EXECUTIVE SUMMARY

INTRODUCTION

It is widely accepted in the scientific community that climate is changing. Climate data is used to design infrastructure and under climate change, historical climate data as the basis of operational design may not be appropriate.

Engineers Canada established the Public Infrastructure Engineering Vulnerability Committee (PIEVC) to oversee a national engineering assessment of the vulnerability of Canadian public infrastructure to changing climate conditions. PIEVC has developed a protocol to guide vulnerability assessments. The Protocol is a procedure to gather and examine available data in order to develop an understanding of the relevant climate effects and their interactions with infrastructure.

Metro Vancouver and PIEVC are cooperating in the jointly-funded Vancouver Sewerage Area (VSA) vulnerability assessment. The vulnerability assessment includes all Metro Vancouver infrastructure and operations within the VSA. The catchment encompasses the City of Vancouver, University of British Columbia (UBC) campus, UBC Endowment Lands, part of the City of Burnaby and part of the City of Richmond. The VSA is approximately 13,000 hectares.

Years 2020 and 2050 were selected for analysis of climate change effects. Much of the combined sewer system that makes up the VSA dates to the 1960s or earlier. 2020 represents an early design life boundary for much of the oldest piping and appurtenances. A key operational target is Metro Vancouver's commitment to elimination of combined sewer overflows (CSOs) in the VSA by 2050. Since the single largest impact of climate change on the VSA was expected to be increased rainfall (and therefore wastewater flow), a 2050 assessment of climate change was considered crucial for Metro Vancouver's sewer separation planning.

Addressing climate change requires two complementary actions: mitigation and adaptation. In Metro Vancouver, minimizing the region's contribution to global climate change is one of the primary goals of the current Air Quality Management Plan. And through a new Energy Planning Program, Metro Vancouver is also actively pursuing opportunities to recover energy within its own operations, often with related benefits of overall reduction in GHG emissions. The degree to which a municipality is able to deal with the impacts of climate change is often referred to as adaptive capacity.

CLIMATE CHANGE

According to the Intergovernmental Panel on Climate Change (a global scientific body set up by the World Meteorological Organization and the United Nations Environment

Program), the warming that has been experienced over the last half century is likely without precedent in at least the past 1,300 years. For the purposes of this project, climate change modelling was performed by Ouranos (a Quebec-based climatology research consortium) using the Canadian Regional Climate Model to quantify expected changes to various climate factors.

In general, all precipitation indices suggest that there will be an increase in total rainfall amount, and in the frequency and magnitude of rainfall events. In addition, modelling projects consistently increasing temperature trends at both the 2020 and 2050 horizons, implying that snowfall will decrease.

Estimated global sea level rise by Ouranos is 0.14 m by the 2050s and 0.26 m by the 2080s. The most recent report from the IPCC has a range in predicted sea level rise by 2100 of between 0.2 m and 0.6 m. Locally, in research conducted by Natural Resources Canada, it is reported that the Fraser River delta areas (Richmond and Delta) are sinking at a rate of 1 mm/yr to 2 mm/yr, while other areas (Vancouver, Burnaby, Surrey, Tsawwassen Heights) are uplifting at a rate of 0 mm/yr to 1 mm/yr. Therefore, for certain areas of the VSA such as Iona Island, global sea level rise will be aggravated by a sinking land surface, increasing the relative sea level rise.

Monthly average minimum and maximum temperatures are predicted to increase by 1.4°C to 2.8°C by the 2050s.

A summary of climate events is outlined below.

Summary of Climate Events.

Climate Event	Expected Change
Intense Rain	Increase in 1-day maximum rainfall: 17% by 2050s (Ouranos) [1]
Total Annual / Seasonal Rain	Increase in total annual precipitation: 14% by 2050s (Ouranos, addendum)
Sea Level Elevation	Increase in global sea level elevation[2]: 0.26 m by 2080s (Ouranos) to 1.6 m by 2100 (Rohling et al, 2007)
Storm Surge	Not quantified. Likely to increase[3].
Floods	Not quantified. Likely to increase.
Temperature (extreme high)	Increases in monthly maximum temperature: 1.4°C to 2.8°C by 2050s (Ouranos)
Drought	Modelling is inconclusive in trend. Average maximum length of dry spell may increase by 0.25 days by 2050s (Ouranos)
Wind (extremes, gusts)	Not quantified. Likely to increase.

