeholders and with Council to comment on the draft strategy. An Action Planning workshop was also held with key staff from the six partner organizations. And finally, the strategy was discussed with the public at Community Open Houses.

4. ADOPTION AND LAUNCH OF THE CLIMATE CHANGE STRATEGY

The revised Climate Change Strategy was approved by each of the four Councils and the two conservation authorities in the summer of 2011. The strategy included specific commitments and timeframes, and for each commitment indicated whether the Region, Area Municipalities or Conservation Authorities had leadership responsibilities. Work on the short-term commitments in the strategy is now underway.

5. SELECTED ADAPTATION COMMITMENTS IN THE PEEL CLIMATE CHANGE STRATEGY

- Complete a vulnerability risk assessment of all infrastructure, of the community (e.g. assessment of human health impacts) and of natural heritage
- Incorporate adaptation considerations into municipal official plans, by-laws and policies as they are updated
- Work with other jurisdictions to urge more stringent provincial action on Ontario's Building Code (to incorporate requirements that make buildings more resistant to high winds and flooding)
- Work with other jurisdictions to develop agricultural strategies in response to weather and other potential climate change impacts
- Enhance emergency management to adapt to climate change considerations
- Undertake specific initiatives to maintain and restore natural habitats and naturalized spaces within urban areas
- Explore the creation of a regional forest management plan for landowners
- Redesign and retrofit stormwater infrastructure to reduce vulnerability to climate change
- Develop and enhance programs to alleviate public health vulnerabilities

Enhance pavement design to prevent buckling due to intense heat events.

OAKVILLE'S ADAPTATION PLANNING PROCESS

The Town of Oakville is one of 16 communities that have joined a new Climate Change Adaptation initiative by ICLEI Canada to aid in the development of municipal adaptation plans. ICLEI developed a five-milestone adaptation framework similar to the five steps for mitigation planning in the Partners for Climate Protection (PCP) program. PCP is jointly run by ICLEI and the Federation of Canadian Municipalities. The program helps municipal governments develop and implement corporate and community climate change mitigation strategies. Niagara Region, St. Catharines and Welland are among the 55 Ontario members of Partners for Climate Protection.

The five milestones for ICLEI's Adaptation partners are outlined in graphic form in their guidebook Changing Climate, Changing Communities:

In 2010, Oakville hosted the ICLEI workshop that introduced their new adaptation initiative and guidebook, and was one of the first Canadian communities to sign on to the project. The City of Windsor and Durham Region are two other Ontario partners.

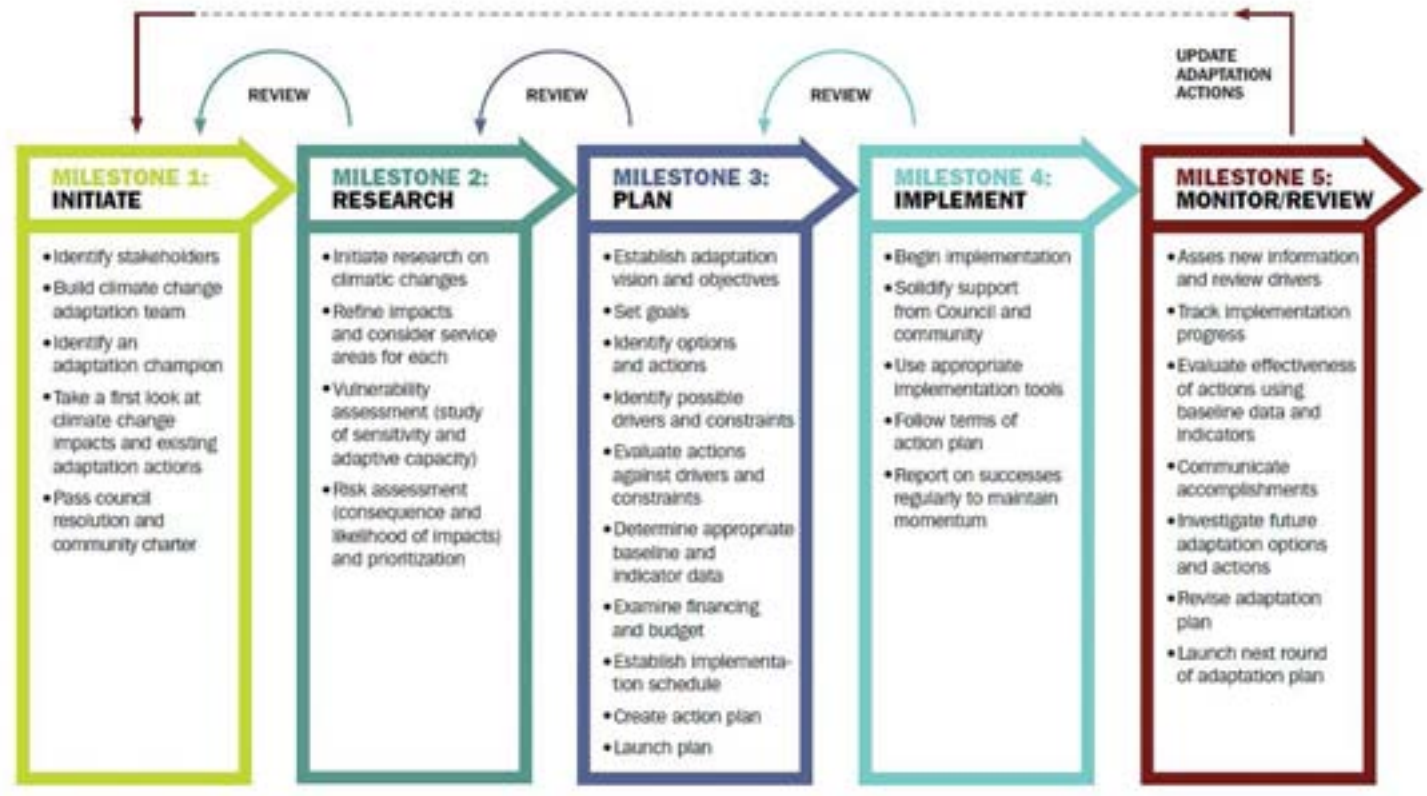
Although municipalities can download the ICLEI guidebook from the internet and work their way through the milestones independently, joining the program allows participants to attend an annual workshop with other municipal members; participate in adaptation planning webinars; network with one another to discuss strategies and obstacles; and access to a range of resources.

Oakville completed Milestone 1 in early 2011 and is now working on Milestone 2.

VULNERABILITY AND RISK ASSESSMENT

TORONTO'S RISK ASSESSMENT FOR TRANSPORTATION SERVICES

The Transportation Services Division of the City of Toronto has recently conducted two climate change risk assessments. The first of these assessments piloted a new tool developed by the City of Toronto and Deloitte Consulting, designed to assess climate risks for assets and operations in all the areas of responsibility in a municipal department. The completed risk assessment was recognized as one of the top five finalists for the Transportation Association of Canada's Environmental Achievement Award for 2011. The City of Toronto has agreed to make this tool available to other Ontario municipalities.



The Division engaged 14 experienced staff knowledgeable about the different assets and operations managed by the Division. This group was trained in the use of the risk assessment tool, and met for 15 half-day sessions to identify and prioritize risks. The group also held 3 half-day workshops to identify adaptation strategies.

