City of Saint John

Risk Rating Manual

Version 3.0

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SAINT JOHN

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1.0 INTRODUCTION

This document presents a risk management framework intended for use in the context of Asset Management by the City of Saint John. Previous versions of this document described the general risk management framework were issued in October (version 1.0) and November (version 2.0) of 2018 and were presented to City staff during December of 2018. The current version of this document (version 3.0) was expanded to include guidance on how to include the quantification of asset service loss risks due to the expected effects of climate change.

2.0 RISK MANAGEMENT FRAMEWORK

The purpose of risk management in the context of Asset Management is to provide municipalities a systematic approach to identifying, evaluating, and mitigating asset risks across all service areas. The approach to risk management consists of the following four steps:

1. Establish the risk management framework (this document)
2. Identify risks
3. Evaluate risks
4. Identify and evaluate mitigation opportunities

The identification of risks to municipal infrastructure assets is based on recognizing risk events for specific assets, while these risk events are evaluated using a rigorous methodology to quantify their likelihood and severity. The identification and evaluation of risks uses a standardized approach in a workshop setting to maximize the input of operations staff in this important process to rank risks and prioritize remedial actions to mitigate these risks.

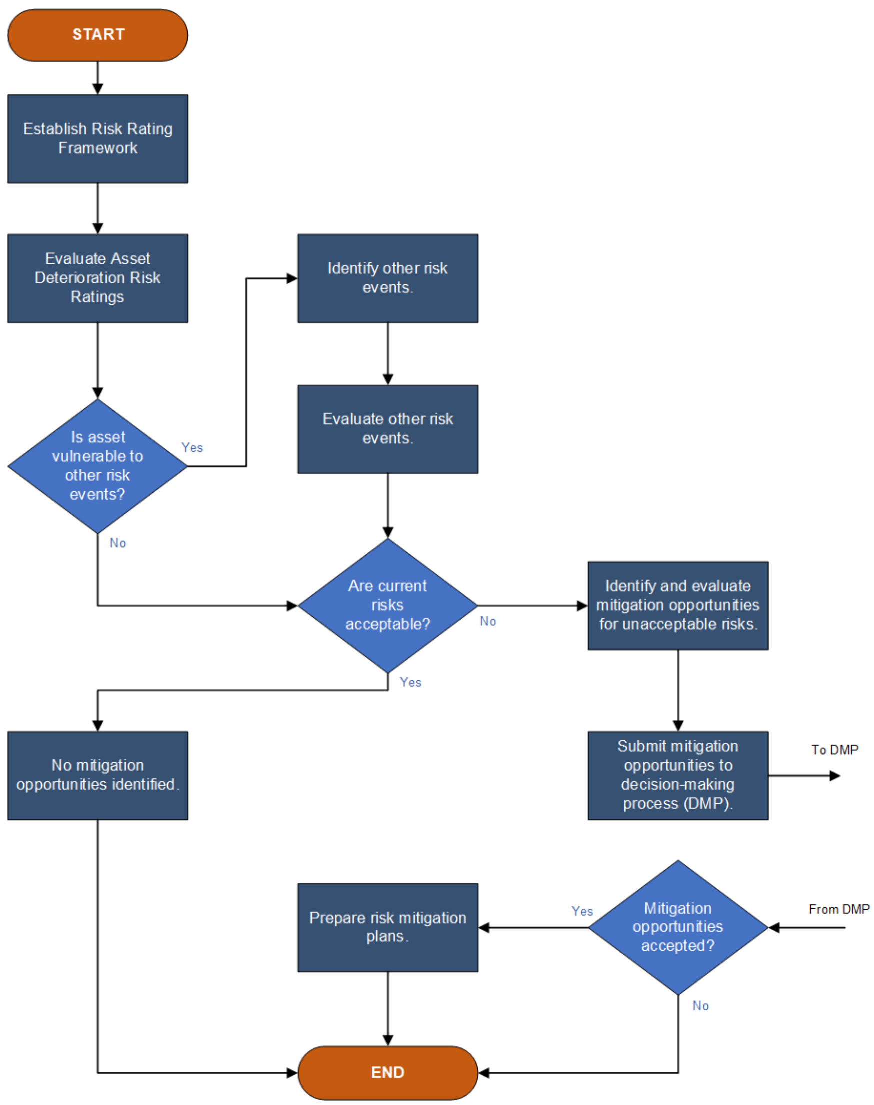
It should be noted the risks ratings developed during the risk management process are approximate and serve to identify remedial activities (such as major maintenance, refurbishment and replacement) that will maximize risk mitigation and service delivery resiliency. As the risk ratings are relative, they are performed using integer scores and reader is cautioned not to obsess over the scoring details by using decimal scores. It should also be noted the risk rating methodology presented below is a “bottom-up” approach, whereby each asset is evaluated independently and in isolation of the overall system it may be part of. Therefore, planners and managers should also consider a “top-down” approach where the impact of risk events on systems or the entire municipality are evaluated.