Notes:
1. Estimate is based on total precipitation, which is assumed to be approximately equivalent to rainfall in the VSA.
2. Does not include local effects such as subsidence and atmospheric effects.
3. Storm surge is a significant contributor to extreme high water events and therefore lack of quantitative data is a critical information gap.

According to Ouranos, climate scenarios are difficult to produce for certain highly localized events (wind gusts, tornadoes, and thunderstorms) or events where processes are complex and depend on a number of factors (hurricanes, ice storms). Therefore, quantitative predictions of wind speed were not provided.

As described in more detail in Section 2, there are a number of uncertainties and assumptions involved in the climate projections listed above and these reflect only limited possible future scenarios for GHG emissions. In addition, regional climate is affected by large-scale oscillations known as:

- El Niño/Southern Oscillation (ENSO); and
- Pacific Decadal Oscillation (PDO).

ENSO is a well-known phenomenon characterized by an east-west shifting pattern in tropical sea surface temperatures. The time scale of the shifts is relatively short: cycles last from 2 to 7 years. Generally, El Niño winters are associated with decreased precipitation in southwestern British Columbia. The reverse trend occurs during La Niña events.

The PDO operates over the entire Pacific basin on a decadal timescale. Phases may persist for about 20 years to 35 years. The PDO shifted to a warm phase in 1976. For coastal B.C., the warm phase generally results in thinner snowpacks due to higher temperatures and generally a greater percentage of precipitation in the form of rain. A consensus has not yet been reached on whether the PDO has shifted to a cool phase.

VANCOUVER SEWERAGE AREA (VSA)

The VSA is largely a combined sewer system. Combined sewers are an older type of collection system that carry both wastewater and stormwater in the same pipe. Combined sewers were less expensive to install and maintain when they were built, generally prior to the 1960's. During heavy rainfall, combined sewers can overflow directly into a nearby waterway such as the Fraser River or Vancouver Harbour, producing a CSO. This overflow provides a "safety valve" that prevents back-ups of untreated wastewater into homes and businesses, flooding in city streets, or bursting underground pipes.

Metro Vancouver's plan is to reduce, then eliminate, CSOs through the process of gradual conversion to a separated sewer system. Metro Vancouver has committed to elimination of CSOs by 2050 in the 2002 Liquid Waste Management Plan (LWMP). The LWMP also commits Metro Vancouver to upgrade Iona Island Wastewater Treatment Plant (IIWWTP) to full secondary treatment no later than 2020. This pilot study is timely, as a planned revision of the LWMP is currently underway.

The VSA is served by the IIWWTP, the second largest wastewater treatment plant in Metro Vancouver. The design peak wet-weather flow (PWWF) of the IIWWTP is 17

m^3/s. The plant provides primary treatment to wastewater from approximately 600,000 people before discharging it through a 7 km, deep-sea outfall into the Strait of Georgia. The plant opened in 1963 and has been expanded six times for growth and treatment upgrades allowing more than 200 billion litres of wastewater to be treated here in 2001.

INFRASTRUCTURE ASSESSMENT

An important part of the Protocol is a qualitative assessment in which professional judgment and experience are used to determine the likely effect of individual climate events on individual components of the infrastructure.

COMBINED SEWERS

It is certain that increased rainfall intensities and volumes will lead to increased flows in the combined sewers in the absence of other mitigating system changes (e.g. increased efforts at green infrastructure). The effect will be reduced capacity to convey sanitary flow to the IIWWTP; as a result, CSOs will be more frequent and discharge greater volumes.