RISK SOURCES INVESTIGATED	AREAS OF CONCERN
Extreme freezing rain	Infrastructure Asset Management
Extreme rain	Expressway and Structures
Extreme heat	Urban Traffic Control
Freeze/thaw cycles	Systems
Extreme snowfalls	Business Systems
Extreme cold	Plant Installation and Maintenance
Extreme wind	Road Operations

Adapted from a presentation by Vesna Stevanovic-Briatico to the Municipal Adaptaion Training Program, Richmond HIll, April 5, 2011

The assessors examined seven types of extreme weather events and how they affect more than 90 assets and services managed by the Division. They then constructed a number of "what if" scenarios to investigate the additional risks that could occur as a result of climate change. What if, for example:

- The city was subjected to a week-long heat wave
- A major snowfall was followed by freezing rain
- Extreme rain fell during winter when the ground was frozen.

For each of these "what if" scenarios, they identified first-order impacts (e.g. pavement softening, flooding, sewage system failure), second order impacts (e.g. roads flooded and blocked; damage to bridges, culverts and road surfaces), third order impacts (e.g. disruption of traffic, costs for repairs...) and so on. They then estimated the likelihood that the identified impacts would occur and the severity of these impacts, to come up with risk ratings of low, medium, high or extreme for each impact.

Most of the identified risks fell into the low or medium category, but about 4% of the current risks identified for road operations were classified as "extreme" (likely or almost certain to occur, and with major or catastrophic consequences if they do occur). However, the number of high risk scenarios is expected to double by 2040-50 and the number of extreme risk scenarios is expected to quadruple in this timeframe.

The assessment included identification of the ways in which the Division currently controls risks, and generated new ideas for future risk controls. Toronto is now able to prioritize actions that will help adapt the City's transportation infrastructure, and to reduce damage and disruption from extreme weather.

Following this departmental risk assessment, Transportation Services also undertook a specific risk assessment of three high-risk culverts in Toronto, with the support of Engineers Canada, and using their risk assessment methodology.

Toronto has 154 major culverts, some of which are vulnerable to intense rainfall that increases the flow of water and collection of debris in the structures. When water flows are high and debris blocks the culverts, the soils around them become saturated and can give way, as they did around the Black Creek culvert at Finch Avenue after the August 19th storm in 2005. The culvert failure, shown in the photo below, demolished a four-lane road, damaged hydro, gas, communication and sewage lines and took many months to reconstruct. The new culvert is sized for a much larger storm and has a new system to manage overland flows as shown in the photos to the left.

City of Toronto culvert at Finch Avenue, 2005 and 2007

The assessment involved several City of Toronto Divisions in addition to Transportation Services. The report was completed recently, but at the time of writing has not yet been reviewed by management of Transportation Services. The report contains recommendations for assessing other culverts in the city, construction of culverts, and maintenance and reporting practices. The report should be released in the spring of 2012.

WEATHERWISE PARTNERSHIP'S ELECTRICAL SECTOR CLIMATE CHANGE RISK ASSESSMENT

A new multi-stakeholder partnership has begun work to assess climate change impacts and facilitate adaptation for key sectors in southern Ontario, and may serve as a model for the much-needed collaboration of governments, the private sector and non-governmental organizations.

In 2011 the City of Toronto and the Greater Toronto CivicAction Alliance joined forces to form the WeatherWise Partnership, a collaboration of public, private and not-for-profit organizations that has begun working together to better protect the region from extreme weather. More than 50 organizations from the financial, insurance, transportation, telecommunications, energy, housing, legal, real estate, engineering and government sectors have participated in meetings to date. The Partnership has pledged to identify risks and prioritize areas for action by businesses, community organizations and governments in the face of more extreme rain, snow, wind and heat.

In the fall of 2011, WeatherWise identified the continuation of electrical power during extreme weather events as its first priority. The Partnership convened an Electrical Sector Working Group to undertake a climate change risk assessment for the sector to:

- Identify extreme weather events expected in the short-, medium- and longer-term
- Survey major customers to determine the risk tolerance of critical infrastructure providers, major employers, emergency responders and others to electrical outages
- Quantify the impacts on key components of the electrical system
- Identify and prioritize a set of adaptation measures for the electrical system and its customers.

The project has established a Core Project Team with representatives from:

- Toronto Hydro
- Hydro One
- Ontario Power Generation
- Ontario Ministry of Energy
- Independent Electricity System Operator
- Ontario Power Authority
- Toronto Environmental Office.

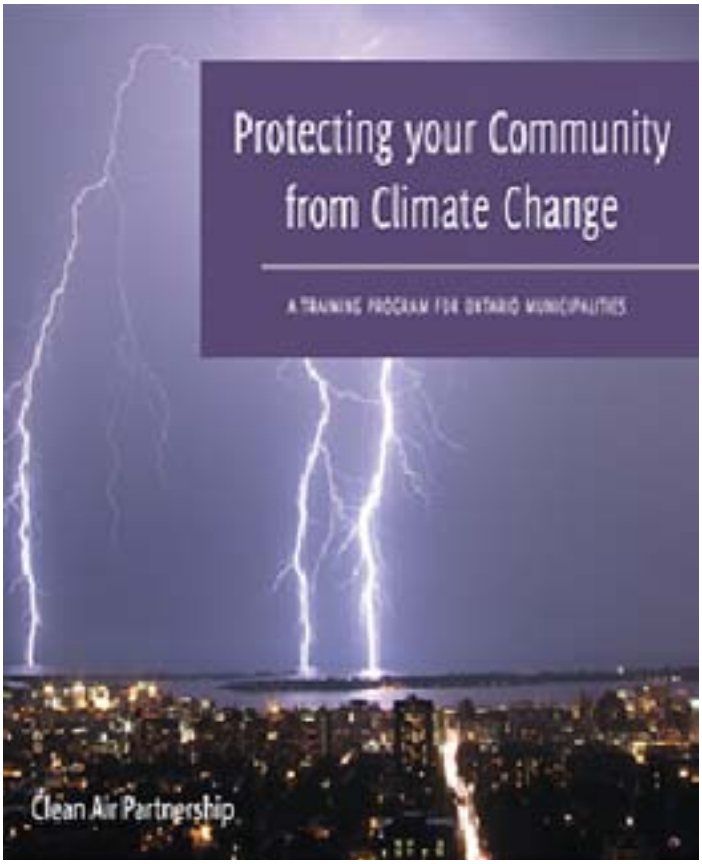
The group is seeking the participation of other utilities in the wider region, including Horizon Utilities, which supplies electricity to Hamilton and St. Catharines. While the focus of the assessment is on the area north of Lake Ontario from Hamilton to Durham, its analysis may be very useful for Niagara as well.

EDUCATION AND ADAPTATION CAPACITY DEVELOPMENT

A number of organizations contribute to climate change adaptation education and capacity development in Ontario. Two of these are described below.

CLEAN AIR PARTNERSHIP'S MUNICIPAL ADAPTATION TRAINING PROGRAM

The Clean Air Partnership has been working on climate change adaptation with municipal governments in Ontario since 2006, conducting research, holding conferences and workshops, and from 2008 to 2010, hosting more than 20 webinars for municipalities on different aspects of climate change adaptation.



