# Report

Associated Engineering

GLOBAL PERSPECTIVE.
LOCAL FOCUS.

# City of Calgary Water Supply Infrastructure

## Climate Change Vulnerability Risk Assessment

May 2011

# Executive Summary 1

## 1 INTRODUCTION

Traditionally infrastructure design codes, standards and practices have been based upon historical climate data, and engineers have relied on this information to provide for long-lasting infrastructure. The uncertainty caused by changing climatic conditions may be undermining the meteorological data used to design infrastructure.

The City of Calgary (The City), in cooperation with Engineer's Canada, embarked on a project to assess the potential vulnerability of its water supply infrastructure to climate change. This vulnerability assessment was conducted in partnership with Engineer's Canada (the business name for the Canadian Council of Professional Engineers), who has established the Public Infrastructure Engineering Vulnerability Committee (PIEVC) to oversee a national engineering assessment of the vulnerability of Canadian public infrastructure to changing climatic conditions.

PIEVC has developed a Protocol, based on standard risk assessment methodologies, to guide climate change vulnerability assessments. The Protocol provides a methodology to gather information and data, which are subsequently used to understand relevant climate effects and their predicted interactions with infrastructure.

Water system upgrades are currently being conducted to gain sufficient capacity to meet the requirements of projected population growth up to at least 2021. The study addresses the potential impacts of future climate change for the years 2020 and 2050.

The scope of the vulnerability risk assessment addresses the entire water supply infrastructure within the City of Calgary boundaries that is owned and operated by The City, including the current design, construction, operation and management of the infrastructure. In addition to the infrastructure within the city boundaries, the scope of work also includes the watersheds in terms of impacts on both the quality and quantity of water available at the intakes, as the source for the supply of the drinking water system. Within the watersheds, infrastructure, not owned or operated by The City, forms critical components to the water supply system, and are addressed in terms of their impact to the raw water source.

## 2 INFRASTRUCTURE

Calgary has two sources of drinking water: the Elbow River and Bow River. Source water is supplied to the drinking water treatment plants by three intakes. Two intakes and associated pump stations on the Bow River serve the Bearspaw Water Treatment Plant. The third intake located in The City's Glenmore Reservoir and Dam serve the Glenmore raw water pump station and treatment plant.

Following treatment, the potable water flows to high-lift pumps. The pumps push water through transmission mains, which transport large volumes of water to strategically located storage reservoirs and pump stations. The City has developed 4,678 km of water pipe infrastructure in Calgary. Some of the transmission mains constructed in the early 1900s are still in use today.

# 3 CLIMATE CHANGE

The entire globe has experienced a changing climate over the past century. Increases in greenhouse gas (GHG) emissions from both human activity and natural variations have attributed to these changes. The Intergovernmental Panel on Climate Change (IPCC) has indicated that the warming is unlike anything experienced in the past 1300 years, and that if no action is taken to reduce GHG emissions, temperatures over the entire globe are expected to increase between 1.1ºC and 6.4ºC over the period 1990 - 2100 (IPCC, 2007).

In estimating the vulnerability of existing infrastructure to anticipated climate change, the PIEVC protocol requires information on various climatic elements. Estimates of these climatic elements facilitate estimations of the exposure the infrastructure will face under future climate change, and highlights which element or climatic condition will have the greatest impact on its vulnerability.

The primary objective of this section is to provide information on baseline parameters and how some of these are predicted to change in the future. The goal is to determine how these changes will impact the City of Calgary's water supply infrastructure. Section 3 of this report highlights the baseline and future climate predictions for Calgary and the Bow and Elbow River Basins.

## 3.1 Baseline Climate

Observed weather data was obtained from Environment Canada's Canadian Climate Normals and the Canadian Daily Climate Data (CDCD). Climate Normals or averages are used to summarize or describe the average climatic conditions of a particular location. The stations used in this study were:

- Calgary International Airport (id: 3031093)
- Kananaskis (id: 3053600)
- Banff (id: 3050520)
- Lake Louise (id: 3053760).

## 3.2 Future Climate

This study used the most recently available information from an ensemble of Global Climate Models (GCMs), i.e., from the IPCC's 4th Assessment Report (AR4), the A2 emission scenario outputs, and looked at the future climate periods centering on the 2020s (2011 - 2040) and 2050s (2041 - 2070) as compared to the 1971 - 2000 baseline period. Each parameter used in this study was derived from a range of ensembles, ranging from a minimum of two 'mean' runs, up to an ensemble of 19 models.

Some of the expected climate changes for the Calgary area and Bow and Elbow Basins include:

- Increased temperatures
- Decreased snowpack
- Earlier melt and earlier onset of spring freshet
- Shorter, warmer winters
- Extended drought conditions
- Changes in precipitation type
- Decreased rain in the summer
- Increased rain in the fall, winter and spring
- Increasing frequency of extreme weather events.

