

Beyond the Storm: A Risk-Based Process and Tool to Enable Better Understanding and Management of Environmental and Climate Risks

Executive Summary

Climate change can have a significant impact on a Transportation agency's infrastructure and operations. The City of Toronto has developed a first of its kind process and tool, which can be used by any jurisdiction to assess climatic risks and identify adaptive actions. Toronto's Transportation Services Division (TSD) anticipates that its climate-related risks are anticipated to increase in significance in the coming decades. Decisions made today regarding capital investments, program delivery and relationships with key partners will be important in ensuring that risks are reduced and the organization's resilience to climate change is improved.

A key step for any organization in establishing an Environmental Management System and achieving environmental due diligence is to determine the level of concern associated with environmental issues including climate change by undertaking an Environmental Risk Assessment. A major component of the City of Toronto's (the City) Climate Change Adaptation Strategy is to develop a process for identifying and assessing risk due to climate change. The City's innovative approach to addressing the above was to develop Toronto's Environmental Risk Assessment Process and Tool (Tool) that assesses general environmental risks, such as: regulatory requirements, impacts to the environment by City operations, as well as the effects of climate change on the delivery of services, management of infrastructure and protection of the natural environment. The Tool enables service and infrastructure providers to identify and prioritize key environmental and climate change impacts and risks, and assess the benefits of various risk mitigation or adaptive actions.

The Tool has been designed in accordance with the international risk-standard ISO 31000, and incorporates insights derived through a benchmarking study analyzing existing approaches to climate risk assessment around the world, practical learned experience and stakeholder engagement. The Tool takes into account elements of ISO 14001, (the international environmental management system standard), as well as many core principles from the field of environmental auditing. The Tool is a software application that enables service and infrastructure providers to identify and prioritize key environmental and climate change impacts and risks, and to conduct a high-level evaluation of the benefits of various risk mitigation and adaption actions.

The purpose of the Tool is to assist the City of Toronto in avoiding significant costs and service disruption that could harm citizens, businesses or the natural environment in Toronto. TSD conducted a pilot application of the Tool across its various business units that manage critical assets and deliver essential services.

Currently, the City has Council's approval (indemnification licensing agreement required) to share the Environmental Risk Assessment Process and Tool with other municipalities, NGOs and universities in Ontario. Given the applicability of the process and Tool, not only to Transportation but to any other operational group within a municipality and/or private sector, Toronto may pursue to expand the above sharing arrangements. A demonstration of the TSD case study provides insights to the benefits and challenges of adopting a risk-based approach to mitigation of environmental risk and climate adaptation planning. The case study will include consideration of how City staff identified risks and where adaptation actions should go ahead or be accelerated. Also, the case study will demonstrate how the Tool may lead to conclusions that more in depth investigations are necessary on specific issues to understand the vulnerabilities and determine appropriate adaptive actions.

Climate Change Risk Assessment (CCRA) Scope

Climate Change has been identified by Toronto City Council as a high priority concern and unanimously approved a "Climate Change Adaptation Strategy" in July 2008. A key component of the strategy was a recommendation to develop a city-wide risk assessment process to identify vulnerabilities and determine priority impacts requiring adaptation strategies. In addition, Toronto's Auditor General has identified the need for an evaluation of current environmental risks. Figure 1, in Appendix 'A', illustrates the Program that addresses and supports these two mandates. Refer to the Appendix 'A' for all figures and all tables throughout the document.

Transportation Services is currently exposed and sensitive to severe weather events. Adaptation to climate change is necessary in order to reduce vulnerabilities, respond effectively to impacts, and capitalize on opportunities that may arise from climate change. It is anticipated that climate change will exacerbate many current climate risks, in particular leading to increased frequency and magnitude of extreme weather events, including more intense and longer-lasting heat waves and smog episodes, more intense rain, increased risk of disease and pest and snowfall events and an increase in back-to-back events such as rain, freezing rain and snow.

Adapting to climate change will become increasingly important to the successful delivery of TSD's mandate and achievement of corporate objectives. Effective management of climate risks is essential to the good governance of the division and demonstrates stewardship over and accountability for public funds. TSD has committed to understanding its key climate change-related risks and identifying areas where management strategies should be implemented to reduce high exposure risks. The City's Toronto Environment Office collaborated with TSD and representatives from a dozen other departments and an external advisory committee to prepare the specifications for the Tool, which was developed by Deloitte, a consultant retained by the City.

