Appendix I: Data and Information Gaps

This appendix outlines the key data and information gaps for each climate change – watershed issue: source water protection, low water response, stormwater management, riverine flooding, and integrated watershed management, including gaps pertaining to guidance materials and tools, as articulated by each of the five Local Adaptation Collaboratives (LACs). The appendix is intended to act as an organic/living document, requiring updating and continuous improvement as more data, information, guidance and tools become available, and as watershed managers become more aware and knowledgeable around their specific needs to enhance their understanding of vulnerability, risk, and adaptation options. While adaptation is typically a "process" of an evolving understanding of climate change risks and its application into action, the purpose of this appendix is to identify the meta data requirements, specifically longitudinal data sets, information, guidance and tools that are used or needed by the LACs for each of the climate change related risks associated with watershed management. In many cases the data and information gaps identified reflect the challenges facing the LACs to establish a comprehensive baseline of their own watershed characteristics, and the gaps that need to be addressed to determine vulnerability to current climate, let alone climate change impacts. In addition to gaps, policy issues pertaining to the regulatory environment framing each climate change – watershed issue are identified. However, in the absence of a more comprehensive policy analysis, the appendix and corresponding report only touches upon related policy issues, and as such the discussion is intended to be more policy relevant rather than policy prescriptive.

I. Source Water Protection:

Source Protection Committees are responsible for overseeing source water protection (SWP) in Ontario. Mississippi-Rideau Source Protection Committee (MRSPC) includes representatives from both the Mississippi Valley Conservation Authority (MVCA) and the Rideau Valley Conservation Authority (RVCA). In terms of addressing climate change, MVCA is somewhat further ahead of RVCA, having done some preliminary work on water budgets with MNR. Their staff's understanding of climate change has also benefited from the receipt of funding through Natural Resources Canada's Climate Change Impacts and Adaptation Program, to support watershed scale science-based research on climate change vulnerability and risks. The Gateway Project has helped facilitate engagement and dialogue between MVCA and RVCA in addition to stimulating some focused internal discussion among the latters' staff around a broad range of climate change vulnerabilities and risks. As a result, RVCA has recently completed an internal review of climate change risks, priorities and needs; however, this report is not yet publicly available. Consequently, their staff is not yet able, or prepared at this time, to identify additional data and information gaps related to climate change risks, beyond what is of public record.

In the absence of the articulation of more specific data and information needs, there are other sources of information that were consulted which provide important insights into what each Conservation Authority has identified as needed to better understand source

water protection and climate change. For example, some information regarding gaps, defined as knowledge limitations, have been identified in the Proposed SWP Assessment Reports for both MVCA and RVCA. Climate change knowledge limitations for MVCA and RVCA, based on a limited analysis and assessment, include:

- Streamflow projection information;
- Development of uncertainty analysis for available local level precipitation and temperature projections;
- Effects of climate change on water budget (precipitation and evapotranspiration); and
- RVCA needs to become comparable to MVCA regarding their knowledge and capacity.

In the absence of being able to express greater detail regarding information needs, it may be that connections between taking actions against current climate conditions vis-à-vis climate change are not yet being made at a substantive level. It is not clear, for example, how far into the future are streamflow projections required, or the degree of uncertainty (and how to deal with uncertainty) regarding current climate data and trends, and climate change projections. Thus, there may be some merit in exploring the staff's current knowledge limitations pertaining to SWP, and revisit them with the MRSPC to determine which of these are a priority for them in addressing risks under current climate, including "low to no regrets" adaptation actions and options that may also reduce vulnerability to climate change. Based on a review of their respective SWP Assessment Report, the following knowledge limitations were identified:

- Delineation of wellhead protection areas, including vulnerability scoring;
- Threats and Issues Evaluation, including managed lands and livestock density calculations;
- Surficial geology mapping for a portion of Frontenac County and Lennox & Addington County;
- A database of Federal lands locations;
- Limited number of stream flow gauges in both the Mississippi Valley and Rideau Valley watersheds;
- Limited coverage for shoreline conditions classification;
- Limitations with the Permit To Take Water (PTTW) provincial database: the current PTTW database only includes permitted (maximum) water taking data, and not actual takings;
- No active climate stations located at the north end of the Mississippi Watershed;
- Limited population statistics to calculate the population of development areas, private services areas, and seasonal residents;
- Digital Official Plan mapping for Addington Highlands, North Frontenac and South Frontenac;
- Lack of surface water quality monitoring stations/programs in close proximity upstream of the municipal surface water intakes;

- Lack of groundwater quality monitoring locations/programs beyond the municipal groundwater systems;
- Lack of water taking data from private wells, agricultural water users, and other non-permitted water users;
- Limited number of stream flow gauges in both the Mississippi Valley and Rideau Valley watersheds, especially for the Tay River subwatershed and the Mississippi River downstream of Appleton;
- Lack of information about groundwater recharge and discharge, and evapotranspiration;
- Limitations were identified with the provincial water well records. For example, better static water levels, well locations and geologic descriptions would greatly improve the understanding of sub-surface conditions and calibration of groundwater models;
- Lack of detailed information about aquifer properties such as hydraulic conductivity, porosity, transmissivity, storativity, and water levels in aquifers;
- Limited amount of information is known about the Nepean Aquifer system;
- Lack of detailed information is available on the overburden conditions in Carp and Kemptville;
- Limited amount of information is known about bedrock faults;
- Lack of information about groundwater recharge and discharge, and evapotranspiration;
- The characterization of groundwater movement in fractured bedrock is not known;
- Lack of information about the location of abandoned wells;
- Limited amount of livestock density data available at local and regional scales;
- Limited documentation available to confirm conditions regarding spills;
- Though some preliminary work has been done in delineating the IPZ-2 for Britannia and Lemieux Island water intakes on the Quebec side of the Ottawa River, further information is needed;
- Limited bathymetric (river bottom) information is available. Additional review and 'ground-truthing' the transport pathways within the Intake Protection Zone (IPZ-2) would be beneficial, especially on private land;
- Limited information is available for transport pathways in the Intake Protection Zone (IPZ-3). For example, extent of drains, trenches, tile drains (also for IPZ-2), and karst features must be determined; and
- Incomplete hydrologic and hydraulic information upstream and in the vicinity of each intake.

Another key resource to identify information needs and gaps is the *Guide for Assessment of Hydrologic Effects of Climate Change in Ontario* which applies to SWPCs in general, and is a document to which one of the LACs (TRCA) served as a technical advisor. This document is a key guide and tool produced in partnership by MNR, the Credit Valley Conservation Authority, and the private sector, to help decision-makers address climate change risks for source water protection. Gaps have been identified in three general areas: (i) meteorological monitoring, (ii) water quantity monitoring, and (iii) water quality

monitoring, as they pertain to climate data and trends, hydrologic data, and climate change and hydrologic models. Data, information and gaps identified in the guide includes:

Climate data and trends:

- Temperature and precipitation, and meteorological observations relevant to hydrology: evaporation, wind speed, relative humidity, solar radiation, cloud cover, etc.) – is in short supply and detailed meteorological/climate data is a significant gap;
- Annual and monthly mean temperature;
- Annual and monthly total precipitation;
- Seasonal distribution of temperature and precipitation;
- Annual and monthly total rainfall;
- Date of spring breakup;
- Extreme rainfall;
- Frequency of severe winter storms;
- 30 minute extremes;
- Daily extremes; and
- Changes in dry periods.