In addition to establishing the risk management framework, this document provides additional guidance and templates to evaluate risk events, particularly those affected by the effects of climate change. Evaluating weather-related risk events for historic and expected future climate conditions will allow the municipality to identify asset vulnerabilities related to climate-change.

Overall, the City planners and asset managers should follow the process laid out in Figure 1 to complete risk analyses of municipal assets. This flow chart emphasizes the following points:

- Rate the risk of asset failure due to deterioration for **all** assets.
- Carefully select other risk events (including current and future climate driven events) to evaluate to avoid unnecessary efforts.
- Assess if current risks are acceptable.
- For unacceptable risks, evaluate and submit risk mitigation opportunities to the larger decision-making process.
- If risk mitigation opportunities have been selected, prepare risk mitigation plans to identify the timing and cost of activities.

Figure 1 - Risk Management Process



2.1 Identify Risks

The risk identification process is intended to recognize **risk events**. Risk events are defined as an occurrence with a *cause* and chain of possible *effects* which impact an asset. Once identified, risks are recorded in a **risk register** (example shown in Table 1).

Table 1 - Risk Register Example

Asset	Risk Event	
	Cause	Effect
Culvert 0001	Deterioration	Structural failure (collapse)
	Extreme rainfall	Structural failure (washout)
Culvert 0002	Deterioration	Headwall failure (scour)
	Extreme Rainfall	Upstream flooding
Culvert 0003	Deterioration	Structural failure (collapse)
	Extreme rainfall	Structural failure (washout)

In asset management, the most common risk event identified is the “(structural) failure of an asset due to deterioration” and it is recommended that **all** municipal assets receive a risk rating for this event. This example highlights the two components of a risk event: a **cause** and an **effect**. For this risk event, the *cause* is “deterioration” (directly related to condition) and the *effect* is “structural failure”. Note, a single asset may be exposed to multiple risk events, and causes may have multiple effects, leading to additional risk events. For this reason, it is recommended City planners carefully identify other risk events as the total number of risks to evaluate can grow quickly.

For the City of Saint John, several potential risk events have been identified (see Table 2). These risk events should be reviewed by each Department to determine which assets are vulnerable and to identify any other risk events which may threaten their assets. Please note the cause and effect of potential risk events (including the expected future effects of climate change) are asset and event specific and are best determined by staff in a workshop setting. The effect column in table 2 is therefore left blank to reflect this unique relationship.

Table 2 - City of Saint John Risk Events

Category	Risk Event	
	Cause	Effect
General	Deterioration	Structural failure
Weather/Natural	Extreme rainfall (inland flooding)	…
	Coastal erosion	…
	Storm surge (coastal flooding)	…
	High winds	…
	Ice Storm	…
	Extreme Heat	…
	Drought	…
	Freeze-thaw cycles	…
	Extreme cold	…
	Sunshine intensity	…
	TBD	…
Other	TBD	TBD

2.2 Evaluate Risks

Risk evaluation allows the identified risks to be analyzed in a systematic manner to determine which risks are the most severe and are unacceptably high. The overall risk to an asset depends on both the **probability** and **consequence** of the risk event. All assets in the City of Saint John are evaluated on a 1 – 25 risk rating matrix, shown in Table 3.

This process evaluates both the probability and consequence of a risk event on a 1 – 5 scale and combines the two values to give an overall risk rating for each event. The 1 – 5 rating scales simplifies the risk evaluation process, synchronizes probability and consequence with asset condition, and is the most common framework used by Canadian municipalities.

Table 3 - Risk Rating Matrix

		Consequence				
		1 Insignificant	2 Minor	3 Severe	4 Major	5 Catastrophic
Probability	1 Improbable	1	2	3	4	5
	2 Unlikely	2	4	6	8	10
	3 Possible	3	6	9	12	15
	4 Likely	4	8	12	16	20
	5 Highly Probable	5	10	15	20	25

- Very Low Risk
- Low Risk
- Medium Risk
- High Risk
- Very High Risk

2.2.1 Probability

The probability of a risk event occurring is directly related to its **cause**. The simplest probability to evaluate in asset management is the probability of asset deterioration, as it is directly related to the current physical *condition* of the asset. For this reason, both the condition ratings and probability ratings for all City assets are to be scored on a 1 – 5 rating scale (see Condition Rating Manual for additional guidance on evaluating asset condition). However, the probability of weather or natural events is less easily determined. Additionally, climate change considerations can have a significant impact on the probability of these impacts. For each of the weather/natural risk events listed in Table 2, additional guidance will be compiled during asset specific workshops to assist municipal planners and managers to determine the probability of these events impacting their assets. As workshops are held to identify and quantify the risk events for the various assets in the City's inventory, information on weather/natural risk events used during these workshops will be compiled in Appendix 1 for future use and reference.