Figure 2 illustrates the inter-relationship between enterprise, environmental and climate change risk and the innovative approach of the CCRA project to develop a Tool for screening and prioritizing all environmental risks with the first application focusing on climate change risks. TSD senior management showed leadership by being the first City Division to pilot the process to better understand where the vulnerabilities lie with respect to its infrastructure and services and the level of risk experienced when exposed to various severe weather events.

The identification of existing and new climate change risks is anticipated to assist the TSD in its efforts to:

- Ensure appropriate resources are allocated for activities that reduce risks and associated climate change costs;
- Mainstream climate change adaptation through adjustments to core functional activities; and
- Identify opportunities for coordinated, cross-functional delivery of climate risk reduction activities.

For the purpose of the pilot study, the following functional groups were identified as having priority assets, infrastructure and services:

- Infrastructure Asset Management and Programming;
- Road Operations; and
- Traffic Management Centre (includes Urban Traffic Controls Systems, Traffic Plant Installation and Maintenance and Transportation Business System).

On the basis of historical experience with various types of weather, the TSD risk assessment team selected seven severe weather types for consideration in the risk assessment: Freeze/Thaw, Extreme Snow, Extreme Heat, Extreme Cold, Extreme Freezing Rain, Extreme Rain and Extreme Wind. Two time horizons were used for assessing climate change risk: 2010-2020 and 2040-2050. Examining risk across time horizons allows for an understanding of the changing nature and significance of risk (i.e., is risk increasing or decreasing over time).

Climate Change Risk Assessment Process

The CCRA process is considered an initial screening activity to test the significance of climate change risks to the achievement of the organizations objectives. The rationale for conducting an initial screening exercise is that it provides a cost-effective basis for identifying and prioritizing risks that may require more detailed Engineering Vulnerability Risk Assessments. The risk assessment process is considered an important component in ensuring compliance with the City of Toronto's draft Policy on Environmental Risk Management.

The climate change risk assessment processes (see Figure 4) consists of four main steps:

1. **Establish the Context:** Define the internal and external organizational factors which influence the assessment, the scope of the assessment, and the criteria against which risks will be assessed;
2. **Risk Identification:** Identify the sources and causes of climate change risks, the vulnerabilities and controls to limit exposure as a result of climate change risks and the resulting impacts on assets and services;
3. **Risk Analysis:** Assign magnitude and likelihood ratings for each risk based on the previously determined assessment criteria and determines an overall risk ranking; and
4. **Risk Treatment:** Prioritize risks on the basis of significance and identify possible controls to reduce risk consequence/ likelihood as well as assessing the effectiveness of those potential risk reduction measures.

Risk Assessment Criteria

Risk analysis involves understanding the level and nature of risk. The objective of the risk analysis is to identify and distinguish between significant risks and risks that are minor or insignificant, and in doing so to provide insight into areas requiring risk prioritization in action plans. Prioritization is essential, because it would be cost prohibitive to even attempt to address all risks. Some level of risk may be acceptable, but conversely, some levels of risks are unacceptable, and require corrective action. This requires a consideration of: magnitude/severity of potential consequences and likelihood of occurrence of the risk (within the defined time horizons).

The assessment of consequence severity and likelihood of occurrence takes into consideration the vulnerability of the assets and services being assessed, whether any risk controls/adaptation measures are in place and their effectiveness at reducing the current consequence and likelihood. The Risk Assessment Tool has a feature whereby risk can be recalculated after new controls have hypothetically or actually been put in place. The level of risk after these new controls have been considered is known as the 'Residual Risk'.

The **Risk Consequence** is assessed for each one of the six impact areas shown in Table 1. Once all consequence types were assessed, the type with the highest ranking is used for reporting purposes. The **Likelihood** of each risk occurring is assessed for each of the two time horizons: Present/Near Term (2010 to 2020) and Medium-Term (2040 to 2050). Probability rate values for each of the seven severe weather types were provided by the Toronto Environment Office for each time horizon, and were factored into the TSD risk assessment team's consideration of likelihood of risk occurrence. The Table 2 provides the likelihood rating level definitions.