Hydrologic data:

- Recharge;
- Runoff;
- Evapotranspiration;
- Variability, amount and seasonality of streamflow;
- Availability of groundwater;
- Water temperature;
- Changes in water use requirements;
- Baseflow information and continuous data are gaps in the current streamflow gauge network ;
- Stream gauges may not be standardized; and
- Data needed on headwater sites, near shore and where watercourses are not typically flood prone.

Climate Change and Hydrologic models:

- Detailed and comprehensive explanation is provided in the Hydrologic Assessment Guide;
- Surface temperature simulated very well, but less so for precipitation and not well for extreme weather events;
- Models tend to overestimate light precipitation and underestimate heavy precipitation;

- Recommendation that climate change impact assessments should use as many scenarios of climate change as possible, to cover a wide range of potential outcomes; scenarios can be derived from differences in climate change model formulations or differences in emission scenarios that drive the climate response;
- 40 SRES scenarios (Special Report on Emission Scenarios) used to inform IPCC TAR (Third Assessment Report) and AR4 (Fourth Assessment Report). These scenarios represent the best available set of scenarios for climate change impact assessments (at the time of this report, all model outputs were available from www.cccsn.ca);
- Storylines have been developed representing different demographic (population), economic (product, financial and labour markets), social (inequality, poverty), cultural (globalization, information technology, electronic media), environmental, technological and governance conditions. Family of storylines are usually drawn from both the A1 and A2 families which emphasize economics and from the B1 and B2 families which stress environmental sustainability, and typically are representative of "low", "medium" and "high" emission scenarios;
- Time periods projected are usually near term (2030), mid-century (2040-2060), and towards the end of the century (2070-2100), but the upcoming AR5 of the IPCC will include near term (2035), long term (2100) and even further outwards to 2300;
- The baseline for projections is usually based on the 1961-1990 record, which is different than the baseline norm used for climate trends (1971-2000);
- When linking climate change models to hydrological models, the potential impacts of climate change on inter-annual or day-to-day variability of climate parameters are not typically represented, missing changes in sequences of wet and dry days and patterns of intense precipitation. Consequently, this can lead to an underestimation of future floods, droughts, groundwater recharge and snow-melt timing;
- Methods described in the Guide are not applicable, or are limited in their applicability, to studies in which short-duration and/or peak flow characteristics are the subject of investigation;
- GCM output has limited local-scale accuracy, and is unable to capture locally significant features such as water bodies and topography;
- Gaps in alternatives drawn from Synthetic and Analogue Scenarios;
- Promising developments in downscaling GCM output to local conditions, but such scenarios are still problematic when it comes to hydrologic conditions (e.g. projecting hourly precipitation);
- Statistical regression models and weather generators under represent extreme precipitation in terms of intensity, duration and frequency;
- Dynamic downscaling using Regional Climate Models (RCMs) can generate output at a 3-hour interval for many meteorological variables relevant to hydrologic modeling, including specific humidity, precipitation, air pressure, air temperature, shortwave radiation, zonal surface wind speed, and Meridional surface wind speed; and
- Models should be able to output daily and hourly streamflow; water balance information, including monthly evapotranspiration, direct overland runoff and

groundwater recharge; and groundwater conditions including aquifer water levels and discharge to streams.

To supplement the use and effectiveness of the guidance document, and address some of the gaps noted above, MNR and MOE are working with York University, TRCA and private sector partners to develop additional communication and training materials, also referred to as eLearning modules, to help facilitate informed decision making regarding adaptation management under climate change. MNR has further initiated its own complementary initiative to identify for each source water protection area an ensemble of GCM scenario output for a selection of weather stations across Ontario that best represents the anticipated climate change conditions at that local scale (http://climate.aquamapper.com). Climate change projections are provided for temperature (minimum and maximum) and precipitation (rainfall, snow and total precipitation) on an hourly and daily basis, for three different time periods: 2011-2040; 2041-2070 and 2071-2100, compared to either the 1961-1990 or 1971-2000 baseline record. Combined, the hydrologic assessment guide, the scenarios and the eLearning materials should be useful aids to assist watershed decision-makers in applying climate change scenarios to various climate change – watershed risks, such as low water response, stormwater management, and source water protection planning, among others, given the caveats noted above. Further, more "hands on" guidance in the use and interpretation of climate model results, how to carry out vulnerability assessments, understanding uncertainty and risk, and the identification of initial no-regrets actions could also be necessary to support the adaptation process.

Policy Issues:

Under the Clean Water Act there are four regulations that were written by MOE:

- Ontario Regulation 287/07 – General
- Ontario Regulation 231/07 – Service of Documents
- Ontario Regulation 284/07 – Source Protection Areas and Regions
- Ontario Regulation 288/07 – Source Protection Committees

Under the Act, source water protection committees are mandated to develop source water protection plans for their watersheds. The primary focus of the Act is to ensure that communities are able to protect their municipal water supplies now and in the future from overuse and contamination. The Act requires Conservation Authorities, municipalities and other stakeholders to work together to identify threats to source water in Assessment Reports (to be completed by 2010) and develop policies to address them in Source Protection Plans (to be implemented in 2012). Given these timelines our engagement with MRSWPC has been very much influenced by their own focus on meeting the requirements of the Act. Addressing climate change was required to be identified in the Assessment Reports as a future threat to municipal water supplies, but undertaking further technical work and incorporation into the actual plan remains somewhat ambiguous despite recommendations from the Ontario Expert Panel Report. How they are engaged to test and optimize The Gateway, and transfer knowledge through a

workshop, will likely be influenced in part by the regulatory requirements under the Clean Water Act. In addition, some of the issues identified may also be regulated by other policies and instruments, such as Permit To Take Water, which is related to drought and low water response.

II. Low Water Response:

Nottawasaga Valley Conservation Authority (NVCA) is the LAC partner on the low water response issue, and has a Low Water Response Team (WRT) in place that consists of local farmers, municipalities and representatives from 4 Provincial Ministries. Overall the watershed is in good health with ample surface water supplies for their needs, as Municipalities draw their water from groundwater, aquifers or Georgian Bay. Innisfill Creek subwatershed, however, tends to be a problem area for low water levels, and has experienced water supply shortages in 7 of the past 12 years, especially in 2007 and most recently in 2011.

A series of questions regarding climate and climate change information needs was submitted to NVCA staff in 2011. Based upon their response, the following climate and hydrologic data were being used to address current climate risks and could be valuable in addressing climate change:

- Air temperature
    - Daily, monthly, seasonal, annual
- Water temperature
    - Daily, monthly, seasonal, annual
- Precipitation: rainfall and snow
    - Daily, monthly, seasonal, annual
- Water levels and flow rates

Further, specific gaps identified included:

- Gaps in stream inflow data;
- Supply side: gap in identifying alternative water supplies;
- Demand side: gap in farmers demonstrating appropriate conservation practices, such as staggered water takings, more efficient irrigation;
- Gap in Low Water Response regulations around trigger levels, and conservation practices when environmental/ecological thresholds are reached;
- Funding gap for further study on instream flows; and
- Gap in reporting what constitutes a scientifically defensible threshold for ecological damage.

NVCA has been dealing primarily with current climate conditions, and although they are aware of climate change risks at a general level, there is limited evidence of them implementing actions that address climate change in a direct or strategic manner. For example, in one of their pilot studies on the 2007 drought, they stated:

> "an emergency plan does not address the basic issues of a limited water supply and a high demand and the potential impacts this creates for the aquatic ecosystem. The long term solution will require the development of an Integrated Water Management Strategy especially for a watershed such as Innisfil Creek where drought conditions are mainly the result of water taking

and where the predictions of the climate models suggest the problems will become more severe."