In 2011, the Clean Air Partnership (CAP) developed and implemented a four-day intensive training program for municipal staff on climate change impacts and adaptation. CAP developed 12 training modules on the following topics:

- An Introduction to Climate Change, Trends and Projections
- Impacts on Ontario Municipalities
- Climate Change Adaptation Planning
- The Adaptation Team
- Creating an Initial Assessment of Vulnerabilities
- Climate Change Risk Assessment
- Identifying and Choosing Adaptation Options
- Integrating Adaptation into Municipal Plans

- Municipal Programs to Implement Adaptation
- Drivers and Barriers
- Communicating to and Engaging Stakeholders
- Indicators of Progress.

Each module has a backgrounder, Powerpoint presentation and a discussion guide or exercise for participants.

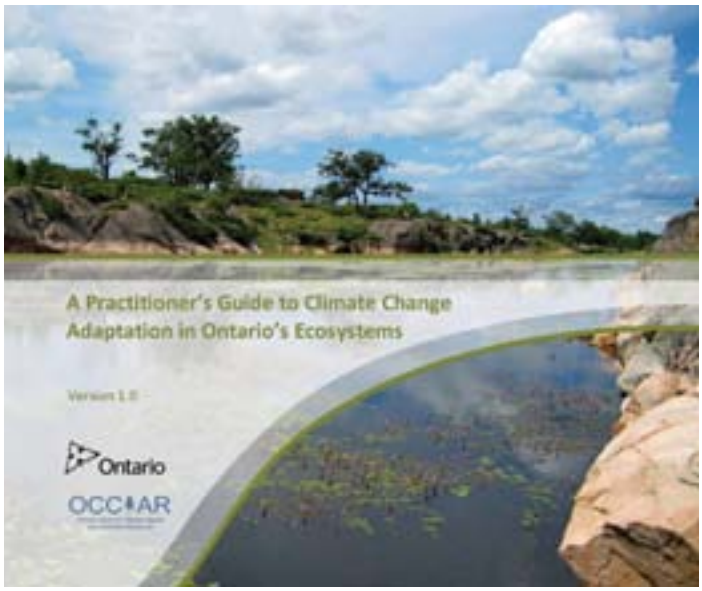
More than 60 municipal representatives participated in the program, which conducted training in four regions of the province. Following the four-day training sessions, CAP organized a "train-the-trainer" program to help course participants who wished to replicate the training in their municipalities or regions.

This program was funded by Natural Resources Canada and the Ontario Ministry of Environment, as part of the work of the Ontario Regional Adaptation Collaborative. CAP is willing to offer the program to municipalities that did not participate in the 2011 sessions. However, because funding for this program has ended, there will be a charge for new training sessions.

ONTARIO CENTRE FOR CLIMATE IMPACTS AND ADAPTATION RESOURCES RISK MANAGEMENT WORKSHOPS

The Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) is a university-based resource hub that provides information and resources to stakeholders and researchers in the field of climate change impacts and adaptation. The Centre began as a hub for climate change impacts and adaptation researchers in Ontario, and created and maintains a website with a large amount of information on these issues. OCCIAR also hosts the Climate Change Adaptation Community of Practice, which facilitates networking among researchers and practitioners to discuss adaptation strategies.

Since 2001, OCCIAR has worked with a variety of municipalities throughout Ontario to disseminate knowledge of the impacts of climate change and has provided guidance on how to adapt to the impacts of climate change. OCCIAR has hosted climate change risk management workshops in communities including Ottawa, Toronto (with the Toronto and Region Conservation Authority), Sudbury, Guelph, Sault Ste. Marie, Thunder Bay, Wingham, St. Catharines, Barrie, Timmins, Sioux Lookout, Hearst, Cochrane, Kapuskasing and Attawapiskat. OCCIAR tailors its workshops in response to the demographic, economic and cultural diversity of these communities.



OCCIAR has played an increasing role recently in adaptive capacity development with Conservation Authorities. OCCIAR has led workshops with the Maitland Valley, Cataraqui, Hamilton and Mississippi Valley Conservation Authorities. In 2010, OCCIAR hosted a workshop for five Conservation Authorities in northern Ontario and is planning a follow-up workshop in March of this year. In addition, working together with Conservation Ontario, OCCIAR recently hosted a series of climate change adaptation workshops for all southern Ontario Conservation Authorities. The work with Conservation Authorities and the Ministry of Natural Resources, led to development of OCCIAR's publication A Practitioners Guide to Climate Change Adaptation in Ontario's Ecosystems.

OCCIAR advocates the risk management approach for dealing with climate change, using Adaptation to Climate Change: A Risk Based Guide for Ontario Municipalities, by Jim Bruce in 2006 and recently updated for the Ministry of Municipal Affairs and Housing. Each session allows OCCIAR to obtain feedback from participants and fine tune the process for subsequent events. As a result, OCCIAR holds an in-depth understanding of the risk management approach to climate change adaptation and has extensive experience in its application to communities across Ontario.

WATER CONSERVATION: MEETING THE CHALLENGE OF REDUCED WATER SUPPLY

CITY OF GUELPH WATER CONSERVATION STRATEGIES

Guelph is one of the few cities in Canada that relies exclusively on underground aquifers (groundwater) to meet its water demands. Groundwater takes longer to replenish than surface water and is more susceptible to overuse. Recent dry summers and droughts have further reduced the water supply. At the same time, Guelph's population is growing. All these factors mean that Guelph's water supply is quite vulnerable to climate change.

Guelph has been active in water conservation for a decade, with programs such as:

- The Outside Water Use Program (created in 2002) which sets three enforceable levels for outside water use, depending on water availability: blue for "careful use"; yellow, which restricts outside use; and red, which stops non-essential uses
- The Royal Flush Toilet Program (introduced in 2003) which established a rebate for installation of low-flow toilets
- The Smart Wash Washing Machine Rebate Pilot Program (launched in 2008) which provided a $100 rebate for homeowners who installed an Energy Star® rated washing machine
- The Landscape Assessment Pilot Program (started in 2008) which provided free 30-minute assessments with a City Landscape Advisor to help residents plan more water efficient gardens
- Many public education and outreach programs including the Waterloo/Wellington Children's Water Festival, Annual Waterworks Open House, and Guelph Water Conservation and Efficiency Awards.

The City's Water Supply Master Plan and City Council's Strategic Plan set water use reduction targets of 10% by 2010, 15% by 2015, and 20% by 2025. To achieve these targets, Council updated their Water Conservation and Efficiency Strategy in 2009, after extensive public consultation. The updated strategy added several additional programs to reduce water consumption, including:

- The Residential, Industrial, Commercial, and Institutional Clothes Washer Rebate Program, which offers a rebate of $200 per clothes washer would be offered to any apartment building owner who replaces a high water volume clothes washer with a water efficient model
- The Grey Water Reuse System Rebate Program that provides a one-time $1,000 rebate for home builders installing grey water reuse systems as part of new home construction
- A Rainwater Harvesting System Rebate of up to $2000 for homeowners who install an approved rainwater harvesting system
- A water efficiency education program for schools based on the Ontario curriculum requirements.