Once consequence and likelihood scores were assigned for each of the risks scenarios, a risk rating was calculated. There are four **Risk Levels**: Extreme, High, Medium, and Low. Definitions for each risk rating level are shown in Table 4. These definitions are subject to approval at the corporate level and were used for the purposes of this pilot only. Ideally, these definitions will be adopted and corporately applied. The overall risk level is calculated as follows: **Risk Rating = Consequence Rating x Likelihood**, illustrated in Table 3.

Findings

Much of Toronto's transportation road infrastructure, including its culverts and bridges – is aging, illustrated in Figure 3. Preventative maintenance upkeep is an ongoing challenge with constant pressures to maintain and/or reduce capital and operating budgets. Exacerbating the above stresses is the growing population and urban intensification which increases demands on infrastructure. On top of all these stresses, extreme weather associated with climate change is causing damage to our infrastructure.

The dependency of TSD asset performance on other City public and private infrastructure is significant. How other divisions and utility providers (e.g. telecommunication and electrical supply) integrate climate change considerations into their planning and delivery will impact the ability of TSD to reduce the harm associated with various types of severe weather. It will be important for TSD to engage other City divisions and groups outside the Corporation (energy sector) to undertake integrated risk reduction strategies where appropriate. The costs of severe weather emergency response and repairs are borne by the insurance industry, private sector, utility providers, and ultimately the tax payer, by way of example Toronto's August 2005 storm cost \$550 million after three hours of rain.

The replacement value of TSD's assets is approximately \$12.1 billion. TSD manages over 90 critical assets and essential services. During the CCRA pilot, seven extreme weather event types were identified and various risks examined over two time period horizons resulting in the examination of 1600 impact scenarios. Figure 5 illustrates the overall risks identified for TSD for the Near Term and Medium Term periods.

The CCRA process relies on various workshop meeting attended by experienced staff trained in the risk assessment process. The Tool was used to record staff knowledge regarding the impacts of various types of extreme weather on assets and services. Basically, the Tool helps capture corporate memory, including key documents in the face of accelerating retirements of senior staff. The workshop meetings lead to the identification of new ideas for risk controls. The Tool was used to document those ideas, as well as existing controls. This type of documentation is useful for providing evidence of due diligence.

To provide a specific example of findings for one of the 90 assets and services examined, Table 5 summarizes the climate change risk assessment results for traffic control signal controllers and indicates some of the impacts from extreme heat. The CCRA process and tool includes a mechanism to evaluate and document risk, and existing and future proposed controls that can mitigate the impacts of extreme weather. The City's current asset value is \$31 million for 2,300 traffic control signals. A 1% failure due to extreme weather would be greater than the current annual controller operating budget. Such failure would have a cascading safety, economic, environmental and social impacts caused due to traffic congestion.

Some examples of actions targeting specific assets and services that came out of the CCRA included:

- Clarity budget accountability by TSD for severe weather emergency response and repairs. Budget accountability, extends to other operating groups, such as Toronto Water, Parks, Forestry & Recreation, Facilities Management and Toronto and Region Conservation Authority. This is a significant driver in motivating operating groups in developing their adaptation and emergency planning strategies;
- Conduct an engineering vulnerability assessment of culverts (using Engineers Canada's PIEVC protocol). Culvert inventory, inspection & maintenance program to take into account climate change/severe weather;
- Consider the value of (safe) Citizen reporting of blocked culverts / debris in waterways;
- Consider how heavy trucks and buses could be rerouted through the City in response to an extended heat event that put road surfaces at risk due to pavement softening;

- In cities currently matching Toronto's projected future climatic conditions (e.g., Charlotte, North Carolina, Washington, D.C.), benchmark their current critical infrastructure management practices; and
- TSD has an existing Business Continuity Management (BCM) plan that is designed to reduce the risk of service delivery interruption resulting from Pandemic Influenza. The risk assessment identified that there is a gap in the division's ongoing communication and training regarding the BCM plan, and that a revised version of the BCM plan needs to be developed to reduce risk of service delivery interruption in the event of server weather.

The following highlights some of the strategic actions that Cities need to take to better understand and manage the impacts of climate change:

- Adopt an Environmental Risk Management Policy for the City;
- Increase awareness and understanding at all levels of organizations and outside the organization;
- Conduct "screening level" risk assessments of critical assets and essential service to identify vulnerabilities;
- Conduct engineering vulnerability assessments for infrastructure that are identified as having a high or extreme associated risk; and
- Prioritize adaptation planning and actions for infrastructure and services that are: at critical risk of failure, with high level of services and that is long lived and requires significant investment to renew or replace.