Probability of risk events can be assessed either qualitatively (e.g. improbable vs. highly probable) or a quantitatively (e.g. will occur in next 5 years or has a 20% chance of occurring or being exceeded any year). For the City of Saint John's asset management program, a 1 – 5 probability rating scale is used and both qualitative and quantitative measures have been defined to assist planners and managers in evaluating their assets (see Table 4). When evaluating the probability of weather or natural events, City planners and managers should use this table in conjunction with the guidance material to be compiled in Appendix 1 to evaluate the probability of risk events for selected assets.

Table 4 - Probability of Failure Definitions

Probability Rating	Qualitative	Quantitative	
		Expected Occurrence	Statistical Probability
1	Improbable	> 20 years	0 - 5%
2	Unlikely	10 – 20 years	5 – 10%
3	Possible	4 – 10 years	10 – 25%
4	Likely	2 – 4 years	25 – 50%
5	Highly Probable	1 year	50 – 100%

2.2.2 Consequence

The consequence of a risk event occurring is directly related to its **effect**. When evaluating the consequence of a risk event, organizations should consider multiple criteria (e.g. cost to recover from the event, health and safety, impact on environment). To incorporate multiple criteria into a consequence evaluation methodology, a multi-criteria analysis or threshold analysis can be used. The multi-criteria analysis includes all relevant criteria and weighs each one according to their relative impact. The threshold analysis sets limits to each of the consequence rankings and if any of the them are “achieved”, then the corresponding consequence rating is used.

For the City of Saint John, a threshold analysis is recommended to simply the evaluation process. A guide to determine the consequence of risk events has been prepared for all City assets and is shown in Table 5. This guide includes the following criteria and an example on its use is shown in Table 6. In this example, the consequence rating for the risk event would be a **3** as it is the maximum consequence rating achieved for the criteria evaluated

Table 5 - Consequence Rating Guide

Consequence Rating		Recovery Cost	Health and Safety	Loss of Service	Environment
1	**Insignificant**	< $,2000	Negligible or no injury.	Small number of customers experiencing minor disruption.	Negligible or no environmental impact.
2	**Minor**	$2,000 - $20,000	Minor personal injury.	Small number of customers experiencing significant disruption.	Impact reversible within 3 months.
3	**Severe**	$20,000 - $100,000	Serious injury with hospitalization.	Significant localized service loss over an extended period.	Impact reversible within 1 year.
4	**Major**	$100,000 - $1M	Loss of life.	Major localized disruption over an extended period.	Impact reversible with 5 years.
5	**Catastrophic**	> $1M	Multiple loss of life or city-wide epidemic.	Major long-term city-wide disruption.	Impact not fully reversible.

Table 6 - Consequence Rating Example

Consequence of Failure		Recovery Cost	Health and Safety	Loss of Service	Environment
1	**Insignificant**	< $,2000	Negligible or no injury.	Small number of customers experiencing minor disruption.	Negligible or no environmental impact.
2	**Minor**	$2,000 - $20,000	Minor personal injury.	Small number of customers experiencing significant disruption.	Impact reversible within 3 months.
3	**Severe**	$20,000 - $100,000	Serious injury with hospitalization.	Significant localized service loss over an extended period.	Impact reversible within 1 year.
4	**Major**	$100,000 - $1M	Loss of life.	Major localized disruption over an extended period.	Impact reversible with 5 years.
5	**Catastrophic**	> $1M	Multiple loss of life or city-wide epidemic.	Major long-term city-wide disruption.	Impact not fully reversible.

2.3 Climate Change

The risk rating methodology presented above directly links risks of asset service loss to age-driven deterioration of asset condition. Specifically, the probability of failure increases as the asset ages and its condition deteriorates (i.e. a new asset in good condition is unlikely to fail while an old asset near the end of it service life and in a poor condition is likely to fail) and assumes the environmental loads experienced by the asset were fully anticipated during its design (i.e. the flows conveyed by a culvert during its service life were anticipated during its design and the risks of overtopping, washout or structural failure from flows in excess of its design capacity are negligible).

However, the effects of climate change are resulting in environmental loads on assets not anticipated during design (i.e. climate change may result in culvert overtopping and washouts from increased flows or a lift station may be flooded from high river flows of storm surges). This in turn results in an increased probability of asset failure not related to age or condition which will not be reflected in the existing risk assessment methodology. In order to quantify the probability of service loss from asset failure due to both age-driven deterioration and the effects of climate change, additional risk events will be evaluated using the risk assessment methodology to quantify risks from extreme (future) weather events. These risks from extreme weather events will be evaluated using a climate change vulnerability assessment.

The climate change vulnerability assessment will be based on the well-established Public Infrastructure Engineering Vulnerability Committee (PIEVC) methodology developed by Engineers Canada and the Institute for Public Works Engineering of Australasia's (IPWEA) risk rating framework and sample risk register. The proposed approach will include the following and will reside in the boxes labelled "Identify other risk events" and Evaluate other risk events" as shown in Figure 1:

1. Quantify the historic environmental loads in Saint John, including but not limited to: design rainfall intensity, wind speed, storm surges, sea level elevations, flood inundation limits, freeze-thaw cycles, extreme and average temperatures. This information will be extracted from published sources.
2. Identify the interaction of these environmental loads with selected infrastructure assets. Asset specific field data will have to be collected to quantify these interactions.
3. Estimate the impacts of these load-asset interactions on the services provided by the assets.
4. Quantify the risks of service loss from asset failure by defining and multiplying the probability of asset service failure under historic environmental loads with the consequence of asset service failure.

5. Repeat steps 1 through 4 for expected future environmental loads. Expected future environmental loads can be obtained published sources based on either down-scaled global circulation model results or projected historic environmental loads.

6. Review the increased risks of asset service loss for both historic and expected future environmental loads for the selected infrastructure assets, extrapolate these results to the entire asset inventory (the City's Geographic Information System will prove especially useful) and identify increases in risk deemed to be unacceptable (as per Figure 1 and section 2.4 below).

7. Identify options to mitigate unacceptable service loss risks for selected typical infrastructure assets and evaluate the cost-benefit of these options (as per Figure 1 and section 2.4 below).

8. Extrapolate the mitigative options and associated cost-benefit results to the entire asset inventory.

The climate change-driven service loss risks developed using the above vulnerability assessment will be combined with the age-driven deterioration service loss risks developed using the existing risk assessment methodology by either adding or averaging the respective risks for each asset in the existing asset risk registers. These revised service loss risks will now reflect both age-based deterioration and climate change risk drivers, and will incorporate climate change-driven risks in the management of the City's asset inventories.

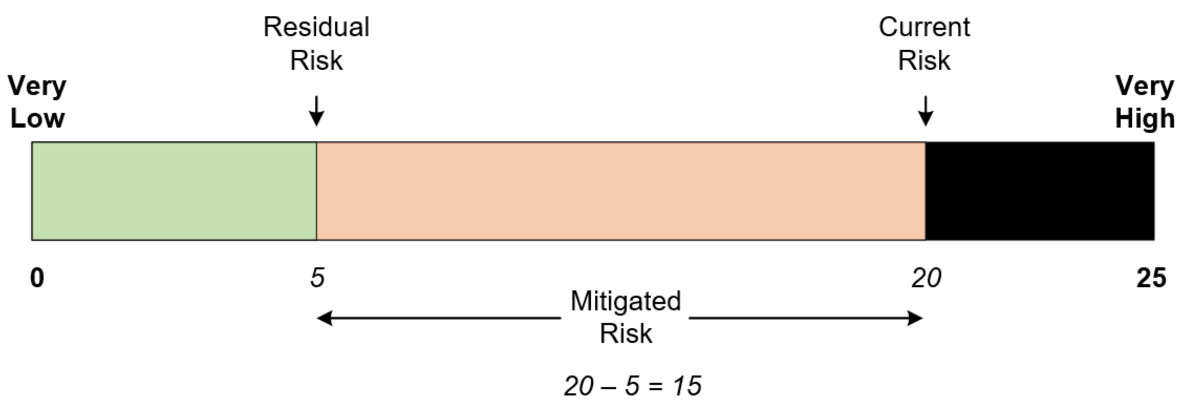
2.4 Identify and Evaluate Mitigation Opportunities

After risk ratings have been quantified, City planners and managers will determine if the current risk is "acceptable". If the risk is deemed to be unacceptable then mitigation opportunities should be identified. A mitigation opportunity is an activity which changes the probability **or** consequence of one or multiple risk events for an asset. Examples of mitigation opportunities include:

- Renew or remove asset
- Better/upgrade asset
- Adjust asset's impact on system

To evaluate the effectiveness of a mitigation opportunity, risk planners need to evaluate the cost and **residual risk** for each opportunity identified. The residual risk of a mitigation opportunity is calculated by estimating the "new" probability and consequence of each risk event *if the mitigation opportunity were to be executed*. The difference between the current risk and the residual risk is the **mitigated risk** and is an indication of how valuable the mitigation opportunity is. This concept is demonstrated graphically in Figure 2 below. Mitigated risks can also be evaluated on a cost-effectiveness basis by dividing the mitigated risk by the cost of each mitigation opportunity.

Figure 2 - Mitigated Risk Calculation



APPENDIX 1

Weather/Natural Risk Event Guidance

To be populated with information from asset specific climate change vulnerability workshops.