The City also initiated studies to evaluate: water loss in the distribution system; , residential water demand; industrial, commercial and institutional water use; and the identification and evaluation of water efficiency and conservation program alternative.

These water conservation activities are a real success story. While the city's population continues to grow, the City's

total water consumption is on a decline. Guelph residents use 190 litres of water each day, compared to the national daily average of 335 litres. This achievement reflects a commitment to water conservation by Guelph residents and will reduce the impact of climate change on Guelph's water supply. For More information see Guelph's Water Conservation and Efficiency Strategy Update (2009).

RESILIENT BUILDINGS

INSTITUTE FOR CATASTROPHIC LOSS REDUCTION

The Institute for Catastrophic Loss Reduction (ICLR) is a non-profit centre established by the insurance industry to conduct research on disaster prevention. The insurance industry is particularly attuned to weather-related disasters and has long been concerned about the impacts of climate change. The Executive Director of ICLR is a lead author for the Intergovernmental Panel on Climate Change.

ICLR is affiliated with the University of Western Ontario, where it runs the Three Little Pigs Project, to test the effects of extreme wind on light-frame housing in a university wind tunnel. The wind tunnel is also used to test protective construction techniques. ICLR Associates at Western have also been involved in leading edge studies to assess flood risks due to climate change.

ICLR has a wide range of activities in addition to research. These include:

- Collaborating with individual insurance companies to build Disaster-Resilient Model Homes that showcase adaptive construction and landscaping. Depending on regional vulnerabilities, the model homes are designed to resist flooding, wildfire, hurricanes, tornadoes or earthquakes. One of these model homes was built in 2008 in Fort Erie. The home was designed to be resistant to extreme winter weather, high winds and rainstorms. It included the following features:
  - ◊ Steel hurricane clips and strapping to secure roof trusses to the framing and braced gable ends to withstand high winds
  - ◊ Reinforced rebar in the foundation
  - ◊ Triple-glazed windows and doors
  - ◊ Laminate shingles installed with additional nails
  - ◊ Ice and water shield over the roof
  - ◊ Spray foam insulation, and
  - ◊ 5/8 inch fire rated drywall
- Hamilton Home Retrofit to showcase methods to reduce basement flooding
- Collaboration with Habitat for Humanity in London and other cities to make affordable housing more resilient to climate extremes, based on building practices that ICLR has asked the province to include in the next revisions to the Ontario Building Code
- Production of guides for more resilient homes, including:
  - ◊ Designed for Safer Living Home Builders' Guide, and
  - ◊ Handbook for Reducing Basement Flooding

ICLR's activities are not limited to promoting more resilient home building and retrofits. The organization also has programs on:

- Disaster planning for small businesses, called Open for Business
- Disaster planning for cities, called RSVP ... for Cities

ICLR has a very active program for communicating about climate change, its impacts, and ways to reduce vulnerability. This program includes research reports, monthly workshops and webinars, conferences, electronic newsletters and Twitter updates on climate change and other disaster news and analysis.

STORMWATER MANAGEMENT

Ontario has been subject to unprecedented numbers of damaging floods in the last decade. Even where overland flooding has not occurred, intense rainfall and rain-on-snow events have combined with urban expansion to increase runoff of polluted stormwater. At the same time, cuts in federal and provincial spending contributed to the deterioration of stormwater and other types of infrastructure. Concern about this situation has led to a number of innovative projects, including the two outlined below.

CREDIT VALLEY CONSERVATION AUTHORITY (CVCA) LOW IMPACT DEVELOPMENT LEADERSHIP

CVCA manages the watershed of the Credit River, which flows south from Orangeville through Caledon, Brampton and Mississauga to Lake Ontario. The Authority is concerned about urban stormwater runoff as one of the major threats to water quality in rivers and streams in the watershed. Climate change exacerbates this threat.

CVCA has become a leader in Low Impact Development (LID) to address these impacts and recently received a $1 million grant from the Province for Showcasing Water Innovations. The organization makes the case for strategies that mimic water flows in natural systems as a way of protecting the health of watersheds, and preventing water pollution, flooding and erosion. LID manages rain where it falls and takes the pressure off stormwater infrastructure. Specific LID techniques include:

- Site design of development projects to increase infiltration of rain water and reduce runoff
- Rainwater harvesting
- Green roofs
- Downspout disconnection
- Vegetated filter strips
- Permeable pavements
- The use of swales, etc.

CVCA is pursuing a number of coordinated strategies to expand the implementation of low impact development in their region. These include:

- Preparation and distribution of LID guides including the Low Impact Stormwater Management Planning and Design Guide, tailored to designers and the Designers Guide for Low Impact Development Construction, a more detailed technical guide for inspectors and contractors
- Urban watershed studies that include fieldwork to identify pollution hotspots and work with stakeholders to implement pollution prevention plans
- A Sustainable Stormwater Management Funding Study that provided an overview of funding mechanisms that municipalities could use to support implementation of LID
- Nine LID workshops that have educated approximately 2000 local and Ontario-wide professionals including municipal and provincial staff, developers, consulting engineers and landscape architects, contractors and municipal inspectors
- Hiring LID specialists to assist designers and plan review staff
- 20 demonstration sites and pilot projects, and performance monitoring for 9 of these, including:
- 30 more LID sites for new developments are in the planning stages
- New strategies for achieving support for LID by appealing to public concerns such as safety and aesthetics.

PROACTIVE ADAPTATION TO PROTECT AGAINST FLOODING IN RICHMOND HILL

In 2010, the Town of Richmond Hill completed its renovation of the Pioneer Park Stormwater Management Facility, the first of its kind to be rebuilt to protect against the more intense storms that are expected as a result of climate change. The new facility received a National Watershed Award from the Federation of Canadian Municipalities and a Technical Innovation Award from the Ontario Public Works Association.

Pioneer Park Stormwater Facility, Town of Richmond Hill

The Town of Richmond Hill is located about 5 kilometers north of Toronto, and has a population of about 190,000. Town officials have had growing concerns about the capacity of the community's existing infrastructure to withstand the combined impacts of rapid urbanization and climate change.

Officials have been especially worried about increases in the frequency and severity of storms, and the potential for flooding. As a result, the Town developed a rating system to measure the performance of 86 stormwater management facilities and prioritize those which needed upgrades to protect against more intense rainfall. Based on data collected from weather stations, stream gauges and water level gauges, the Town made the Pioneer Park Stormwater Management Facility a priority and decided to reconstruct the facility, incorporating climate change factors into the design to help it withstand storms and protect against future flooding.

The original stormwater system was built in the 1980's to serve 26 hectares of residential development. Today it receives stormwater from 740 hectares of nearby subdivisions. The facility borders a major road, with a nearby hospital, and police and fire department headquarters, all of which could be cut off by a flood. A tributary of the East Don River had previously been degraded by erosion, sedimentation and raised water temperatures as it passed through the stormwater pond. A snow storage facility is located upstream of the pond, and in quick melt conditions, could contribute to flooding. The stormwater facility includes a wet pond, a dry pond to catch overflow in high water conditions, an oil-and-grit separator to improve the quality of water that gets released to receiving water bodies, and other features.