In order to find a relationship between total CSO and rainfall amount, monthly CSO volume was plotted against average monthly rainfall. Based on the derived linear relationship, approximately 30% of the monthly rainfall overflows, regardless of season. The Ouranos climate scenario report projects a seasonal rainfall increase of 18% for the December-January-February period by 2050. This provides an indication that additional sewer separation effort may be required to meet Metro Vancouver's CSO elimination goals. Further study is recommended to identify appropriate measures to meet these goals (which may include adaptive management, along with hydrologic and hydraulic modelling).

As the combined system is increasingly separated, inflow and infiltration (I&I) will become the primary concern with increasing rainfall intensities and volumes.

PUMP STATIONS

Increased flows at the pump stations may exceed pump station capacity, which could result in overflows locally or upstream. The health and environmental impact would be considered severe, but based on current operation the probability is low.

IONA ISLAND WASTEWATER TREATMENT PLANT

Hydraulic constraints within the collection system physically limit the amount of wet-weather wastewater flow that can be conveyed to the IIWWTP, and under the existing LWMP, the planned maximum capacity of the plant is 17 m^3/s. Therefore, even though climate change may result in an increase in the magnitude and frequency of intense rainfall events and thus increase the potential to generate wet-weather flows, higher peak flow rates are not expected to be received at the IIWWTP. Over time, some of the reductions to peak flow in the regional system as a result of sewer separation will be partially offset by other factors such as population growth and age-related inflow and infiltration rate decay.

However, more frequent wet-weather events (i.e. events per year) could impact the treatment process in other ways. For example, primary clarification performance may be reduced during wet-weather flow events, which could result in more days per year with increased contaminant mass loading to the marine environment in the short-term, and to the secondary treatment system in the long-term. Similarly, grit removal efficiencies are notably reduced during high-flow events.

In addition, increased frequency of such events would reduce process redundancy "windows" (e.g. clarifiers and screens taken out of service for maintenance). This situation could leave the IIWWTP with greater exposure to operations difficulties and more frequent events with increased primary effluent loading.

An increase in the average sea level would impact IIWWTP effluent disposal hydraulics. Here the primary context is the additional energy needed to pump effluent through the marine outfall due to the increase in the static head. Given the sea level predictions, it is highly probable that there will be a climate effect on this infrastructure component. Overall, a low response severity factor was selected for the assessment.

Increases in storm surge, and associated static head, will also impact the effluent outfall system from an internal jetty conduit/outfall pipe pressure perspective. The severity of this response was deemed to be critical since information exists that suggests the jetty conduit structure is under designed for the original design conditions.

Most of the IIWWTP site is above the recently estimated 2.9 m geodetic elevation total water level (i.e. 1:200 yr return frequency winter storm surge with high tide combined with a Fraser River winter flood, for a 95% confidence interval but excluding climate change and wind wave effects) (nhc, 2006). The same conclusion applies to a 3.5 m elevation that includes an assumed 0.6 m freeboard. However, based on available drawings, much of the site, including the access road, appears to be only minimally higher in elevation than the 3.5 m level. Factoring in the change in average sea level rise and land sinking, as well as potential wind wave effects, suggests that little margin may be available in the future.

OTHER VULNERABILITY FACTORS

Other factors influencing infrastructure vulnerability are noted as follows.

Sewer Separation. It was correctly pointed out by Metro Vancouver staff that the reduction in sewer flow from sewer separation will, at many locations, be vastly greater than the increase due to climate-based rainfall effects. Sewer separation will significantly decrease peak flows in the collection system and to the IIWWTP. Note that some Metro

Vancouver regional sewers will eventually be turned over to the City of Vancouver (COV) for stormwater conveyance, and some regional sewers will likely remain for sanitary sewer conveyance to the IIWWTP. Since the separation program is still in its early stages, a unique opportunity exists to adequately size the separate stormwater and sanitary sewers for the effects of climate change.

Long Range Plans. Construction projects that are part of long range plans will improve system operations, presumably increasing the ability to manage CSOs.