Recommendations

Recognizing that climate change is possibly the world's largest environmental problem, TSD has developed a series of recommendations to cope with physical effects of climate change that can harm infrastructure, service delivery and the environment. These recommendations are relevant to TSD and any other transportation organizations.

Recommendations are structured around six core elements of an effective environmental and climate change risk management system. Recommendations focus on building an integrated environmental and climate risk management program. The recommendations are:

- Identify a **senior management sponsor** responsible for implementation of a climate risk management program;
- Develop a **climate risk management governance structure** with identified roles and responsibilities, and accompanying climate risk charter and policy;
- Implement a **communication and training program** to educate staff in the risk management process;
- Ensure **ongoing risk assessments**, as new information on climate becomes available and as organizational or operational changes occur;
- Identify **climate risk indicators and reporting** requirements for its risk management program. These indicators may be helpful in evaluating Service Delivery Plans and tracking performance; and
- Integrate **risk management programs** with other key business processes within the organization, strategic planning, reporting and day-to-day decision making.

Figure 1: Work Program

This project addresses two key mandated initiatives:

- General Environmental Risk Assessment (from Auditor General);
- Climate Change Risk Assessment (from Council).

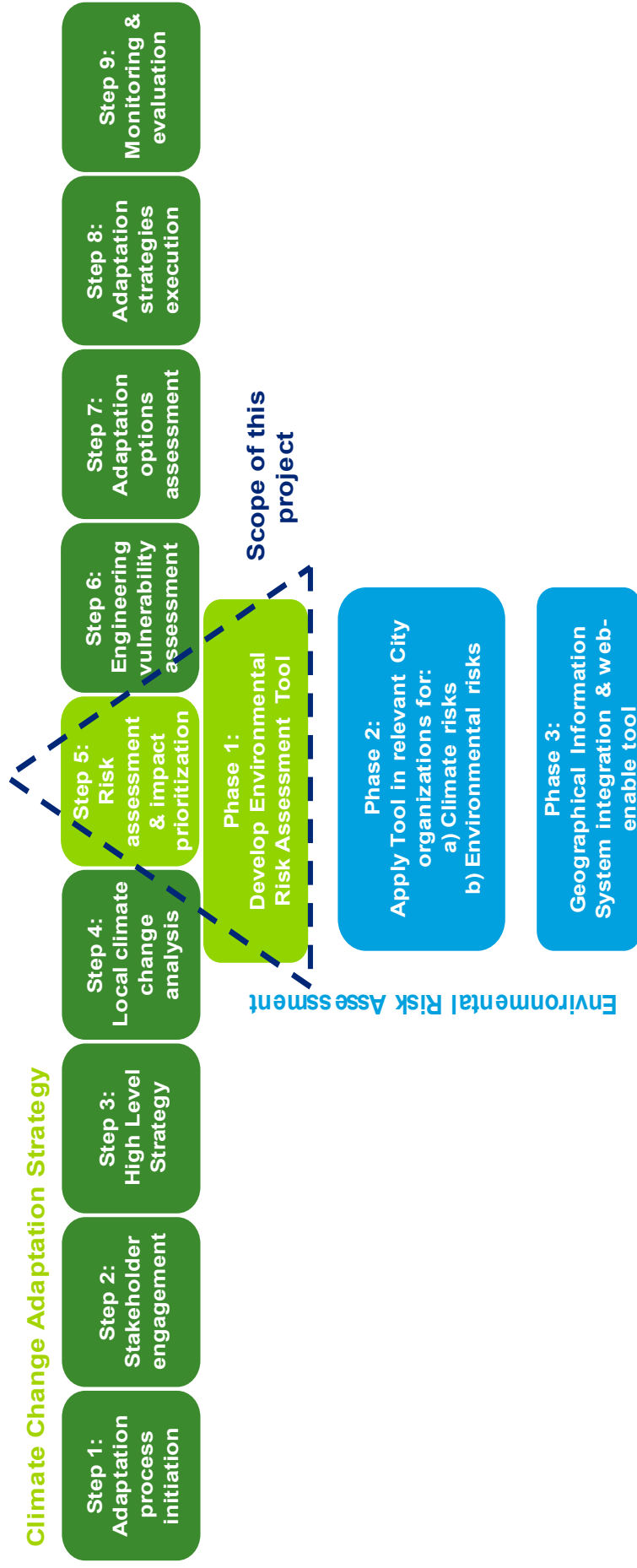
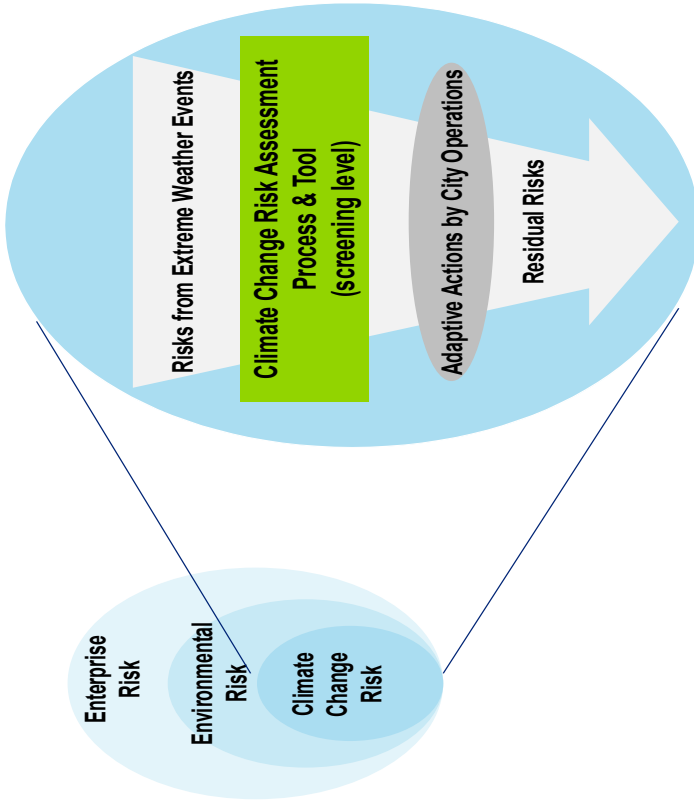