The project increased the capacity of the stormwater system to withstand a 100-year flood – far beyond the capacity of most stormwater systems in Ontario. The Town also worked with the Toronto Region Conservation Authority to construct a new channel that would protect fish and allow them to swim upstream to spawn, created new wetlands, and added Carolinian trees and other vegetation to the surrounding parklands.

The Town is conducting ongoing monitoring to ensure that the facility continues to function properly. The lessons learned from the construction and operations of the facility are now being applied to three new stormwater rehabilitation projects in Richmond Hill.

EMERGENCY MANAGEMENT

EMERGENCY MANAGEMENT IN YORK REGION'S DRAFT ADAPTATION STRATEGY

Like all municipalities in Ontario, York Region is required to conduct annual exercises to test the effectiveness of their Emergency Plan. The Region has a strong focus on extreme weather hazards in its emergency planning. In the last seven years of annual exercises to test and evaluate the Region's readiness for emergencies, five have focused on severe weather events. The 2011 exercise simulated a severe summer storm resulting in multiple impacts in two municipalities. The 2010 exercise simulated an emergency based on a severe thunderstorm microburst causing a widespread power blackout and cascading equipment failures. The 2008 and 2006 exercises simulated different flooding events in the region. The 2005 exercise tested response to a severe winter snow storm event. Some of these exercises predated York Region's work on climate change adaptation.

York's adaptation planning began with a 2008 discussion paper and workshop that brought together staff from the regional government, local municipalities, conservation authorities, utilities, school boards, emergency management, police, fire and ambulance services to discuss climate change impacts and potential responses. Emergency managers and responders subsequently played a strong role in developing the Region's Draft Climate Change Adaptation Action Plan, released in November 2011. The draft plan identifies emergency response as one of six key areas that require action, and places more emphasis on emergency response than many recent adaptation strategies.

The Draft Adaptation Plan included a number of recommendations that pertain to emergency preparation and response, Including:

- Better communicate emergency response system and incident management so that departments understand who does what when, what are the roles and responsibilities
- Enhance tracking of climate change related incidents
- Review Department programs and emergency plans to prepare for increased numbers and scope of climate change related events
- Determine response and recovery capabilities in case of lengthy extreme weather events
- Include more specific information on climate change hazards in the Emergency Plan
- Explore the need to update flood and hazard mapping with the conservation authorities
- Partner with local municipalities, agencies, businesses, etc. to open cooling centres, emergency centres, and establish distribution centres for emergency assistance
- Partner with local businesses and media on heat awareness and home emergency kits
- Work with hospitals to track heat-related Emergency Room admissions
- Build on Heat Advisory Notification program to establish a Regional Extreme Weather Notification program
- Consider requiring emergency plans for multi-story building tenants and residents
- Identify and map vulnerable populations to provide support during extreme weather events
- Develop emergency preparedness tools for people with disabilities
- Develop a fire response plan for the Regional forest.

Although climate change is not yet explicitly addressed in York Region's Hazard Identification and Risk Assessment and its Emergency Plan, the Emergency Management department is keen to incorporate climate change analysis into its work to better safeguard the region's population from its impacts.

LINKS TO OTHER CASE STUDIES

A growing number of organizations have written case studies of climate change adaptation by communities across Canada. Brief outlines are provided below, along with links to the case studies.

NATURAL RESOURCES CANADA (NRCAN)

NRCAN has gathered together eleven short case studies of community adaptation processes across Canada in its publication Adapting to Climate Change: An Introduction for Canadian Municipalities. Each case study focuses on different aspects of adaptation. For example:

- City of Kamloops' Wildfire Protection Plan
- Metro Vancouver's Stormwater Management Program
- Edmonton's Urban Forest Management Plan
- Regina's Water Conservation Program
- London, Ontario's Adaptation Strategy (to Protect Against Flooding)
- Toronto's Heat Health Alert System
- Québec City's Environmental Services Adaptation Plan.

CLEAN AIR PARTNERSHIP (CAP)

CAP has recently facilitated a number of case studies of potential interest to the Niagara region. These are available on their Community Adaptation Initiative website. The reports include:

- Integrating Adaptation into the Town of Ajax's Official Plan
- Adapting to Changing Flood Patterns in the City of Hamilton
- Creating a Regional Climate Change Strategy in Peel
- Community Based Adaptation in Brampton through the Neighbourhood Retrofit Action Plan
- A Street Tree Survival Strategy in Toronto

CAP has also published two other reports that examine municipal and regional climate change adaptation planning efforts:

- Cities Preparing for Climate Change: A Study of Six Urban Regions
- Climate Change Adaptation in the City of Toronto: Lessons for Great Lakes Communities

A shorter case study of Toronto's adaptation process, Climate Change Adaptation Planning in Toronto: Progress and Challenges, is available from the World Bank.

ONTARIO CENTRE FOR CLIMATE IMPACTS AND ADAPTATION RESOURCES (OCCIAR)

OCCIAR is a resource hub for information on climate change impacts and adaptation and is based at Laurentian University in Sudbury. OCCIAR has recently released a case study on:

- Climate Change Adaptation in the City of Greater Sudbury

OCCIAR has also conducted numerous workshops with municipalities and conservation authorities to help these agencies develop climate change adaptation programs. One of their municipal workshops was held in St. Catharines in 2008. A workshop was also held in 2011 for the Hamilton Conservation Authority and the City of Hamilton. Workshop Reports are available on the OCCIAR website.

COLUMBIA BASIN TRUST (CBT)

CBT develops and delivers a variety of programs in support of communities located in the Columbia watershed in the southeast corner of B.C. The organization established a Communities Adapting to Climate Change Initiative in 2008, to work with communities to identify the risks of climate change and then develop recommendations and plans to address these risks.

CBT has prepared case studies on the adaptation process in five communities that have completed adaptation plans. Most of these processes were involved the participation of a range of community members and community organizations.

- Castlegar Case Study
- Regional District of Central Kootenay/Kaslo Case Study
- Rossland Case Study
- Kimberley Case Study
- Elkford Case Study

All of these case studies, along with a variety of other relevant reports, are available at the Columbia Basin Trust Adapting to Climate Change website.

NORTHERN CLIMATE EXCHANGE (NCE)

NCE has been working since 2000 to respond to growing concerns about the impacts of climate change in northern Canada. NCE has initiated and reported on Community Climate Change Adaptation Projects in at least four northern communities including:

- WhiteCAP: Whitehorse Adaptation Project
- Dawson Adaptation Project
- Atlin Adaptation Project
- Mayo Community Climate Change Adaptation Project

Reports on all of these adaptation projects are available on the Northern Climate Exchange Community Climate Change Adaptation Projects website.

APPENDIX B

RESOURCES AND REFERENCES

Note: A number of the references in this report are for documents and figures prepared by scientists at the former Adaptation and Impacts Research Section of Environment Canada. Unfortunately, Environment Canada has dismantled this Section, stopped its Impacts and Adaptation work and taken many of these documents off its website. As a consequence, several of the resources and references included here are no longer publically available.