Infrastructure Replacement. Replacement of aging infrastructure decreases the risk of system blockages and provides the opportunity to install larger mains or separate systems.

Green Infrastructure. Increasing efforts at building green infrastructure may be used to increase resiliency in adapting to climate change. Metro Vancouver has completed significant efforts studying and promoting green infrastructure over the past number of years, with the overarching goal of net environmental benefits at a watershed scale. Green infrastructure initiatives are also expected to form a significant component of the updated LWMP, currently under development.

Inflow & Infiltration Reduction and Age Based Rate Decay. Sanitary sewer loads can decrease with inflow & infiltration reduction programs (at the municipal or regional level), but generally increase due to material deterioration over time.

Population Growth. Population growth will increase sanitary sewer loading over the entire study period. The COV is planning for an increase from 580,000 in 2006 to 675,000 in 2021.

Land Use. Planned densification can increase impervious area, leading to more runoff and combined sewer loading.

Water Conservation. Water conservation programs reduce indoor water use, decreasing sanitary loading.

Seismic Events. Landslides or ground shifting caused by seismic events break or degrade infrastructure integrity.

CONCLUSIONS

In general, it is noted that the VSA is fortunately situated with respect to climate change effects relative to other locations in Canada. Vancouver rarely experiences extreme or catastrophic weather events such as ice storms, tornadoes, drought or extreme cold. Perhaps the greatest magnitude threat is flooding of the Fraser River, and many predict this risk to decline in response to climate change.

The climate factors identified as threats to infrastructure vulnerability will be evidenced as gradual changes. In fact, the greatest pressure to initiate adaptive action comes not from climate change, but from timing of planned infrastructure improvement plans such as the treatment plant upgrades and combined sewer separation program. So while climate change effects may reveal vulnerabilities, Metro Vancouver is in an ideal position to proactively mitigate and adapt to these challenges.

The key priorities with respect to climate change adaptation in the collection system centre on increased rainfall and the associated potential increase in sewer flow, both under combined and separate sewer configurations. Accelerated separation may be necessary to achieve the target of CSO elimination by 2050. The extent of the work required requires additional study.

The vulnerabilities judged to be of the highest priority at the treatment plant are those associated with the effluent disposal system and the IIWWTP site itself because of the storm surge climate variable.

While ranked as lower priorities, the potential impacts of an increase in average sea level on the IIWWTP site and associated infrastructure are also important due to the significant uncertainty and wide range in predicted future increases in mean sea level. Additional study is required to develop more detailed information and conduct detailed analyses in the context of these potential vulnerabilities.

There are several lower-ranked potential treatment system vulnerabilities due to precipitation-related climate variables that potentially exist independent of the LWMP design limit of 17 m3/s. These vulnerabilities are related to facility capacity and redundancy, which in turn affects capacity. At this point there is considerable uncertainty in the significance (i.e. response severity) of these vulnerabilities, particularly given the relative magnitude of the estimated climate effects and the potential ability of Metro Vancouver's sewer separation policy to mitigate these vulnerabilities. Additional study to develop the relationship between these climate variables and the resultant impact on wet-weather wastewater flows may provide enhanced information to assess potential impacts on the treatment system. However, given Metro Vancouver's planned secondary treatment program for the VSA, a more practical approach is to deal with these vulnerabilities as the upgraded treatment is being planned and designed. In this case, Metro Vancouver would consider and account for potential changes in infrastructure capacity as part of the secondary treatment program development, and in the context of other uncertainties (e.g. sewer separation, future population growth, water consumption reduction), without explicitly conducting additional specific study.

The current capacity of standby power available at the IIWWTP is already a vulnerability, which is anticipated to be further exaggerated by climate change. Metro Vancouver should consider the need for remedial action to address this vulnerability.

Given the age of the IIWWTP infrastructure, it is recommended that the additional studies required consider the remaining service life of the components and in the context of other potential issues (e.g. seismic). Even if climate change-related vulnerabilities are deemed to exist, they may be overshadowed by other issues that when resolved can simultaneously address climate vulnerabilities.