Figure 2: CCRA Scope

- Climate change risk is a subset of environmental risk



- Scope of project is developing a process for screening & prioritizing all environmental risks - first application will focus on climate change risks

Figure 3: Age of Road Infrastructure in Toronto

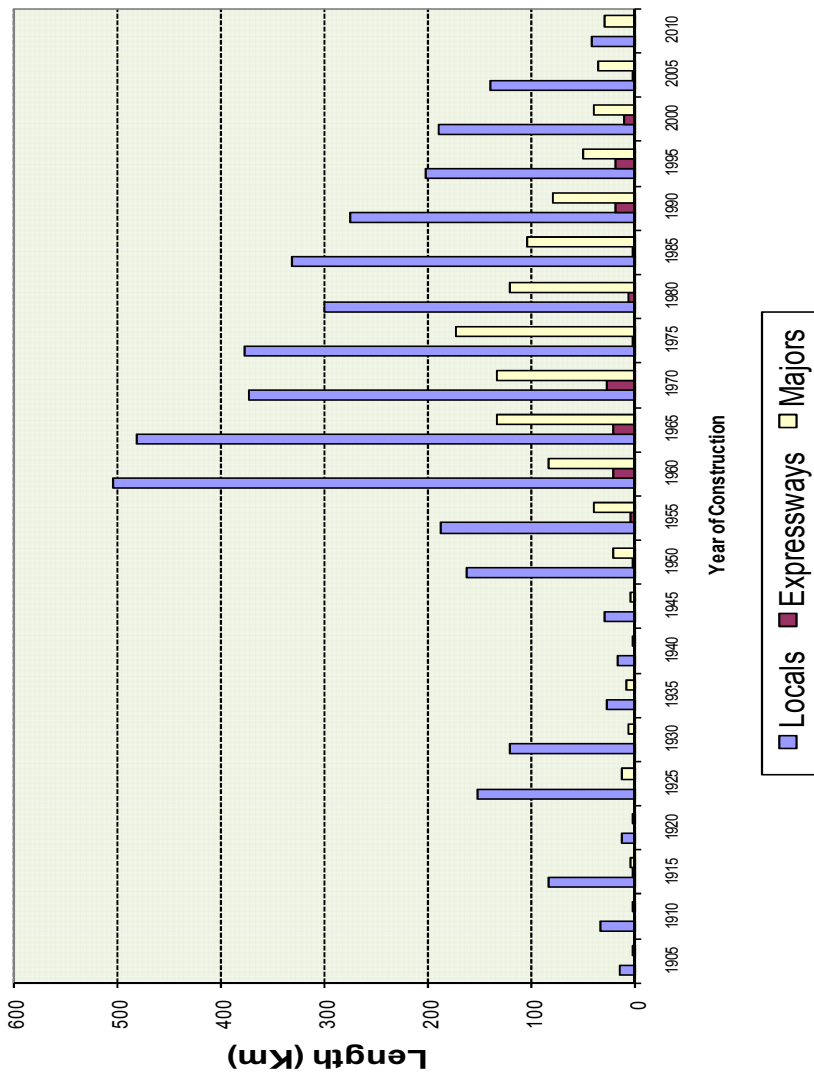


Figure 4: Environmental Risk Assessment Process

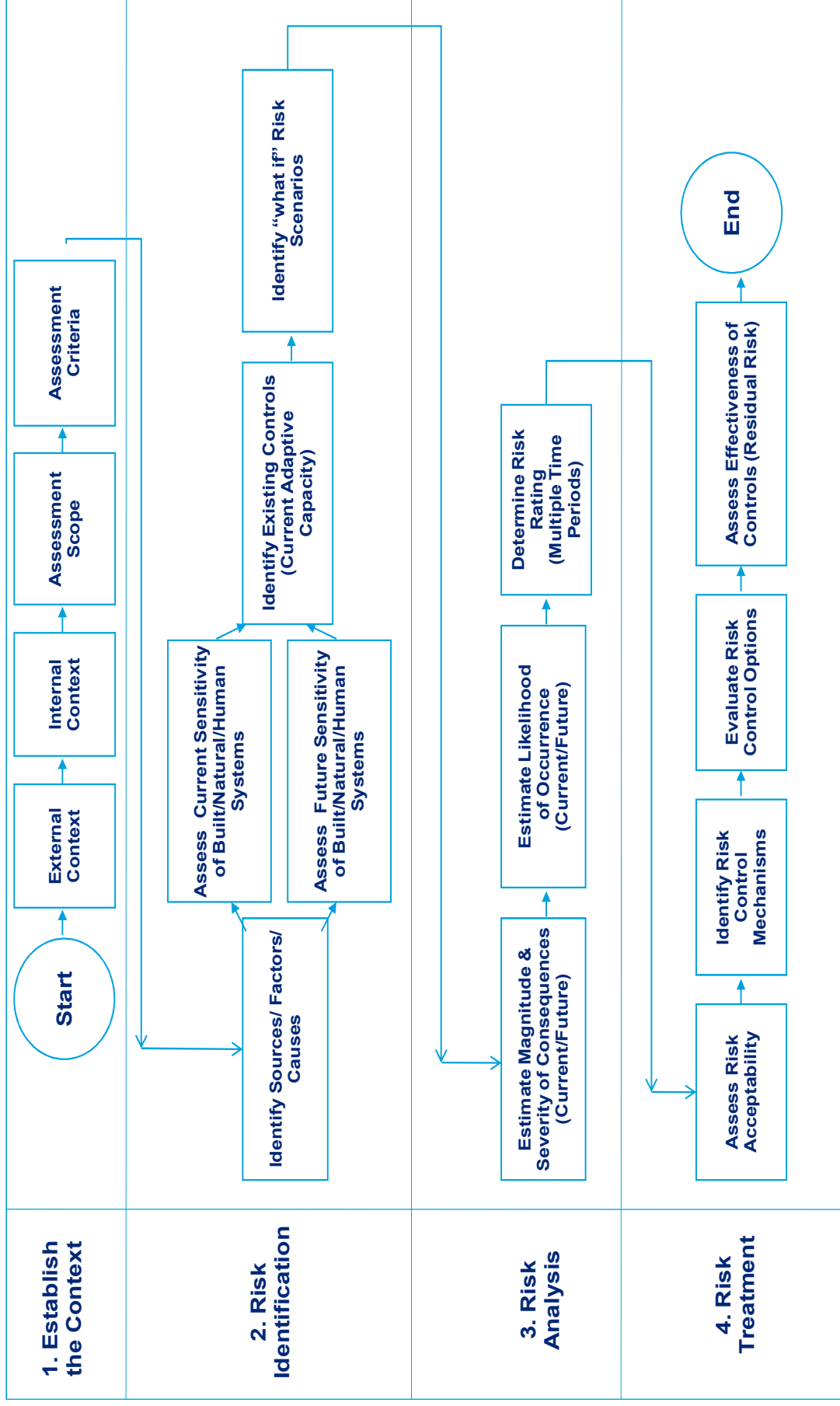


Table 1: Risk Consequence Definitions

	Insignificant (1)	Minor(2)	Moderate(3)	Major(4)	Catastrophic(5)
Premises Infrastructure Assets	No or very limited loss of physical assets Isolated assets affected	Limited loss of physical assets Isolated or a few assets affected	Loss of large but replaceable physical assets Most assets affected but impact on broader system / network is moderate	Loss of significant physical assets System / network wide impact leading to some loss of infrastructure / premises/ asset function	Loss of key physical assets System / network wide impact leading to total loss of infrastructure / premises/ asset function
Cost/Time (including Reputation)	Costs / damages incurred represent <1% capital / operating budget variance No or very minor media attention	Minor costs / damages incurred representing 1-5% capital / operating budget variance Localized community/ interest group/ stakeholder concern and some media attention	Moderate costs / damages incurred representing 5-10% capital / operating budget variance Localized community/ interest group/ stakeholder concern and moderate media attention	Significant costs / damages incurred representing 10-25% capital / operating budget variance Significant loss of confidence in City products and services and considerable media attention Public / media outcry for removal of government official	Massive costs / damages incurred representing >25% capital / operating budget variance Complete loss of confidence in City products and services and sustained media attention Public / media outcry for change in administration and council