However, in their Integrated Water Management Strategy Report published a year later, there is no mention of climate change risks. Despite this gap, there are many facets of NVCA activities that could be utilized to help enhance their adaptive capacity to climate change. For instance, NVCA has capacity in GIS (Geographic Information Systems), and does extensive monitoring through their Watershed Monitoring Program and their Flood and Erosion Hazard Management Program. They participate in and contribute to the Provincial Water Quality Monitoring Network, where they test water quality at 11 sites within the watershed. Eight water samples are collected at each site every year, including periods of low water and storm events. They also participate in and contribute to the Provincial Groundwater Monitoring Network, and operate 13 monitoring wells at 7 sites. NVCA participates in the Natural Heritage Program, and wetland approximation mapping has been completed for the watershed.

Four dams are operated by the NVCA: Tottenham, New Lowell, Utopia and Tiffin with the former three having monitoring instrumentation installed since 2005. The Inland Stream Temperature Monitoring Program is also highly relevant to dealing with low water conditions. NVCA employs data loggers to monitor temperatures over a two-week period, each summer, including dry, warm weather periods. Instream temperatures are compared to air temperatures to determine whether the stream sections are cold, cool or warm. There is no mention of the number of monitoring sites, but they monitor benthic invertebrates at 35 sites each year. Two of the 10 subwatersheds are measured each year, so they are able to cover the entire watershed every 5 years.

Current issues:

Ongoing development pressures, adverse climate and water resource conditions, along with experiences relating to the implementation of Ontario Low Water Response in 2007, suggest that an IWRMS for the Innisfil Creek subwatershed is needed to ensure that human and environmental water needs can be balanced effectively. To illustrate, the water use assessment completed by WESA and AMEC in the summer of 2008 showed that sixty-eight percent (68%) of the survey participants reported a shortage of water at some point since 2001. Furthermore, experiences during dry summers, such as those which occurred in 2007, demonstrate that intensive use of surface water resources in Innisfil Creek and its tributaries is not sustainable. Innisfil Creek and its tributaries are not appropriate sources of water for many large-scale users. Feasible water supply alternatives need to be identified, along with realistic options for water conservation and efficiency.

In 2006 NVCA produced a subwatershed plan which identified a number of areas of concern. The primary issues raised by the Innisfil Creek subwatershed residents included:

- Protection of significant natural areas and green spaces such as woodlands, wetlands, stream valleys (the habitats for their local wildlife);

- Restoration of degraded natural areas, where possible (improving wildlife habitats);
- Maintenance and where possible improvement of stream conditions (to a level capable of supporting sport fisheries);
- Low flows especially during dry summers;
- Protection of ground water quality and quantity to protect their drinking water; and
- Protection of residents from flood and erosion damage.

Agricultural uses such as sod and potato farms, market gardens and nurseries use surface water for irrigation. Water usage has been an issue during summer months (particularly during dry years) as it affects stream base flows. Some residents have expressed concerns regarding the lack of Innisfil Creek base flow, particularly upstream of its confluence with Penville Creek. They are concerned that the lack of flow is having a negative impact on the fish and wildlife communities that depend on this water to survive. For example frogs, crayfish and minnows have been concentrated in small pools making them easy pray for raccoons and skunks. The lack of flows also prevented fish from migrating into portions of the creek to spawn. This is in direct contrast to other areas such as conditions around the headwaters, which still support a healthy aquatic habitat including cold water fish species.

In 2011, NVCA and the WRT continued to have concerns around the requirements for issuing low water conditions as one progressed from normal to Level 1 through Levels 2 and 3. These concerns included:

- Uncertainty regarding the data/information requirements to establish a Level 3 declaration;
- Meeting requirements regarding historical assessment of stream flow, precipitation and groundwater conditions;
- Indicators such as fisheries thresholds; economic evaluations of the agricultural sector; and
- Recommendations for prioritization of water use restrictions (Level 3); and, impact assessments of water restrictions.

Based on their initial meeting of their WRT in July 2011, a number of specific concerns and potential data gaps were identified, as expressed by various stakeholders:

1. Updating of water budgets, and estimates of accumulated rainfall required to alleviate low water conditions;
2. Actual real time water takings compared to PTTW;
3. Calculations of conservation measures by large water takers; and
4. The disconnect between actual water level conditions and monitoring and reporting requirements.

In the immediate aftermath of the WRT meeting, NVCA staff tentatively identified the following areas for possible discussion with ACER and MNR around The Gateway Project:

1. Fact sheets developed by the province to delineate potential impacts of climate change to various water use sectors via the WRT;
2. On-going provincial support for local agricultural based water users groups, associations, etc.;
3. Provincially outlined and agency-agreed upon standards to delineate that voluntary actions in level 1 and 2 has been accomplished to declare a level 3 for the significant sectors- agricultural and municipal;
4. Core data - stream flow and precipitation data (e.g. potential to get real time data for the stream gauges from EC to aid in the SW takers; enhance concentration where lacking);
5. Agreed upon process by the water directors to move quickly (within 5 days) to a level 3 condition;
6. Annually update PTTW list provided to the WRT, blanket across the province, by June 15 cleaned of expired permits, temporary permits, and clearly denoted Surface Water vs Ground Water permits and by sector. Annual release of level 1,2,3 that occurred throughout the province and length of the declaration to all WRTs;
7. Frequent MOE inspections to get the non-PTTW holders into compliance. (e.g. why should the program aim at those who are adopting appropriate conservation measures compared to those who are taking water illegally);
8. The EBR release of the updated MNR low water document;
9. Populated AgRI mapping from OMAFRA in key suspect subwatersheds along with delineation of irrigation networks (if possible);
10. Fact sheets developed by the province to delineate potential impacts of climate change to various water use sectors via the WRT;
11. On-going provincial support for local agricultural based water users groups, associations, etc.; and
12. Provincially outlined and agency-agreed upon standards to delineate that voluntary actions in level 1 and 2 has been accomplished to declare a level 3 for the significant sectors- agricultural and municipal.

Shortly after the WRT, MNR and ACER met with NVCA staff to introduce the Gateway tool and address in more detail the data and information needs identified in the Gaps Analysis. The “wish” list for data included: stream flow, rainfall/precipitation data/snow, air temperatures, potential and actual evapotranspiration, water holding capacity and soil storage, moisture deficit, water temperature, water levels, and Permit To Take Water. In particular, the following information would be helpful to NVCA staff address their knowledge gaps in addressing low water response more effectively:

1. Permit To Take Water: location of the extraction, site of application, real time to annual records of water taking , and annually updated PTTW list provided to the WRT by June 15 cleaned of expired permits, temporary permits, and clearly denoted

Surface Water versus Ground Water permits and by sector;

2. Watershed characterization: mapping of crop type (similar to the AgRI mapping completed by OMAFRA) done on a annual basis. Mapping of the irrigation network on an annual basis. Annual production numbers of core, irrigation-dependent crops (e.g. sod, potatoes, carrots, onions, etc.) including tonnage, economic value of crop; summary of crop insurance pay-outs (to determine economic impacts). Other sector impacts, e.g. socio-economic impacts to golf courses;
3. Municipal water restriction: summary of the municipal water restriction programs, description of impacts to the water levels;
4. Chemistry/biology: surface water and sediment chemistry data and fish, benthic macroinvertebrate, and algae data to detail the environmental impacts to water courses;
5. Finalization and roll out of the groundwater low water indicator methodology; and
6. Outreach materials: Actions like water conservation outreach, public education on water resources should be the part of this program. This could include fact sheets developed by the province to delineate potential impacts of climate change to various water use sectors via the WRT. Annual release of level 1,2,3 that occurred throughout the province and length of the declaration to all WRTs.

In response to these gaps and concerns, it is possible that NVCA could benefit from The Gateway in the following way:

- Help produce case studies on past rainfall events following droughts to inform the precipitation amounts needed to help end a drought situation;
- Draw from the SWP program that has actual water use numbers;
- Utilize groundwater data to identify trends in seasonality, recharge periods and volumes, and baseflow data;
- Update the subwatershed water balance (budget); and
- Additional data for guidance available from various Ministries, including data for socio-economic analysis.

Policy issues:

Although NVCA has expressed many concerns around the Low Water Response process, there are many other regulations and policies that affect their activities and operations. These include:

- Provincial Policy Statement 2005 (PPS) – wise water management at the watershed level;
- Source water protection legislation;
- Intergovernmental Action Plan;
- Nottawasaga Valley Watershed Management Plan (1996-2015) deals with water management issues across the entire Nottawasaga River Valley, a drainage area of 3,360km^2. Purpose of the plan: "To conserve natural resources within the watershed in a co-operative, integrated manner in which human needs are met in balance with the need to sustain the natural environment";

- Oak Ridges Moraine Conservation Plan; and
- Other policy areas: Conservation Authorities Act R.S.O. 1990 (CAA); Provincial Policy Statement (2005) – issued under Section 3 of the Planning Act; Nottawasaga Valley Watershed Management Plan (1995); and Watershed Plan Strategic Review (2006); Stormwater Management Planning and Design Manual (MOE, 2003); Fish Habitat Protection Guidelines for Developing Areas (MNR, 1994); *NVCA Engineering Development Review Guidelines*; Fisheries Habitat Management Plan – Nottawasaga Valley Conservation Authority Area of Jurisdiction (March 2009); Erosion & Sediment Control Guideline for Urban Construction (TRCA, 2006) Natural Channel Systems: Adaptive Management of Stream Corridors in Ontario, including Natural Hazards Technical Guides for River and Stream Systems: Flooding Hazard Limit, Erosion Hazard Limit and Hazardous Sites Technical Guides (MNR 2002); Great Lakes – St. Lawrence River System and Large Inland Lakes Technical Guides for Flooding, Erosion and Dynamic Beaches in support of Natural Hazards Policies 3.1 of the Provincial Policy Statement (MNR 2002).

Note that most of these regulations and policies have not be reviewed or assessed in this project regarding their role in enabling or inhibiting climate change adaptation. This is a significant knowledge gap that requires further consideration and is recommended as a key next step.

III. Stormwater Flooding: Peterborough and Otonabee Region Conservation Authority

IV. Stormwater Management: Toronto Region Conservation Authority, City of Toronto and municipalities across the Greater Toronto Area

Originally the climate change categories to be addressed in this project included flooding and stormwater management, and made a distinction between riverine flooding and stormwater flooding. The LACs selected and engaged in these areas have had recent experience with each of these issues, specifically stormwater flooding throughout the City of Peterborough in 2002 and then again in 2004, and as a result of a severe storm event on August 19th, 2005. The 2005 event led to a breach of a culvert and subsequent collapse of Finch Avenue in the north end of the City of Toronto, in addition to other stormwater-related flooding across the Greater Toronto Area (GTA). Both flood events in the City of Peterborough resulted in serious property damage, economic business loss, damage and interruption of municipal services that occurred through the backup of sanitary sewage into basements and uncontrolled overland flows. Similarly, the severe precipitation event and subsequent stormwater flooding in August 2005 across the GTA was the most costly weather related hazard in the history of Ontario, exceeding that of Hurricane Hazel in 1954.

Engagement with each LAC has been initiated through their respective primary Conservation Authorities, with TRCA in the GTA and the Otonabee Region Conservation Authority (ORCA) which encompasses the City of Peterborough. Engagement with TRCA has been driven largely by their need to learn more about municipal data and information needs around stormwater issues, which in part reflects the separation of responsibility between Conservation Authorities (e.g. flood plain management) and municipalities (e.g. stormwater management). Initial engagement with municipalities across the GTA have involved TRCA at a separate meeting at their Kortright facility in November 2010, followed by a meeting with the Southern Ontario Stormwater Working Group, held in Oakville, Ontario. Separate meetings were also held with some individual municipalities, notably Toronto, Mississauga and Richmond Hill, in addition to meetings with the City of Peterborough and ORCA held in the summer of 2010. A subsequent meeting of the Southern Ontario Stormwater Working Group was held in September 2011 which was used to introduce The Gateway, and solicit further response from those GTA municipalities in attendance regarding key information gaps and needs. As a bonus, the City of Peterborough was also in attendance (as host) of this second meeting, giving them the opportunity to directly interact with their GTA counterparts in stormwater operations and planning.

After early engagement meetings with the stormwater flooding LAC, it became evident that while the 2004 Peterborough storm event consisted of both stormwater and riverine flooding, the former was considered to be much more significant than the latter in contributing to the localized flood conditions throughout the City. At least this was the perception and understanding of local planning officials within the City of Peterborough, which was a view shared by some representatives of ORCA, in addition to experts based

at Trent University. However, MNR and other ORCA officials remained concerned that the role and issue of riverine flooding was a significant factor, and that the relationship between stormwater flooding, sewage spillage into the riverine system, and surface water quality issues downstream also needed to be explored. This would eventually require broader stakeholder engagement, including those responsible for managing water flows in the Trent-Severn waterway (e.g. Parks Canada), and communities and individual households impacted downstream.

At the city level, the primary area of concern has been stormwater flooding, with more focus on addressing vulnerability to current climate rather than climate change. This is partly due to the aging stormwater infrastructure in Peterborough, and the unique situation with Jackson Creek flowing directly through the downtown core. A review of policy initiatives and documents in the aftermath of the 2002 and 2004 floods reflected a stove pipe or silo approach to dealing with specific watershed issues such as the separation of quality from quantity issues regarding stormwater management. Further consultation with various stakeholders across the LAC has suggested that there has been limited dialogue in terms of taking an integrated approach to address these issues. More positively, the Gateway Project has helped engage key stakeholders in this manner. At a meeting with MNR, ACER, and the Peterborough/ORCA LAC in July, 2011 to discuss information and data gaps, two representatives from ORCA and two City of Peterborough staff members (planning and emergency response) were brought together for the first time to discuss climate change risks on watershed issues. The limited dialogue around specific information needs and a general lack of a coordinated approach to address individual issues, coupled with the adoption of a stove-piped approach, underscored the need to take more of proactive role in stimulating internal discussions regarding climate change risks to watershed management and adaptation options. This has subsequently led the project team to explore linkages between all climate change – watershed management issues, as well as the need to extend engagement activities to include a broader suite of stakeholders.

The locational and stationary characteristics of the storm cell that sat over Peterborough on July 14th and 15th, 2004, was strictly bounded by the City's political boundaries, with even rain gauges north and south of the downtown (e.g. Trent University and Peterborough Airport respectively) recording substantially lower levels of precipitation than what fell across most of the city. Further, since the Trent-Severn waterway is one of the most regulated waterways in the country, it is widely accepted that riverine flooding is not normally a problem, at least regarding flood plain management. Nonetheless, it is believed that stormwater flooding, primarily in Downtown Peterborough, likely involved spillage from combined storm and sewers, leading to some contamination of the Otonabee River downstream, possibly causing surface water quality problems from communities south of the storm event. This issue is being explored with ORCA and the Trent Source Protection Coalition. ACER was also invited to attend the first advisory committee meeting of the Peterborough Stormwater Quality Management Plan held in October, 2011, with the addition of climate change onto the agenda.

Given the predominant focus on stormwater quantity management and to a lesser extent upon stormwater quality management within the City of Peterborough, a case can be made to look at the two "stormwater" LACs as being more closely connected than what was originally envisaged, with Peterborough/ORCA representing a LAC addressing stormwater flooding, and TRCA/GTA representing a LAC addressing stormwater management. In addition, the situation in Peterborough/ORCA could be seen as overlapping with four of the climate change risk issues addressed in the Gateway project, namely stormwater management, riverine flooding, source water protection and integrated watershed management. As a result, if Peterborough/ORCA moves forward to address individual or multiple climate change – watershed issues in this manner, they would likely benefit from utilizing The Gateway to discover and access best practices, experiences and case studies that draw upon their LAC partners who are taking the lead on climate change adaptation. This includes learning from actions taken by Richmond Hill and TRCA on addressing climate change risks for stormwater ponds and dams, source water protection and the application of climate change scenarios on hydrologic processes, and integrated watershed management through the creation of climate change consortiums and collaborative partnerships.

Surveys were issued to both LACs in the fall of 2010, including members from the southern Ontario stormwater working group, which was comprised of engineers from across the GTA. Follow up meetings were also held with the City of Mississauga and the City of Richmond Hill, early in 2011. However, survey responses were received only from ORCA, while face-to-face interviews yielded some supplementary information from Mississauga, Toronto and Richmond Hill, in addition to the follow up session to introduce The Gateway tool to the southern Ontario stormwater working group in September, 2011. In the opinion of one senior engineer who understood the issue, the lack of response from municipal stormwater engineers did not necessarily reflect a lack of interest, but rather a lack of awareness and understanding of the issue, including vulnerability, climate change projections, risks and adaptation options. Upon further analysis of documents and reports produced in both LACs, it became evident that TRCA is among the country's leaders in taking action on climate change and watershed management, and some municipalities (notably Toronto and Richmond Hill) as well. This is in direct contrast with Peterborough and ORCA who are at best trying to redress past planning and engineering decisions that has saddled the community with an outdated and antiquated stormwater system.

In the follow up meeting with the southern Ontario stormwater working group in September, 2011, the general discussion addressed some additional gaps regarding data and information needs. The importance of updated and improved regional Intensity-Duration-Frequency (IDF) curves and the application of climate change scenarios was mentioned, as was the basic need to document, map and otherwise identify stormwater systems in municipalities. Surprisingly, some municipalities do not even have a comprehensive database and inventory of their existing stormwater systems, let alone areas of vulnerability. Even flood plain mapping may be in need of updating in many municipalities. Further, engineers also expressed concern regarding the difference between the design standards and actual/current performance of stormwater ponds, which

can be significant, especially over long periods of time (e.g. many ponds were built in the 1960s and 1970s).

Peterborough and ORCA:

From the ORCA survey response the following information and data sources were identified, including gaps:

- Monitoring network consists of 3 stream gauges owned by ORCA, in addition to those operated by Environment Canada. They have 6 rain gauges in their network, and have the capacity to undertake snow surveys during the winter. However, they require a more expansive stream gauge and rain gauge network, in addition to groundwater monitoring and assessment that connects to stream flows.
- More general education is needed about climate change risks and how they affect watershed issues.
- There is interest but limited capacity to address climate change in future planning.
- There is concern over the potential for increased flooding (especially flash flooding) from more frequent and severe storms.
- Information is needed on rainfall, streamflows, groundwater and temperature to adjust standards for flood frequency, and help steer development away from the floodplain.
- There are few partnerships between Peterborough, ORCA, MNR and Trent University that address climate [change] related issues.
- Financial constraints places limits upon and inhibits adaptive capacity. There are no municipal requirements to mainstream climate change into decision-making, although recognized that the Ministry of Infrastructure has recently announced possible requirements regarding the development of asset management plans, which is to consider climate change risks.
- No adaptation measures have been used to date in response to climate change, and none are currently under consideration.
- Improved analysis and forecasting is required, including better communication and education regarding climate change risks.
- Additional concerns include low water levels, prolonged periods of drought, decreased water quality, and changes in ecosystem health as reflected by shifts in cold water to warm water fish species.

In response to the 2002 and 2004 floods, the City of Peterborough retained a consultant to develop a Watershed Master Plan, including a series of subwatershed assessments. The purpose of these assessments was to identify the severity and frequency of flooding, and associated damages, and identify alternative and cost effective solutions, ranking these in terms of flood reduction, erosion and water quality effectiveness. Key findings included:

- Unprecedented heavy rainfall of an intensity of more than twice the current design standard;
- Insufficient storm sewer capacity caused primarily by ineffective water collection and undersized pipes. Approximately 80% of the City's storm trunk sewers

examined do not meet current 5-year standards (e.g. insufficient to accommodate a 1 in 5 year storm event).
- Poorly defined overland flow routes caused primarily by the filling in of natural waterways over time. Over 225 properties in the City are vulnerable to overland flow damage from a 100-year storm event.
- Unwanted water getting into the sanitary sewer system leading to system overflow.

The focus in Peterborough has been entirely on analyzing the current risk of flooding in the city, with essentially no consideration of climate change. This is problematic for a 40- to 50-year plan to rebuild the stormwater system, especially since the life expectancy of infrastructure is expected to last well beyond 50 years. Further, a recent RFP for a stormwater quality management master plan class environmental assessment did not consider climate change, although intervention into the planning of the consultative process brought an invitation to ACER to participate on the advisory committee and added climate change to the agenda of the first meeting. This is a step in the direction suggested in the recent Ministry of Infrastructure report *Building Together* which stipulates that future asset management plans would have to show how climate change adaptation was included in the project design. Local officials at the City of Peterborough acknowledged awareness of this report during the July meeting at MNR, and were able to identify additional gaps, including:

- Current priorities have been to upgrade infrastructure to meet current requirements, and monitor rainfall data and stream flows, and are disconnected from climate change.
- Consideration of climate change into watershed master plan needs to be justified, and would require council to approve of any additional expenditures beyond current standards.
- Looking for guidance from the update of the Stormwater management Planning and Design Manual (2003) and the Provincial Policy Statement.

The meeting with the stormwater quality management plan held in October, 2011, outlined the approach being taken by a consulting firm to undertake an environmental assessment of Peterborough's stormwater system from a water quality perspective, specifically:

- Providing the City with information on the current status of stormwater ponds that are owned and operated by the City;
- Developing recommendations regarding the operation and maintenance of the ponds, and potential improvements to the ponds; and
- Examining opportunities to improve stormwater treatment for areas in the City that currently do not have specific measures in place to treat stormwater.

From this meeting there seemed to be three areas where The Gateway could serve a function in assisting this process. First, to direct the consultants to data and information that would help them assess the 28 stormwater ponds under review, including help in

identifying "hot spots" that need to receive priority attention. Second, MOE had raised concerns that most ponds constructed in the past 30-40 years no longer meet their 2003 criteria for minimum flow. It was suggested that to be in compliance the assessment process should be comparing current performance of the stormwater system (28 stormwater ponds, and over 60 other intake/outtake locations) to the original design characteristics. This would likely involve comparing performance with the original Certificate of Approval, which would have been issued by MOE to the developer at the time of construction, with the City of Peterborough receiving a copy. However since many of the city records were lost or destroyed during the 2004 flood, it is expected that the City/Consultant will need to submit a formal request for information to MOE for their records. Third, there was some discussion whether there was a need to consider climate change in the assessment, and if so, how that would be done. ORCA suggested that linking climate change scenarios to IDF curves would be useful to the process, and reported that the region currently uses updated IDF curves which are based on climate data up to 2007. Additional consideration of climate change was unclear, until there was further identification of specific data and information needs and gaps in assessing the current performance of their stormwater system from a water quality perspective.

TRCA and the GTA:

In contrast, TRCA and some GTA municipalities are further ahead in addressing climate change risks and stormwater management. However, a review of information gleaned from the webpages of 9 local and 4 regional municipalities across the GTA suggests that the degree of adaptive capacity is highly uneven when it comes to addressing stormwater and climate change. Nonetheless, a number of gaps have been identified in municipal or regional climate change reports, strategies and plans, including:

- The need for long-term meteorological monitoring stations to produce baseline climate/weather data;
- Education and outreach to inform political decision-making to ensure climate change resilient development;
- Lack of understanding of which existing policies, standards, by-laws, codes and guidelines need to be reviewed and updated to reflect climate change;
- Infrastructure design standards that consider climate change;
- More funding required to support Conservation Authorities to develop the next generation of flood risk assessments and make changes to management policies governing floodplain development that accommodates the potential for greater flooding in the future; and
- Need for an integrated ecosystem approach to stormwater management planning.

In addition TRCA has undertaken numerous research activities on climate change impacts and adaptation over the past decade, and they have been actively engaged on three recent climate change collaboratives: the Toronto Urban Climate Change Network, the York University – GTA Climate Consortium for Research Action Integration, and the Ontario Region Climate Change Consortium. Among their publications relevant to The Gateway Project include a review of adaptation plans and practices as they pertain to

stormwater and floodplain management, and their report regarding the application of the Public Infrastructure Engineering Vulnerability Committee (PIEVC) assessment tool to two dams. In their 2009 review of the stormwater and floodplain management literature for the Region of Peel, for example, they identified the following knowledge gaps:

- More examples are needed of climate change adaptation plans by government agencies, municipalities or other sectors that are both prescriptive and detailed.
- Uncertainty about the magnitude of potential climatic changes, and their manifestation at the local scale in terms of changes in seasonal precipitation distribution and changes in the frequency and magnitude of extreme events.
- Difficulty in defining new standards in the face of such high levels of uncertainty as the costs associated with upgrading or replacing infrastructure that are in many cases directly correlated to the magnitude of climate change.
- While there are many provincial climate change action plans that recommend undertaking infrastructure vulnerability studies assuming future climatic conditions will change, there is little guidance available on how climate change impacts can be assessed or on specific adaptation. No federal or provincial initiatives provide sufficient guidance or insights on climate change adaptation in stormwater or floodplain management.

Although York Region has not yet developed a regional adaptation strategy, both the City of Vaughan and the Town of Richmond Hill are notable for their progress at the municipal level to address climate change risks to stormwater management. The August 19th storm in 2005 that caused the flooding of Black Creek and the collapse of Finch Avenue in Toronto also created havoc in many parts of Vaughan. More than 80 percent of the entire area of the City of Vaughan experienced 100-year storm conditions or worse, leading to flooding damage at various locations across the city for both minor and major stormwater systems. As a result, Vaughan Council has recently approved the development of a city-wide storm drainage/storm water management master plan study. In addition, a detailed GIS database of the City's existing sewer and watermain infrastructure is being developed, including an analysis of critical flooding related data, as part of the development of a comprehensive Flood Emergency Response Plan. Although climate change is not explicit in these documents, it is recognized as a potential stress on stormwater infrastructure in the latest Official Plan. Under the Community Sustainability and Environmental Master Plan, engineering design criteria for storm drainage and stormwater management facilities will be reviewed and assessed regarding their capacity to manage the anticipated impacts of climate change, meet the standards of emerging legislation, and to ensure protection from significant flooding.

The Town of Richmond Hill is on the forefront of stormwater management in Canada, including consideration of climate change in their long-term planning. The Town has a $16 million 10-year Storm Water Management Capital Plan for storm water facility rehabilitation that was approved in 2008, with its primary focus on flood protection, risk management/health and safety issues, and operations and maintenance considerations, and secondary consideration for erosion control and slope stabilization, spills management, environmental issues and community concerns. They have extensive

collaborative partnerships with University based scientists and Conservation Authorities beyond TRCA. Of note, they are working with Trent University water scientists on stormwater ponds. The Town of Richmond Hill's first rehabilitation project was the Pioneer Park Stormwater Management Facility, involving a total redesign and redevelopment of a 1980s facility that had inappropriate volume, experienced frequent blockages, and created a backwater condition with resulting environmental impacts. The adaptation measures incorporated included enhancing flood protection above 100-year return storm levels, strengthening the environmental and hydrological function and health of the watershed, and protecting fish and wetland habitat.

The project won the Federation of Canadian Municipalities National Watershed Award 2010 for leadership in climate change adaptation by reducing flood and water damage vulnerability, and the Ontario Public Works Association 2010 Technical Innovation Award. The Town of Richmond Hill is the only municipality in Canada that has a department exclusively dedicated to stormwater management. Staff is committed to working with ACER and MNR to identify information and data that was used in the retrofit projects to date, and explore ways that The Gateway can help other municipal stormwater decision-makers access similar data in their communities. Of note, senior staff identified the need to update IDF curves as a significant knowledge gap (updated nationally to 2007 where data allowed and available on the Environment Canada web site).

The City of Toronto is notable for the $500 million in insured and other damages attributable to the August 19th 2005, storm event that caused flooding along Black Creek and the failure of a corrugated steel pipe culvert under Finch Avenue. The original culvert was only designed to accommodate a 5-year return event. Although climate change per se was not directly considered, the new structure was designed to a higher standard, including the capacity to accommodate peak flow for both the regional storm and 100-year return storm. There are also a number of initiatives and programs worth noting that either directly or indirectly apply to stormwater system adaptation to climate change such as the Wet Weather Flow Master Plan, the Green Roof Pilot Incentive Program, the Green Development Standard, and mandatory downspout disconnection at the household level.

Climate Change Risk Assessment Tools for Stormwater:

In 2010 the City of Toronto contracted Deloitte Touche Consultants to develop and test an environmental risk assessment tool on climate change risks for two municipal departments: social housing services and transportation services. The latter includes culverts and stormwater systems. The assessment guide and tool is considered useful to help municipalities undertake a high level scan of climate change risks, and is viewed by many as complementary to the more project specific and infrastructure oriented PIEVC assessment tool developed by Engineers Canada. The City of Toronto is currently applying the PIEVC assessment tool to three culverts (including one immediately downstream from the reconstructed Finch Avenue/Black Creek culvert), but this study is still in progress and a report may not be available until 2012.

However, TRCA recently tested the PIEVC assessment tool for two flood control dams: Claireville and G. Ross Lord Dam and Reservoir. Climate parameters considered in the study included: High Temperature, Low Temperature, Heat Wave, Cold Wave, Extreme Diurnal Temperature Variability, Freeze Thaw, Heavy Rain, Heavy 5-Day Total Rainfall, Winter Rain, Freezing Rain, Ice Storm, Heavy Snow, Snow Accumulation, Blowing Snow/Blizzard, Lightning, Hailstorm, Hurricane/Tropical Storm, High Wind, Tornado, Drought/Dry Period, and Heavy Fog. Historical climate data was derived from a variety of sources: Environment Canada's Canadian Climate Normals, Climate Data Online, the Ontario Node of the Canadian Atmospheric Hazards Network, and the Canadian Daily Climate Data. Given the proximity of the weather station to the two dams, Pearson Airport weather data was used in the analysis, although the above-mentioned sources did not provide much information on ice storms, lightning, hurricanes or tornadoes.

Various sources for climate change projections were analyzed using model output from Environment Canada's Climate Change Scenario Network (CCCSN) Scatter Plots and Bioclimate Profiles, the IPCC 4th Assessment Report Regional Climate Projections chapter, and scientific journals presenting regional and local projections. Using the CCCSN, median output for three emissions scenarios were used: A2 (high), AIB (medium) and B1 (low), comparing the projected 2041-2070 30-year period (typically referred to as the 2050s) to the 1971-2000 normals. Of note, a major gap exists insofar as the study did not include a detailed hydrologic or hydraulic assessment of changed dam inflow regimes or the assessment of the change in risk of dam failure as a result of changes in the regime of extreme events such as the Probable Maximum Flood (PMF). This was not included since there is insufficient understanding of climate change on extreme events, and that the dams assessed already exceeded stringent design standards to accommodate large floods.

One additional report is worth noting, which is an important contribution to the climate change risks assessment toolkit, and fills a significant knowledge gap regarding the updating of IDF curves and how they may change under different climate change scenarios. A McMaster University report, funded through the Ontario Ministry of Transportation, applies updated and future IDF curves under different climate change scenarios to design standards for drainage infrastructure. Data for two different locations was used in the analysis. In southern Ontario the Grand River Region was selected, and in northern Ontario the Kenora and Rainy River Region. Key gaps identified in the report include:

- Given the coarse resolution of Canadian Global Circulation Models (CGCM), downscaling is necessary to obtain appropriate local scale information (precipitation series) representing the future climate conditions;
- Projected intensity-duration-frequency (IDF) curves with analysis and comparison based on the downscaled data for each local weather station;
- Updated weather station records of daily precipitation;
- Trend analysis on maximum daily precipitation for local weather stations;

- Assistance in selecting the appropriate climate change scenarios that are the most likely to reflect the future climate trends in Ontario;
- Assistance in using spatial downscaling techniques to downscale the GCM outputs and generate future precipitation series representing the local conditions;
- Assistance in performing time series analysis on predicted precipitation data and rainfall impacts to assess possible trend in the frequency and magnitude of storm events in the selected study regions; and
- Assistance in addressing the regional and local details of the climate which are influenced by spatial heterogeneities in the regional physiography and how they affect regional downscaling of GCM's (and spatial differences in the causal storm or atmospheric processes forcing the extremes).

There is some concern on the horizon regarding the capacity of Environment Canada to continue to contribute to, if not lead, efforts to update IDF curves and apply them in a climate change context. Recently announced budget cuts by the Federal Government includes senior scientists working on both IDF curves and various tools that have been used by decision-makers to assess climate change risks, including the CCCSN and the Canadian Atmospheric Hazards Network.

Policy issues:

The main policy issues around stormwater management includes the updating of the Provincial stormwater guidelines, and any compliance requirements regarding performance measures of their existing stormwater system compared to the original design standards for minimum flow as identified in the Certificates of Approval. Given the integrative nature of the stormwater-flooding-surface water relationship, it may also be necessary to look more closely at their source water protection activities, as directed through the Clean Water Act. There are also potential funding options that could be explored through the Water Opportunities Act that could support some climate change - stormwater infrastructure projects.

V. Integrated Watershed Management and Northern Ontario Perspective:

City of Sudbury and the Nickel District Conservation Authority – The Greater Sudbury Climate Change Consortium

The Northern Ontario LAC consists of a broad and integrated set of stakeholders that involves members from Municipal departments across the City of Sudbury, the regional Conservation Authority representing the Nickel District (NDCA), and University scientists based at Laurentian University. This has created a LAC that brings both a northern perspective and perhaps the best example in the Province of Ontario of an integrated approach to watershed management. Through the creation of the Greater Sudbury Climate Change Consortium (GSCCC), in 2009, the Northern Ontario LAC has been engaged in cutting edge climate change research, assessment and public engagement. In recent months their activities have expanded to include the Social Planning Council in addressing human and social vulnerability and needs, building upon a solid foundation of science based research conducted over 6 years. Their greatest strengths that they bring to the project include an approach that is better described as an integrated approach to climate change risk and adaptation within a watershed (rather than integrated watershed management). In addition, there is potential for their extensive work to date to be used to inform The Gateway and provide multiple case studies for the benefit of the other LACs, and for pushing the boundaries of their own climate change agenda, such as the consideration of social equity. Sudbury has also been included in some of the outreach activities of OCCIAR and CAP as part of their ORAC deliverables, in addition to being subject to the requirements of the Clean Water Act and therefore responsible for delivering an assessment of source water protection needs and a source water protection plan.

There have been three meetings held in Sudbury from July 2010 to October 2011, and additional meetings with experts familiar with the research work done to date. During the last meeting held in October, 2011, ACER and MNR provided updates on Gaps and Needs, and introduced The Gateway Tool. Engagement with the northern LAC on needs and gaps has tended to focus on mining and extracting this information from a wide body of research reports and studies carried out by their various partners since 2006. Not surprisingly no direct responses to our survey questions were given when we presented them in July 2010, although the survey was a useful guide to frame the discussion, with assurances that all answers could be found in their documents. The northern LAC has entered into a MOU with ACER to support a joint position to help facilitate the testing and optimization of The Gateway, and the knowledge transfer workshops. There is also potential to tap into the expertise of a Post Doctoral Fellow based at Laurentian University, who is focusing on source water protection and climate change.

Over the past 5-6 years the approach developed and adopted by the GSCCC has shifted from climate change impacts research to enhancing the community's ability to adapt by:

- Acknowledging shared responsibilities for taking action;
- Building understanding between stakeholders in the community; and

- Developing public participation in ecosystem management and integrated decision making and planning.

In assessing climate change and the City of Sudbury on an ongoing basis, the following knowledge gaps have informed their approach, all of which generically apply to climate change risks and watershed management:

1. What are the socio-economic and ecological vulnerabilities to existing and future climate across economic and social sectors, human health, infrastructure and ecosystems of a diversified Canadian Shield community such as Greater Sudbury?
2. How should information about climate change scenarios and potential impacts be structure and framed in order for it to be effectively integrated into municipal and stakeholder decision-making? and
3. What actions, at what levels, are needed to develop adaptive capacity and ensure that adaptation strategies are developed and implemented?

In responding to these gaps, a bottom-up approach involving the engagement of community stakeholders further identified the following initial objectives:

- Establishing risk assessment-based, climate vulnerability profiles across the sectors of the Greater Sudbury community for existing climate and future climate scenarios;
- Estimating the socio-economic consequences of the climate vulnerability profiles;
- Determining what information and communication strategies are most effective in enhancing the adaptive capacity and sustainability of the community; and
- Identifying and triggering adaptive responses (among the existing ones) and actions in the community, including the integration of adaptive strategies into Greater Sudbury's Official Plan and emergency preparedness planning.

A brief summary of climate change activities in the LAC over the past 6 years illustrates an impressive collaborative effort to address climate change risks and adaptation needs from an integrated perspective, and provides further insights into water-related information and data needs, gaps, concerns and issues:

- Funding secured in 2005 through NRCan involving 26 partners to undertake a climate change vulnerability assessment of the Greater Sudbury Area – report published in 2007;
- Produced risk assessment-based profiles of vulnerable sectors, estimated socio-economic consequences, determined information and communication strategies most effective to enhance adaptation, and identify adaptive responses in the community including the integration of adaptive strategies into Greater Sudbury's Official Plan and emergency preparedness planning;
- Key vulnerabilities defined through public engagement included water, municipal infrastructure, energy, health of vulnerable people, and industry, while communication and awareness represent significant challenges;

- In response the NDCA commissioned a position paper on the actions to be taken to continue enhancing the adaptive capacity of the community, which was approved in March 2009. The City of Greater Sudbury Municipal Council endorsed the establishment of the Greater Sudbury Climate Change Consortium in November 2009;
- 2007 assessment was based on 2 GCMs and 3 emission scenarios (low, medium and high);
- 2010 update drew on the Environment Canada's CCCSN ensemble output available at the time;
- Detailed climate trend data and climate change projection data has been compiled for the Greater Sudbury Area including:

    - Average air temperature, mean annual and seasonal for 3 times periods (2020s, 2050s and 2080s) based on 1971-2000 record;
    - Precipitation in mm, mean annual and seasonal for 3 time periods; and
    - Projections in the number of frost free days, growing season, and heat wave duration.

- Consequences: indirect impacts issues of soil conservation, agricultural conservation and the need for more public gardens. Such issues are not necessarily related to climate change per se. but it is clear that climate change will play a role in affecting those components. For example, with greater wind disturbance, extreme rainfall or long periods of drought, it is expected that soil erosion may be increasing in areas where the system is already stressed by top soil stripping for nurseries or in areas where suburban sprawl exacerbate the environmental conditions through soil compaction and removal of trees. Agricultural activities at the local level can be promoted as a way to reduce these pressures, depending on the type of agricultural practices being adopted;
- In natural and managed environments, pest and invasive species are predicted to increase in terms of diversity and abundance. Such species tend to modify the natural biodiversity and in many cases, affect ecosystem functions and services. For example, the introduction of aquatic weeds and toxic algae in lakes can impact the filtering capacity of the lake as well as reduce light intensity, thus affecting fish survival and the level of oxygen in the system; and
- Businesses will also be impacted by climate change, especially in terms of extreme events. For example, when asked about damage to basement storage, respondents were prompted to answer in terms of habits of many local companies, i.e. essential files and records in basement storage facilities. There is a need for increased awareness and then development of alternative avenues for storage considering that many have to keep them for legal reasons while not having the capacity to store in other spaces of their business.

The Greater Sudbury Climate Change Consortium has also piloted the PIEVC assessment tool in 2008 on roads and associated infrastructure. In this report they considered temperature, precipitation (rainfall and snowfall), wind and frost, as well as cumulative effects. At the time of the study (began in 2007), they drew upon what was best available

at the time in terms of GCM output, and used one climate change scenario produced by Ouranos. Gaps in the climate data not available for climate change assessments included snow during a rapid melt event, ice build up, ice accretion, freezing rain, hurricanes and tornadoes, and thunderstorms. Although the risk assessment component focuses on roads, there is some consideration of surface stormwater infrastructure such as culverts, ditches and catch basins, in addition to underground infrastructure such as stormwater systems. Policy needs has also been cited as a significant gap, particularly in terms of assessing the broader and inclusive range of municipal, provincial and federal policies that affect local decision-making, including those around land use planning.

Climate Change position paper published in 2009 further situates climate change impacts and risks more directly within the context of water-related issues, specifically natural ecosystems, managed environment, and water resources:

- Natural ecosystems:
    - More fire damage;
    - New disease vectors;
    - More invasive species;
    - Decrease in water quality (more eutrophication and algal blooms);
    - Possible changes in quantity due to higher temperatures and less precipitation;
    - More extreme weather events;
    - Lower lake levels due to higher temperatures and less precipitation;
    - Sulfur and heavy metal release due to drying up of lakes and marshes; and
    - Impacts on cold water aquatic species, such as lake trout, as water temperatures increase, water levels decrease and development pressures increase.

- Managed environment (sectors):
    - Tourism: less snow for skiing and snowmobiling, shorter ice fishing season, less clean water for boating and swimming;
    - Municipal infrastructure: more road repair with increased frequency of freeze-thaw cycles, more power outages, flooding;
    - Electric Utilities: lower water levels resulting in less hydropower production;
    - Agriculture: new pests, more extreme weather events, reduction in soil moisture;
    - Health: heat waves, contaminated drinking water, diseases, contaminated beaches and swimming areas leading to more enteric related illnesses, pressure on emergency response units;
    - Mining: need for large amounts of water;
    - Building sector: new safeguards needed to protect shorelines and wetlands; and

- Insurance costs.

- Water resources:

  - Increased stress on drinking water supplies;
  - Shoreline erosion and increased pesticide and fertilizer run-off;
  - Increased public education needed on drought and more frequent storm events;
  - Increased need for more in depth flood plain management planning;
  - Flash flooding in later winter months due to changes in spring rainfall intensity and snowmelt runoff;
  - Limited information on drainage infrastructure such as type, size, location, age and conveyance capacity;
  - PIEVC study recommendation for database of hydraulic information for city culverts;
  - First generation Source Protection Plan needs to include climate change considerations;
  - Increasing water temperatures and decreasing water levels could lead to increased health risks, and put significant pressure on infrastructure;
  - Increased development along shores of lakes used for municipal or private drinking water will exacerbate these problems;
  - Need more stringent development standards for shorelines;
  - Lake Wahnapitae could become the primary municipal drinking water supply source, and steps need to be taken now to protect this vitally important water resource; and
  - Increased threat of invasive species upon water quality.

While it is recognized that the City of Sudbury has a strong capacity to adapt, the report identifies a number of gaps that can be addressed through action items aimed at enhancing adaptive capacity. These include:

1. Establishing a Climate Change Consortium;
2. Protection of Lakes, from invasive species and algal blooms;
3. Enhancement of Flood Warning System that addresses freeze-rain-thaw sequence. Includes re-assessment of flood prone vulnerable areas every 5-10 years, and development of a more integrated warning system to avoid incidents that may occur during flash flooding;
4. Water and wastewater infrastructure upgrades, including ability to withstand freeze-thaw exposure and other extremes;
5. Improved climate and biophysical modelling at the watershed level, including regional downscaling in order to protect water supply and municipal infrastructure;
6. Protect municipal drinking water, by integrating climate change into drinking water source protection;
7. Prevent water-borne diseases and contamination, by engaging Sudbury District Health Unit to monitor for West Nile Virus and release of toxic chemicals from

extreme weather events; and

8. Public education for all residents of the watershed to better understand the vital role that lakes and the water supply play in their lives and the need for their protection, especially in the face of climate change

Policy issues:

Given the breadth of the climate change issues addressed to date by the GSCCC, there is likely a long list of policy issues that reflect many of those faced by their southern LAC counterparts, regarding specific climate change – watershed issues. For example, they are subject to the Clean Water Act, and may be eligible for funding through the Water Opportunities Act. Policy issues around stormwater guidelines and low water response program also apply. Perhaps reflecting the integrative nature of the GSCCC, they have also pointed out the importance of looking at a broader suite of policies, particularly around land use planning which may be contradictory to their efforts to adapt effectively to climate change.