GENERAL RESOURCES

Expert Panel on Climate Change Adaptation. (2009). Adapting to Climate Change in Ontario: Towards the Design and Implementation of a Strategy and Action Plan. The Queen's Printer for Ontario. Retrieved from http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/std01_079212.pdf

Lemmen, D.S., Warren, F.J., LaCroix, J. & Bush, E., eds. (2007). From Impacts to Adaptation: Canada in a Changing Climate 2007. Natural Resources Canada. Retrieved from http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/assessments/132

1. CLIMATE BASICS

Pachauri, R.K. & Reisinger, A. (2007). Climate Change 2007 Synthesis Report. Intergovernmental Panel on Climate Change, Geneva. Retrieved from http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html

National Aeronautics and Space Administration. (2011). Global Climate Change: Vital Signs of the Planet. Retrieved from http://climate.nasa.gov/causes/

2. CLIMATE TRENDS AND PROJECTIONS FOR NIAGARA

AMEC Environment and Infrastructure. (2012). City of Welland Stormwater and Wastewater Risk Assessment: Technical Report.

Bourdages, L. & Huard, D. (2010). Climate Change Scenario over Ontario. Consortium on Regional Climatology and Adaptation to Climate Change. Retrieved from http://www.ouranos.ca/Ontario/Results_html/Rapport.pdf

Cao, Z. & Ma, J. (2009). Summer Severe-Rainfall Frequency Trend Variability over Ontario, Canada. Journal of Applied Meteorology and Climatology, 48(9), pp.1955-1960. Retrieved from http://journals.ametsoc.org/doi/abs/10.1175/2009JAMC2055.1?journalCode=apme

Cheng, C.S., Auld, H., Li, G., Klaassen, J., & Li, Q. (2007). Possible Impacts of Climate Change on Freezing Rain in South-Central Canada using Downscaled Future Climate Scenarios. National Hazards and Earth System Sciences, 7(1), pp. 71-87. Environment Canada. (2011). Heavy Rain Events in Ontario.

Fenech, A. & Shaw, T. (2010, December). Niagara Region's Changing Climate: Preliminary Results. Presentation to the Niagara Climate Change Network.

Great Lakes Environmental Research Laboratory. (2011). Water Levels of the Great Lakes: 2011 Update. Retrieved from http://www.glerl.noaa.gov/pubs/brochures/lakelevels/lakelevels_03_2011.pdf

Hamilton & Whitelaw. (2001). Climate Change Trends along the Niagara Escarpment. Niagara Escarpment Commission. Retrieved from http://www.escarpment.org/_files/file.php?fileid=fileRiKfhRuycr&filename=file_hamilton.pdf

Phillips, D. (2011). Historical Drought-Related Events. Environment Canada.

Sushama, L., Khaliq, N. & Laprise, R. (2010). Dry Spell Characteristics over Canada in a Changing Climate as Simulated by the Canadian RCM. Global and Planetary Change, 74(1), pp.1-14. Retrieved from http://www.sciencedirect.com/science/article/pii/S0921818110001578

Trapp, R.J., Diffenbaugh, N.S., Brooks, H.E., Baldwin, M.E., Robinson, E.D., & Pal, J.S. (2007). Changes in Severe

Thunderstorm Environment Frequency During the 21st Century Caused by Anthropogenically Enhanced Global Radiative Forcing. Proceedings of the National Academy of Sciences of the United States of America, 104(50), pp. 19719-19723. Retrieved from http://www.pnas.org/content/104/50/19719.short

U.S. Global Change Research Program. (2009). National Climate Change. In T.R. Karl, J.M. Melillo, and T.C. Peterson (Eds.) Global Climate Change Impacts in the United States (pp. 27-40). New York: Cambridge University Press. Retrieved from http://downloads.globalchange.gov/usimpacts/pdfs/National.pdf

3. LIKELY IMPACTS OF CLIMATE CHANGE IN NIAGARA

Auld, H., Klaassen, J., & Comer, N. (2007). Weathering of Building Infrastructure and the Changing Climate: Adaptation Options. Retrieved from http://www.ec.gc.ca/Publications/C35FAE12-0531-46F3-9378-BDF10096234DWeatheringOfBuildingInfrastructureAndTheChangingClimateAdaptationOptionsOccasionalPaper11.pdf

Canadian Cooperative Wildlife Health Centre. (2007). Type E Botulism in Birds. Retrieved from http://www.ccwhc.ca/wildlife_health_topics/botulism/botulisme_org.php

Colombo, S.J. (2008). Ontario's Forests and Forestry in a Changing Climate. Ontario: Ministry of Natural Resources. Retrieved from http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@climatechange/documents/document/276928.pdf

Goel, P.K., MacRitchie, S., Kaltenecker, G., Zaletnik, K., Cameron, I., Ramanathan, L., ... Fleischer, F. (2007). Canada-Ontario Agreement (COA) Respecting the Great Lakes Basin Ecosystem: Climate Change Monitoring Review Project. Retrieved from http://conservationontario.ca/watershed_management/documents/COA_CC_Guidance_Doct_Jan_2011_final.pdf

Great Lakes Water Quality Board. (2003). Climate Change and Water Quality in the Great Lakes Basin. Retrieved from http://www.ijc.org/php/publications/html/climate/index.html

Lemmen, D.S., Warren, F.J., & Lacroix, J. (2007). From Impacts to Adaptation: Canada in a Changing Climate 2007. Retrieved from http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/assessments/132

Hatfield, J.L., Boote, K.J., Kimball, B.A., Ziska, L.H., Izaurralde, R.C., Ort., D. Thomson, A.M., & Wolfe, D. (2011). Climate Impacts on Agriculture: Implications for Crop Production. Agronomy Journal. 103(2):351-370. Retrieved from http://www.ars.usda.gov/research/publications/publications.htm?seq_no_115=243239

Hunt, S., Newman, J., & Otis, G. (2006). Threats and Impacts of Exotic Pests under Climate Change: Implications for Canada's Forest Ecosystems and Carbon Stocks. Retrieved from http://www.biocap.ca/rif/report/Hunt_S.pdf

Millerd, F. (2007). Global Climate Change and Great Lakes International Shipping. Retrieved from: http://onlinepubs.trb.org/onlinepubs/sr/sr291_millerd.pdf

Mortsch, L., Ingram, J., Hebb, A. & Doka, S. (Eds). (2006). Great Lakes Coastal Wetland Communities: Vulnerabilities to Climate Change and Response to Adaptation Strategies. Retrieved from http://publications.gc.ca/collections/Collection/En56-210-2006E.pdf

Munich Reinsurance. (2011). Overall Picture of Natural Catastrophes in 2010. Retrieved from http://www.munichre.com/en/media_relations/press_releases/2011/2011_01_03_press_release.aspx

National Round Table on the Environment and the Economy. (2011). Paying the Price: Canada-Wide Costs of Climate Change. Retrieved from http://nrtee-trnee.ca/climate/climate-prosperity/the-economic-impacts-of-climate-change-for-canada/paying-the-price-canada-wide-costs-of-climate-change

Natural Resources Canada. (2007). Impacts on Agriculture. Retrieved from http://www.nrcan.gc.ca/earth-sciences/products-services/publications/climate-change/climate-change-impacts-adaptation/818

Natural Resources Canada. (2007). Impacts on Transportation Infrastructure. Retrieved from http://www.nrcan.gc.ca/earth-sciences/products-services/publications/climate-change/climate-change-impacts-adaptation/288

Niagara Peninsula Source Protection Authority. (2011). Niagara Peninsula Source Protection Area. In Approved Assessment Report Niagara Peninsula Source Protection Area, pp 7-46. Retrieved from http://www.sourceprotection-niagara.ca/pdf/ApprovedAR/Text/Chapter%202.pdf

Rutter, J.M., Ciborowski, J., DePinto, J., Bade, D., Baker, D., Bridgeman, T.B., and Pennuto, C.M. (2011). Lake Erie Nutrient Loading and Harmful Algal Blooms: Research Findings and Management Implications. Retrieved from http://www.ohioseagrant.osu.edu/_documents/publications/TS/TS-060%2020June2011LakeErieNutrientLoadingAndHABSfinal.pdf

Shaw, A.B. (2008). The Implications of Climate Change for the Ontario Wine Industry. Presentation to the Workshop Adapting to Climate Change in the Niagara Region, St. Catharines. Retrieved from http://www.climateontario.ca/doc/publications/TonyShawOCCIAR_SC.pdf

Varrin, R., Bowman, J., & Gray, P.A. (2007). The Known and Potential Effects of Climate Change on Biodiversity in Ontario's Terrestrial Ecosystems: Case Studies and Recommendations for Adaptation. Ontario: Ministry of Natural Resources. Retrieved from http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@climatechange/documents/document/276927.pdf

Wolfe, D. (2010). Climate Change Impacts on Northeast Agriculture: Overview. Retrieved from http://www.climateandfarming.org/pdfs/FactSheets/Impacts.pdf

Seguin, J. (Ed.). (2008). Human Health in a Changing Climate: a Canadian Assessment of Vulnerabilities and Adaptive Capacity. Retrieved from http://www.sindark.com/NonBlog/Articles/hc-cc-report/CCandHealth.pdf

4. CLIMATE CHANGE ADAPTATION IN NIAGARA

Association for Canadian Educational Resources. (2011). Planting for Change (P4C). Retrieved from http://acer-acre.ca/programs/planting-for-change-p4c

Canadian Climate Change Scenarios Network. (2011). Canadian Climate Change Scenarios Network. Retrieved from http://cccsn.ca/?page=main

City of St. Catharines. (2011). Tending our Garden City: the City of St. Catharines Sustainability Strategy. Retrieved from http://www.stcatharines.ca/en/governin/resources/ISCPwholefinalJuly18.pdf

City of St. Catharines, Recreation and Community Services Department. (2011). Urban Forestry Management Plan. Retrieved from http://www.stcatharines.ca/en/documents/documentuploads/OfficialDocumentsAndPlans/doc_634382068333613909.pdf

Environment Canada. (2012). National Climate Data and Information Archive. Retrieved from http://climate.weatheroffice.gc.ca/climate_normals/index_e.html

Forkes, J. (2010). Urban Heat Island Mitigation in Canadian Communities. Retrieved from http://www.cleanairpartnership.org/files/Background%20Paper%20Final.pdf

Goel, P.K., MacRitchie, S., Kaltenecker, G., Zaletnik, K., Cameron, I., Ramanathan, L., Fleischer, F. (2007). Canada-Ontario Agreement (COA) Respecting the Great Lakes Basin Ecosystem: Climate Change Monitoring Review Project. Retrieved from http://conservationontario.ca/watershed_management/documents/COA_CC_Guidance_Doct_Jan_2011_final.pdf

Heinen, W. (2011). 2011 Growing Season: Niagara Report. Retrieved from http://www.vineandtreefruitinnovations.com/OtherReports/Niagara_2011_Growing_Season_Final.pdf

Henschel, S. (2012). Energy Savings Made Quick. Retrieved from http://www.niagarathisweek.com/community/environment/article/1280758

Ministry of Natural Resources. (2012). Climate Change Mapping Tool. Retrieved from http://www.mnr.gov.on.ca/en/Business/ClimateChange/1ColumnSubPage/STDPROD_093198.html

Niagara Peninsula Conservation Authority. (2010). Natural Areas Inventory 2006-2009. Retrieved from http://www.npca.ca/wp-content/uploads/NAI-Vol-1.pdf

Niagara Peninsula Conservation Authority. (2012). NPCA HydroServer. Retrieved from http://www.his.npca.ca/hydroserver

Niagara Peninsula Conservation Authority. (2010). Stormwater Management Guidelines. Retrieved from http://www.npca.ca/wp-content/uploads/NPCASWMManual-Guidelines.pdf

Niagara Region. (2012). A Mesoscale Weather Monitoring Network for Niagara Region. Retrieved from http://www.niagararegion.ca/living/water/mesoscale-climate-weather-monitoring.aspx

Niagara Region. (2012). Historical Data for West Nile Virus in Niagara Region. Retrieved from http://www.niagararegion.ca/living/health_wellness/wnv/statistics-west-nile.aspx

Public Safety Canada. (2009). Your Emergency Preparedness Guide. Retrieved from http://www.getprepared.gc.ca/_fl/guide/national-eng.pdf

Weather Innovations Incorporated. (2012). Weather Innovations Incorporated. Retrieved from http://www.weatherinnovations.com/

Vineland Research and Innovation Centre. (n.d.). Greening Ontario Highways: Vineland Research and Innovation Centre. Retrieved from http://vinelandresearch.com/pub/docs/CaseStudy2GreeningOntHighways.pdf

Vineland Research and Innovation Centre. (n.d.). World Crops in Ontario. Retrieved from http://vinelandresearch.com/pub/docs/CaseStudy3WorldCrops.pdf

5. FILLING THE GAPS

Government of Alberta, Sustainable Resource Development. (2010). Climate Change Adaptation Framework Manual. Retrieved from http://www.srd.alberta.ca/MapsPhotosPublications/Publications/documents/ClimateChangeAdaptationFrameworkManual-April%202010.pdf

Penney, J. & Wieditz, I. (2007). Cities Preparing for Climate Change: A Study of Six Urban Regions. Retrieved from http://www.cleanairpartnership.org/pdf/cities_climate_change.pdf

Halifax Regional Municipality. (2012). Climate SMART: Be Cool – Reduce Global Warming and Climate Risks. Retrieved from http://www.halifax.ca/climate/

Peel Region. (2010). Peel Climate Change Strategy: Adaptation Background Report. Retrieved from http://www.peelregion.ca/planning/climatechange/reports/pdf/adaptation/gap.pdf

United Kingdom Climate Impacts Program. (2012). LCLIP: Local Climate Impacts Profile. Retrieved from http://www.ukcip.org.uk/lclip/

APPENDIX A: CASE STUDIES

ACC/CCA Community of Practice. (2011). The Climate Change Adaptation Community of Practice. Retrieved from http://www.ccadaptation.ca/?signin&r=%2f%3faction%3dsigninaction%253dsignin

Bruce, J.P., Egener, M., & Noble, D. (2006). Adapting to Climate Change: A Risk-Based Guide for Ontario Municipalities. Natural Resources Canada.