Environment	Very minor, non-permanent environmental release promptly contained / damage requiring no clean-up measures No regulatory action	Small uncontained release below legal limit Non-permanent environmental damage requiring very limited clean-up efforts. Regulatory warning or order	Moderate environmental damage with moderate clean-up required, no permanent damage. Permit violation Charges leading to fines	Major environmental damage / extended clean-up required/ some permanent damage Charges leading to fines and/or criminal liability	Irreparable, significant damage to environment Criminal charges and/or civil liability
Logistics Supply Chain, Utilities and Transport Infrastructure	No disruption of City supplies Utilities and transport system continue to function as usual, with no impact on City operations or clients	Limited disruption of supply chain due to isolated events, with City inventory able to cope Isolated incidences of power / water outages / transport system delays, with limited impact on City operations or clients	Suppliers experience moderate delays, with City inventories experiencing shortages Numerous/localized incidences of power / water outages / transport system delays, with moderate impact on City operations or clients	Suppliers are unable to provide materials for a prolonged period of time, with City inventory shortages leading to temporary disruption of services Widespread power / water outages / transport system delays, with significant impact on City operations or clients	Suppliers are unable to provide materials for an extensive period of time, with City inventory shortages leading to lengthy disruption of services Total failure of power / water / transport system, leading to shut-down of City operations and massive disruption of clients