As climate research and climate models continuously develop and evolve, and further and larger GCM ensembles become available and outputs from CCCSN and PCIC in particular continually broaden the information they provide, such information and tools will continue to be useful and pragmatic in studies such as these. In addition, as regional climate model (RCM) information continues to develop and become more readily available from organizations such as Ouranos, NARCCAP and the Earth System Grid, finer regionally based resolution outputs will become more and more available as well. To date, RCM resolutions have been limited to few runs from few models, and would typically be driven by one GCM. RCM outputs have some advantages but acquiring these high resolution simulations remains very time consuming and hence costly. Therefore, the use of the largest ensemble of GCM models available to provide and capture the variability from each individual model, is the best available methodology to date in providing useful future climate data for climate change vulnerability and impacts assessments.

Expanding the future scenarios to include the most recent IPCC Assessment Report (AR5) and model runs from this assessment once available, including the future period centering on the 2080s (2071 - 2100) and including other emission scenarios (e.g., A1B and B1) would further broaden and hence strengthen the anticipated future variability. Additionally, further research is needed in deriving extreme climatic events.

These models are tools that provide values of anticipated climate change. As such, the goal is to capture the broad range of values outputted from the models. Although the models are continually evolving and improving with complex physical and mathematical formulas, there is always a level of uncertainty or possible error that could exist in the outputs, and as such, these values should always be interpreted with care. The values derived in this study are meant only for the region of interest and should only be used within this area.

# 4 INFRASTRUCTURE ASSESSMENT

The first assessment portion of the study is applying professional judgement and experience to conduct a qualitative assessment to determine the effect of climate events on components of the infrastructure.

## 4.1 Watershed

Both the Elbow and Bow River watersheds may be impacted by climate change in terms of quantity and quality of water available to the supply of the water treatment systems. Changes in precipitation, quantity and types (rain versus snow), and increased temperature may impact timing and quantity of stream flows. Increased rain may impact water quality from increased overland runoff with increased sedimentation and organics. Higher temperatures compounded with dryer conditions and increased storm events could result in more and larger forest fires.  A large fire could have a profound effect on raw water quality (especially in the small Elbow watershed) and the effect could last for years (S5). Water quality would be impacted with increased sediments, high levels of organic carbon, nutrients and heavy metals, from debris and increased soil erosion.

## 4.2 Ghost and Bearspaw Dam and Reservoir

The Ghost and Bearspaw Dam and Reservoir may be negatively impacted by temperature swings, increased precipitation (runoff), decrease in precipitation (drought), winds (soil erosion) and decrease in river flows. However, the risks associated with a performance response were considered in terms of the negative impact to The City's water supply as a result, as opposed to a direct impact on the infrastructure.

## 4.3 Glenmore Dam and Reservoir

The Glenmore Dam and Reservoir may be negatively impacted by temperature swings, changes in timing of river flows, and flooding. The reservoir has limited storage capacity, and though not designed for the intent of providing flood control, The City has operational procedures in place to mitigate the effects of flooding downstream.

## 4.4 Glenmore, and Bearspaw Raw Water Pump Stations and Intakes

The raw water pump stations and intakes may be negatively impacted by temperature swings, increased precipitation (flooding), and decrease in precipitation (drought).

## 4.5 Storage and Distribution (critical pump stations/reservoirs, feedermains)

Focus of the impacts of climate change in the distribution system was given to the priority (critical) infrastructure components as identified by The City's long range planning vulnerability study. Priority infrastructure was selected for assessment, as classified by The City as critical, where required to maintain a supply of water to consumers.

### 4.5.1 Pump Stations and Reservoirs - Operational

Extreme temperatures typically result in increased demand, requiring increased flows and pressures (increased load on the pumps). The City's long range planning identifies the need for upgrades before capacities are reached, and exceeding the operating demands is unlikely. All stations have redundant pumps and some with engine driven units to maintain operation. Continuous monitoring may identify a change in peak factors, however an overall change in supply is unlikely.

### 4.5.2 Pump Stations and Reservoirs - Physical

The physical components of the distribution pump stations may be impacted by changes in temperature and flooding. In the past, operations have experienced breakers tripping during periods of high demands and high temperatures, requiring attention by staff. The City is conducting ongoing assessments of the pump stations and working towards corrective actions. Overheating could occur if corrections have not considered an increase in the extreme. All stations have redundant pumps and some with engine driven units to maintain operation, however, until operating staff can reach the station to install fans if required there would be a loss of some capacity and function.

The basement of the Memorial Drive Pump Station (on the critical priority list) is located within the 1-in-100 year flood plain, and The City is currently conducting a study to further assess its vulnerability. The City has a FERM plan in place, however it is possible flooding could negatively impact the pump station. Flooding of a station with damage to electrical systems would result in a loss of the ability to operate the station.

## 4.6 Water Treatment Plant (Process Components)

In the past, increased runoff conditions had created increased turbidity and impacted/overloaded the conventional pretreatment systems. However, with the recent upgrades to Actiflo® pretreatment, the main process systems are designed to handle high turbidity events during runoff periods - therefore a negative interaction resulting from climate change is not anticipated in terms of process systems capacities or operations, other than a potential for an increase in residuals handling and chemical usages. Similarly, although an increase in temperature (and resulting water temperature) could result in algae growth and increased organics (disinfection by-product precursors and taste and odour compounds), the facilities now have some chemical systems in place to help mitigate taste and odour events.

A large forest fire event would impact the source water quality. This in turn would have a significant impact on the water treatment process which would probably be able to address increased turbidity but could have problems addressing the high levels of organic carbon, nutrients and heavy metals that could be present. Additional treatment processes may be required to address the change in water quality to meet drinking water standards.

### 4.7 Supporting Systems

#### 4.7.1 Buildings

The lab facilities have experienced HVAC overloads during previous heat wave conditions, and with continued increases in temperature it is probable it could happen again. The addition of fans requires a change in serviceability, but does not have a direct impact on the ability to supply water.

#### 4.7.2 Power Sources

Temperature extremes result in increase in power consumption throughout the region and it is possible in the future to see a reduction in available power. Power outages could require a reduction in production capacity, and increased operation and maintenance of standby generators.

#### 4.7.3 Other Vulnerability Factors

Some of the other factors affecting the functionality (load and capacity) of the water supply system include population and water demand increases, policies within the watershed, changes in policies and regulations regarding uses within the watershed, and changes in regulations regarding drinking water standards.

## 5 CONCLUSIONS

In general the City of Calgary is fortunate to have robust treatment processes in addition to two raw water sources and redundancy within the distribution system. Operation and management plans are in place to reduce both the probability and severity of negative climate-infrastructure interactions occurring.

The climate changes identified as having a negative impact to infrastructure will be seen as gradual changes, and ongoing monitoring can identify trending of changes and be incorporated into long-range plans. The vulnerabilities judged as the highest priorities are those associated with extreme events such as flooding, drought, and compounding events.

### 5.1 Water Source

As climate change occurs, it is anticipated that the watersheds may change as well, in terms of the quantity of water available, when it is available and the quality of water. Changes in temperature and precipitation may both impact the water quality and level of contaminants from forest fires, algae, increased runoff, etc. in the raw water source to the drinking water facilities. Continued monitoring and studies to address the potential for change are recommended. Maintaining networks within the scientific community to learn from the experiences of others with new and emerging issues will help to mitigate potential impacts in the future.

The City of Calgary's raw water intake system is fairly adaptable to the impacts of future climate changes, with two sources of raw water and three intakes. The redundancy provides some flexibility in shifting production from one source or intake to another in the event one becomes compromised. However, supply is still limited in terms of water quantity by water withdrawal licences and priorities of withdrawal rights.

The Glenmore Reservoir has limited storage capacity, and limited ability to mitigate potentials for flooding. The reservoir was not designed as a flood control structure, and The City currently has Flood Emergency Responses Plans in place to react in the event of flooding and mitigate flooding effects. However, as future climate projections predict a potential for increased storm events and increases in the maximum instantaneous flows for the Elbow River, The City should give some consideration to the functionality of the reservoir. During drought conditions The City has water conservation measures in place to reduce demands on the system.

### 5.2 Treatment Facilities

Recent and planned upgrades to the treatment facilities provide for robust systems, with adaptive capacities to withstand many of the potential impacts of climate change. Increased precipitation and storm events leading to a potential for decrease in water quality (increased turbidity, pathogens from runoff) are expected to be handled by the upgraded pretreatment systems. Additionally, ongoing upgrades include the provision of ultraviolet disinfection which will provide a multiple disinfection barrier against the potential for increased numbers of pathogens. However, in the event of a large forest fire, the treatment systems are likely able to handle the impacts of increased sedimentation, but increased organics, nutrients and metals may require additional treatment technologies to meet drinking water standards.

The City has built-in redundancy within the distribution system with the ability to cross-serve pressure zones and move water within the system. City staff, however have identified concerns with The City's definitions for level of service with regard to treated water storage capacities. Water conservation policies and management practices currently in place have helped reduce demand during critical periods, reducing the load on the distribution systems and downstream wastewater treatment plants. Vulnerabilities may exist with consecutive peak demand periods and the ability of the reservoirs to catch-up once the storage volumes are depleted.

### 5.3 Storage and Conveyance

Pump stations within the distribution system have experienced increased loadings, compounded with increased temperatures, resulting in overloads to MCCs, and tripping of breakers. The facilities themselves have built-in redundancies with standby engines or generators. However, increased operator/maintenance attention is required to install temporary fans during high heat periods. A review of the HVAC systems of some of the older facilities is recommended with remedial action to follow.

### 5.4 Supporting Systems

Though some staff have been prevented from accessing facilities in the past due to storm events, The City has reduced risk of impacts to the water supply system, due to staff being unavailable or unable to get to the facilities as a result of cross training programs in place to ensure trained staff/system operators are available at all times.

Similar to those impacts identified with the distribution pump stations, supporting facilities have also experienced increased loading of the HVAC systems during high temperature periods. As climate change models project an increase in the extreme daily temperatures and increased heat wave durations, consideration should be given to review of HVAC design codes and an assessment of existing facilities to identify remedial actions.

An increase in temperature/heat duration presents potential impacts related to HVAC systems/electrical and controls and the availability of standby generation at all facilities including the water treatment plants. Glenmore Water Treatment Plant has limited operational capacity while functioning on standby power. A review of standby power capacity at critical facilities is recommended.