City of Guelph. (2009). Water Conservation and Efficiency Strategy Update. Retrieved from http://www.guelph.ca/uploads/ET_Group/waterworks/WCE%20Study/WCES%20Final%20Report.pdf

City of Ottawa. (2008). Climate Change Adaptation Plan Process. Retrieved from http://ottawa.ca/calendar/ottawa/citycouncil/occ/2008/08-28/pec/ACS2008-PTE-ECO-0013.htm

City of Toronto. (2012). Climate Change Adaptation. Retrieved from http://www.toronto.ca/teo/adaptation/index.htm

City of Toronto. (2012). The Weatherwise Partnership. Retrieved from http://www.toronto.ca/teo/adaptation/resilience.htm

Clean Air Partnership. (2010). Adaptation Strategies. Retrieved from http://www.cleanairpartnership.org/adaptation_strategies

Clean Air Partnership. (2011). Community Adaptation Initiative. Retrieved from http://www.cleanairpartnership.org/CAI

Columbia Basin Trust. (2011). Adapting to Climate Change. Retrieved from http://www.cbt.org/Initiatives/Climate_Change/?Adapting_to_Climate_Change

Credit Valley Conservation Authority. (2011). Designer's Guide for Low Impact Development Construction. Retrieved from http://www.creditvalleyca.ca/sustainability/lid/images/CVC%20LID%20Manual-DRAFT%209-23-11.pdf

Credit Valley Conservation Authority. (2011). Low Impact Development. Retrieved from http://www.creditvalleyca.ca/low-impact-development/

Credit Valley Conservation Authority & Toronto and Region Conservation Authority. (2010). Low Impact Development Stormwater Management Planning and Design Guide. Retrieved from http://www.sustainabletechnologies.ca/Portals/_Rainbow/Documents/LID%20SWM%20Guide%20-%20v1.0_2010_1_no%20appendices.pdf

ICLEI Canada. (2011). Changing Climate, Changing Communities. Retrieved from http://www.iclei.org/index.php?id=8708

Institute for Catastrophic Loss Reduction. (2011). Building Resilient Communities. Retrieved from http://www.iclr.org/_index.php

Institute for Catastrophic Loss Reduction. (2011). Hamilton Home Retrofitted to Reduce the Risk of Basement Flooding. Retrieved from http://www.iclr.org/images/Hamilton_retrofit_release.pdf

Institute for Catastrophic Loss Reduction. (2009). Handbook for Reduced Basement Flooding. Retrieved from http://www.iclr.org/images/Basement_Flood_Handbook_-_ICLR_-_2009.pdf

Institute for Catastrophic Loss Reduction. (2009). Home Builder's Guide. Retrieved from http://www.iclr.org/images/New_home_builders_guide.pdf

Institute for Catastrophic Loss Reduction. (2011). Open for Business. Retrieved from http://www.iclr.org/businesses/openforbusinesstm.html

Institute for Catastrophic Loss Reduction. (2011). RSVP... for Cities. Retrieved from http://www.iclr.org/communities/rsvpforcities.html

Kelly, G. (2010). Built to a New Code. Canadian Underwriter. Retrieved from http://www.iclr.org/images/Built_to_a_new_code_CU_Grant_Kelly.pdf

Kovacs, P. (2005). Promoting Resilient Homes. Canadian Underwriter. Retrieved from http://www.iclr.org/images/Promoting_05_May.pdf

Natural Resources Canada. (2011). London Ontario's Climate Change Adaptation Strategy. Retrieved from http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/municipalities/726

Northern Climate Exchange. (2011). Community Climate Change Adaptation Projects. Retrieved from http://www.taiga.net/nce/adaptation/projects.html

Northern Climate Exchange. (2011). Impacts and Adaptation. Retrieved from http://www.taiga.net/nce/adaptation/index.html

Ontario Centre for Climate Impacts and Adaptation Resources. (2012). Climate Change Adaptation in the City of Greater Sudbury. Retrieved from http://www.climateontario.ca/doc/casestudies/Sudbury%20Case%20Study%20-%20Final1.pdf

Ontario Centre for Climate Impacts and Adaptation Resources. (2012). Welcome to OCCIAR. Retrieved from http://www.climateontario.ca/

Ontario Centre for Climate Impacts and Adaptation Resources. (2012). Workshop Reports. Retrieved from http://www.climateontario.ca/workshops.php

Ontario Centre for Climate Impacts and Adaptation Resources & Ministry of Natural Resources Climate Change Program. (2012). A Practitioner's Guide to Climate Change Adaptation in Ontario's Ecosystems. Retrieved from http://www.climateontario.ca/doc/Tools/A%20Practitioners%20Guide%20to%20ClimateChange%20Adaptation%20in%20Ontario%27s%20Ecosystems%20Ver%201%202011.pdf

Oulahen, G. (2010) Habitat for Resilience. Canadian Underwriter. Retrieved from http://www.canadianunderwriter.ca/news/habitat-for-resilience/1000389796/

Penney, J. & Wieditz, I. (2007). Cities Preparing for Climate Change: A Study of Six Urban Regions. Clean Air Partnership. Retrieved from http://www.cleanairpartnership.org/pdf/cities_climate_change.pdf

Penney, J. (2008). Climate Change Adaptation in the City of Toronto: Lessons for Great Lakes Communities. Clean Air Partnership. Retrieved from http://www.cleanairpartnership.org/files/Penney_%20J_2008_Climate%20Change%20Adaptation%20in%20the%20City%20of%20Toronto.pdf

Penney, J. & Dickinson, T. (2009). Climate Change Adaptation Planning in Toronto: Progress and Challenges. World Bank. Retrieved from http://siteresources.worldbank.org/INTURBANDEVELOPMENT/rces/336387-1256566800920/6505269-1268260567624/Penney.pdf

Region of Peel. (2011). Adaptation Background Report. Retrieved from http://www.peelregion.ca/planning/climatechange/reports/aug132010-adaptation.htm

Region of Peel. (2012). Peel Climate Change Strategy. Retrieved from http://www.peelregion.ca/planning/climatechange/reports/pdf/climate-chan-strat-rep.pdf

Richardson, G.R.A. (2010). Adapting to Climate Change: An Introduction for Canadian Municipalities. Natural Resources Canada. Retrieved from http://www.nrcan.gc.ca/earth-sciences/climate-change/community-adaptation/municipalities/373

Town of Oakville. (2012). Climate Change Adaptation Initiative. Retrieved from http://www.oakville.ca/environment/climate-change-adaptation-initiative.html

Town of Richmond Hill. (2011). Pioneer Park Stormwater Management Rehabilitation Project. Retrieved from http://www.richmondhill.ca/documents/pioneer_park_stormwater_management_presentation.pdf

University of Western Ontario. (2011). Ideas on the Edge. (The Three Little Pigs Project). Retrieved from http://www.oit.on.ca/Downloads/Storypdfs/Western-Bartlett.pdf

York Region. (2011). Draft Climate Change Adaptation Plan and Stakeholder Workshop. Retrieved from http://www.york.ca/NR/rdonlyres/2ziaxgik7ysw26n5x3iqx77e4ba3q3wj73msi3bwtk53ieohvwiqd4zhnbtb52odktyg/rpt+9+cls+2.pdf

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