People Staff, and Clients of City Services	No injuries/ medical treatment No impairment of well-being / quality of life	Minor injuries / first aid or minor illness Minor discomfort or displacement	Serious injuries to clients or staff resulting in non-permanent injury / Lost time incident Workplace/living conditions are temporarily rendered unusable/unavailable, with moderate disruption to productivity and living arrangements/ quality of life (e.g. need temporary shelter)	Serious injuries to clients or staff resulting in some permanent disability Staff/ clients/ residents are unable to use City facilities and services for a sustained period with significant impact on work and living arrangements / quality of life (e.g. displaced from own residences)	Death and/ or significant permanent disability of clients or staff Staff/ clients/ residents are permanently unable to use City facilities and services –with catastrophic impact on work and living arrangements / quality of life (e.g. unable to find suitable alternative living arrangements)
Corporate Processes Functions, and Service Delivery	No or very minor disruption in delivery of essential services, projects or processes No increase in demand for services	Minor disruption in delivery of essential services, projects or processes Minor increase in demand for services, but manageable within existing budget	Moderate disruption in delivery of essential services, projects or processes Moderate increase in demand for services, requiring increasing frequency of delivery and minor budget	Significant disruption in delivery of essential services, projects or processes Significant increase in demand for services, requiring large increase in frequency/breadth of delivery and moderate budget provision	Unable to perform essential services , projects or processes for extended period

Table 2: Likelihood Rating Definitions

Likelihood Rating	5	Almost Certain – the risk will occur	90-100% probability	Multiple times in one year
	4	Very Likely – the risk will probably occur	55-90% probability	One time per year
	3	Likely – the risk could occur	30-55% probability	One time per decade
	2	Unlikely – the risk may occur	5-30% probability	One time per hundred years
	1	Rare – the risk will occur only in exceptional circumstances	<5% probability	One time per two-hundred and fifty years

Table 3: Risk Rating

		Consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likelihood	Almost Certain	M	M	H	E	E
	Very Likely	L	M	H	H	E
	Likely	L	M	M	H	H
	Unlikely	L	L	M	M	M
	Rare	L	L	L	L	M

Table 4: Risk Level Definitions

Risk Level	Description
Extreme	Primary or critical risks requiring immediate attention. They may have a high or low likelihood of occurrence, but their potential consequences are such that they must be treated as a high priority. Deputy City Manager involvement is essential. DCM to follow City protocol for notification of City Manager, Mayor or Council.
High	These risks are classed as significant. They may have high or low likelihood of occurrence, but their potential consequences are sufficiently serious to warrant appropriate consideration. Senior management involvement (e.g. Division Head) is essential. The Deputy City Manager should be informed.
Medium	These risks are less significant, but may cause upset and inconvenience in the short-term. Operations Management should ensure that preventive controls and mitigation plans are established and maintained, and risks are re-assessed at appropriate intervals. The Division Head should be informed.
Low	These risks are both unlikely to occur and not significant in their impact. Risks should be managed by routine procedures. Employees and contractors should be made aware of risks.

Table 5: Detailed Summary of High and Extreme Risk and Controls

Unit	Asset Name	Risk Source	Time Period	Impact	Current Controls	Proposed Controls
Traffic Plant Installation and Maintenance	Traffic Control Signal – RESCUE-Controllers	Extreme Heat	2040-2050	Infrastructure Damage, Vehicle collision, Death-Bodily Injury, Claims	<ul style="list-style-type: none"> Ongoing monitoring of traffic signal controllers New upgraded Controllers being installed have new features that help increase resilience by including cabinet heaters, cooling fans and also using lighter coloured exterior paint The fan turns on at 35 C and heater at 1C. The Controller spec is max. 70 C to -35 C as measured inside the controller (not ambient temperature) There is a conflict monitor inspection every 6 months Maintenance and installation is 100% contracted 	<ul style="list-style-type: none"> Perform a study to determine the relationship between the temperature inside the controller cabinet versus ambient air temp Monitor the use of the heater and cooling fan to see if the frequency of use is increasing As part of routine inspections, include the inspection of the heating and cooling system Accelerate the installation of environmental controls Scheduled system-wide monitoring of the signals by Communication System Operator (CSO) Install an audible signal at the CSO station that is activated when there is a controller failure Improve coordination and delivery of work program between Transportation Division and Bell Engage manufacturers to develop controller components that meet the future heat thresholds Install air conditioners to existing cabinets or inside future cabinets for critical intersections – emergency routes Install UPS – uninterrupted power supply for critical intersections – emergency routes Third party verification of cabinet performance under extreme heat Engineering vulnerability risk assessment of cabinet performance Implement an Asset Management System
			2010-2020	Power Outage, Signal Malfunction, Increase in Workload, Increase in Operating Budget		
			2040-2050	Power Outage, Signal Malfunction, Traffic congestion, Increase in emissions due to congestion		
			2010-2020	Power Outage, equipment inoperable, Vehicle collisions, Claims		
			2040-2050	Power Outage, equipment inoperable, Vehicle collisions, Media / public attention		
			2040-2050	Health Problems, Increase in absenteeism, Delay of critical service delivery		
			2040-2050	Reduced Workforce, Delay of critical service delivery, Traffic congestion, Increase in emissions due to congestion		
			2040-2050	Reduced Workforce, Delay of critical service delivery, Vehicle collision, Claims		

Transportation Services Overall Risk

Figure 5:

