AECOM Imagine it. Delivered.

City of Prince George

# Integrated Stormwater Management Plan

## *Guiding Document*


**Prepared by:**

AECOM Canada Ltd.
3292 Production Way, Floor 4
Burnaby, BC V5A 4R4
Canada

T: 604 444 6400
F: 604 294 8597
www.aecom.com


**Prepared for:**

City of Prince George
1100 Patricia Boulevard
Prince George, B.C.
V2L 3V9


**Date:** August 10, 2021

**Project #:** 60628231

## Distribution List

| # Hard Copies | PDF Required | Association / Company Name |
|---|---|---|
| | ✓ | **Error! Reference source not found.** |
| | ✓ | AECOM Canada Ltd. |

## Version History

| Version # | Date | By: | Description |
|---|---|---|---|
| 1 | July 23, 2021 | Nancy Hill | Draft for Review |
| 2 | August 10, 2021 | Nancy Hill | Final – revised based on City comments |

AECOM Canada Ltd.
3292 Production Way, Floor 4
Burnaby, BC V5A 4R4
Canada

T: 604 444 6400
F: 604 294 8597
www.aecom.com

Kristy Bobbie, AScT
Asset Manager, Asset Management Division
1100 Patricia Blvd,
Prince George, BC V2L 3V9

August 10, 2021

***Project #***
60628231

Dear Ms. Bobbie:

**Subject: Integrated Stormwater Management Plan Guiding Document**

Please find attached the final version of the Guiding Document, which has been revised based on your feedback.

Sincerely,
**AECOM Canada Ltd.**

Nancy Hill

Nancy Hill, P.Eng.
Project Manager
Nancy.hill@aecom.com

NH:
Encl.

# Statement of Qualifications and Limitations

The attached Report (the "Report") has been prepared by AECOM Canada Ltd. ("AECOM") for the benefit of the Client ("Client") in accordance with the agreement between AECOM and Client, including the scope of work detailed therein (the "Agreement").

The information, data, recommendations and conclusions contained in the Report (collectively, the "Information"):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the "Limitations");
- represents AECOM's professional judgement in light of the Limitations and industry standards for the preparation of similar reports;
- may be based on information provided to AECOM which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the Report and the Agreement; and
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time.

AECOM shall be entitled to rely upon the accuracy and completeness of information that was provided to it and has no obligation to update such information. AECOM accepts no responsibility for any events or circumstances that may have occurred since the date on which the Report was prepared and, in the case of subsurface, environmental or geotechnical conditions, is not responsible for any variability in such conditions, geographically or over time.

AECOM agrees that the Report represents its professional judgement as described above and that the Information has been prepared for the specific purpose and use described in the Report and the Agreement, but AECOM makes no other representations, or any guarantees or warranties whatsoever, whether express or implied, with respect to the Report, the Information or any part thereof.

Without in any way limiting the generality of the foregoing, any estimates or opinions regarding probable construction costs or construction schedule provided by AECOM represent AECOM's professional judgement in light of its experience and the knowledge and information available to it at the time of preparation. Since AECOM has no control over market or economic conditions, prices for construction labour, equipment or materials or bidding procedures, AECOM, its directors, officers and employees are not able to, nor do they, make any representations, warranties or guarantees whatsoever, whether express or implied, with respect to such estimates or opinions, or their variance from actual construction costs or schedules, and accept no responsibility for any loss or damage arising therefrom or in any way related thereto. Persons relying on such estimates or opinions do so at their own risk.

Except (1) as agreed to in writing by AECOM and Client; (2) as required by-law; or (3) to the extent used by governmental reviewing agencies for the purpose of obtaining permits or approvals, the Report and the Information may be used and relied upon only by Client.

AECOM accepts no responsibility, and denies any liability whatsoever, to parties other than Client who may obtain access to the Report or the Information for any injury, loss or damage suffered by such parties arising from their use of, reliance upon, or decisions or actions based on the Report or any of the Information ("improper use of the Report"), except to the extent those parties have obtained the prior written consent of AECOM to use and rely upon the Report and the Information. Any injury, loss or damages arising from improper use of the Report shall be borne by the party making such use.

This Statement of Qualifications and Limitations is attached to and forms part of the Report and any use of the Report is subject to the terms hereof.

*AECOM: 2015-04-13*

# Authors

**Report Prepared By:**

Nancy Hill, P.Eng.
Project Manager

**Report Reviewed By:**

Janie Bergeron, P.Eng.
Deputy Project Manager

# Table of Contents

page



## List of Figures



## Appendices

# 1. Introduction

This Guiding Document provides an overview of the City's recently completed Integrated Stormwater Management Plan (ISMP). The document was developed to answer four key questions for stormwater management in the City of Prince George; namely:

- What do we have? A description of the current state of stormwater management in the City;
- What do we want? A summary of the vision and goals for stormwater management in the City;
- How do we put this into action? The action items that are needed in order to realize the vision and goals developed for the City's stormwater management program; and
- Are we on target? A strategy for ensuring that the City's ISMP successfully achieves the City's stormwater goals and that the ISMP adapts as needs change.

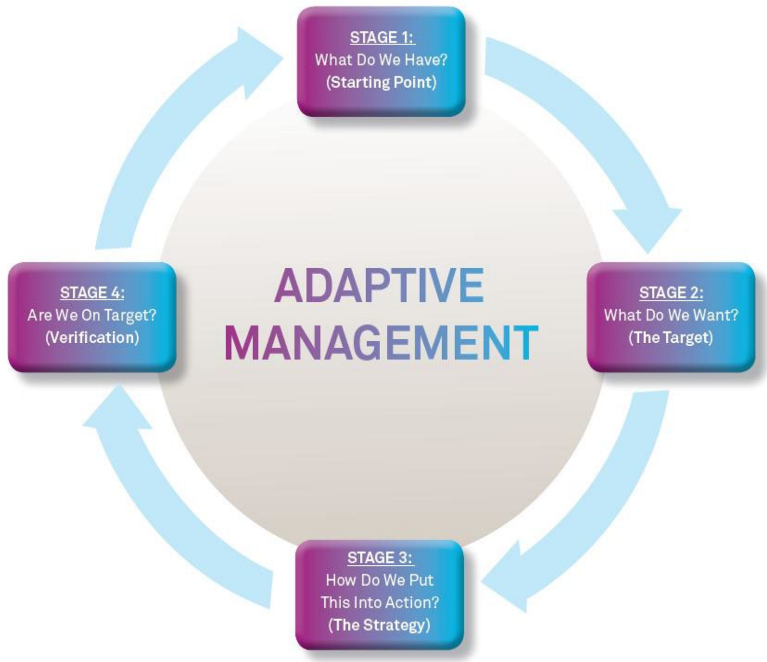



**Figure 1: Guiding Document Approach**

A summary of this approach is provided in the preceding figure. A Roadmap, which is a visual summary of the Guiding Document, is provided in **Section 4**.

The action items outlined within **Section 4** of this document are the key action items that are considered the most important. All action items identified as part of this ISMP are listed within a spreadsheet that is replicated in **Appendix A**.

The detailed analysis completed as part of the ISMP is described within four Technical Working Papers (TWP):

- TWP #1: Technical Background
- TWP #2: Engineering & Asset Management Issues
- TWP #3: Policy and Regulatory Review
- TWP #4: Financing Options

These TWPs are provided as **Appendices B-E** to this Guiding Document.

# 2. What Do We Have?

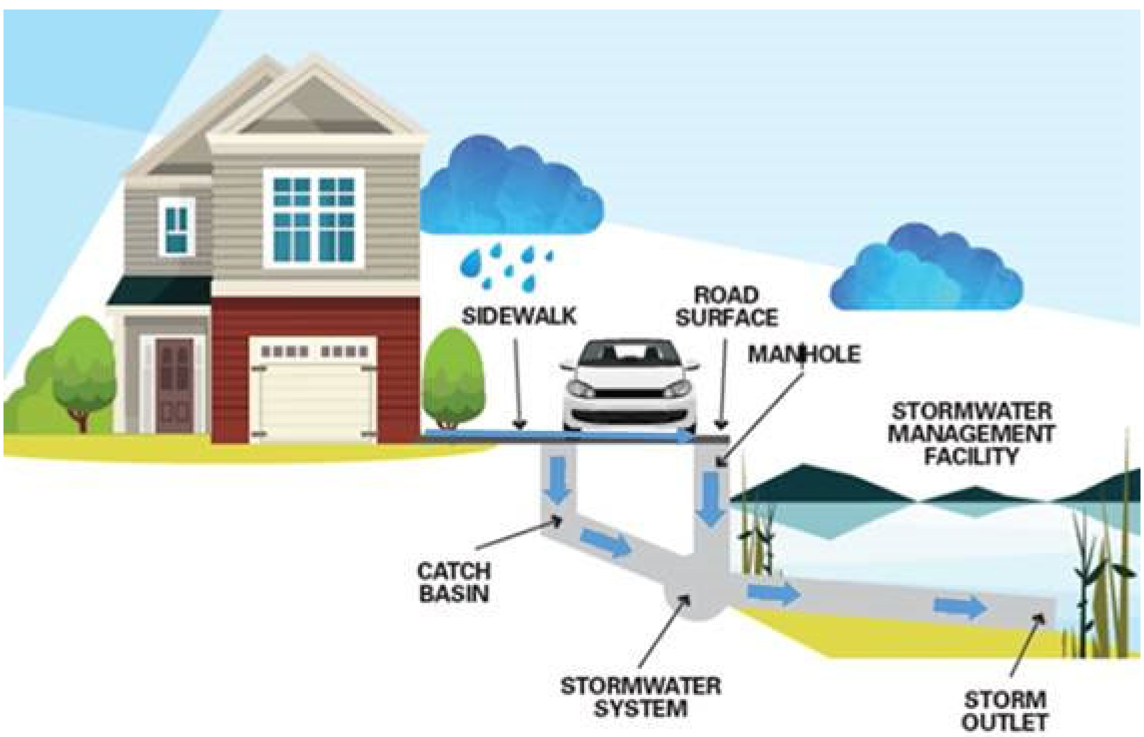
This section provides a description of the current state of stormwater management in the City of Prince George; which includes areas of strength as well as several challenges that the City is currently facing.

## 2.1 What is Stormwater Management

Stormwater comes from the rain and melted snow that flows over land and into storm drains (e.g. catch basins), ditches or creeks. Natural landscapes soak up some or all the stormwater that falls on it like a sponge and recharges the groundwater. Impervious surfaces, such as pavement, prevent rain and melted snow from naturally soaking into the ground. Instead the water runs quickly into catch basins, drainage ditches, and creeks before ultimately flowing to the Fraser and Nechako Rivers.

The City uses a system of catch basins, storm sewers, ditches, culverts, ponds, pump stations, subsurface infiltration facilities and creeks to manage and convey stormwater that runs-off private properties as well as public rights-of-way (e.g., roads). The following schematic shows a typical section of a municipal stormwater system. It is important to note that only some of the City's stormwater run-off is treated by a stormwater management facility (i.e. pond) before being discharged to the natural receiving environment (e.g. creek or river).

**Figure 2: Typical Municipal Stormwater System**



The City manages stormwater to prevent flooding and erosion and to protect watersheds, including creeks and groundwater aquifers. In order to do this the City has constructed over $300 million of stormwater infrastructure which includes:

- 385 km of storm sewers;
- 690 km of ditches;
- 962+ culverts;
- 5,789 catch basins;
- 6 stormwater pump stations;
- 4,087 manholes;
- 21,227 lateral lines (connections to properties, catch basins etc.);
- 73 subsurface infiltration facilities;
- 26 engineered ponds; and
- 293 outlets to receiving waters.

This means that the City is responsible for inspecting, cleaning, repairing, and replacing these assets, as required. In addition to the engineered assets listed above, there are the following natural assets within the City of Prince George which also help manage and convey stormwater:

- 1,276 km of creeks and rivers; and
- Thousands of natural ponds, wetlands, and lakes.

## 2.2 Strengths

The City has already completed a lot of work in the area of stormwater and asset management that was used in the development of this ISMP and will continue to be used to support the City as it further develops its stormwater management program. Completed work that the City can continue to leverage includes:

- Construction of $304 million worth of stormwater infrastructure;
- Six watershed drainage plans (WDP) that cover most of the developed areas of the City;
- Asset management policies and tools that are already in place; and
- A significant amount of performance-based data and annual benchmarking.

## 2.3 Challenges

The City currently faces challenges in the following areas with respect to stormwater management:

- Sprawling development;
- Aging infrastructure;
- Erosion;
- Climate change;
- Increase in environmental and safety regulatory requirements;
- Lack of dedicated funding;
- Protection of natural assets that help manage stormwater; and
- Need for updated City bylaws.

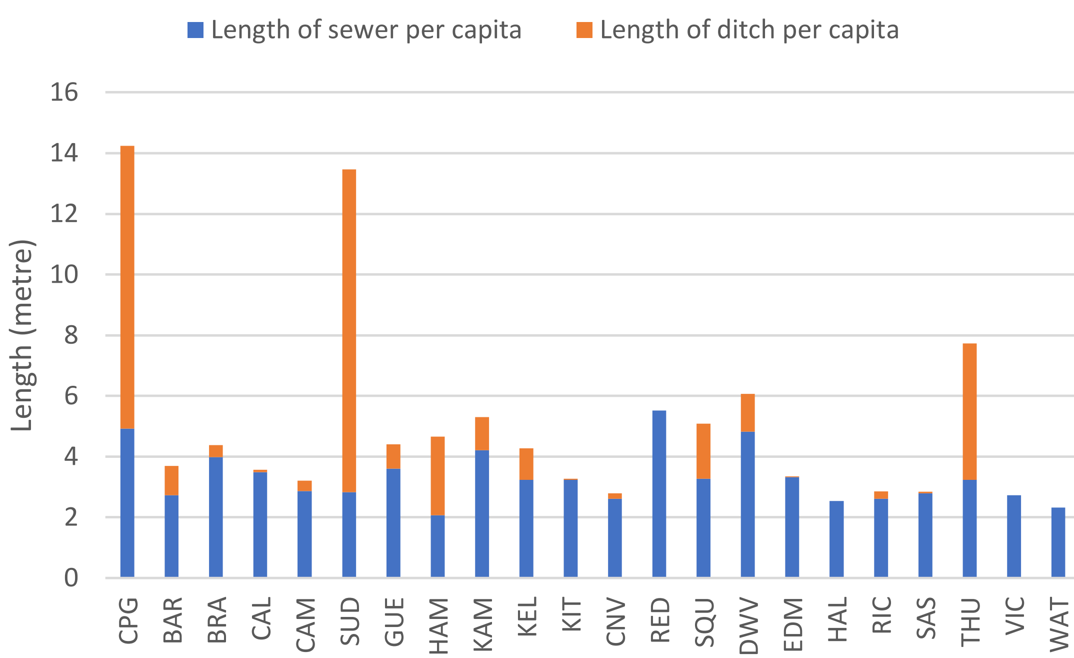
These challenges are described in more detail below.

**Sprawling Development**

The historical pattern of growth in Prince George is typical of many places in Canada. It initially grew around a small downtown core and key industries, with a grid of walkable streets providing access to shopping and amenities. The City Boundary was expanded 12 times from 1953 to 1975 where the City grew from 5.1 square kilometres to over 300 square kilometres. This rapid growth emphasized suburban housing separated from amenities, employment, and services. Servicing the sprawling City required massive investments in stormwater management infrastructure. The rapid growth included the amalgamation of smaller communities and the inheritance of the substandard infrastructure that came with them.

Today, the resulting development is geographically spread-out but with a relatively small population. This creates challenges, particularly with respect to infrastructure funding, as the City has a relatively small population that needs to fund the maintenance and renewal of a fairly large stormwater system. The length of the City of Prince George's stormwater system (sewer and ditch) per resident was compared to 21 other Canadian municipalities (see following figure). Due to Prince George's historical form of development (sprawling, low density) it was found to have the greatest length of stormwater system per resident.

**Figure 3: Length of Stormwater System per Capita for Canadian Municipalities**



**Aging Infrastructure**
Starting in the 1950s, Prince George experienced a population boom and was considered one of the fastest growing cities in Canada. Much of its stormwater management system dates from that period of rapid growth. Over the last 10-20 years, cities across North America have been coming to terms with the hidden costs of this rapid, low-density growth. The City's stormwater infrastructure has been wearing out, resulting in very costly infrastructure rehabilitation and replacement. This was apparent in the recent collapse of a large storm sewer under Winnipeg Street in 2018, which cost $1.7 million to repair (see following photo).

The City does not regularly inspect the condition of its storm sewers and culverts and therefore cannot anticipate and prevent future infrastructure failures nor accurately plan for future infrastructure renewal needs.

**Figure 4: 2018 Winnipeg Street Storm Sewer Repair**

Fortunately, there weren't any vehicles caught in the Winnipeg Street sinkhole. The following photo shows a sinkhole in Ottawa in 2012, where a travelling vehicle was caught in the sinkhole and the driver suffered injuries.

**Figure 5: 2012 Sinkhole In Ottawa**

**Erosion**
Erosion typically occurs when large amounts of stormwater quickly flows over bare soils. This can occur during construction when a site is cleared of vegetation and the stormwater is not properly managed (see following figure) or in a creek or gully when stormwater from upstream development is not sufficiently controlled.

The City's existing bylaws are not strong enough to ensure that developers and contractors implement strong erosion and sediment control practices and the City's existing design standards do not require new development to reduce the volume of stormwater run-off from their sites. Not only has this caused damage to natural watercourses and wetlands, but it has also resulted in excessive amounts of sediment washing into the City's stormwater system which is costly to remove and can reduce the system's capacity to control flooding.

**Figure 6: Erosion and Sediment**

**Climate Change**
In 2020, the City developed *Climate Change Adaptation Strategies for the Community of Prince George* which noted that extreme precipitation events are likely to become more intense and more frequent. Since most stormwater assets last 50-100 years it is important that stormwater assets that are installed today are designed for future weather events under climate change. Therefore, the City must integrate climate change adaptation into its current stormwater design criteria.

**Provincial and Federal Regulatory Requirements**
Due to increases in safety and environmental regulations from senior levels of government it is costing more time and money for the City to do work on its stormwater system.

**Funding**

Stormwater management is funded primarily through property taxes. Because this is not a dedicated source of funding, stormwater must compete each year with other infrastructure needs for funding. Debt is used to finance many capital needs (i.e. culvert failures), which must then be paid back using property taxes.

The demand for stormwater funding increases as new development results in additional infrastructure to maintain. Also increasing regulatory requirements with respect to safety and the environment makes stormwater maintenance and renewal work more costly to complete than before. The result is that the City only has enough budget to react to issues when they arise and preventative maintenance activities (e.g. cleaning and inspection) that prevent incidents (e.g. flooding and infrastructure failure) are not completed. The City of Prince George currently spends $1.35 per metre annually on the maintenance of its stormwater system which is less than half of the national median ($2.85/m) when compared to other Canadian cities who participate in the National Water and Wastewater Benchmarking Initiative.

Increases to existing stormwater funding and greater inspection of its stormwater system would also allow the City to replace deteriorated infrastructure before catastrophic failure (e.g. sinkholes within roadways from collapsed culverts). The average age of the City's storm sewers and culverts is 40 years and most pipes are expected to last 30-80 years (depending on material). This means that some of the City's stormwater system has already reached the end of its expected service life. It is therefore not surprising that the City has experienced some recent failures within its stormwater system.

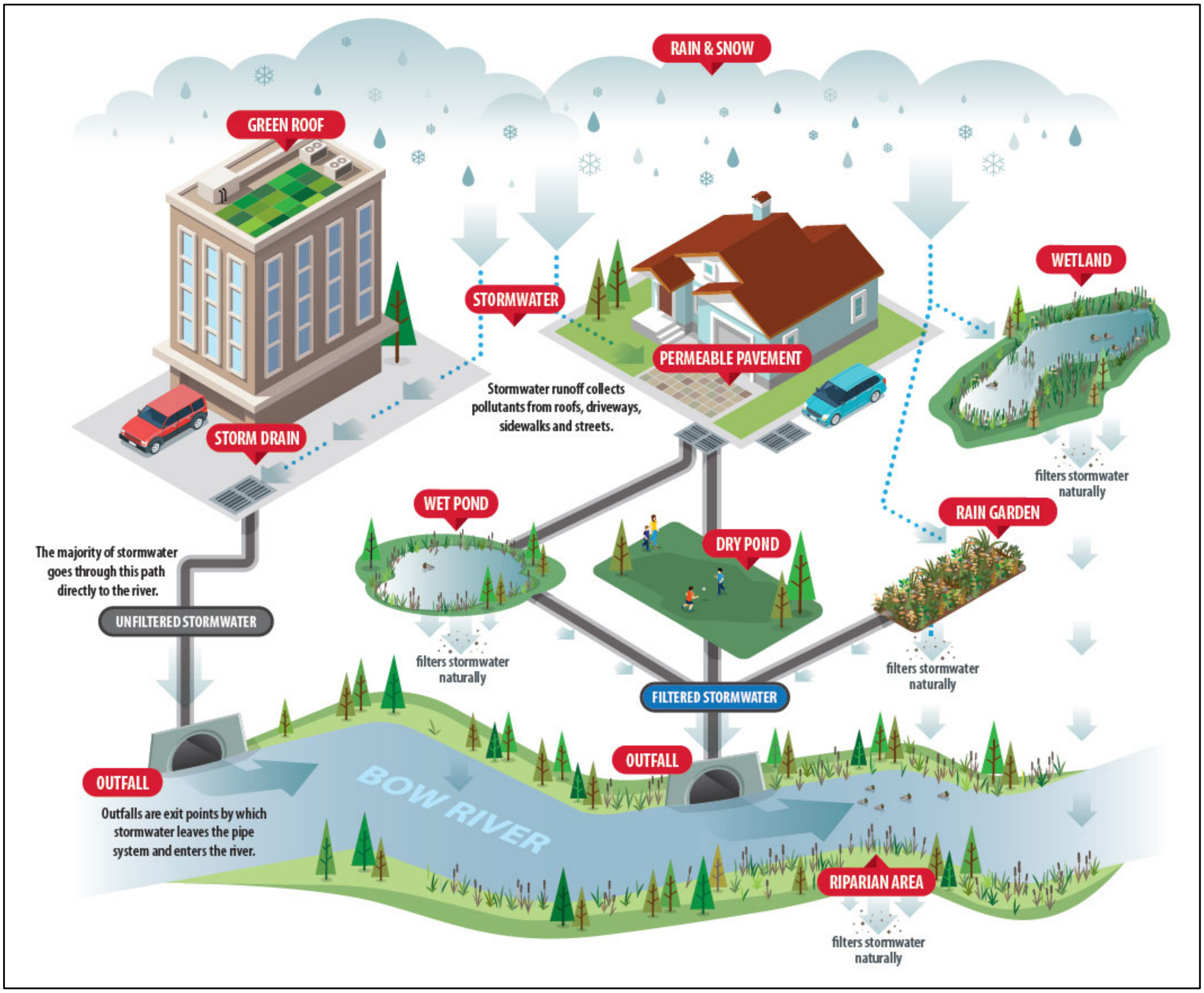
If the City does not increase stormwater funding to sustainable levels, it risks pushing significant infrastructure costs onto future generations. Long-term infrastructure costs will likely increase due to the cost of reacting to and cleaning up after emergency infrastructure failures.

It is important that City staff, Council and residents understand and value stormwater management in order to support any increases to funding. This is not always the case since stormwater infrastructure is often underground and out of mind. Residents are more likely to support funding infrastructure such as recreational facilities or roads that are more visible.

**Natural Assets**

Natural assets such as wetlands, creeks, riparian areas and forests and green engineered assets such as ditches and rain gardens, provide important stormwater management functions such as the absorption and moderation of stormwater flows. Natural assets and ditches are commonly threatened by development and existing bylaws are not strong enough to protect important natural and green engineered assets. Options for using green infrastructure for new development are not sufficiently outlined in the City's Stormwater Design Guidelines. The following figure from the City of Calgary shows an example of a stormwater system that fully integrates green infrastructure.

**Figure 7: Example Stormwater System that Integrates Green Infrastructure[1]**




**City Bylaws**

In addition to the bylaw related issues already raised, the City's existing bylaws are not strong enough to ensure polluters pay for clean-up. Currently, when someone causes a spill that enters the City's stormwater system the City takes on the legal and financial liability. The City also has difficulty enforcing existing stormwater related bylaws that lack "teeth" and with limited enforcement staff.

[1] Stormwater management (calgary.ca)

# 3. What Do We Want?

After detailing the City's existing stormwater management program, the next step was to identify the desired future stormwater program for the City of Prince George. This began with the identification of an overall vision for stormwater management in Prince George supported by several goals that align with the myPG four pillars; namely:

- Social Health & Well-Being;
- Environmental Leadership & Climate Change;
- Economic Growth & Development; and
- City Government & Infrastructure.

## 3.1 Vision

The following vision was developed for stormwater management at the City of Prince George.

*"Sustainable and cost-effective service delivery of stormwater management that protects life, property, and a healthy environment.'*

## 3.2 Goals

In order to support the vision, the following four goals were identified for stormwater management at the City of Prince George.

| | | | |
|---|---|---|---|
| Enhance livability through beautification, connections to nature and recreational opportunities | Preserve and enhance the health of the community's watersheds | Protect life and property from flooding & erosion | Infrastructure costs are minimized and apportioned equitably |

Every action item that the City undertakes should support one or more of these goals.

# 4. How Do We Put This into Action?

All previously identified action items (e.g. through previous watershed drainage plans) with newly identified action items through the development of this ISMP were consolidated into a comprehensive list presented in **Appendix A**. All action items support one or more of the goals identified in the previous section. The action items were prioritized based on the project prioritization framework developed for this ISMP. The prioritization framework considers economic, environmental, and social benefits and approximate costs for each action item.

Listed below are the key action items with the highest priority.

## 4.1 Key Action Items

The key action items with the highest priority are grouped into the following four areas:

- Education & outreach;
- Resources (including funding);
- Asset inspection and renewal; and
- Policy and Bylaw Updates.

**Education & Outreach**

- Educate staff, Council, and residents on the value of stormwater management
- Educate developers, designers, contractors, and City staff on Bylaw/Design Guideline requirements

**Resources**

- Establish sustainable funding and sufficient staffing to implement action items and achieve goals

**Asset Inspection & Renewal**

- Establish storm sewer/culvert condition assessment program
- Complete highest priority stormwater asset renewal projects to reduce risk

**Policy & Bylaw Updates**

- Strengthen erosion and sediment control requirements within City bylaws
- Update Subdivision & Development Servicing Bylaw and Design Guidelines to consider climate change, control water quality and quantity, and mandate new standards
- Update the Storm Sewer Bylaw to clearly outline responsibilities and prevent harmful discharges
- Strengthen the enforceability of polluter pays principles within City bylaws
- Establish green infrastructure strategy (allow better access to grant funding)
- Update Development Cost Charges (DCC) rates
- Protect existing natural assets that serve key watershed functions

Many of these action items were identified through a review of best practices from other similar municipalities.

## 4.2 Roadmap

The vision, goals and key action items that were developed as part of the ISMP are summarized in the following figure.

**Figure 8: City's Roadmap for Stormwater Management**

### VISION

**Sustainable and cost-effective service delivery of stormwater management that protects life, property, and a healthy environment.**

### PILLARS

- Social Health & Well-being
- Environmental Leadership & Climate Action
- Economic Growth & Development
- City Government & Infrastructure

### GOALS

- Enhance livability through beautification, connections to nature and recreational opportunities
- Preserve and enhance the health of the community's watersheds
- Protect life and property from flooding & erosion
- Infrastructure costs are minimized and apportioned equitably

### ACTION ITEMS

**Education & Outreach**

- Educate staff, Council and residents on the value of stormwater management
- Educate developers, designers, contractors and City staff on Bylaw/Design Guideline requirements

**Resources**

- Establish sustainable funding and sufficient staffing to implement action items and achieve goals

**Asset Inspection & Renewal**

- Establish storm sewer/culvert condition assessment program
- Complete highest priority stormwater asset renewal projects

**Policy & Bylaw Updates**

- Strengthen erosion and sediment control requirements within City bylaws
- Update Subdivision & Development Servicing Bylaw and Design Guidelines to consider climate change, control water quality and quantity, and mandate new standards
- Update the Storm Sewer Bylaw to clearly outline responsibilities and prevent harmful discharges
- Strengthen the enforceability of polluter pays principles within City bylaws
- Establish green infrastructure strategy
- Update Development Cost Charges (DCC) rates
- Protect existing natural assets that serve key watershed functions

# 5. Are We On Target?

Like many municipalities, stormwater management at the City of Prince George is spread out over many departments and even different groups within those departments. Roles and responsibilities need to be clearly defined and having an overall “owner” for stormwater management can be more effective when trying to advance a municipal stormwater program.

It is recommended that the City assign an ISMP “owner” who is tasked with managing the implementation of the ISMP, tracking its progress, and updating it as needed. A full list of prioritized action items to support the implementation of the ISMP are listed in **Appendix A**.

The ISMP owner will need to clearly identify roles and responsibilities for each action item. The list of action items will need to be periodically updated as actions are completed, new information is received and priorities change. It is recommended that the ISMP owner develop annual ISMP progress updates that can be communicated to senior management and Council.

It is recommended that the ISMP has a more comprehensive review every five years to determine if it needs to be significantly updated and/or revised. The following actions will help the City determine whether and how the ISMP needs to be revised:

- Regular inspection of stormwater assets such as storm sewers, culverts, ponds, and ditches;
- Flow monitoring;
- Water quality monitoring;
- GIS data updates;
- Updates to existing watershed drainage plans and/or development of new watershed drainage plans;
- Tracking of stormwater performance measures as determined through the City’s recent Levels of Service Development Project; and
- Tracking of completed ISMP action items.

# Appendix A

## Action Item List

| # | Primary Goal (note: many of these actions support multiple goals) | Action Item / Recommendation | Score Total | City Capital Cost increased for inflation and climate change | O&M Costs |
|---|---|---|---|---|---|
| 1 | Enhance livability through beautification, connections to nature and recreational opportunities | Further public education by using parks and trails to inform on watershed health. | 6 | $100,000 | |
| 2 | Infrastructure costs are minimized and apportioned equitably | Implement a Sediment and Erosion Control Bylaw (includes construction sites) | 8 | $10,000 | |
| 3 | Infrastructure costs are minimized and apportioned equitably | Develop a regular storm sewer and ditch inspection program | 8 | | $134,750 |
| 4 | Infrastructure costs are minimized and apportioned equitably | Open ditches/bioswales over paved swales or piped conveyance (where there aren't erosion concerns) | 7 | $0 | |
| 5 | Infrastructure costs are minimized and apportioned equitably | Secure sustainable funding (e.g. dedicated levy or utility). | 7 | $200,000 | |
| 6 | Infrastructure costs are minimized and apportioned equitably | Update City of Prince George Development Procedures and Tree Protection bylaws. Strengthen the Tree Protection Bylaw by increasing the area covered by the bylaw and allow for the recovery of City costs associated with rectifying problems caused by infractions. | 7 | $10,000 | |
| 7 | Infrastructure costs are minimized and apportioned equitably | Stormwater Management Rebate Program | 7 | $10,000 | |
| 8 | Infrastructure costs are minimized and apportioned equitably | Complete highest priority stormwater asset renewal projects (tbd after culvert/sewer condition assessment program) | 7 | | |
| 9 | Infrastructure costs are minimized and apportioned equitably | Educate staff, Council and residents on the value of stormwater management | 7 | $25,000 | |
| 10 | Infrastructure costs are minimized and apportioned equitably | Update GIS Database for Stormwater (includes updated catchments, missing culverts, missing ditches, screens, creek names, sub-surface infiltration facilities, sewer elevations, storage basin sizes and natural assets) | 6 | $10,000 | |
| 11 | Infrastructure costs are minimized and apportioned equitably | Conduct culvert condition assessments in other PG watersheds and implement a similar program. | 6 | | $55,000 |
| 12 | Infrastructure costs are minimized and apportioned equitably | Cap trails near escarpment watercourses with less erodible material. | 6 | $70,000 | |
| 13 | Infrastructure costs are minimized and apportioned equitably | Develop BMP (includes LID/GI) strategy (goals, constraints, internal capabilities and funding opportunities). Require BMPs on future developments (residential, non-residential, roadways etc) which include the disconnection of impervious areas, minimizing earthworks and grading, retaining existing vegetation, limiting effective impervious area and implementation of ponds/LID/GI measures. Create a Stormwater BMP circular. | 6 | $25,000 | |
| 14 | Infrastructure costs are minimized and apportioned equitably | Update Development Cost Charges (DCC) rates | 6 | $10,000 | |
| 15 | Infrastructure costs are minimized and apportioned equitably | Update the Storm Sewer Bylaw to improve definitions, to revise the list of prohibited discharges, to allow for in-field measurement of sediment concentration, to clearly specify the types of properties that require an oil and grit separator (including large surface parking lots and industrial properties) and associated maintenance requirements, to be consistent with the Sanitary Sewer Use Bylaw particularly with respect to unauthorized discharges (i.e. spills), to explicitly state who is responsible for maintaining, renewing and | 6 | $10,000 | |
| 16 | Infrastructure costs are minimized and apportioned equitably | Promote effective application of the Design Guidelines by mandating adherence of the Design Guidelines through Bylaw; having enough well-trained staff to review design submissions; and educating developers, designers, contractors, and City staff on the requirements within the Design Guidelines, Subdivision and Development Servicing Bylaw and Storm Sewer Bylaw. | 6 | $100,000 | |
| 17 | Infrastructure costs are minimized and apportioned equitably | Update Zoning Bylaw to limit impervious surfaces | 5 | $10,000 | |
| 18 | Infrastructure costs are minimized and apportioned equitably | Improve inspection of properties under construction for stormwater related aspects (lot grading, soil depths, downspouts etc). Educate and train City inspectors. | 5 | $55,000 | |
| 19 | Infrastructure costs are minimized and apportioned equitably | Implement new regulation regarding onsite snow storage and sediment capture, including the maintenance of new and existing systems. | 5 | $10,000 | $50,000 |
| 20 | Infrastructure costs are minimized and apportioned equitably | Cleanout accumulated sediment from storm sewer inlets at escarpment base. | 5 | $25,000 | |
| 21 | Infrastructure costs are minimized and apportioned equitably | Enforce current ESC regulations for ongoing development. | 5 | | $25,000 |
| 22 | Infrastructure costs are minimized and apportioned equitably | Commence a sediment management program. See HBS WDP for more details. | 5 | | |
| 23 | Infrastructure costs are minimized and apportioned equitably | Where possible, use existing storm sewers (need to confirm existing downstream capacities). See UHPH WDP for more details. | 4 | | |
| 24 | Infrastructure costs are minimized and apportioned equitably | Monitor slope instabilities of main drainage course (BCR) | 4 | | |
| 25 | Preserve and enhance the health of the community's watersheds | Upgrade culvert at Domano Boulevard to remove barrier to fish passage | 9 | $1,000,000 | |
| 26 | Preserve and enhance the health of the community's watersheds | Ensure "protected" wetlands are actually preserved and protect wetlands that are not currently protected under municipal legislation (i.e. not directly connected to a fish-bearing stream)). In particular protect/preserve wetland habitat in Malaspina Watershed. | 7 | $55,000 | |
| 27 | Preserve and enhance the health of the community's watersheds | Replace/modify problem culverts (Bittner) | 7 | $50,000 | |
| 28 | Preserve and enhance the health of the community's watersheds | Stream Corridor Management. Ensure "protected' riparian areas (eg 30 m) are actually preserved and protect important riparian areas that are not currently protected under municipal legislation (i.e. riparian areas of a stream that is not fish-bearing). Coordinate with desired wildlife cooridors and habitat areas (e.g. Watercourses B, C, and J in UHPH). | 7 | $10,000 | |
| 29 | Preserve and enhance the health of the community's watersheds | Implement roadside BMPs on future boundary road extension | 6 | $55,000 | $500 |
| 30 | Preserve and enhance the health of the community's watersheds | 5-year culvert maintenance program | 6 | $141,120 | |

| # | Primary Goal (note: many of these actions support multiple goals) | Action Item / Recommendation | Score Total | City Capital Cost increased for inflation and climate change | O&M Costs |
|---|---|---|---|---|---|
| 31 | Preserve and enhance the health of the community's watersheds | Protect undevelopable land through the establishment of parks and protected zones to reduce the possibility of any future development in these areas. | 6 | $1,000,000 | |
| 32 | Preserve and enhance the health of the community's watersheds | Include water quality treatment features in detention ponds where possible for new developments. | 6 | $10,000 | |
| 33 | Preserve and enhance the health of the community's watersheds | Infiltration testing | 6 | $10,000 | |
| 34 | Preserve and enhance the health of the community's watersheds | Assess Foreman road drainage channel issues as a result of commercial development at the corner of Foreman Rd and Hwy 16E. | 6 | $100,000 | |
| 35 | Preserve and enhance the health of the community's watersheds | Hudson's Bay Slough Enhanced Wetland | 6 | $1,182,480 | $30,400 |
| 36 | Preserve and enhance the health of the community's watersheds | Improve fisheries habitat in lower slough. | 6 | $580,320 | $14,900 |
| 37 | Preserve and enhance the health of the community's watersheds | Increase development permit areas within the OCP bylaw to include all significant flood and slope hazards, and to protect all valuable natural areas, such as riparian areas of streams that provide nutrients to downstream fisheries and wetlands that are not directly connected to fish-bearing streams | 6 | $25,000 | |
| 38 | Preserve and enhance the health of the community's watersheds | Treatment at outfalls. This series relates to West Fraser Subcatchments | 5 | $55,000 | |
| 39 | Preserve and enhance the health of the community's watersheds | Clean Cowart Road outfall culvert inlet | 5 | $5,000 | |
| 40 | Preserve and enhance the health of the community's watersheds | Plant roadside ditches with native species | 5 | $5,000 | |
| 41 | Preserve and enhance the health of the community's watersheds | Prevent recreational vehicle crossing at Park Drive | 5 | $10,000 | |
| 42 | Preserve and enhance the health of the community's watersheds | Clean debris at Heyer Road Outfall | 5 | $10,000 | |
| 43 | Preserve and enhance the health of the community's watersheds | Adjust future road alignments along Parkridge Creek to avoid riparian impacts. | 5 | $10,000 | |
| 44 | Preserve and enhance the health of the community's watersheds | Culvert upgrades for fish passage | 5 | | |
| 45 | Preserve and enhance the health of the community's watersheds | Stormwater BMPs for ex. roadways | 5 | | |
| 46 | Preserve and enhance the health of the community's watersheds | 2-year culvert maintenance program | 5 | $285,376 | |
| 47 | Preserve and enhance the health of the community's watersheds | Construct a wetland at the outlet of the proposed Nordic Drive storm trunk. | 5 | $250,000 | |
| 48 | Preserve and enhance the health of the community's watersheds | Prohibited areas for aggregate extraction should be extended to include undeveloped areas of the watershed. | 5 | $5,000 | |
| 49 | Preserve and enhance the health of the community's watersheds | Replace/modify CN Rail culvert (Haggith) | 5 | $100,000 | |
| 50 | Preserve and enhance the health of the community's watersheds | Fish passage culvert inspection (Bittner) | 5 | | $5,000 |
| 51 | Preserve and enhance the health of the community's watersheds | Sediment pond in Carrie Jane Gray Park - Winnipeg St. Branch | 5 | $330,720 | $8,500 |
| 52 | Preserve and enhance the health of the community's watersheds | Sediment pond in Carrie Jane Gray Park - Massey St. Branch | 5 | $330,720 | $8,500 |
| 53 | Preserve and enhance the health of the community's watersheds | Hudson's Bay Slough Sediment Forebay | 5 | $1,170,000 | $30,000 |
| 54 | Preserve and enhance the health of the community's watersheds | Eight locations for remedial creek work. | 5 | $83,580 | |
| 55 | Preserve and enhance the health of the community's watersheds | Address erosion downstream of Simon Fraser resulting from the Domano/Westgate Storm Pond and changes to the pond. | 5 | $200,000 | |
| 56 | Preserve and enhance the health of the community's watersheds | Conduct condition assessments of its detention ponds every five years | 5 | | $26,000 |
| 57 | Preserve and enhance the health of the community's watersheds | Water Quality monitoring at Latrobe Outfall | 4 | $200,000 | |
| 58 | Preserve and enhance the health of the community's watersheds | Erosion protection measures at outfalls | 4 | $550,000 | |
| 59 | Preserve and enhance the health of the community's watersheds | Maintain cleaning of utility corridor along Parkridge Creek, initiated in 2018 (BC Hydro responsibility) | 4 | | |
| 60 | Preserve and enhance the health of the community's watersheds | Replace crossing structure with clear span bridge - Northwood Road | 4 | $1,380,960 | |
| 61 | Preserve and enhance the health of the community's watersheds | Replace crossing structure with clear span bridge - Private Drive | 4 | $421,120 | |
| 62 | Preserve and enhance the health of the community's watersheds | Replace crossing structure with clear span bridge - Private Drive | 4 | $421,120 | |
| 63 | Preserve and enhance the health of the community's watersheds | Discourage any further crossings over the mainstem of McMillan Creek and provide incentive to existing landowners to replace crossings that have been found to be barriers. | 4 | $0 | |
| 64 | Preserve and enhance the health of the community's watersheds | Monitor areas in close proximity to major tributaries for sedimentation and contamination such as Meadow Park. | 4 | $0 | $10,000 |
| 65 | Preserve and enhance the health of the community's watersheds | Implement water quality monitoring at outfall to Lansdowne Creek to meet Aquatic Life standards of the Provincial Water Quality Guidelines. | 4 | | $10,000 |
| 66 | Preserve and enhance the health of the community's watersheds | Improve erosion & sediment control at power line R.O.W. crossing (Guay) | 4 | | $5,000 |

| # | Primary Goal (note: many of these actions support multiple goals) | Action Item / Recommendation | Score Total | City Capital Cost increased for inflation and climate change | O&M Costs |
|---|---|---|---|---|---|
| 67 | Preserve and enhance the health of the community's watersheds | Improve erosion & sediment control along access road near Continental Way (BCR) | 4 | | $5,000 |
| 68 | Preserve and enhance the health of the community's watersheds | Water quality monitoring program | 4 | | $10,000 |
| 69 | Preserve and enhance the health of the community's watersheds | Monitor and remediate erosion sites | 4 | | |
| 70 | Preserve and enhance the health of the community's watersheds | Four locations for remedial creek work. | 4 | $13,930 | |
| 71 | Preserve and enhance the health of the community's watersheds | Eight locations for remedial creek work. | 4 | $521,380 | $13,500 |
| 72 | Preserve and enhance the health of the community's watersheds | Treat runoff from snow storage facilities | 3 | $550,000 | |
| 73 | Preserve and enhance the health of the community's watersheds | Replace crossing structure with clear span bridge - Private Drive | 3 | $421,120 | |
| 74 | Preserve and enhance the health of the community's watersheds | Provide micro snow-dumps in local parks. | 3 | | |
| 75 | Preserve and enhance the health of the community's watersheds | Improve runoff control along Foreman Road (Graves) | 3 | | $5,000 |
| 76 | Protect life and property from flooding & erosion | Update Hazardous Slope mapping | 8 | $10,000 | |
| 77 | Protect life and property from flooding & erosion | Update Design Manual (and associated Subdivision & Servicing Bylaw) to consider Climate Change (including IDF update), design storms (10 year and rain on storm), run-off limits from new development (ie limit post-development flows to pre-development rates), open channels in lieu of pipes, design requirements for OGS, ESC plans be prepared and monitoring by a professional, limitiations on the use of CSP, improved pond and wetland design standards, require O&M cost estimates and cleanout schedules, adoption of ponds after vegetation is established, evaluating erosive velocities for channels donwstream of detention facilities, sewer relining specifications, limiting basements in high-risk areas, lot grading guidelines for developers, maximum grades and velocities, revised minimum depths of cover, bike friendly catch basins, and procedure for utility disconnects. | 7 | $55,000 | |
| 78 | Protect life and property from flooding & erosion | Establishing a Flood Construction Level (FCL) (Parkridge Creek-Upstream of Highway 16) | 7 | $10,000 | |
| 79 | Protect life and property from flooding & erosion | Monitor beaver activity at Highway 16 culverts | 6 | $10,000 | |
| 80 | Protect life and property from flooding & erosion | Replace crossing structure with clear span bridge - McMillan Drive | 6 | $630,560 | |
| 81 | Protect life and property from flooding & erosion | Investigate capacity of Hudson Bay Slough storm sewer | 6 | $131,000 | |
| 82 | Protect life and property from flooding & erosion | Winnipeg Street Pipe Upgrade | 6 | $561,600 | $3,600 |
| 83 | Protect life and property from flooding & erosion | Future development on Cranbrook Hill should limit flows to pre-development levels. | 6 | | |
| 84 | Protect life and property from flooding & erosion | Develop future WDP's in areas with known issues or proposed future development (ie North Nechako). Future WDP's should include climate change considerations, cost estimates, use of City prefered modeling software, dual drainage model with 2D modeling where surface flooding issues are identified, assessment of culverts for fish passage, identification of sites where infiltration is not desirable, use of project prioritization framework, updates to GIS data, assessment of full build-out conditions and updates to natural asset inventory. | 6 | $250,000 | $250,000 |
| 85 | Protect life and property from flooding & erosion | Culvert Upgrade - Lattman Road (AEID: C-260) | 5 | $250,000 | |
| 86 | Protect life and property from flooding & erosion | Replace crossing structure with clear span bridge - Hofferkamp Road | 5 | $1,321,600 | |
| 87 | Protect life and property from flooding & erosion | Subcatchment diversion | 5 | $234,000 | $1,500 |
| 88 | Protect life and property from flooding & erosion | Subcatchment diversion | 5 | $156,000 | $1,000 |
| 89 | Protect life and property from flooding & erosion | Victoria St. Crossing Upgrade | 5 | $530,400 | $3,400 |
| 90 | Protect life and property from flooding & erosion | Pine St. Crossing Upgrade | 5 | $530,400 | $3,400 |
| 91 | Protect life and property from flooding & erosion | Oak St. Crossing Upgrade | 5 | $530,400 | $3,400 |
| 92 | Protect life and property from flooding & erosion | Dredge/Widen Lowland Channels | 5 | $187,200 | $1,200 |
| 93 | Protect life and property from flooding & erosion | Proposed storm water detention pond north of Hwy. 16 / Marleau Rd. | 5 | $805,950 | |
| 94 | Protect life and property from flooding & erosion | Proposed storm water detention pond north of Hwy. 16 / Westgate Ave. | 5 | $704,460 | |
| 95 | Protect life and property from flooding & erosion | Encourage Airport BMPs | 4 | | |
| 96 | Protect life and property from flooding & erosion | Culvert Upgrade - Buckingham Road (AEID: C-232) | 4 | $550,000 | |
| 97 | Protect life and property from flooding & erosion | Beaver management | 4 | $156,000 | |
| 98 | Protect life and property from flooding & erosion | Snow Removal in Vanway Neighbourhood | 4 | $156,000 | |
| 99 | Protect life and property from flooding & erosion | Replace crossing structure with clear span bridge - Highway 97 Crossing | 4 | $1,500,800 | |

| # | Primary Goal (note: many of these actions support multiple goals) | Action Item / Recommendation | Score Total | City Capital Cost increased for inflation and climate change | O&M Costs |
|---|---|---|---|---|---|
| 100 | Protect life and property from flooding & erosion | Replace crossing structure with clear span bridge - Iona Road | 4 | $757,120 | |
| 101 | Protect life and property from flooding & erosion | Replace crossing structure with clear span bridge - OSL Road Crossing | 4 | $757,120 | |
| 102 | Protect life and property from flooding & erosion | Replace crossing structure with clear span bridge - OSL Road Crossing | 4 | $757,120 | |
| 103 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 4 | $34,060 | |
| 104 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 4 | $34,060 | |
| 105 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 4 | $28,820 | |
| 106 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 4 | $18,340 | |
| 107 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 4 | $17,030 | |
| 108 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 4 | $64,190 | |
| 109 | Protect life and property from flooding & erosion | Major system pipe upgrade | 4 | $170,300 | |
| 110 | Protect life and property from flooding & erosion | Major system pipe upgrade | 4 | $133,620 | |
| 111 | Protect life and property from flooding & erosion | Major system culvert upgrade | 4 | $259,380 | |
| 112 | Protect life and property from flooding & erosion | Installation of a diversion pipe through the Pine Valley Golf Course to an infiltration gallery | 4 | $100,000 | |
| 113 | Protect life and property from flooding & erosion | Highway 16 Culvert Twinning | 4 | $483,600 | $3,100 |
| 114 | Protect life and property from flooding & erosion | Utility Crossing Upgrade | 4 | $530,400 | $3,400 |
| 115 | Protect life and property from flooding & erosion | Upland St. Crossing Upgrade | 4 | $530,400 | $3,400 |
| 116 | Protect life and property from flooding & erosion | Queensway Floodbox Capacity Increase | 4 | $702,000 | $4,500 |
| 117 | Protect life and property from flooding & erosion | Ospika Boulevard Pipe Upgrade with Shane Creek Detention Pond | 4 | $1,049,880 | $6,800 |
| 118 | Protect life and property from flooding & erosion | Redwood Street Pipe Upgrade | 4 | $56,160 | $400 |
| 119 | Protect life and property from flooding & erosion | Storm sewer upgrades on Caledonia Crescent. | 4 | $47,760 | |
| 120 | Protect life and property from flooding & erosion | Storm sewer upgrades on Caledonia Crescent. | 4 | $41,790 | |
| 121 | Protect life and property from flooding & erosion | Storm sewer upgrades on the 7100-block of St. Lawrence Avenue. | 4 | $61,690 | |
| 122 | Protect life and property from flooding & erosion | Storm sewer upgrades on the 7100-block of St. Lawrence Avenue. | 4 | $55,720 | |
| 123 | Protect life and property from flooding & erosion | Storm sewer upgrades on Rideau Drive. | 4 | $69,650 | |
| 124 | Protect life and property from flooding & erosion | Storm sewer upgrades on Brock Drive. | 4 | $53,730 | |
| 125 | Protect life and property from flooding & erosion | Storm sewer upgrades on Rideau Drive. | 4 | $61,690 | |
| 126 | Protect life and property from flooding & erosion | Storm sewer upgrades near the outfall at York Drive / Varsity Avenue | 4 | $21,890 | |
| 127 | Protect life and property from flooding & erosion | Storm sewer upgrades near the outfall at York Drive / Varsity Avenue | 4 | $29,850 | |
| 128 | Protect life and property from flooding & erosion | Storm sewer upgrade on the outfall at Laval Place | 4 | $163,180 | |
| 129 | Protect life and property from flooding & erosion | Storm sewer and culvert upgrades on St. Patrick Avenue at Glen Lyon Way. | 4 | $45,770 | |
| 130 | Protect life and property from flooding & erosion | Storm sewer and culvert upgrades on St. Patrick Avenue at Glen Lyon Way. | 4 | $25,870 | |
| 131 | Protect life and property from flooding & erosion | Storm sewer upgrade for proposed Westgate Development | 4 | $274,620 | |
| 132 | Protect life and property from flooding & erosion | Storm sewer upgrade for proposed Westgate Development | 4 | $189,050 | |
| 133 | Protect life and property from flooding & erosion | Storm sewer upgrade for proposed Westgate Development | 4 | $69,650 | |
| 134 | Protect life and property from flooding & erosion | Storm sewer upgrade for proposed Westgate Development | 4 | $179,100 | |

| # | Primary Goal (note: many of these actions support multiple goals) | Action Item / Recommendation | Score Total | City Capital Cost increased for inflation and climate change | O&M Costs |
|---|---|---|---|---|---|
| 135 | Protect life and property from flooding & erosion | Proposed storm water detention pond in the vicinity of O'Grady Road and Marleau Road. | 4 | $276,610 | |
| 136 | Protect life and property from flooding & erosion | Storm sewer upgrade on O'Grady Road near Domano Boulevard. | 4 | $59,700 | |
| 137 | Protect life and property from flooding & erosion | Storm sewer upgrade on Moriarty Place | 4 | $33,830 | |
| 138 | Protect life and property from flooding & erosion | Storm sewer upgrade on the 5500-block of Trent Drive. | 4 | $45,770 | |
| 139 | Protect life and property from flooding & erosion | Detention pond west of Southridge Avenue near O'Grady Road and St. Anne Crescent. | 4 | $543,270 | |
| 140 | Protect life and property from flooding & erosion | Detention pond west of Southridge Avenue near O'Grady Road and St. Anne Crescent. | 4 | $766,150 | |
| 141 | Protect life and property from flooding & erosion | Storm sewer upgrades along Domano Boulevard | 4 | $147,260 | |
| 142 | Protect life and property from flooding & erosion | Storm sewer upgrade on Domano Boulevard south of Glen Lyon Way | 4 | $95,520 | |
| 143 | Protect life and property from flooding & erosion | Storm sewer upgrades on O'Grady Road just before Southridge Avenue. | 4 | $147,260 | |
| 144 | Protect life and property from flooding & erosion | Storm sewer upgrade on 7800-block of Queens Crescent. | 4 | $15,920 | |
| 145 | Protect life and property from flooding & erosion | Storm sewer upgrade on 7700-block of Queens Crescent. | 4 | $43,780 | |
| 146 | Protect life and property from flooding & erosion | Storm sewer upgrade on 7700-block of Osgoode Drive. | 4 | $43,780 | |
| 147 | Protect life and property from flooding & erosion | Storm sewer upgrade on 7600-block of Kingsley Crescent. | 4 | $41,790 | |
| 148 | Protect life and property from flooding & erosion | Storm sewer upgrade on Hartford Crescent. | 4 | $39,800 | |
| 149 | Protect life and property from flooding & erosion | Storm sewer upgrades on 7600-block of St. Patrick Avenue. | 4 | $187,060 | |
| 150 | Protect life and property from flooding & erosion | Storm sewer upgrade on Vista View Road | 4 | $83,580 | |
| 151 | Protect life and property from flooding & erosion | Proposed storm water detention pond at Domano Blvd. / Glen Lyon Way | 4 | $310,440 | |
| 152 | Protect life and property from flooding & erosion | Proposed storm water detention pond at Glen Lyon Way / St. Patrick Ave. | 4 | $708,440 | |
| 153 | Protect life and property from flooding & erosion | Proposed storm water detention pond at Glen Lyon Way / St. Patrick Ave. | 4 | $459,690 | |
| 154 | Protect life and property from flooding & erosion | Storm water detention pond (undeveloped area - St. Lawrence Ave.) | 4 | $545,260 | $14,000 |
| 155 | Protect life and property from flooding & erosion | Storm water detention pond (undeveloped area - St. Mary Cres.) | 4 | $411,930 | $10,500 |
| 156 | Protect life and property from flooding & erosion | Storm water detention pond (undeveloped area) | 4 | $730,330 | $18,500 |
| 157 | Protect life and property from flooding & erosion | Storm water detention pond (undeveloped area) | 4 | $509,440 | $13,000 |
| 158 | Protect life and property from flooding & erosion | Culvert upgrade underneath the road parallel to Hwy. 16 (Marleau Rd.). | 4 | $37,810 | |
| 159 | Protect life and property from flooding & erosion | Install a new rain gauge in the NW quadrant of the City | 4 | $25,000 | |
| 160 | Protect life and property from flooding & erosion | Implement flow monitoring program to establish baseline values. | 3 | $65,500 | $20,000 |
| 161 | Protect life and property from flooding & erosion | Upgrade one pipe segment (8 m) | 3 | $18,000 | |
| 162 | Protect life and property from flooding & erosion | Upgrade eleven pipe segments (502 m) | 3 | $847,000 | |
| 163 | Protect life and property from flooding & erosion | Culvert Upgrade - Leslie Road (AEID: C-310) | 3 | $550,000 | |
| 164 | Protect life and property from flooding & erosion | Culvert Upgrade - Collena Street (AEID: C-312) | 3 | $550,000 | |
| 165 | Protect life and property from flooding & erosion | Culvert Upgrade - Hilltop Road (AEID: C-254) | 3 | $550,000 | |
| 166 | Protect life and property from flooding & erosion | Culvert Upgrade - Hilltop Road (AEID: C-255) | 3 | $550,000 | |
| 167 | Protect life and property from flooding & erosion | Culvert Upgrade - Hilltop Road (AEID: C-503) | 3 | $550,000 | |
| 168 | Protect life and property from flooding & erosion | Culvert Upgrade - Bunce Road (AEID: C-117) | 3 | $550,000 | |

| # | Primary Goal (note: many of these actions support multiple goals) | Action Item / Recommendation | Score Total | City Capital Cost increased for inflation and climate change | O&M Costs |
|---|---|---|---|---|---|
| 169 | Protect life and property from flooding & erosion | Culvert Upgrade - Kimball Road (AEID: C-249) | 3 | $550,000 | |
| 170 | Protect life and property from flooding & erosion | Culvert Upgrade - Bilnor Road (AEID: C-243) | 3 | $550,000 | |
| 171 | Protect life and property from flooding & erosion | Culvert Upgrade - Purdue Road (AEID: C-221) | 3 | $550,000 | |
| 172 | Protect life and property from flooding & erosion | Major system pipe upgrade | 3 | $872,460 | |
| 173 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 3 | $45,850 | |
| 174 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 3 | $187,330 | |
| 175 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 3 | $128,380 | |
| 176 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 3 | $136,240 | |
| 177 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 3 | $154,580 | |
| 178 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 3 | $40,610 | |
| 179 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 3 | $49,780 | |
| 180 | Protect life and property from flooding & erosion | Minor system pipe upgrade | 3 | $51,090 | |
| 181 | Protect life and property from flooding & erosion | Major system pipe upgrade | 3 | $28,820 | |
| 182 | Protect life and property from flooding & erosion | Major system culvert upgrade | 3 | $247,590 | |
| 183 | Protect life and property from flooding & erosion | City to adjust current development design standards and typical road cross sections to accommodate snow storage within the arterial road ROW. | 3 | | |
| 184 | Protect life and property from flooding & erosion | Upgrade 20 lowest priority undersized conduits only when they have reached the end of their service life (see Table 6-7). | 3 | | |
| 185 | Protect life and property from flooding & erosion | Subcatchment diversion | 3 | $1,207,440 | $7,740 |
| 186 | Protect life and property from flooding & erosion | Redwood Street Pipe Upgrade | 3 | $308,880 | $2,000 |
| 187 | Protect life and property from flooding & erosion | Johnson Street Pipe Upgrade | 3 | $608,400 | $3,900 |
| 188 | Protect life and property from flooding & erosion | Irwin Street Pipe Upgrades | 3 | $1,048,320 | $6,800 |
| 189 | Protect life and property from flooding & erosion | Storm sewer upgrade for proposed Westgate Development | 3 | $543,270 | |
| 190 | Protect life and property from flooding & erosion | Storm sewer upgrade for proposed Westgate Development | 3 | $509,440 | |
| 191 | Protect life and property from flooding & erosion | Storm sewer upgrade for proposed Westgate Development | 3 | $756,200 | |
| 192 | Protect life and property from flooding & erosion | Storm sewer upgrades near Westgate Avenue for future conditions | 3 | $87,560 | |
| 193 | Protect life and property from flooding & erosion | Storm sewer upgrades near Westgate Avenue for future conditions | 3 | $97,510 | |
| 194 | Protect life and property from flooding & erosion | Storm sewer upgrades near Westgate Avenue for future conditions | 3 | $95,520 | |
| 195 | Protect life and property from flooding & erosion | Storm sewer upgrades near Westgate Avenue for future conditions | 3 | $47,760 | |
| 196 | Protect life and property from flooding & erosion | Storm sewer upgrades near Westgate Avenue for future conditions | 3 | $29,850 | |
| 197 | Protect life and property from flooding & erosion | Storm sewer upgrades on Chartwell Crescent | 3 | $79,600 | |
| 198 | Protect life and property from flooding & erosion | Storm sewer upgrades at 6000 Simon Fraser Avenue. | 3 | $37,810 | |
| 199 | Protect life and property from flooding & erosion | Storm sewer upgrades at 5900 Simon Fraser Avenue. | 3 | $43,780 | |
| 200 | Protect life and property from flooding & erosion | Storm sewer upgrades on Selkirk Crescent. | 3 | $61,690 | |
| 201 | Protect life and property from flooding & erosion | Storm sewer upgrades on the 6500-block of Domano Boulevard. | 3 | $125,370 | |
| 202 | Protect life and property from flooding & erosion | Storm sewer upgrade on Tyner Boulevard | 3 | $230,840 | |
| 203 | Protect life and property from flooding & erosion | Storm sewer upgrade west of Southridge Avenue near O'Grady Road and St. Anne Crescent. | 3 | $35,820 | |
| 204 | Protect life and property from flooding & erosion | Proposed storm water detention pond in the near Albert Pl. (south). | 3 | $415,910 | |
| 205 | Protect life and property from flooding & erosion | Proposed storm water detention pond in the near Domano Blvd. (west). | 3 | $427,850 | |
| 206 | Protect life and property from flooding & erosion | Upgrade three pipe segments (258 m) | 2 | $405,000 | |

| # | **Primary Goal** (note: many of these actions support multiple goals) | **Action Item / Recommendation** | **Score Total** | **City Capital Cost increased for inflation and climate change** | **O&M Costs** |
|---|---|---|---|---|---|
| 207 | Protect life and property from flooding & erosion | Upgrade five pipe segments (341 m) | 2 | $517,000 | |
| 208 | Protect life and property from flooding & erosion | Culvert Upgrade - Reynolds Road (AEID: C-225) | 2 | $517,000 | |
| 209 | Protect life and property from flooding & erosion | Major system pipe upgrade | 2 | $1,307,380 | |
| 210 | Protect life and property from flooding & erosion | Major system culvert upgrade | 2 | $441,470 | |
| 211 | Protect life and property from flooding & erosion | Lower Main Slough Pool | 2 | $4,680,000 | $30,000 |
| 212 | Protect life and property from flooding & erosion | Jarvis Street Pipe Upgrade | 2 | $2,308,800 | $14,800 |
| 213 | Protect life and property from flooding & erosion | Miscellaneous deficiencies (numerous) | 2 | $1,225,000 | $49,000 |
| 214 | Protect life and property from flooding & erosion | Culvert Upgrade - Hilltop Road (AEID: C-257) | 1 | $1,225,000 | |
| 215 | Protect life and property from flooding & erosion | Culvert Upgrade - Reynolds Road (AEID: C-504) | 1 | $1,225,000 | |
| 216 | Protect life and property from flooding & erosion | Culvert Upgrade - Reynolds Road (AEID: C-227) | 1 | $1,225,000 | |
| 217 | Protect life and property from flooding & erosion | Culvert Upgrade - Haldi Lake Road (AEID: C-139) | 1 | $1,225,000 | |
| TOTAL | | | | $66,608,046 | $ 926,390 |

# Appendix B

## Technical Working Paper #1 – Technical Background

City of Prince George

# Integrated Stormwater Management Plan

## *Technical Working Paper #1 – Technical Background*

**Prepared by:**

AECOM Canada Ltd.
3292 Production Way, Floor 4
Burnaby, BC   V5A 4R4
Canada

T: 604 444 6400
F: 604 294 8597
www.aecom.com

**Date:** February, 2021

**Project #:** 60628231

## Distribution List

| # Hard Copies | PDF Required | Association / Company Name |
|---|---|---|
| | ✓ | City of Prince George |
| | ✓ | AECOM Canada Ltd. |

# Statement of Qualifications and Limitations

The attached Report (the "Report") has been prepared by AECOM Canada Ltd. ("AECOM") for the benefit of the Client ("Client") in accordance with the agreement between AECOM and Client, including the scope of work detailed therein (the "Agreement").

The information, data, recommendations and conclusions contained in the Report (collectively, the "Information"):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the "Limitations");
- represents AECOM's professional judgement in light of the Limitations and industry standards for the preparation of similar reports;
- may be based on information provided to AECOM which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the Report and the Agreement; and
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time.

AECOM shall be entitled to rely upon the accuracy and completeness of information that was provided to it and has no obligation to update such information. AECOM accepts no responsibility for any events or circumstances that may have occurred since the date on which the Report was prepared and, in the case of subsurface, environmental or geotechnical conditions, is not responsible for any variability in such conditions, geographically or over time.

AECOM agrees that the Report represents its professional judgement as described above and that the Information has been prepared for the specific purpose and use described in the Report and the Agreement, but AECOM makes no other representations, or any guarantees or warranties whatsoever, whether express or implied, with respect to the Report, the Information or any part thereof.

Without in any way limiting the generality of the foregoing, any estimates or opinions regarding probable construction costs or construction schedule provided by AECOM represent AECOM's professional judgement in light of its experience and the knowledge and information available to it at the time of preparation. Since AECOM has no control over market or economic conditions, prices for construction labour, equipment or materials or bidding procedures, AECOM, its directors, officers and employees are not able to, nor do they, make any representations, warranties or guarantees whatsoever, whether express or implied, with respect to such estimates or opinions, or their variance from actual construction costs or schedules, and accept no responsibility for any loss or damage arising therefrom or in any way related thereto. Persons relying on such estimates or opinions do so at their own risk.

Except (1) as agreed to in writing by AECOM and Client; (2) as required by-law; or (3) to the extent used by governmental reviewing agencies for the purpose of obtaining permits or approvals, the Report and the Information may be used and relied upon only by Client.

AECOM accepts no responsibility, and denies any liability whatsoever, to parties other than Client who may obtain access to the Report or the Information for any injury, loss or damage suffered by such parties arising from their use of, reliance upon, or decisions or actions based on the Report or any of the Information ("improper use of the Report"), except to the extent those parties have obtained the prior written consent of AECOM to use and rely upon the Report and the Information. Any injury, loss or damages arising from improper use of the Report shall be borne by the party making such use.

This Statement of Qualifications and Limitations is attached to and forms part of the Report and any use of the Report is subject to the terms hereof.

*AECOM: 2015-04-13*

# Authors

**Report Prepared By:**

Nancy Hill, P.Eng.
Project Manager

**Report Reviewed By:**

Ian Rennie, P.Eng.
Municipal Civil Engineer, Water

**Report Reviewed By:**

Pippy Warburton, P.Eng.
Senior Water Resources Engineer

# Executive Summary

As part of the City's Integrated Stormwater Management Plan (ISMP), AECOM conducted a review of the City's Watershed Drainage Plans (WDP) and stormwater related GIS data. This Technical Working Paper (TWP) #1 summarises the results of this review; including.

- A review and summary of the City's six WDPs;
- A summary of the gaps with each of the WDPs with respect to geography, cost estimates, modeling, consideration of climate change, environmental assessments and geotechnical assessments;
- Recommendations for addressing gaps related to the WDPs;
- Identification of new stormwater related projects and completed projects since the WDPs were developed;
- A review of existing project prioritization frameworks;
- A proposed new project prioritization framework for the City of Prince George;
- A summary of the priorities of the action items from the WDPs (and other projects identified since the WDPs were developed) when the proposed new project prioritization is applied to them;
- A review of the City's GIS data related to stormwater; and
- A GIS gap reduction plan.

Recommendations resulting from this review are outlined below.

**<u>Future WDPs/WDP Updates</u>**

Some areas not currently included within a WDP are already developed or may be developed in the near future. Selecting areas for developing new WDPs, in order of priority, should be:

1. Areas with known issues (e.g. flooding, erosion, etc.);
2. Areas where new development is occurring or soon to occur (e.g. North Nechako); and
3. Areas of existing development.

Any future WDPs or updates of existing WDPs should include the items listed below.

1. Consideration of climate change. Use results from the IDF CC tool used for the West Fraser River & Parkridge Creek WDP until the City has developed a future looking IDF curve based on improved rainfall data and climate change considerations.
2. Cost estimates of proposed projects – using the City's new approach of providing high level cost estimates as a range.
3. Flow and water quality monitoring.
4. Use of a preferred modelling software package, as identified by the City
5. Development of a dual drainage model (1D) with 2D models developed, where needed, to assess problem areas where surface flooding issues have been identified.
6. Assess whether culverts are fish friendly and whether the watershed has intact riparian function.
7. Consider surficial geology, geomorphology, slopes, municipal and private well sites, contaminated sites and older industrial/commercial sites to identify areas where increased infiltration should not be done without site specific studies.
8. Action items should be prioritized using the newly proposed stormwater project prioritization framework.
9. Provide any updated catchments, asset inventory, elevations etc., to the City so they can update their GIS accordingly.
10. Model future conditions under full build-out, as defined by the OCP, as well as existing conditions.
11. Provide updates to the natural asset inventory that the City will soon be developing.

**GIS**

We recommend that the City update the following features in its GIS as staff availability allows:

- Correcting catchment boundaries, adding catchment areas and correcting typos (i.e. Beaverly);
- Adding creek names;
- Adding culverts, open channels/ditches, outfalls, natural ponds and asset attributes (e.g. elevations, material, condition etc.) that have been accurately identified through past WDPs, where the data has been readily provided to the City;
- Identifying and recording drainage systems associated with roadways that do not currently have a storm sewer or ditch associated with them in GIS;
- Adding stormwater asset condition and risk data into GIS when it becomes available;
- Adding all stormwater assets such as monitoring stations, dikes, grates/screens and subsurface infiltration facilities that are not currently in the City's GIS;
- Adding other asset attribute information that is currently missing such as storage basin size; and
- Adding natural assets such as riparian areas once the City has completed its natural asset inventory.

The ditch and screen/grate inventory could be completed as other O&M work is being conducted (e.g. collect screen/grate info during culvert inspections, collect ditch info during pavement condition assessments or street sweeping).

**Recommended Projects**

The Watershed Drainage Plans recommended a total of 261 action items. Since the WDPs were issued 6 action items have been completed and 4 new action items have been identified as new issues have arisen. A new project prioritization framework, that was developed for this ISMP, was applied to the action items in order to score them and sort them by high priority (maximum score of 9) to low priority (minimum score of 0). The following action items were given the highest priority score (i.e. scores of 7-9 out of a highest possible score of 9). The action items, which have a total estimated cost of $1.2M to $5M, are listed in order of priority
.

1. Replace the Domano culvert on Parkridge Creek with a structure that would be fish passable in response to DFO requirements.
2. Introduce better erosion and sediment control measures (e.g. new erosion and sediment control bylaw);
3. Update hazardous slope mapping.
4. Secure sustainable levels of stormwater funding (e.g. Drainage levy or stormwater utility with credit/rebate program). In order to successfully secure sustainable funding levels the public needs to be educated on the value of stormwater management.
5. Protect wetlands and important riparian areas that are not currently protected under municipal legislation (i.e. riparian areas of a stream that is not fish-bearing but drains to a fish-bearing stream or a wetland that is not directly connected to a fish-bearing stream).
6. Update Design Guidelines to consider climate change (e.g. increase the design storm and minimum pipe size/slope). This will be addressed further in TWP #2.
7. Replace/modify culverts in poor condition, under a significant road, whose modification/replacement would also provide fisheries benefits (e.g. Bittner Creek).
8. Protect important wildlife corridors and core habitat areas that are not addressed through existing riparian area protection.
9. Implement Best Management Practices/Low Impact Development (BMP/LID) standards for new development in catchments to fish-bearing streams and associated public education circulars. This concept will be discussed further in TWP's 2 and 3.
10. Expand floodplain development permit areas in certain areas along Parkridge Creek.
11. Update Prince George Bylaws (DCC, Development Procedures, and Tree Protection).

Through further discussions with City staff and the completion of this ISMP, additional action items may be identified and should be added to the overall Action Item List (see Appendix C). Similarly, the City may decide to eliminate action items proposed by completed WDPs. In this way, the compiled Action Item list can become a "living" document that is regularly updated as issues arise, projects are completed and priorities change.

# Table of Contents

page



# List of Figures



# List of Tables

# Appendices

# 1. Introduction

As part of the City's Integrated Stormwater Management Plan (ISMP), AECOM conducted a review of the City's Watershed Drainage Plans (WDP) and stormwater related GIS data. This Technical Working Paper (TWP) #1 summarises the results of this review; including.

- Review watershed drainage plans for technical (capacity, environmental, geotechnical, hydrogeology, etc.) issues and to note any gaps;
- Apply climate projections for consideration, where needed;
- Develop a framework for prioritizing stormwater projects;
- Prioritize recommendations for addressing stormwater technical issues (with cost estimates, where possible);
- Develop a WDP gap reduction plan;
- Review existing GIS data; and
- Prepare GIS asset data inventory gap reduction plan.

# 2. Watershed Drainage Plan Review

## 2.1 Geography

The City has completed the following six watershed drainage plans (WDP):

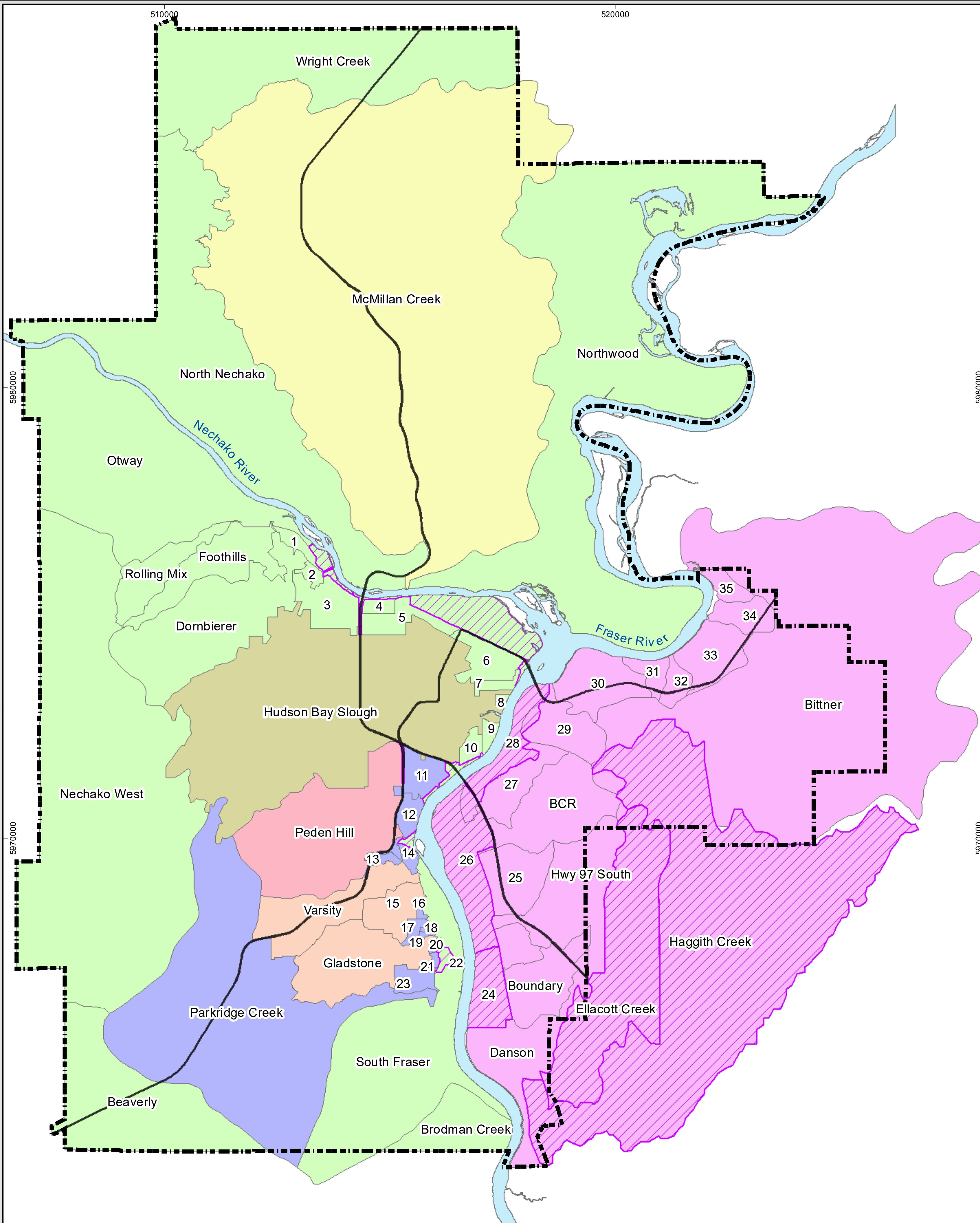
- University Heights & Peden Hill;
- West Fraser River & Parkridge Creek;
- Gladstone, Varsity & Trent;
- Hudson's Bay Wetlands;
- McMillian Creek; and
- East Prince George.

The areas of the City not covered by any of the six watershed drainage plans are shown in green in the following figure. They are mostly areas along the Fraser and Nechako Rivers and along the northern, western, southern and northeastern edges of the City limits. In particular, the following catchments are not covered by a WDP: Wright Creek, Northwood, North Nechako, Otway, Rolling Mix, Foothills, Dornbierer, Nechako West, , Brodman Creek, South Fraser, Stirling, King, Lyon, Hammond, Cameron, Patricia, 17th Avenue, South Fort George and Queensway. Land uses that are within these areas include industrial (e.g. Canfor, railyards, Chemtrade, Pittman Asphalt, Rolling Mix Concrete etc.), commercial (downtown and other), agricultural, cleared but undeveloped areas (e.g. Domano Blvd), newly developing areas (e.g. Malaspina), forested areas, various residential areas (e.g. near downtown, North Nechako and rural), and Parks.

The areas that are hatched in the following figure are areas that are not included within a catchment in the City's GIS. These areas are mostly in East Prince George and along the south shore of the Nechako River (including the railyards). The catchments in East Prince George that are not within the City's GIS are Willow Creek South, Willow Creek North, Unnamed (Fraser River), Ellacott Creek and Haggith Creek (some of which is outside the City boundaries). The portions of these catchments that are within the City limits mostly contain industrial areas, forested areas, and the Prince George airport.

There are minor errors in the City's 'Stormwater Catchment Areas' GIS layer. These have been identified in the individual WDPs and through discussions with City staff. The following edits should be made to improve the accuracy of the City's GIS, to ensure that previous work is retained, and to aid in future asset management and infrastructure planning tasks. These edits would be easier if the City had the original data files from each of the WDPs.

- Update Peden Hill and neighbouring catchments as per the suggested catchment area in the WDP for University Heights/Peden Hill.
- Update the new and existing catchment areas (including the stream headwater areas that extend beyond the City's boundary) as delineated in the East Prince George WDP.
- Update the new and existing catchment boundaries included in the West Fraser River and Parkridge Creek WDP.
- Review the extents of the South Fraser catchment to potentially correct the catchment delineations of the neighbouring catchments north of Parkridge Creek.
- Review Appendix A of the MacMillan Creek WDP to update catchment boundaries.
- Consider updating other catchment areas beyond the City's boundary including Brodman Creek, Beaverly, Nechako West, Otway, North Nechako, Wright Creek, and Northwood.
- Update the spelling of Beaverly.




| | | | |
|---|---|---|---|
| 1. Stirling | 10. Queensway | 19. Guelph | 28. Unnamed (Fraser River) |
| 2. King | 11. Ferry Ave | 20. Imperial | 29. Guay |
| 3. Lyon | 12. Lansdowne | 21. Jean De Brebuef | 30. Pickering Outfalls |
| 4. Hammond | 13. Hwy 16 West | 22. Malaspina | 31. Hawk |
| 5. Cameron | 14. Cowart | 23. Latrobe | 32. Airport Hill |
| 6. Patricia | 15. Trent | 24. Willow Creek South | 33. Hwy 16 East |
| 7. 17th Ave | 16. Delhi | 25. Continental Way | 34. Graves |
| 8. Fort George Park | 17. Essex | 26. Willow Creek North | 35. Foreman |
| 9. South Fort George | 18. Fairmont | 27. Great Street | |

Basemapping from ESRI (World Topology), Gov't of BC GeoBC), AECOM 2014.

N
W E
S

0 1 2 3
Kilometres

1:90,000

NAD 1983 UTM Zone 10N

This drawing has been prepared for the use of AECOM's client and may not be used, reproduced, or relied upon by third parties, except as agreed by AECOM and its client, as required by law, or for use by governmental reviewing agencies. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that modifies this drawing without AECOM's express written consent.

## Legend

**Watershed Drainage Plan Catchment Areas**

- No Watershed Drainage Plan
- East Prince George
- Gladstone, Varsity, & Trent
- Hudson Bay Slough
- McMillan Creek
- Parkridge Creek & West Fraser
- University Hill / Peden Hill
- Catchment not in City GIS
- Prince George Boundary
- Provincial Highways

Overview Map


CITY OF PRINCE GEORGE

City of Prince George Integrated Stormwater Management Plan
Location: Prince George, BC

# Watershed Drainage Plans Catchment Areas

10 December 2020

AECOM

Figure 1

File Location: C:\Workspace\60628231 - Prince George ISMP\434 GIS\FIG1-2020-12-10-Catchment Map-60628231.mxd Date Revised: December 10, 2020 Reviewed By: Paper Size: 11"x17" Scale is referenced to the specified paper size.

## 2.2 Existing Watershed Drainage Plans Summary

A general summary of the six WDPs is provided in the following table in order of completion (from the earliest to most recently completed). Additional descriptions of the six WDPs are provided in the sub-sections that follow.

The estimated costs of WDP recommendations in the following table have been extracted directly from the reports and have not been increased to account for inflation or climate change. This will be addressed in **Section 2.7**. **Section 2.7** also provides details about what else is missing from the WDP cost estimates. Therefore, the cost estimates provided in the following table should be considered as low (i.e. underestimates the actual cost of achieving all the action items outlined in each respective WDP).

**Table 1 WDP Summary**

| WDP | Year | Significant Considerations | Recommendations | Original Cost Estimates |
|---|---|---|---|---|
| **Gladstone, Varsity & Trent** | 2002 | • Negative impacts from previous/ existing development, including sediment, fecal coliform, urban debris and encroachments into riparian setbacks<br>• Upgrades needed to meet City's Design Criteria<br>• Fish habitat downstream of study area | • Storm sewer upgrades to convey the 5-year future development flow;<br>• Detention ponds/constructed wetlands to limit post-development flows for the 2 and 5-year return periods to pre-development (Gladstone/Trent) or limit the 5-year post-development peak flow to less than 50% of the 2-year (Varsity). Ponds will also limit the 100-year post-development flow to pre-development levels.<br>• Creek erosion protection<br>• Maintain stream setbacks | $8.8 M |
| **Hudson's Bay Slough** | 2007 | • Natural watercourses<br>• Escarpment | • Upgrade capacity of select storm sewers, culverts, channels and Queensway flood box capacity<br>• Lower upper slough pool<br>• Implement source controls and detention storage for future development on Cranbrook Hill<br>• Require source controls on properties that are likely to produce sediment or hydrocarbons<br>• Enhance the upper wetland (for improved water quality treatment, aesthetics, maintenance and recreation) and lower wetland (for improved fisheries habitat).<br>• Assess the sediment accumulations in the downtown drainage system.<br>• Implement a sediment management program and by-law.<br>• Prioritize the drainage system for CCTV. | $17.5 M plus cost to remove sediment from downtown storm sewers (costs TBD) |
| **East Prince George** | 2013 | • Fish bearing streams<br>• Culverts in poor condition<br>• Watercourses susceptible to erosion<br>• Ravine stability concerns | • Water quality monitoring for BCR/Danson sites<br>• Protect existing riparian buffers along the Fraser River<br>• Wetland compensation program/protocol.<br>• Beaver management plan<br>• Culvert assessment (fish passage and hydraulics)<br>• Improve sediment control along Foreman Road<br>• Monitor the terrain instability associated with the main drainage course within the Airport Hill catchment.<br>• Improve erosion and sediment control at key watercourse crossings.<br>• Monitor slope instabilities of the main drainage course within the BCR catchment.<br>• Replace / modify key Haggith Creek culverts *(Willowcale culvert subsequently replaced and bridge installed).*<br>• Enforce 30 m top of bank riparian setbacks from all future developments.<br>• Use vegetated open channel bioswales in lieu of piped systems. | No cost estimates provided |

| WDP | Year | Significant Considerations | Recommendations | Original Cost Estimates |
|---|---|---|---|---|
| | | | • Require stormwater best management practices (BMP) on future developments and training of City inspection staff.<br>• Encourage the Prince George Airport Authority to apply the recommended stormwater best management practices.<br>• Develop a flow monitoring program.<br>• Monitor and complete remediation, as necessary, of the five identified erosion sites<br>• Create a Stormwater Best Management Practices Circular.<br>• Create a Stormwater Management Rebate Program linked to DCCs.<br>• Create a drainage utility fee based on effective impervious area.<br>• Modify applicable City of Prince George bylaws. | |
| **University Heights & Peden Hill** | 2016 | • Fish-bearing streams downstream of study area<br>• Erosion of the escarpment watercourses<br>• 14 pipes in the minor system and 4 pipes in the major system do not have sufficient capacity under existing conditions | • Use diversion piping to convey excess run-off from existing development down the escarpment to prevent erosion of the escarpment watercourses.<br>• Volume reduction and source controls in new development where soils permit and slope stability is not a concern.<br>• Use detention and diversion piping to convey excess run-off from new development where soils or stability concerns do not permit stormwater infiltration.<br>• Treat and monitor stormwater entering Lansdowne Creek.<br>• Improve the City's Erosion and Sediment Control regulations.<br>• Retain riparian areas. | $4.5 M |
| **McMillan Creek** | 2017 started 2011 | • condition of infrastructure<br>• fish passage<br>• water quality<br>• wildlife values<br>• future expansion<br>• maintenance<br>• erosion and stability issues | • Replacement of critical crossings (Aberdeen crossing completed using an open bottom structure - $1M).<br>• Culvert maintenance program<br>• Public education on the importance of this watershed<br>• Continued replacement of infrastructure<br>• Incorporation of BMP for capture, infiltration and retention<br>• Update of the City Design Guidelines<br>• Securing long term funding for infrastructure<br>• Limitation of development in sensitive riparian areas<br>• Best management practices for construction and maintenance activities. | $10.2M |
| **West Fraser River & Parkridge Creek** | 2020 | • Capacity constraints | • Capacity upgrades<br>• Establishing a minimum building elevation within the Parkridge Creek floodplain<br>• Strengthening bylaws and design criteria to establish BMP for new development<br>• Treatment at outfalls<br>• Protect wetland habitat<br>• Water quality monitoring<br>• Erosion protection at outfalls to the Fraser River | $14M |

### *2.2.1 Gladstone, Varsity and Trent WDP*

The Gladstone, Varsity and Trent WDP was completed in 2002 by Associated Engineering. The Gladstone, Varsity, and Trent catchments are located in the southwestern section of the City of Prince George. Significant development has occurred in these watersheds and consists primarily of residential development with pockets of institutional and commercial development. If the impacts of continued urban development on storm water runoff are not addressed, the peak runoff rates will increase as a result of diminished naturally occurring flood storage and ground infiltration areas.

To provide a level of service consistent with the City's Design Criteria, a combination of detention ponds and sewer/culvert upgrades are recommended for the three watersheds. The recommended storm sewer upgrades provide sufficient capacity to convey the 5-year future development flow. In Gladstone and Trent, the proposed detention ponds are designed to limit post-development flows for the 2 and 5-year return periods to pre-development levels. In Varsity, the proposed ponds are designed to limit the 5-year post-development peak flow to less than 50% of the 2-year post-development peak. As well, the reported storage volume of each pond limits the 100-year post-development flow to pre-development levels.

Recommended upgrades to the Gladstone drainage network include creek erosion protection, 10 wet pond/constructed wetlands, and 16 storm sewer upgrades. The new ponds/wetlands are mostly proposed in undeveloped areas except for one constructed wetland within a grassed site between St. Mark's Crescent and Domano Blvd. A figure showing the proposed ponds and upgrades is provided in **Appendix E.** The total capital cost for all recommended upgrades is estimated at $4,190,000 in 2002 dollars. Urban development in the lower portion of this catchment eliminated the former watercourses. The undeveloped upper areas contain open channels with limited aquatic values. However, retaining the riparian corridors through these areas provides opportunities for trail networks and environmental protection. Maintaining stream setbacks can limit sediment and other pollutants from entering the stream.

Recommended upgrades to the existing Trent drainage network include three wet ponds/constructed wetlands and 16 storm sewer upgrades. The estimated cost of the three ponds, which are proposed in currently undeveloped areas, is $725,200 and the total cost of the storm sewer upgrades is $427,600 including engineering and contingency. The total estimated capital cost is $1,152,800 in 2002 dollars. No environmental recommendations are provided for the Trent watershed as no streams or suitable fish habitats were identified.

Recommended upgrades to the existing Varsity drainage network include 2 new wet ponds/constructed wetlands in undeveloped areas, 14 storm sewer upgrades, 2 culvert upgrades, and creek improvements. The total estimated capital cost for all the recommended upgrades is $3,350,200 in 2002 dollars. Impacts of existing urban development in the Varsity catchment include increased fine sediment input, reduced water quality including fecal coliform levels in Varsity Creek, encroachments on riparian setbacks, and increased urban debris in and around streams. Stream setbacks (leave strips) should be provided downstream of Domano Boulevard. As well, setbacks are recommended for future development areas in the upper watershed. Although no fish are expected in this area, flow from these upper areas drain directly into fish bearing waters. The lower portions of Varsity Creek should be considered for community-based clean-up and restoration efforts.

### *2.2.2 Hudson's Bay Slough WDP*

The Hudson's Bay Slough WDP, now named the Hudson's Bay Wetlands, was completed in 2007 by Associated Engineering. The Hudson Bay Wetlands is located in the center of Prince George. The upland areas of Cranbrook Hill include protected wilderness areas, Shane Lake, the University of Northern B.C., and numerous natural watercourses. The central escarpment is mostly undeveloped and is bisected by University Way. The lower gradient area, east of the escarpment, is largely developed and includes residential, commercial, institutional, and recreational areas. The Hudson's Bay Slough WDP combined parks and trail development with storm water management needs.

Most development within the current urban area is expected to be redevelopment and densification of existing areas. Changes in drainage characteristics caused by development can increase flooding concerns, channel erosion and sediment loads, and lead to degradation of water quality and aquatic habitat.

Issues and recommendations within the WDP are outlined below.

- Upgrading sections of the enclosed drainage system subject to surcharging as per the hydraulic model and re-routing certain sub-catchments.
- Preventing flooding in the low-lying areas by upgrading culverts, improving channels, lowering the upper slough pool, and increasing the Queensway flood box capacity.
- Implementing source controls and detention storage for future development on Cranbrook Hill.
- Require source controls on properties that are likely to produce large quantities of sediment or hydrocarbons (e.g. automobile service stations and maintenance shops, machinery storage areas, commercial parking lots etc.).
- Enhancing the upper wetland for more effective water quality treatment, to improve its aesthetics, address maintenance issues, and provide recreational opportunities.
- Enhancing the lower wetland to improve fish habitat.
- Maintaining the integrity of the flood protection provided by Queensway flood box.
- Assessing the sediment accumulations in the downtown area drainage system. Note that since this WDP was prepared the City has conducted sediment sampling in the Winnipeg St Stormwater System and is completing a Management & Treatment Plan for this system.
- Commencing a sediment management program, including the installation of sediment trapping manholes, catch basins, chambers, basins, and ponds, and the development of an erosion and sediment control by-law.

The WDP also discussed O&M activities for sediment removal and the prioritization of the drainage system for a condition survey. The total cost of the proposed initiatives was $17.5 million, in 2007 dollars, plus any cost to remove sediment from the downtown storm sewer system. These costs will be provided upon completion of the current Winnipeg St. Stormwater Management & Treatment Plan.

### *2.2.3 East Prince George WDP*

The East Prince George WDP was completed as draft in 2013 by Associated Engineering. The East Prince George watershed is lightly developed (66% undeveloped – mostly forest) with the primary developed land uses being urban residential (18%) and industrial (9%) and includes the Prince George airport. Approximately half of the study area is located within the City of Prince George and the other half is part of the Regional District of Fraser – Fort George.

The majority of flow routes within the watershed are natural watercourses (including streams classified as fish-bearing), roadside ditches and associated culverts. 32 of the 303 culverts are in poor physical condition.

There are five watercourses within the watershed that are highly susceptible to erosion. Large portions of their upstream drainage areas are allotted for future development. Recommendations include a ravine stability assessment with monitoring and to prevent development from directing increased flows to these watercourses.

The WDP identified four locations in the watershed where inadequate hydraulic capacity may cause localized flooding. It was recommended that hydraulic investigations of each location be conducted to determine if culverts should be upgraded or upstream controls should be put in place. The four locations are:

- 2400 mm diameter CSP culvert within Haggith Creek at Willow Cale Road. Note that this culvert has subsequently been replaced;

- 600 mm diameter CSP culvert within the Airport Hill watercourse at Hwy 16,
- 1500 mm diameter CSP culvert within Bittner Creek at Graves Road, and
- System of several culverts that conveys flow within the lower Boundary catchment.

The WDP recommends suites of best management practices (BMP) for different land uses to be applied to future development in the watershed.

Specific recommendations listed in the WDP are outlined below.

- Implement a water quality monitoring program for streams entering the Fraser River from the BCR and Danson sites to identify possible contaminant loadings.
- Designate significant forested slopes and existing riparian buffers along the Fraser River as “protected greenway corridors” to allow for wildlife movement through East Prince George.
- Develop a wetland compensation program/protocol to maintain the quantity of existing wetland habitat during future land development.
- Develop and implement a beaver management plan that includes dam modification, debris management, population management, and dam removal, as required.
- Conduct a detailed Fish Passage assessment of culverts within the Bittner Creek watershed and replace or modify problem culverts in a prioritized manner.
- Improve runoff control along Foreman Road to minimize sediment introduction to the drainage courses. Since the completion of this WDP, new commercial development on Foreman Road has implemented on-site stormwater controls but there is concern that longer duration of peak flows may increase, not decrease downstream erosion.
- Monitor the terrain instability associated with the main drainage course within the Airport Hill catchment.
- Improve erosion and sediment control at the Guay catchment watercourse crossing of the power line ROW access road and the steep access road near Continental Way at the main BCR drainage course. City staff have noted that this crossing is problematic with flows sometimes over-topping Continental Way during the spring melt.
- Monitor the slope instabilities of the main drainage course within the BCR catchment.
- Replace / modify culverts at the Willow Cale Road and CN Rail crossings with Haggith Creek. The culvert at the Willow Cale Rd crossing was replaced along with a bridge subsequent to the development of this WDP.
- Enforce 30 m top of bank riparian setbacks from all future developments.
- Use vegetated open channel bioswales in lieu of piped systems for surface water conveyance.
- Enforce the application of the recommended stormwater best management practices on future industrial, commercial and urban developments (based on infiltration testing results). City staff noted that infiltration does not work in the uplands but there may be potential (to be confirmed) for BCR and Danson.
- Encourage the Prince George Airport Authority to apply the recommended stormwater best management practices.
- Complete detailed hydraulic analyses of several culverts to determine if upgrades are required.
- Develop a flow monitoring program.
- Create a Stormwater Best Management Practices circular.
- Educate and train City of Prince George staff responsible for inspection of required on-site stormwater best management facilities.
- Create a Stormwater Management Rebate Program linked to DCCs.
- Create a drainage utility fee with the rate structure developed to reflect the effective impervious area of each property. It should be noted that the City attempted to implement a drainage utility in 2012 with little uptake from the community.
- Modify applicable City of Prince George bylaws.

The East Prince George WDP is currently being updated to include the Boundary Road project and Industrial development that has occurred since the report was first developed.

### *2.2.4 University Heights and Peden Hill WDP*

The University Heights and Peden Hill WDP was conducted in 2016 and finalized in 2020 by KWL. The 747 ha University Heights/Peden Hill (UH/PH) watershed is located in the south-central portion of the City of Prince George. The western half of the watershed is a largely undeveloped forested upland area. East of the uplands is a steep escarpment that separates the uplands from the largely developed lowlands that extend to the Fraser River. The watershed drains into Lansdowne Creek that flows just south and adjacent to the WWTP and directly into the Fraser River. Approximately 45% of the catchment is zoned forest or greenbelt, 27% is institutional, 14% is single-family residential and the remaining land is comprised of multifamily, commercial, industrial, utilities, and road dedication. Future development activities include redevelopment in the lowlands and new development in the uplands resulting in an increase from 23% to 48% total impervious area once built-out to the OCP.

All the watercourses in the catchment area are non-fish bearing and do not contain overwintering habitat or suitable spawning habitat. The Cranbrook Hill escarpment is acknowledged as a barrier to upstream fish passage. As well, the storm sewer outfall on Lansdowne Creek is an impassable barrier to upstream fish passage. Lansdowne Creek is the receiving water for the watershed and is known to support fish, therefore maintaining water quality is critical. The catchment area provides a variety of habitat types and seral stages for wildlife indigenous to the area.

124 pipes were assessed, and it was found up to 14 pipes in the minor system and 4 pipes in the major system do not have sufficient capacity under existing conditions. Build-out conditions were also assessed but no considerations were made for climate change.

The one detention pond located in the study area (Maurice Drive Pond) was found to have sufficient capacity using the City's criteria under current land use conditions. However, under future land use conditions, additional ponds or an expansion of this pond would be required to meet the criteria. City staff have noted that a large amount of sediment has already accumulated in this pond that requires removal, but the pond design does not accommodate easy maintenance access nor does it provide an area to decant sediment prior to removal by truck.

In order to mitigate the impacts of development it was recommended to:

- Use diversion piping to convey excess run-off from existing development down the escarpment to prevent erosion of the escarpment watercourses;
- Volume reduction and source controls in new development where soils permit and slope stability is not a concern;
- Use detention and diversion piping to convey excess run-off from new development where soils or stability concerns do not permit stormwater infiltration;
- Monitor and treat stormwater through wet detention ponds/constructed wetlands, on-site source controls and OGS prior to entering Lansdowne Creek;
- Improve the City's Erosion and Sediment Control regulations; and
- Retain riparian areas.

Recommended measures were estimated to cost a total of $4.5 million in 2016 dollars.

### *2.2.5 McMillan Creek WDP*

The McMillan Creek WDP was started in 2011 and revised in 2017 by DWB Consulting. McMillan Creek watershed is primarily undeveloped with rural residential, commercial, and light industrial activity. The watershed system includes both traditional stormwater systems and natural drainage with many crossing structures. There is future development proposed in the watershed in both developed and undeveloped portions of the watershed.

Major concerns include the condition of infrastructure, fish passage through the system, water quality, wildlife values, future expansion, maintenance, erosion and stability issues. Proposed improvements include:

- Replacement of critical crossings;
- Execution of a culvert maintenance program;
- Public education for the understanding of the importance of this watershed;
- Continued replacement of infrastructure;
- Incorporation of alternative stormwater management strategies including capture, infiltration and other natural retention methodologies;
- An update of the City Design Guidelines to account for increased runoff and minimum pipe sizes for both storm sewers and drainage culverts;
- Securing of long-term funding for infrastructure;
- Limitation of development in sensitive riparian areas;
- Limitation of sedimentation and contamination, protection of areas for parks and concise best management practices for construction and maintenance activities.

In addition to the items recommended above, the City is conducting water quality monitoring of McMillan Creek.

Maintenance costs were estimated at $630,000 including the Hofferkamp chamber upgrades and required crossing replacements were estimated at $9.6 million in 2017 dollars.

### *2.2.6 West Fraser River & Parkridge Creek WDP*

The West Fraser River & Parkridge Creek WDP was completed in 2020 by Associated Engineering. The West Fraser River drainage area itself is not a single watershed but consists of 12 subcatchments that drain independently to the Fraser River. The West Fraser River subcatchments are highly developed with predominantly single-family residential land use and are drained primarily by underground storm infrastructure leading to outfalls into the Fraser River. Some of the northern subcatchments (Cowart, Hwy 16 W., Lansdowne, and Ferry Avenue) have some overland drainage features (i.e. ditch/culverts).

The Parkridge Creek watershed encompasses the area from the main stem outlet to the Fraser River to the creek's headwaters. The Parkridge Creek watershed is primarily rural, with limited single family and commercial developments and meanders across the BC Hydro power line between Hwy 16W and the Fraser River at two locations. Except for a small developed area downstream of Parkridge Pond that has a local piped storm system, most of the area is drained by a ditch and culvert network discharging to various tributaries of Parkridge Creek.

The study's drainage areas were modelled to assess the performance of the existing drainage system as well as future development conditions with considerations of the impacts of climate change on increased rainfall within the area. The study recommendations addressed the following issues:

- Capacity constraints and recommended upgrades to reduce the risk of flooding;
- Establishing a minimum building elevation within the Parkridge Creek floodplain;
- Limiting land clearing unless proper stormwater controls are implemented;. City staff noted that this could be achieved with a new erosion and sediment control bylaw.
- Strengthening bylaws and design criteria to establish BMP (best management practices) for new development; and
- Additional environmental considerations such as treatment at outfalls (consisting of OGS or settling tanks), protecting wetland habitat, water quality monitoring, and erosion protection measures at outfalls to the Fraser River.

## 2.3 Modelling Assessments

The following table outlines the software packages used to model the minor system and the major system for each of the WDP. The minor system is typically designed to convey the flow from frequent storms (i.e. less than 5-year storm) and generally consists of storm sewers, catch basins, gutters and ditches. The major system is typically designed to manage the flow from larger storms (i.e. 5-100 year storm) and generally consists of streets, channels, ponds, natural watercourses, and ravines.

The table also notes the extent to which the major system was modeled for each of the WDP.

**Table 2 WDP Modeling Software**

| WDP | Minor System Modeling Software | Major System Modeling Software |
|---|---|---|
| **Gladstone, Varsity & Trent** | Hydra 6.1 | No major system modeling done except for pond volume sized for 100-year storm. Overland flow path capacity was not analysed. |
| **Hudson's Bay Slough** | Visual Hydro | Visual Hydro (lowland areas) |
| **East Prince George** | PCSWMM | PC SWMM |
| **University Heights & Peden Hill** | XPSWMM | XP SWMM – overland flow paths on private property, storm sewers on private property and culverts in open channels. Did not assess road surfaces or creek open channels. |
| **McMillan Creek** | EPA SWMM | EPA SWMM - Main stem crossings and detention ponds only |
| **West Fraser River & Parkridge Creek** | PCSWMM | Mike 21 (2D model) |

As can be seen in the previous table, the City's previous WDPs have been developed using six different modeling software packages. The City may want to consider selecting one or two preferred modeling software packages for any future WDPs. This would allow the City to:

- Ensure that consultants use modeling software that can produce accurate results for the conditions within the City of Prince George;
- Consolidate models between watersheds particularly where there is overflow from one watershed to another;
- More easily develop in-house modeling capabilities for conducting simple updates (e.g. pipe rebuilt), for conducting "what-if" scenarios (e.g. proposed new development, or proposed system upgrade), and for reviewing consultants' work; and
- More easily work with a single consulting firm for model updates.

Most of the City's WDPs (four out of six) were produced using a SWMM based model. SWMM based hydrology models work particularly well in urban areas. SWMM based hydrology models can also be applied to rural areas but this must be done carefully as SWMM models are often badly misapplied when used for rural areas. A modeling software such as Visual Otthymo works well in rural areas.

In selecting a preferred software package(s) the City should consider the:

- Price to purchase the software and on-going licensing costs;
- Ability to have licenses for more than one user;
- Usability, particularly for staff that do not model regularly;
- Ability to model urban and rural areas;
- Compatibility with the City's GIS, risk models and other planning tools; and
- Whether the consultant community has the knowledge/software to support future modeling projects cost-effectively.

## 2.4 Environmental Assessments

Each of the WDP included an environmental assessment. We reviewed each of the WDP to determine if they included the following:

1. Inventory and condition of watercourses, wetlands, sloughs and lakes etc.; noting any issues such as erosion, stream channel stability and substrate condition.
2. Noted which waterbodies within the study area are fish-bearing and/or drain to a fish-bearing waterbody.
3. Identified the presence of fish barriers and whether culverts are fish friendly.
4. Identified areas of fish habitat including any critical habitats (i.e. spawning) and whether there were signs of negative impacts.
5. Assessed water quality and noted any water quality issues.
6. Noted any water quantity issues.
7. Determined whether there was intact riparian function (i.e. natural vegetation, sufficient width and connected corridors).

The table below summarizes whether each of the WDP addressed the six issues identified above and whether there were any notable gaps. Note that a checkmark under column 2 “Fish bearing analysis” does not mean that the watershed is fish bearing but that the WDP determined whether any waterbodies within the study area are fish-bearing or not. Likewise, a checkmark under column 4 “Fish habitat analysis” does not mean that there is fish habitat within the study area but that the WDP determined whether there is fish habitat or not. A black checkmark indicates that the issue was fully addressed, a grey checkmark indicates that the issue was partially addressed, and an X indicates that the issue was not addressed at all.

**Table 3 Issues Reviewed as Part of Each WDP Environmental Assessment**

| WDP | 1. Inventory & condition of waterbodies | 2. Fish-bearing analysis | 3. Fish barriers & fish friendly culverts | 4. Fish habitat analysis | 5. Water Quality | 6. Water Quantity | 7. Riparian Function | Gap Summary |
|---|---|---|---|---|---|---|---|---|
| **Gladstone, Varsity & Trent** | ✔ | ✔ | ✓ | ✔ | ✔ . | ✔ | ✔ | No comments on whether culverts are fish friendly. |
| **Hudson's Bay Slough** | ✔ | ✓ | ✓ | ✔ | ✓ | ✔ | X | Field information is old (2003). EDI recommended spring sampling to determine fish species present and additional assessments prior to completing any works, with particular consideration of the lower slough. No comments on whether culverts are fish friendly. Water quality investigations were preliminary in nature. They recommend further water quality investigations prior to implementation of proposed measures. No mention of riparian corridors. |
| **East Prince George** | ✔ | ✔ | ✓ | ✔ | ✓ | ✓ | ✔ | No comments on whether culverts are fish friendly. No mention of flow monitoring or model calibration. Mentions possible water quality issues but no water quality sampling completed or historic data available. |
| **University Heights & Peden Hill** | ✔ | ✔ | ✓ | ✔ | ✓ | ✓ | ✓ | No comments on whether culverts are fish friendly. The condition of the greenbelt and riparian area/wildlife corridors is not known; therefore, can't determine intact riparian function. Mentions water quality concerns but no water quality sampling completed or historic data available. No flow monitoring conducted or model calibration. |
| **McMillan Creek** | ✔ | ✔ | ✔ | ✔ | ✔ | ✓ | ✔ | No mention of flow monitoring or model calibration. |
| **West Fraser River & Parkridge Creek** | ✔ | ✔ | ✔ | ✔ | ✔ | ✓ | ✓ | Insufficient information on riparian vegetation, width sufficiency and connectivity. No flow monitoring of minor drainage system or Parkridge Creek. |

**Table Legend**

✔ Issue was fully addressed
✓ Issue was partially addressed
X Issue was not addressed

In general, the environmental assessments were comprehensive and addressed most of the issues relevant to a watershed drainage plan. The most common gap noted is that the four oldest WDP did not comment on whether the culverts within the study area are fish friendly. Also four of the WDPs did not indicate any flow monitoring. Flow monitoring can help assess current flow conditions within critical fish-bearing streams and can improve the reliability of future hydrologic and hydraulic models through model calibration. The third most common gap is that three of the WDP did not sufficiently determine intact riparian function and two of the WDPs were completed with no water quality data (either historic or acquired during the WDP).

## 2.5 Geotechnical Assessments

A summary of the geotechnical and hydrogeological issues reviewed in each of the WDP and any noted gaps are provided below.

**Geological/ Geotechnical information**
Most of the WDP relied on Surficial Geology Mapping (Armstrong JE and Leaming SF, 1969, GSC Map 3-1969). This is likely the best source of geological information and represents the upper 2m of unconsolidated material. The East Prince George WDP relied on BC Soil mapping for geological information which represents shallower soils and is more intended for agricultural purposes but will still provide some useful information.

The West Fraser & Parkridge Creek WDP used a geotechnical hazard assessment map which considers surficial geology, geomorphology and slope analysis. This is a good approach and should be extended across the entire City to highlight areas where increased infiltration should not be done without site specific studies to determine if there would be a negative geotechnical result such as slope instability or excessive seepage onto nearby properties (especially downslope).

**Water Supply**
Prince George relies on groundwater for its water supply. Over 80 per cent of the city's water wells tap into aquifers that are refilled by the Nechako River. These aquifers provide nearly 18 billion litres of water each year through six municipal wells. Raw water is chlorinated according to Northern Health Authority guidelines. Three of the municipal wells are along the south side of the Nechako River, two of the wells are along the west shore of the Fraser River and one of the wells is along the east side of the Fraser River. The later 3 wells are standby. Only one of the WDP considered the presence of these wells and recommended not infiltrating stormwater near the municipal wells.

The provincial government's aquifer and well mapping site indicates many aquifers and wells within City limits. The presence and need to protect these wells were not mentioned or assessed in any of the WDP.

**Contaminant Sources**
Infiltration is not recommended in areas of soil contamination such as landfills, contaminated sites or older industrial/ commercial areas. This issue is recognized in some of the WDP but none of them provided maps or detailed information. The BSC contaminated site registry is searchable and can provide maps and other information on contaminated sites. This should be considered before spending effort on increased infiltration by preparing mapping with both zoning and contaminated site registry information.

If the City conducted more water quality monitoring as part of future/updated WDPs or as part of an on-going water quality monitoring it would help identify and confirm contaminant sources.

**Gap Summary**
Based on the gaps identified above we would recommend that the City develop the following:

1. City wide geohazard map based on slopes, soil types, drainage channels and riparian setbacks;
2. Aquifer map with municipal wells, municipal well capture zones and residential wells;
3. City wide map showing contaminated sites and older industrial areas; and
4. Ensure that future WDP and WDP updates consider surficial geology, geomorphology, slopes, municipal and private well sites, contaminated sites and older industrial/commercial sites to identify areas where increased infiltration should not be done without site specific studies.

## 2.6 Climate Projections

The City has completed the following studies recently in the areas of climate change adaptation and stormwater:

- Adapting to Climate Change in Prince George: An overview of adaptation priorities (2009)
- Implementing Climate Change Adaptation in Prince George, BC Volume 4: Flooding (2012)
- Climate Change Impacts on Rainfall and Freeze-Thaw Events in Prince George ( 2014)
- Climate Change Adaptation Strategies for the Community of Prince George (2020)

These reports have made the following observations with respect to stormwater related climate change for the City of Prince George:

- More precipitation will likely fall as rain rather than snow
- More frequent incidences of extreme rainfall events and “localized?” flooding.
- Incidences of flooding could result from a variety of causes: riverine flooding from freshets or ice jams; and drainage system flooding from storm sewers surcharging or overland flow.
- Increased slope instability including riverbank erosion and loss of riparian habitat.
- Based on the limited available rainfall data (mostly Prince George Airport) the existing IDF curve seems sufficient for statistically representing historical rainfall events, but the City has not yet reviewed the IDF curves in consideration of future climate change.
- The number of freeze-thaw cycles has not recently increased, but City staff report that the apparent severity or impact of the freeze-thaw cycles seems to have increased.
- Rising annual temperatures leading to increased invasive species. This may be an issue for detention ponds, ditches, watercourses, riparian setbacks, wetlands and other forms of green infrastructure.
- Warmer winters and changes in freeze-thaw cycles could result in an increase in required road salting (and associated water quality impacts).

The extent to which each of the WDP have considered climate change are presented in the following table.

**Table 4 WDP Considerations of Climate Change**

| WDP | Year | Considered Climate Change? |
|---|---|---|
| **Gladstone, Varsity & Trent** | 2002 | No. |
| **Hudson’s Bay Slough** | 2007 | No. |
| **East Prince George** | 2013 | No but an update to the East PG WDP is underway. |
| **University Heights & Peden Hill** | 2016 | No. The consultant concluded that the summer events are the governing storms and they did not think that there will be an increase in summer storms. |
| **McMillan Creek** | 2017 | Modelled the 1 in 10-year storm rather than the 1 in 5-year storm to account for climate change. This represents a 20% increase in the 1-hour storm and a 13% increase in the 24-hour storm. |
| **West Fraser River & Parkridge Creek** | 2020 | Used IDF-CC tool for climate projections. 2100 increase in precipitation of 35% (RCP 8.5 emissions scenario) |

It is recommended that once the City has developed a future looking IDF curve based on improved rainfall data that considers climate change, that the hydraulic/hydrologic models created to support each WDP be updated with the new IDF curves and that the recommendations from each WDP be updated accordingly.

In the meantime, if the City is completing any of the projects identified in one of the WDP that did not consider climate change, then it should as a minimum, consider the impacts of increased rainfall by 35% (as per the IDF CC tool used for the West Fraser River & Parkridge Creek WDP). It should be noted that increasing a pipe by one size represents a 34% increase in capacity, on average (when considering pipes from 375 mm to 1200 mm in diameter). Increasing the diameter of a storm sewer replacement project by one size will typically increase the cost of a project by a marginal amount (e.g. 15%). Note that the percentage increase for each jump in pipe size is not equal and should be assessed for each project. Likewise, the impact and associated cost of considering climate change for non-pipe projects (e.g. detention pond, erosion stabilization etc.), would need to be reviewed separately for each recommended project.

## 2.7 Cost Estimates

The estimated costs of WDP recommendations that were provided in Table 1 in **Section 2.2** were extracted directly from the reports. The costs provided in each of the WDP typically only included capital costs that would be incurred by the City. Developer costs or "internal" City costs for policy changes etc. were not typically provided. Operations and maintenance costs are provided in few WDPs and were estimated as a percentage of capital cost (i.e. 1-4%).

The West Fraser River & Parkridge Creek WDP provided most of their cost estimates in the form of ranges (i.e. $10k, $10-$100k, $100k-$1M). Averages within the range provided were used to develop the total in **Table 1**.

In addition to internal costs, the WDPs omitted specific information as follows:

- <u>McMillan Creek</u> – Did not provide cost estimates for some of the recommended projects (i.e. proposed wetland, establishing parks & trails, culvert condition assessment, general mainstem crossing improvements, providing incentives to landowners to replace creek crossings that are fish barriers, develop and use BMP). They also did not detail what types of incentives could be offered to landowners to replace creek crossings that are fish barriers.

- <u>University Heights/Peden Hill</u> – Did not provide cost estimates for some of the recommended projects (i.e. cleaning out accumulated sediment from storm inlets, capping trails, establishing greenbelt areas/wildlife corridors, diverting runoff from watercourses, oil-grit separators, snow-dumps, upgrading culverts at the end of their service lives, water quality monitoring).

- <u>Hudson Bay Slough</u> – Did not provide a cost estimate for conducting a field investigation and assessment of sediment accumulations in the downtown area. This work is currently being done.

- <u>Gladstone, Varsity and Trent</u> – Did not provide cost estimates for some of the recommended projects (i.e. public trails and stream corridor management).

As previously noted, the costs provided in the summary table in **Section 2.2** were not increased to consider inflation or climate change. We have therefore provided a high-level estimate of the relevant cost increases for each of the WDP to consider inflation and climate change.

*<u>Construction Cost Inflation</u>*

Five of the six WDP were completed between 2002 and 2017 and therefore the cost estimates of the recommended projects need to be updated. In order to bring the costs to 2020 values, we would need to consider inflation.

The B.C. Construction Industry inflation rates are provided in the following table. These inflation rates are general to B.C. and not specific to Prince George. However, the City of Prince George has found that they have been experiencing an average annual inflation rate of approximately 5% recently, which is similar to the BC Construction Inflation Rates. Therefore, we will be using the BC Construction Inflation Rates to bring the historic cost estimates to 2020 levels.

**Table 5 BC Construction Inflation Rates**

| Year | Inflation Rate |
|---|---|
| **2002** | 6% |
| **2003** | 8% |
| **2004** | 9% |
| **2005** | 10% |
| **2006** | 10% |
| **2007** | 6% |
| **2008** | 5% |
| **2009** | 3% |
| **2010** | 3% |
| **2011** | 2% |
| **2012** | 2% |
| **2013** | 2% |
| **2014** | 2% |
| **2015** | 3% |
| **2016** | 3% |
| **2017** | 4% |
| **2018** | 6% |
| **2019** | 6% |
| **2020** | 4% |

In **Section 2.6**, we estimated that modifying pipe related projects to consider climate change could result in a project cost increase of 15%. Note that this a very high-level estimate and the actual increase for any given project would need to be assessed individually.

Most of the estimates provided in the WDPs were very high level and should be presented as a range to better reflect their level of accuracy. The high-level cost estimates provided in the WDPs should be presented as a range from -50% to +100%.

The original cost estimates in the WDPs were:

- increased by 15% to account for climate change if climate change had not already been considered in the WDP;
- increased to 2020 levels based on the construction cost inflation rates previously presented; and
- adjusted and presented as a range from -50% to +100% to consider the level of accuracy of the cost estimating within the WDPs.

The cost estimate adjustments and revised cost estimates are provided in the following table.

**Table 6 Adjusting WDP Cost Estimates for Climate Change and Inflation**

| WDP | Year | Considered Climate Change | Original Cost of Recommendations & Inflation Increase | Cost of Recommendations when considering climate change, inflation and range of accuracy |
|---|---|---|---|---|
| **Gladstone, Varsity & Trent** | 2002 | No. Increase cost estimate by 15%. | $8.8M<br>Increase cost estimate by 84% for inflation. | $9M - $35M |
| **Hudson's Bay Slough** | 2007 | No. Increase cost estimate by 15%. | $17.5M<br>plus cost to remove sediment from downtown sewers - costs TBD.<br>Increase cost estimate by 41% for inflation. | $14M-$55M<br>plus cost to remove sediment from downtown sewers |

| WDP | Year | Considered Climate Change | Original Cost of Recommendations & Inflation Increase | Cost of Recommendations when considering climate change, inflation and range of accuracy |
|---|---|---|---|---|
| **East Prince George** | 2013 | No. increase cost estimate by 15%. | No cost estimates provided | No cost estimates provided |
| **University Heights & Peden Hill** | 2016 | No. Increase cost estimate by 15%. | $4.5M<br>Increase cost estimate by 16% for inflation | $3M - $12M |
| **McMillan Creek** | 2017 started 2011 | Somewhat. No increase for climate change required. | $10.2M<br>Increase cost estimate by 12% for inflation. | $6M-$23M |
| **West Fraser River & Parkridge Creek** | 2020 | Yes. No increase for climate change required. | $14M | $7M-$28M |
| | | **Total** | | **$38M-$152M**<br>plus East PG projects and cost to remove sediment from downtown sewers |

## 2.8 Gap Analysis

The following table outlines the main gaps identified as part of the WDP review and priorities for addressing these gaps. Ideally the City would address all the gaps identified in the following table to get a better view of the City's stormwater system. In light of limited funds and staff time, many of the recommended activities to address the gaps can be deferred until particular trigger events occur (i.e. proposed development, implementation of WDP recommendations, new or revised WDP).

**Table 7 WDP Gap Summary and Priorities for Reducing Gaps**

| Gap | Description | Priority for Addressing |
|---|---|---|
| Geographic Area | Parts of the City are not addressed by a WDP | Some areas not currently included within a WDP are already developed or may be developed in the near future. Priorities for developing new WDPs should be:<br>1. Areas with known issues (flooding, contamination etc.).<br>2. Areas where new development is occurring or soon to occur i.e. North Nechako<br>3. Areas of existing development. |
| Climate Change | 4 out of the 6 WDP did not consider climate change | Need to address climate change whenever a new WDP is being completed, an existing WDP plan is being updated and/or any recommended projects from an existing WDP are being considered/implemented. |
| Prioritization | The six WDP did not use a consistent methodology for prioritizing projects. | New and updated WDPs should use the same prioritization framework for recommended projects (see **Section 3**). |
| Modeling Software | Different software packages were used for different WDP, making updates, reviews and consolidation more challenging. | The City should select preferred stormwater modeling software package(s) before completing any new WDPs or WDP updates. Having all of the City's watersheds modelled in the same or similar software will make it easier for the City to complete updates or assessments in house. It will also allow the City to consolidate the models between two areas that were assessed under different WDPs but may be hydraulically connected, even if the connection is only due to "overflows/spilling" during design storms. This will result in easier and more accurate modeling of these "spillover" events. |
| Major System Modeling | McMillian Creek, University Heights and Peden Hill WDP only completed selective modeling of the major system. | New or updated WDP should develop a dual drainage model (1D) with the use of 2D modeling, where needed to assess problem areas where surface flooding issues have been identified. |

| Gap | Description | Priority for Addressing |
|---|---|---|
| Flow/quality Monitoring | Some of the WDPs were developed with no data from water quality or flow monitoring. | In the absence of an on-going flow monitoring/water quality sampling program (ideal scenario), the City should conduct water quality sampling and flow monitoring in conjunction with each WDP in order to: identify, confirm and improve understanding of watershed issues; and to improve the reliability of hydrologic and hydraulic models through model calibration. |
| GIS | Not all the catchment areas and stormwater assets are accurately depicted in GIS | The City could update their GIS catchment areas and stormwater assets with those identified in each of the WDP as workloads allow. See **Section 5**. |
| Future Conditions | Hudson Bay Slough WDP only modelled existing conditions and not future conditions under future development. | The City should model future conditions before any future development occurs in the watershed. |
| Cost Estimates | The East PG WDP did not provide cost estimates for any of the recommendations and other WDPs did not provide cost estimates for some of the recommendations. | The City will need to develop cost estimates when evaluating or considering recommended projects that have not had a cost estimate provided. |
| Environmental Assessments | Some of the WDP did not assess whether culverts are fish friendly and whether the watershed has intact riparian function. | New and updated WDPs should address whether culverts are fish friendly and whether the watershed has intact riparian function. Any drainage projects or development plans should consider, where relevant, fish friendly culverts and preserving riparian function. |
| Geotechnical Assessments | Not all the WDP considered well sites, contaminated sites, and historical land use. | New and updated WDPs should consider surficial geology, geomorphology, slopes, municipal and private well sites, contaminated sites and older industrial/commercial sites to identify areas where increased infiltration should not be done without site specific studies. |
| Natural Assets | The WDPs mentioned the presence and importance of natural assets without developing a natural asset inventory. | The City will be developing a natural asset inventory that future WDPs should update, as necessary. |

# 3. Additional Drainage Planning

In addition to and subsequent to the development of the Watershed Drainage Plans (WDPs), the City has:

- Completed some of the action items proposed in the WDPs;
- Reassessed and revised some of the action items proposed in the WDPs;
- Collected new information about its system and drainage related issues; and
- Identified new priorities not identified in the WDPs.

These changes and additional information are outlined below.

The Hudson’s Bay Slough WDP recommended assessing the sediment in the downtown drainage system. Since this WDP was prepared the City has conducted sediment sampling in the Winnipeg St Stormwater System and is completing a Management & Treatment Plan for this system. The City is working to address downstream contamination in the Hudson’s Bay wetland.

The University Heights and Peden Hill WDP recommended introducing volume control measures for stormwater run-off. One proposed project to help achieve this would be the installation of a diversion pipe through the Pine Valley Golf Course to an infiltration gallery. This project has been added to the list of action items.

Maurice Drive Pond, within the University Heights and Peden Hill Watershed, already has accumulated a large amount of sediment. It will not be easy to clean-out as the pond design does not accommodate easy maintenance access nor does it provide a drying area to decant sediment prior to removal by truck. The pond should be retrofitted to establish good maintenance vehicle access, to improve grouting, and sediment should be removed. The City would first need to complete a study to prepare a design and confirm the amount of sediment to be removed. This project has been added to the list of action items.

In the spring of 2020, the Parkridge Creek culvert at Domano Boulevard failed and was repaired. While the City has implemented a temporary fix, there is a need for a more permanent solution which provides fish passage. The proposed permanent solution is an open bottom structure at an estimated cost of $1 million. The City will likely get warnings about the need for fish passage from DFO in the spring of 2021. This project was already proposed by the WDP and has given the highest priority due to the fact that it is likely to become a regulatory requirement.

Groundwater seepage has been found to be problematic in some areas, particularly for homes built at the bottom of slopes (e.g. Brock Drive, Selkirk Crescent, sidewalk lifting on the west side of Domano Boulevard just before College Heights etc.). This needs to be considered when implementing proposals for stormwater infiltration.

There are issues in the Varsity watershed due to erosion caused by upstream development. In particular, there is erosion downstream of Simon Fraser as a result of more continuous flows from the Domano/Westgate Storm Pond. This erosion will need to be addressed and changes to the Domano/Westgate Storm Pond should be investigated. This project has been added to the list of action items.

In 2018 a large storm sewer pipe (2400 mm CSP) along Winnipeg Street (near the intersection of 20$^{th}$ Avenue) collapsed, causing a sinkhole. A large section of pipe was replaced at a cost of $1.7 million.

Other projects identified in the Watershed Drainage Plans that have been completed since the WDPs were issued are outlined below.

- Parkridge Creek and West Fraser WDP: Culvert upgraded at Highway 16 during the Highway’s project to expand to 4 lanes.

- McMillan Creek WDP: Replaced a crossing structure with a clear span bridge on Aberdeen Road.
- McMillan Creek WDP: Replaced a crossing structure with a clear span bridge on Goose Country Road.
- University Heights/Peden Hill: Diverted flow from culvert C11 south along the east side of Tyner Boulevard by blocking culvert C12.
- East Prince George WDP: Airport Hill drainage project completed (terrain instability associated with the drainage course).
- East Prince George WDP: Replaced Willow Cale Road culvert on Haggith Creek with a bridge and culvert.

The City will be developing a natural asset inventory in 2021, with the assistance of grant funding.

# 4. Prioritization Framework

Due to limited available funding and the need to demonstrate prudent risk-based fiscal management, the City must prioritize the completion of identified projects. The City, and its consultants, have used different methods for prioritizing projects for different initiatives. The City would like to develop a standard framework that can be used for comparing and prioritizing all projects.

This section describes existing prioritization frameworks used within the City, standard frameworks developed by industry organizations and proposes a new consolidated framework that can be used by the City to compare projects from different initiatives.

## 4.1 Existing Frameworks

The City of Prince George is investigating and/or implementing 3 types of prioritization frameworks:

1. A network level risk framework: they are currently being used within Powerplan (formerly called RIVA) for the water and sanitary systems and have been used for their Water and Sanitary Master Plans. As part of the ISMP, a network level risk assessment will be done for the City's storm sewer system.
2. A project prioritization framework: this is what AECOM will be developing for prioritizing action items from the six WDP's. The City had previously developed a draft framework that was not implemented. See Appendix A).
3. An option selection framework for selecting between various options for a given project. This is commonly based on a cost-benefit analysis type of framework. This type of prioritization is out of scope for this assignment.

A detailed summary of the existing prioritization frameworks used within the City and standard frameworks developed by industry organizations is provided in Appendix A. A brief summary of each of the frameworks is provided in the following table.

**Table 8 Existing Framework Summary**

| | Framework | Summary | Pros | Cons | Recommendations |
|---|---|---|---|---|---|
| **1** | West Fraser River & Parkridge Creek WDP | • Cost<br>• Risk/criticality<br>• Land requirements<br>• Life cycle cost analysis<br>• Environmental Impact<br>• Feasibility<br>• Functionality<br>• Acceptability to Environmental Agencies<br>• Acceptability to the Public<br>• Acceptability to the City<br>• Environmental Mitigation/Compensation Works | Based on OCP goals:<br>- Protect life and property from stormwater related flooding<br>- Provide appropriate drainage service to the community<br>- Preserve and improve environmental quality<br>- Protect watercourses from erosion and sedimentation<br>- Reduce inconvenience from surface ponding and flooding<br>- Promote orderly, cost effective, and sustainable development<br>- Minimize the overall cost of the stormwater system to the City (liability, capital, environmental and operational)<br>- Promote public access for recreational and environmental education or pursuits | No point system<br><br>Could streamline goals (current overlap) | Use some of the factors as input into a prioritization framework, then reintegrate projects into a new prioritization framework |
| **2** | University Heights/Peden Hill WDP | Addressed flooding, erosion and water quality issues in short (existing issues); medium (future issues) and long (policy issues) term. | Addressed economic and environmental issues | Not a risk-based approach | Need to integrate projects into a new prioritization framework |
| **3** | East PG WDP | The proposed action items were given a score of one (low) to ten (high) for each of the following three considerations:<br>• the relative costs versus benefits (cost-benefit ratio score);<br>• difficulty to implement, and;<br>• their probable effectiveness within the East Prince George watershed. | Scoring system | Not clear how points were awarded.<br><br>Would require quantification of environmental benefits, social benefits, difficulty to implement and probable effectiveness. | Good general approach but would need more information/direction to apply to other studies. May also want to think about how to best capture social and environmental benefits. |
| **4** | McMillan Creek WDP | Projects broken into Major/secondary concerns based on risk. Projects then based on location (main stem, tributary, closed piped network) and broken into short, medium, long term. | Risk based | Not sure if location (main stem, tributary or closed pipe network) consistently correlates with risk levels. Need more info on what constitutes high vs low risk. | |
| **5** | Hudson's Bay Slough WDP | Projects were prioritized based on perceived need. | Good approach for dealing with a specific topic (stormwater) in a specific area. | No formal prioritization framework. | Would be difficult to apply to a consolidation of multiple studies. |

| | | | | | |
|---|---|---|---|---|---|
| **6** | Gladstone, Trent & Varsity WDP | Prioritization based on timing (existing vs future needs) | Addressed the timing of development. | Doesn't address the issue of too many existing projects | The issue of timing with development should be applied to an overall prioritization framework |
| **7** | CPG Enterprise Risk Management | Priorities based on financial, operational, staff/public, reputational and strategic consequences. | Risk based approach. | Doesn't address environment, benefits, or regulatory requirements. Hasn't received senior management approval. Redundancy between categories. | Base framework could be used with modifications to content. |
| **9** | Water Master Plan | Risk based approach that considers condition and capacity. | Risk based approach. Aligned with Powerplan, GIS, sanitary mains, drainage mains. | Specific to water mains. | See #12 below. |
| **11** | Sewer Master Plan | Risk based approach that considers condition and capacity. | Risk based approach. Aligned with Powerplan, GIS, water mains, drainage mains. | Specific to sanitary mains. | See #12 below |
| **12** | Powerplan (RIVA) – Drainage | Risk based approach that considers condition and insufficient capacity (i.e. that causes flooding). | Risk based approach. Aligned with Powerplan, GIS, water mains, sanitary mains. | Does not consider environmental impacts from quantity or quality. Does not consider benefits (i.e. amenities). | Could be used as a sub-prioritization framework for renewal of drainage mains only within a greater prioritization framework |
| **13** | CPG Project Level Risk Analysis | Risk based approach that considers H&S, reputation, legal, relationships, services/systems, environment, cultural heritage. | Risk based approach that encompasses more considerations than ERM framework. | Does not consider costs or benefits (i.e. looks at negative not positive). | Base framework could be used with modifications to content. |
| **14** | EMBC (Emergency Management BC) | Risk based approach based on consequences of failure. | Risk based approach which is similar to CPG's ERM (Enterprise Risk Management). | Does not consider environmental impact. Does not consider cost or benefit of solutions. | Base framework could be used with modifications to content. |
| **15** | NAMS (National Asset Management System) | Risk based approach for identifying asset priorities | Risk based approach that CPG has used on previous AM projects | Does not consider cost or benefit of solutions. Mixed opinions in industry about the NAMS risk framework | |
| **16** | Eagle Creek ISMP (City of Burnaby) | Cost benefit point-based approach that considers economic, environmental and social consequences. | Simple but comprehensive scoring system Based on drainage project considerations. | Doesn't consider likelihood. Not aligned with other CPG systems. | Content could be used to modify other risk-based approaches. |

## 4.2 Proposed Framework

Through discussions with City Staff and a review of existing documents we have developed a generic project prioritization framework for the City of Prince George as shown in **Appendix B**. This prioritization framework could be applied to any asset type.

The following table (Table 9) takes the intentions of the generic prioritization framework but adds stormwater related details so that it can be used to prioritize stormwater related projects. This stormwater specific table will be used to prioritize the action items from the six watershed drainage plans.

It is recommended that the City complete an additional check for each of the prioritized projects to see if it meets the City's strategic objectives and if is it already identified as an action item within one of the City's existing action plans.

**Table 9 Stormwater Project Prioritization Framework for the City of Prince George**

| | High<br>Score=3 | Medium<br>Score=2 | Low<br>Score=1 | None<br>Score=0 |
|---|---|---|---|---|
| **Social** | • Prevents known/existing flooding risk that impacts > 25 developed properties and/or 500 people/users (traffic turnover rate)<br>• Prevents closure of critical road. (i.e. due to flooding or pipe collapse). Critical road can include an arterial, road without an easy detour or impacts access to critical facilities such as hospital. Projects include monitoring of asset condition or replacement of assets in poor condition.<br>• Provides a park/trail of regional significance<br>• Protects > 5 developed properties from erosion<br>• Will result in the equitable distribution of costs and services across the City and across generations | • Prevents theoretical flooding risk (modeled) based on existing development and design standards<br>• Prevents closure of non-critical road and > 5 users/traffic turnover rate (i.e. due to flooding or pipe collapse). Projects include monitoring of pipe condition or replacement of assets in poor condition.<br>• Provides local amenity – small park, beautification (i.e. rain gardens, trees etc.)<br>• Protects 5 or fewer developed properties from erosion. | • Prevents theoretical flooding risk (modeled) based on future development<br>• Not completing the project may result in nuisance flooding<br>• Prevents closure of non-critical roads with minimal user impact (< 5 users/traffic turnover rate)<br>• Replacement of asset in fair condition<br>• Leads to a more informed and educated public<br>• Improves aesthetics (i.e. debris pick-up) | • No social benefit from completing the project and no negative social impact from not completing the project. |
| **Economic** | • Net cost is positive or <$10,000 to the City<br>• Replacement of an asset in poor condition<br>• Unrecoverable cost to the community is <$10,000 | • Net capital cost is between $10,000 and $250,000 and/or net annual cost is < $25,000<br>• Unrecoverable cost to the community is between $10,000 and $250,000 | • Net capital cost is between $250k and $1 M and/or annual cost is between $25k and $100k<br>• Unrecoverable cost to the community is between $250,000 and $1,000,000 | • Cost is >$1M and/or annual cost is >$100k<br>• Unrecoverable cost to the community is > $1,000,000 |
| **Environmental** | • Preserves, creates or provides access to high level habitat (wetlands, spawning grounds, fish-bearing channels, wildlife corridors)<br>• Protects valuable natural asset and provides ecosystem services (e.g. drinking water aquifer, wetland known to moderate flow/heat, capture contaminants, etc.)<br>• Reduces City's environmental liabilities<br>• Is broad reaching and has multiple environmental benefits (e.g. climate adaptation, fisheries, air quality, water quality/quantity, etc.) | • Preserves moderate level habitat (riparian areas, non-fish bearing channels, large forested areas)<br>• Removes sediment or contaminants? from the system in fish bearing watersheds (or prevents sediment from entering the watershed)<br>• Install water quality treatment in fish bearing watersheds<br>• Controls flows in fish-bearing watersheds<br>• Replace culvert in poor condition in fish bearing stream (avoids collapse and negatively impacting stream) | • Removes sediment from the system in non-fish bearing watersheds<br>• Install water quality treatment in non-fish bearing watersheds<br>• Controls flows in non-fish-bearing watersheds<br>• Replaces culvert in poor condition in non-fish bearing stream or culvert in fair condition in fish-bearing stream<br>• Remove debris<br>• Public education promoting environmental stewardship | • No environmental benefit from completing the project and no negative environmental impact from not completing the project. |

Notes
- *Maximum score is 9. Scores can range from 0-9.*
- *Mandated projects (i.e. through municipal, provincial or federal legislative requirements, orders, warnings, and agreements such as development or partnership agreements) have an automatic score of 9.* This includes projects that are mandated through environmental legislation, including locally protected areas (Riparian Protection – DP areas).*
- *Unrecoverable costs to the community include costs that will not be reimbursed through insurance nor can be passed on to the consumer without significant impacts (i.e. significant loss of sales).*
- *Note that planned service disruptions (e.g. due to maintenance/construction) typically result in less significant impacts because alternatives can be put in place. Whereas unplanned service disruptions due to emergencies (e.g. pipe collapse, extreme weather event) typically result in greater service impacts.*
- *Many of the proposed projects will result in some costs to the City but some of the projects will also result in some savings (i.e. deferred maintenance). Therefore, Net costs = total costs – total savings*

## 4.3 Prioritized Projects - WDP

We compiled a list of action items from the six WDPs. There was a total of 261 action items. Note that some of the action items are duplicates as multiple WDPs might have made the same recommendation such as "Develop an Erosion and Sediment Control Bylaw". The prioritization framework was applied to each of the action items resulting in a prioritization score. The highest score possible (meaning a high priority project) is nine (9) and the lowest score possible (meaning a very low priority project) is zero (0). The percentage of action items that were assigned a prioritization score from 0 to 9 are shown in the following figure.

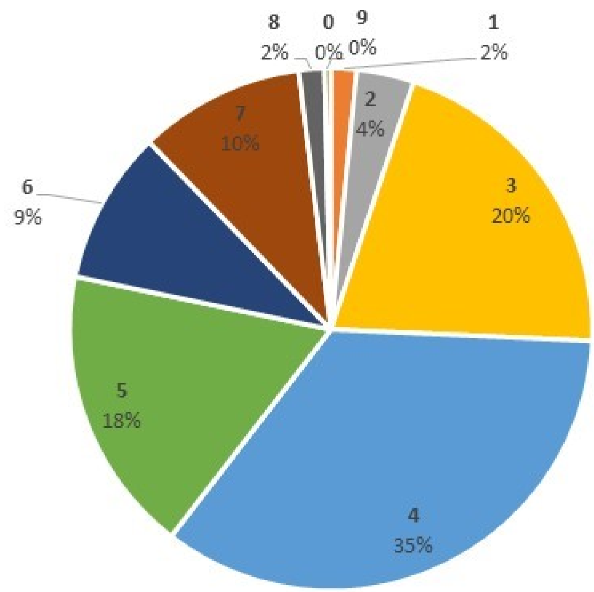



**Figure 2 Percentage of Action Items with a Prioritization Score from 0 (low) to 9 (high)**

No proposed WDP projects received a score of zero. This is not surprising as an action item with no economic, social or environmental benefit is unlikely to be recommended within a WDP. The majority of the projects (74%) have a score of 3-5, meaning that they have a moderate priority. The highest priority projects have a score of 6-8 (20%). Because of the way the prioritization framework was set-up, these projects are typically ones that provide economic, environmental and social benefits and/or avoid significant negative economic, environmental and social impacts. In other words, these are synergistic projects that provide multiple benefits and/or reduce multiple risks.

The number of actions items and estimated cost of completing the action items in each of the score categories are presented in the following table. The cost estimates have been updated to consider inflation since the respective WDP was produced and increased by 15% if the WDP didn't consider climate change. The cost estimates do not include costs for action items proposed by the East Prince George as no cost estimates were developed as part of that WDP. Note that some of the action items are similar in scope (e.g. implementation of BMP/LID standards for new development or better protection of riparian areas was recommended by several WDPs). The action items that are duplicated tend to be policy related and will therefore not have a significant impact on the cost estimates (e.g. have a cost estimate of approximately $10,000).

The cost estimates are presented in a range (lower to upper) to reflect that they there are high level cost estimates produced for general planning purposes.

**Table 10 Summary of Action Item Cost Estimates by Prioritization Score**

| Score | # of Action Items | Lower range (-50%) Cost Estimate | Upper range (+100%) Cost Estimate |
|---|---|---|---|
| 9 | 1 | $ 500,000 | $ 2,000,000 |
| 8 | 4 | $ 15,000 | $ 60,000 |
| 7 | 26 | $ 730,000 | $ 2,920,000 |
| 6 | 24 | $ 2,093,000 | $ 8,371,000 |
| 5 | 45 | $ 4,135,000 | $ 16,542,000 |
| 4 | 88 | $ 9,006,000 | $ 36,024,000 |
| 3 | 52 | $ 7,549,000 | $ 30,196,000 |
| 2 | 9 | $ 6,096,000 | $ 24,384,000 |
| 1 | 4 | $ 1,100,000 | $ 4,400,000 |
| 0 | 0 | $ - | $ - |
| Total | 253 | $ 31,224,000 | $124,896,000 |

A summary of the projects with the highest priority score are provided below.

Only one project received a score of nine, the Domano culvert on Parkridge Creek, as the City has been informed by DFO that the culvert needs to be fish passable during all seasons. In other words, it was given a score of nine due to regulatory requirements. No projects score a nine by receiving the highest score in all three categories (economic, social and environmental).

There are four action items with a score of eight (8) with an estimate cost to complete of $15,000 to $60,000 (mostly internal staff work). Three of these action items are related to introducing better erosion and sediment control measures (e.g. new erosion and sediment control bylaw); and one of the action items is to update hazardous slope mapping.

There were 26 projects with a score of seven (7) at an estimated cost to the City of $730,000-$2,920,000. Projects with a score of seven fell under the categories listed below.

- Secure sustainable levels of stormwater funding (e.g. Stormwater utility with credit/rebate program). In order to successfully secure sustainable funding it will be important to educate the public on the value of stormwater management.
- Protect wetlands and important riparian areas that are not currently protected under municipal legislation (i.e. riparian areas of a stream that is not fish-bearing but drains to a fish-bearing stream or a wetland that is not directly connected to a fish-bearing stream).
- Protect important wildlife corridors and core habitat areas that are not addressed through existing riparian area protection.
- Expand floodplain development permit areas in certain areas along Parkridge Creek.
- Update Design Guidelines to consider climate change (e.g. increase the design storm and minimum pipe size/slope). This will be addressed further in TWP #2.
- Update Prince George Bylaws (DCC, Development Procedures, and Tree Protection).
- Implement Best Management Practices/Low Impact Development (BMP/LID) standards for new development in catchments to fish-bearing streams and associated public education circulars. This concept will be discussed further in TWP's 2 and 3.
- Replace/modify culverts in poor condition, under a significant road, whose modification/replacement would also provide fisheries benefits (e.g. Bittner Creek).

There are 24 projects with a score of six (6) at an estimated cost to the City of $2M - $8.2M. The projects fell under the categories listed below.

- Culvert upgrades/replacements where the existing culvert is in poor condition and under a critical road or a road with moderate use and an upgrade would provide fisheries' benefits (e.g. McMillan Dr, Parkridge Creek/West Fraser).
- Assess culverts for condition and ability to allow fish passage, where relevant
- Stormwater system maintenance including culvert maintenance
- Update GIS
- Monitor beaver activity
- Cap trails near escarpment watercourses with less erodible material
- Investigate capacity of Hudson Bay Slough storm sewer
- Include water quality treatment features in detention ponds where possible for new developments
- Require developments through bylaws and the Design Guidelines to install BMP/LID to control flow and quality in catchments to non-fish bearing streams. Feasibility should be confirmed through infiltration testing.
- BMP/LID integrated into existing/upgraded roadways that control flow and quality in catchments to fish-bearing streams
- Address Foreman road drainage channel issues as a result of commercial development at the corner of Foreman Rd and Hwy 16E
- Hudson's Bay Wetlands - enhance wetland along with providing improved educational and recreational opportunities
- Improve fish habitat in the Lower Hudson Bay Wetland along with providing improved educational and recreational opportunities
- Protect undevelopable land

There are 45 projects with a score of five (5) at an estimated cost to the City of $4.1M - $16.5M. The projects with a priority score of five fall under the categories listed below.

- Culvert upgrades that provide multiple benefits (i.e. fisheries, prevent flooding, prevent road closure/sinkhole) but where the benefits/risk are not as great as those projects that have a score of 6 (ex. Victoria/Pine/Oak St)
- Establishing flood construction levels for Parkridge Creek upstream of Highway 16
- Improved sediment management (e.g. cleaning sediment from the system, construction of sediment ponds & forebays, sediment capture from snow storage)
- Improving outfalls (e.g. treatment at Hwy 16 and Latrobe, cleaning Cowart Road, cleaning Heyer Road)
- Public engagement
- Enforcement of existing/proposed regulations included staff training and increased inspections
- Oil & Grit Separator (OGS) requirements for certain industrial properties and large parking lots
- Remedial creek work
- Use of native species (e.g. planting of roadside ditches)
- Protecting creeks from vehicles (e.g. preventing recreational vehicle crossing at Park Drive and adjusting future road alignments away from riparian areas)
- Culvert upgrades to be completed by other organizations (e.g. BC Hydro, CN Rail)
- Storm sewer and zoning bylaw upgrades
- BMP/LID integrated into existing/upgraded roadways that control flow and quality in catchments to non-fish-bearing streams
- Design manual updates
- Protecting areas from aggregate extraction
- Controlling flows (e.g. subcatchment diversions in Hudson Bay watershed, new detention ponds in already developed areas in fish-bearing watersheds, addressing Domano/Westgate pond)

Note that this is a high-level project prioritization framework. Each project should be reviewed for compliance with City strategies and undergo a more detailed cost-benefit review. This is especially important for projects where no cost was given in the WDP.

All the Action Items, with their prioritization score, are listed **in Appendix C**. Through further discussions with City staff and the completion of this ISMP, additional action items may be identified and should be added to the overall Action Item List. Similarly, the City may decide to eliminate action items proposed by completed WDPs. In this way, the compiled Action Item list can become a “living” document that is regularly updated as issues arise, projects are completed and priorities change.

# 5. GIS

## 5.1 Existing GIS

The City's GIS data is publicly accessible through the City's Open Data Portal. The City of Prince George's stormwater data is well structured and is modeled as a geometric network in GIS allowing the City to track flow paths and direction.

All the key stormwater asset attributes are set up in the City's GIS, but much of the attribute data is missing. This can be common with municipalities because they tend to set up their data based on an ESRI model and keep most of the default attribute settings, but don't have the data or resources to gather the data to fill the attributes. For instance, there is very little condition data or risk scores. It is likely that the City does not have condition data or risk scores on the majority of its stormwater assets rather than it being a GIS issue. However, once this data is obtained, it will be important to add it to the GIS database.  Data resulting from the Network Level Risk Assessment task for the next Technical Working Paper (TWP #2: Engineering Issues) should be uploaded into the City's GIS database.

The City's GIS does not include green infrastructure (e.g. rain gardens) or stormwater assets related to LID (e.g. permeable pavement). It is assumed that the City does not currently have any of these types of assets. The City's GIS does denote streams, marshes and swamps, but not their riparian areas. Creeks are not named in the City's GIS. The City's pending new natural asset inventory initiative should help address any of these gaps. It is important that once the City's natural asset inventory is completed, the City's GIS should be updated accordingly.

As the six WDPs were completed, the respective consultants found that some important data was missing and used LIDAR, aerial imagery and field investigations to obtain the data necessary to complete the WDP. The following WDPs reported that the listed assets weren't accurately or comprehensively included in the City's GIS:

- Hudson Bay Slough - culverts and open channels
- Gladstone, Varsity and Trent - creeks & culverts
- McMillan - culverts, outfalls & natural ponds
- East Prince George WDP - culvert locations/ material/ size/ condition, watercourse, roadside ditches dimensions
- West Fraser River & Parkridge Creek WDP - none of the culverts in GIS had invert elevations, and 85% of the storm pipes in the study area were missing invert elevations.

The consultant for the University Heights Peden Hill WDP completed the culvert inventory (table provided in Appendix B).

24% of Prince George's roads within GIS (224 km of 945 km) don't have a storm sewer or ditch associated with them, which suggests that the City's ditch inventory is not complete. We determined that only 8% of the gravity mains in the City had invert elevations.

The areas that are hatched in Figure 1 are areas that are not included within a catchment in the City's GIS. These areas are mostly in East Prince George and along the south shore of the Nechako River (including the railyards). The catchments in East Prince George that are not within the City's GIS are Willow Creek South, Willow Creek North, Unnamed (Fraser River), Ellicott Creek and Haggith Creek (some of which is outside the City boundaries).

The following table indicates which key attributes for specific stormwater assets are within the City's GIS. A black check indicates that the data is complete (i.e. >75%) or nearly complete. A grey checkmark indicates that some of the data is there (i.e. 25-75%). An x indicates that very little data is within the City's GIS (i.e. < 25%).

**Table 11 GIS Info Summary**

| Asset Type | City Quantity * | Known Inventory Gaps | Install Date | Size | Elevation | Condition | Material | Sub-assets | Owner |
|---|---|---|---|---|---|---|---|---|---|
| Catch basins | 5755 | ✓ | ✓ | ✓ | **X** (256/5846 have values) | **X** | **X** (4/5846 have value)s | **X** (5/5846 show grates) | ✓ |
| Catchment areas | 53 | ✓ missing 5 | n/a | ✓ | n/a | n/a | n/a | n/a | n/a |
| Discharge points | 348 | ✓ | ✓ | **X** (68/371 have values) | **X** (105/371 have values) | **X** | **X** (16/371 have values) | **X** (Wall/ apron) | ✓ |
| Fitting | 284 | ✓ | ✓ | ✓ | ✓ | **X** | ✓ | n/a | ✓ |
| Gravity mains | 383 km | ✓ | ✓ WDP reported some culverts missing | ✓ | **X** | **X** | ✓ | n/a | ✓ |
| Inlet | 213 | ✓ | ✓ | ✓ | ✓ | **X** | ✓ | ✓ Wall/ apron but no grates or screens | ✓ |
| Lift station | 8 | ✓ | ✓ | **X** | ✓ | **X** | **X** | **X** | ✓ |
| Storm structure (lift facilities) | 7 | ✓ | ✓ | **X** | ✓ | **X** | **X** | **X** | **X** |
| Manhole | 4072 | ✓ | ✓ | ✓ | **X** (451/4072 have values) | **X** | **X** | **X** | ✓ |
| Pressurized main | 150 m | ✓ | ✓ | ✓ | **X** | **X** | ✓ | **X** | ✓ |
| Storage basin | 25 | ✓ | ✓ | **X** < 6% show capacity | ✓ | **X** | **X** | **X** | ✓ |
| Lateral line | 227 km, 21,227 | ✓ | ✓ | ✓ | ✓ | **X** | ✓ | **X** | ✓ |
| Open channel | 690 km | ✓ 24% of roadways show no sewer or ditch | **X** | **X** | **X** | **X** | **X** | **X** | ✓ |
| Hydrography line/ poly | 1982 km, 28 $km^2$ | ✓ | n/a | **X** | **X** | **X** | **X** | ✓ 25% indicate fish presence or not | **X** |
| Flow monitoring station | 1 | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Subsurface infiltration facilities | 73 | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |
| Dike | 3.6 km | **X** | **X** | **X** | **X** | **X** | **X** | **X** | **X** |

* The quantity is taken from GIS where the asset type is in GIS, otherwise it was taken from the NWWBI data.

✓ *Indicates that the data is complete or nearly complete (i.e. >90%) in GIS*
✓ *Indicates that a significant portion (i.e. >25%) of the data is in GIS*
X *Indicates that very little (i.e. < 25%) of the data is in GIS*

## 5.2 GIS Gap Reduction Plan

As previously mentioned, many of the asset attributes do not have data. However, some attributes are more critical than others. For instance, knowing the installation date is generally more useful than knowing the manufacturer. The following table below outlines the more critical GIS gaps.

**Table 12 Key Stormwater Related GIS Gaps**

| Asset Type | Attribute | Gap |
|---|---|---|
| **Various** | Elevation | Only 8% of storm mains, 4% of catch basins, 0.12% of open channels and 28% of discharge points have elevations. |
| **Various** | Condition | There is a lack of stormwater asset condition data in the City's GIS. This is likely due to the City having limited information about the condition of its stormwater assets. The City must first conduct the condition assessments and then enter the data into GIS. |
| **Various** | Inventory | The following asset types are missing from the City's GIS: some of the catchment areas (see Figure 1), dikes, monitoring stations, subsurface infiltration facilities, and some of the ditch network. |
| **Various** | Risk scores | The City has yet to conduct a risk assessment of its storm system. Once this has been done, the results should be linked to the City's GIS. |
| **Various** | Size/capacity | City's GIS doesn't include the size/capacity for its lift stations, storage basins, and open channels |
| **Creeks** | Names | Creek names should be added to GIS to facilitate system analysis and understanding. |
| **Water bodies (Hydrography line)** | Sub-assets | Only 25% of the waterbodies indicate whether there are fish present or not. |
| **Inlets/ Discharge Points** | Sub-assets | The presence of grates or screens could not be found in the City's GIS, which is important for maintenance planning. |

Based on the GIS gaps identified in the previous section, we recommend that the City address the most significant gaps by completing the following actions.

- Incorporate missing data that was obtained during the preparation of each of the WDP (i.e. inventories, elevations, presence of fish etc.)
- Complete condition assessments of its stormwater assets and record the results within GIS
- Complete a risk assessment of its stormwater system and record the results within GIS
- Complete the ditch and screen/grate inventory as other O&M work is being conducted (i.e. collect screen/grate info during culvert inspections, collect ditch info during pavement condition assessments or street sweeping)

# 6. Conclusions & Recommendations

## 6.1 Conclusions

In conclusion, this Technical Working Paper #1 provided the following items:

1. A review and summary of the City's six WDPs (see **Section 2**);
2. A summary of the gaps with each of the WDPs with respect to geography, cost estimates, modeling, consideration of climate change, environmental assessments and geotechnical assessments (see **Section 2.8**);
3. Recommendations for addressing gaps related to the WDPs (see **Section 2.8** and **6.2**);
4. Identification of new stormwater related projects and completed projects since the WDPs were developed (see **Section 3**);
5. A review of existing project prioritization frameworks (see **Section 4.1**);
6. A proposed new project prioritization framework for the City of Prince George (see **Section 4.2**);
7. A summary of the priorities of the action items from the WDPs (and other projects identified since the WDPs were developed) when the proposed new project prioritization is applied to them (see **Section 4.3**);
8. A review of the City's GIS data related to stormwater (see **Section 5.1**); and
9. A GIS gap reduction plan (see **Section 5.2** and **Section 6.2**).

## 6.2 Recommendations

**Future WDPs/WDP Updates**

Some areas not currently included within a WDP are already developed or may be developed in the near future. Selecting areas for developing new WDPs, in order of priority, should be:

1. Areas with known issues (e.g. flooding, erosion, etc.);
2. Areas where new development is occurring or soon to occur (e.g. North Nechako); and
3. Areas of existing development.

Any future WDPs or updates of existing WDPs should include the items listed below.

1. Consideration of climate change. Use results from the IDF CC tool used for the West Fraser River & Parkridge Creek WDP until the City has developed a future looking IDF curve based on improved rainfall data and climate change considerations.
2. Cost estimates of proposed projects – using the City's new approach of lower to upper range for high level estimates.
3. Flow and water quality monitoring.
4. Use of a preferred modelling software package, as identified by the City
5. Develop a dual drainage model (1D) with the use of 2D modeling, where needed, to assess problem areas where surface flooding issues have been identified.
6. Assess whether culverts are fish friendly and whether the watershed has intact riparian function.
7. Consider surficial geology, geomorphology, slopes, municipal and private well sites, contaminated sites and older industrial/commercial sites to identify areas where increased infiltration should not be done without site specific studies.
8. Action items should be prioritized using the newly proposed stormwater project prioritization framework.
9. Provide any updated catchments, asset inventory, elevations etc. to the City so that they can update their GIS accordingly.
10. Model Future conditions under full build-out as well as existing conditions.
11. Provide updates to the natural asset inventory that the City will soon be developing.

**GIS**

We recommend that the City update the following features in its GIS as staff availability allows:

1. Correcting catchment boundaries, adding catchment areas and correcting typos (i.e. Beaverly);
2. Adding creek names;
3. Adding culverts, open channels/ditches, outfalls, natural ponds and asset attributes (e.g. elevations, material, condition etc.) identified through past WDPs, where the data had been readily provided to the City;
4. Identifying and recording drainage systems associated with roadways that do not currently have a storm sewer or ditch associated with them in GIS;
5. Adding asset condition and risk data into GIS when it becomes available;
6. Adding all stormwater assets such as monitoring stations, dikes, grates/screens and subsurface infiltration facilities that are not currently in the City's GIS;
7. Adding other asset attribute information that is currently missing such as storage basin size; and
8. Adding natural assets such as riparian areas once the City has completed its natural asset inventory.

The ditch and screen/grate inventory could be completed as other O&M work is being conducted (e.g. collect screen/grate info during culvert inspections, collect ditch info during pavement condition assessments or street sweeping).

**Recommended Projects**

By applying the newly developed stormwater prioritization framework to identified actions items we recommend that the City prioritize completing the following projects listed below at an estimated cost of $1.2M to $5M.

1. Replace the Domano culvert on Parkridge Creek with a structure that would be fish passable in response to DFO requirements.
2. Introduce better erosion and sediment control measures (e.g. new erosion and sediment control bylaw);
3. Update hazardous slope mapping.
4. Protect wetlands and important riparian areas that are not currently protected under municipal legislation (i.e. riparian areas of a stream that is not fish-bearing but drains to a fish-bearing stream or a wetland that is not directly connected to a fish-bearing stream).
5. Update Design Guidelines to consider climate change (e.g. increase the design storm and minimum pipe size/slope). This will be addressed further in TWP #2.
6. Secure sustainable levels of stormwater funding (e.g. Stormwater utility with credit/rebate program).
7. Replace/modify culverts in poor condition, under a significant road, whose modification/replacement would also provide fisheries benefits (e.g. Bittner Creek).
8. Protect important wildlife corridors and core habitat areas that are not addressed through existing riparian area protection.
9. Implement Best Management Practices/Low Impact Development (BMP/LID) standards for new development in catchments to fish-bearing streams and associated public education circulars. This concept will be discussed further in TWP's 2 and 3.
10. Expand floodplain development permit areas in certain areas along Parkridge Creek.
11. Update Prince George Bylaws (DCC, Development Procedures, and Tree Protection).

If the City is completing any of the projects identified in one of the WDPs that did not consider climate change, then it should, as a minimum, consider the impacts of increased rainfall by 35% (as per the IDF CC tool used for the West Fraser River & Parkridge Creek WDP).

City staff should identify if there are any desired action items, such as condition assessment of the storm sewer system, that are currently not captured by the compiled action list.

# Appendix A

## Existing Prioritization Frameworks

City of Prince George

# Prioritization Framework Review

**Prepared by:**

AECOM Canada Ltd.
3292 Production Way, Floor 4
Burnaby, BC   V5A 4R4
Canada

T: 604 444 6400
F: 604 294 8597
www.aecom.com

**Prepared for:**

City of Prince George
1100 Patricia Boulevard
Prince George, BC  V2I 3V9
Canada

**Date:** September, 2020

**Project #:** 60628231

# Table of Contents

# 1. Prioritization from PG WDP’s

## 1.1 Parkridge Creek & West Fraser

The goals of this WDP were based on the City’s stormwater management policy and OCP and are listed below.

- Protect life and property from stormwater related flooding
- Provide appropriate drainage service to the community
- Preserve and improve environmental quality
- Protect watercourses from erosion and sedimentation
- Reduce inconvenience from surface ponding and flooding
- Promote orderly, cost effective, and sustainable development
- Minimize the overall cost of the stormwater system to the City (liability, capital, environmental and operational)
- Promote public access for recreational and environmental education or pursuits
- Develop a watershed drainage plan process to define and access drainage servicing schemes for different catchment areas of the City.

Each of the recommended projects were evaluated using the criteria listed below.

- Cost
- Risk/criticality
- Land requirements
- Life cycle cost analysis
- Environmental Impact
- Feasibility
- Functionality
- Acceptability to Environmental Agencies
- Acceptability to the Public
- Acceptability to the City
- Environmental Mitigation/Compensation Works

This WDP didn’t have a formal prioritization framework but some proposed projects were noted as high priorities based on the attributes of a given project (i.e. treatment for outfall into fish-bearing waters). Presumably the high priority projects were ones that best met the goals of the WDP and scored well based on the evaluation criteria, as previously listed.

## 1.2 University Heights/Peden Hill

The objectives of the University Heights/Peden Hill WDP are to:

- Identify areas currently or potentially susceptible to flooding and erosion;
- Analyse the performance of the existing infrastructure drainage system;
- Identify water quantity and quality constraints; and
- Recommend optimal short term, medium term and long term plans.

The WDP noted that the key issues in the watershed are:

- Adequacy of the drainage conveyance systems;
- Erosion, sedimentation and slope failures;
- Mitigating the impacts of future development;
- Protection of environmental values; and
- Operations works, monitoring, and maintenance.

Recommendations from this WDP were categorized as short, medium and long term based on the following criteria:

- Short term: stormwater system improvements to address existing deficiencies;
- Medium term: stormwater servicing strategy to accommodate proposed new development; and
- Long term: long term strategies for rainfall management policy, monitoring, asset management and operational management to meet the need for growth.

## 1.3 East Prince George

The East Prince George WDP was developed with the following objectives in mind:

- Consider the City's long-range growth needs;
- Facilitate sustainable growth of development;
- Enhance and protect natural areas; and
- Address current drainage problems and inadequacies.

The proposed action items were given a score of one (low) to ten (high) for each of the following three considerations:

- the relative costs versus benefits (cost-benefit ratio score);
- difficulty to implement, and;
- their probable effectiveness within the East Prince George watershed.

The maximum possible score is thirty. Proposed actions items were then categorized as high, medium and low priority based on the following scores:

- High > 24
- 20 ≤ Medium <24
- Low < 20

## 1.4 McMillan Creek

The McMillan Creek WDP broke down problem areas into two main categories:

- Areas of major concern; and
- Areas of secondary concern.

Areas of major concerns were identified as problem areas where extensive flooding or failing crossing structures may pose serious threats to public safety and/or downstream infrastructure, including risks to riparian habitat. These areas of concern have been recognised as critical and were recommended for immediate attention and upgrading. They were further prioritised based on the location within the watershed:

- McMillan Creek mainstem crossings both private and City owned;
- Tributary crossings; and
- All other storm infrastructure including storm sewer and drainage culverts (Mainstem, tributary or stormwater drainage system).

Secondary concerns pose a lower risk than areas of major concern. These drainage structures are in lower risk areas or where capacities constraints are less of a concern. As with areas of major concern these problem areas have been separated by the location within the watershed, such as McMillan Creek, tributaries or storm drainage infrastructure.

Proposed projects were then categorized based on short (1-5 year), medium (5-10 year) and long term (+10 year). Short term improvements include those classified to have the greatest benefit on the health of the watershed and limit the risk to public safety. The major concerns are those found to be associated with the highest level of risk regarding public safety and deterioration of the watershed. Replacement or remediation of all of the structures outlined under major concerns is costly and may not be achievable within one or even two years. Therefore, a plan was developed that will allow for the replacement or repair of the various structures as budget permits.

Medium term planning strategies were developed to provide recommendations for stormwater management in new developments that include passive systems to provide remedial treatment and limit peak flows. Furthermore, medium term planning concepts ensure that short-term improvements have been successfully implemented and that improvements have been monitored for ease of future applications.

The long term projects involve the implementation of new long term stormwater management strategies to address new development and rehabilitation of existing deficiencies.

## 1.5 Hudson’s Bay Slough

Recommended projects were listed in order of priority. No formal prioritization framework was provided, only that project priority was based on the most pressing issues identified. The WDP reports that the most pressing issue was frequent flooding of the downtown bowl area.

Projects were divided into horizons of 5, 10 and 20 years based on the following:

- 5-year projects involve relieving the capacity constraints of the lowland drainage channel of the Hudson’s Bay Slough and sediment interception facilities at the base of Cranbrook Hill and within the closed drainage system;
- 10-year projects involve enclosed system capacity upgrades and dredging of the lower slough pool; and
- 20-year projects involve environmental enhancements and integration with the trail network and lesser enclosed system upgrades.

## 1.6 Gladstone, Trent & Varsity

Implementation of the recommended improvements of the three watersheds involved prioritizing each upgrade according to present need and projected future development patterns. Proposed projects were categorized based on short (1-5 year), medium (5-10 year) and long term (+10 year).

Existing sewers which are undersized for the existing development condition and existing creek erosion areas were identified as high priority for the short-range. Following this immediate need, the remaining upgrades were prioritized according to the expected development patterns within the three watersheds.

# 2. City of Prince George Risk Frameworks

## 2.1 Enterprise Risk Management

The table below is the Impact Table of CPG's Enterprise Risk Management Tool Kit that was developed for the Canada Winter Games in 2015. This was developed knowing the City did not already have an existing ERM Framework in place and therefore had to fast track its development and implementation in a fashion that would work both for the City and the Host Society. Every effort was taken to keep it as simple as possible in order to maximize its efficacy. The formalized foundational process involving the City's Senior Management level to develop its own risk appetite was deliberately bypassed due to time constraints.

| | Risk Category | | | | |
|---|---|---|---|---|---|
| | **Financial** | **Operational** | **Staff & Public** | **Reputational** | **Strategic** |
| **1 Insignificant** | The NET financial impact to the City is likely to be below <$500,000 | Minimal impact on the City's operational objectives in the lead up to and during the Canada Winter Games.<br>➢ No noticeable change in service from the public perspective | Minimal impact on the staff and public. For example:<br>➢ Single or multiple persons unable to perform work for one day<br>➢ Single or multiple Canada Winter Games participants unable to perform their roles for a period of one day | Minimal negative impact on the City's reputation.<br>➢ No unusually negative coverage of the City as a host of the CWG | Minimal impact on the City's strategic objectives and ability to achieve them. |
| **2 Minor** | The NET financial impact to the City is likely to be between $500,000 - $2,000,000 | Minor impact on the City's operational objectives in the lead up to and during the Canada Winter Games:<br>➢ Intermittent loss of services to the public of less than 3 hours<br>➢ Intermittent interruption of IT systems/e-mail less than once per month | Minor impact on the staff and public. For example:<br>➢ Single or multiple persons unable to perform work for a period of one week<br>➢ Single or multiple Canada Winter Games participants unable to perform their roles for a period of more than one day | Minor impact on the City's reputation. For example:<br>➢ Local news coverage of a negative nature for less than two days<br>➢ Independent report published which is somewhat negative<br>➢ A few Isolated reports critical of the city as host of the CWG (short lived) | Minor impact on the City's strategic objectives and ability to achieve them. For example:<br>➢ City policy decision has some negative impact on sustainability |
| **3 Moderate** | The NET Financial impact to the City is likely to be between $2,000,000 - $5,000,000 | Moderate impact on the City's operational objectives in the lead up to and during the Canada Winter Games; for example:<br>➢ Routine loss of services to the public of between 3 hours and week<br>➢ Routine interruption of IT systems/e-mail each week<br>➢ A noticeable change in normal service as a result of hosting the CWG | Moderate impact on the staff and public. For example:<br>➢ One person with serious long-term injury/illness connected with City endeavours or Canada Winter Games participants<br>➢ Low morale amongst staff from a single department | Moderate impact on the City's reputation. For example:<br>➢ Significant negative local media attention about the City's conduct of the Canada Winter Games<br>➢ Some negative national attention in the media about the City's conduct of the Canada Winter Games | Moderate impact on the City's strategic objectives and ability to achieve them. For example:<br>➢ City policy decision has moderate negative impact on a large segment of the population<br>➢ The decision has serious effects on sustainability for the City. |
| **4 Major** | The NET financial impact to the City is likely to be between $5,000,000 - $10,000,000 | Major impact on the City's operational objectives in the lead up to and during the Canada Winter Games; for example:<br>➢ Loss of basic services to the public for a period longer than a week<br>➢ Any event that could affect the quality of the water supply<br>➢ A very noticeable change in normal service as a result of hosting the CWB | Major impact on the staff and public. For example:<br>➢ Multiple persons with serious long-term injury/illness connected with City endeavours or Canada Winter Games participants<br>➢ Low morale amongst most City staff | Major impact on the City's reputation. For example:<br>➢ Public safety issue receives significant press coverage and public attention<br>➢ Extensive negative local story with significant negative national exposure about the City's conduct of the Canada Winter Games<br>➢ Organizational effectiveness called into question<br>➢ The 2015 CWG will not be the next "best games ever". | Major impact on the City's strategic objectives and ability to achieve them. For example:<br>➢ City policy decision has major impact on public services or safety<br>➢ City policy decision has significant negative sustainability implications |

| Risk Category | | | | | | |
|---|---|---|---|---|---|---|
| | | Financial | Operational | Staff & Public | Reputational | Strategic |
| 5 | **Catastrophic** | The NET financial impact to the City is likely to be greater than $10,000,000 | Catastrophic impact on the City's operational objectives in the lead up to and during the Canada Winter Games. For example:<br>➢ Complete operational failure of a critical system for a sustained amount of time<br>➢ Total inability to provide basic civic services for an extended period of time<br>➢ Substantial loss of staff resources and civic infrastructure | Catastrophic impact on the staff and public. For example:<br>➢ Deaths (single or multiple) of anyone connected with City endeavours or Canada Winter Games participants | Catastrophic impact on the City's reputation. For example:<br>➢ Poor public safety response results in significant loss of life and property<br>➢ Major litigation against City immanent<br>➢ Significant negative national media coverage about the City's conduct of the Canada Winter Games<br>➢ The 2015 CWG are considered unsuccessful | Catastrophic impact on the City's strategic objectives and ability to achieve them. For example:<br>➢ City policy decision has catastrophic impact on public safety, services and emergency response<br>➢ Extent of incident has significant effect on policy decision in the foreseeable future<br>➢ Sustainability of the City is critically compromised |

RISK PRIORITY MATRIX (Heat Map)

| | | Impact | | | | |
|---|---|---|---|---|---|---|
| | | 1<br>Negligible | 2<br>Minor | 3<br>Moderate | 4<br>Major | 5<br>Catastrophic |
| Likelihood | 5<br>Almost Certain | | | | | |
| | 4<br>Likely | | | | | |
| | 3<br>Possible | | | | | |
| | 2<br>Unlikely | | | | | |
| | 1<br>Improbable - Rare | | | | | |
| | Emerging | | | | | |

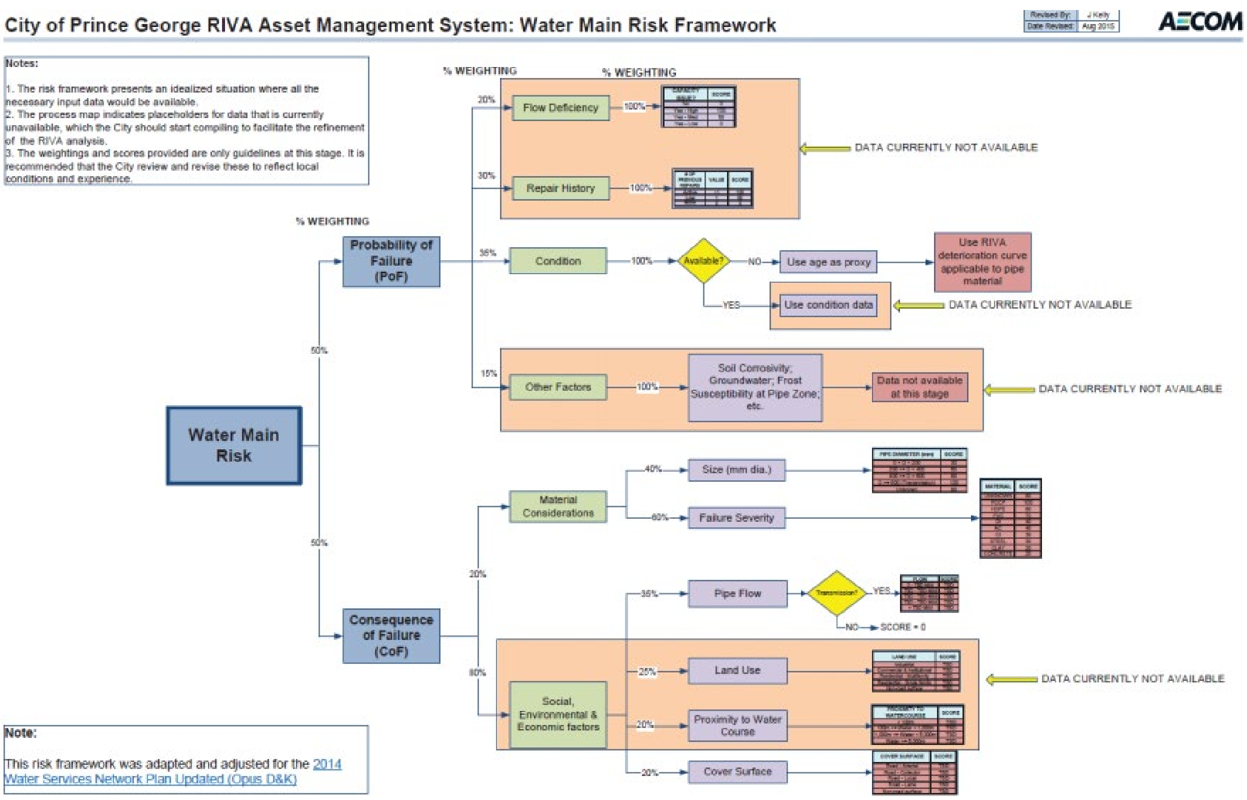
RISK MANAGEMENT PRIORITIES

Probability and impact assessments will enable us to develop priority ratings for each risk. Risks will be assessed and prioritized into the following four risk categories:

| | | |
|---|---|---|
| | **Very High** | • Management of this risk is critical to the success of the City in meeting its goals and avoiding negative outcomes.<br>• Improving the risk mitigation is required<br>• Requires detailed research, planning and decision making at senior levels of management, may require attention from the Senior Management Team<br>• ERM Steering Committee must be kept informed |
| | **High** | • Management of this risk is very important but not critical to the success of the City in meeting its goals and avoiding negative outcomes.<br>• Improving the risk mitigation (if possible) is recommended<br>• Senior management attention and action needed. |
| | **Moderate** | • Management of this risk is important to the success of the City in meeting its goals and avoiding negative outcomes.<br>• Improving the risk mitigation is not required at this stage<br>• Management control and responsibility must be specified. |
| | **Minor** | • Management of this risk is not material to the success of the City in meeting its goals and avoiding negative outcomes.<br>• Improving the risk mitigation is not required<br>• Can be managed by routine controls and procedures. |
| | **Emerging** | • Continue to monitor this risk<br>• ERM Steering Committee to be kept informed of any significant change. |

## 2.2 RIVA – Water Main Risk Framework

In 2009 the City implemented RIVA – Real-time Infrastructure Valuation Analysis, long-term capital planning tool for our linear infrastructure. During that process Water, Sewer, Storm and Pedestrian Risk Frameworks were developed. This is the Water Main Risk Framework. The weightings and scores provided by AECOM were only guidelines at that point.



## 2.3 Water Service Network Plan 2014

CPG's Water Master Plan was updated in 2014, which included a review of the RIVA Water Main Risk Framework and subsequent analysis. CPG's GIS provided some of the criteria and the analysis resulted in a list of capital projects. CPG is working towards including the risk scores as attributes to our water assets within our GIS.

The risk score is based on the following attributes:

- Pipe Diameter/Type
- Pipe Age
- Pipe Material
- Transmission Mains
- Land Use Classification
- Cover Surface
- Pressure Classification
- Riparian Protection Area Classification

Table 3-1 Parameters for Scenario Development

| Parameters for Scenario Development | | | |
|---|---|---|---|
| Land Use | Diameter/Type | Cover Surface | Riparian Protection Area |
| Single Family | <250 mm | Local Roads & Lanes | Within |
| Multi-Family | ≥250 mm | Major/Minor Collectors | Outside |
| Light Commercial | Transmission Main | Highway/Arterial | - |
| Highway Commercial | - | - | - |
| Industrial & Non-Essential Institutional | - | - | - |
| Community Facilities | - | - | - |

Table 3-2 Probability of Failure Ranking

| | Rank | | | | |
|---|---|---|---|---|---|
| | 1-2 | 3-4 | 5-6 | 7-8 | 9-10 |
| Age | <10 years | - | 10-50 years | - | 50-70 years |
| Material | HDPE, Polyethylene, Ductile Iron and Steel | - | PVC and Copper | Asbestos Cement | Cast Iron |
| Static Pressure | - | - | <40 psi<br>40-60 psi<br>60-80 psi | 80-100 psi | >100 psi |

Tables 4-2 and 4-1 show the Land Use and Road Class rankings that were used in the Water Master Plan.

Table 4-1 Land Use Ranking

| Land Use | Rank |
|---|---|
| Unassigned | 0 |
| Single Family | 1 |
| Multi-Family | 2 |
| Light Commercial | 3 |
| Highway Commercial | 4 |
| Industrial & Institutional | 5 |
| Community Facilities | 6 |

Table 4-2 Road Use Classification

| Road class | Road type |
|---|---|
| 0 | Hwy Connector |
| 1 | N/A |
| 2 | Highways |
| 3 | Arterial |
| 4 | Major Connector |
| 5 | Minor Connector |
| 6 | Local |
| 7 | Lanes |
| 8 | Unassigned |
| 9 | Highway Ramps |

Tables 3-3 and 3-4 show the heat map and actions required depending on the level of risk. The High and very high ranked capital projects are either in the works or are in our Capital Expenditure Plan for the next 5 years.

Table 3-3 Risk Matrix

| Risk Matrix | | | | | |
|---|---|---|---|---|---|
| Probability | Consequences | | | | |
| | Insignificant | Minor | Moderate | Major | Catastrophic |
| Rare | L | L | M | M | H |
| Unlikely | L | L | M | M | H |
| Possible | L | M | H | H | H |
| Likely | M | M | H | H | VH |
| Almost Certain | M | H | H | VH | VH |

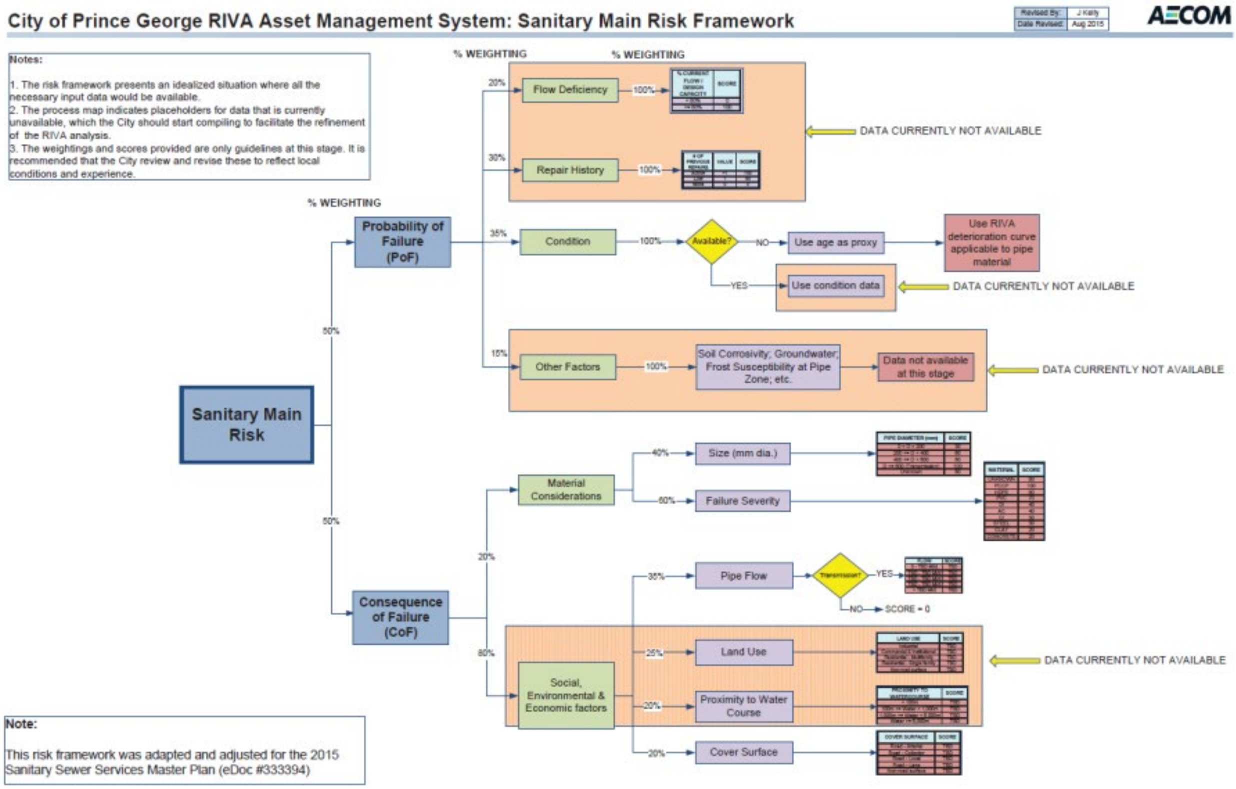
For each risk level, an 'Action Required' was identified. The appropriate response for each risk level was crafted in collaboration with expert asset management staff in BC and New Zealand, and follows Table 3-4 below.

Table 3-4 Risk Rating & Action Priority

| Level of Risk | Rank | Action required timing |
|---|---|---|
| Very High Risk | 9-10 | Immediate corrective action (i.e. action is required now) |
| High Risk | 7-8 | Prioritized action required (i.e. make safe and program in current/next program) |
| Medium Risk | 5-6 | Planned action required (i.e. make safe and include in forward programs) |
| Low Risk | 1-4 | Manage by routine procedures |

## 2.4 RIVA - Sanitary

This is the Sanitary Main Risk Framework that came from CPG's RIVA implementation.




## 2.5 Sewer Master Plan

The RIVA framework was used in the Sewer Master Plan project to assess the risk associated with each recommended project of which you can see an example in Table ES-2. CPG will be working towards adding the risk scores as attributes to their Sewer network within their GIS.

**Table 5.5 - Risk Score Summary**

| Criteria | | Score | Description |
|---|---|---|---|
| Probability of Failure | Capacity | 25* | Modelled Flow / Existing Capacity |
| | Known Service Issues | 12.5 | Service issue identified during workshop |
| | Pipe Age | 12.5 | Refer to ***Table 5.6*** |
| Consequence of Failure | Pipe Size & Material | 10 | Refer to ***Table 5.7*** and ***Table 5.8*** |
| | Restricts Development | 10 | OCP PWWF > Existing PWWF = score of 5<br>OCP PWWF > Existing PWWF and<br>Existing PWWF > (Design capacity – 5 L/s) = score of 10 |
| | Impacts ICI | 10 | ICI parcels impacted |
| | Environmental Impact | 20 | Asset failure harms environmentally sensitive area or watercourse |
| Total Risk Score | | 100* | |

* Score may be greater than listed value if modelled flow exceeds 100% of the existing capacity

**Table 5.6 - Risk Score from Age**

| Asset Age | Score % |
|---|---|
| Unknown | 60 |
| 100<=A | 100 |
| 90<=A<100 | 95 |
| 80<=A<90 | 85 |
| 70<=A<80 | 75 |
| 60<=A<70 | 65 |
| 50<=A<60 | 60 |
| 40<=A<50 | 35 |
| 30<=A<40 | 25 |
| 20<=A<30 | 15 |
| 10<=A<20 | 5 |
| 0<A<10 | 1 |

**Table 5.7 - Risk Score from Pipe Size**

| Diameter (mm) | Score % |
|---|---|
| Unknown | 80 |
| 0<D<300 | 25 |
| 300<=D<500 | 80 |
| 500<=D | 100 |

**Table 5.8 - Risk Score from Material**

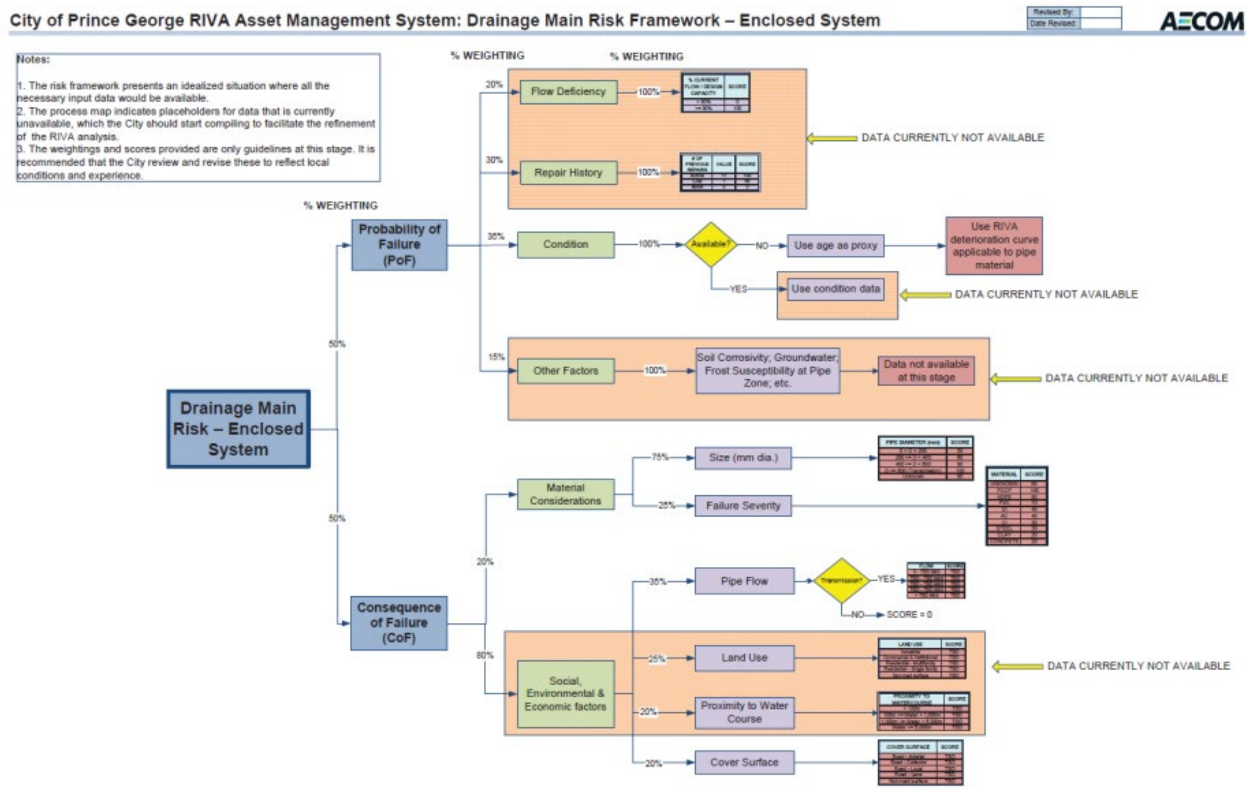
| Material | Score % |
|---|---|
| Unknown | 80 |
| PCCP | 100 |
| HDPE | 80 |
| PVC | 70 |
| DI | 40 |
| AC | 40 |
| CI | 30 |
| Steel | 30 |
| Clay | 20 |
| Concrete | 20 |

**Table ES-2 - Short Term Upgrades**

| Project ID | Project Description | Probability of Failure | | | Consequence of Failure | | | | | Risk Score | Length | Model ID | Existing Dia. (mm) | Proposed Diameter (mm) | Capital Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Capacity Deficiency | Asset Age | Known Service Issue | Failure Severity (Size & Material) | Restricts Development | ICI Impact | Environmental Impact | > 5000 PE Impact | | | | | | |
| E-1 | Replace PW115 with 125 L/s firm capacity pump station, expandable to 375 L/s firm capacity | ✔✔ | | ✔ | ✔ | ✔✔ | | ✔ | | 141 | - | PW115 | - | - | $ 2,000,000 |
| E-2 | Decomission existing pump station PW125, construct new 2297 m, 300 mm dia. gravity sewer from PW125 to Southridge Dr. | ✔✔ | | | ✔ | ✔✔ | ✔ | ✔ | | 124 | 2,297 | CDT-119 | - | 300 | $ 2,596,061 |

## 2.6 RIVA - Drainage

A Drainage Risk Framework was also developed during the RIVA implementation. CPG has not done any work on this since the implementation but are working towards condition assessments on their storm network which will help answer a part of the risk framework.




## 2.7 Project Level

PG has a large focus right now on project level risk analysis where a project is investigated, and several options are recommended. They are holding Risk workshops with all levels of their organization to brainstorm the risks of each option and determine which option would result in a lower residual risk.

**CONSEQUENCE ANALYSIS**

| Consequence | Insignificant | Minor | Moderate | Major | Catastrophe |
|---|---|---|---|---|---|
| General Description | No Injuries, low financial loss | Minor Injuries, not requiring medical treatment. Minor financial loss | First Aid treatment required, on-site release immediately contained; medium financial loss. | Medical treatment required, on-site release contained with outside assistance; high financial loss. | Extensive injuries; off-site release with detrimental effects; major financial loss. |
| Health and Safety | No Injuries | Minor first aid treatment requried only | Reversible injury requiring hospitalization | Moderate, reversible injury or impairment (<30%) to several people | Single fatality or significant irreversible injury to > 10 people |
| Community / Government / Reputation / Media | Minor Complaint | Public concern restricted to local complaints | Minor, adverse local public or media attention and complaints | Serious public or media outcry with national coverage | International media condemnation |
| Legal | Legal Action Unlikely | Low-level legal matter | Minor legal issues, non-compliances and breaches of regulation | Serious breach of regulation with investigation or report to authourity with prosecution and / or mderate fine possible | Very significant fines and prosecutions. Multiple litigation actions. |
| Relationships | Damage Easily Rectified by City Staff | Concerted effort required by City Staff to rectify damage | Serious issues; requires Senior Management involvement | Very critical issues which regire Mayor and Council and CAO intervention | Irreparable damage requiring Provincial or Federal involvement intervention |
| Services/Systems | Failure of a service with a known workaround | Minor failure of a service on a local basis | Moderate failure of a service on a community basis. | Serious failure of a key service on a regional basis. | Serious and extended failure of a key service on a regional basis. |
| Environmental Effects | No lasting effects, Low-level impacts on biological or physical environment. Limited damage to minimal area of low significance. | Minor effects on biological or physical environment. Minor short-medium term damage to small area of limited significance. | Moderate effects on biological or physical enviornment but not affecting ecosystem. Moderate short-medium term widespread impacts (e.g. Oil spill causing impacts on shoreline). | Serious environmental effects with some impairment of ecosystem function (e.g. displacement of a species). Relatively widespread medium-long term impacts. | Significant environmental impacts with complete impairment of ecosystem function. Long-term widespread impacts on significant environment (e.g. unique habitat, national park) |
| Cultural Heritage | Low-level cultural impacts. Low-level repairable damage to commonplace Structures | Minor medium-term cultural impacts on local population. Minor damage to structures / items of some significance. Minor infringement or cultural heritage. Mostly repairable. | On-going cultural issues. Permanent damage to structure / items of cultural significance or signifcant infringement of cultural hertage / sacred locations. | On-going serious cultural issues. Significant damage to structures / items of cultural significance or signifcant infringement or destruction of cultural hertage / sacred locations. | Significant widespread cultural impacts Irreparable damage to highly valued structures / items / locations of cultural significance. Highly infringement of cultural heritage. |

**PROBABILITY ANALYSIS**

| Likelihood | Likelihood Description |
|---|---|
| Probable | Happens repeatedly during the project life |
| Likely | Could easily happen and has occurred on a previous project more than once |
| Possible | Could happen and has occurred in other situations / other projects |
| Unlikely | Hasn't happened yet but it is possible that it could |
| Rare | Hasn't happened and can't imagine it actually ever happening. |

**RISK ANALYSIS MATRIX**

| Consequence / Likelihood | Insignificant | Minor | Moderate | Major | Catastrophic |
|---|---|---|---|---|---|
| Probable | H | H | E | E | E |
| Likely | M | H | H | E | E |
| Possible | L | M | H | E | E |
| Unlikely | L | L | M | H | E |
| Rare | L | L | M | H | H |

**RISK STATUS KEY**

| | |
|---|---|
| | L - LOW |
| | M - MEDIUM |
| | H - HIGH |
| | E - EXTREME |

The table below shows an example of one option of the Foothills Watermain Twinning project that OPUS recommended and the resulting residual risk.

East Side Risk Issues - Concerns resulting from:

| Item | Description | Concerns | Mitigation | Construction<br>Probability after mitigation | O&M<br>Probability after mitigation | Consequence | Risk Impact |
|---|---|---|---|---|---|---|---|
| 1 | Gas Main Interference and Issues | Crossings (3)<br>Incorrect field locator | Diligence on Crossings<br>Extra care on locates - vactor<br>Fortis standing by on crossings | 1 | 1 | 4 | Moderate 1 |
| 2 | Hydro Conflict and Issues | Light poles @ 650 & Highl'd Dr<br>No conflicts foreseen | Locate / be diligent in light pole areas | 1 | 1 | 1 | Low 0 |
| 3 | Conflict with Storm | Dictates watermain alignment<br>Separation regulation forces watermain into road | No defined mitigation measures | 1 | 2 | 2 | Low 0 |
| 4 | Traffic | Conflict during construction<br>Possible conflict during ops | Arrange for lane closures<br>Traffic control<br>Detour signs and notifications | 2 | 3 | 5 | Extreme 4 |
| 5 | Watermain Failure | Corrosion<br>Joint separation<br>Freezes | Poly wrap DI pipe<br>TR Flex pipe<br>Insulate. Increase depth, away from Rd. | 1 | 3 | 5 | Extreme 4 |
| 6 | Loss of Road Structure | Watermain joint failure<br>Improper or weak Re & Re<br>Bedding carries groundwater<br>Poor or misdirected drainage<br>Alignment too close to edge | TR Flex pipe<br>Good construction inspection and testing<br>Trench bulkheads<br>Drainage control by design | 1 | 1 | 1 | Low 0 |
| 7 | Trench Issues | Trench stability<br>Trench slopes impinge on road<br>Spoil pile | Subcut<br>Trench cage<br>Shoring | 2 | 4 | 4 | High 3 |
| | | | | | | Total | 4.3 |

## 2.8 CPG Draft Project Prioritization Framework

City staff began developing a project prioritization framework for the City of Prince George. It was never finalized and implemented. Points and weighting were given in the following areas:

- Mandate;
- Population-user impact;
- Project readiness;
- Risk to City service delivery;
- Growth & renewal;
- Change in demand; and
- Strategic alignment.

# 3. EMBC Consequence of Loss Rating Table

Emergency Management of BC's Critical Infrastructure Identification & Rating Workbook "All Hazards Approach" for the Flood Protection Program, dated July 4, 2008, includes the following table. The table shows consequence of loss which is one aspect of risk management (i.e. risk = consequence x probability).

## APPENDIX E: CI CONSEQUENCE OF LOSS RATING TABLE

JELC Critical Infrastructure - Consequence of Loss Criteria – Lower Mainland Region of British Columbia

General Rating Instructions:

- For each asset, choose the appropriate Consequence of Loss rating (0.1 to 15) for each impact below using the descriptions in the rows. The total will be the asset rating.
- Consider all hazards; evaluate maximum credible damage to asset (definition overleaf) from any hazard. E.g. Terrorism may result in highest impact for Public confidence.

| Impact Factor<br>Score | Severe<br>15 | Very High<br>5 | High<br>3 | Medium<br>1 | Low<br>0.5 | Very Low<br>0.1 |
|---|---|---|---|---|---|---|
| **Population Impact**<br>• Estimate number of possible fatalities, serious injuries or people evacuated due to loss of asset being ranked.<br>• Do not include people inconvenienced.<br>• Consider maximum credible damage only. | Greater than 10,000 people | Between 1,000 and 10,000 people | Between 100 and 1000 people | Between 50 and 100 people | Between 4 and 50 people | Less than 4 people |
| **Recovery Cost Impact**<br>• Estimate cost to restore the asset to a functional state.<br>• Consider alternate solutions if less costly. | Direct damage and restoration > $1 billion | Direct damage and restoration $100 million to $1 billion | Direct damage and restoration $10 to $100 million | Direct damage and restoration $5 to $10 million | Direct damage and restoration $1 to $ $5 million | Direct damage and restoration under $1 million |
| **Own Sector Impact**<br>• Estimate effect of loss of the asset on the sector in which asset resides (e.g. Transportation).<br>• Consider redundancies, alternate suppliers if available. | Sector may shut down nationally or debilitating impact internationally | Debilitating impact on sector nationally | Debilitating impact on sector provincially or regionally | Debilitating impact on sector municipally<br>Or<br>Significant impact on sector provincially or regionally | Significant impact on sector municipally | Moderate impact on sector municipally |
| **Other Sectors Impact**<br>• Estimate effect of loss of the asset on the other sectors (not the one in which asset resides).<br>• Consider redundancies, alternate suppliers if available. | Debilitating impact on other sectors nationally | Debilitating impact on other sectors provincially or regionally | Debilitating impact on other sectors municipally<br>Or<br>Significant impact on other sectors provincially or regionally | Significant impact on other sectors municipally | Moderate impact on other sectors municipally | Minor impact on important missions of other sectors (municipally) |
| **Recovery Time Impact**<br>• Estimate the time to restore the asset to a functional state.<br>• Consider alternate solutions if time can be reduced (consistent with Recovery Cost Impact above). | Very long recovery time (longer than one year) | Long recovery time (months to 1 year) | Significant recovery time (weeks to 1 month) | Brief recovery time (days to 1 week) | Very Brief recovery time (hours to 1 day) | Minimal recovery time (minutes) |
| **Public Confidence Impact**<br>• Estimate the effect of the loss of the asset on public confidence in the ability of the relevant government to preserve public health and safety, economic security, or to assure the provision of essential services. | High National risk & ability to control in doubt | Perceived high National risk & low ability to control risk<br>Or<br>High Provincial or Regional risk & ability to control in doubt | Perceived high Provincial or Regional risk & low ability to control risk<br>Or<br>High Municipal risk & ability to control in doubt | Perceived high Municipal risk & low ability to control risk | Perceived moderate Municipal risk & moderate ability to control risk | Perceived low Municipal risk & high ability to control risk |

# 4. NAMS Risk Management Template

Several City staff attended the NAMS (National Asset Management Strategy) workshop supported by Asset Management BC that was developed by the Institute of Public Works and Engineering Australasia. This is a program that provides templates and analytics to create Asset Management Plans and includes an Infrastructure Risk Management Plan. CPG is just starting down the road of implementing NAMS as a standard for the City's AMP's and are working inter-departmentally to further explore the Risk Management Plan template and how it would fit within the organization.

# 5. Prioritization Frameworks – Other ISMP

## 5.1 Eagle Creek ISMP (City of Burnaby)

The projects were prioritised (high, medium, low) using the scoring system laid out in **Table 1** below.

**Table 1 Scoring System based on Anticipated Social, Economic and Environmental**

| | High<br>score=3 | Medium<br>score=2 | Low<br>score=1 |
|---|---|---|---|
| **Social** | - Not completing the project will result in significant risks to public health and safety or property damage<br>- Provides a "destination" amenity to residents from across the City | - Not completing the project may result in a risk to public health and safety or property damage<br>- Provides an amenity to local residents | - Unlikely risk<br>- No significant amenity |
| **Economic** | - Not completing this project will result in a significant cost to the City of Burnaby<br>- No construction or operating cost to complete this project<br>- Would result in overall cost savings | - Not completing the project may result in future costs to the City<br>- <$100,000 capital cost and <$1,000 per year operating cost | - no available funding source<br>- >$100,000 capital cost and/or >$1,000 per year operating cost |
| **Environmental** | - Would provide significant new spawning, overwintering and rearing habitat for anadromous fish<br>-Would provide significant new spawning habitat for resident fish | - Would significantly benefit downstream habitat for anadromous fish (i.e. control flows and water quality)<br>- Would provide significant new rearing habitat for resident fish | - Possible secondary environmental benefits (i.e prevention of incidents through greater public education)<br>- No gain in habitat |

Each project was given a score of 1-3 based on anticipated social, economic and environmental benefits. The scores in each of these areas were added up to a maximum score of nine (9). Each project was then given an overall ranking based on its total score; as outlined below.

- High – total score of 8 to 9;
- Medium – total score of 5 to 7;
- Low – total score of 3 to 4

# 6. Summary – Existing Frameworks

The City of Prince George is investigating and/or implementing 3 types of prioritization frameworks:

1. A network level risk framework: they are currently being used within RIVA for the water and sanitary systems and have been used for their Water and Sanitary Master Plans (see descriptions in previous sections). As part of the ISMP, a network level risk assessment will be done for the City's storm sewer system.
2. A project prioritization framework: this is what AECOM will be developing for prioritizing action items from the six WDP's. The City has developed a draft framework (was never implemented and is presented in the previous sections.
3. An option selection framework for selecting between various options for a given project. This is commonly based on a cost-benefit analysis type of framework.

The table below provides a summary and evaluation of the various prioritization frameworks described in the previous sections.

| | Framework | Summary | Pros | Cons | Recommendations |
|---|---|---|---|---|---|
| 1 | Parkridge Creek & West Fraser WDP | • Cost<br>• Risk/criticality<br>• Land requirements<br>• Life cycle cost analysis<br>• Environmental Impact<br>• Feasibility<br>• Functionality<br>• Acceptability to Environmental Agencies<br>• Acceptability to the Public<br>• Acceptability to the City<br>• Environmental Mitigation/Compensation Works | Based on OCP goals:<br>- Protect life and property from stormwater related flooding<br>- Provide appropriate drainage service to the community<br>- Preserve and improve environmental quality<br>- Protect watercourses from erosion and sedimentation<br>- Reduce inconvenience from surface ponding and flooding<br>- Promote orderly, cost effective, and sustainable development<br>- Minimize the overall cost of the stormwater system to the City (liability, capital, environmental and operational)<br>- Promote public access for recreational and environmental education or pursuits | No point system<br><br>Could streamline goals (current overlap) | Use some of the factors as input into a prioritization framework, then reintegrate projects into a new prioritization framework |
| 2 | University Heights/Peden Hill WDP | Addressed flooding, erosion and water quality issues in short (existing issues); medium (future issues) and long (policy issues) term. | Addressed economic and environmental issues | Not a risk based approach | Need to integrate projects into a new prioritization framework |
| 3 | East PG WDP | The proposed action items were given a score of one (low) to ten (high) for each of the following three considerations:<br>• the relative costs versus benefits (cost-benefit ratio score);<br>• difficulty to implement, and;<br>• their probable effectiveness within the East Prince George watershed. | Scoring system | Not clear how points were awarded.<br><br>Would require quantification of environmental benefits, social benefits, difficulty to implement and probable effectiveness. | Good general approach but would need more information/direction to apply to other studies. May also want to think about how to best capture social and environmental benefits. |
| 4 | McMillan Creek WDP | Projects broken into Major/secondary concerns based on risk. Projects then based on location (main stem, tributary, closed piped network) and broken into short, medium, long term. | Risk based | Not sure if location (main stem, tributary or closed pipe network) consistently correlates with risk levels.<br>Need more info on what constitutes high vs low risk. | |
| 5 | Hudson's Bay Slough WDP | Projects were prioritized based on perceived need. | Good approach for dealing with a specific topic (stormwater) in a specific area. | No formal prioritization framework. | Would be difficult to apply to a consolidation of multiple studies. |
| 6 | Gladstone, Trent & Varsity WDP | Prioritization based on timing (existing vs future needs) | Addressed the timing of development. | Doesn't address the issue of too many existing projects | The issue of timing with development should be applied to an overall prioritization framework |
| 7 | CPG Enterprise Risk Mgmt | Priorities based on financial, operational, staff/public, reputational and strategic consequences. | Risk based approach. | Doesn't address environment, benefits, or regulatory requirements.<br>Hasn't received senior management approval.<br>Redundancy between categories. | Base framework could be used with modifications to content. |
| 9 | Water Master Plan | Risk based approach that considers condition and capacity. | Risk based approach.<br>Aligned with RIVA, GIS, sanitary mains, drainage mains. | Specific to water mains. | See #12 below. |
| 11 | Sewer Master Plan | Risk based approach that considers condition and capacity. | Risk based approach.<br>Aligned with RIVA, GIS, water mains, drainage mains. | Specific to sanitary mains. | See #12 below |

| | | | | | |
|---|---|---|---|---|---|
| 12 | RIVA – Drainage | Risk based approach that considers condition and insufficient capacity (i.e. that causes flooding). | Risk based approach.<br>Aligned with RIVA, GIS, water mains, sanitary mains. | Does not consider environmental impacts from quantity or quality.<br>Does not consider benefits (ie amenities). | Could be used as a sub-prioritization framework for renewal of drainage mains only within a greater prioritization framework |
| 13 | CPG Project Level Risk Analysis | Risk based approach that considers H&S, reputation, legal, relationships, services/systems, environment, cultural heritage. | Risk based approach that encompasses more considerations than ERM framework. | Does not consider costs or benefits (ie looks at negative not positive). | Base framework could be used with modifications to content. |
| 14 | EMBC | Risk based approach based on consequences of failure. | Risk based approach which is similar to CPG's ERM. | Does not consider environmental impact.<br>Does not consider cost or benefit of solutions. | Base framework could be used with modifications to content. |
| 15 | NAMS | Risk based approach for identifying asset priorities | Risk based approach that CPG has used on previous AM projects | Does not consider cost or benefit of solutions. Mixed opinions in industry about the NAMS risk framework | |
| 16 | Eagle Creek ISMP | Cost benefit point-based approach that considers economic, environmental and social consequences. | Simple but comprehensive scoring system<br>Based on drainage project considerations. | Doesn't consider likelihood<br>Not aligned with other CPG systems | Content could be used to modify other risk based approaches |

**Contact**

**Nancy Hill, P.Eng.**
M +604 790-1637
nancy.hill@aecom.com

# Appendix B

## Proposed Generic Prioritization Framework for the City of Prince George

**Table B1 Generic Project Prioritization Framework for the City of Prince George**

| | High<br>Score=3 | Medium<br>Score=2 | Low<br>Score=1 | None<br>Score=0 |
|---|---|---|---|---|
| **Social** | • Not completing the project will result in significant impacts to public health and safety, property and/or highly valued cultural assets<br>• Provides a "destination" amenity to residents from across the City (recreational, educational or cultural)<br>• Not completing the project will impact other infrastructure and result in significant service disruptions *(*e.g. significantly impacts critical infrastructure/services, >25 developed properties and/or > 500 traffic turnover rate*)*<br>• Will result in the equitable distribution of costs and services across the City and across generations | • Not completing the project will result in moderate impacts to public health and safety, property and/or highly valued cultural assets<br>• Provides an amenity to local residents (recreational, educational or cultural)<br>• Not completing the project will impact other infrastructure and result in moderate service disruptions *(*e.g. impacts non-critical infrastructure/services >500 traffic turnover rate and/or impacts critical services < 500 traffic turnover rate,<br>• Not completing the project will result in a significant loss of public confidence, typically due to intense negative media exposure. | • Not completing the project may result in minor service disruptions (i.e. minor impact to < 500 traffic turnover rate or significant impact to < 5 traffic turnover rate)<br>• Minor recreational, educational or cultural benefits<br>• Not completing the project may result in minor negative recreational, educational or cultural impacts<br>• Not completing the project will result in a small loss of public confidence (e.g. localized, < 50 people). | • No risk to health, safety, property or other services<br>• No amenity<br>• No cultural impact<br>• No service disruptions<br>• No loss in public confidence (may include single letter to local press with no adverse media article) |
| **Economic** | • Not completing the project will result in a significant unrecoverable cost to the community (>$1M)<br>• City's net life cycle cost to complete the project is <u><</u> $10,000. Consider costs and savings resulting from the project, including the costs that would have resulted from not completing the project)<br>• Large borrowing debt decision required through Council and Alternate Approval Process or Referendum<br>• Completing the project will result in significant economic benefits to the community (i.e. development, tourism etc.) | • Not completing the project will result in a moderate unrecoverable cost to the community ($250k - $1M)<br>• City's net life cycle cost to complete the project is between $10k to $250k capital cost and <$25,000 per year operating cost<br>• Completing the project will result in moderate economic benefits to the community (i.e. development, tourism etc.) | • Not completing the project may result in minor unrecoverable cost to the community (<$250k)<br>• Net cost to the City is between $250k and $1M capital cost and/or between $100k and $25k per year operating cost<br>• Possible minor economic benefits to the community | • Not completing the project will not likely result in costs to the community<br>• Net cost to the City >$1M capital cost and/or >$100k operating cost<br>• No economic benefits to the community |
| **Environmental*** | • Not completing the project will result in a significant negative environmental impact<br>• Completing the project will result in a significant positive environmental impact, improved ecosystem services or protect natural assets?<br>• Should also include meeting environmental regulations | • Not completing the project will result in a moderate negative environmental impact<br>• Completing the project will result in a moderate positive environmental impact | • Not completing the project will result in a minor negative environmental impact<br>• Completing the project will result in a minor positive environmental impact | • No environmental impact (positive from doing the project or negative from not doing the project) |

<u>Notes</u>

Maximum score is 9. Scores can range from 0-9.

Mandated projects (i.e. through municipal, provincial or federal legislative requirements, orders, warnings, and agreements such as development or partnership agreements) have an automatic score of 9.* This includes projects that are mandated through environmental legislation, including locally protected areas (Riparian Protection – DP areas).

Unrecoverable costs to the community include costs that will not be reimbursed through insurance nor can be passed on to the consumer without significant impacts (i.e. significant loss of sales).

Note that planned service disruptions (e.g. due to maintenance/construction) typically result in less significant impacts because alternatives can be put in place. Whereas unplanned service disruptions due to emergencies (e.g. pipe collapse, extreme weather event) typically result in greater service impacts.

Many of the proposed projects will result in some costs to the City but some of the projects will also result in some savings (i.e. deferred maintenance). Therefore, Net costs = total costs – total savings

# Appendix C

## Watershed Drainage Plans – Action Items Prioritization & Scoring

See Edoc #564822 for Prioritized Action Items

Some important notes regarding the Action Items and their Scoring:

1. Because some of the WDPs did not provide cost estimates, AECOM had to develop a very high level approximation of the cost of some of the action items (i.e. <$10k, $10k-$250k, $250k-$100M, >$1M) in order correctly score the action item. The actual cost estimate for these action items is still unknown and therefore not included.
2. Sometimes the "same action item" in different WDP's or within the same WDP will have a different score depending on whether it has an impact on a fish-bearing stream or not or a significant roadway or not.
3. The impact of a road closure due to an asset failure was estimated based on the location of the road, seeing how many properties it served etc. Traffic counts were not readily available.
4. Assigning the correct score for some of the action items was clear, but for some it was more ambiguous. In other words, the total score for an action item could be $\pm$1. Some of these more "controversial" action item scorings can be discussed further with City staff. Comments on action items that warrant further discussion are highlighted in the action item spreadsheet.

| ID | Action Item / Recommendation | Watershed Drainage Plan | Year | Economic score | Social Score | Env't Score | Score Total | WDP Prioritization | Original Capital Costs | City Cost increased for Inflation and CC | O&M Costs | Environmental benefits/ detriment | Social benefits (including protection of property) | Bylaw / Guidelines | Overlap with other Actions | Asset ID or Model ID | Discharge Point *(please add this column and comments)* | Completed? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F100-1 | Upgrade three pipe segments (258 m) | Parkridge Creek & West Fraser | 2020 | 1 | 1 | 0 | 2 | Deficient under future climate change | $405,000 | $405,000 | | Potentially aggravate existing erosion processes in downstream watercourses | Mitigate future flooding issues upstream | | | 63, 69, 67 | Ferry Ave | |
| F100-2 | Upgrade one pipe segment (8 m) | Parkridge Creek & West Fraser | 2020 | 2 | 1 | 0 | 3 | Deficient under future climate change | $18,000 | $18,000 | | Potentially aggravate existing erosion processes in downstream watercourses | Mitigate future flooding issues upstream | | | 4761 | Wiens Road | |
| F100-3 | Upgrade eleven pipe segments (502 m) | Parkridge Creek & West Fraser | 2020 | 1 | 2 | 0 | 3 | Deficient under existing and future climate change | $847,000 | $847,000 | | Potentially aggravate existing erosion processes in downstream watercourses | Mitigate future flooding issues upstream | | | 1255, 1267, 1266, 1256, 1257, 1261, 1258, 1262, 1260, 1264, 1265 | Cowart cross-culvert to a pipe down to the river backwater channel | |
| F100-4 | Upgrade five pipe segments (341 m) | Parkridge Creek & West Fraser | 2020 | 1 | 1 | 0 | 2 | Deficient under future climate change | $517,000 | $517,000 | | Potentially aggravate existing erosion processes in downstream watercourses | Mitigate future flooding issues upstream | | | 3080, 3083, 3078, 3081, 3082 | Drains to wetlands on lower bench that parallels the future Malaspina Extension | |
| WF-1- This series relates to West Fraser catchmen | Treatment at outfalls. This series relates to West Fraser Subcatchments | Parkridge Creek & West Fraser | 2020 | 2 | 0 | 3 | 5 | Prioritize Hwy 16 and Latrobe (fish bearing) | $10,000-$100,000 | $55,000 | | Positive: Remove contaminants before runoff is discharged from the storm system for all subcatchments | | | | | Drains to cowart Rd outfall and Parkridge creek south of Latrobe Pl. also collects Loedel Cres | |
| WF-2 | Protect / Preserve wetland habitat in Malaspina Watershed | Parkridge Creek & V | 2020 | 3 | 2 | 2 | 7 | | N/A | 10000 | | Positive: Wetland areas should be preserved, or compensation provided for lost natural wetlands due to development of future roadways along the lower Fraser River bench. | Preserved wetlands can be kept for educational/recreational purposes as well. | | | | Drains to Fraser River Benchland s outfall recently up graded | |
| WF-3 | Water Quality monitoring at Latrobe Outfall | Parkridge Creek & V | 2020 | 2 | 0 | 2 | 4 | Pre-treatment should be prioritized at this outfall. | $10,000-$100,000 | $55,000 | | Positive: Identify specific contaminant concerns with poor water quality from this outfall during rain on snow events. | | | | | Drains directly to Parkridge Cr. | |
| WF-4 | Erosion protection measures at outfalls | Parkridge Creek & West Fraser | 2020 | 2 | 0 | 2 | 4 | Outfalls requiring erosion protection include Imperial, Guelph, Latrobe, Fairmont, Essex, Delhi, Cowart, Ferry Avenue. | $100,000-$1,000,000 | $550,000 | | Positive | | | | | Most drain to Wetlands on Fraser River Benchlands other than Ferry Ave. that drains directly into the Fraser River. | |
| WF-5 | Clean Cowart Road outfall culvert inlet | Parkridge Creek & V | 2020 | 3 | 0 | 2 | 5 | | <$10,000 | $5,000 | | Neutral | Prevent washing of ditch material into the culvert. | | | | Fraser River backwater Channel | |
| | Culvert Upgrade - Leslie Road (AEID: C-310) | Parkridge Creek & West Fraser | 2020 | 1 | 1 | 1 | 3 | Fair condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | Not in City Database | | |
| | Culvert Upgrade - Collena Street (AEID: C-312) | Parkridge Creek & V | 2020 | 1 | 1 | 1 | 3 | Fair condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | Not in City Database | | |
| | Culvert Upgrade - Hilltop Road (AEID: C-254) | Parkridge Creek & V | 2020 | 1 | 1 | 1 | 3 | Fair condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | Not in City Database | | |
| | Culvert Upgrade - Hilltop Road (AEID: C-255) | Parkridge Creek & V | 2020 | 1 | 1 | 1 | 3 | Fair condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | Not in City Database | | |
| | Culvert Upgrade - Hilltop Road (AEID: C-257) | Parkridge Creek & V | 2020 | 1 | 0 | 0 | 1 | Good condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | Not in City Database | | |
| | Culvert Upgrade - Hilltop Road (AEID: C-503) | Parkridge Creek & V | 2020 | 1 | 1 | 1 | 3 | Fair condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | Not in City Database | | |
| | Culvert Upgrade - Lattman Road (AEID: C-260) | Parkridge Creek & V | 2020 | 1 | 2 | 2 | 5 | Poor condition | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | 3982 | | |
| | Culvert Upgrade - Bunce Road (AEID: C-117) | Parkridge Creek & West Fraser | 2020 | 1 | 1 | 1 | 3 | Fair condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | 3969 | | |
| | ~~Culvert Upgrade - Highway 16 (AEID: C-217)~~ | ~~Parkridge Creek & West Fraser~~ | ~~2020~~ | ~~1~~ | ~~3~~ | ~~2~~ | | ~~Poor condition~~ | ~~$100,000-$1,000,000~~ | | | ~~May have negative effects downstream as the resulting higher flows increases the erosion potential.~~ | ~~May exacerbate downstream flooding risks.~~ | | | ~~Not in City Database~~ | | Complete |
| | Culvert Upgrade - Kimball Road (AEID: C-249) | Parkridge Creek & West Fraser | 2020 | 1 | 1 | 1 | 3 | Fair condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | Not in City Database | | |
| | Culvert Upgrade - Bilnor Road (AEID: C-243) | Parkridge Creek & West Fraser | 2020 | 1 | 1 | 1 | 3 | Fair condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | Not in City Database | | |
| | Culvert Upgrade - Reynolds Road (AEID: C-504) | Parkridge Creek & West Fraser | 2020 | 1 | 0 | 0 | 1 | Upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | 15801 | | |
| | Culvert Upgrade - Reynolds Road (AEID: C-225) | Parkridge Creek & West Fraser | 2020 | 1 | 1 | 0 | 2 | Fair condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | Not in City Database | | |
| | Culvert Upgrade - Reynolds Road (AEID: C-227) | Parkridge Creek & West Fraser | 2020 | 1 | 0 | 0 | 1 | Good condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | Not in City Database | | |
| | Culvert Upgrade - Haldi Lake Road (AEID: C-139) | Parkridge Creek & West Fraser | 2020 | 1 | 0 | 0 | 1 | Good condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | 3972 | | |
| | Culvert Upgrade - Purdue Road (AEID: C-221) | Parkridge Creek & West Fraser | 2020 | 1 | 1 | 1 | 3 | Fair condition, upgrade not recommended | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | Not in City Database | | |
| | Culvert Upgrade - Buckingham Road (AEID: C-232) | Parkridge Creek & West Fraser | 2020 | 1 | 2 | 1 | 4 | Poor condition | $100,000-$1,000,000 | $550,000 | | May have negative effects downstream as the resulting higher flows increases the erosion potential. | May exacerbate downstream flooding risks. | | | 3990 | | |
| | Establishing a Flood Construction Level (FCL) (Parkridge Creek-Upstream of Highway 16) | Parkridge Creek & West Fraser | 2020 | 2 | 3 | 0 | 5 | | Internal Costs to City, increased development costs | $5,000 | | | Reduces building damage potential over time. | | | | | |
| Parkridge Creek watershed PK-1 | Plant roadside ditches with native species | Parkridge Creek & West Fraser | 2020 | 3 | 0 | 2 | 5 | | <$10,000 | $5,000 | | Positive | | | | | | |
| PK-2 | Implement roadside BMPs on future boundary road extension | Parkridge Creek & West Fraser | 2020 | 2 | 2 | 2 | 6 | | $10,000-$100,000 individually, cost goes down per unit if part of a larger program | $55,000 | $500 | Positive | | | X | | | |
| PK-3 | Monitor beaver activity at Highway 16 culverts | Parkridge Creek & West Fraser | 2020 | 3 | 2 | 1 | 6 | | <$10,000 | $5,000 | | N/A | | | | | | |
| PK-4 | Floodplain development permits in flooded area upstream of Highway 16 | Parkridge Creek & West Fraser | 2020 | 3 | 3 | 1 | 7 | | Internal Costs to City, could charge an application fee. | $5,000 | | N/A | | X | | | | |
| PK-5 | Maintain cleaning of utility corridor along Parkridge Creek, initiated in 2018 | Parkridge Creek & West Fraser | 2020 | 1 | 1 | 2 | 4 | | $100,000-$1,000,000 | | | Positive | | | | | | |
| PK-6 | Upgrade culvert at Domano Boulevard to remove barrier to fish passage | Parkridge Creek & West Fraser | 2020 | 1 | 2 | 3 | 9 | Fair condition, Bridge recommended | >$1,000,000 | $1,000,000 | | Positive, particularly if bridge is installed | | | X | | | |
| PK-7 | Develop future residential areas in Parkridge Creek with stringent stormwater management considerations | Parkridge Creek & West Fraser | 2020 | 2 | 1 | 2 | 5 | | Internal Costs to City/Developers | $5,000 | | Positive | | X | X | | | |
| PK-8 | Treat runoff from snow storage facilities | Parkridge Creek & West Fraser | 2020 | 1 | 0 | 2 | 3 | | $100,000-$1,000,000 | $55,000 | | Positive | | | X | | | |
| PK-9 | Prevent recreational vehicle crossing at Park Drive | Parkridge Creek & West Fraser | 2020 | 3 | 0 | 2 | 5 | | Internal Costs to City | $10,000 | | Positive | | | | | | |
| PK-10 | Clean debris at Heyer Road Outfall | Parkridge Creek & West Fraser | 2020 | 3 | 1 | 1 | 5 | | | $10,000 | | Positive | | | | | | |
| PK-11 | Adjust future road alignments along Parkridge Creek to avoid riparian impacts. | Parkridge Creek & West Fraser | 2020 | 3 | 0 | 2 | 5 | | Internal Costs to City | $10,000 | | Positive | | | | | | |
| PK-12 | Beaver protection | Parkridge Creek & West Fraser | 2020 | 2 | 2 | 0 | 4 | | $10,000-$100,000 | $55,000 | | Negative | | | | | | |
| PK-13 | Snow Removal in Vanway Neighbourhood | Parkridge Creek & West Fraser | 2020 | 2 | 2 | 0 | 4 | | $10,000-$100,000 | $55,000 | | N/A | | | | | | |
| PK-14 | Culvert upgrades for fish passage | Parkridge Creek & West Fraser | 2020 | 1 | 1 | 3 | 5 | | | | | Positive | | | X | | | |
| West Frase | Strengthen wording in Subdivision and Development Servicing Bylaw around stormwater management | Parkridge Creek & West Fraser | 2020 | 3 | 0 | 2 | 5 | | Internal Costs to City | $10,000 | | Positive | | X | X | | | |
| G-2 | Implement a Sediment and Erosion Control Bylaw | Parkridge Creek & West Fraser | 2020 | 3 | 3 | 2 | 8 | | Internal Costs to City | $10,000 | | Positive | | X | X | | | |
| G-3 | Update Design Criteria Manual to include Climate Change Considerations | Parkridge Creek & West Fraser | 2020 | 3 | 2 | 2 | 7 | | Internal Costs to City | $50,000 | | Positive | | X | X | | | |
| G-4 | Update Storm Sewer System Bylaw | Parkridge Creek & West Fraser | 2020 | 3 | 0 | 2 | 5 | | Internal Costs to City | $10,000 | | Positive | | X | X | | | |
| G-5 | Update Zoning Bylaw | Parkridge Creek & West Fraser | 2020 | 3 | 0 | 2 | 5 | | Internal Costs to City | $10,000 | | Positive | | X | | | | |

| ID | Action Item / Recommendation | Watershed Drainage Plan | Year | Economic score | Social Score | Env't Score | Score Total | WDP Prioritization | Original Capital Costs | City Cost increased for Inflation and CC | O&M Costs | Environmental benefits/ detriment | Social benefits (including protection of property) | Bylaw / Guidelines | Overlap with other Actions | Asset ID or Model ID | Discharge Point *(please add this column and comments)* | Completed? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| G-6 | Culvert Inspections/Replacement | Parkridge Creek & West Fraser | 2020 | 2 | 2 | 2 | 6 | | $10,000-$100,000 | $55,000 | | Positive | | | X | | | |
| G-7 | Public Engagement | Parkridge Creek & West Fraser | 2020 | 3 | 1 | 1 | 5 | | Internal Costs to City | $10,000 | | Positive | | | | | | |
| G-8 | Implement residential on-site stormwater management techniques and include requirements in appropriate bylaws | Parkridge Creek & West Fraser | 2020 | 2 | 1 | 2 | 5 | | Internal Costs to City, Costs to Residents | $25,000 | | Positive | | | X | | | |
| G-9 | Stormwater BMPs for commercial and multifamily lots | Parkridge Creek & West Fraser | 2020 | 2 | 0 | 2 | 4 | | Internal Costs to City, Costs to Developers | $25,000 | | Positive | | | X | | | |
| G-10 | Stormwater BMPs for roadways | Parkridge Creek & West Fraser | 2020 | 2 | 1 | 2 | 5 | | Costs to City, Depends on Scope | | | Positive | | | X | | | |
| G-11 | Update GIS Database for Stormwater | Parkridge Creek & West Fraser | 2020 | 2 | 3 | 1 | 6 | | Internal Costs to City | $125,000 | | N/A | | | | | | |
| G-12 | Update Hazardous Slope mapping | Parkridge Creek & West Fraser | 2020 | 3 | 3 | 2 | 8 | | Internal Costs to City | $10,000 | | N/A | | | | | | |
| G-13 | Regular stormwater system maintenance | Parkridge Creek & West Fraser | 2020 | 2 | 2 | 2 | 6 | | $10,000-$100,000 | $55,000 | | Positive | | | X | | | |
| G-14 | Conserve natural vegetation, limit tree removal | Parkridge Creek & West Fraser | 2020 | 3 | 1 | 3 | 7 | | $10,000-$100,000 | $55,000 | | Positive | | | X | | | |
| G-15 | Improve inspection related to stormwater management | Parkridge Creek & West Fraser | 2020 | 2 | 1 | 2 | 5 | | $10,000-$100,000 | $55,000 | | Positive | | | X | | | |
| G-16 | Update IDF Curves | Parkridge Creek & West Fraser | 2020 | 3 | 2 | 2 | 7 | | Internal Costs to City, may require outside consultant. $10,000- | $55,000 | | Positive | | | X | | | |
| G-17 | Recommend open ditches over paved swales | Parkridge Creek & West Fraser | 2020 | 3 | 1 | 2 | 6 | | $10,000-$100,000 | $55,000 | | Positive | | | | | | |
| G-18 | Protect wetlands | Parkridge Creek & West Fraser | 2020 | 2 | 2 | 3 | 7 | | $10,000-$100,000 | $55,000 | | Positive | | | X | | | |
| G-19 | Update Design Standards Manual | Parkridge Creek & West Fraser | 2020 | 2 | 1 | 2 | 5 | | $10,000-$100,000 | $55,000 | | Positive | | | X | | | |
| | Replace crossing structure with clear span bridge - Hofferkamp Road | McMillan Creek | 2017 | 0 | 2 | 3 | 5 | Short Term (1-5 years), Replacement Priority 1 | $1,180,000 | $1,321,600 | | | | | | 159 | Nechako River at Cameron Street Bridge | |
| | ~~Replace crossing structure with clear span bridge - Aberdeen Road~~ | ~~McMillan Creek~~ | ~~2017~~ | ~~0~~ | ~~2~~ | ~~3~~ | | ~~Short Term (1-5 years), Replacement Priority 2~~ | ~~$1,448,000~~ | | | | | | | ~~157~~ | | Complete |
| | Replace crossing structure with clear span bridge - McMillan Drive | McMillan Creek | 2017 | 1 | 2 | 3 | 6 | Short Term (1-5 years), Replacement Priority 3 | $563,000 | $630,560 | | | | | | 138 | | |
| | Replace crossing structure with clear span bridge - Northwood Road | McMillan Creek | 2017 | 0 | 1 | 3 | 4 | Short Term (1-5 years), Replacement Priority 4 | $1,233,000 | $1,380,960 | | | | | | 160 | | |
| | 2-year culvert maintenance program | McMillan Creek | 2017 | 1 | 2 | 2 | 5 | Short Term (1-5 years) | $254,800 | $285,376 | | | | | X | | | |
| | 5-year culvert maintenance program | McMillan Creek | 2017 | 2 | 2 | 2 | 6 | Short Term (1-5 years) | $126,000 | $141,120 | | | | | X | | | |
| | Onsite storage of snow | McMillan Creek | 2017 | 1 | 1 | 2 | 4 | Short Term (1-5 years) | | | | Positive | | | X | | | |
| | Conduct culvert condition assessments in other PG watersheds and implement a similar program. | McMillan Creek | 2017 | 2 | 2 | 2 | 6 | Short Term (1-5 years) | | | | | | | X | | | |
| | Further public education through the establishment of parks and trails that inform on watershed health. | McMillan Creek | 2017 | 1 | 3 | 1 | 5 | Short Term (1-5 years) | | | | | | | | | | |
| | Follow BMPs for improvements to existing practices and for the construction of new systems. | McMillan Creek | 2017 | 3 | 1 | 2 | 6 | Short Term (1-5 years) | | | | | | | X | | | |
| | Replace crossing structure with clear span bridge - Private Drive | McMillan Creek | 2017 | 1 | 1 | 2 | 4 | Medium Term (5-10 years) | $376,000 | $421,120 | | | | | | 176 | | |
| | Replace crossing structure with clear span bridge - Highway 97 Crossing | McMillan Creek | 2017 | 0 | 3 | 1 | 4 | Medium Term (5-10 years) | $1,340,000 | | | | | | | 188 | | |
| | Replace crossing structure with clear span bridge - Iona Road | McMillan Creek | 2017 | 1 | 1 | 0 | 2 | Medium Term (5-10 years) | $676,000 | $757,120 | | | | | | 173 | | |
| | Replace crossing structure with clear span bridge - OSL Road Crossing | McMillan Creek | 2017 | 1 | 2 | 1 | 4 | Medium Term (5-10 years) | $676,000 | $757,120 | | | | | | 153 | | |
| | Replace crossing structure with clear span bridge - OSL Road Crossing | McMillan Creek | 2017 | 1 | 2 | 1 | 4 | Medium Term (5-10 years) | $676,000 | $757,120 | | | | | | 154 | | |
| | ~~Replace crossing structure with clear span bridge - Goose Country Road~~ | ~~McMillan Creek~~ | ~~2017~~ | ~~1~~ | ~~2~~ | ~~2~~ | | ~~Medium Term (5-10 years)~~ | ~~$676,000~~ | | | | | | | ~~156~~ | | Complete, waiting for |
| | Replace crossing structure with clear span bridge - Private Drive | McMillan Creek | 2017 | 1 | 1 | 1 | 3 | Medium Term (5-10 years) | $376,000 | $421,120 | | | | | | 179 | | |
| | Replace crossing structure with clear span bridge - Private Drive | McMillan Creek | 2017 | 1 | 1 | 2 | 4 | Medium Term (5-10 years) | $376,000 | $421,120 | | | | | | 180 | | |
| | Incorporate alternative stormwater management strategies [LIDs] in to new developments. | McMillan Creek | 2017 | 3 | 1 | 2 | 6 | Medium Term (5-10 years) | | | | | | | X | | | |
| | Construct a wetland at the outlet of the proposed Nordic Drive storm trunk. | McMillan Creek | 2017 | 1 | 2 | 2 | 5 | Medium Term (5-10 years) | | | | | | | | | | Outlet structure |
| | Consider environmental constraints such as sensitive riparian features for proposed developments. | McMillan Creek | 2017 | 3 | 2 | 2 | 7 | Medium Term (5-10 years) | | $10,000 | | | | | X | | | |
| | Update City Design Guidelines to account for 1 in 10 year storm events, minimum pipe sizes, and gradients for both storm sewers and culverts. | McMillan Creek | 2017 | 3 | 2 | 2 | 7 | Medium Term (5-10 years) | | $10,000 | | | | X | X | | | |
| | Preserve watershed health through mainstem crossing improvements and integrated stormwater management strategies. | McMillan Creek | 2017 | 0 | 0 | 3 | 3 | Long Term (10+ years) | | | | | | | | | | |
| | Secure consistent funding through the integration of a stormwater utility program. | McMillan Creek | 2017 | 2 | 3 | 2 | 7 | Long Term (10+ years) | | $200,000 | | | | X | X | | | |
| | Enforce existing policies and bylaws on new developments and existing landowners regarding sedimentation and stormwater management. Implement new regulation regarding onsite snow storage and sediment capture, including the maintenance of new and existing systems. | McMillan Creek | 2017 | 2 | 1 | 2 | 5 | Long Term (10+ years) | | $10,000 | $50,000 | | | X | X | | | |
| | Limit future land use [of] rural development near sensitive riparian areas. Discourage any further crossings over the mainstem of McMillan Creek and provide incentive to existing landowners to replace crossings that have been found to be barriers. | McMillan Creek | 2017 | 2 | 0 | 2 | 4 | Long Term (10+ years) | | | | | | X | X | | | |
| | Prohibited areas for aggregate extraction should be extended to include undeveloped areas of the watershed. | McMillan Creek | 2017 | 3 | 0 | 2 | 5 | Long Term (10+ years) | | $5,000 | | | | X | | | | |
| | Careful consideration should be given to development in wetlands and sensitive riparian ecosystems | McMillan Creek | 2017 | 3 | 2 | 2 | 7 | Long Term (10+ years) | | $10,000 | | | | X | X | | | |
| | Monitor areas in close proximity to major tributaries for sedimentation and contamination such as Meadow Park. | McMillan Creek | 2017 | 2 | 0 | 2 | 4 | Long Term (10+ years) | | $0 | $10,000 | | | | | | | |
| | Protect undevelopable land through the establishment of parks and protected zones to reduce the possibility of any future development in these areas. | McMillan Creek | 2017 | 1 | 3 | 2 | 6 | Long Term (10+ years) | | $1,000,000 | | | | X | | | | |
| | Continue to use and develop BMPs that can be used for the construction and maintenance of new and existing systems. | McMillan Creek | 2017 | 2 | 2 | 2 | 6 | Long Term (10+ years) | | | | | | | X | | | |
| S1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 2 | 0 | 4 | Short Term | $26,000 | $34,060 | | | | | | ST_1221 | | |
| S1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 2 | 0 | 4 | Short Term | $26,000 | $34,060 | | | | | | ST_1222 | | |
| S1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 2 | 0 | 4 | Short Term | $22,000 | $28,820 | | | | | | ST_1223 | | |
| S1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 2 | 0 | 4 | Short Term | $14,000 | $18,340 | | | | | | ST_1224 | | |
| S1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 2 | 0 | 4 | Short Term | $13,000 | $17,030 | | | | | | ST_1225 | | |
| S1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 2 | 0 | 4 | Short Term | $49,000 | $64,190 | | | | | | ST_1226 | | |
| S1 | Major system pipe upgrade | University Heights/ | 2016 | 2 | 2 | 0 | 4 | Short Term | $130,000 | $170,300 | | | | | | ST_2354 | | |
| S1 | Major system pipe upgrade | University Heights/ | 2016 | 0 | 2 | 0 | 2 | Short Term | $998,000 | $1,307,380 | | | | | | ST_2422 | | |
| S1 | Major system pipe upgrade | University Heights/ | 2016 | 1 | 2 | 0 | 3 | Short Term | $666,000 | $872,460 | | | | | | ST_2580 | | |
| S1 | Major system pipe upgrade | University Heights/ | 2016 | 2 | 2 | 0 | 4 | Short Term | $102,000 | $133,620 | | | | | | ST_3157 | | |
| S1 | Major system culvert upgrade | University Heights/ | 2016 | 2 | 2 | 0 | 4 | Short Term | $198,000 | $259,380 | | | | | | C11 | | |

| ID | Action Item / Recommendation | Watershed Drainage Plan | Year | Economic score | Social Score | Env't Score | Score Total | WDP Prioritization | Original Capital Costs | City Cost increased for Inflation and CC | O&M Costs | Environmental benefits/ detriment | Social benefits (including protection of property) | Bylaw / Guidelines | Overlap with other Actions | Asset ID or Model ID | Discharge Point *(please add this column and comments)* | Completed? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S2 | Cleanout accumulated sediment from storm sewer inlets at escarpment base. | University Heights/ | 2016 | 2 | 1 | 2 | 5 | Short Term | N/A | $25,000 | | | | | | | | |
| S2 | Cap trails near escarpment watercourses with less erodible material. | University Heights/ | 2016 | 2 | 2 | 2 | 6 | Short Term | N/A | $70,000 | | | | | | | | |
| S2 | Enforce current ESC regulations for ongoing development. | University Heights/ | 2016 | 2 | 1 | 2 | 5 | Short Term | N/A | | $ 25,000.00 | | | | X | | | |
| S3 | Investigate capacity of Hudson Bay Slough storm sewer | University Heights/Peden Hill | 2016 | 2 | 2 | 2 | 6 | Short Term | $100,000 | $131,000 | | | | | | | | |
| M1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 1 | 0 | 3 | Medium Term | $35,000 | $45,850 | | | | | | ST_641 | | |
| M1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 1 | 0 | 3 | Medium Term | $143,000 | $187,330 | | | | | | ST_1046 | | |
| M1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 1 | 0 | 3 | Medium Term | $98,000 | $128,380 | | | | | | ST_1047 | | |
| M1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 1 | 0 | 3 | Medium Term | $104,000 | $136,240 | | | | | | ST_1050 | | |
| M1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 1 | 0 | 3 | Medium Term | $118,000 | $154,580 | | | | | | ST_1051 | | |
| M1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 1 | 0 | 3 | Medium Term | $31,000 | $40,610 | | | | | | ST_2365 | | |
| M1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 1 | 0 | 3 | Medium Term | $38,000 | $49,780 | | | | | | ST_2377 | | |
| M1 | Minor system pipe upgrade | University Heights/ | 2016 | 2 | 1 | 0 | 3 | Medium Term | $39,000 | $51,090 | | | | | | ST_2383 | | |
| M1 | Major system pipe upgrade | University Heights/ | 2016 | 2 | 1 | 0 | 3 | Medium Term | $22,000 | $28,820 | | | | | | ST_3166 | | |
| M1 | Major system culvert upgrade | University Heights/ | 2016 | 1 | 1 | 0 | 2 | Medium Term | $337,000 | $441,470 | | | | | | C7 | | |
| M1 | Major system culvert upgrade | University Heights/ | 2016 | 2 | 1 | 0 | 3 | Medium Term | $189,000 | $247,590 | | | | | | C9 | | |
| M2 | Establish greenbelt areas to provide several large core habitat areas for wildlife. Enlarge greenbelt area around Watercourse J to encompass all the tributaries | University Heights/Peden Hill | 2016 | 3 | 2 | 2 | 7 | Medium Term | N/A | | | | | X | X | | | |
| M2 | Establish designated wildlife corridors for connectivity between large core habitat areas concentrating on Watercourses B and C. Enlarge riparian/wildlife corridor through Watercourse B2 to create continuous connection between Watercourses B and C | University Heights/Peden Hill | 2016 | 3 | 2 | 2 | 7 | Medium Term | N/A | | | | | X | X | | | |
| M3 | ~~Divert runoff from watercourses~~ | ~~University Heights/~~ | ~~2016~~ | ~~1~~ | ~~0~~ | ~~2~~ | | ~~Medium Term~~ | ~~N/A~~ | | | | | | | | | Complete |
| M3 | Where possible, use existing storm sewers (need to confirm existing downstream capacities) | University Heights/ | 2016 | 2 | 0 | 2 | 4 | Medium Term | N/A | | | | | | | | | |
| M4 | Construct detention facilities in all new development to detain post-development flows to pre-development rates. Developers and consultants should consult with the City for the current criteria. | University Heights/ | 2016 | 3 | 2 | 1 | 6 | Medium Term | N/A | | | | | | X | | | |
| M5 | Include water quality treatment features in detention ponds where possible for new developments. | University Heights/ | 2016 | 3 | 1 | 2 | 6 | Medium Term | N/A | | | | | | X | | | |
| M5 | Construct oil/grit separators as spill control devices for gas stations, high risk spill industry, large parking lots. | University Heights/ | 2016 | 2 | 1 | 2 | 5 | Medium Term | N/A | | | | | | | | | |
| M5 | Provide ESC measures during construction. | University Heights/ | 2016 | 2 | 1 | 2 | 5 | Medium Term | N/A | | | | | | | | | |
| M6 | City to adjust current development design standards and typical road cross sections to accommodate snow storage within the arterial road ROW. | University Heights/Peden Hill | 2016 | 2 | 1 | 0 | 3 | Medium Term | N/A | | | | | | X | | | |
| M6 | Provide micro snow-dumps in local parks. | University Heights/Peden Hill | 2016 | 2 | 1 | 0 | 3 | Medium Term | N/A | | | | | | X | | | |
| L1 | Upgrade 20 lowest priority undersized conduits only when they have reached the end of their service life (see Table 6-7). | University Heights/Peden Hill | 2016 | 3 | 0 | 0 | 3 | Long Term | Not Provided | | | | | | | | | |
| L2 | Adopt the City's Design Guidelines (2001) as a Development Bylaw. | University Heights/Peden Hill | 2016 | 3 | 0 | 0 | 3 | Long Term | N/A | | | | | X | | | | |
| L2 | Enact Erosion & Sediment Control Bylaw. | University Heights/Peden Hill | 2016 | 3 | 3 | 2 | 8 | Long Term | N/A | | | | | X | X | | | |
| L3 | Implement water quality monitoring at outfall to Lansdowne Creek to meet Aquatic Life standards of the Provincial Water Quality Guidelines. | University Heights/Peden Hill | 2016 | 2 | 0 | 2 | 4 | Long Term | N/A | | $10,000 | | | | | | | |
| L3 | Implement flow monitoring program to establish baseline values. | University Heights/Peden Hill | | 2 | 0 | 1 | 3 | Long Term | $50,000 | $65,500 | $20,000 | | | | | | | |
| | Study/prelim design to assess the clean-out and retrofit of Maurice Drive Pond | Post UHPH watershed | | 2 | 1 | 2 | 5 | | | $100,000 | | | | | | | | |
| | Installation of a diversion pipe through the Pine Valley Golf Course to an infiltration gallery | Post UHPH watershed | | 2 | 1 | 1 | 4 | | | $100,000 | | | | | | | | |
| - | Protect Greenway Corridors | East Prince George | 2013 | 3 | 2 | 2 | 7 | High Priority | | | | | | X | X | | | |
| ~~E4.1~~ | ~~Monitor terrain instability in drainage course (Airport Hill)~~ | ~~East Prince George~~ | ~~2013~~ | ~~2~~ | ~~0~~ | ~~1~~ | | ~~High Priority~~ | | | | | | | | | | Complete |
| E8.1 | Monitor slope instabilities of main drainage course (BCR) | East Prince George | 2013 | 2 | 0 | 2 | 4 | High Priority | | | | | | | | | | |
| - | Wetland compensation program | East Prince George | 2013 | 2 | 2 | 3 | 7 | High Priority | | | | | | X | X | | | |
| E15.1 | Replace/modify ~~Willow Cale Road &~~ CN Rail culverts (Haggith) | East Prince George | 2013 | 1 | 1 | 3 | 5 | Moderate Priority | | | | | | | | | | Willowcale Rd Crossing |
| - | Beaver management plan | East Prince George | 2013 | 2 | 2 | 0 | 4 | Moderate Priority | | | | | | | X | | | |
| E1.2 | Replace/modify problem culverts (Bittner) | East Prince George | 2013 | 2 | 2 | 3 | 7 | Moderate Priority | | $1,000,000 | | | | | | | | |
| E6.1 | Improve erosion & sediment control at power line R.O.W. crossing (Guay) | East Prince George | 2013 | 2 | 0 | 2 | 4 | Moderate Priority | | | | | | | | | | |
| E8.2 | Improve erosion & sediment control along access road near Continential Way (BCR) | East Prince George | 2013 | 2 | 0 | 2 | 4 | Moderate Priority | | | | | | | | | | |
| E1.1 | Fish passage culvert inspection (Bittner) | East Prince George | 2013 | 2 | 0 | 3 | 5 | Moderate Priority | | | | | | | | | | |
| E3.1 | Improve runoff control along Foreman Road (Graves) | East Prince George | 2013 | 2 | 0 | 1 | 3 | Low Priority | | | | | | | | | | |
| - | Water quality monitoring program | East Prince George | 2013 | 2 | 0 | 2 | 4 | Low Priority | | | | | | | | | | |
| .1 | Establish 30m riparian setbacks | East Prince George | 2013 | 3 | 2 | 2 | 7 | High Priority | | | | | | X | X | | | |
| .3 | Require Industrial & Commercial BMPs | East Prince George | 2013 | 2 | 2 | 2 | 6 | High Priority | | | | | | X | X | | | |
| .4 | Require Urban BMPs | East Prince George | 2013 | 3 | 1 | 1 | 5 | High Priority | | | | | | X | X | | | |
| .11 | Educate and train City inspectors | East Prince George | 2013 | 3 | 0 | 2 | 5 | High Priority | | | | | | | | | | |
| .14 | Update City of Prince George bylaws (DCC, Development Procedures and Tree Protection) | East Prince George | 2013 | 3 | 2 | 2 | 7 | High Priority | | | | | | X | | | | |
| .2 | Bioswales in Lieu of Piped Conveyance | East Prince George | 2013 | 3 | 2 | 2 | 7 | Moderate Priority | | | | | | | X | | | |
| .7 | ~~Upgrade Willow Cale / Haggith Culvert~~ | East Prince George | 2013 | 2 | 0 | 3 | 5 | Moderate Priority | | | | | | | | | | Complete |
| .9 | Monitor and remediate erosion sites | East Prince George | 2013 | 2 | 0 | 2 | 4 | Moderate Priority | | | | | | | | | | |
| .10 | Create a Stormwater Best Management Practices Circular | East Prince George | 2013 | 3 | 2 | 2 | 7 | Moderate Priority | | | | | | | | | | |
| .12 | Stormwater Management Rebate Program | East Prince George | 2013 | 2 | 3 | 2 | 7 | Moderate Priority | | | | | | | | | | |

| ID | Action Item / Recommendation | Watershed Drainage Plan | Year | Economic score | Social Score | Env't Score | Score Total | WDP Prioritization | Original Capital Costs | City Cost increased for Inflation and CC | O&M Costs | Environmental benefits/ detriment | Social benefits (including protection of property) | Bylaw / Guidelines | Overlap with other Actions | Asset ID or Model ID | Discharge Point *(please add this column and comments)* | Completed? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| .13 | Create a drainage utility fee | East Prince George | 2013 | 2 | 3 | 2 | 7 | Moderate Priority | | | | | | X | X | | | |
| .5 | Encourage Airport BMPs | East Prince George | 2013 | 2 | 0 | 2 | 4 | Low Priority | | | | | | | | | | |
| .8 | Flow monitoring program | East Prince George | 2013 | 2 | 0 | 2 | 4 | Low Priority | | | | | | | | | | |
| .6 | Infiltration testing | East Prince George | 2013 | 2 | 2 | 2 | 6 | Low Priority | | | | | | | | | | |
| | Assess Foreman road drainage channel issues as a result of commercial development at the corner of Foreman Rd and Hwy 16E. | Post EPG WDP | | 2 | 2 | 2 | 6 | | | $100,000 | | | | | | | | |
| | ~~Field investigation/assessment of sediment accumulations in downtown area.~~ | Hudson Bay Slough | 2007 | 2 | 3 | 2 | 7 | | | | | Positive | | | | | | |
| | Commence a sediment management program. | Hudson Bay Slough | 2007 | 1 | 2 | 2 | 5 | | | | | Positive | | | | | | |
| P03-1 | Winnipeg Street Pipe Upgrade | Hudson Bay Slough | 2007 | 1 | 3 | 0 | 4 | | $360,000 | $561,600 | $3,600 | | | | | Not provided | | |
| P03-2 | ~~Patricia Boulevard Interconnection Pipe~~ | ~~Hudson Bay Slough~~ | ~~2007~~ | ~~2~~ | ~~3~~ | ~~0~~ | | | ~~$22,000~~ | | ~~$220~~ | | | | | ~~Not provided~~ | | Complete |
| P03-3 | Subcatchment diversion | Hudson Bay Slough | 2007 | 0 | 3 | 0 | 3 | | $774,000 | $1,207,440 | $7,740 | | | | | Not provided | | |
| P03-4 | Subcatchment diversion | Hudson Bay Slough | 2007 | 2 | 3 | 0 | 5 | | $150,000 | $234,000 | $1,500 | | | | | Not provided | | |
| P03-5 | Subcatchment diversion | Hudson Bay Slough | 2007 | 2 | 3 | 0 | 5 | | $100,000 | $156,000 | $1,000 | | | | | Not provided | | |
| P04-1 | Highway 16 Culvert Twinning | Hudson Bay Slough | 2007 | 1 | 3 | 0 | 4 | | $310,000 | $483,600 | $3,100 | | | | | Not provided | | |
| P04-2 | Utility Crossing Upgrade | Hudson Bay Slough | 2007 | 1 | 3 | 0 | 4 | | $340,000 | $530,400 | $3,400 | | | | | Not provided | | |
| P04-3 | Upland St. Crossing Upgrade | Hudson Bay Slough | 2007 | 1 | 3 | 0 | 4 | | $340,000 | $530,400 | $3,400 | | | | | Not provided | | |
| P04-4 | Victoria St. Crossing Upgrade | Hudson Bay Slough | 2007 | 2 | 3 | 0 | 5 | | $340,000 | $530,400 | $3,400 | | | | | Not provided | | |
| P04-5 | Pine St. Crossing Upgrade | Hudson Bay Slough | 2007 | 2 | 3 | 0 | 5 | | $340,000 | $530,400 | $3,400 | | | | | Not provided | | |
| P04-6 | Oak St. Crossing Upgrade | Hudson Bay Slough | 2007 | 2 | 3 | 0 | 5 | | $340,000 | $530,400 | $3,400 | | | | | Not provided | | |
| P04-7 | Dredge/Widen Lowland Channels | Hudson Bay Slough | 2007 | 2 | 3 | 0 | 5 | | $120,000 | $187,200 | $1,200 | | | | | Not provided | | |
| P04-8 | Queensway Floodbox Capacity Increase | Hudson Bay Slough | 2007 | 1 | 3 | 0 | 4 | | $450,000 | $702,000 | $4,500 | | | | | Not provided | | |
| P06 | Lower Main Slough Pool | Hudson Bay Slough | 2007 | 0 | 2 | 0 | 2 | | $3,000,000 | $4,680,000 | $30,000 | | | | | Not provided | | |
| P01 | Jarvis Street Pipe Upgrade | Hudson Bay Slough | 2007 | 0 | 2 | 0 | 2 | | $1,480,000 | $2,308,800 | $14,800 | | | | | Not provided | | |
| P02A | Ospika Boulevard Pipe Upgrade with Shane Creek Detention Pond | Hudson Bay Slough | 2007 | 1 | 2 | 1 | 4 | | $673,000 | $1,049,880 | $6,800 | | | | | Not provided | | |
| P07 | Redwood Street Pipe Upgrade | Hudson Bay Slough | 2007 | 1 | 2 | 0 | 3 | | $198,000 | $308,880 | $2,000 | | | | | Not provided | | |
| P08 | Redwood Street Pipe Upgrade | Hudson Bay Slough | 2007 | 2 | 2 | 0 | 4 | | $36,000 | $56,160 | $400 | | | | | Not provided | | |
| P09 | Johnson Street Pipe Upgrade | Hudson Bay Slough | 2007 | 1 | 2 | 0 | 3 | | $390,000 | $608,400 | $3,900 | | | | | Not provided | | |
| P10 | Irwin Street Pipe Upgrades | Hudson Bay Slough | 2007 | 1 | 2 | 0 | 3 | | $672,000 | $1,048,320 | $6,800 | | | | | Not provided | | |
| | Future development on Cranbrook Hill should limited flows to pre-development levels. | Hudson Bay Slough | 2007 | 3 | 2 | 1 | 6 | | | | | | | X | | | | |
| | Improve stormwater quality from properties that are likely to produce large quantities of sediment or hydrocarbons. | Hudson Bay Slough | 2007 | 2 | 0 | 2 | 4 | | | | | | | X | | | | |
| SP08 | Sediment pond in Carrie Jane Gray Park - Winnipeg St. Branch | Hudson Bay Slough | 2007 | 1 | 2 | 2 | 5 | | $212,000 | $330,720 | $8,500 | | | | | | | |
| SP09 | Sediment pond in Carrie Jane Gray Park - Massey St. Branch | Hudson Bay Slough | 2007 | 1 | 2 | 2 | 5 | | $212,000 | $330,720 | $8,500 | | | | | | | |
| E01 | Hudson's Bay Slough Sediment Forebay | Hudson Bay Slough | 2007 | 0 | 3 | 2 | 5 | | $750,000 | $1,170,000 | $30,000 | Positive | | | | | | |
| E02 | Hudson's Bay Slough Enhanced Wetland | Hudson Bay Slough | 2007 | 0 | 3 | 3 | 6 | | $758,000 | $1,182,480 | $30,400 | Positive | | | | | | |
| E03 | Improve fisheries habitat in lower slough. | Hudson Bay Slough | 2007 | 1 | 3 | 2 | 6 | | $372,000 | $580,320 | $14,900 | Positive | | | | | | |
| | Implement infiltration LIDs | Hudson Bay Slough | 2007 | 3 | 2 | 2 | 7 | | | | | | | X | X | | | |
| | Use simpler infiltration approaches of SFD properties where appropriate. | Hudson Bay Slough | 2007 | 3 | 1 | 2 | 6 | | | | | | | X | X | | | |
| | Micellaneous deficiencies (numerous) | Hudson Bay Slough | 2007 | 0 | 2 | 0 | 2 | | $1,225,000 | $1,225,000 | $49,000 | | | | | | | |
| 7.3.1 | Sediment Control Bylaw for Construction Sites | Hudson Bay Slough | 2007 | 3 | 3 | 2 | 8 | | | 10000 | | | | X | X | | | |
| 7.3.2 | Bylaws regulating discharge from private property (primary concern is quality, peak flows could also be included) | Hudson Bay Slough | 2007 | 3 | 1 | 2 | 6 | | | | | | | X | X | | | |
| 7.3.3 | Development standards that support stormwater infiltration (LIDs) | Hudson Bay Slough | 2007 | 3 | 2 | 2 | 7 | | | | | | | X | X | | | |
| GS-1 | Four locations for remedial creek work. | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 1 | 4 | Short Term (5 year plan), existing creek concerns | $7,000 | $13,930 | | | | | | | | |
| VS-1 | Eight locations for remedial creek work. | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 2 | 5 | Short Term (5 year plan), existing creek concerns | $42,000 | $83,580 | | | | | | | | |
| TS-1 | Storm sewer upgrades on Caledonia Crescent. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, existing condition | $24,000 | $47,760 | | | | | | HF62B-HF63D | | |
| TS-1 | Storm sewer upgrades on Caledonia Crescent. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, existing condition | $21,000 | $41,790 | | | | | | HF62A-HF62B | | |
| TS-2 | Storm sewer upgrades on the 7100-block of St. Lawrence Avenue. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, existing condition | $31,000 | $61,690 | | | | | | HE52A-HE64A | | |
| TS-2 | Storm sewer upgrades on the 7100-block of St. Lawrence Avenue. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, existing condition | $28,000 | $55,720 | | | | | | HE53B2-HE52A | | |
| TS-3 | Storm sewer upgrades on Rideau Drive. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, existing condition | $35,000 | $69,650 | | | | | | HF64C-HF64D | | |
| TS-3 | Storm sewer upgrades on Brock Drive. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, existing condition | $27,000 | $53,730 | | | | | | HF64B-HF64C | | |
| TS-3 | Storm sewer upgrades on Rideau Drive. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, existing condition | $31,000 | $61,690 | | | | | | HF64D-HF64A2 | | |
| VS-2 | Storm sewer upgrades near the outfall at York Drive / Varsity Avenue | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, existing condition | $11,000 | $21,890 | | | | | | HF65B_V7 | | |
| VS-2 | Storm sewer upgrades near the outfall at York Drive / Varsity Avenue | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, existing condition | $15,000 | $29,850 | | | | | | HF65A_HF65B | | |
| VS-3 | Storm sewer upgrade on the outfall at Laval Place | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, existing condition | $82,000 | $163,180 | | | | | | HG31A_V13 | | |
| GS-2 | Storm sewer and culvert upgrades on St. Patrick Avenue at Glen Lyon Way. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, existing condition | $23,000 | $45,770 | | | | | | GC22_GC21 | | |
| GS-2 | Storm sewer and culvert upgrades on St. Patrick Avenue at Glen Lyon Way. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, future condition | $13,000 | $25,870 | | | | | | HD24A_HD24B | | |

| ID | Action Item / Recommendation | Watershed Drainage Plan | Year | Economic score | Social Score | Env't Score | Score Total | WDP Prioritization | Original Capital Costs | City Cost increased for Inflation and CC | O&M Costs | Environmental benefits/ detriment | Social benefits (including protection of property) | Bylaw / Guidelines | Overlap with other Actions | Asset ID or Model ID | Discharge Point *(please add this column and comments)* | Completed? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VS-4 | Storm sewer upgrade for proposed Westgate Development | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), Westgate Development | $138,000 | $274,620 | | | | | | A-B | | |
| VS-4 | Storm sewer upgrade for proposed Westgate Development | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 0 | 3 | Short Term (5 year plan), Westgate Development | $273,000 | $543,270 | | | | | | B-C | | |
| VS-4 | Storm sewer upgrade for proposed Westgate Development | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), Westgate Development | $95,000 | $189,050 | | | | | | D-C | | |
| VS-4 | Storm sewer upgrade for proposed Westgate Development | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 0 | 3 | Short Term (5 year plan), Westgate Development | $256,000 | $509,440 | | | | | | C-E | | |
| VS-4 | Storm sewer upgrade for proposed Westgate Development | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 0 | 3 | Short Term (5 year plan), Westgate Development | $380,000 | $756,200 | | | | | | E-F | | |
| VS-4 | Storm sewer upgrade for proposed Westgate Development | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), undersized for 2-year RP, existing condition | $35,000 | $69,650 | | | | | | VC18_VC17 | | |
| VS-4 | Storm sewer upgrade for proposed Westgate Development | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Short Term (5 year plan), Westgate Development | $90,000 | $179,100 | | | | | | VC21_VC20(F-G) | | |
| VS-5 | Storm sewer upgrades near Westgate Avenue for future conditions | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 0 | 3 | Short Term (5 year plan), undersized for 5-year RP, future condition | $44,000 | $87,560 | | | | | | GE25A_GE25B | | |
| VS-5 | Storm sewer upgrades near Westgate Avenue for future conditions | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 0 | 3 | Short Term (5 year plan), undersized for 5-year RP, future condition | $49,000 | $97,510 | | | | | | GE24A_GE25A | | |
| VS-5 | Storm sewer upgrades near Westgate Avenue for future conditions | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 0 | 3 | Short Term (5 year plan), undersized for 5-year RP, future condition | $48,000 | $95,520 | | | | | | GE24B_GE24A | | |
| VS-5 | Storm sewer upgrades near Westgate Avenue for future conditions | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 0 | 3 | Short Term (5 year plan), undersized for 5-year RP, future condition | $24,000 | $47,760 | | | | | | DETENTION POND_GE24B | | |
| VS-5 | Storm sewer upgrades near Westgate Avenue for future conditions | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 0 | 3 | Short Term (5 year plan), undersized for 5-year RP, future condition | $15,000 | $29,850 | | | | | | GE24D_DETENTION POND | | |
| VS-6 | Storm sewer upgrades on Chartwell Crescent | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 0 | 3 | Short Term (5 year plan), undersized for 5-year RP, future condition | $40,000 | $79,600 | | | | | | GE23B_GE23C | | |
| TM-1 | Storm sewer upgrades at 6000 Simon Fraser Avenue. | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 0 | 3 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $19,000 | $37,810 | | | | | | HF63C-HF63D | | |
| TM-1 | Storm sewer upgrades at 5900 Simon Fraser Avenue. | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 0 | 3 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $22,000 | $43,780 | | | | | | HF63B-HF63C | | |
| TM-2 | Storm sewer upgrades on Selkirk Crescent. | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 0 | 3 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $31,000 | $61,690 | | | | | | HF63G-HF63B, HF63F-HF63G, HF63E1-HF63F, HF63A-HF63E1 | | |
| TM-3 | Storm sewer upgrades on the 6500-block of Domano Boulevard. | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 0 | 3 | Medium Term (10 year plan), undersized for 5-year RP, future condition | $63,000 | $125,370 | | | | | | HF61D-HF61C, HF61C-HF61B, HE65F-HF61D | | |
| TM-4 | Proposed storm water detention pond in the vicinity of O'Grady Road and Marleau Road. | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 1 | 4 | Medium Term (10 year plan), stormwater detention | $139,000 | $276,610 | | | | | | Pond P1 | | |
| VM-1 | Storm sewer upgrade on Tyner Boulevard | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 0 | 3 | Medium Term (10 year plan), undersized for 2-year RP, future condition | $116,000 | $230,840 | | | | | | HF15C_V19 | | |
| VM-2 | Storm sewer upgrade on O'Grady Road near Domano Boulevard. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $30,000 | $59,700 | | | | | | HF24F_HF24A | | |
| VM-3 | Storm sewer upgrade on Moriarty Place | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $17,000 | $33,830 | | | | | | HF45B_HF45A | | |
| VM-4 | Storm sewer upgrade on the 5500-block of Trent Drive. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $23,000 | $45,770 | | | | | | A5_V1 | | |
| GM-1 | Detention pond west of Southridge Avenue near O'Grady Road and St. Anne Crescent. | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 1 | 4 | Medium Term (10 year plan), stormwater detention | $273,000 | $543,270 | | | | | | Pond P4-1 | | |
| GM-1 | Detention pond west of Southridge Avenue near O'Grady Road and St. Anne Crescent. | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 1 | 4 | Medium Term (10 year plan), stormwater detention | $385,000 | $766,150 | | | | | | Pond P4-2 | | |
| GM-1 | Storm sewer upgrade west of Southridge Avenue near O'Grady Road and St. Anne Crescent. | Gladstone, Trent, & Varsity | 2002 | 2 | 1 | 0 | 3 | Medium Term (10 year plan), undersized for 2-year RP, future condition | $18,000 | $35,820 | | | | | | G7_HE13D | | |
| GM-2 | Storm sewer upgrades along Domano Boulevard | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $74,000 | $147,260 | | | | | | HE42D_HE42E, HE41A_HE42D | | |
| GM-3 | Storm sewer upgrade on Domano Boulevard south of Glen Lyon Way | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $48,000 | $95,520 | | | | | | HD44C_HD44B | | |
| GM-4 | Storm sewer upgrades on O'Grady Road just before Southridge Avenue. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $74,000 | $147,260 | | | | | | HE14B_HE14A, HE24A2_HE14B | | |
| GM-5 | Storm sewer upgrade on 7800-block of Queens Crescent. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $8,000 | $15,920 | | | | | | HE52F_HE52B | | |
| GM-6 | Storm sewer upgrade on 7700-block of Queens Crescent. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $22,000 | $43,780 | | | | | | HE62B_HE62A | | |
| GM-7 | Storm sewer upgrade on 7700-block of Osgoode Drive. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $22,000 | $43,780 | | | | | | HE61C_HE61B | | |
| GM-8 | Storm sewer upgrade on 7600-block of Kingsley Crescent. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $21,000 | $41,790 | | | | | | HE81C_HE81B | | |
| GM-9 | Storm sewer upgrade on Hartford Crescent. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $20,000 | $39,800 | | | | | | JE13E_JE13A | | |
| GM-10 | Storm sewer upgrades on 7600-block of St. Patrick Avenue. | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $94,000 | $187,060 | | | | | | HD45E1_HE31B, HD35B_HD45E1 | | |
| GM-11 | Storm sewer upgrade on Vista View Road | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Medium Term (10 year plan), undersized for 5-year RP, existing condition | $42,000 | $83,580 | | | | | | GE82A_GE82B | | |
| GM-12 | Proposed storm water detention pond at Domano Blvd. / Glen Lyon Way | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 1 | 4 | Medium Term (10 year plan), stormwater detention | $156,000 | $310,440 | | | | | | Pond P1A | | |
| GM-13 | Proposed storm water detention pond at Glen Lyon Way / St. Patrick Ave. | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 1 | 4 | Medium Term (10 year plan), stormwater detention | $356,000 | $708,440 | | | | | | Pond P1-1 | | |
| GM-14 | Proposed storm water detention pond at Glen Lyon Way / St. Patrick Ave. | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 1 | 4 | Medium Term (10 year plan), stormwater detention | $231,000 | $459,690 | | | | | | Pond P1-2 | | |
| GL-1 | Storm water detention pond (undevloped area - St. Lawrence Ave.) | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 1 | 4 | Long Term (10+ years), stormwater detention | $274,000 | $545,260 | $14,000 | | | | | GLADP3 | | |
| GL-2 | Storm water detention pond (undevloped area - St. Mary Cres.) | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 1 | 4 | Long Term (10+ years), stormwater detention | $207,000 | $411,930 | $10,500 | | | | | GLADP6 | | |
| GL-3 | Storm water detention pond (undevloped area) | Gladstone, Trent, | 2002 | 1 | 2 | 1 | 4 | Long Term (10+ years), | $367,000 | $730,330 | $18,500 | | | | | GLADP2 | | |
| GL-4 | Storm water detention pond (undevloped area) | Gladstone, Trent, | 2002 | 1 | 2 | 1 | 4 | Long Term (10+ years), | $262,000 | $521,380 | $13,500 | | | | | GLADP5-1 | | |
| GL-5 | Storm water detention pond (undevloped area) | Gladstone, Trent, | 2002 | 1 | 2 | 1 | 4 | Long Term (10+ years), | $256,000 | $509,440 | $13,000 | | | | | GLADP5-2 | | |
| TL-1 | Proposed storm water detention pond in the near Albert Pl. (south). | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 0 | 3 | Long Term (10+ years), stormwater detention | $209,000 | $415,910 | | | | | | Pond P2-1 | | |
| TL-2 | Proposed storm water detention pond in the near Domano Blvd. (west). | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 0 | 3 | Long Term (10+ years), stormwater detention | $215,000 | $427,850 | | | | | | Pond P2-2 | | |
| VL-1 | Proposed storm water detention pond north of Hwy. 16 / Marleau Rd. | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 2 | 5 | Long Term (10+ years), stormwater detention | $405,000 | $805,950 | | | | | | Pond 3-1 | | |
| VL-2 | Proposed storm water detention pond north of Hwy. 16 / Westgate Ave. | Gladstone, Trent, & Varsity | 2002 | 1 | 2 | 2 | 5 | Long Term (10+ years), stormwater detention | $354,000 | $704,460 | | | | | | Pond 3-2 | | |
| VL-3 | Culvert upgrade underneath the road parallel to Hwy. 16 (Marleau Rd.). | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | Long Term (10+ years), undersized for 5-year RP, existing condition | $19,000 | $37,810 | | | | | | VC35_VC34 | | |
| 9.1 | Storm Water Control Strategies (Ponds and Policies) | Gladstone, Trent, & Varsity | 2002 | 3 | 2 | 2 | 7 | | Not Provided | | | | | X | X | | | |
| 9.2 | Stream Corridor Management | Gladstone, Trent, & Varsity | 2002 | 3 | 2 | 2 | 7 | | Not Provided | | | | | X | X | | | |
| 9.2.1 | Public Access Trails | Gladstone, Trent, & Varsity | 2002 | 2 | 2 | 0 | 4 | | Not Provided | | | | | | | | | |
| | Address erosion downstream of Simon Fraser resulting from the Domano/Westgate Storm Pond and changes to the pond. | Post GTV WDP | | 2 | 1 | 2 | 5 | | | $200,000 | | | | | | | | |

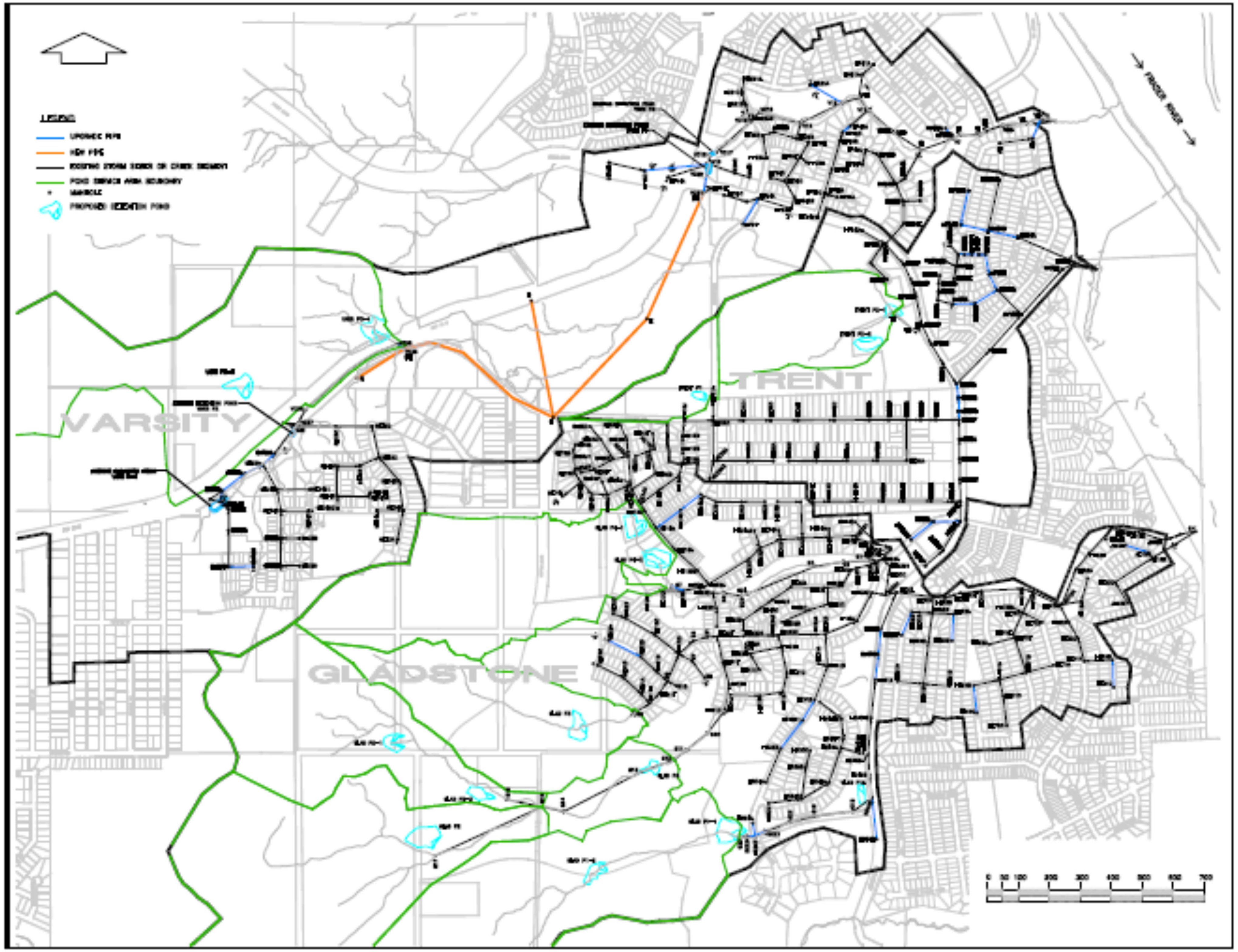
# Appendix D

## Existing Watershed Drainage Plans

- Gladstone Varsity & Trent – eDoc #19521
- Hudson Bay Wetland – eDoc #461586
- East PG – eDoc #316371
- University Heights – eDoc #556253
- McMillan Creek – eDoc #446995 and Appendices eDoc #446999
- West Fraser River & Parkridge Creek – eDoc #524269

# Appendix E

## Proposed Upgrades for the Gladstone, Varsity and Trent WDP




| NO. | DATE | ENG. | BY | SUBJECT |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

REVISIONS

| | |
|---|---|
| PROJECT NO. | [illegible] |
| SCALE | NOT TO SCALE |
| DRAWN | S.G. |
| DESIGNED | J.L. |
| CHECKED | |
| APPROVED | |
| APPROVED | |
| DATE | NOV. 2002 |

ASSOCIATED ENGINEERING

CITY OF PRINCE GEORGE
WATERSHED DRAINAGE PLANS

RECOMMENDED UPGRADES PLAN

FUTURE DEVELOPMENT CONDITION

| DRAWING NUMBER | REV. NO. | SHEET |
|---|---|---|
| 2142-0-023 | | 23/27 |

**Contact**

Nancy Hill, P.Eng.
Project Manager
T: +1 604.790.1637
E: nancy.hill@aecom.com

# Appendix C

## Technical Working Paper #2 – Engineering & Asset Management Issues

City of Prince George

# Integrated Stormwater Management Plan

## *Technical Working Paper # 2 – Engineering and Asset Management Issues*

**Prepared by:**

AECOM Canada Ltd.
3292 Production Way, Floor 4
Burnaby, BC V5A 4R4
Canada

T: 604 444 6400
F: 604 294 8597
www.aecom.com

**Date:** April, 2021

**Project #:** 60628231

## Distribution List

| # Hard Copies | PDF Required | Association / Company Name |
|---|---|---|
| | ✓ | City of Prince George |
| | ✓ | AECOM Canada Ltd. |

# Statement of Qualifications and Limitations

The attached Report (the “Report”) has been prepared by AECOM Canada Ltd. (“AECOM”) for the benefit of the Client (“Client”) in accordance with the agreement between AECOM and Client, including the scope of work detailed therein (the “Agreement”).

The information, data, recommendations, and conclusions contained in the Report (collectively, the “Information”):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the “Limitations”);
- represents AECOM’s professional judgement in light of the Limitations and industry standards for the preparation of similar reports;
- may be based on information provided to AECOM which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the Report and the Agreement; and
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time.

AECOM shall be entitled to rely upon the accuracy and completeness of information that was provided to it and has no obligation to update such information. AECOM accepts no responsibility for any events or circumstances that may have occurred since the date on which the Report was prepared and, in the case of subsurface, environmental or geotechnical conditions, is not responsible for any variability in such conditions, geographically or over time.

AECOM agrees that the Report represents its professional judgement as described above and that the Information has been prepared for the specific purpose and use described in the Report and the Agreement, but AECOM makes no other representations, or any guarantees or warranties whatsoever, whether express or implied, with respect to the Report, the Information or any part thereof.

Without in any way limiting the generality of the foregoing, any estimates or opinions regarding probable construction costs or construction schedule provided by AECOM represent AECOM’s professional judgement in light of its experience and the knowledge and information available to it at the time of preparation. Since AECOM has no control over market or economic conditions, prices for construction labour, equipment or materials or bidding procedures, AECOM, its directors, officers and employees are not able to, nor do they, make any representations, warranties or guarantees whatsoever, whether express or implied, with respect to such estimates or opinions, or their variance from actual construction costs or schedules, and accept no responsibility for any loss or damage arising therefrom or in any way related thereto. Persons relying on such estimates or opinions do so at their own risk.

Except (1) as agreed to in writing by AECOM and Client; (2) as required by-law; or (3) to the extent used by governmental reviewing agencies for the purpose of obtaining permits or approvals, the Report and the Information may be used and relied upon only by Client.

AECOM accepts no responsibility, and denies any liability whatsoever, to parties other than Client who may obtain access to the Report or the Information for any injury, loss or damage suffered by such parties arising from their use of, reliance upon, or decisions or actions based on the Report or any of the Information (“improper use of the Report”), except to the extent those parties have obtained the prior written consent of AECOM to use and rely upon the Report and the Information. Any injury, loss or damages arising from improper use of the Report shall be borne by the party making such use.

This Statement of Qualifications and Limitations is attached to and forms part of the Report and any use of the Report is subject to the terms hereof.

*AECOM: 2015-04-13*

# Authors

**Report Prepared By:**

Nancy Hill, P.Eng.
Project Manager

**Report Reviewed By:**

Christiaan Lombard, P.Eng.
Asset Management Lead

# Executive Summary

AECOM Canada Ltd. ("AECOM") has been contracted by the City of Prince George ("the City") to develop an Integrated Stormwater Management Plan (ISMP) so the City can fully understand and work towards sustainable service delivery of stormwater management. One of the major tasks of this assignment was to review various engineering issues associated with the City's stormwater system including:

- Developing a rain gauge monitoring program;
- Identifying natural assets and determining appropriate green infrastructure (lid) options for the City;
- Proposing amendments to the subdivision and development servicing bylaw and associated draft design guidelines;
- Identifying requirements for development contributed assets;
- Assessing stormwater asset risk;
- Making recommendations for an asset condition program; and
- Identifying asset longevity options.

The results of the review of engineering issues and recommendations is provided in this Technical Working Paper (TWP#2). A summary of key findings is provided below.

**Rain Gauge Monitoring Program**

There are 15 existing and historic precipitation gauges in and around the City. Of those 15 gauges, there are two that are still active and have reliable long-term data. We recommend that the City install a new (third) rain gauge in the northwest of the City to better capture rainfall patterns in the northern part of the City which are likely to vary from other sections of the City and will help inform future development north of the Nechako River. A third rain gauge would also help the City identify changes in rainfall patterns due to climate change.

**Natural Assets and Low Impact Development (LID)**

The City has many valuable natural assets (rivers, creeks, lakes, marshes, swamps, and forests) that help in the management of stormwater. The City should further develop its stormwater/roads maintenance program (e.g., street sweeping, ditch cleaning and catch basin sump cleaning) to help protect these natural assets. The City is currently analysing its natural assets in more detail as part of a separate initiative.

The City also has assets such as infiltration facilities, ditches, ponds, and underground storage facilities that are defined as green infrastructure, LID, or stormwater best management practices (BMPs). However, the City does not have a comprehensive LID strategy for new development. It is recommended that the City adopts an LID strategy for new development that focuses on features that have been found to work in northern climates. Features such as bioswales, bioretention cells, soil systems, permeable interlocking concrete pavement, perforated pipe, chamber systems, rain gardens, and soakaway pits have been found to work in northern climates under the right conditions (e.g., in consideration of topography/elevations, groundwater, other infrastructure, soils and pre-treatment).

To develop an LID strategy the City will need to:

- Identify goals;
- Identify budget, maintenance, climatic and operational constraints; and
- Identify internal capabilities and external opportunities to fund the construction and maintenance of LIDs.

To be successful, the City should maximise the life of LID features through pre-treatment, design all features with maintenance in mind, and educate internal and external stakeholders.

**Revise Subdivision and Development Servicing Bylaw and Draft Design Guidelines**
The Subdivision and Development Servicing Bylaw and Draft Design Guidelines should be revised to address:

- Climate change and new design storms (i.e., 10-year storm and rain on snow events);
- Setting limits on allowable run-off rates and volumes and requirements for stormwater treatment for new development;
- Allowing for and even requiring the use of open channels rather than storm sewers under certain conditions;
- Design requirements for oil-grit separators;
- Requiring erosion and sediment control (ESC) plans to be prepared and monitored by a professional and extending the need for an ESC plan to more types of development;
- Limitations on the use of corrugated steel pipe for culverts, sewers and catch basins;
- Improving design standards for detention ponds, particularly for constructed wetlands;
- Requiring detention pond operations and maintenance (O&M) cost estimates and recommended cleanout schedules from designers and only accepting ponds once appropriate and approved vegetation is established;
- Determining erosive velocities for vulnerable stream channels before designing upstream detention facilities;
- Specifying installation requirements for sewer relining projects to minimize environmental and health risks;
- Limiting the installation of basements in areas of high risk due to groundwater and flooding;
- Developing lot grading guidelines for developers;
- Specifying maximum grades in ditches and sewers and maximum velocities in sewers;
- Reviewing minimum depth of cover for storm sewers;
- Specifying bike-friendly catch basins; and
- Specifying the procedure for utility disconnects.

The Design Guidelines are only effective if they are effectively applied. The City can help promote effective application by:

- Mandating adherence of the Design Guidelines within the Subdivision and Development Servicing Bylaw;
- Having enough well-trained staff to review design submissions; and
- Educating developers, designers, contractors, and City staff on the requirements within the Design Guidelines, Subdivision and Development Servicing Bylaw and Storm Sewer Bylaw.

**Condition Assessment**

The City has started a regular condition assessment program for its pump stations and cross culverts. The City conducts periodic inspections for its detention ponds. It is recommended that the City:

- Maintain its pump station and cross culvert condition assessment program;
- Conduct condition assessments of its detention ponds every five years; and
- Develop a regular storm sewer and ditch inspection program.

Developing a regular storm sewer condition assessment program will allow the City to:

- Better forecast infrastructure renewal and rehabilitation needs;
- Avoid infrastructure failures and the resulting economic, social, and environmental costs; and
- Leverage cost-effective methods to extend the life of assets before the asset becomes too deteriorated and must be replaced.

In addition to the recommendations and issues identified above this report includes the following:

- Lifecycle costs for standard stormwater assets;
- Risk scoring methodology and risk scores for the City's storm mains, culverts, pump stations, ditches, catch basins, detention ponds; inlets and discharge points; and
- Information on assessing the condition of and rehabilitating storm sewers.

# Table of Contents

Page

**Executive Summary**

**Table of Contents**

# List of Figures



# List of Tables

# Appendices

# 1. Introduction

AECOM has been contracted by the City of Prince George to develop an Integrated Stormwater Management Plan (ISMP) so the City can fully understand and work towards sustainable service delivery of stormwater management. One of the major tasks of this assignment was to review various engineering issues associated with the City's stormwater system including:

- Developing of a rain gauge monitoring program;
- Identifying natural assets and determining appropriate green infrastructure options for the City of Prince George;
- Proposing amendments to the Subdivision and Development Servicing Bylaw and associated Draft Design Guidelines;
- Identifying requirements for development contributed assets;
- Assessing stormwater asset risk;
- Developing recommendations for an asset condition program;
- Identifying asset longevity options; and,
- Identifying replacement costs for existing and proposed engineered assets.

The results of the review of engineering issues and recommendations is provided in this Technical Working Paper (TWP#2).

# 2. Rain Gauge Monitoring Program

The growing concern of cities and municipalities towards effective stormwater management emerge from the increasing frequency and amplitude of problems related to rainwater runoff. Issues such as creek erosion, flooding, and pollution of natural water bodies can lead to significant costs for municipalities. While the conversion of natural land to impervious surfaces or inadequately managed runoff are undoubtedly some of the causes explaining the increasing importance of these issues, the most important factors to take into account are the increase in precipitation intensity and number of days with heavy rainfall observed across Canada since 1950 and particularly pronounced in British Columbia (Vincent et al. 2018, Picketts et al., 2009).

In addition, some municipalities may experience greater impacts from freeze-thaw events (e.g. rainfall on snow events). If these new observed tendencies pose serious concern, the situation is unlikely to change for the better in the future, since across the scientific community there is a consensus that the amplitude and frequency of short-duration (a day or less) extreme precipitation is projected to increase based on emission scenarios over the second half of the 21st century (Environment and Natural Resources Canada, 2019). Governments and scientists often request stakeholders to consider changes in precipitation trends in their planning. However, very few tools are at the disposal of stakeholders to characterize or forecast precipitation trends at the local scale.

A rain gauge monitoring plan will provide essential technical information (e.g. IDF curves, back-to-back precipitation events information, water balance estimation) for infrastructure design, track local scale changes in precipitation and provide an estimation of the long-term evolution of these changes. Given that the most effective and sustainable stormwater management plans include actions to be taken by citizens on their properties, information gained from the rain gauge monitoring plan could also be used as an important mobilization tool to motivate citizens to undertake concrete actions. The main goal of this rainfall monitoring plan is to propose the optimal alternative for future computations of IDF curves within the City of Prince George, based on existing rainfall monitoring resources (i.e., gauges and data types) and an instrumentation strategy for new rainfall gauges. To achieve this goal, the following specific objectives were identified:

1. Review of the actual rainfall monitoring resources in the Prince George City area;
2. Identify optimal locations to install new rainfall monitoring stations,
3. Provide technical information on rainfall monitoring station instruments,
4. Suggest analysis of the collected rainfall data;
5. Short-term improvement of IDF curves; and
6. Raising citizen awareness about rainfall dynamics.

## 2.1 Review of instrumented stations and available data

Numerous climatological stations have been installed within the vicinity of the City of Prince George. From the meteorological stations listed within the Pacific Climate Impacts Consortium Data Portal[1] accessed in January 202115 were equipped with rainfall and/or total precipitation measurement instruments, which recorded historical series of precipitations within the Prince George area.

Differences between rainfall and precipitation data are related to the instrument types used at the meteorological station. A station equipped with both a rain gauge and a snow gauge can provide the portion of total precipitation that has fallen as rain or snow. Depending on the instruments installed, a post-processing of the measured precipitation using other meteorological variable (e.g. air temperature, relative humidity) can also be used to

[1] https://data.pacificclimate.org/portal/pcds/map/

distinguish liquid and solid precipitation. More details on instruments, measurement types and post-processing will be provided later on.

Depending on the instrument types, available energy sources and the objectives of the meteorological station, rainfall or total precipitation can be recorded for different periods. Time steps for meteorological measurement usually available through online open data portals (e.g., ECCC, PCIC) are monthly, daily, or hourly. However, these period statistics are sometime computed from raw measurements computed at shorter time intervals at the station, such as 15-min or below. Data from these shorter intervals can sometimes be obtained by a direct request to the meteorological manager and be adapted for some specific data analysis (e.g. rainfall intensity, IDF curve computation). More details on possible measurements analysis are provided later on.

The following figure shows the location of the rain or precipitation gauges that have been installed within the City of Prince George, as well as the shortest data interval available for each station. We are aware that other rain gauges had historically been in operation within the City's limits (see McElhanney Consulting Services Ltd. report, 2014, Figure 1-2), but these gauges were not included in this review since the historical collected data were not available and the gauges are no longer in operation.

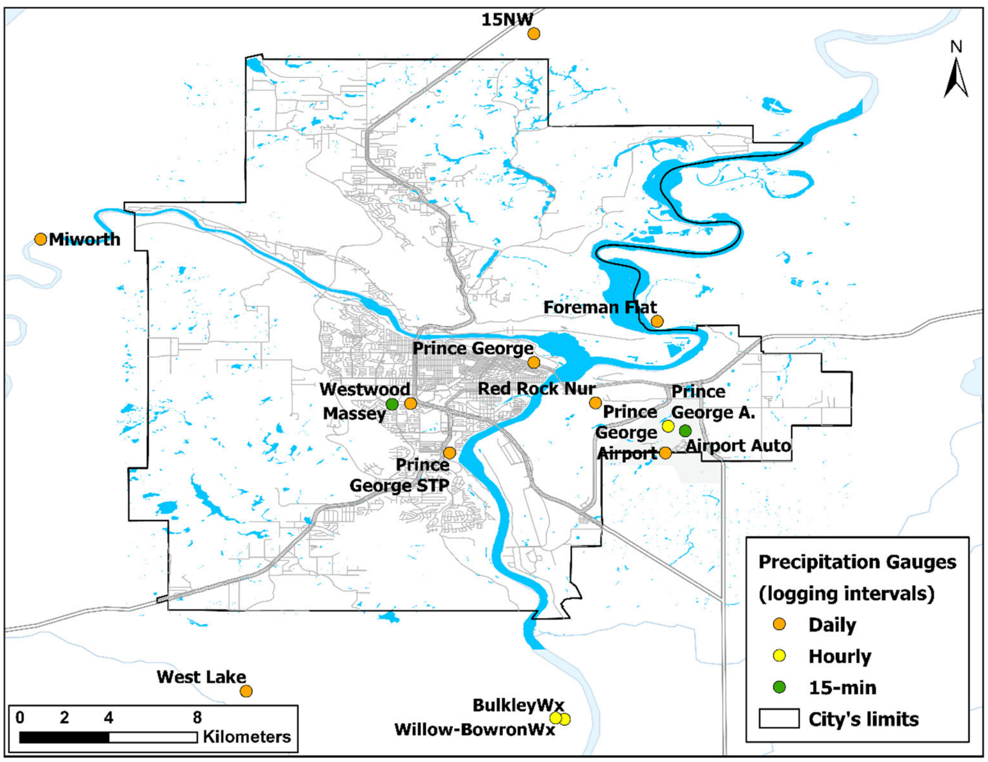



**Figure 1 Locations and Data Intervals of Precipitation Gauges in Prince George**

Locations and available data were first recovered from the PCIC Data Portal and classified based on the network managing the station, available measurement logging intervals, the monitoring period, the quality of the data series and the available measurements. The manager of the stations was contacted to determine if shorter measurement intervals were available and any details regarding the instruments used at the stations.

Details were provided by Environment Canada for stations; Prince George Airport (1096439), Airport Auto (1096453) and Massey Auto (1096454), that are still in operation and that could be used in the near future. Station Prince George Airport (1096439), that is managed by NavCanada, has data available daily since 2014, but are not continually validated, which means they must be interpreted with caution.

Both station Airport Auto (1096453) and Massey Auto (1096454) are equipped with automated total precipitation weighing gauges (Geonor & Pluvio), measuring at intervals of 15-min. Although the quality of data is validated by ECCC, the precipitation data are not precise for solid precipitation (snow). Liquid precipitations (Rainfall) during summer months are not problematic and liquid precipitation during transition periods (temperatures close to freezing point) could be validated using a comparison with monitored air temperature, relative humidity, and computed dew point. These points are detailed in future sections.

Table 1 summarizes the details of the instrumented precipitation stations.

**Table 1 Summary of the available data at the meteorological station equipped with precipitation gauges**

| Climate station ID | Name | Network | Measurements interval | | Monitoring period | | | Climate variables | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Precipitation | | Others |
| | | | Available Online | Obtain from EC | Start | End | Data gaps | Rainfall | Total | |
| 1096439 | Prince George Airport | NavCan | Daily | Hourly | 2014 | 2020 | limited | | X | X |
| 1096450 | Prince George A. | EC | Daily | Hourly | 1960 | 2002 | limited | X | X | X |
| 1096453 | Airport Auto | EC | Hourly | 15-min | 2009 | 2020 | limited | | X | X |
| 1096468 | Prince George STP | EC | Daily | - | 1975 | 2020 | limited | X | X | X |
| 1096470 | Westwood | EC | Daily | - | 1974 | 1976 | limited | X | X | X |
| 1096454 | Massey | EC | Hourly | 15-min | 2012 | 2020 | limited | | X | X |
| 1096435 | Prince George | EC | Daily | - | 1956 | 1957 | limited | X | X | X |
| 1096460 | Foreman Flat | EC | Daily | - | 1962 | 1966 | limited | X | X | X |
| 1096458 | 15NW | EC | Daily | - | 1984 | 2004 | limited | X | X | X |
| 1096465 | Miworth | EC | Daily | - | 1985 | 2002 | limited | X | X | X |
| 1096455 | West Lake | EC | Daily | - | 1999 | 2011 | limited | X | X | X |
| 109220 | Red Rock Nur | ARDA | Daily | - | 1969 | 2002 | Frequent | X | | X |
| 1113694 | BulkleyWx | FLNRO-FERN | Hourly | - | 2007 | 2018 | limited | X | | X |
| 1095439 | Willow-BowronWx | FLNRO-FERN | Hourly | - | 2007 | 2018 | limited | X | | X |
| 1113682 | CPFWx | FLNRO-FERN | Hourly | - | 2007 | 2018 | limited | X | | X |

** ECCC : Environment and Climate Changes Canada; ARDA: Agricultural and Rural Development Act; FERN: Forest Ecosystem Research Network*

Of these 15 stations, 11 were characterized with long (long enough to be analyzed) series of data and with only limited periods of missing data. Stations Prince George Airport, Prince George A. and Airport Auto are all located within the Prince George Airport limits and the two latter stations can be used (with caution with the instrument used) as a prolongation of the series of data recorded at the first station.

| Years/ Stations | Prince George Airport | Prince George A. | Airport Auto | Prince George STP | Massey | 15NW | Miworth | West Lake | BulkleyWx | Willow-BowronWx | CPFWx |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1967** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1968** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1969** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1970** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1971** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1972** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1973** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1974** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1975** | ALL | -- | -- | INC. | -- | -- | -- | -- | -- | -- | -- |
| **1976** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1977** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1978** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1979** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1980** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1981** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1982** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1983** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1984** | ALL | -- | -- | ALL | -- | INC. | INC. | -- | -- | -- | -- |
| **1985** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1986** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1987** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1988** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1989** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1990** | ALL | -- | -- | ALL | -- | ALL | LIM. | -- | -- | -- | -- |
| **1991** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1992** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1993** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1994** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1995** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1996** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1997** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1998** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1999** | ALL | -- | -- | ALL | -- | ALL | LIM. | INC. | -- | -- | -- |
| **2000** | ALL | -- | -- | ALL | -- | ALL | ALL | ALL | -- | -- | -- |
| **2001** | ALL | -- | -- | ALL | -- | ALL | ALL | ALL | -- | -- | -- |
| **2002** | ALL | -- | -- | ALL | -- | ALL | INC. | ALL | -- | -- | -- |
| **2003** | ALL | -- | -- | ALL | -- | ALL | -- | ALL | -- | -- | -- |
| **2004** | ALL | -- | -- | ALL | -- | INC. | -- | LIM. | -- | -- | -- |
| **2005** | ALL | -- | -- | ALL | -- | -- | -- | ALL | -- | -- | -- |
| **2006** | ALL | -- | -- | ALL | -- | -- | -- | ALL | -- | -- | -- |
| **2007** | ALL | -- | -- | ALL | -- | -- | -- | LIM. | INC. | INC. | INC. |
| **2008** | ALL | -- | -- | ALL | -- | -- | -- | INC. | ALL | LIM. | ALL |
| **2009** | INC. | INC. | INC. | ALL | -- | -- | -- | -- | INC. | ALL | ALL |
| **2010** | -- | ALL | LIM. | LIM. | -- | -- | -- | -- | ALL | INC. | INC. |
| **2011** | -- | ALL | LIM. | LIM. | -- | -- | -- | -- | ALL | INC. | ALL |
| **2012** | -- | ALL | ALL | LIM. | -- | -- | -- | -- | ALL | ALL | INC. |
| **2013** | -- | ALL | ALL | LIM. | INC. | -- | -- | -- | ALL | INC. | ALL |
| **2014** | -- | ALL | ALL | LIM. | ALL | -- | -- | -- | ALL | INC. | ALL |
| **2015** | -- | ALL | ALL | LIM. | ALL | -- | -- | -- | INC. | ALL | ALL |
| **2016** | -- | ALL | ALL | LIM. | ALL | -- | -- | -- | ALL | ALL | ALL |
| **2017** | -- | ALL | ALL | LIM. | ALL | -- | -- | -- | ALL | ALL | INC. |
| **2018** | -- | ALL | ALL | LIM. | ALL | -- | -- | -- | INC. | INC. | -- |
| **2019** | -- | ALL | LIM. | LIM. | ALL | -- | -- | -- | -- | -- | -- |
| **2020** | -- | ALL | ALL | ALL | ALL | -- | -- | -- | -- | -- | -- |

Table 2 summarizes the available data for each station and each year since 1967. The comparison of the time series available at the stations shows two periods where spatial distribution of precipitation could be investigated due to overlapping time series between stations. The first period is between 1985 and 2000, where precipitation values are available for stations Prince George Airport, Prince George STP, 15NW and Miworth. There are also some years between 2008 and 2017 for which 4 or 5 stations recorded precipitation simultaneously, but there is no period longer than 2 years for continuous comparison for precipitation data between stations.

| Years/ Stations | Prince George Airport | Prince George A. | Airport Auto | Prince George STP | Massey | 15NW | Miworth | West Lake | BulkleyWx | Willow-BowronWx | CPFWx |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **1967** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1968** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1969** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1970** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1971** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1972** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1973** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1974** | ALL | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **1975** | ALL | -- | -- | INC. | -- | -- | -- | -- | -- | -- | -- |
| **1976** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1977** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1978** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1979** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1980** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1981** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1982** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1983** | ALL | -- | -- | ALL | -- | -- | -- | -- | -- | -- | -- |
| **1984** | ALL | -- | -- | ALL | -- | INC. | INC. | -- | -- | -- | -- |
| **1985** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1986** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1987** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1988** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1989** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1990** | ALL | -- | -- | ALL | -- | ALL | LIM. | -- | -- | -- | -- |
| **1991** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1992** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1993** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1994** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1995** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1996** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1997** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1998** | ALL | -- | -- | ALL | -- | ALL | ALL | -- | -- | -- | -- |
| **1999** | ALL | -- | -- | ALL | -- | ALL | LIM. | INC. | -- | -- | -- |
| **2000** | ALL | -- | -- | ALL | -- | ALL | ALL | ALL | -- | -- | -- |
| **2001** | ALL | -- | -- | ALL | -- | ALL | ALL | ALL | -- | -- | -- |
| **2002** | ALL | -- | -- | ALL | -- | ALL | INC. | ALL | -- | -- | -- |
| **2003** | ALL | -- | -- | ALL | -- | ALL | -- | ALL | -- | -- | -- |
| **2004** | ALL | -- | -- | ALL | -- | INC. | -- | LIM. | -- | -- | -- |
| **2005** | ALL | -- | -- | ALL | -- | -- | -- | ALL | -- | -- | -- |
| **2006** | ALL | -- | -- | ALL | -- | -- | -- | ALL | -- | -- | -- |
| **2007** | ALL | -- | -- | ALL | -- | -- | -- | LIM. | INC. | INC. | INC. |
| **2008** | ALL | -- | -- | ALL | -- | -- | -- | INC. | ALL | LIM. | ALL |
| **2009** | INC. | INC. | INC. | ALL | -- | -- | -- | -- | INC. | ALL | ALL |
| **2010** | -- | ALL | LIM. | LIM. | -- | -- | -- | -- | ALL | INC. | INC. |
| **2011** | -- | ALL | LIM. | LIM. | -- | -- | -- | -- | ALL | INC. | ALL |
| **2012** | -- | ALL | ALL | LIM. | -- | -- | -- | -- | ALL | ALL | INC. |
| **2013** | -- | ALL | ALL | LIM. | INC. | -- | -- | -- | ALL | INC. | ALL |
| **2014** | -- | ALL | ALL | LIM. | ALL | -- | -- | -- | ALL | INC. | ALL |
| **2015** | -- | ALL | ALL | LIM. | ALL | -- | -- | -- | INC. | ALL | ALL |
| **2016** | -- | ALL | ALL | LIM. | ALL | -- | -- | -- | ALL | ALL | ALL |
| **2017** | -- | ALL | ALL | LIM. | ALL | -- | -- | -- | ALL | ALL | INC. |
| **2018** | -- | ALL | ALL | LIM. | ALL | -- | -- | -- | INC. | INC. | -- |
| **2019** | -- | ALL | LIM. | LIM. | ALL | -- | -- | -- | -- | -- | -- |
| **2020** | -- | ALL | ALL | ALL | ALL | -- | -- | -- | -- | -- | -- |

**Table 2 Periods of available precipitation data at stations.**

** ALL: No data gap during that year.*
** LIM: Limited data gap (less than 20-days of missing values).*
** INC: Incomplete data for that year.*

For the period 1985-2000 of overlapping precipitation data, some statistics related to rainfall intensity were computed to investigate if differences between rainfall patterns were observed within the vicinity of Prince George. Statistics computed were the annual maximum daily rainfall, the average annual rainfall amount for rainy days, and the total annual number of days for which more than 15-mm of rain were measured. The average for each statistic was subsequently computed for the period 1985-2000 and for each station. Precipitation intensity refers to a specific amount of accumulation of precipitation over a specific period. Also note here that statistics were computed from rainfall data available at stations and only for days where the recorded mean air temperature was above 0°C. These criteria are insufficient for a precise analysis of rainfall data aimed at computing IDF curves. However, they are deemed acceptable for the purpose of investing general patterns in precipitation.

**Table 3 Rainfall statistics for the period of overlapping data between Prince George stations.**

| | Meteorological stations | | | |
|---|---|---|---|---|
| **Statistics for the common period (average 1985-2001)** | **Prince George Airport** | **Prince George STP** | **15NW** | **Miworth** |
| **Daily maximum recorded rainfall (mm)** | 23.8 | 23.7 | 24.5 | 25.2 |
| **Number of days with rainfall > 15 mm** | 4.1 | 3.6 | 5.5 | 5.2 |
| **Mean rainfall amount (mm) for rain days** | 3.6 | 3.5 | 3.7 | 4.3 |

Simonovic et al. from Western University developed a tool (IDF_CC Tool 4.5) to facilitate access and extrapolation of IDF curves by municipal managers across Canada. The IDF curves presented within the "gauged locations" section of the latest version of the *IDF_CC Tool* (4.5) are directly retrieved from the values computed and available within the Environment Canada IDF dataset, released in Mar/2020 (Environment and Climate Change Canada, 2020). The latest version of the IDF_CC tool also includes a module for ungauged locations. That module allows for the computation of IDF values from a gridded dataset produced from the IDF curves at the gauged stations Gaur et al. (2020). The dataset used to produce the interpolation maps of the IDF value can also be downloaded to produce more analysis for a specific area. The latest values computed from the IDF curves for the meteorological station Prince George Airport (1096439) were retrieved from the IDF_CC Tool and are shown in Table 4.

These values do not consider the potential impacts of climate change, thus the IDF_CC Tool also proposes different scenarios of climate change impacts on IDF curves. According to an optimistic (RCP2.6[2]) or a pessimist (RCP8.5[3]) climate change scenarios presented within the tool, the rainfall amounts (mm) associated with the period and recurrences detailed in table 4, are subject to an increase of 7-9% or 14-17% respectively to both climate change scenarios. The rainfall amounts under different climate change scenarios are provided in **Appendix C**.

**Table 4 Precipitation amounts (mm) from the IDF curves at the Prince George Airport (1096439).**

| | | Recurrence (years) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **2** | **5** | **10** | **20** | **25** | **50** | **100** |
| **Periods** | **5 min** | 4.5 | 6.5 | 8.1 | 10.0 | 10.7 | 13.0 | 15.8 |
| | **10 min** | 6.1 | 8.6 | 10.6 | 12.8 | 13.6 | 16.3 | 19.4 |
| | **15 min** | 7.0 | 9.9 | 12.3 | 15.1 | 16.1 | 19.5 | 23.5 |

2 *RCP 2.6: Representative Concentration Pathway where radiative forcing peaks at 3 W/m2 before 2100, declining to 2.6 W/m2 by 2100. RCP 2.6 provides a future concentration scenario that would lead to the lowest climate change severity, when compared to scenarios associated with RCP 8.5.*

3 *RCP 8.5: Representative Concentration Pathway resulting in radiative forcing of 8.5 W/m2 by 2100, and where radiative forcing continues to rise beyond 2100. This RCP provides a future concentration scenario that would lead to the most severe climate change impacts, when compared to all other RCPs.*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **30 min** | 8.2 | 11.7 | 14.4 | 17.4 | 18.5 | 22.0 | 26.1 |
| | **1 h** | 9.8 | 13.6 | 16.6 | 19.9 | 21.0 | 24.8 | 29.1 |
| | **2 h** | 11.7 | 15.5 | 18.7 | 22.5 | 23.9 | 28.8 | 34.6 |
| | **6 h** | 16.7 | 21.5 | 25.4 | 29.8 | 31.4 | 36.8 | 43.0 |
| | **12 h** | 20.8 | 26.1 | 30.4 | 35.2 | 36.9 | 42.7 | 49.4 |
| | **24 h** | 27.5 | 34.2 | 38.6 | 42.9 | 44.3 | 48.5 | 52.8 |

** Recurrence values were computed from Generalized Extreme values (GEV) analysis.*

## 2.2 Rainfall patterns and distribution of Rain Gauges

*The Guide to Meteorological Instruments and Methods of Observation* of the World Meteorological Organization (WMO) details the principal issues of rain gauges instrumentation and data processing. Precipitation measurements are particularly sensitive to exposure, wind and topography, and metadata describing the circumstances of the measurements are particularly important for users of the data. The analysis of precipitation data is much easier and more reliable if the same gauges and siting criteria are used throughout the network. This should be a major consideration in designing a network of rain gauges.

Rain gauge stations should therefore not be positioned arbitrarily, but according to the location of stations already in place, the observed past, and recent trends in regional precipitation patterns and local or smaller scale landscape characteristics. We propose a scale nested approach (i.e., regional, local, and micro scales) to assess if the locations of actual rain gauges could be enough to capture spatial variability in precipitation or if not, the optimal locations for new rain gauges. Since information communicated regarding the objectives of the City with its rain gauge monitoring plan reflects the desire to improve the precision of the IDF curves computed from the available data, the analysis of scale patterns will give a specific attention to rainfall intensity. Logistical aspects of station locations, such as accessibility and security, will also be considered for this rain gauge monitoring plan.

The first factor to consider in a Prince George rain gauge monitoring plan is the spatial distribution of existing and possible future gauges. Precipitation events are a complex phenomenon, changing in time and amplitude due to numerous factors, including global atmospheric dynamics and smaller scale interactions with landscape features (e.g. topography, surficial water). The spatial distribution of precipitation could be greatly variable, even within relatively small areas. Given that precipitation measurements are also particularly sensitive to smaller-scale landscape variability (e.g. trees, building), ideal locations for precipitation measurements must consider all the circumstances mentioned above.

### *2.2.1 Regional scale*

The first patterns analyzed at the regional scale were those that emerged from the 1985-2000 averages of the rainfall intensity statistics (maximum daily rainfall, number of days with more than 15-mm of rain, average total rainfall amount for rainy days) computed at the rain gauges stations within the vicinity of Prince George. To better visualize the spatial patterns, the computed statistics were interpolated using ArcGIS interpolation tools. The following figure illustrates the interpolate maps.

The daily maximum rainfall and the average rainfall for rain days clearly show an increase in rainfall amount from east to west across the City. A north to south decrease in the number of days with rain with more than 15-mm is also observed. For all statistics, the lowest rainfall values are observed at the station Prince George STP (1096468) and tend to increase in the west and north directions.

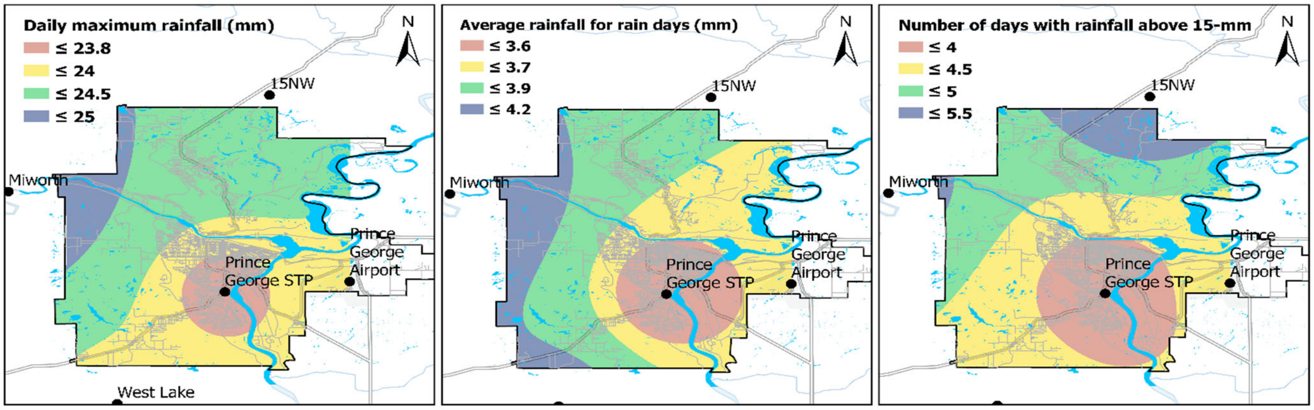



**Figure 2 Interpolation maps for rainfall data from 1985-2000 averages**

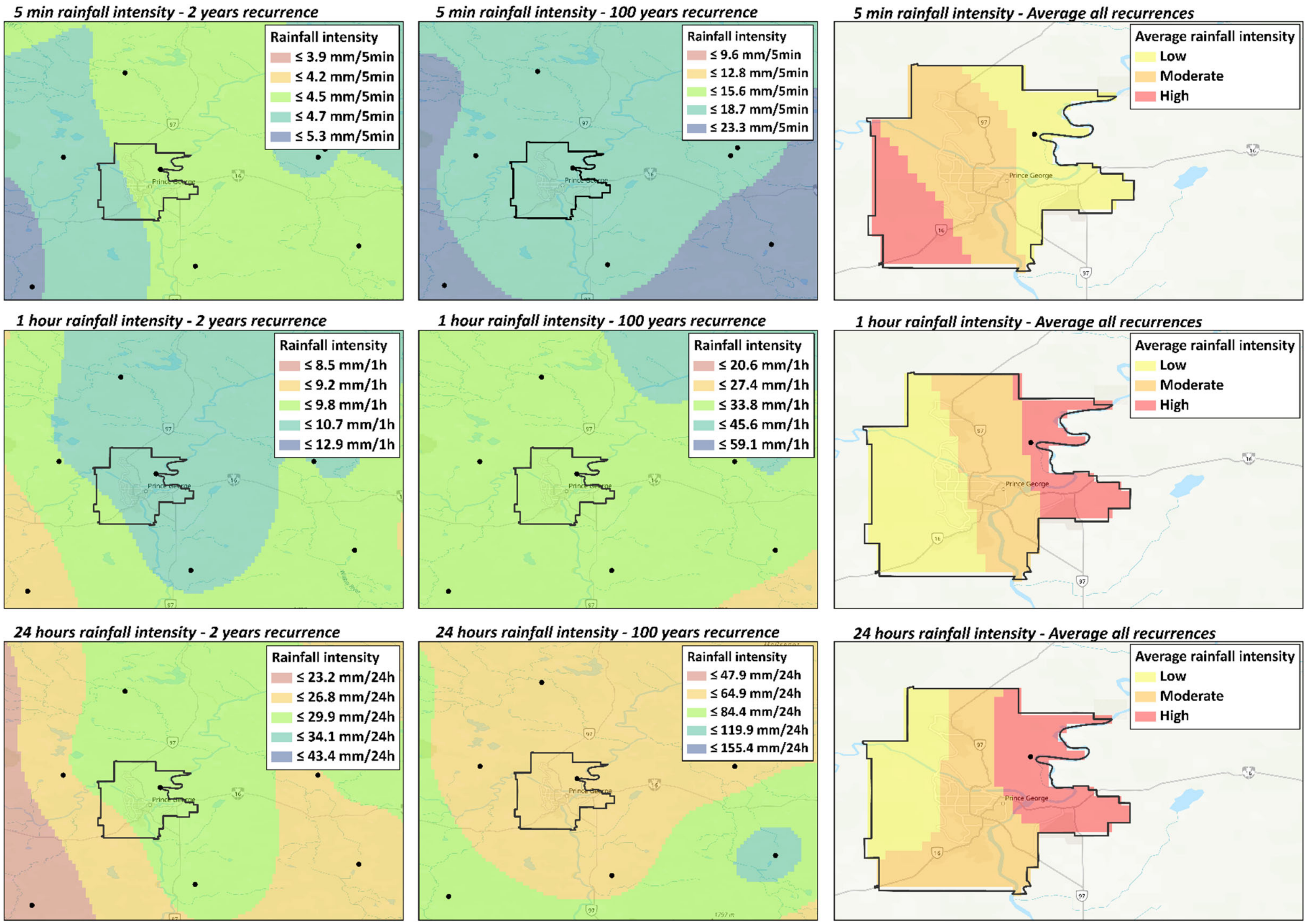



**Figure 3 Rainfall intensity patterns from IDF values retrieved from the IDF_CC Tool 4.5**

Following the same logic, interpolations of the rainfall intensities retrieved from the IDF_CC Tool 4.5 gridded tool for the computation of IDF curves in non gauged areas, were performed for the periods of 5-minutes, 10-minutes, 15-minutes, 30-minutes, 1-hour, 2-hour, 6-hour, 12-hour, and 24-hour, as well as for the recurrence periods of 2-years, 5-years, 10-years, 20-years, 25-years, 50-years and 100-years. The maps of the interpolated rainfall intensities for the periods of 5-minutes, 1-hour, 24-hour, and the probabilities of occurrence of 2-years and 100-years are shown on the previous figure. A superposition of the interpolated maps for each of the recurrence probabilities was thereafter conducted respectively for the 5-min, 1-h, 24-h periods to identify three specific rainfall intensity classes (i.e., low, moderate and high intensities) to better distinguish the spatial patterns in rainfall intensities. Maps of rainfall intensities classes are also shown in the preceding figure. Even if the intensity classes for the 5-min period are inverted compared to the intensities observed for the periods of 1-h and 24-h, we clearly observe a vertical alignment or a east-west pattern in the distribution of the rainfall intensities classes for all analyzed periods.

The Airport Auto (1096453) and Massey Auto (1096454) meteorological stations or rain gauges remaining in operation (2020) are respectively located (1) east of the city's limits and centrally located in the south-north direction, or (2) centrally located in both east-west and south-north directions.

These positions of the rain gauges suggest that the potential variations in rainfall intensities within the City's limits, highlighted by the rainfall intensities classes derived from the IDF curves of the IDF_CC Tool 4.5, will be partially captured by the rain gauges. Regarding the position of these two rain gauges and the fact that both are recording rainfall at a 15-min interval, they will greatly improve the computation of IDF curves and their spatial application across the city. However, the instrumentation of two supplemental rain gauges within the (1) western and (2) northern portions of the City's territory could help to capture the variability in rainfall patterns observed in both maps of the 1985-2000 rainfall statistics or maps of the IDF rainfall intensity classes. The instrumentation of supplemental rain gauges will also greatly improve the precision of the transposition of rainfall statistics computed for the gauge locations to every other location across the City's limits (spatial estimation technique will be discussed later on).

### *2.2.2 Local scale*

Analysis carried out at the local scale aims to ensure the quality and generalization of acquired data and limit potential errors related to wind effect or rainfall interception. Recommendations for rain gauge sites at the local scale will be based on (1) guidelines from the *Guide to Meteorological Instruments and Methods of Observation,* of the World Meteorological Organization (WMO) and (2) the logistical recommendations of the City of Prince George.

In general, ideal sites for rain gauge instruments do not have steep slopes, irregular surrounding topography, high density of trees or buildings. Based on logistics the City of Prince George suggested using City's water pump station sites or the campus of the University of Northern British Columbia (UNBC) for potential rain gauge sites.

The following figure shows the locations of the rain gauges remaining in operation, the city's water pump station sites (some of which have tipping bucket precipitation gauges that are not calibrated nor online) and the proposed areas for potential supplemental rain gauges. The zoomed areas show contour lines (5m) and some parcels that present good potential for rain gauges based on topography, tree or building density, but also according to the rainfall patterns observed at the regional scale.

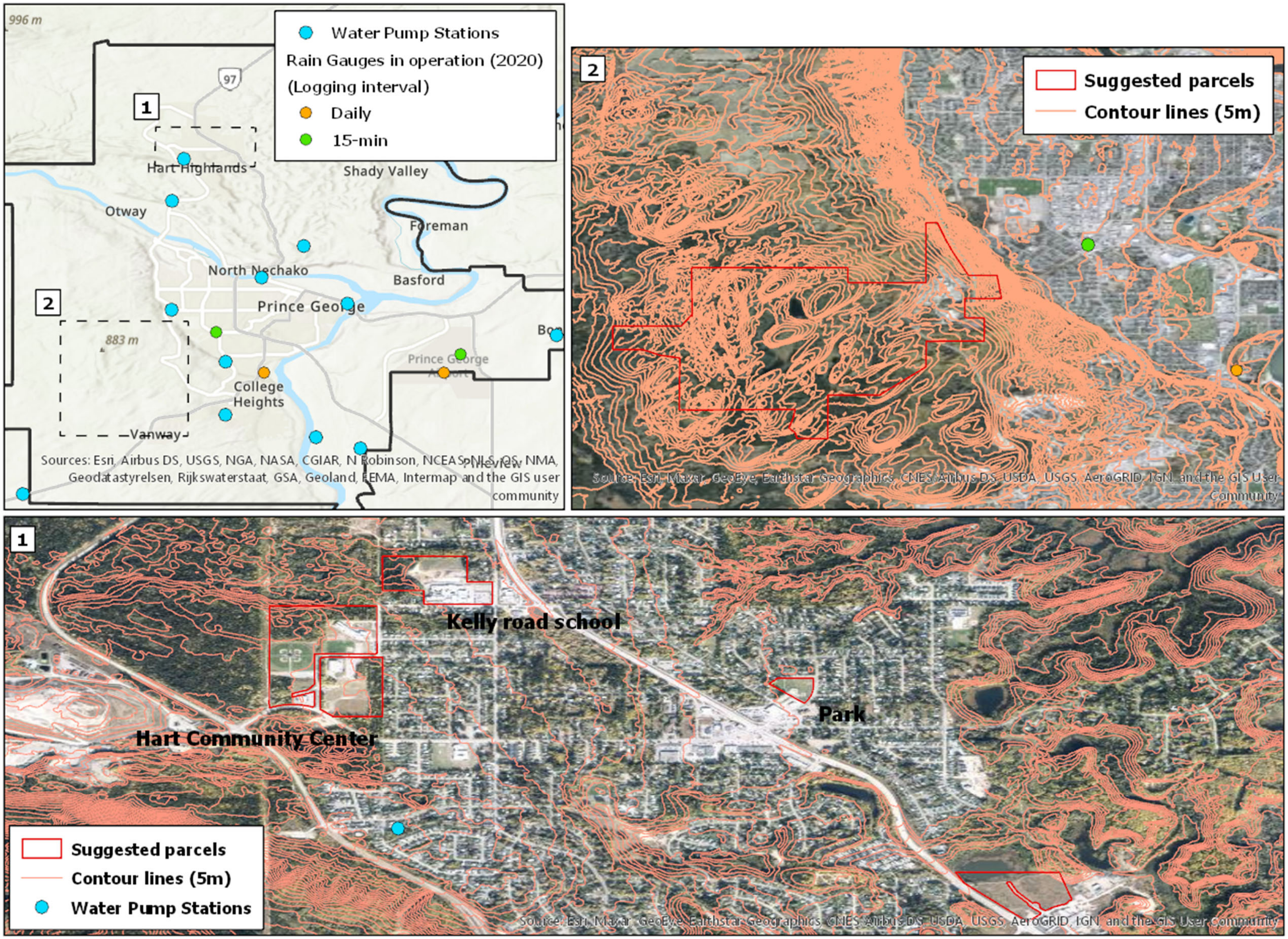



**Figure 4 Suggested areas for supplemental rain gauges**

The City's water pump station located within the Hart Highlands (see zoomed area 1 on previous figure), is in a good general location to capture the variability in rainfall patterns in the north of the City but satellite imagery shows buildings and trees that may negatively impact data quality if a rain gauge was located there. The previous figure shows three potentially better sites (Cpl Darren Fitzpatrick Bravery Park, Hart Community Centre, Elksentre Arena and Kelly Road School) for locating a new rain gauge.

UNBC is not ideal for the installation of a rain gauge, due to the significant changes in topography and the density of the tree cover (see zoomed area 2 on previous figure). However, much of the south-west or west portions of the City, where it would be beneficial to install a supplemental rain gauge to capture the observed variability in rainfall intensities, is characterized by steep slopes and dense tree cover. Therefore, if the City were to install a rain gauge in the southwest/west portion of the City it could be located at UNBC, but it would involve ground measurements detailed in the section below.

Based on the observed rainfall patterns, the range of rainfall statistics values observed within the city and the location of the Airport Auto (1096453) and Massey Auto (1096454) meteorological stations, the instrumentation of a supplemental rain gauge within the UNBC campus might not be necessary to fulfill the objectives (e.g. improvement of IDF curves precision and transposition of values across the city) of rainfall data processing by the City of Prince George. Comparatively, the instrumentation of a supplemental rain gauge within the northern portion of the city (zoomed area 1), will greatly improve the precision of rainfall statistics transposition across the city. Moreover, the improvement rainfall statistics transposition precision will be even more important for the northern portion of the city, where more residential or industrial development is observed.

### *2.2.3 Micro scale*

The micro scale characterization first refers to the measurements that must be performed in the field to minimize measurement errors related to trees or building effects on wind or rainfall interception. The logistical details of the instrumentation sites such as instrument maintenance, power supply or collected data transmission should also be considered at this scale. The information collected on this scale will also influence the final choice of the rainfall measurement or data transmission instruments. Information collected here is also essential to ensure compliance of rain gauge technical instrumentation criteria detailed in the following table. It's also important to note that criteria for rainfall or snowfall are significantly different.

Characterization or on-site measurements detailed here were not achieved but are detailed as recommendations to the City as tasks to perform for the final selection of sites. The following table details the measurements or validations to perform on site for the final selection or confirmation of sites.

**Table 5 Micro scale measurements or criteria for the final selection of rain gauge site(s)**

| Criteria / measurements | Details |
|---|---|
| **1-** Distance from surrounding obstacles (e.g. building or trees) | Measurements of the horizontal distance between the identified site and the surrounding obstacles. The rain gauge should have a horizontal separation that is twice as long as the height of the surrounding obstacle. |
| **2-** Height or vertical angle from the top of surrounding obstacles (e.g., building or trees) | The height of surrounding obstacles should be determined to ensure that the obstacle height is less than twice the horizontal distance between the selected rain gauge site and the obstacle. The height of the obstacle can be derived from the horizontal distance and the angle from the potential rain gauge site and the top of the obstacle. A laser rangefinder could be used to perform these measurements. |
| **3-** Specific site characteristics | Sites on a slope or on the roof of a building should be avoided. |
| **4-** Surface types | Surface surrounding the rain gauge site should be covered with a material enhancing water infiltration (e.g. short grass, gravel, or shingle). Hard, flat surfaces, such as concrete, should be avoided to prevent the splashing of raindrops. |
| **5-** Security of the site | Possibility to install safety fences around the rain gauge station, to prevent vandalism or displacement of the instruments. |
| **6-** Access to power supply | The accessibility to an energy source greatly simplifies the instruments required or the management of the rainfall monitoring. |
| **7-** Access to cellular or Internet network for data transmission | The access to a cellular network should not be an issue in Prince George. The transmission data or access to the rain gauge station via a cellular network is essential for efficient monitoring and management of the collected rainfall data. However, it requires a cellular plan. The access to an Internet network could provide less expensive options for data transmission. |

## 2.3 Instrumentation Technical Information

In the City of Prince George, the measure of total precipitation accounts for both liquid (rain) and solid (snow) precipitation. Precipitation that falls in between rain or snow, such as freezing rain are not distinguished for most Environment and Climate Changes Canada (ECCC) climate stations and remains a studied dynamic to limit potential error related to rain or snow specific measurement. The amount of precipitation, expressed in millimetres (mm), refers to the depth of water which would have accumulated if the surface of the earth were horizontal and none of the water were lost as runoff, evaporation or absorbed into the ground. The total amount of precipitation should be clearly distinguished from total snow that falls or accumulates on the ground that is expressed in centimetres (cm).

The previous section showed that four meteorological stations remain in operation within the City limits. From these stations, two are managed, validated by ECCC and measurements recorded at a 15-min interval allowing the characterization of rainfall intensity over a short period and the improvement of IDF curves. Regarding the need to use these stations' measurements to improve rainfall dynamics understanding, limit risks or damages related to rainfall and to limit the need for supplemental rain gauges to be instrumented, we first need to better characterize the measurement types carried out at these stations. The measurements will guide the instrumentation of supplemental rain gauges to allow comparison of the data collected at the different stations.

### 2.3.1 Measurements at the ECCC stations

Information within the following sections is retrieved from the following sources; Mekis et al. (2018), Meteorological Service of Canada (2012), Mileska et al. (2019) and Wang et al. (2017). Precipitation variables detailed at Environment Canada meteorological station are outlined below.

- **Total precipitation (mm)**: The sum of the total rainfall and the water equivalent of the total snowfall in millimetres (mm), observed at the location during a specified time interval.
- **Total rain (mm)**: The total rainfall, or amount of all liquid precipitation in millimetres (mm) such as rain, drizzle, freezing rain, and hail, observed at the location during a specified time interval.
- **Total snow (cm)**: The total snowfall, or amount of frozen (solid) precipitation in centimetres (cm), such as snow and ice pellets, observed at the location during a specified time interval.

For some stations, all three variables are provided, while only total precipitation is provided for more recent automated stations. Other climatic variables, such as air temperature, dew point, relative humidity, wind direction, wind speed, atmospheric pressure, are also provided at many ECCC stations.

In Canada, station automation started generally in the 1990s, with more and more stations being recently automated. Prior to automatization, most stations were equipped with manual rain gauge (called Type-B). Snowfall measurements are conducted with a Standard Snow Ruler. The amount of liquid and solid precipitation was determined by a correction of the total amount of water collected in the rain gauge by the snow water equivalent (SWE) of the snow depth accumulated on the ground during the precipitation interval. A daily correction factor was recently developed to improve the precision of that calculation.

The newly automated Environment Canada meteorological stations are usually equipped with two main types of all-weather precipitation gauges, the Fischer and Porter weighing gauge or the Geonor. These automated gauges cannot distinguish between solid or liquid states of precipitation. Additional information from auxiliary optical or other present weather sensors are required to help distinguish precipitation type. Both Prince George meteorological stations Airport Auto (1096453) and Massey (1096454) are equipped with this type of automated all-weather precipitation gauges. Within their hourly database available online ECCC provides a weather indicator (e.g. rain, snow, drizzle, hail, freezing rain) that can be used to distinguish rainfall measurement from the melt of other sources of precipitation. ECCC also processes the 15-min data collected at the gauge to identify trace (T) levels of precipitation (< 0.2-mm), a value of 0.1-mm thereafter applied during rain conditions. For snow conditions, the trace adjustment factor can range from 0.03 to 0.07-mm depending on the station location. Rainfall distinction from total precipitation could also be conducted using the hourly dry bulb temperature and the dewpoint temperature computed from the relative air humidity. These variables are provided for the ECCC stations located in Prince George.

### 2.3.2 Climatic measurements and monitoring systems

The City should aim to use similar instruments or measurement methods, for any new rain gauges in order to simplify data processing and validations that will allow for the comparison of the collected measurements with those measured at the ECCC stations already in operation. Some instrument types are proposed in the following table for the measurement of precipitation or climate variables necessary for post-processing of the precipitation data. The instrument descriptions aim to guide the city in their future decisions for future instrumentation and for official submission requests for the instrument and the instrumentation of the station. Regardless of the type of instruments chosen for the measurement of precipitation or for data transmission, resources for instrument maintenance and data processing will be necessary.

**Table 6 Instruments proposed for the measurements of precipitation**

| Measurement types | Instrument | | Common particularities | Specific characteristics |
|---|---|---|---|---|
| **All-weather precipitation gauges** *(Weighing Gauge)* | Geonor T-200B |  | • Gauges have a protective housing with a container inside for collecting the precipitation.<br>• Gauges use precision vibrating wires (VW) transducer to weight and determine the precipitation collected.<br>• Gauges used at ECCC meteorological station network.<br>• With the use of antifreeze, any solid precipitation is melted in the container, but snow can accumulate over the gauge ring.<br>• A small amount of oil within the bucket will prevent evaporation.<br>• Really good for precipitation intensity measurements.<br>• These gauges are good for long-term use. | • Available in 600, 1000 or 1500-mm total volume, has to be emptied when full.<br>• Conservative resolution<br>•-40°C to 60°C operating temperature range.<br>• Easy compatibility with Campbell Scientific data loggers. |
| | OTT Pluvio² L |  | | • Available in 750 or 1500-mm total volume, has to be emptied when full.<br>• Conservative resolution of 0.1-mm.<br>• -40°C to 60°C operating temperature range.<br>• Can be equipped with heated ring to prevent snow accumulation on the ring. |
| **All-weather precipitation gauges** *(Tipping bucket)* | YOUNG - 52202-L |  | • The NavCan meteorological stations are equipped with this type of gauge.<br>• The precipitation collected by a pair of buckets that are balanced about a horizontal axis, when a predetermined amount of water has been collected, the bucket tips, spilling out the water and placing the other half of the bucket to receive water. Each tip of the bucket is recorded, and the record obtained indicates the amount or rate of precipitation. | • Has a thermostat-controlled internal heater that melts snow or other frozen precipitation.<br>• Conservative resolution of 0.1-mm.<br>• -20°C to 50°C operating temperature range.<br>• Do not require to be emptied.<br>• Required more significative energy consumption.<br>• Easy compatibility with Campbell Scientific data loggers. |

**Table 7 Instruments proposed for the measurement of rainfall**

| Measurement type | Instrument | | Common particularities | Specific characteristics |
|---|---|---|---|---|
| **Rainfall gauges** *(Tipping bucket gauge)* | Campbell Scientific - RainVUE20 |  | • The precipitation collected by a pair of buckets that are balanced about a horizontal axis, when a predetermined amount of water has been collected, the bucket tips, spilling out the water and placing the other half of the bucket to receive water. Each tip of the bucket is recorded, and the record obtained indicates the amount or rate of precipitation.<br>• Do not perform well for the measurement of other precipitations than rain.<br>• Might need to be removed during winter.<br>• Easy compatibility with Campbell Scientific data loggers. | • Unique aerodynamic shape to minimize wind effects and increase accuracy.<br>• Conservative resolution of 0.3-mm.<br>• 1°C to 70°C operating temperature range.<br>• Do not require to be emptied. |
| | Texas Electronics - TE525WS |  | | • Basic tipping bucket gauge.<br>• Conservative resolution of 0.3-mm.<br>• 0°C to 50°C operating temperature range.<br>• Do not require to be emptied. |

**Table 8 Instruments proposed for the measurement of climatic variables needed for the post processing of precipitation data**

| Measurement type | Instrument | | Common particularities | Specific characteristics |
|---|---|---|---|---|
| **Air temperature and relative humidity** | Campbell Scientific - HygroVUE10 |  | • Air temperature and relative humidity sensors typically consist of two separate sensors packaged in the same housing.<br>• Easy compatibility with Campbell Scientific data loggers. | • Calibration is easy to carry out by simply changing the sensor element.<br>• -40°C to 60°C operating temperature range.<br>• Conservative temperature resolution of ±0.2°C.<br>• Conservative relative humidity resolution of ±2%. |
| | HUMICAP - HMP155A |  | | • Calibration cannot be done in the field, as it requires an experienced technician and specialized equipment.<br>• -80°C to 60°C operating temperature range.<br>• Conservative temperature resolution of ±0.2°C.<br>• Conservative relative humidity resolution of ±1.7%. |

**Table 9 Protection for the proposed instrument**

<table>
<tr><th>Measurement type</th><th colspan="2">Instrument</th><th>Common particularities</th><th>Specific characteristics</th></tr>
<tr><td rowspan="2">Measurement Shields</td><td>Novalynx - Wind Screen</td><td></td><td rowspan="2">• Instruments could work without shields, though shields greatly improve the reliability of the measurements.</td><td>• The wind screen mounted around a rain or snow gauge helps to minimize the effect of wind on the rain or snow measurements.<br>• Wind effect is especially important for snow measurements.<br>• For comparative purposes of the rainfall measurements, if ECCC stations are using wind shields it will be preferable to also use a similar shield.</td></tr>
<tr><td>R. M. Young - Solar Radiation Shield</td><td></td><td>• Temperature sensors at meteorological stations are always equipped with a solar radiation shield.<br>• Its louvred construction allows air to pass freely through the shield, thereby keeping the probe at or near ambient temperature<br>• This shield includes the hex nut adapter for relative humidity sensors.</td></tr>
</table>

**Table 10 Instruments proposed for the record and transfer of the measurements**

| Utility | Instrument | | Common particularities | Specific characteristics |
|---|---|---|---|---|
| **Computer - data loggers** | Campbell Scientific - CR1000X |   | • All Campbell scientific data loggers and communication devices can easily be used together, in terms of connections and programming.<br>• All Campbell Scientific instruments are reliable and rugged, they are the most commonly used for environmental applications in North America, making it easier to find resources for programming and maintenance of the instruments.<br>• Other companies may provide all-in-one logging and communicating systems | • CR1000X is the general use data loggers of Campbell Scientific that provides measurement and control for a wide variety of applications.<br>• Allow programming measurement and pre-processing routines of the collected data. |
| **Communication** | Campbell Scientific - Ethernet Interface NL121 |   | | • The easiest and lowest-cost way to add an Ethernet interface connection, allowing the data logger to communicate directly using a variety of Internet protocols. |
| | Campbell Scientific - Cellular Module CELL205 |   | | • External cellular modules that provide serial or CS I/O connectivity to a number of 4G LTE cellular networks |
| | Campbell Scientific - Ethernet Interface NL121 |   | | • Wi-Fi WLAN (wireless local area network) interface that provides connectivity to your data logger through your existing Wi-Fi network or any available Wi-Fi hotspot. |

The choice of instrument set up should consider (1) micro-scale characteristics of the selected site, (2) collection purposes and post-processing, as well as (3) the resources available for the maintenance of the station. Stands for the mounting of instruments and security fences should also be considered for instrument protection. Depending on the selected instrument the cost varies between $10,000 and $15,000, as well as $5,000 - $10,000 for programming. The choice of Campbell Scientific instruments has been presented here since they can provide pre-build operation programs for the instruments, provide tutorials or training for the resources responsible for station operation and is the more commonly used instrument in North America.

### *2.3.3 Technical criteria for instrument installation*

**Rain gauges**

- The rain gauge orifice must be placed above the maximum expected depth of snow cover.
- The height of the orifice should also be placed high enough to limit potential in splashing from the ground.
- To limit wind effect on measurements, the height of the rain gauge orifice from the ground should be limited as mush as possible in respect to the first two criteria (The most commonly used elevation height varies between 0.5 and 1.5 m).
- The height of surrounding obstacles should be less than twice the horizontal distance between the rain gauge orifice and the obstacle.
- The rain gauge orifice must be level to the ground.
- Installation on slopes or on building roofs should be avoided.

**Temperature and relative humidity**

- World Meteorological Organization (WMO) standards for temperature and relative humidity measurements are approximately 1.5-m above the ground.
- The sensors must be housed in ventilated radiation shields to prevent thermal radiation effects.
- The sensors should not be closer than four times the height of any obstruction's height.
- The sensors should be at least 30-m away from large paved areas.
- Since temperature and relative humidity will be used to interpret precipitation data they should be located close to the gauge.

## 2.4 Rainfall measurement processing

The typical rainfall measurement process is outlined below.

1. Computation of rainfall amount from total precipitation data (using dew point and distinguishing snow vs rain).
2. Rainfall measurement analysis:
   a) Annual and historical statistics.
   b) Overview of IDF computation curves.
   c) Spatial transposition of rainfall statistic values across the City limits.

## 2.5 Short-term improvement of IDF curves

It would take many years to collect sufficient data to develop an IDF curve for the proposed new rain gauge. However, in the short term, the City could compare data from the proposed new rain gauge with data from the existing airport rain gauge to determine if a “correction factor” should be applied to the airport IDF curve for any new development in the northern section of the City. The new rain gauge could also be used to help determine if there are any significant impacts due to climate change.

## 2.6 Raising citizen awareness about rainfall

AECOM is working with the City to develop an interactive map and database that could be used to show the collected rainfall data and that can be shared within the Open Data Portal of the City. Public mapping examples for consideration can be found at the links below.

1. City of Philadelphia : https://phl-water.maps.arcgis.com/apps/webappviewer/index.html?id=c5d43ba5291441dabbee5573a3f981d2

2. Story map Maryland :
https://maryland.maps.arcgis.com/apps/Cascade/index.html?appid=b6beb09709724ce39037584cbc497d0d

3. Monitoring of water quality (French):
https://rpns.maps.arcgis.com/apps/MapSeries/index.html?appid=ac38c90bfdc74158b3d67afa6f19f0ad

4. Vulnerability to erosion (French) :
https://rpns.maps.arcgis.com/apps/MapSeries/index.html?appid=41b21acc6f8b4e6d999ab236c74e2a52

## 2.7 Recommendations

Based on the observed rainfall patterns at the regional scale, the location of the Airport Auto (1096453) and Massey Auto (1096454) meteorological stations should capture a wide range of rainfall variability within the Prince George city's limits. However, to better capture the rainfall observed, the installation of an additional precipitation gauge within the North - Northwest section of the City (see Area 1 in Figure 4) is recommended. The northwest section of the City would be preferable to the northern area of the City. A third rain gauge will greatly improve the precision of rainfall statistics transposition across the city. Moreover, the improvement rainfall statistics will be even more important for the northern portion of the City, where more residential or industrial development is observed, and these areas are more susceptible to rainfall related problems than forested or agricultural areas.

By developing its own rain gauge monitoring stations, the City of Prince George will also improve its understanding of rainfall dynamics within its territory. It is recommended that a new rain gauge station use similar instruments and measurement protocol as the surrounding ECCC stations. Similar instrumentation will facilitate data comparison.

It would take many years to collect sufficient data to develop an IDF curve for the proposed new rain gauge. However, in the short term, the City could compare data from the proposed new rain gauge with data from the existing airport rain gauge to determine if a "correction factor" should be applied to the airport IDF curve for any new development in the northern section of the City.

# 3. Green Infrastructure

## 3.1 Prince George's Existing Natural Assets, Green Infrastructure and LID

Natural stormwater assets are commonly defined as natural features such as wetlands, forests, floodplains etc. that serve a stormwater function. The City's Geographic Information System (GIS) includes the following stormwater specific natural assets:

- Rivers/streams: 1,276 km
- Lakes: 41 (1.8 $km^2$)
- Marshes: 99 (0.78 $km^2$)
- Swamps: 1,297 (4.97 $km^2$)

There are other natural assets such as forests that also serve important stormwater functions such as rainfall interception, evapotranspiration, and erosion control.

Green infrastructure is a term commonly used for "engineered" assets such as rain gardens that have a natural component and are designed to mimic nature. The Green Infrastructure Ontario Coalition (Stormwater Systems - Green Infrastructure Ontario) defines green stormwater infrastructure (sometimes referred to as Low Impact Development) as infrastructure that intercepts, absorbs, and holds stormwater, helping reduce the amount of runoff entering sewers during rain events. The absorption and storage process also filters pollutants which improves water quality. It cites examples of these systems as:

- Bioswales;
- Permeable pavement;
- Rain gardens;
- Stream naturalization; and,
- Downspout disconnection.

Unfortunately, there is not a universally agreed upon standard for what is or isn't considered green infrastructure (GI) versus low impact development (LID) or best management practices (BMP). In general, the term green infrastructure is more commonly used on the West Coast, whereas the term Low Impact Development is more commonly used in other areas of Canada. Some practitioners consider GI to be a sub-set of LID, which can also include engineered systems such as rainwater harvesting. In any case, stormwater management using GI or LID practices involves keeping and using water close to its point of origin (i.e. keeping the raindrop where it falls). Therefore, stormwater ponds, which tend to be regional or "end of pipe" facilities are considered as a BMP but not as green infrastructure or LID.

Through the National Water and Wastewater Benchmarking Initiative, the City reported owning the following assets, which can be considered as green stormwater infrastructure (GI), LID (low impact development) or BMP's (best management practices):

- Surface infiltration facilities: 2
- Subsurface infiltration facilities: 73
- Ditches: 690 km
- Stormwater ponds: 26
- Underground storage facilities: 2

The City has implemented soil systems (see Section 3.5) adjacent to City Hall and is looking to implement bioswale with the new Fire Hall. The City has other assets such as catch basin sumps (5,750 catch basins) that can help provide pre-treatment and protect green infrastructure and natural assets downstream. In addition, the City does require disconnected downspouts for certain types of development.

The City is currently refining and assessing its natural asset inventory with the Municipal Natural Asset Initiative (MNAI), so we have focused our assessment on LID/green infrastructure options suitable for the City of Prince George.

## 3.2 Prince George's Current Standards

The City of Prince George's Subdivision and Development Servicing Bylaw and draft Design Guidelines permit or require the following BMP/ green infrastructure (GI)/ LID features:

- Infiltration facilities/ recharge chambers;
- Sediment basins/ traps;
- Storage facilities (wet pond, dry pond, constructed wetlands, channel storage);
- Roof leader disconnection; and
- Minimum building elevation (> 100-year flooding level).

## 3.3 Interviews with Other Municipalities

AECOM set up structured interviews with staff from municipalities across Canada that are directly involved with green infrastructure/LID implementation. AECOM structured the interviews to provide the information outlined below.

- Identify suitable practices implemented in cities which have a similar climate to that of Prince George
- Outline the critical considerations to be made when making implementation decisions, including:
  - The identification of constraints which may preclude GI /LID implementation in certain circumstances;
  - Operations;
  - Maintenance;
  - Budget; and
  - Education.
- Provide information regarding pre-treatment approaches that will help to extend the useful service life of various systems and highlight several common pre-treatment devices/approaches used.
- Identify potential funding sources to help offset some of the costs associated with GI/LID implementation.

The interviewed staff shared successes, challenges and lessons learned as it pertains to GI/LID implementation, with the goal of providing transferrable knowledge to the City to ensure streamlined and successful LID implementation. This sub-section of the report provides a synthesis of the information collected.

Interviewees were from municipalities that have comparable climates and physical constraints (tight soils, shallow groundwater, etc.) to the City of Prince George. Table 11 and Table 12 below summarize the climatic conditions within the municipalities evaluated as they compare to those of the City.

**Table 11 Cities with Comparable Temperatures to Prince George, BC***

| Climate Parameter | *Prince George, BC* | Calgary, AB | Thunder Bay, ON | Ottawa, ON | Sudbury, ON | Edmonton, AB | London, ON | Guelph/Waterloo, ON | Peterborough, ON |
|---|---|---|---|---|---|---|---|---|---|
| **Mean Winter Temp. (°C)** | -6.1 | -5.2 | -9.7 | -6.5 | -9.3 | -9.4 | -3.2 | -4.1 | -5.4 |
| **Mean Summer Temp. (°C)** | 14.5 | 15.3 | 16.6 | 19.9 | 17.9 | 16.7 | 19.6 | 18.8 | 18.3 |

**Data obtained from Canadian Climate Normals (GOC, 2021)*

**Table 12: Cities with Comparable Climates to Prince George, BC***

| Climate Parameter | *Prince George, BC* | Calgary, AB | Thunder Bay, ON | Ottawa, ON | Sudbury, ON | Edmonton, AB | London, ON | Guelph/Waterloo, ON | Peterborough, ON |
|---|---|---|---|---|---|---|---|---|---|
| **Winter Rainfall (mm)** | 27.7 | 3.9 | 22.5 | 101.6 | 63.6 | 4.4 | 160.2 | 133.2 | 111.8 |
| **Annual Rainfall (mm)** | 420.2 | 326.4 | 554.3 | 755.5 | 675.7 | 338.8 | 845.9 | 776.8 | 712.5 |
| **Annual Snowfall (cm)** | 234 | 128.8 | 241.2 | 175.4 | 263.4 | 118.1 | 194.3 | 159.7 | 151.2 |
| **Total Annual Precipitation (mm)** | 654.1 | 418.8 | 795.5 | 919.5 | 903.3 | 446.1 | 1011.5 | 916.5 | 855.3 |

**Data obtained from Canadian Climate Normals (GOC, 2021)*

While a Canadian City with a climate identical to that of Prince George was not identified, the chosen municipalities identified in Table 11 and Table 12 are sufficiently similar to permit comparison. Table 13summarizes the representatives interviewed, as well as population for the seven comparable municipalities.

**Table 13 Representatives and Population of the Municipalities Interviewed**

| Municipal Jurisdiction | Representatives Contacted | Population |
|---|---|---|
| **Thunder Bay, ON** | • A. Ward - City of Thunder Bay Engineering Dept. | 121,621 |
| **Ottawa, ON** | • D. Conway - Senior Engineer, Stormwater Management (SWM) Projects, Ottawa.<br>• K. Bertrand - P.Eng., Project Engineer, Stormwater Rehabilitation.<br>• L. Jolliet - City of Ottawa Engineering Dept. | 934,243 |
| **Sudbury, ON** | • P. Javor, MSc, P.Eng. - City of Sudbury Engineering Dept. | 164,689 |
| **Peterborough, ON** | • I. Boland, C.E.T - City of Peterborough Senior Watershed Project Manager. | 115,245 |
| **London, ON** | • A. Sonnes – City of London Stormwater Engineering Division. | 494,069 |
| **Edmonton, AB** | • A. Mangory - Senior Drainage Engineer, City of Edmonton. | 932,546 |
| **Calgary, AB** | • B. Van Duin - Drainage Technical Lead, Development Planning. Infrastructure Planning, Water Resources, City of Calgary<br>• L. Van Duin, B.Sc.[2] Executive Director Alberta Low Impact Development Partnership. | 1,392,609 |

*1 – Data obtained from the Census Profile, 2016 Census (Statistics Canada, 2019).*
*2 – Representative of a Regional authority on LID implementation; not of a municipality.*

Municipalities interviewed were invited to share their knowledge and experience with GI/LID, generally pertaining to the following topics:

- Preferred GI/LID types;
- Challenges associated with GI/LID implementation;
- GI/LID sustainability; and
- Lessons learned through GI/LID implementation.

## 3.4 Recommended Implementation Approach

Several recurring themes emerged during the interviews with other municipalities. These findings are summarized below within the sequence a municipality would follow when developing and implementing a GI/ LID strategy. All municipalities interviewed reported that GI/LID features can work in cold climates, provided they are properly designed

### *3.4.1 Identify Goals Based on Existing and Emerging Issues*

A crucial consideration when developing a GI/LID implementation strategy is to determine what the program is aiming to accomplish. The goal of a GI/LID program will shape the selection of suitable features. To determine a goal, it is first recommended to consider the existing and emerging stormwater management (SWM) needs for the different catchments within a jurisdiction. Goals may include, but are not limited to, the following:

- Stormwater volume control;
- Increased protection against flooding;
- Water quality protection and/or improvement;
- Climate change resiliency; and
- Increasing property value.

A unique selection of GI/LID feature types can be combined to successfully achieve any of the above goals. For example, flood risk reduction goals may lead to an approach which emphasizes the creation of large subsurface storage infrastructure, such as vault or chamber-type systems installed below parking lots, parks and other open spaces Goals centred around water quality improvement may use a combination of pre-cast treatment devices (e.g. oil-grit separators, etc.) and non-proprietary approaches, such as bioretention, tree pits and similar landscaped features. Clear SWM goals will drive the selection of appropriate LID features.

### *3.4.2 Identify Constraints*

After considering goals, it is recommended to consider potential constraints which may limit the selection of appropriate LID features, or which may have to be addressed through the design process. The municipalities interviewed highlighted common constraints; several of which are highlighted below, for consideration by the City of Prince George.

- **Soil constraints**: Some forms of vegetation used in GI/LID features may not thrive in certain soils. If vegetation options are limited, hydraulic conductivity will be affected, and ultimately drawdown times which will limit volume reduction and retention performance. Tight soil types, such as clay-rich soils, can also give rise to groundwater mounding concerns, and soil stability concerns, which may in turn affect road subgrades for those GI/LID features associated with right-of-way (ROW) environments.
- **Slopes**: Steep slopes may increase overland flow velocities and necessitate the inclusion of energy dissipation measures at GI/LID inlet locations. Steep slopes may also make stormwater retention difficult, particularly in right-of-ways.
- **Land Use**: GI/LID types may be more difficult to implement in downtown areas with zero lot line developments, especially when compared to greenfield suburban development areas. This does not mean that GI/LID can not be implemented in compact locations, but rather that it will have a bearing on the type of GI/LID features which may be suitable.

- **Adjacent Infrastructure / Utilities:** The presence of utilities and related infrastructure is an important consideration, particularly in retrofit applications. Under such circumstances, modular GI/LID feature types may be more desirable than linear features, as their geometry and footprint may be more easily modified to avoid pre-existing utilities.
- **Budgetary constraints:** Some GI/LID types are more expensive than others, but typically come with the advantage of having a higher unit area performance while also being suitable in a retrofit application where numerous constraints may be present.
- **Maintenance and equipment constraints:** Successful GI/LID selection and feature component design must reflect the equipment and capabilities of the municipality’s operations staff. For example, it may be difficult to maintain sump-based pre-treatment devices without the correct vacuum equipment.
- **Legislative / Sourcewater Protection:** The use of GI/LID features in wellhead protection areas is generally limited to filtration and reuse, unless the sourcewater is clean (i.e. free of road salt).

### *3.4.3 Identify Capabilities (Operations, Maintenance, Budget)*

Similar to the identification of constraints described above, the City should next assess its own capabilities with respect to operating and maintaining GI/LID features – both in terms of the type of GI/LID (i.e. type of maintenance required) as well as overall portfolio size (i.e. volume of maintenance required). The City should only implement GI/LID features that are within the means of the City’s operation and maintenance staff, and budget. For example, it would be unwise to implement a subsurface perforated pipe infiltration system if the City does not have the ability to periodically scope and flush the perforated pipe, and to provide maintenance of upstream pre-treatment devices. This issue was raised several times during the municipal interviews completed.

Operational Capabilities

Discussions with the City of Ottawa and the City of London provided additional context regarding the importance of considering operational capabilities when selecting suitable GI/LID feature types for implementation. In the City of London, for example, many of the currently implemented GI/LID features require collaboration among several departments in order to successfully operate and maintain, including Parks, Public Works, Sewer Operations, Roads, and Stormwater Engineering. While smaller municipalities may not have the same type or number of departmental structures, a clear understanding of who is responsible for what parts of each GI/LID feature will be critical to ensuring the successful implementation of any GI/LID. It was strongly advised that Prince George consider the capabilities of internal departments that will be involved with the operation and maintenance of GI/LID features before including a specific GI/LID type within its implementation portfolio.

Maintenance Capabilities

Interviewees unanimously recommended GI/LID options which include point-source pre-treatment components to maximize the lifespan of GI/LID features and to facilitate maintenance. Although point source pre-treatment techniques are widely preferred among the municipalities consulted, it is recognized that such approaches are not always possible to include as part of feature’s overall design.

In the City of Thunder Bay, pre-treatment requirements are high due to the application of road sand during winter maintenance. Proprietary pre-treatment retrofit devices that are able to directly capture road sand/sediments are not sized correctly to fit within the City of Thunder Bay’s stormwater infrastructure. The City has therefore been forced to use surface inlet pre-treatment techniques which include curb cuts with riprap energy dissipators, which requires laborious manual maintenance in order to remove sediment from the interstices of the riprap. City staff have suggested avoiding the use of riprap as a pre-treatment approach for this reason.

Selecting GI/LID feature types and components which are congruent with the maintenance capabilities of the City has been strongly advised in all discussions that AECOM had with municipal staff as part of this assignment. Considering the maintenance capabilities of the City of Prince George will provide insight into the suitable range of

GI/LID features, as well as the constituent components that are maintainable by the community while providing the desired level of service.

Budget Capabilities

The budget that a municipality has in order to implement, operate, and maintain GI/LID features must also be carefully considered. Smaller communities with modest budgets may struggle to fund the capital, operational and maintenance requirements associated with certain types of GI/LID (e.g. modular proprietary units), so a limited number of implementation options may be available.

During discussions with staff from the City of Thunder Bay, it was noted that the City's 2016 Stormwater Management Plan (SWMP) forms the "backbone" of the City's approach to securing funding for their LID implementation program. In the SWMP, a database was developed which identified 550 locations within public lands where potential LID implementation may be suitable. This database identifies locations, approximate sizes, depths, and other important factors to consider as part of preliminary LID design. The City has used this section of the SWMP to leverage third-party funds, and ultimately build many of their LID projects to date. The City of Thunder Bay has committed to an eight-year program of $500,000 per year, for eight years, to complete LID projects, with support from the federal government. They have accessed over $5 million in funding to date for LID and have built 20 facilities. Having a plan which identified locations and approximate stormwater retention volumes, etc. positioned the City to access Federal funding when grant opportunities became available. This is a method that a smaller City – not unlike Prince George - has used to fund LID projects.

Based on dialogue with municipalities that have followed a similar path to Thunder Bay's siting plan, like the City of Ottawa, the following general steps may be considered.

- Beyond identifying locations, the City of Prince George could complete preliminary designs as a means of confirming site-specific implementation feasibility and obtaining preliminary cost estimates. This information would be useful for obtaining funding and setting budgets for GI/LID projects.
- Pursuing grants: Governmental organizations may provide funding for cities who wish to implement GI/LID, particularly demonstration projects. Examples include:
  - Environmental and climate change-based grants available across Canada;
    - Disaster Mitigation and Adaption (DMAP) fund;
    - CleanBC Communities Fund;
  - Third parties:
    - City of Mississauga, Ontario partnered with TD Bank through their Green Streets program. Partnering with external organizations is an option.

While securing funding is a critical step in the GI/LID implementation process, a City that wishes to do so should carefully consider how to utilize such monies for these types of projects. Improperly designed GI/LID can have high downstream costs that stem from difficulties in operating and maintaining some intricate or difficult-to-access components. The City of Prince George should carefully assess the operability of any GI/LID feature types it considers.

### *3.4.4 Planning for Success*

Understanding the Need for Effective Pre-Treatment

The long-term effectiveness of any GI/LID feature largely depends on two factors: effective pre-treatment and regular maintenance. City staff from Prince George have informed AECOM that winter sand application is a regular road maintenance practice for the community. Sand application is intended to improve road safety by providing traction during icy conditions. In municipalities which employ a similar winter maintenance approach (e.g. Thunder Bay, Calgary, and Sudbury), a recurring item of note was the need to design robust pre-treatment devices for any

GI/LID features which would be expected to receive winter runoff impacted by sand application. Therefore, identifying a range of effective pre-treatment approaches for catch basin and surface inlet GI/LID practices should be a priority for the City. This is a similar recommendation to what the City received from Associated Engineering as part of the Winnipeg St. Outfall Plan. Pre-treatment approaches are discussed later**.** It is strongly recommended that the City recognize the need for a robust pre-treatment approach at this early stage in the GI/LID implementation process and plan accordingly.

Designing with Maintenance in Mind

The City of Ottawa has provided a method they currently use to reduce the operational workload requirements of City staff for their own GI/LID implementations. The City has a Right-of-Way (ROW) team that implements a standard agreement used with community groups in order to permit access to ROW infrastructure (ditches, boulevards, etc.). Community volunteers assist with plant maintenance at several locations where vegetated/landscaped GI/LID features have been implemented. Cities such as Ottawa are finding methods of granting community access to GI/LID infrastructure in a safe and legal manner, which in turns provides operational and maintenance cost savings. This method also gives communities the opportunity to be involved with these important infrastructure improvements, in a safe, engaging, and positive way. The City of Vancouver has a green streets program and boulevard gardening initiative which encourages and supports residents to care for landscaped areas within the public right-of-way[4]. The City of Prince George may wish to utilize a similar approach in order to build community support through active engagement and to reduce the long-term maintenance requirements required of the City's operations group.

Representatives from the City of Ottawa and London have both highlighted the impacts of seasonality and GI/LID location on GI/LID maintenance requirements. Landscapers completing private property maintenance in areas adjacent to GI/LID features have been observed disposing of leaves, grass clippings and branches in some GI/LID features, which are sometime misunderstood to be ditches or depressions where it is acceptable to do so. If the City of Prince George wishes to design and implement GI/LID features within a treed area, then the City should be prepared to handle the increased maintenance requirements associated with removing leaves that may hinder performance. The City of London has used their mascot "Filter Phil" to educate the public on the importance and maintenance of GI/LID features.

GI/LID features should also be designed and installed to minimize irrigation needs. Considerations such as plant selection, timing of planting and size of plants installed (e.g. larger stalks from 2-gallon pots rather than smaller plugs) will all help reduce irrigation needs.

Overcoming Internal and External Barriers

*Education*

In each of the interviews with municipalities and experts, the most commonly reoccurring topic of conversation with AECOM staff pertained to education. There is a need to identify suitable ways to keep relevant parties involved in the GI/LID implementation process educated on the nuanced aspects associated with each feature type. Based on the information gathered in the interviews, the following is strongly advised:

- Educate local engineers and consulting firms on the City's preferred GI/LID options, namely with respect to their design;
- Educate the public regarding the fundamental aspects of GI/LID in a way that the public can understand – what it is, what it does, why it matters to the community, etc.; and
- Educate contractors on how to correctly build GI/LID.

[4] https://vancouver.ca/home-property-development/beautifying-your-boulevard-and-street.aspx *April 2021*

Some designers that may be involved with GI/LID implementation in the City of Prince George may not have the experience necessary to facilitate optimal implementation. For this reason, working with the right designers was identified during the municipal consultation process as an important component for successful GI/LID implementation. Hiring outside consultants from organizations with certified GI/LID professionals is one method for directly obtaining qualified engineers. Having certified engineers with a good track-record of GI/LID design will improve implementation success rates. Likewise, the City could educate their engineering staff internally, possibly by working with the University of Northern B.C. or GI/LID authorities which exist across the country. The City of London has worked with the University of Western Ontario and the City of Toronto has worked with the University of Toronto to monitor the performance of GI/LID features

In addition to developing and/or obtaining qualified designers (whether internal or external) for GI/LID design and implementation, the City will also need to work to ensure that other internal employees are trained in the basics of GI/LID functionality, operations, and maintenance. For example; Parks department staff (which often include a sizable contingent of seasonal or summer staff with a resultingly high turnover rate), maintenance staff, and other departments that will be involved with the GI/LID implementation process will need to be educated on the GI/LID systems they will encounter. Organizations such as the Alberta Low Impact Development Partnership (ALIDP) and the Green Infrastructure Leadership Exchange exist to encourage and teach organizations about GI/LID, and what to consider when developing a detailed approach to LID implementation. The Credit Valley Conservation (CVC) Authority is one of Ontario's 36 watershed-based management agencies and is another resource which offers online webinars on topics ranging from GI/LID design to construction, operation, maintenance, monitoring and more. Education of both internal and external staff at many levels is a key component of successful GI/LID implementation. The Partnership for Water Sustainability in BC[5] and Fraser Basin Council[6] also offer resources to help municipalities in B.C. better manage natural assets and implement GI/LID.

In addition to educating internal staff, municipal representatives also highlighted the importance of educating the broader public. The general public is a key stakeholder in this regard, but they may be unaware or may have misconceptions about the role GI/LID features play in serving their community. When educating the public about GI/LID features, some municipalities have found success by presenting simplified concepts to explain GI/LID features and functions. This includes replacing complex technical terms with those that are easier to understand. For example, GI/LID features are often presented as flood risk reduction and erosion protection features, ecosystems, rain gardens, and pollinator habitats.  Removing the technical language barrier will keep the public engaged and supportive of this progressive approach to managing stormwater and improving the environmental quality within the community.

In both Peterborough and Thunder Bay, Ontario, a rain garden subsidy program exists. These municipalities provide private property owners with a $500 dollar rebate towards any on-property rain garden which is constructed after homeowners complete an online educational training course (approximately two hours in length). Public education seminars ensure that GI/LID features are built correctly. Supporting LID implementation on private property helps build stormwater management education within the community which will build public support for GI/LID implementation.

Representatives from the City of Calgary and the City of London emphasized the importance of utilizing educated contractors for GI/LID installation. Experienced contractors can be difficult to find and, therefore, some organizations have begun to educate and train contractors themselves. Landscape Ontario has created a program to certify contractors as Fusion Landscape Professionals (FLPs). The City of London is hosting a FLP training session to build a local market of landscape contractors qualified to build water-sensitive landscape installations such as rain gardens and other low-tech GI/LID features for residential property owners (https://horttrades.com/fusion). The City of Prince George can use these programs as models should they consider

[5] *https://waterbucket.ca/ April 2021*
[6] *https://www.fraserbasin.bc.ca/ April 2021*

pursuing training for landscapers and contractors who may be engaged as part of a broader GI/LID implementation program. Along with contractor education programs, regular construction inspection also supports successful implementation outcomes. Staff from the City of Thunder Bay recommended full time construction inspection to ensure that features are installed according to design. Construction inspection also serves a dual purpose, as staff can use the time on-site as an opportunity to further educate and build GI/LID knowledge among contractors.

*Accessing Private Lands*

In the Cites of Ottawa, Peterborough, London, and Thunder Bay, Ontario, reimbursement programs have provided a means to engage and compensate private residents for GI/ LID implemented on private property. Private property makes up the majority of the total land fabric in a municipality, therefore it is advantageous to promote the adoption of GI/LID among members of the public. For example, rain garden programs which reimburse residents a portion of the installation costs have been successful in Thunder Bay, London, and Peterborough. Rain garden programs for private property have been especially successful as rain gardens are not an overly complex GI/LID feature type and can be more easily embraced by the public. However, some municipalities have had less success in promoting the adoption of GI/LID features on private property due to the logistics and administration required to implement such programs. Alternatively, partnerships can also be made with commercial and industrial developments and educational institutions, which would allow for increased access to private property, while reducing administration costs. Private property access expands the potential locations for GI/LID implementation and may therefore be of interest to the City of Prince George when identifying suitable ways to achieve its stormwater management goals.

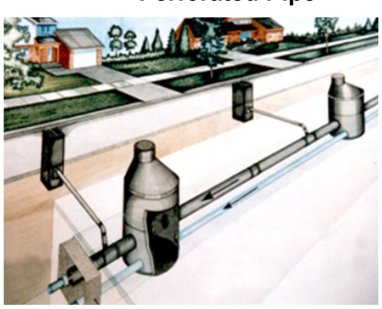
## 3.5 Options for Prince George

A summary of the broad range of GI/LID feature types that may be considered by the City of Prince George is provided in Table 14. Pre-treatment techniques and devices which would be beneficial to the City of Prince George are presented in **Section 3.6**.

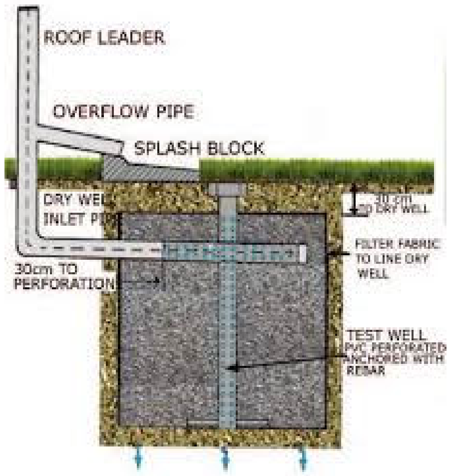
Note that GI/LID's may not be suitable in areas where there is a high risk of pollutants that cannot easily be dealt with through pre-treatment facilities (i.e. certain industrial areas). The table shows GI/LID options for private property and within public right-of ways. The advantage of having GI/LID features on private property is that rainfall is being managed where it lands, and the City does not need to bear the burden of maintenance. The downside is that it is typically more difficult to ensure the long-term survivability of GI/LID features installed on private property. Some municipalities ensure maintenance of on-site GI/LID features through a stormwater credit program (i.e. the property owner only gets their credit if they can provide evidence of maintenance), through the business license renewal process (for non-residential properties), and/or through easements or registration on title that allows the City to inspect and maintain the features.

**Table 14 LID Options**

| LID Types | Description |
|---|---|
| **Bioswale – Right-of-way**<br> | - Consist of open channel surface conveyance within the boulevard areas, commonly behind a curb<br>- Small check dams incorporated within bioswale designs can be used to detain surface water and to promote infiltration/filtration through filter media.<br>- A small amount of retention storage can be incorporated within such designs in order to ensure that water is available for vegetation throughout the interceding periods between rainfall events. |

| LID Types | Description |
|---|---|
| **Bioretention Cell**<br> | - Bioretention facilities provide filtration and attenuation of stormwater runoff. A subsurface retention area can be incorporated within the design to provide groundwater recharge benefits as well, depending on the opportunities and constraints in the area.<br>- Bioretention cells differ from bioswales, as bioretention is focused on volume reduction and water quality treatment (without a conveyance function), while bioswales serve to convey runoff and provide pre-treatment and water quality improvements |
| **Soil Systems**<br><br><br>The example pictured is a supported soil system. | - Soil systems are typically proprietary, and provide effective, modular on-site SWM by means of absorption, interception, and evapotranspiration.<br>- Soil cells typically require low/no maintenance.<br>- Alberta is one of the world's leading implementers of soil cells in North America.<br>- Examples of proprietary soil systems include Silva Cells, Storm Tree, Deeproot, City Green and Blue Green Urban.<br>- The City of Prince George has implemented these systems in front of City Hall and is looking to install them elsewhere. |
| **Permeable Interlocking Concrete Pavement (PICP)**<br> | - PICP can be used to infiltrate stormwater runoff from sidewalk, multi-use trails and parking lots that don't receive winter sanding.<br>- PICP can be configured to incorporate a subsurface granular storage reservoir in order to attenuate and retain additional stormwater runoff. |
| **Perforated Pipe**<br> | - Perforated pipe systems consist of a subsurface perforated pipe located either within a boulevard or underneath the travelled surface of the roadway.<br>- Perforated pipe systems receive runoff and retain a portion of the runoff within a surrounding gravel envelope. |

<table>
<tr><th>LID Types</th><th>Description</th></tr>
<tr><td>Chamber System<br></td><td>- Chamber or crate-style systems are installed underground, such as beneath parking lots.<br>- These systems receive runoff and attenuate stormwater flows. They are readily adaptable and can be modified to provide partial retention of stormwater.<br>- Chamber systems can be designed for peak flow attenuation, erosion control, as well as water quality treatment.</td></tr>
<tr><td>Rain Garden<br></td><td>• A rain garden is a landscaped LID feature that is meant to replace an area of land to collect stormwater runoff from surrounding pervious and impervious surfaces.<br>• Rain Gardens offer stormwater infiltration benefits, a natural method of water quality improvement, increased flood prevention, and potential stream channel erosion control (in areas with low native soil infiltration rates).<br>• Rain Gardens are often recommended to be installed on private lands, due to the low maintenance requirements involved post-implementation. In addition, rain gardens may attract birds, butterflies, and beneficial mosquito-repelling insects. Rain Gardens complement any type of landscape found in a neighborhood.<br>- Rain Garden incentive programs are commonly used by municipalities to achieve stormwater management goals in a City through private land access.</td></tr>
</table>

<table>
<tr><th>LID Types</th><th>Description</th></tr>
<tr><td>


Soakaway Pit
</td><td>
<ul>
<li>A Soakaway is a simple excavation with sidewalls lined using geotextile fabric. The excavations are filled with void forming material, such as granular stone, which receives runoff from a perforated inlet pipe. The runoff can infiltrate slowly through the pit, into the surrounding native soil.</li>
<li>Soakaways offer stormwater infiltration benefits, water quality improvement and potential stream channel erosion control (at low infiltration rates).</li>
<li>Soakaways may increase the risk of groundwater contamination in areas where concentration of chlorine and sodium from road de-icing salts in urban runoff are high. Soakaways are therefore recommended in urban locations where sand is used as the primary method of winter maintenance, such as many of the residential locations in the City of Prince George, but rather should only receive relatively clean runoff, such as from rooftops</li>
<li>Soakaways are commonly installed on private lands. Property owners need to be educated on the routine and long-term maintenance requirements of the implemented Soakaways (which are minimal).</li>
<li>Soakaway installation on private lands can be used in conjunction with an incentive program, such as a storm sewer user fee; based on the area of impervious cover on private land that is connected to a storm sewer. Alternatively, Soakaways can be installed in stormwater easements (between private lands), or in an expanded right-of-way, where municipal staff can access the facilities to assist with maintenance when required.</li>
</ul>
</td></tr>
<tr><td>

Bioswale – private property
</td><td>
<ul>
<li>A Bioswale is an open channel LID feature occasionally installed in new and existing residential developments.</li>
<li>Bioswales provide stormwater conveyance, attenuation, and nominal water quality treatment. When designed appropriately, bioswales provide infiltration benefits as well.</li>
<li>These features provide a conveyance function. In private property settings, this may result in the drainage of stormwater across two or more private properties. Municipalities have highlighted the difficulties of enforcing the function and use of such features in a rear yard setting. Property owners may fill in their section of a bioswale or place a backyard fence through the swale – both of which prevent the correct functioning of the LID.</li>
<li>Municipalities caution against rear-yard bioswale implementation without an easement or without having such features registered on title to ensure their protection for the long-term.</li>
<li>The City of Prince George is looking at installing a bioswale at the new Fire Hall in Carrie Jane Gray Park.</li>
</ul>
</td></tr>
</table>

LID features are customizable to suit site constraints and meet stormwater management objectives; as such, many different configurations exist. The aforementioned examples are not intended to be exhaustive, but rather they are intended to provide a broad representation of LID options which may be suitable in the City of Prince George. Preferred/recommended LID feature types will change based on the desired SWM goals of a City, as highlighted in **Section 3.4**. For example:

- Stormwater volume control goals can be met through the use of underground infiltration galleries;

- Large-scale protection against flooding can be provided by subsurface chamber systems;
- Water quality protection and/or improvement goals can be met by a focus on pre-treatment application and bioretention cells for water filtration;
- Climate change resiliency goals are best met with a combination of systems, including bioretention, EES Etobicoke exfiltration system (EES), etc., and
- Increasing property values can be achieved though a combination of well designed, aesthetically pleasing LID features.

Minnesota is considered a leader in green stormwater infrastructure in cold climates in North America. The green infrastructure section of its stormwater manual[7] would be a good resource for the City of Prince George as it looks to implement an LID strategy.

High level cost estimates for different LID features can be determined using the following costing tool from the Toronto Region Conservation Authority's Sustainable Technologies program.
https://sustainabletechnologies.ca/lid-lcct/

### *3.5.1 Considering Lessons Learned*

The representatives and experts that were interviewed have provided the City of Prince George with key takeaways derived from their LID implementation experiences thus far, summarized below.

*City of Peterborough, ON*

- Permeable Parking Lots
    - These are particularly beneficial in winter climates. Water is able to quickly infiltrate through surface pavers, resulting in less standing water, reducing the need for sand and salt application.
    - In order for permeable parking lots to maintain their infiltration capabilities, designs must take into consideration expected traffic loads. Over-compaction of compressible materials (e.g. topsoil within paving stones) due to higher than expected traffic has been a recurring issue, reducing infiltration capabilities.
    - Peterborough's permeable parking lots consist of concrete paving stones interlaid with a sod surface. Over-compaction of the sod also reduces the ability of grass to grow between paving stones.
- Peripheral Bioswales
    - The City advises careful consideration of hydrology, specifically as it pertains to the depth of the local water table, when designing and implementing bioswales. Bioswales located below the water table will not meet their function of promoting infiltration.

*City of London, ON*

- Rain Garden Subdivision Retrofits
    - Homeowners were given treatment options for their boulevards (i.e. sod or flowers) as part of a City subsidized boulevard rain garden retrofit program. The City noted that homeowners provided better upkeep to sod retrofits as opposed to flowers. The City has now defaulted to a sod/simple grass finish for such projects unless homeowners specifically ask otherwise.
- Structurally supported soil systems (e.g. Silva cells)

---

7 https://stormwater.pca.state.mn.us/index.php?title=Green_Stormwater_Infrastructure_(GSI)_and_sustainable_stormwater_management

- The City's Forestry department is hesitant to allow irrigation of trees from stormwater that contains salt (i.e. winter road run-off). Preventing salt from impacting the trees can be incorporated into the design and this needs to be communicated to stakeholders (i.e. Parks staff). Note that the City of Prince George has developed tree and plant lists to help residents, developers and landscapers choose salt tolerant species (see Appendix B).

*City of Ottawa, ON*

- Roadside Retrofit Bioretention Units
  - The City of Ottawa experienced high vegetation mortality when bioretention units were online during the early stages of plant development. The City recommends keeping bioretention units offline until vegetation is well established to ensure vegetation can flourish when exposed to regular pulses of ROW runoff.
  - Inlet maintenance and grading requires more consideration and attention to detail than was initially anticipated. An inlet with insufficient grading will not allow for adequate inflow of stormwater, particularly during high-intensity events. Sediment and debris can block inlets that are too small, thereby leading to ever greater bypass.
  - Trash accumulation is a common problem in roadside retrofits; therefore, a municipality needs to consider the existing road design and surrounding land use.
- Boulevard Bioretention
  - In constrained retrofit applications, the City has observed that only very limited surface storage within such features is possible.
  - Surrounding tree-cover provides too much shade for some plants to develop within the features, therefore plants need to be selected accordingly.
  - Damage to cast iron curb inlets and garden edgings was noted during snow removal activities – this was specific to bioretention bump outs. As a result, bump-outs should only be considered in certain locations and designed accordingly.

Additional details related to the above can be found in the summarized interview transcripts provided in **Appendix A**.

## 3.6 Pre-Treatment

Winter sand application is a regular maintenance practice for the City of Prince George; therefore, pre-treatment methods and devices are recommended to be used in conjunction with LID features to improve water quality, reduce maintenance and increase LID longevity.

There are numerous pre-treatment devices available, many of which are suitable for use in retrofit applications within existing infrastructure (i.e. catch basins and manholes). Other pre-treatment devices and approaches are applicable to surface inlets and include a mix of proprietary and non-proprietary elements. Examples of both surface and catch basin inlet devices are described below. Choosing a preferred device for the City of Prince George should be done in conjunction with Operations staff.

3. Devices Installed within Precast Infrastructure:

a) Catch Basin Shield

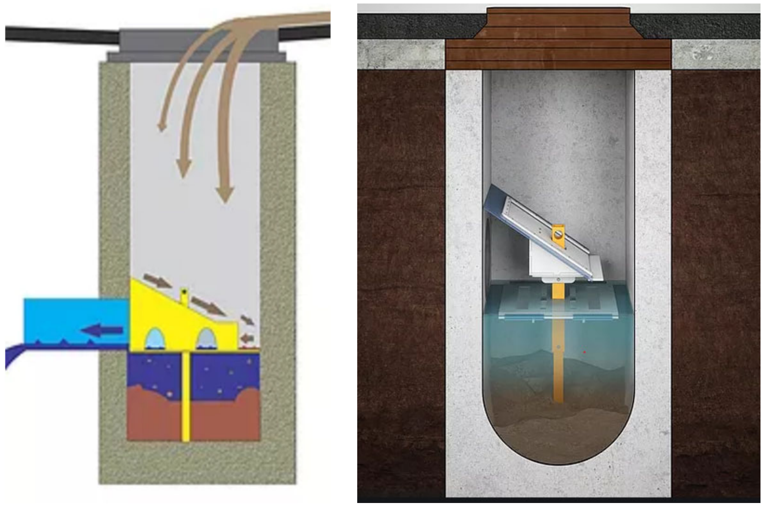


**Figure 5 Catch Basin Shield (CB Shield, 2021)**

- The CB Shield is a proprietary insert placed in a catch basin.
- The system functions by allowing sediment to settle between designed slots, while water flows towards the outlet.
- The insert prevents sediment in CB sumps from being washed into the outlet waterways during high flows.
- The system features an adjustable leg for height alteration to fit various catch basin sizes. Installation requires less than two minutes of time.
- The device can reach 80% TSS removal.

b) Catch Basin Pre-treatment Snout


**Figure 6 Catch Basin Pre-Treatment Snout (BMP, 2021)**

- A catch basin pre-treatment Snout is installed on the outlet of a catch basin.
- Heavy particles sink within the sump, while a vented hood skims off floatable debris and free oils.
- A variety of variations and enhancement components exist; from hydrocarbon capture skirts to simple trash collection in stormwater runoff.
- New models have also been developed to reduce turbulence and velocity in runoff, further increasing sediment capture.

c) EnviroHood

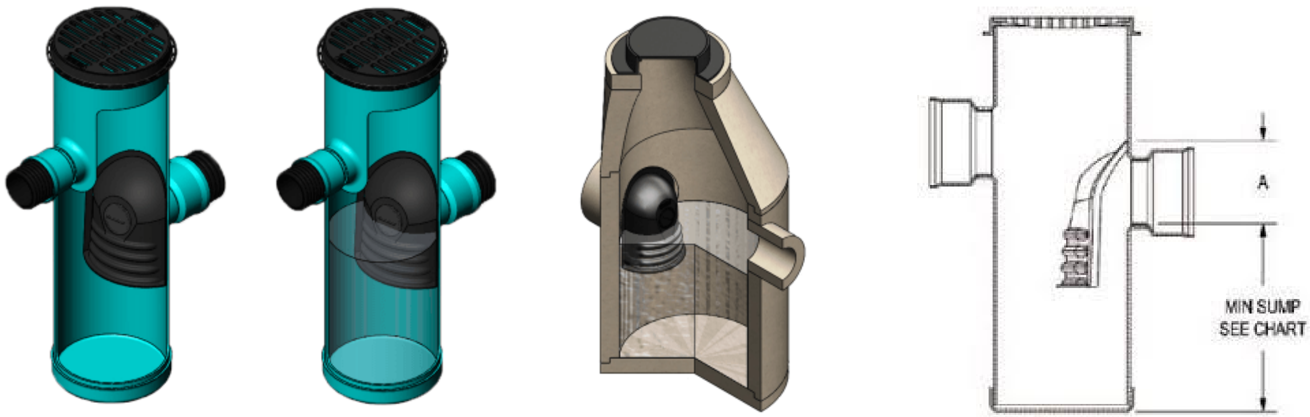



**Figure 7 EnviroHood (ADS, 2021)**

- EnviroHoods are stormwater management devices that are installed on the inside of catch basins and manholes.
- They provide effective pre-treatment of floating debris and oil in stormwater runoff.
- Molded from High Density Polyethylene (HDPE).

d) LittaTrap

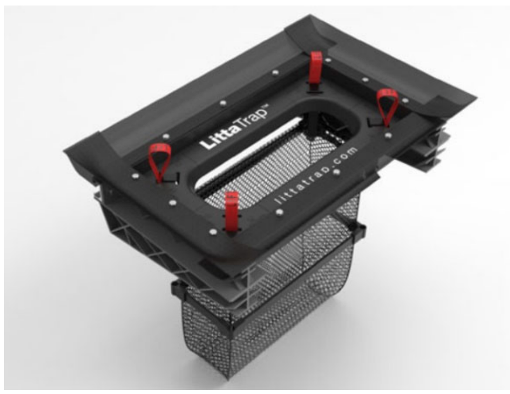



**Figure 8 Littatrap (Enviropod, 2021)**

- The patented stormwater management retrofit design reduces the energy of inflowing water to capture total suspended solids (TSS) in the basket and sump system.
- Stores all the captured dry gross pollutants.
- Comes in a range of sizes to fit most catch basins.

4. Surface Inlet Pre-Treatment:

a) Rain Guardian Bunker

**Figure 9 Surface Inlet Pre-Treatment - Rain Guardian Bunker (Rain Guardian, 2021)**

- Lightweight and durable and can support over 300 lbs (136 kg) on the top grate.
- Easily installed in rain gardens and bioretention units.
- Quick and easy cleanout/maintenance.
- Well suited for residential applications.

b) Rain Garden Bunker

**Figure 10 Surface Inlet Pre-Treatment - Rain Garden Bunker (Rain Guardian, 2021)**

- The Rain Guardian Bunker is a type of bioretention pre-treatment unit that captures stormwater from a surface inlet.
- The device consists of a recycled plastic build which provides weather and corrosion resistance.
- The device achieves 60-90% solids reduction in stormwater runoff.

### *3.6.1 Site Specific Feasibility Screening Criteria*

When working with specific candidate sites for LID implementation, feasibility screening criteria, as presented in Table 15, should be considered. These criteria should be considered during the early selection and design phases of LID implementation for any given candidate site.

**Table 15 Feasibility Assessment Criteria for LID Design and Selection**

| Criteria | Description |
|---|---|
| **Outlet Location** | Ability of the LID system to discharge to a suitable outlet or overflow (storm sewer or watercourse) based on capacity, elevations, and additional infrastructure requirements. |
| **Overflows** | Ability of inlet elevations of stormwater to the LID feature to remain congruent with the location of overflow appurtenances; ensure adequate freeboard is maintained and that LID features do not surcharge onto roadways or otherwise impact drainage system functionality. |
| **Topographic/ Elevation Constraints** | Ability of the proposed LID servicing option to be integrated within the existing/proposed grades without the need for significant alteration. This would include all surface and sub-surface infrastructure. |
| **Influent Location(s)** | The ability of LID features to accept stormwater at or below grade via curb inlet or daylighted CB lead according to ultimate road/area design. Also includes the ability of a given LID system to receive runoff from multiple point-source inlets. |
| **Stormwater Quality** | Ability of LID features to function in the face of anticipated sediment/water quality pollutant loadings; risk of clogging and ease of long-term maintenance. |
| **Groundwater** | LID feature's ability to maintain desired separation between the base of the feature and the seasonally high groundwater elevation (typically 1m). |
| **Utility Conflicts** | Proposed LID system must not conflict with existing or proposed utilities; SWM approach must be able to be integrated within existing land use topology. |
| **Road Structure** | Ability of the proposed LID system to be integrated within the proposed streetscape without compromising the road subbase due to prolonged saturation within bearing soils or within the travelled ROW. Long-term design life of the SWM feature must also not be compromised. |
| **Safety and Sightlines** | Ability of proposed LID system to be integrated within the proposed road design without compromising vehicle sightlines or pedestrian safety. LID system must meet loading requirements if placed within 1 m of any travelled area. |
| **Drainage Functionality** | LID system must satisfy SWM objectives (filtration, attenuation, and retention to the extent possible) without sacrificing or placing at risk the conveyance capacity or functionality of the remaining drainage system. Conveyance of drainage from external areas, risk of road surface ponding and possible surcharging are all impacts to be considered. |
| **Vegetation Viability** | Ability of surface vegetated practices to thrive with little to no maintenance, including long-term irrigation. Vegetation and planting beds (if present) must also be resistant to invasive species, salt, freeze-thaw and weeds. |
| **Maintenance Requirements** | Proposed LID measures must be resilient in the face of day-to-day operation and require minimal regular maintenance while reliably providing a high level of service to the surrounding area even during winter rainfall events or freeze-thaw periods. Inlets need to be chosen carefully to minimize maintenance needs in the winter (i.e. an inlet design that does not need to be regularly cleared of snow). |
| **Cost Effectiveness** | Relative cost of the various LID options which satisfy all other criteria and constraints. |

## 3.7 Recommendations for Prince George

AECOM conducted interviews with municipalities and organizations in several regions of the country to provide the City of Prince George with introductory guidance intended to support the City with the development of a successful LID implementation strategy. The information presented follows the general steps that should be taken when developing an LID implementation program. Past successes, challenges, and lessons learned shared by municipal representatives from many jurisdictions have been included with the goal of avoiding unnecessary challenges in Prince George. LID feature and components - including pre-treatment devices - have been presented which would be suitable to the City of Prince George.  This report can be used as a guide during the early stages of LID design and installation in the City. The steps toward LID implementation can be summarized as follows:

- Identify goals based on existing and emerging SWM issues;
- Identify budget, maintenance, climatic and operational constraints;
- Identify internal capabilities and external opportunities to fund the construction, operation, and maintenance of LID features;
- Plan for success by:
    - Maximizing service life through effective pre-treatment;
    - Designing all features with maintenance in mind; and
    - Overcoming internal and external barriers through education and private landowner partnerships.

# 4. Subdivision & Development Servicing Bylaw and Design Guidelines

A subdivision and development servicing bylaw allows a city to regulate the subdivision and development of land in order to promote the orderly and economic development of a city. The bylaw sets the requirements for the provision of works and services for development. This includes Infrastructure Specifications, similar to those found in the Master Municipal Construction Documents (MMCD).

The City's Design Guidelines were developed in 2001 to guide engineers and the development industry in the design of engineering servicing facilities and systems. The Design Guidelines have been noted as "Draft" since 2001 and are not enacted by bylaw. However, they are used to provide the minimum design criteria and standards for proposed works. Stormwater related items addressed include the widths of rights of ways, utility separation, drainage principles, storm runoff computation, minor system design, major system design, storage facility design (including ponds, constructed wetlands and channel storage), infiltration facilities, other storage options and pump stations.

The City of Prince George is currently reviewing its Subdivision & Development Servicing Bylaw and draft Design Guidelines to identify any required or desired updates. We have reviewed the stormwater sections of the City's Subdivision & Development Servicing Bylaw and draft Design Guidelines as well as similar bylaws and design guidelines from other municipalities. With input from City staff, we have identified a number of issues and proposed solutions for the City to consider as it revises its Subdivision & Development Servicing Bylaw and draft Design Guidelines. Identified issues include:

- Climate Change (updated IDF, 1:10 year, min pipe size/slope etc.);
- Stormwater volume/rate and quality controls, including the use of green infrastructure and LID;
- Design requirements for the sizing of oil and grit separators and access for maintenance;
- Erosion and sediment control;
- Standards for culverts, detention ponds and liners (for relining sewers); and
- Maximum allowable sewer/culvert grades and requirements for energy dissipation to avoid the wearing out of pipes.

## 4.1 Climate Change and Design Storms

The draft Design Guidelines were prepared in 2001 and the Intensity-Duration Frequency (IDF) curve presented in the guidelines, which is based on Environment Canada's weather station at the Prince George Airport, dates from 1997. Since then Environment Canada has updated the IDF curve for the airport, which needs to be revised in draft Design Guidelines.

Historically and increasingly, it has been found that intense rainfalls can be very localized in nature. Therefore, a single rain gauge may not capture (i.e. may miss) some significant rainfalls and may underreport rainfall frequency within a municipality. This is why many municipalities are setting up multiple rain gauges within their municipalities to better capture local rainstorms and to define design storm frequency more accurately. This was further discussed in Section 2.0.

In addition to recent increases in rainfall intensity, it is projected that the City will experience even greater increases in rainfall intensity due to climate change. Since most stormwater infrastructure that is currently being installed is designed to last over 50 years, it is important that infrastructure design considers future increases in rainfall intensities.

The Design Guidelines state that the minor system design storm is the 5-year storm, however the City is now requiring the 10-year storm. This is a great first step for increasing capacity to manage more intense rainfalls. The Design Guidelines need to be revised to state that the 10-year storm is the design storm for the minor system. The City is working to implement a new rainfall monitoring program that will refine the City's IDF curve and can be used to help project future climate projections. Until this program is implemented, the City could apply the 30% increase projected by the University of Western Ontario's IDF CC tool to help design infrastructure for future rainfall amounts (https://www.idf-cc-uwo.ca/).

The City of Prince George also experiences other rainfall events that are less intense but may cause flooding due to snow and frozen catch basins. The City may want to provide a range of design events for consideration, such as:

1. Intense rainfall – 10-year design storm;
2. Rain on snow event – 2-year storm; 100% imperviousness – minor and major system available; and
3. Rain on snow event with frozen catch basins – 2-year storm; 100% imperviousness – only major system available.

The City's Design Guidelines stipulate runoff coefficients to be used in the determination of stormwater flows for the design of drainage system components. Run-off coefficients, which range from zero to one are used specifically to estimate the proportion of rainfall that reaches the stormwater system. The higher the coefficient the greater the proportion of rainfall that runs off into the stormwater system. Paved areas such as roadways have a high run-off coefficient and landscaped areas have a low run-off coefficient. It is recommended that the City review the run-off coefficients that it specifies in its Design Guidelines (see Table 5.3.5.2.1 in the Design Guidelines). Currently the City specifies a runoff coefficient of 0.1-0.25 for Parks, Playgrounds, Cemeteries and Agricultural Land. The City of Greater Sudbury specifies a runoff coefficient of 0.1-0.35 for these land use types. Whereas the City of Surrey specifies a run-off coefficient of 0.25-0.3 for these land use types. Using too low of a run-off coefficient would result in design engineers underestimating the amount of run-off and under sizing stormwater infrastructure.

The City is currently developing a Climate Action Workplan to identify priorities in five-year increments. The recommendations in this TWP are in line with comments expressed at the recent Climate Action Workshop; particularly with respect to post-construction vegetation survivability, changing climate (e.g. greater stormwater flows), overland flow from frozen catch basins, and the benefits of infiltrating stormwater back into the ground.

## 4.2 Stormwater Controls

The Subdivision and Development Servicing Bylaw could be used as a tool to enact current best practises in stormwater management as it pertains to stormwater runoff rates, volumes, and quality. Setting stormwater controls can be performance based (e.g. infiltrate and/or retain the first 25 mm of rainfall) or prescriptive (e.g. maximum impermeable areas, disconnected downspouts and the construction of rain gardens and boulevard swales) or a combination of both (e.g. a developer can construct required features or meet the performance target). A performance-based approach tends to work better in a municipality where developers are well-versed in the design and construction of low impact development (LID) as it typically requires modeling, analysis, and the knowledge of the performance of different LID features. As the City of Prince George is relatively new in the use of LID features, it may want to consider a combined approach where it offers a prescriptive option that is easy for developers new to LID to follow but to also provide a performance based option that offers flexibility to those developers who may have specific constraints and can successfully develop an effective LID strategy.

Stormwater volume, rate and quality restrictions can be applied to private property and public rights-of-way at the time of development or redevelopment. The City's Design Guidelines do offer options for managing the quantity of stormwater (e.g. storage and infiltration facilities) but do not specify exactly how much needs to be stored or infiltrated during frost free periods as well as during winter months. Many municipalities require post-development flows to match pre-development flows. Note that this must be done carefully so that it does not increase the duration of erosive forces on downstream channels. This can be achieved by controlling stormwater volumes (e.g. through infiltration, vegetative uptake, and evapotranspiration) as well as by controlling discharge rates from storage facilities below the erosive velocity of the downstream channel.

In order to manage the quantity of stormwater the City's Design Guidelines outline the design of stormwater storage facilities and stormwater infiltration facilities. More specifically the Design Guidelines provide general design parameters and specific requirements that must be considered and addressed in the planning and design of stormwater storage facilities as well as the requirement for a maintenance and service manual. The Design Guidelines also outline general design requirements that must be considered in the planning and design of stormwater infiltration facilities. The City's Subdivision and Development Servicing Bylaw provides a standard drawing for a recharge chamber. The City would benefit from providing more specific requirements for the design and maintenance of stormwater infiltration facilities on private property and within the road rights-of-way.

Section 17 of the City of Edmonton's Drainage Design Standards[8] outlines design criteria that applies to the design of LID facilities including bioretention gardens, bioretention basins, box planters and soil cells. Section 17.6 of Edmonton's Standards addresses cold climate design considerations. The City of Edmonton's Low Impact Development Best Management Practices Design Guide addresses the design of other LID facilities.

The City of Surrey's Design Manual provides details on the design of infiltration trenches and the associated Standard Drawings provide a typical infiltration trench details.

The City's current DG specify that no new ditches shall be created for servicing land development projects on Municipal rights-of way, except in designated lowland areas in the floodplains where poor soil exists. However, with a growing interest in low impact development to moderate stormwater flows, the City may want to consider allowing ditches and other open channels.

When considering whether to use/permit an open channel or a buried pipe the City should consider many factors such as:

- Whether it is fish-bearing;
- Desired aesthetic;
- Maintenance;
- Topography/slope;
- Soil types/erodibility; and
- Need to control flows.

The table below outlines when channels or pipes may be more desirable.

**Table 16 Evaluation of Open Channels vs. Pipes**

| Asset type | Preferred | Undesirable |
|---|---|---|
| **Open channel** | • If small reductions in velocity (i.e. 1% slope) and volume are desired (help downstream system) | • If it is a street with high levels of contamination (oil, debris, sediment etc.) that would be difficult to contain/clean within an open channel<br>• Areas with high levels of pedestrian traffic and on-street parking (i.e. downtown areas) |
| **Pipe** | • If no reduction in velocity is desired (i.e. <0.5% slope)<br>• If high velocity is expected (i.e. >4% slope) | • In general (i.e. under normal conditions) open channels better mimic the natural water balance and help reduce and detain stormwater |

[8] *https://www.edmonton.ca/residential_neighbourhoods/documents/Volume_3_Drainage_.pdf*

| | | |
|---|---|---|
| | • A road with high levels of contamination (oil, debris) that would be easier to contain and clean within a traditional curb and gutter, CB/OGS configuration | |

## 4.3 Oil Grit Separators

Prince George's Design Guidelines do not include design requirements for oil-grit separators (OGS). Design requirements would help the City and developers determine the appropriate sizing for any OGS as well ensure proper access for maintenance. The City of Surrey's Design Criteria Manual (Section 5.6 and associated Standard Drawings[9]) provides a good example of design requirements for oil-grit separators Surrey's design criteria also requires that the Consultant provide an operation and maintenance (O&M) manual and outlines what should be included. The City of Surrey's Design Criteria are schedules to the City's Subdivision and Development By-law.

Note that the locations or property types that require oil-grit separators are outlined in the City of Prince George's Storm Sewer Bylaw (Section 2.9). Recommendations for amending the types of properties or locations (such as prior to discharge to a fish-bearing watercourse) that require an oil-grit separator are outlined in Technical Working Paper #3. Note that some municipalities such as the City of Surrey reiterate the property types that require an oil-grit separator within their Design Guidelines.

## 4.4 Erosion and Sediment Control

The City's existing bylaws do not have the required provisions to ensure erosion and sediment control (ESC) best practices are followed. The Storm Sewer Bylaw prohibits discharge for sediment (>500 ppm) which is significantly higher than best practice and requires laboratory testing to confirm. The City of Prince George's Design Guidelines only requires developers to produce erosion and sediment control plans for certain types of development. The City does not specify what the ESC plans should contain nor that they be prepared and monitored by a qualified professional. Whereas, the City of Kelowna requires developers to retain a Qualified Professional (P.Eng., RPBio, P.Ag, AScT, CPESC, CISEC or CESCL) responsible for inspecting and monitoring the ESC Facilities (Schedule 4 of Kelowna's Subdivision, Development and Servicing Bylaw - Bylaw 7900). It is important that negative environmental and infrastructure impacts and resulting liability from insufficient erosion and sediment control lies with the developer and not the City.

In order to improve erosion and sediment control associated with all development including the clearing of land before subdivision, the City has investigated the development of a new Erosion and Sediment Control Bylaw. However, the City is currently considering the strengthening of existing bylaws, particularly the Subdivision and Development Servicing Bylaw, to help address some of the ESC issues. Updating the development and building permit requirements to extend the need for an ESC plan to more types of development and requiring the services of a Qualified Professional for ESC in larger developments would help strengthen ESC requirements associated with new development. Also adding requirements to the Subdivision and Development Servicing Bylaw with respect to vegetation such as how soon it needs to be installed and minimum survivability (e.g. 80% survivability after one year).

## 4.5 Culverts

Developers will construct road crossing culverts as required for new development, but it is then typically up to City to maintain and renew these culverts at the end of their service life. Corrugated steel pipes (CSP) are typically cheaper to install but the material's lifespan is shorter, on average, than other pipe materials such as concrete or HDPE. Allowing developers to install pipes with shorter lifespans creates a greater financial burden on the City as

[9] https://www.surrey.ca/sites/default/files/media/documents/DesignCriteria.pdf

the City will be required to repair or replace the culvert earlier than if other pipe materials were used. The advantage to metal pipes such as CSP is that is allows for easy locating in the winter when culverts need to be cleared for drainage. However, non-metal pipes could be constructed with a metal component (e.g. metal collars or imbedded steel) to facilitate winter locates.

The City's Subdivision and Development Servicing Bylaw (Section 02641 in Division 2) only lists corrugated steel pipe as an option for constructing culverts. The City should reconsider allowable culvert materials, particularly in areas known to have corrosive soils.

Any crossings (driveway or road) of fish-bearing streams should be constructed using an open bottom structure (typically concrete) to maintain a natural channel bottom and facilitate fish passage. The City is planning to meet with the Province to discuss which culverts need to be made fish passable. Some streams (e.g. high up in the Parkridge watershed) are noted as "fish inferred" but they are dry for portions of the year. The City can use the environmental assessment associated with each of the Watershed Drainage Plans to help determine which channels would likely provide valuable fish habitat if culverts were made fish passable.

The City's Design Guidelines, Subdivision and Development Servicing Bylaw or Storm Sewer Bylaw do not address who owns driveway culverts and who is responsible for their maintenance, repair, renewal and upgrading, when required It is important to specify whether it is the City or the property owner who is responsible for driveway culverts. We will be conducting a survey with municipalities across Canada to determine how other municipalities handle driveway culvert maintenance and renewal.

## 4.6 Detention Ponds

Prince George's Design Guidelines recommend the use of wet ponds, dry ponds, and constructed wetlands for controlling the flow of stormwater. We have identified the following areas where the Design Guidelines could be improved with respect to stormwater detention ponds:

- Provide design details for constructed wetlands. Currently the Design Guidelines only provide design details for wet ponds and dry ponds;
- The design details do not mention the need to provide an area adjacent to the pond that would be suitable for the dewatering of removed sediment during maintenance;
- The design details do not mention the need to provide upstream treatment (e.g. oil-grit separator) in areas where excessive sediment or contamination may be a concern (e.g. industrial areas, arterial roadways or high-crash intersections); and
- The design details do not mention the need to provide a bypass so that the pond can be "closed" for maintenance or to contain any spills.

The City of Ottawa has a comprehensive manual on the design of stormwater management facilities which would be a good reference for the City of Prince George.

As previously mentioned, it is important that ponds and their outlets are properly designed so that they do not increase downstream channel erosion. This can occur if the outflow from the ponds extend the duration of "medium" flows that exceed the scour velocity of a channel. The Varsity Creek ravines have experienced erosion due to development and the resulting flow from the upland areas. The upland area is cleared of trees which greatly increases run-off and ponds can make things worse if they just increase the duration of erosive forces.

The Design Guidelines specify that designers must provide a maintenance manual for each pond designed. The Guidelines should also require what the maintenance manual shall include and cost estimates for completing the recommended maintenance activities so that the City can better plan future maintenance needs. Section 16.5 of the

City of Edmonton's Drainage Design Criteria[10] outlines what shall be included in a stormwater management facility's Maintenance and Service Manual. Some cities will also ask the developer to complete or pay for the maintenance until the community that the pond services is mostly or completely built out.

The City should not accept detention ponds until after vegetation is established, the vegetation is shown to survive (e.g. 80% survivability after one year) and the performance of the pond is proven over an extended period. The UniverCity development on top of Burnaby Mountain requires all on-site GI/LID features and ponds to be monitored for performance for a minimum of two years before the ponds are accepted by the City of Burnaby.

Temporary detention ponds used for erosion and sediment control during construction should be addressed in the City's Erosion and Sediment Control requirements. The City of Burnaby outlines clear erosion and sediment control needs during construction, including the performance and maintenance of temporary detention ponds[11]

## 4.7 Relining – Fish Friendly Standards

The Design Guidelines do not provide details on relining options for City storm sewers. Relining is not often an option for deteriorated storm sewers since they may require upsizing due to increased development, higher design standards and climate change. However, when upsizing is not required and relining is an option, design engineers should be provided some guidance on acceptable relining options and protocols that do not adversely affect the downstream natural environment

The main concern of culvert/storm sewer relining is that it is an outdoor plastic manufacturing process (installing and curing), which is a less controlled environment when compared to regular manufacturing that could happen in a factory (more controlled environment). During the curing, cutting, and handling (if poorly done) of the installed material, some chemical products could be emitted/produced, which could have some impacts on the natural environment. There have been some reported unwanted environmental consequences (fish kill and water contamination) in different locations across North America due to some high levels of certain chemicals. Relining of a culvert within a fish bearing stream must also be evaluated to ensure fish-passage after construction, particularly as relining typically reduces the diameter of the culvert. There are also health and safety concerns as some gases are produced during the curing process, and if workers are not wearing proper PPE (protective personal equipment), it may cause some health implications.

In general, the chemical contamination incidents that were reported was mostly found to be attributed to the improper handling of the material by the contractor. This could be due to reduced quality assurance/control measures during the installation and curing and/or poor specifications that did not establish control measures to limit consequences.

Generally, the most utilized material for lining contains styrene products and is one of the main materials used in the City of Toronto in rehabilitating storm, combined and sanitary sewers. There has been some utilization of non-styrene products that are believed to have less of an environmental impact. However, there is no definitive research that explicitly states the fact that this material has zero environmental consequences from a chemical and environmental perspective. But some cities request to use non-styrene resins in outfalls or places that are closer to water bodies.

Generally, the use of lining, whether it is styrene or non-styrene, should have enough specifications to enhance the material handling and installation process to minimize the environmental impacts. In addition, there are some instances where contractors are advised to use the UV method instead of hot water or steam in the curing process. This could also reduce some environmental and health impacts. UV is generally more expensive than hot water or

[10] [10] *https://www.edmonton.ca/residential_neighbourhoods/documents/Volume_3_Drainage_.pdf*
[11] *https://www.burnaby.ca/Assets/Sediment+Control+Information.pdf*

steam. In cases hot water is used for curing, this water may need to be collected by a vacuum truck and disposed of at a specific location but not to flow through the system.

There is a list of recommendations/specifications to minimize environmental impacts of lining that should be considered when tendering such a job, including but not limited to:

- Contractor shall capture particles and shavings created during any CIPP cutting activities and not permit entry into the environment. This capture activity may include but is not limited to a portable device to capture emitted particulate dust.
- Contractor shall not permit floating materials to enter the surface water or nearby vegetation.
- Materials deposited on the particle collection mat or barrier material shall be collected and disposed of.

The City may only want to consider relining culverts/sewers that are not fish-bearing nor upstream of fish-bearing channels until the City is comfortable that local contractors can adequately minimize environmental impacts. More information about relining and other methods for extending the life of storm mains are provided in **Section 8**.

## 4.8 Basements

In areas where there are no storm sewers (e.g. ditches only) or a high groundwater table (e.g. swamp) basements can be problematic. Allowing basements in these areas can lead to the following problems:

- Dependence on pumps to manage flow from perimeter drains;
- Illegal cross connections (i.e. perimeter drains) are tied to the sanitary system; and
- Excessive flow in the storm system (e.g. from perimeter drains that are essentially “draining” the swamp).

In the absence of a geotech report requirement, the City can amend the Subdivision & Development Servicing Bylaw and/or OCP Bylaw to provide stronger clauses that limit basements in designated areas with supporting inspection/enforcement to prevent the aforementioned problems from occurring.

## 4.9 Education

The City of Prince George recognizes the value of providing education material to better inform developers, contractors, and property owners of the requirements within the Subdivision & Development Servicing Bylaw and associated Design Guidelines and how to achieve them. The City has already produced some development related educational material but understands that there are still gaps, where additional information should be provided. In particular the City sees the need to produce lot grading related information similar to the Lot Grading Guidelines provided by the City of Edmonton.[12]

Lot grading information would be particularly useful in the communication of cross drainage easement agreements and the need to maintain backyard swales throughout development and occupancy. After development this becomes a civil matter between two property owners, but issues are often brought to the City and the City would benefit from improved public information.

As the development of individual homes or duplexes are exempt from the Subdivision & Development Servicing Bylaw, lot grading of individual properties would be better addressed in the Building Bylaw.

[12] https://www.edmonton.ca/programs_services/documents/ResidentialGuidelines.pdf March 2021

## 4.10 Maintenance

The success of the Design Guidelines is dependent on a good supporting maintenance program. For instance, sediment traps that are shown in the Design Guidelines will only be successful if they are periodically cleaned of the collected sediment. In addition, a regular storm maintenance program that includes street sweeping, catch basin sump cleaning and ditch cleaning will also help remove sediment from the system, protect natural assets and reduce the frequency and cost for sewer and pond cleaning.

The Storm Sewer Bylaw defines service connections as “the pipe which may include an inspection chamber or clean out connecting a storm sewer to the drainage system constructed upon private property.” Section 3.8.3 of the Subdivision & Development Servicing Bylaw states “Provide cleanout on service line at location indicated” but does not provide any more details. The Design Guidelines do not make any reference to clean-outs.

## 4.11 Grades

The City’s Design Guidelines (DG) state that the maximum velocity in an unlined ditch shall be 1 m/s. The DG states that on steep slopes, grade control structures may be used to reduce velocities, but they do not state a maximum slope for ditches. With respect to sewers the DG state that where design velocities are supercritical or in excess of 2 m/s, special provision shall be made to protect against displacement of sewers by erosion or shock. No upper limit to flow velocities or grades in storm sewers is defined. However, when supercritical flow does occur (where steep grades are utilized) the designer shall provide appropriate analysis and justification and make provisions in the design to ensure that structural stability and durability concerns are addressed. Flow throttling or energy dissipation measures to prevent scour will be required to control the flow.

## 4.12 Cover

The City’s DG states that “storm sewers shall be installed at a depth lower than the frost line that is generally at a depth of about 2.2 m and be able to service properties on both sides of the roadway”. This is significantly deeper than other municipalities, such as the City of Waterloo which have a minimum cover of 1.5 m. The DG do not specify a maximum depth of cover, just stating that pipes deeper than allowable for Class III pipe must be specially designed for their specific conditions. The City has conducted a study related to depth of cover in other municipalities and is considering reducing the amount of cover due to climate change.

## 4.13 Catch Basins

The City of Prince George’s DG do not mention the need for bike friendly catch basins or manhole covers. City of Surrey requires bicycle friendly top/side inlet style catch basins on all arterial roads per their standard drawings. These types of inlets can also help with snow and leaves.

The City of Prince George’s DG state that catch basins shall be provided at upstream end of radius at intersections and at low points. They go on to state that low points are not to be located within curb returns at intersections. The City of Vancouver’s Engineering Design Manual goes a bit further by specifying that catch basins are not to be located in painted cross walks or curb ramps. The Vancouver manual specifies that catch basins are to be located at the beginning of the curb return or higher side of crosswalk.

The City of Prince George’s Subdivision and Development Servicing Bylaw provides a reference drawing for a corrugated steel catch basin. A concrete catch basin would have a greater lifespan, on average, particularly in corrosive soils.

## 4.14 Application

The Design Guidelines are only effective if they are actually applied. The City can help promote application by:

- Mandating adherence of the Design Guidelines within the Subdivision and Development Servicing Bylaw;
- Having enough well-trained staff to review designs by designers, contractors, and developers; and
- Educating developers, designers, contractors, and City staff on the requirements within the Design Guidelines, Subdivision and Development Servicing Bylaw and Storm Sewer Bylaw.

## 4.15 Miscellaneous

The City's Subdivision and Development Servicing Bylaw and Design Guidelines do not provide standard drawings or a process for utility disconnects.

# 5. Development Contributed Assets

As per the City's Subdivision & Development Servicing Bylaw and Drainage DCC Bylaw, development is required to construct and/or contribute to the construction of stormwater assets. In this section we will outline issues related to development contributed stormwater assets and full life-cycle costs for these assets.

As previously mentioned, the Design Guidelines state that developers must provide an O&M manual for any newly constructed stormwater pond. However, the Design Guidelines do not require estimated O&M costs to complete the recommended activities within the O&M manual. The Design Guidelines should be amended to require the provision of O&M cost estimates for any new ponds.

## 5.1 Life Cycle Costs for Development Contributed Stormwater Assets

The life cycle costs of various stormwater assets are provided in the following table to assist the City when approving developments and to assist with planning for ongoing maintenance after the assets are taken over by the City. Descriptions of the various columns are described below.

- 2021 Unit Cost: Cost to construct the asset on a per unit basis (e.g. $ per metre or $ per pond)
- Annual maintenance cost: Average cost per year to inspect, clean and repair the asset on a per unit basis
- ESL: Estimated Service Life
- Cost/unit (1 life cycle): The total capital and maintenance costs for an asset over its estimated service life
- LCC/unit (100 years): The life cycle costs include the total capital and maintenance costs for an asset over a 100-year span. It could represent multiple life spans. The goal is to normalize costs between assets with different life spans.

The cost estimates were consolidated from various stormwater asset management plans completed for Canadian municipalities. The cost estimates in the table do not include monitoring costs (e.g. water quality sampling or flow monitoring).

### Table 17 Life Cycle Costs for Typical Stormwater Assets

| Asset Type | Details | Unit | 2021 Unit Cost | Annual Maintenance Cost ($/Uni | ESL (years) | Cost/unit (1 life cycle) | LCC/unit (100 years) |
|---|---|---|---|---|---|---|---|
| Drainage Pipe | Gravity - PVC - 250 mm | m | $492 | $0.70 | 80 | $548 | $685 |
| Drainage Pipe | Gravity - PVC - 300 mm | m | $564 | $0.70 | 80 | $620 | $775 |
| Drainage Pipe | Gravity - PVC - 375 mm | m | $636 | $0.70 | 80 | $692 | $865 |
| Drainage Pipe | Gravity - PVC - 450 mm | m | $708 | $0.70 | 80 | $764 | $955 |
| Drainage Pipe | Gravity - PVC - 525 mm | m | $780 | $0.70 | 80 | $836 | $1,045 |
| Drainage Pipe | Gravity - PVC - 600 mm | m | $876 | $0.70 | 80 | $932 | $1,165 |
| Drainage Pipe | Gravity - Conc - 675 mm | m | $936 | $0.70 | 80 | $992 | $1,240 |
| Drainage Pipe | Gravity - Conc - 750 mm | m | $1,080 | $0.70 | 80 | $1,136 | $1,420 |
| Drainage Pipe | Gravity - Conc - 900 mm | m | $1,104 | $0.70 | 80 | $1,160 | $1,450 |
| Drainage Pipe | Gravity - Conc - 1050 mm | m | $1,284 | $0.70 | 80 | $1,340 | $1,675 |
| Drainage Pipe | Gravity - Conc - 1200 mm | m | $1,584 | $0.70 | 80 | $1,640 | $2,050 |
| Drainage Pipe | Gravity - Conc - 1350 mm | m | $1,848 | $0.70 | 80 | $1,904 | $2,380 |
| Drainage Pipe | Gravity - Conc - 1500 mm | m | $1,980 | $0.70 | 80 | $2,036 | $2,545 |
| Drainage Pipe | Gravity - Conc - 1800 mm | m | $2,124 | $0.70 | 80 | $2,180 | $2,725 |
| Drainage Pipe | Gravity - Conc - 2100 mm | m | $2,520 | $0.70 | 80 | $2,576 | $3,220 |
| Culvert | CSP 400-450 mm | m | $570 | $0.70 | 30 | $591 | $1,970 |
| Culvert | CSP 525 mm | m | $650 | $0.70 | 30 | $671 | $2,237 |
| Culvert | CSP 600 mm | m | $700 | $0.70 | 30 | $721 | $2,403 |
| Culvert | CSP 675 mm | m | $722 | $12.50 | 30 | $1,097 | $3,657 |
| Culvert | CSP 750 mm | m | $745 | $12.50 | 30 | $1,120 | $3,733 |
| Culvert | Conc 900 mm | m | $1,104 | $12.50 | 80 | $2,104 | $2,630 |
| Culvert | Conc 1050 mm | m | $1,284 | $12.50 | 80 | $2,284 | $2,855 |
| Culvert | Conc 1200 mm | m | $1,584 | $12.50 | 80 | $2,584 | $3,230 |
| Culvert | Conc 1350 mm | m | $1,848 | $12.50 | 80 | $2,848 | $3,560 |
| Culvert | Conc 1500 mm | m | $1,980 | $12.50 | 80 | $2,980 | $3,725 |
| Culvert | Conc 1800 mm | m | $2,124 | $12.50 | 80 | $3,124 | $3,905 |
| Culvert | Conc 2100 mm | m | $2,520 | $12.50 | 80 | $3,520 | $4,400 |
| Ditch | | m | $50 | $5.00 | 50 | $300 | $600 |
| Biofiltration Swale | | m | $500 | $83.33 | 25 | $2,583 | $10,333 |
| Infiltration Trench | | m | $380 | $83.33 | 25 | $2,463 | $9,853 |
| Rain Garden | | m | $500 | $83.33 | 25 | $2,583 | $10,333 |
| Catch Basin | | Ea | $3,500 | $45.00 | 80 | $7,100 | $8,875 |
| Manhole | | Ea | $5,000 | $32.50 | 80 | $7,600 | $9,500 |
| Dry Detention Pond | | Ea | $150,000 | $1,000 | 50 | $200,000 | $400,000 |
| Wet Detention Pond | | Ea | $250,000 | $1,000 | 25 | $275,000 | $1,100,000 |

# 6. Risk Assessment

Risk can be defined as a product of the probability of asset failure (PoF) and the consequences of asset failure (CoF) or criticality as shown below.

**Risk = Probability of Failure × Consequence of Failure**

AECOM developed a network level risk assessment and prioritization methodology that considers condition, capacity, and criticality (e.g. potential impact of failure). The risk prioritization methodology was developed starting with the risk framework within the 2009 RIVA Business Process Maps and then refined based on available information/data and in consultation with Prince George staff.

The tables below show the prioritization methodology, or scoring system, used to determine the risk of the City's Stormwater Assets for each main asset type. The scoring system is based on a scale of 1 to 10 where 10 represents the highest risk. 50% of the risk score is based on an asset's probability of failure and 50% of the risk score is based on an asset's consequence of failure.

**Table 18 Risk Scoring Methodology: Stormwater Mains and Culverts**

| PoF/CoF Weighting | | Sub- Weighting | | Description | Score | Data source |
|---|---|---|---|---|---|---|
| 50% | Probability of Failure | 35% | Flow Deficiency | insufficient capacity for 5 yr design storm | 10 | WDP |
| | | | | none | 0 | |
| | | 25% | Repair history | > 1 repair | 10 | Cityworks |
| | | | | 1 repair or multiple inspections | 5 | |
| | | | | none | 0 | |
| | | 40% | Condition | 0 remaining ESL or found to be in bad condition | 10 | GIS |
| | | | | 0-10 yr remaining ESL | 8 | |
| | | | | 10-20 yr remaining ESL | 6 | |
| | | | | 20-30 remaining ESL | 4 | |
| | | | | 30-40 remaining ESL | 2 | |
| | | | | > 40 yr remaining ESL | 0 | |
| 50% | Conse quence of Failure | 35% | Pipe Flow | ≥ 900 mm | 10 | GIS |
| | | | | 750 | 8 | |
| | | | | 675 | 6 | |
| | | | | 600 | 5 | |
| | | | | 525 | 4 | |
| | | | | 450 | 3 | |
| | | | | 375 | 2 | |
| | | | | ≤300 mm | 1 | |
| | | 25% | Zoning (bylaw 7850 - class) | Business, Industrial, Commerical, Utility, site specific | 10 | GIS |
| | | | | recreation & Institution | 6 | |
| | | | | residential | 4 | |
| | | | | rural | 2 | |
| | | 20% | Downstream receiving environment (catchment) | Immediately discharges to a fish/inferred fish bearing channel/body downstream | 10 | GIS |
| | | | | Eventually flows to a fish bearing body (ie farther downstream) | 5 | |
| | | | | No fish habitat before Fraser/Nechako | 2 | |
| | | 20% | Cover surface | arterial | 10 | GIS |
| | | | | collector | 6 | |
| | | | | local | 4 | |
| | | | | lane | 3 | |
| | | | | non-road surface | 1 | |

**Table 19 Risk Scoring Methodology: Pump Stations**

| PoF/CoF Weighting | | Sub-Weighting | | | Score | Data source |
|---|---|---|---|---|---|---|
| 50% | Probability of Failure | 30% | Redundancy | No back-up pump | 10 | Condition assessment report |
| | | | | Back-up pump | 0 | |
| | | 35% | Condition - pump | Condition assessment score <50 | 10 | GIS & Condition assessment report |
| | | | | Condition assessment score 50-60 | 8 | |
| | | | | Condition assessment score 60-70 | 6 | |
| | | | | Condition assessment score 70-80 | 4 | |
| | | | | Condition assessment score 80-90 | 2 | |
| | | | | Condition assessment score >90 | 0 | |
| | | 35% | Condition - facility | Condition assessment score <50 | 10 | |
| | | | | Condition assessment score 50-60 | 8 | |
| | | | | Condition assessment score 60-70 | 6 | |
| | | | | Condition assessment score 70-80 | 4 | |
| | | | | Condition assessment score 80-90 | 2 | |
| | | | | Condition assessment score >90 | 0 | |
| 50% | Conse quence of Failure | 50% | Flow (size) | > 200 hP | 10 | GIS |
| | | | | >100 hP | 7 | |
| | | | | >50 hP | 5 | |
| | | | | 25-50 | 4 | |
| | | | | 10-25 | 3 | |
| | | | | 5-10 | 2 | |
| | | | | <5 | 1 | |
| | | 25% | Adjacent Land Use | ICI (industrial commerical institutional); environmentally sensitive area | 10 | GIS |
| | | | | multi-residential | 7 | |
| | | | | residential | 4 | |
| | | | | agricultural/ park | 3 | |
| | | | | undeveloped/forest | 0 | |
| | | 25% | Adjacent cover surface | arterial | 10 | GIS |
| | | | | collector | 6 | |
| | | | | local | 4 | |
| | | | | lane | 3 | |
| | | | | non-road surface (eg park) | 1 | |

**Table 20 Risk Scoring Methodology: Channels**

| PoF/CoF Weighting | | Sub-Weighting | | | Score | Data source |
|---|---|---|---|---|---|---|
| 50% | Probability of Failure | 100% | Condition | known problem area | 10 | WDP |
| | | | | none | 0 | |
| 50% | Conse quence of Failure | 35% | Flow (down stream culvert) | ≥ 900 mm | 10 | GIS |
| | | | | 750 | 8 | |
| | | | | 675 | 6 | |
| | | | | 600 | 5 | |
| | | | | 525 | 4 | |
| | | | | 450 | 3 | |
| | | | | 375 | 2 | |
| | | | | ≤300 mm | 1 | |
| | | 25% | Zoning Class | Business, Industrial, Commerical, Utility, site specific | 10 | GIS |
| | | | | recreation & Institution | 6 | |
| | | | | residential | 4 | |
| | | | | rural | 2 | |
| | | 20% | Downstream receiving environment (catchment) | Fish bearing/infered fish | 10 | GIS |
| | | | | Eventually flows to a fish bearing channel (ie farther downstream) | 5 | |
| | | | | No fish habitat before Fraser/Nechako | 2 | |
| | | 20% | Adjacent surface (<20 m) | arterial | 10 | GIS |
| | | | | collector | 6 | |
| | | | | local | 4 | |
| | | | | lane | 3 | |
| | | | | non-road surface | 1 | |

**Table 21 Risk Scoring Methodology: Catch Basins**

| PoF/CoF Weighting | | Sub-Weighting | | | Score | Data source |
|---|---|---|---|---|---|---|
| 50% | Probability of Failure | 50% | Issue | known problem area; multiple maintenance visits | 10 | Cityworks |
| | | | | none | 0 | |
| | | 50% | Condition | 0 remaining ESL or found to be in bad condition | 10 | GIS |
| | | | | 0-10 yr remaining ESL | 8 | |
| | | | | 10-20 yr remaining ESL | 6 | |
| | | | | 20-30 remaining ESL | 4 | |
| | | | | 30-40 remaining ESL | 2 | |
| | | | | > 40 yr remaining ESL | 0 | |
| 50% | Conse quence of Failure | 35% | Land Use | Business, Industrial, Commerical, Utility, site specific | 10 | GIS |
| | | | | recreation & Institution | 6 | |
| | | | | residential | 4 | |
| | | | | rural | 2 | |
| | | 25% | Downstream receiving environment (catchment) | Immediately discharges to a fish bearing channel/body downstream | 10 | GIS |
| | | | | Eventually flows to a fish bearing body (ie farther downstream) | 5 | |
| | | | | No fish habitat before Fraser/Nechako | 2 | |
| | | 40% | Cover surface | arterial | 10 | GIS |
| | | | | collector | 6 | |
| | | | | local | 4 | |
| | | | | lane | 3 | |
| | | | | non-road surface | 1 | |

**Table 22 Risk Scoring Methodology: Storm Storage Basins/Ponds**

| PoF/CoF Weighting | | Sub-Weighting | | | Score | Data source |
|---|---|---|---|---|---|---|
| 50% | Probability of Failure | 100% | Condition (pond assessment) | Poor | 10 | Detention Pond Inspection report 2014 |
| | | | | Fair | 6 | |
| | | | | Unknown | age (see below) | |
| | | | | Good | 2 | |
| | | | | Brand New | 0 | |
| | | 100% (if condition unknown) | Age | > 25 year | 10 | GIS |
| | | | | 20-25 yr | 8 | |
| | | | | 15-20 | 6 | |
| | | | | 10-15 yr | 4 | |
| | | | | 2-10 yr | 2 | |
| | | | | < 2 yr | 0 | |
| 50% | Conse quence of Failure | 35% | Storage Capacity | large (capacity > 10,000) | 10 | GIS |
| | | | | medium (1000-10,000) | 6 | |
| | | | | small <1000 m3 | 3 | |
| | | 20% | Zoning | Business, Industrial, Commerical, Utility, site specific | 10 | GIS |
| | | | | recreation & Institution | 6 | |
| | | | | residential | 4 | |
| | | | | rural | 2 | |
| | | 25% | Downstream receiving environment (catchment) | Immediately discharges to a fish bearing channel/body downstream | 10 | GIS |
| | | | | Eventually flows to a fish bearing body (ie farther downstream) | 5 | |
| | | | | No fish habitat before Fraser/Nechako | 2 | |
| | | 20% | Cover surface within 50 metres | arterial | 10 | GIS |
| | | | | collector | 6 | |
| | | | | local | 4 | |
| | | | | lane | 3 | |
| | | | | non-road surface | 1 | |

**Table 23 Risk Scoring Methodology: Inlets**

| PoF/CoF Weighting | | Sub-Weighting | | | Score | Data source |
|---|---|---|---|---|---|---|
| 50% | Probability of Failure | 50% | Repair history | > 1 inspection | 10 | Cityworks |
| | | | | others | 0 | |
| | | 50% | Condition | 0 remaining ESL or found to be in bad condition | 10 | GIS |
| | | | | 0-10 yr remaining ESL | 8 | |
| | | | | 10-20 yr remaining ESL | 6 | |
| | | | | 20-30 remaining ESL | 4 | |
| | | | | 30-40 remaining ESL | 2 | |
| | | | | > 40 yr remaining ESL | 0 | |
| 50% | Conse quence of Failure | 35% | Pipe Flow | ≥ 900 mm | 10 | GIS |
| | | | | 750 | 8 | |
| | | | | 675 | 6 | |
| | | | | 600 | 5 | |
| | | | | 525 | 4 | |
| | | | | 450 | 3 | |
| | | | | 375 | 2 | |
| | | | | ≤300 mm | 1 | |
| | | 25% | Zoning | Business, Industrial, Commerical, Utility, site specific | 10 | GIS |
| | | | | recreation & Institution | 6 | |
| | | | | residential | 4 | |
| | | | | rural | 2 | |
| | | 20% | Classification of Channel | Fish presence/fish inferred channel (immediately downstream) | 10 | GIS |
| | | | | Within a catchment that has fish (farther downstream) | 5 | |
| | | | | No fish habitat before Fraser/Nechako | 2 | |
| | | 20% | Cover surface | arterial | 10 | GIS |
| | | | | collector | 6 | |
| | | | | local | 4 | |
| | | | | lane | 3 | |
| | | | | non-road surface | 1 | |

The City has one dam, the Shane Lake Dam. The risk scoring of the dam was based on the 2020 Shane Lake Dam Failure Consequences Classification Report. The dam was given the following risk scores:

- PoF: 4, since beaver activity could cause a risk failure

- CoF: 10, since dam failure could threaten downstream property and human safety

The data and risk scoring framework was entered into Innovyze's InfoAsset Planner to calculate the risk for the various stormwater assets. These scores can be used to inform sustainable infrastructure management within the City through prioritization of inspection, maintenance, rehabilitation, and renewal of linear and non-linear stormwater infrastructure. The outputs of the model could also be used as inputs to the City's asset management system Powerplan, GIS and into any MS-Excel file. The City will be provided an Excel file with PoF, CoF and risk score by AssetType and AssetID.

The assets are given a risk score from 0 to 10, where:

- Very low risk: 0-2;
- Low risk: 2-4;
- Moderate risk: 4-6;
- High Risk: 6-8; and
- Very high risk: 8-10.

The risk scores for the City's stormwater assets by type can be seen in the following figures.

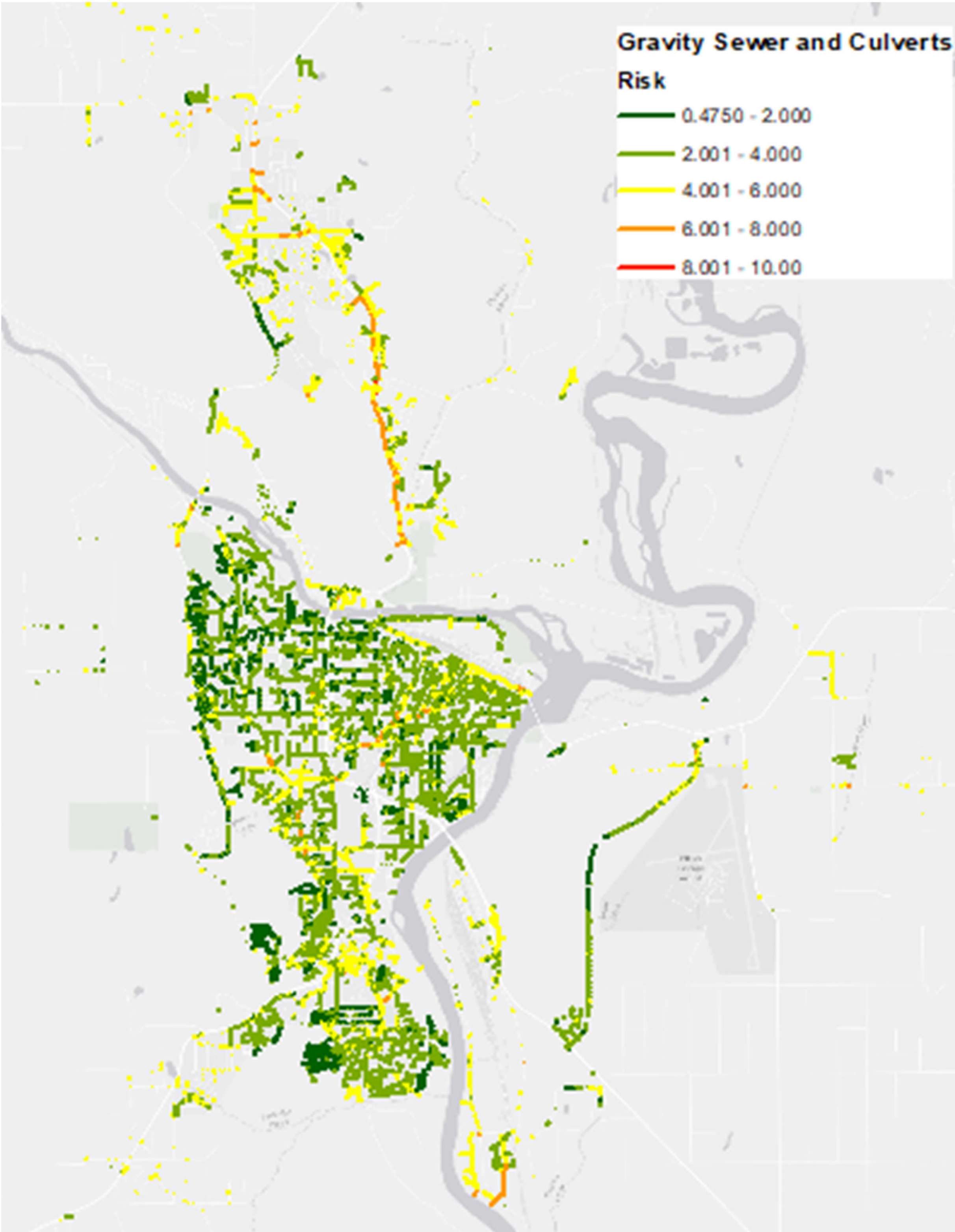



**Figure 11 Risk Score for Sewer Mains and Culverts**

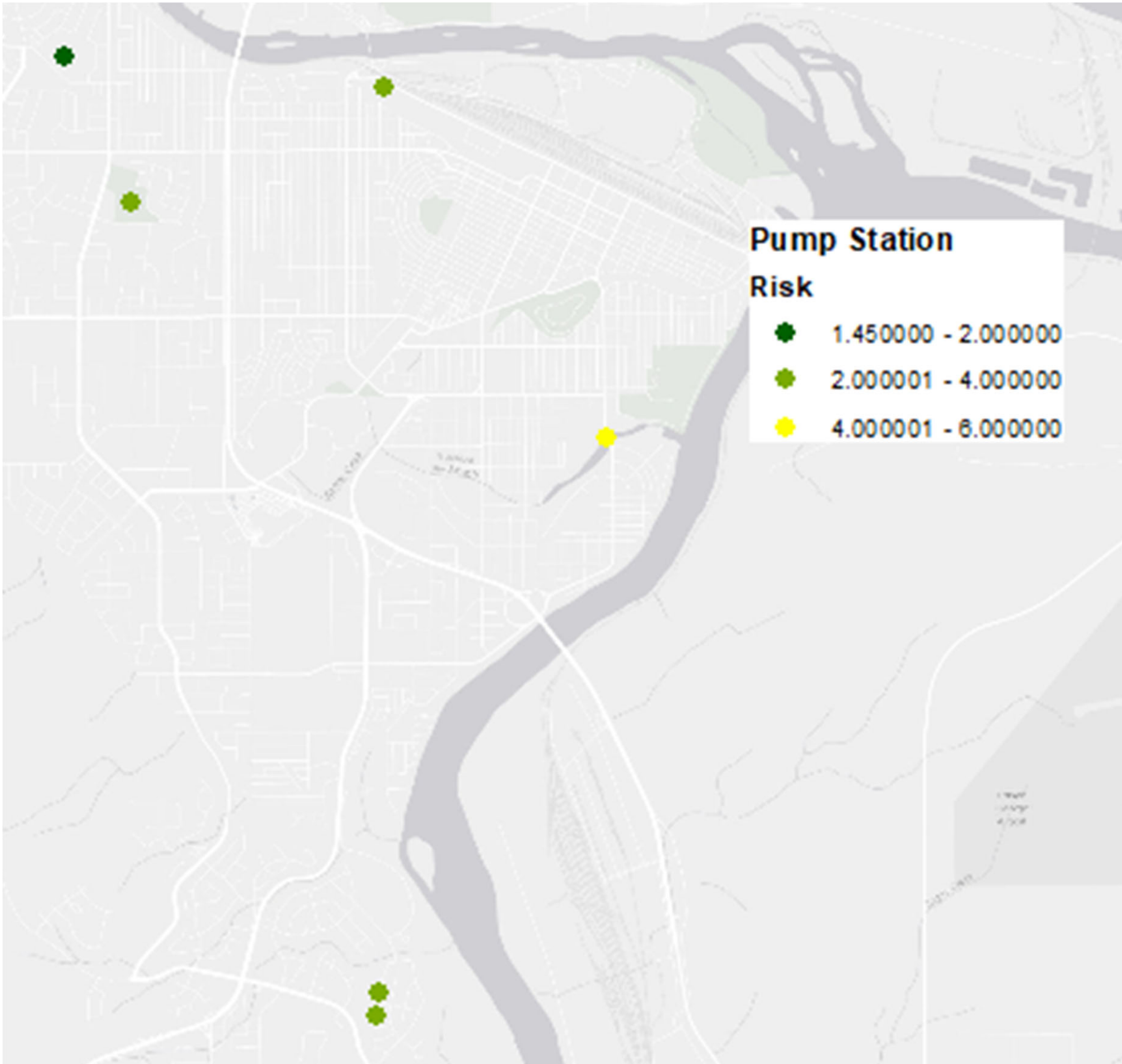



**Figure 12 Risk Score for Pump Stations**

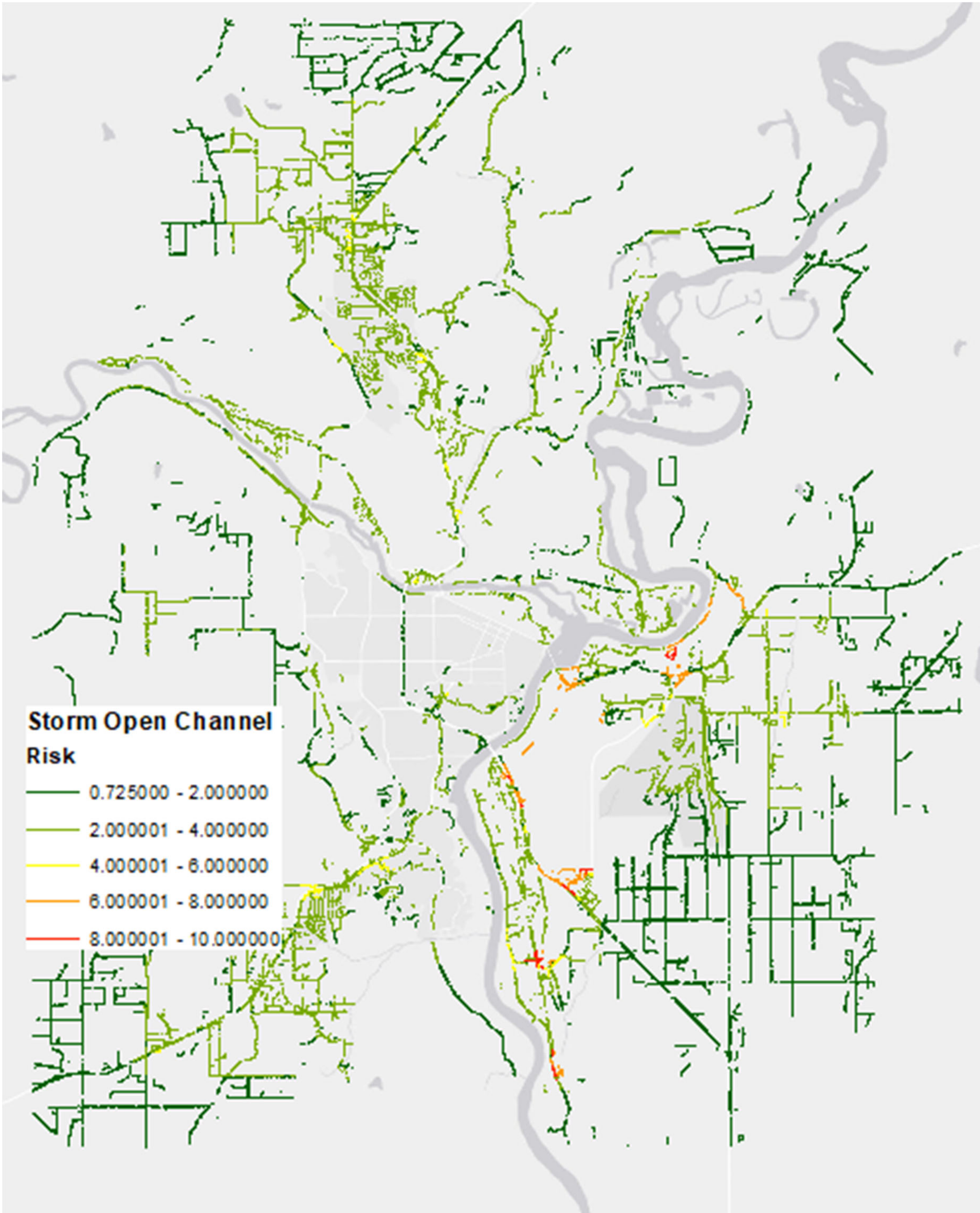



**Figure 13 Risk Score for Channels**

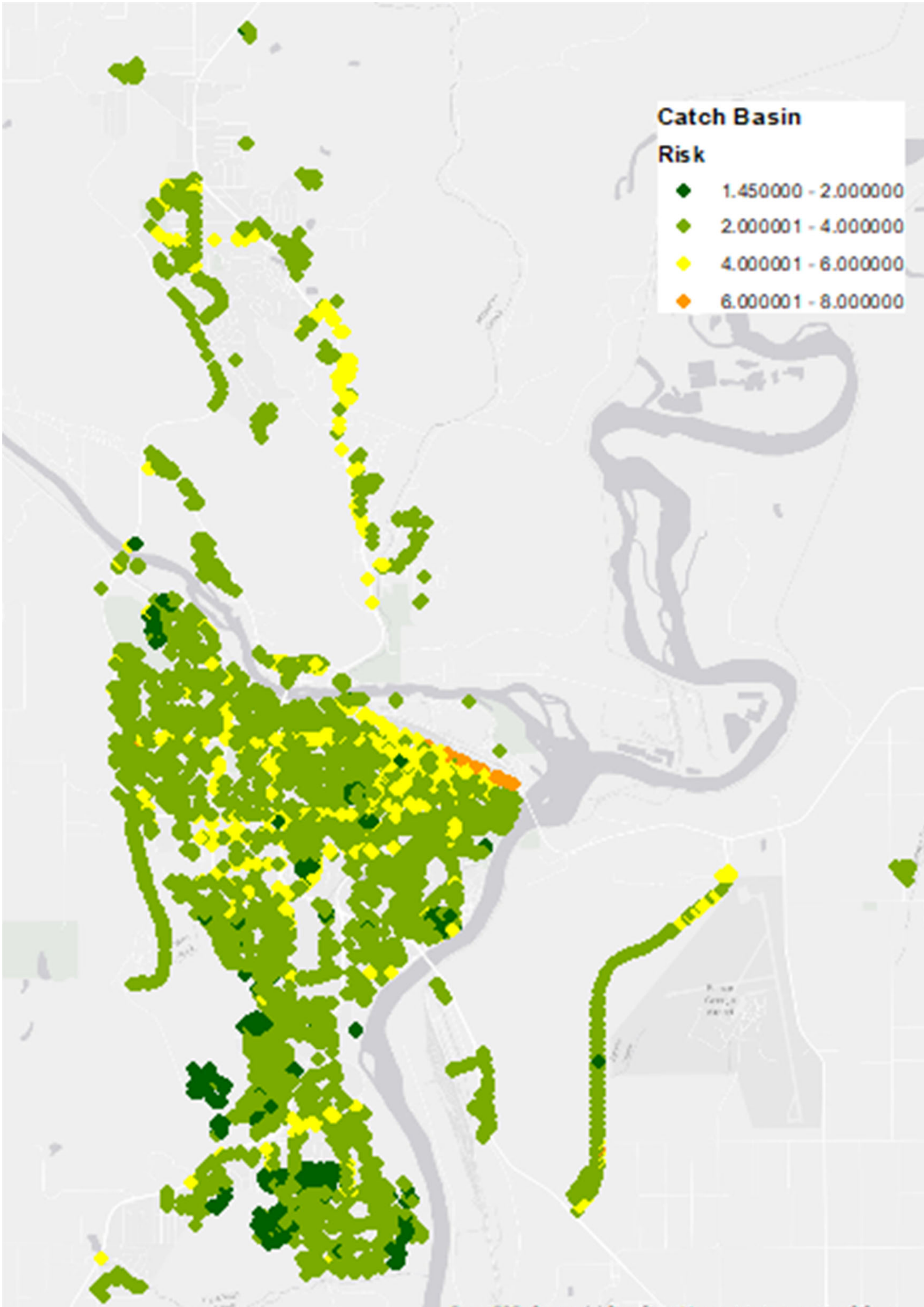



**Figure 14 Risk Score for Catch Basins**

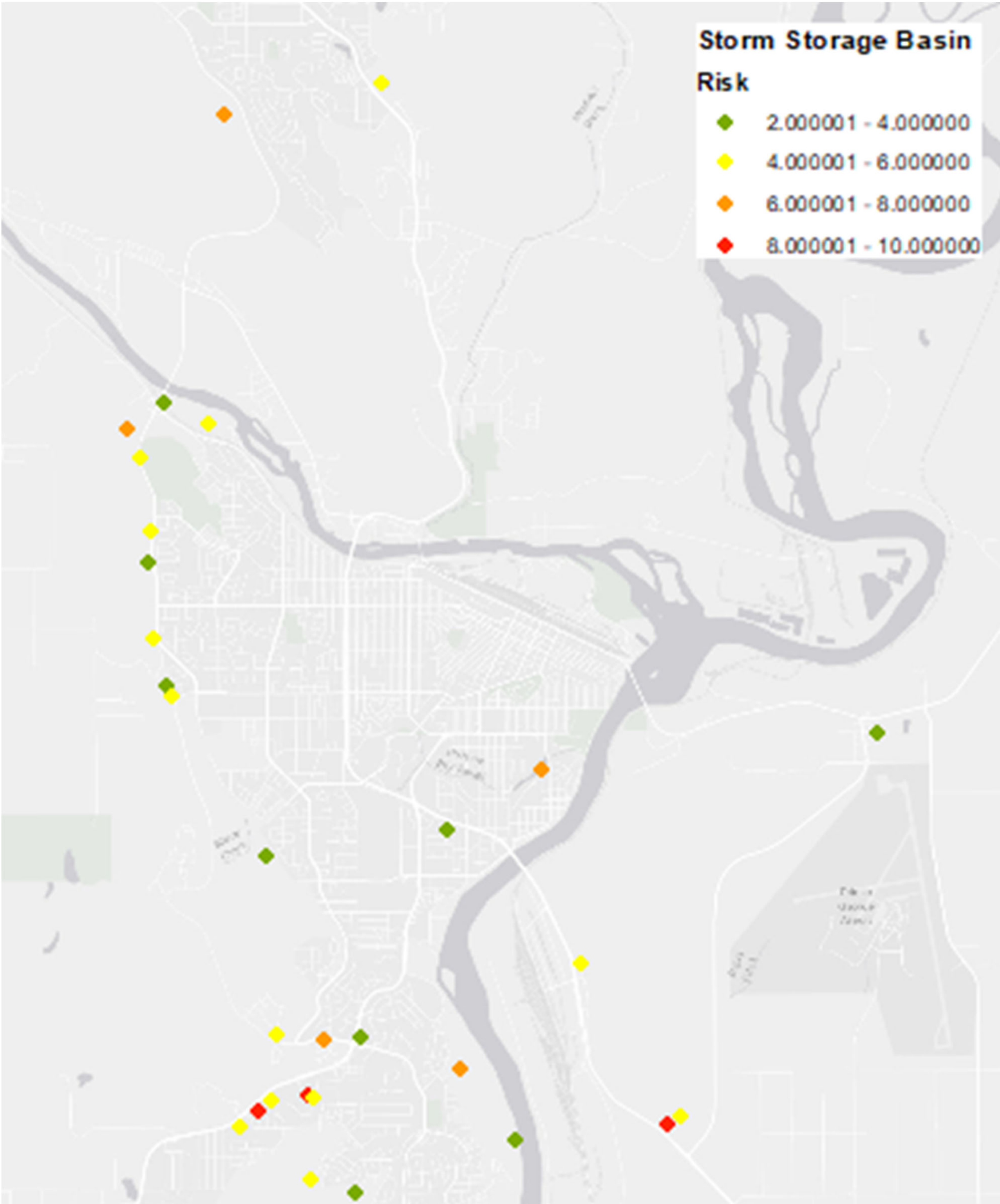



**Figure 15 Risk Score for Detention Ponds (e.g. Storm Storage Basin)**

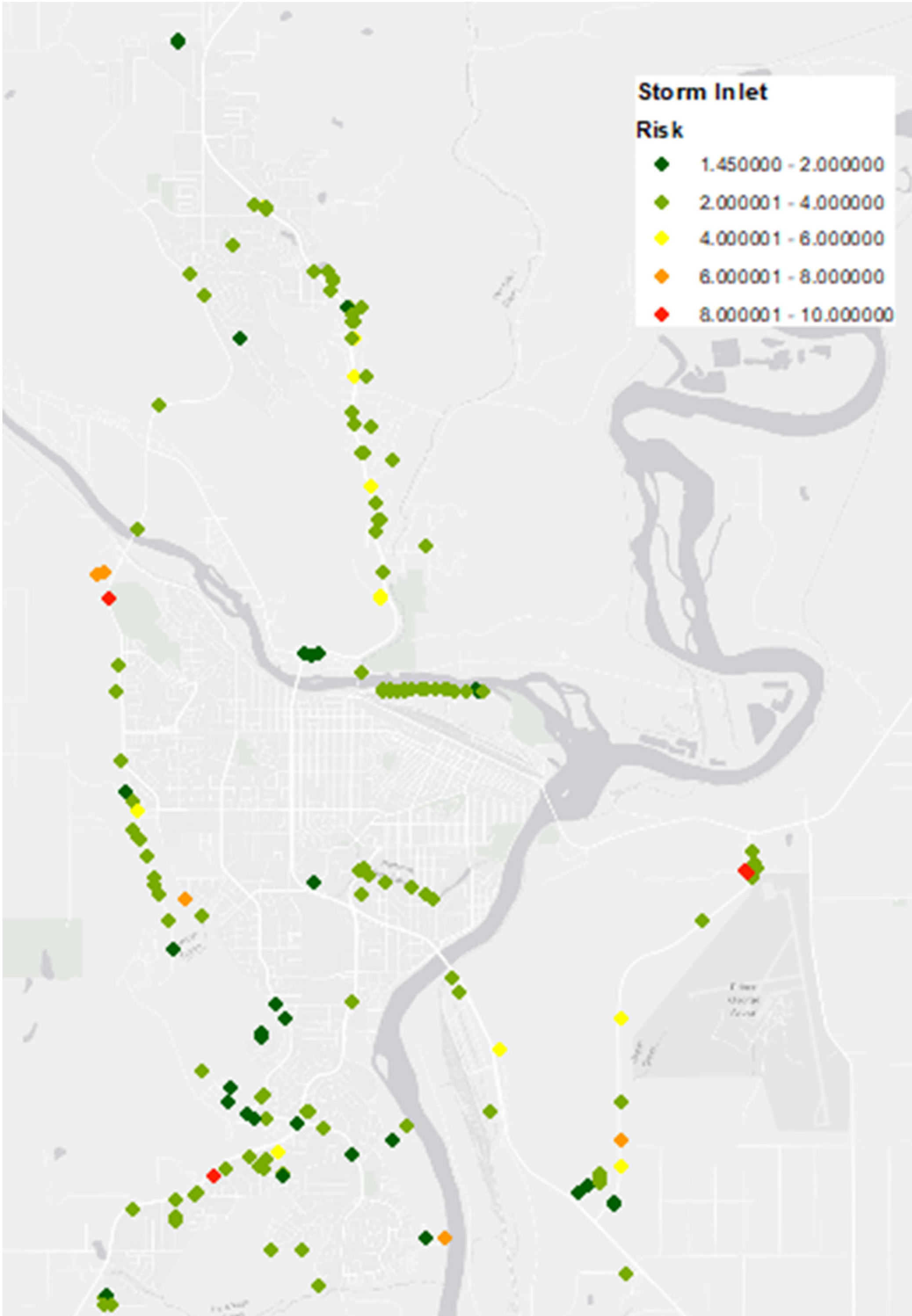



**Figure 16 Risk Score for Inlets**

The figure below shows the risk score for each of the discharge points. The risk score for discharge points was derived from the asset immediately upstream of the discharge point.

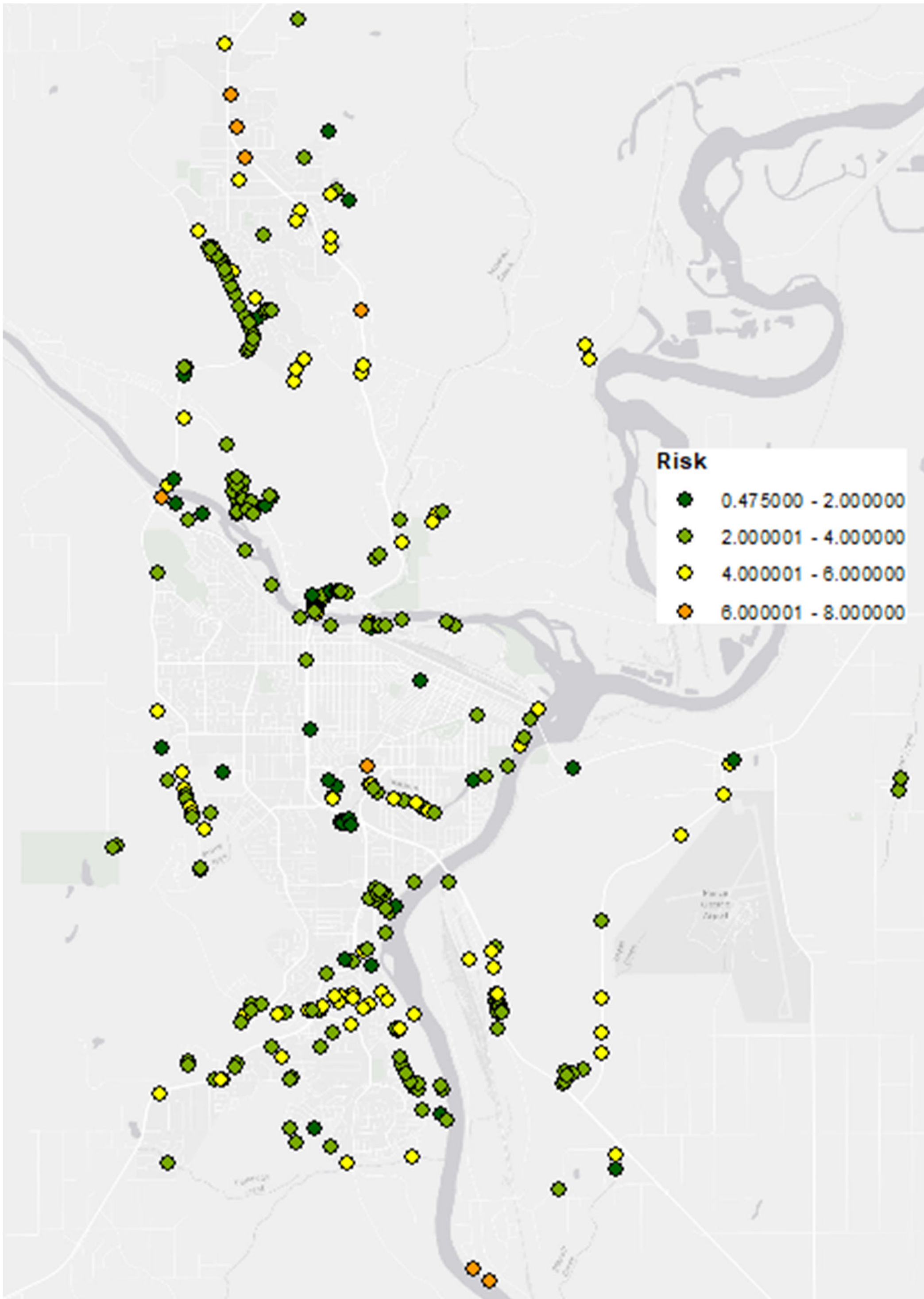



**Figure 17 Risk Score for Discharge Points**

# 7. Condition Assessment

## 7.1 Overview

Condition assessment is one of the primary steps utilized prior to performing maintenance, rehabilitation, or replacement activities. In sewers, the most commonly used inspection technique is the Closed-Circuit Television (CCTV). The results from this inspection are used to evaluate the internal condition of the pipeline to determine the structural and operational condition.

The North American Sewer Service Companies (NASSCO) developed the Pipeline Assessment Certification Program (PACP) standard, which is currently utilized by municipalities across Canada and the United States (US). In PACP, each defect is assigned a code, where each defect code has a specific condition grade ranging from 1 to 5.

Similarly, NASSCO has developed a standard to evaluate vertical sewer assets including manholes and catch basin. The Manhole Assessment Certification Program (MACP) has a similar methodology and defect categorization for evaluation. These assets are inspected using panoramic camera to generate unfolded 360-degree image of the inspection from rim to channel/bench, where applicable.

The condition grades are assigned for two group defect categories, the structural and operational (service). The grades and definitions are listed below (Table 24).

**Table 24 PACP Condition Grades**

| Grade | Definition |
|---|---|
| **5** | Most significant defect grade |
| **4** | Significant defect grade |
| **3** | Moderate defect grade |
| **2** | Minor to moderate defect grade |
| **1** | Minor defect grade |

Assigning defect grades are dependent on the quality of the defect coding and inspection. While PACP has a Pipe Rating Index formula (weighted average formula) to grade the inspected segments, many cities and municipalities are driven by the maximum score from each defect group.

The interpretation of the grade computed based on the observed defects is as follows (Table 25):

**Table 25 Inspected Segment Grade Interpretation**

| Grade | Definition |
|---|---|
| **5** | Immediate attention needed |
| **4** | Poor; will be become grade 5 in near future |
| **3** | Fair; moderate defects |
| **2** | Good; the pipe has not begun to deteriorate |
| **1** | Excellent; no to minor defects |

These grades are most commonly translated into the Likelihood of Failure (LoF). When a pipe's LoF is combined with its CoF to generate overall risk, the City can use the information to prioritize subsequent inspections, repairs, or renewal.

Establishing a program that would annually inspect pipelines and manholes/catch basins will aid in accomplishing three main objectives. The first relates to structural condition deficiencies and forms the basis for updating overall system upgrading requirements (short- and long-term). The second identifies re-inspection frequencies associated with sewer infrastructure that has no short-term upgrading requirements. The third is to identify portions of the infrastructure that have specialized cleaning requirements such as intruding lateral removal, root growth that cannot be removed by non-mechanical sewer cleaning equipment, etc.

## 7.2 Condition Assessment Tools

### *7.2.1 Closed Circuit Television (CCTV)*

CCTV is a method used to record videos for underground pipelines. It is used to inspect pipelines that can be too small or dangerous for humans to enter. In their early stages, CCTV cameras were winched between two manholes to record the condition of the pipeline. Over time, CCTV cameras were mounted on top of a crawler or a float. Operators were able to control the movement of the robot, as well as that of the camera, from far distances. The camera records the inner-surface condition of the pipeline and supplies information above the flow line. Later, experts use the recorded video to interpret, comment on, and make conclusions about the pipeline's condition based on a standard (e.g. PACP). Although some sophisticated technologies have been introduced for sewer inspection, CCTV is still the most commonly utilized technique in North America.

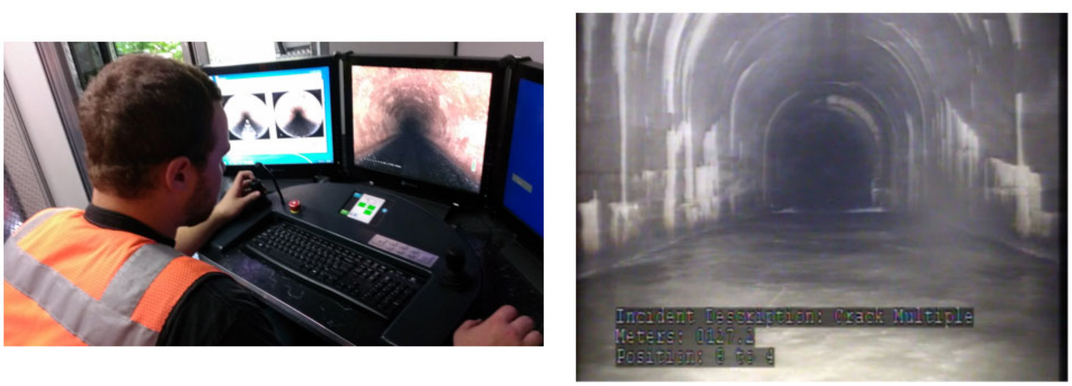



**Figure 18 CCTV Inspection**

### 7.2.2 Zoom-in Camera

Zoom-in cameras provide still imagery and/or recorded video. Unlike the conventional CCTV camera, a zoom camera remains stationary and records the data where it is installed. The camera is lowered to the manhole while it is mounted on a pole, crane, truck, or tripod. Then it can record the data by zooming in the camera. The distance coverage along the pipeline is highly dependent on the capability of the camera and the internal condition of the pipe. Generally, a zoom-in camera can provide information between 30 to 50 m from the location where it is installed (this is dependent on the actual internal environment of the asset being assessed).

### 7.2.3 Laser Profiler

The laser profiler is a technology that is able to detect and quantify the changes in the vertical and horizontal shape of pipelines, known as the deformation of a pipeline. It can also feed the operators with a profile of the interior pipeline wall.

There are two types of laser profilers: a two-dimensional (2-D) laser profiler and a three-dimensional (3-D) laser profiler (see Figure 19). The 2-D laser profiler technology is based on a ring of light, generated from a laser, around the wall of the pipeline. A camera, usually a CCTV camera, which is attached on the same crawler, detects the ring of light, and stores the laser image for further analysis. Using CCTV alone, the operator may not observe any deflection along the pipeline while analyzing the recorded video.

The 3-D laser uses laser point beams, which have a receiver and a two-way transmitter. The output of the inspection is a 3-D plot of X, Y, and Z coordinates of the pipeline (point cloud). The point cloud data captures the full pipeline segment and the true cross section of the pipeline, unlike the 2-D laser profiler, which utilizes single-data acquisition. The extracted 3-D representation of the pipe shows its real cross section regardless of the divergence angle from the centerline of the pipeline.

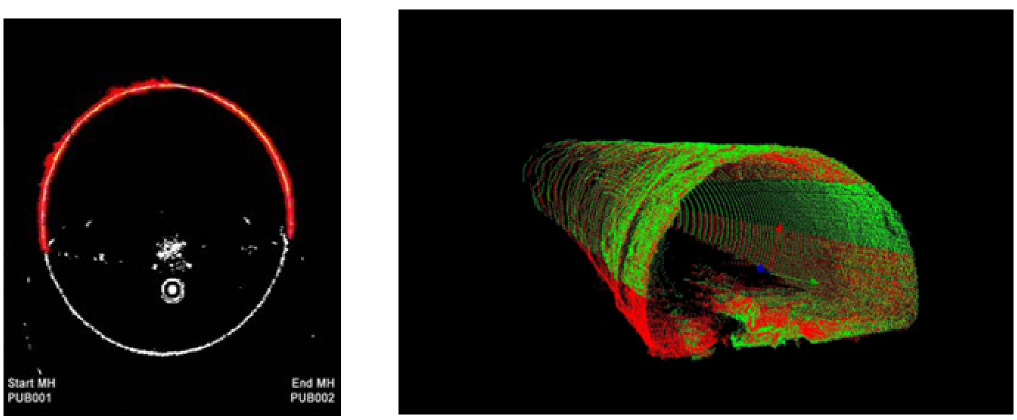



**Figure 19 2D and 3D Laser Profiler Outputs (acquired from Redzone Robotics and AET Robotics)**

### 7.2.4 Sonar

Sonar is an application of acoustical technologies. It is based on the implementation of sound energy where the magnitude of the frequency is higher than humans can hear. Sound beams travel through the inspected material. The waves reflect whenever there is a change in the density of material. Some of the reflected waves pass through the new medium, whereas others return to the surface. The image produced by the sonar sensor is affected by the selection of the acoustic frequency. When the acoustic frequency increases, the penetrating power decreases. The sonar sensor is mainly utilized below the flow line to measure the volume of any settled deposits.

### *7.2.5 Multi Sensor Robots*

A robot with multiple sensors can be used in a single inspection to obtain numerical information, where applicable.

*SewerVue Multi Sensor*

SewerVue includes multiple sensors including CCTV, laser, and pipe penetrating radar (PPR) (see Figure 20). The latter applies the theory of a radar system, where an antenna produces high-frequency radio waves. PPR is applied in-pipe, so the signal will penetrate the pipe's wall to the surrounding soil. The system can operate using two or three antennas that are able to detect several frequencies to evaluate the surroundings and the structure of the pipe itself. The SewerVUE robot, which applies the concept of PPR, can provide information about the wall's thickness, rebar's alignment, cover, and the condition of the pipe's liners for nonferrous pipe materials. The robot is also equipped with CCTV and LIDAR technologies.

**Figure 20 SewerVue Multi-Sensor**

*Redzone Multi Sensor*

There are a variety of sensors deployed by Redzone Robotics to study the condition of sewers (see Figure 21) by deploying a variety of technologies and sensors. The selection of a robot is dependent on the size, technology used and access requirements. In general, the majority of the robots host multiple sensors including laser, sonar, and CCTV.

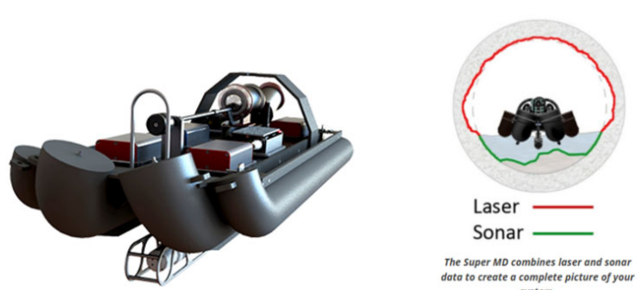



**Figure 21 Super MD by Redzone Robotics**

Typically, these multi-sensor inspections are used to inspect large pipelines, culverts, or any critical linear asset to maximize the data collection which will improve engineers' informed decisions.

### *7.2.6 Manhole Panoramic Inspection*

Vertical sewer assets, such as catch basins and manholes, are usually inspected using Panoramic cameras to produce unfolded images to help in assessing the asset. The camera is carried by a tripod and lowered through the manhole to record the internal condition of the asset. Some advanced cameras can also develop a 3D reconstructed point cloud interactive model to increase the level of information for the inspected asset.

**Figure 22 Manhole Panoramic Inspection Results**

## 7.3 Condition Assessment Frequency

Generally, the frequency of inspecting sewers ranges between 1 to 30 years. The frequency is typically driven by three main parameters which are the vulnerability, condition, and its consequence of failure. Pipelines in poor condition with a moderate or high consequence of failure could be prioritized for inspection in the next 1 to 3 years.

While prioritizing sewer inspections is usually dependent on previous CCTV data, the City could initially rely on a reliable desktop model to infer the probable condition of the assets. The desktop model can be developed using existing asset data (age, material, etc.). This was done as part of the risk model described in the previous section.

## 7.4 Approximate Cost Estimate

The cost of inspections differs based on the technology and whether the City conducts the inspection themselves or hires a contractor. Table 26 shows high level cost estimates of camera inspection, excluding an engineering firm analysis of the inspections. Multi sensor applications costs vary significantly depending on the technology and size of the asset.

**Table 26 Condition Assessment Costs (CCTV and Panoramic)**

| Tool | Rate |
|---|---|
| Pipeline CCTV Inspection | \$5 to \$15/m |
| Manhole Panoramic Inspection | \$200 to \$250/manhole |

# 7.5 Prince George's Condition Assessment Program

**Storm Sewers**

The City does not have a comprehensive storm sewer inspection program. The City typically only inspects its storm sewers by CCTV as part of construction or to address urgent issues. However, it is recommended that the City inspect approximately 5% of its storm sewer system per year. That would result in each sewer being inspected, on average, every 20 years, which is common good practice. The City has recently purchased a CCTV camera (a Rausch with a lateral launch camera) and software (ITPipes) that can integrate with the City's computerized maintenance management system, Cityworks. This should assist with implementing a condition inspection program for storm sewers.

When a sewer is inspected will depend on its condition and criticality. The City will need to inspect the entire system once to establish a baseline condition and help establish future inspection priorities. In the absence of existing condition information, the City can determine CCTV priorities based on risk scores determined in the previous section. It would not be efficient to inspect sewers in exact order of risk as that would involve jumping from one area of the City to another. But the City could be divided into zones where higher risk pipes are grouped together.

In the short-term, the City could use the risk model scores to prioritize and "trigger" sewer inspection. In the future, once the system has been inspected by CCTV, the City can use PACP scores for prioritizing and triggering inspections.

In order to complete a high-level cost-benefit review of a planned maintenance approach we have leveraged historical data from the City. NWWBI data shows that the City experienced one emergency storm sewer repair for every 100 km of storm sewer in 2019. As the City's system ages, this number will likely increase. The City has had some recent storm sewer failures: the Victoria Street sinkhole that cost $38,000 to repair and the Winnipeg Street sinkhole that cost over $1 million to repair. At an estimated cost of $10 per metre, it would cost $100,000 per 100 km to CCTV the system. Note that inspections are typically done on a 20-year cycle, on average. So, the annualized cost of sewer inspection is $5,000 per 100 km. CCTV inspections would allow the City to identify and address issues in a planned manner (see following section on asset longevity) which is less costly than making emergency repairs once a sinkhole has formed.

In summary, our high-level estimate based on current benchmarking data predicts that spending $5,000 per 100 km on preventative maintenance would avoid many of the economic, social, and environmental costs associated with emergency repairs. There are other advantages to a CCTV program which includes better planning of renewal needs and being able to extend the life of the assets through less costly interventions that can be applied to an asset before it has completely deteriorated and can only be entirely replaced.

**Culverts**

There are typically three types of culvert inspections:

- External visual inspection to look for erosion, blockages, headwall deterioration etc.;
- Walk through internal inspection of large culverts, and
- CCTV internal inspection.

Currently the City of Prince George uses summer students to do external cross culvert inspections. Critical culverts should be inspected annually. As with storm sewers the prioritization and "triggers" for culvert inspection can be refined once the City has completed initial inspections of all its culverts. Also, it would not be efficient to inspect culverts in exact order of risk as that would involve jumping from one area of the City to another. But the City could be divided into zones where higher risk culverts are grouped together.

**Pump Stations**

Short staffing in the plant operations staff has reduced regular visual inspections of pump stations from weekly to monthly. More frequent inspections are conducted when possible. The pump station near Hudson Bay Wetland has the highest risk and should be the first pump station to receive additional inspections, when possible.

The City last completed a condition assessment of all its pump stations in 2018. Regular condition assessments (e.g. every 5 years) are recommended. More frequent condition assessments can be triggered by issues found during the City's monthly inspections.

**Ditches**

Ditches need to be inspected and cleaned periodically, including vegetation control and ditching. Ditch inspections can be done in conjunction with other work such as culvert inspection or street sweeping. If the ditch inspection is done in conjunction with another activity then the prioritization of the inspection will likely be determined by that other activity. However, if ditch inspection is done on its own then the "open channel" risk scoring can be used to identify priorities. As previously mentioned, it would not be efficient to inspect ditches in exact order of risk as that would involve jumping from one area of the City to another. But the City could be divided into zones where higher risk ditches are grouped together.

**Ponds**

Ponds need to be inspected for blockages, sediment accumulation, debris, erosion, vegetation (including invasive species), safety, and deterioration of hard assets such as headwalls and fences. Many of the inspections will be regular (i.e. annual inspection after spring melt) but some more detailed inspections may be triggered by sediment accumulation or asset failure. The City currently visits its stormwater ponds annually and does more thorough assessments periodically. The last condition assessment of the ponds was completed in 2019. It is recommended to complete condition assessments every 5 years.

**Catch Basins**

Catch basins can have three types of inspections:

- Structural condition assessment to determine if and when repairs need to be done;
- Grate inspection to determine if there are blockages that need to be addressed to allow full flow; and
- Sump inspection to determine the amount of accumulated sediment and when it needs to be cleaned.

Some municipalities inspect and clean their catch basin sumps annually in the spring to remove accumulated road sand and other debris. Grate inspections will typically happen if a problem has occurred or if there is a known "problem" catch basin that needs to be inspected prior to storms or snow melt. Structural condition assessments which happen less frequently could be conducted based on age and/or risk.

**Outfalls**

Many municipalities try to inspect their outfalls to creeks and other water bodies annually for blockages, erosion and evidence of spills or contamination. The City could prioritize the inspection of its outfalls based on the risk score given to "discharge points".

**Creeks**

Some municipalities try to inspect their creeks through an annual "walking of the creek", to look for issues such as erosion. Flagging found issues such as erosion would help the City determine priorities, along with fish classification, for inspections. The biggest challenge with prioritizing creek stretches for inspection is that the creeks in the City's GIS are broken down into large segments (e.g. > 100 m) so shorter sections of creek cannot be easily modeled. As mentioned above under "outfalls", the City should be inspecting outfall locations within creeks.

# 8. Asset Longevity

There are different technological options for extending the life of existing assets (e.g. cathodic protection) but there are also other options such as implementing optimal maintenance practices, rehabilitation interventions and a risk-based asset management approach to extend asset longevity.

At the asset management level, failure risk reduction is achieved by either reducing the probability of failure or the consequence of failure (or both). This is most often achieved by a capital or maintenance expenditure that must be compared with the savings associated with risk reduction. Treatment options and associated costs to reduce asset failure risk must consider the type of asset and local conditions. The selection of an appropriate treatment can either be a manual process or can be automated through a computerized Optimized Decision Making (ODM) process which the City currently utilizes, called Powerplan.

Treatments can be selected to address Performance Deficiencies and Operational Deficiencies. These categories are further described as follows.

## 8.1 Performance Deficiencies

The rehabilitation of sewer infrastructure to address the risk exposure associated with performance deficiencies can be placed into two broad categories:

- Renovation; and
- Replacement.

Renovation can be defined as methods in which the sewer is improved by incorporating the original sewer host pipe. The best example of this is the use of cured-in-place pipe (CIPP) technology for spot repairs or full segment relining. Renovation technologies utilize the existing sewer and involve minimal to no excavation. The City utilizes this method of renovation regularly for its sanitary sewers.

Replacement can be defined as methods by which the pipe is replaced entirely from manhole-to-manhole or in spot locations. This is typically done by utilizing either minimal or traditional excavation techniques.

The three aspects of performance deficiencies that must be considered include:

- Structural Integrity;
- Materials Deterioration (pipe fabric decay by corrosion, abrasion, etc.); and
- Hydraulic Capacity.

A hydraulic model study is typically required to identify hydraulic capacity performance issues, while a condition assessment is required to identify structural integrity and material deterioration performance issues. All performance (capacity) deficiencies can be rectified by replacement methods. Structural integrity and materials degradation may be rectified by renovation methods; however, the greater the deficiency, the less cost effective the renovation technique may be. The evaluation of replacement versus renovation must be made on a case-by-case basis.

Renovation of sewer infrastructure implies rehabilitation by trenchless methods that utilize the existing sewer as part of the process. Several treatment options to address structural or material deficiencies are outlined as follows:

- Pure Trenchless Categories
    - Stabilization (grouting technologies)

    - Full Segment Renovation (lining)
    - Trenchless Point Repair

- Minimum Excavation / Replacement Categories
    - External Point Repair
    - Full Segment Renewal
    - Augmented Renovation (lining with external repair)

### *8.1.1 Stabilization*

These technologies stabilize the structure and arrest the deterioration process or specific defect but do not structurally enhance the existing sewer structure. Stabilization repairs for small diameter domestic sewers can employ a variety of chemical grouts (e.g. acrylamide, polyurethane) injected with remote sealing packer technology. Other means of stabilization could occur from personnel-accessible locations in larger diameter sewers (i.e. from a nearby manhole) to enable a localized internal repair of the pipe by manual application. Minor defects such as infiltration or cracking within the sewer that are typically limited to 5% to 10% of the total segment length may be repaired using stabilization methods such as spot patching, pressure grouting, or chemical grouting. While stabilization as a rehabilitation technique is typically a very low capital cost with minimal surface disruption, it usually has a very short effective design life. Chemical grouting is generally used in North America to address infiltration related deficiencies for pipes that are not personnel-accessible (less than 600mm diameter) or to prepare pipes for relining in areas with excessive infiltration. Other traditional stabilization methods such as localized patching or the re-pointing of bricks, require personnel entry and are therefore limited to larger diameter sewers (greater than 1,200mm), or to personnel-accessible sewers (close to a manhole, 600mm to 900mm diameter).

### *8.1.2 Full Segment Renovation*

Full segment renovation can be used to address defects distributed throughout the segment or to address several defect clusters. Full segment renovation is effective in addressing material degradation and pipe wall defects including cracks, fractures, spalling, or holes (where there is no voiding of the backfill). In diameters greater than 1200mm and where deformation is excessive (greater than 10% loss of cross section), the constructability and cost effectiveness should be reviewed on a case-by-case basis. Work for smaller diameter pipe is typically carried out by cured-in-place pipe (CIPP) methods. Larger diameter pipe may warrant review of alternate technologies such as segmental liners or short pipe relining.

### *8.1.3 Trenchless Point Repair*

Trenchless Point Repair (TPR) provides an effective means of addressing localized pipe defects where there is minimal loss of structural integrity. A TPR is normally assigned to pipe wall defects including cracks, fractures, spalling, or holes (where there is no voiding of the backfill). The benefit of using a TPR is that there is minimal surface disruption and the sewer can be repaired in a fraction of the time of traditional excavation-based repair methods. Key limitations include diameter (less than 1200mm), defect length (less than 10m), and deformation (less than 10% loss of cross section). Typically, the use of point repair technologies is limited to 3 or 4 localized instances or 20% to 30% of total length in a given manhole-to-manhole segment and the complete absence of defects in between the repair areas.

### *8.1.4 External Point Repair*

External Point Repair (EPR) is used to address severe localized defects where trenchless point repairs are not technically feasible to be constructed. As with trenchless point repairs, typically the use of point repair technologies is limited to 3 or 4 instances or 30% to 40% of total length in a given manhole-to-manhole segment and the complete absence of defects in between the repair areas.

### 8.1.5 Full Segment Renewal

Full Segment Renewal is used to address severe defects distributed throughout the segment length or to address several defect clusters. The nature of the defects renders relining technologies either technically infeasible or of an unacceptable construction risk.

Renewal involves the replacement of the existing sewer and this can be accomplished using minimum excavation (pipe bursting, tunnelling, directional drilling, etc.) or traditional open-cut installation techniques. The following figure identifies an example performance deficiency in which a Full Segment Renewal treatment would be appropriate.

### 8.1.6 Augmented Full Segment Renovation

In some cases, a combination of the previous treatments would provide the most suitable solution. The most common example would be when an EPR is required to rectify a single severe defect (i.e. hole with a void, collapsed section, or obstruction in the main) that prevents Full Segment Renovation. Once the EPR is complete, the trenchless work (full or point) proceeds. Similarly, the use of a stabilization treatment can be used to prepare a pipe for relining.

### 8.1.7 Cost Estimates

High level cost estimates for different treatment options are provided in the following table.

**Table 27 Cost Estimates for Sewer Treatment Options**

| Intervention | From (mm) | To (mm) | Unit Cost | Unit | Mobilization |
|---|---|---|---|---|---|
| **EPR** | 0 | 524 | $2,000 | Each | $6,500 |
| **EPR** | 525 | 99,999 | $2,500 | Each | $7,500 |
| **Replace** | 0 | 374 | $800 | m | |
| **Replace** | 375 | 599 | $850 | m | |
| **Replace** | 600 | 1,049 | $70 | m | |
| **Replace** | 1,050 | 1,499 | $1,300 | m | |
| **Replace** | 1,500 | 1,800 | $1,800 | m | |
| **Replace** | >1,800 | | $2,800 | m | |
| **TPR** | 0 | 374 | $1,125 | Each | $2,500 |
| **TRP** | 375 | 599 | $1,550 | Each | $3,000 |
| **TPR** | 600 | 9,999 | $2,000 | Each | $3,500 |
| **Stabilize** | 0 | 749 | $1,000 | Each | $1,500 |
| **Stabilize** | 750 | 9,999 | $2,000 | Each | $3,000 |
| **Line** | 0 | 449 | $515 | m | |
| **Line** | 450 | 749 | $775 | m | |
| **Line** | 750 | 899 | $915 | m | |
| **Line** | 900 | 1,349 | $1,400 | m | |
| **Line** | 1,400 | 9,999 | $2,000 | m | |

*EPR = External Point Repair*
*TPR = Trenchless Point Repair*

## 8.2 Operational Deficiencies

Operational defects such as deposits and roots can reduce the operational performance of sewers and can impact the ability to assess structural integrity, particularly in cases where operational defects prevent a complete CCTV inspection. It may be necessary to assign several treatments in order to restore operational performance and to facilitate a complete inspection. Several treatment options can be utilized to restore operational performance, as identified through the Condition Assessment process, and are outlined as follows:

- **Clean and Re-inspect** - In the event that a complete inspection is not obtained or that 20% of the pipe cross-section is full of deposits, the sewer needs to be cleaned. Cleaning the sewer should facilitate the ability to obtain a complete CCTV inspection.
- **Obstruction Removal** - Intruding obstructions can reduce the cross-sectional area of the sewer. Obstructions should be removed if there is a cross-sectional loss of 20% or greater or when it prevents a complete CCTV inspection.
- **Root Removal** - Used to address root masses in the pipe. Root removal is required if the cross-sectional loss of the sewer is 20% or greater or when it prevents a complete CCTV inspection.
- **Solid Debris Removal** - Used to address heavy encrustation, calcified debris, asphalt, or concrete deposits in the pipe. Solid debris removal is required to restore the operational performance if there is a cross-sectional loss of 20% or greater or when it prevents a complete CCTV inspection.

## 8.3 Relining Storm Sewers and Environmental Considerations

Typically, the main environmental concern of lining is that it is an outdoor plastic manufacturing process (installing and curing), which is a less controlled environment when compared to regular manufacturing that could happen in a factory. Further information about environmental considerations with the relining of storm sewers are outlined in Section 4.7.

## 8.4 City of Prince George Considerations

The City is already taking important steps that help asset longevity (e.g. asset management, maintenance management, relining, spot repairs, sediment removal etc.).

Old corrugated steel pipe (CSP) from amalgamated areas do not have asphalt coating and are showing signs of deterioration, whereas more recent installations of CSP have asphalt coating. The City could look at relining some of the older CSP, especially the deep culverts to extend their life. Note that some of these pipes may be too deteriorated or have hydraulic capacity issues that will necessitate full segment renewal.

The most important steps that the City can take to extend the longevity of its stormwater assets are:

- Change the list of allowable materials that can be used in new construction, particularly in areas with corrosive soils. Some cities no longer allow CSP to be used for sewers or cross culverts. Over the long run CSP can be more costly than other materials such as concrete because it has a shorter life span.
- Inspect the entire stormwater system to identify cost-effective rehabilitation opportunities before the assets become too deteriorated and the more costly treatment of full renewal is the only option.

Choosing the right treatment option for a given asset will also depend on the consequence of failure. Some assets, such as rural residential driveway culverts that are not a fish bearing channel can be allowed to run to failure. However, allowing the failure of a fish-bearing culvert or a large sewer under an arterial roadway would be costly from an economic, social, and environmental perspective. With high risk assets, the City can justify the cost of inspection, preventative maintenance, and rehabilitation such as stabilization or relining.

# Appendix A : LID Interview Transcripts

AECOM Canada Ltd.
410-250 York St.
London, ON, N6A 6K2
Canada

T: 1-519-673-0510
www.aecom.com

Project Name: Prince George ISMP

Date of Meeting: December 14th, 2021
Time: 11:00 – 12:00
Project #: 60628231
Location: Conference Call

Attendees: Bill Trenouth Ph.D, P.Eng., CAN-CISEC – AECOM Water Resources Engineering

Aaron Ward – City of Thunder Bay Engineering Dept.

Prepared By: Nick Szendrey

Regrets:

Regarding: LID implementation for the City of Prince George / Thunder Bay Stormwater Plan

# Minutes of Meeting

**Discussion**

**Thunder Bay stormwater plan**

- Done by EOR.
- Key thing: push for Green Infrastructure (GI)
- From a Climate Change (CC) resiliency perspective, T-Bay notes that this is their “buffer” against CC.

**LID:**

- Identified 550 location on public lands where LID could go.
- A table in Volume 2 of their SWM MP – identifies locations, approx. size, etc.
- The above table has been key to in leveraging third-party funds to build their projects to date.
- They have an eight-year program (500K per year) for the next 5 years to do LID with the federal government
- T-Bay is fiscally conservative as well, but this let’s them leverage external funds.
- Accessed over 5 million dollars to date, including funding up to 8 years from now as well
- 20 facilities have been built since the SWM MP was approved.
- Because their LID is mapped out, this helps them capitalize on opportunities when they do construction.
- Winter sand: a key consideration. **Need pre-treatment**…still working on how to do this
- OGS is useful for sand, floatables, etc.

- Thunder Bay has three divisions involved in LID maintenance: roads (culverts, etc.), environment (CBs and pipes), parks (landscaping)
- Cleaning of rock inlets needs to be contracted out, since no one wants to do those things
- Winter:  as the snowbank melt, they leave behind a ton of junk.
- Two sites sampled: by a grad student
- Lakehead University: Brant Muir. Monitored three LID sites around T-Bay. Check online!
- 90% are bioretention/biofiltration – very similar
- Infiltration trenches are the third type
- 7-8-foot frost depth. Sub drains within the frost zone. No problems
- Keep the features offline. Provide full-time construction inspection. Understand what your material suppliers are capable of. You need to start with a washed sand.
- Public buy-in: hit the public repeatedly with the same messaging.
- Need consistent, simple messaging.  "Keep it Superior", is the example T.B uses. Public approval for this is key.
- People understand the word "flooding", but they don't understand "water quality".
- T-Bay has their own "Residential Rain Garden Program", where they cover 100% of the cost up to $500 to build rain gardens on private property.
- 1.5-2-hour webinar is mandatory. This is common among municipalities with a subsidiary program.
- They have evening tours of LID features – private rain gardens are more popular than the municipal ones

**Post-meeting Notes**

Thunder Bay has created a progressive approach towards LID involving:

1. Identifying a detailed list of potential locations for retrofit/greenfield opportunities.
2. This led to the ability to leverage third party funds to begin working with LID.

This seems to be a common approach for fiscally conservative municipalities wishing to be progressive. Mapping out LID locations has allowed them to capitalize.

AECOM Canada Ltd.
410-250 York St.
London, ON, N6A 6K2
Canada

T: 1-519-673-0510
www.aecom.com

Date: December 22, 2020

Time: 9:30 – 10:30

Project #: 60628231

Location: Conference Call

Attendees: Bill Trenouth Ph.D, P.Eng., CAN-CISEC – AECOM Water Resources Engineering

Darlene Conway – Senior Engineer, SWM Projects Ottawa
Karine Bertrand - P.Eng,. Project Engineer, Stormwater Rehabilitation
Laurent Jolliet – City of Ottawa Engineering Dept.

Prepared By: Nick Szendrey

Regrets:

Regarding: LID implementation for the City of Prince George / City of Ottawa SWM / LID in Ottawa

# Minutes of Meeting

**Quick background/overview – Darlene**

Why is Ottawa undertaking SMW retrofits/and LID program?
Focus on ROW bioretention, although the City is moving into other LID types
Most of Ottawa's DT core has NO water quality/quantity control
City has planned ROW retrofits for many areas over the next 20 years, based on reconstructions, etc.

*Ottawa took the approach of discussing several examples of recent LID implementation – highlighting success/failures/challenges to aid Prince George on their journey.

**Sunnyside Avenue– Karine**
Constructed in 2015
Monitoring wells in the features; water typically draws down in ~10 hours
City has lots of tight soils, so what Ottawa has capitalized on are areas with sandy soils, or soils where they can do infiltration
Project involved bump outs (traffic calming). 0.5 ha area
Native soil infiltration rate is 43mm/h
Ottawa plans on replicating the bump outs in future projects
**Biggest challenge** city has had is getting water into the LID (inlet design). Therefore, bump outs have been great for getting the water into the LID.
Features include secondary (side) inlet for backup. They don't work super-well.

Other lessons learned: grading of bioretention bump outs, etc. had to be redone to comply with AODA requirements. Plants had to be removed and work had to be redone, which was a problem.
**Next lesson:** bump outs changed the turning radius. In the winter, the snow made it hard to see the turn. This led to damage to the curb and the garden. Concrete was poured over the biomedia at the affected corner to protect the LID feature.
Side inlets haven't been working (due to design). Careful design consideration is key, especially for inlets; this has been a recurring topic across several interviews.
Primary inlet: "We have not found the optimal design". The river stone inlets are cleaned twice per year (spring and summer), but they are still silting up and leading to bypass. Next attempt is to lower the river stone inlets, so water can pass over if things are silted up.
Overflow CB's need to be set low enough that a plough won't grab them

Performance: 70% runoff volume reduction, but this has decreased recently (possibly from siltation at the inlets leading to bypass).
Bypass has been noticed through the beehive riser rings
Average drawdown time is 6.5 hours, design drawdown time is 48 hours

Winter monitoring was completed – facilities worked in the winter during melt events. Drawdown still observed – way below the 48 hours drawdown time. In general, the facility still works in the winter.

**Plantings** – lots of trial and error. Half of the plants trialed failed in the bioretention facilities. For Ottawa, tall grasses have worked best ((Heavy Metal Switch Grass). Native drought-tolerant species have worked best. They are lower maintenance as well. Canada anemone. Water every week for first 1-2 years during the dry season. Coneflowers did not work.

**More Lessons:**
Inlet maintenance underestimated
Gardening volunteers have been awesome for "adopting" some of the gardens and doing weeding, cutting back plants, and doing light maintenance. If Prince George can do the same, they should collaborate with any naturalist, pollinator or related club. This is done through the City's "adopt a road" or "adopt a park" program. Historically, these revolved around picking up litter, for example. It has taken some work to evolve this to capture gardening work using community members.

Detailed construction specs – more details needed. There is a learning curve for everyone – not just the city, but the consultants and contractors too. Even for small things like sub-drain placement, contractors need hand holding
City comment: no issues with operation or challenges with freezing for the facility monitored.
Frost depth is recognized to be 1.8 m (minimum depth of cover for water mains)

**<u>Stewart Street – Laurent</u>**

Located in urban core of City.

Context: 2.2m of extra asphalt width. Based on this, they narrowed the road, implemented GI and built a bike lane. Soils were good – sandy ("Sandy Hills" is name of neighborhood). CDA = 2.4 ha

Narrowed the ROW width 2.2 m (0.9m of one side of the road, 1.3m on the other). Continuous subdrain on either side of the road.

Lesson learned: verify the CDA with DEM, site visit and Google Streetview.
I:P ratio up to 20:1.
Problem: we did not have enough width to work within the ROW. When it is too narrow, we do not have enough ponding depth not enough freeboard. Also, for a small feature people may not notice it and we have had people drive through them
For Stewart street, they used a corrugated interior pipe → big problem for fluching. Not maintainabel. Use 30-45 degree bends at access points.
Underdrain invert elevations hsould be surveyed – as built survey required
Overflows. Need to be 150 – 300mm above base of filter bed
Plastgic underdrains → not good. Use metal made traffic rated CB overflows.
Curb inlet – clogs with debrsi (leaves). These inlet types do not allow for enough depression.

**Lessons:**
specify the planting window
Use tall grass – help stop people from stepping through the gardens
Use plants that are shade tolerant when planting beneath trees
Avoid garden edging
Check existing garbage pickup practices – do people throw bags in the boulevard?
Grading – always a struggle. When you are tight for space, it is even harder. (dirt on sidewalks, etc.)
"When it is flat, it is hard"
Do private property owners blow their leaves? If so, they will end up in your boulevard bioretention/gardens. This will fill your garden and block your inlets, etc. They will also smother your vegetation. When there are lots of trees around, expect to do fall maintenance.
Landscape contractors (private property) drove through the facility and did some damage.
Detailed as-built required.
LID needs to consider street layout/topology (Peel streetscape toolbox, City of Toronto LID design guidelines.

**Biomedia:**
Consultants are learning. Finding good contractors is also a challenge. We need to be extra clear on the drawings to make sure there is no confusion. This includes the biomedia. Contractors will still get it wrong – P index, etc. Need to do a hand-mix first, followed by trial run, etc.

CB details are also a challenge.

Coordination between departments = we are still working out some of the details. They ARE SWM facilities, so responsibility rests with SWM operations.

Other projects (high GW table; monitoring pending)

- Chapel Hill Park 'n Ride – Darlene

Surface bioretention: the focus is more challenging conditions: tight soils (5 mm/h)
Adjacent to a highly eroded creek (Mud Creek, no SWM controls)
GW table is very high as well. "If we can't infiltrate, we will filter and provide peak flow control"

LID implementation is not just driven by MECP RVCT, but also by subwatershed studies and response to developer comments that "you can't do anything because of XYZ challenges".

**Hemmingwood Way – Laurent**

To facilitate implementation, the City has developed a hydrology guideline.

Another bioretention project. 14.5m boulevard, but not a very busy street
Located in SW quadrant of City
6 bioretention cells (bump outs) in the suburban core of the City

Site also had very high groundwater levels (seasonally they are above the bottom of the facility).

Pre-drilled holes in the CBs were again a problem on this street (like Stewart St.)

City has guidelines for "challenging" areas – area with clay, high GW, etc. it is still in draft, but has been put out to the development industry for comment

City is working on a screening tool (GIS-based tool) to make sure that they take advantage of road retrofit projects and select the best dozen or so candidates for retrofit implementation.

Something in the infrastructure master plan (online)? Darlene will check with the hydro g guidelines.
City also looking at

- **Post-meeting Notes**
  - Ottawa provided several slideshows regarding this information to AECOM, to coincide with this interview.

AECOM Canada Ltd.
410-250 York St.
London, ON, N6A 6K2
Canada

T: 1-519-673-0510
www.aecom.com

| | | | |
|---|---|---|---|
| Project Name: | Prince George ISMP | Date of Meeting: | January 6th, 2021 |
| | | Time: | 11:00 – 11:20 |
| | | Project #: | 60628231 |
| Attendees: | Nick Szendrey, B.Eng. - AECOM Water Resources EIT | Location: | Conference Call |
| | Alan Mangory, Senior Drainage Engineer, City of Edmonton | | |
| | | Prepared By: | Nick Szendrey |
| Regrets: | | | |
| Regarding: | LID implementation in the City of Edmonton | | |

# Minutes of Meeting

**Discussion:**

- Not yet majorly promoting LID in Edmonton. The city is very behind in comparison to surroundings like Calgary.
- Some experience/success with bioswales in cold climate. This is the LID Alan has seen achieved successfully.
- Edmonton has begun to slowly promote bioretention in areas of playgrounds, or areas where flooding is common.

▪ **Closing Remarks**

▪ **Post-meeting Notes**

Alan emphasized finding a way to work with Calgary, or a way to achieve their guidance. Calgary has shown to be the most productive and progressive with LID in Alberta. This is where Prince George can find the most useful and relevant information to aid in their LID journey.

AECOM Canada Ltd.
410-250 York St.
London, ON, N6A 6K2
Canada

T: 1-519-673-0510
www.aecom.com

Project Name: Prince George ISMP

Date of Meeting: January 6th, 2021
Time: 12:00 – 12:45
Project #: 60628231
Location: Conference Call

Attendees: Nick Szendrey, B.Eng. - AECOM Water Resources EIT

Paul Javor, MSc, P.Eng., City of Sudbury

Prepared By: Nick Szendrey

Regrets:

Regarding: LID implementation in the City of Sudbury / General LID information

# Minutes of Meeting

**Introduction**

- LID in Sudbury is developing. Current problem – bedrock eliminates infiltration
- Blasting is commonly used to deal with any development
- Areas without bedrock have very swampy conditions so another problem for infiltration. These issues combine to make LID difficult.

**Winter Control Practices and Difficulties Associated**

- Paul tries to talk about winter control practices with everyone
    - Everyone uses salt they use sand they use sand on 80% of roads (5% salt,95% sand mix). The quantity of sand used is extremely large.
- Bio-soils with collection pipes, seeing some attention but high standards of quality
- No water balance, it is all runs off in Sudbury; high water table
- They look at biofiltration – swales with perforated pipes underneath
- Problem is sand clogging; a need for pre-treatment is extreme.
- Attempts that haven't worked out:
    - No attempts, some approval; everyone fears the sand – even the highly progressive LID organizations.
- Some subdivisions with 100% infiltration, no outlet, very specific geography. varying geography is a massive challenge in the city, and a big consideration when thinking LID.

In Prince George, Similar winter practices exist; using sand, quite as much. Still, Sudbury could be a good comparable location.

Why sand? Sand is cheaper and prevents harming aquatic life, they have long winters and they can have a snow packed road

- Most practitioners from southern Ontario and no one knows the impact of so much sand. He is really stressing how detrimental it is. The climate is not the problem. This is good information, as Sudbury uses a significant greater quantity of sand in road treatment compared to any other municipality in this study. Prince George should take this advice into key consideration, especially if they wish to implement LID on sand routes. Focus on pre-treatment.

- OGS very useful in Sudbury to take out the particles - gritty road sand.
- Only LID concepts with plans approved in Sudbury. No major progress down this road.

**Slow development:**

- 400 lot subdivisions with 20-40 builds a year – (Sudbury development rate)
- Tough to find people dealing with road sand b/c they are usually not progressive municipalities.

**Closing Remarks**

- Paul builds large OGS (biggest there are) for retrofits on Ramsy lake, etc. lots of cast in place chambers 50x20x30 ft, doubled one of these (two side by side)
- No community outreach; however, a conservation grant was achieved to look at one LID in a community parking lot… indirectly the city funds this (as they pay the conservation)

- LID Maintenance is limited by public without equipment. So how does one truly eliminate the maintenance issue by allowing community programs to do it for the city?

**Post-meeting Notes**

AECOM Canada Ltd.
410-250 York St.
London, ON, N6A 6K2
Canada

T: 1-519-673-0510
www.aecom.com

| | |
|---|---|
| Project Name: | Prince George ISMP |
| Date of Meeting: | January 7th, 2021 |
| Time: | 11:00 – 12:00 |
| Project #: | 60628231 |
| Location: | Conference Call |
| Attendees: | Bill Trenouth Ph.D, P.Eng., CAN-CISEC – AECOM Water Resources Engineering<br>Nick Szendrey, B.Eng., AECOM Water Resources EIT<br><br>Bert Van Duin - Drainage Technical Lead, Development Planning. Infrastructure Planning, Water Resources. City of Calgary |
| Prepared By: | Nick Szendrey |
| Regrets: | |
| Regarding: | LID implementation in the City of Calgary / Considerations and recommendations for Prince George |

# Minutes of Meeting

**Introductions**

- *Bert offers to have Prince George contact him at the City of Calgary to come in (post COVID), to discuss and see things for themselves.*

- Bert's journey is ongoing, still in the process of trying to sort out rather than seeing the optimal distribution of grey/green infrastructure.

**Discussion**

- Source control practice documents Bert created are still quite relevant today (found on city website).
- Specific LID used in Calgary, driven by the need for volume runoff control from hydrogeological modification perspective
- Approach: not necessarily an infiltration type of hydrology – more evapotranspartive
  - Approaches most effective with this perspective are:
    - Capture of runoff, rainwater harvesting or SW capture in larger storm ponds
    - Very large ponds in Calgary reflecting pre dev flow rates (small?)
    - Irrigation from ponds back onto the land is used, interesting!
    - Making a clear distinction between bioretention and raingardens

- Raingardens used as landscape approach
- Alberta water quality perspective… targets are geared towards removal of large particles (>75um)
- With that, pilot projects over the last decade
  - Originally starting with bioretention
  - ALDP collaboration talk about w Leta (good work with rain gardens and demonstrating their performance)
- Bert mentions the current scope of updating their SWM strategy, starting to move towards not wanting conditions in communities to get worst (flood control perspective and water quality loading perspective)
- Phosphorous management plan in beau river
- Source water protection – surface water based i.e. water is coming from the mountains; starting to drive discussions more but has not translated into hard guidelines or targets making it difficult to go after constituents other than sediment b/c of where provincial guidelines are at and municipalities wanting to do the absolute minimum.
- They are not near a wholesale LID level. More so, a hydrological level; but even then, industry pushes back.
- **Their approaches – the need for proper pre-treatment is incredibly important. Sand being used in Prince George makes it important there specifically should they go down this route.**
  - While we use salt for de icing, they use sand, grit, etc. more often. This poses a massive challenge
  - Looking at things from a water balance perspective, avg annual basis expressing water runoff volumes, moisture conditions, and an appreciation towards the landscape/engineering world

**Questions**

- **Q**. Bill - "You draw a hard line between bioretention and rain gardens; wondering when you say that, what is the driver behind saying and acknowledging that?"
  - **Answer:** the distinction is a terminology functionality perspective, ppl mixing up different practices that are functionally different.
    - Bioretention; looked at from a treatment perspective
    - Rain gardens: runoff volume control perspective. Loadings I/P ratio being pushed as important – they are fundamentally different
  - When you are dealing with people, clear terminology is extremely important.

- **Q**. Bill - "You mentioned hydro modification of the hydro cycle; do you look at seasonal variation… 60% of runoff is in a 2 week period in the spring in southern Ontario; in the winter, seasonally high GW is natural to see very little infiltration… under these types of conditions.. if it is natural to see seasonally high variations, do you look at it with this much granularity?"

  - **Answer:** NO, pre-dev. runoff is largely associated with the spring conditions. He has considered it more of a perspective of looking at it from wetlands impacting steams.
  - Lots of cattle terrain growing, like small stream land in Ontario; for the wetlands, he has been talking about more about mimicking hydro period since it fits more towards impacts on nesting birds and such rather than the streams
    - For the streams; can you potentially push more flow through them but still stick within the cumulative stress type environments b/c naturally there would have been very little flow going through them in the later part of the summer: still, pre-development runoff volumes are still very small ; still 3-5% max of what the precipitation would be… thus it is putting a high demand on doing that volume control.
    - With the tight clay soils as well, they are cautious of not trying to curate unrealistic expectations of what he calls "deep infiltration" that may result in

seepage issues into ex basements, or sanitary sewer; or cause slope stability issues.

- #1 consideration was driven by these acknowledgements

- Keep in mind, here in Alberta, a lot of work has been done pertaining to public health safety aspects b/c harvesting and re use approaches are quite attractive – lots of unique and good research done beyond what most jurisdictions have done thus far. They are simply waiting for Alberta PHS to publish what is needed.
  - When this becomes available, he feels that people will start looking at the guiding document on this. All of our stormwater will have wastewater signatures; So, they have really been putting a lot of emphasis on how we deal with this.
  - Largely what we see from storm ponds and inadvertent cross connections lead to the above. And it doesn't take a lot to see the clear signature. In some areas they wonder about exfiltration and infiltration processes (exfiltration from sanitary).

- **Q**: How does sand usage on roads affect LID implementation today (types etc,)?
  - **Answer**: pre-treatment is paramount; still trying to sort out the best way to do this. Leaning towards using something like a sump as part of the inlet and getting away from riprap. Expectations and maintenance make it not work long term.
    - Challenge they have in Calgary is being a community with CBs with no sumps in them (removed in 40s/50s).
    - leads to issues with high sediment loading to river, over 90% into beau river comes from storm, saturated system and sands/gravels in conveyance issues
    - Protecting LID becomes a component of this
  - The option as well may involve closing off certain features in the winter months.
    - Calgary would rather not for logistical issues.
    - Turning pump off slows flow but lets sediment through
    - They don't use OGS b/c the top freezes over in the winter, so sediment goes through them
  - Still resolving.

- Q: Bert, you talked about freezing; with respect to LID features, has Calgary had issues with winter performance and functioning?
  - **Answer**: lot of myths from a winter perspective says Bert… Says the biggest issue pertaining to winter is the vegetation.
  - Calgary is in a harsh environment with shanooks, huge temp swings and so it can get very dry.
  - Being able to find vegetation that can survive is a tough journey.
    - Many landscape industries don't understand what is needed so it's a challenge. This has led Bert to setting artificial conditions with an extremely low pallet for species that would survive. Creates an internal balance between the need for high permeability and the ability for moisture retention to sustain vegetation.

- **Question**: Speaking with struggles of plant selection; has the city had to overcome issues with respect to material availability and need to modify the specs of the LID?
- **Question**: have there been challenges with training/onboarding contractors especially for larger retrofit projects?
  - Degree of implementation is relatively so low, so they deal with a vary narrow list of contractors who think they can do it.

- Progress on supply constraints – some of the suppliers are from the Calgary area so it makes their life easier. (mentioned some standard that they are working on/updating testing protocols and such for contractors).
- Bert says some reliable suppliers are now available but what's still missing is the specializing of including nutrients effectively. Controlling leaching, etc. should be kept in mind.
    - Huge need for education with all the turnover (on all levels!)
    - Prince George should keep an eye on what they are doing in Alberta in terms of education efforts.
    - Interior BC shows lots of interest in their education methods. Looking to put more on the web as well.
    - Bert really highlights modules; on storm cells, and other LID types for use. Modules discuss treatment requirements, maintenance, etc. Find these on the City of Calgary website

**Q:** online sources about implementation/monitoring of LIDs that you can share?

- **A:** UofCalgary / Alberta on things like this – papers published with this info.
- This past summer LID inspection project looking at 30 bio retention, soil cell, swale implemented over past decade, but report hasn't been released; he will share with Prince George, but it might be after completion of this work.

**Q:** The City of Ottawa highlighted some bumpouts, biosoil retrofits, etc. Ottawa highlighted people putting junk in them, driving in the bioretention cells, leaves being blown in. Any similar experiences in Calgary? How can these issues be mitigated?

- **Answer**: Similar experiences yes, trying to address them in their LID modules to minimize potential impacts. One thing to keep in mind is seeing a diff between green field installations and retrofit installations. Having to do with catchment condition (stabilized, etc), potential for high sediment loadings going into them.
    - Greenfields vs retrofits establishment; vegetation growth, practices, etc.
    - Hard to establish vegetation when water and contaminants are already going through them
        - Mentions construction sediment overloading bioretention's.
        - ESC in winter months.
    - *Cognisant of difference between retrofit vs greenfield will help handle this problem discussed in the question*
    - Operation people need to be involved EARLY!
    - Design with maintenance in mind.

**This leads to new challenges**

- Challenges with interactions between engineering and parks departments. Engineers create LID and then push them to parks department to maintain. Funding for departments does not properly consider this! Working with so many levels in a municipal workplace creates a difficult environment in this sense. One department cannot typically do all the work for LID which is the main issue.
- Bert touches on turnover in municipalities. Need some dedication to some aspects of LID to avoid training/retraining.

**Closing Remarks**

- Bert mentions keeping up with climate change as an issue.
- Wants to see finished product and says to let prince George chat with him if they please. He is happy to help in all aspects!

AECOM Canada Ltd.
410-250 York St.
London, ON, N6A 6K2
Canada

T: 1-519-673-0510
www.aecom.com

| | | | |
|---|---|---|---|
| Project Name: | Prince George ISMP | Date of Meeting: | January 8th, 2021 |
| | | Time: | 11:00 – 12:00 |
| | | Project #: | 60628231 |
| Attendees: | Nick Szendrey, B.Eng. - AECOM Water Resources EIT | Location: | Conference Call |
| | Leta Van Duin, B.Sc. Executive Director Alberta Low Impact Development Partnership | Prepared By: | Nick Szendrey |
| Regrets: | | | |
| Regarding: | LID implementation in the City of Calgary / Considerations and recommendations for Prince George/ LID technical guidance | | |

# Minutes of Meeting

**Information from Leta**

**Considerations:**

- Everybody is fixated on bioswales, but their role should probably be less prominent.
- Not about doing LID just to do LID, they want to solve a problem. Need to do things for specific reasons
- Thinking about how you want to do maintenance, going to sumps – how will u get the sediment out of the things
- is it an ancillary benefit to implementation of SWM? Then focus energy to the correct locations. Otherwise, the approach should be different…

Example cases:

- OGS are great for sediment removal If its all you care about; but if you are also trying to get nutrient removal, urban heat islands, air quality, etc, suddenly the scale is tipped towards vegetation practice.
- Driving political imagination.
- New vs existing development – things change. With new development, you could implement as you build. With old, a step back may need to be taken to move forwards.

- Specifically: ditches are go-to options because people understand them. Some additional infiltration from the increase in uncompacted soil volume, and increased slope to a regular ditch.
  Soil uptake processes, volume attenuation, providing adequate treatment (if at all).
  How much, and what did you improve?

- Not working in the private realm means not enough performance; you won't get what is required this way.

- *Background: Flood in 2013 caused province to influx money to monitor and demonstration on these topics, this is why Calgary is a step ahead*

- Rain gardens for flood attenuation. On lot/site rain gardens are like mini dry ponds and the province is beginning to recognize it. *Rain gardens have been a topic of conversation across all interviews completed in this municipal scan.*
  - Risk around maintenance and filling things in, but still worth doing.

- **Calgary doesn't have incentivizing programs yet** because of how they bill for stormwater and such. its not a line item; so how do u incentivize it? Saskatoon/Victoria has looked at these programs. too soon though, but maybe in the future.

Education/Testing:

- Leta has completed 12 residential development sites to work on construction aspects, worker/resident attitude towards LID, etc… Bigger community sites completed to educate.
  - Landscape architects think they know but in terms of detailed design they have a high degree of handholding. Leta says there are construction videos and residential practices coming out "imminently" that we could reference.
  - Leta wishes to begin working with some form of landscaper certification program to help educate companies on LID requirements/needs, to improve success rate.
  - Residential landscaping community is not used to dealing with "elevation". This is an issue that arises, when you request specific heights for aspects of LID. A way around this is simplifying terms used. For example, calling these gardens and cells "bathtubs" really helped contractors understand what to construct.
  - Calling things pollinator habitats, biodiversity, flood mitigation helps sell LID to people; they can wrap their head around the good in these terms.

Good examples of LID to look towards:

- Currie barracks in Calgary – medium/high density communities, which are limited by downstream pipe size; so very highly motivated (land value), to minimize the pond size and meet the capacity.
- LID is everywhere here. Automatic irrigation, "literally a menu of options when you bought homes." Rain gardens and barrels. Story: high value land = may be easier to achieve LID
- green conveyance, bioretention through the community towards a central amenity feature which is the pond but also is the park. There are outlets for varying storm sizes into underground storage. Long story short – get creative! Budget helps.

**LID in the Winter:**

- Pilot project from the university where they plow literally on top of the LID and Leta has been monitoring it but in general it works out fine. The snow doesn't affect this functioning much at all.

**Bioretention and Vegetation:**

- Inlets are weak points of bioretention – Leta has a good handle on the vegetation. She says she did a review for the CSA standard for vegetation. She created a very generic list of vegetation that can be used.

- The plant pallet u can use is narrow but generally is universal across the country! Climate typically affects media selection rather than plant selection. It may be a struggle to find vegetation combined with inlet methods that work, but once this is achieved it should be smoother sailing.
- For residential rain gardens Leta recommends using a typical loam – rather than 1/3 topsoil, 1/3 compost and 1/3 sand (typical garden mix more easily obtainable).
- meeting local conditions in texture is key. Regular loam is good for rain gardens because we can rely on soil structure, not texture.
- Correctly considering soil structure will lead to success with rain gardens. Finding a soil structure that works for Prince George may be a unique process, as conditions likely are not the same where Leta has typically worked.
- For bioretention: Focus on surviving the drought season each year.

**Suppliers:**

- Leta has found one supplier does the correct bioretention media across Alberta. She thinks its because there aren't enough projects that require it… (they do have multiple locations though). But there are the correct media available and its possible to achieve. the demand just needs to exist to make it more accessible, as companies haven't been given a reason to make the correct mixtures. They don't use sandy media for bioretention.

**More examples:**

- Blvd retrofit in red deer where they stripped the sod and added plants at the stripped sod height to buy several inches of absorptive capacity during large rain events. Very simple, not conventional but simple!
- Mowed every week, etc. Requires a good amount of maintenance. This is still a simple way to think LID and head down this path.
- There's nothing really close to a wholesale solution. Prince George needs to find what works for <u>them</u>.

**Closing Remarks**

- Leta feels like she has a good understanding of making these LID work in terms of getting in done correctly in the field. She has experience. It would warm her heart to help communities like Prince George properly implement them. She is very knowledgeable on the subject.
- Leta can help with vegetation lists
- Leta doesn't want to be called in after something is built incorrectly; She wants to help early in the process to stop people from doing it wrong and keep them thinking LID rather than scare themselves away.
- Leta says to look at modules highlighting resilient landscaping practices. Big believer in this; fascinating for engineers, big problems to solve, etc.
- Just volume control you're after? Fancy LID are not the way to go; keep it simple!

AECOM Canada Ltd.
410-250 York St.
London, ON, N6A 6K2
Canada

T: 1-519-673-0510
www.aecom.com

Project Name: Prince George ISMP

Date of Meeting: January 8th, 2021
Time: 13:00 – 13:30
Project #: 60628231
Location: Conference Call

Attendees: Bill Trenouth – AECOM Water Resources Engineering, Ph.D, P.Eng., CAN-CISEC

Ian Boland, C.E.T – City of Peterborough Senior Watershed Project Manager

Prepared By: Nick Szendrey

Regrets:

Regarding: LID implementation in the City of Peterborough

# Minutes of Meeting

**Discussion Points:**

Peterborough has no LID in the ROW yet. They do have LID in parking lots but have struggled in implementing these.

Permeable Pavers: turnstone and some bioswales.

Rear yard infiltration swales – primary form of LID in new subdivisions. This is because no easements, no protections required. The problem: Survival of vegetation.

Want to implement a SWM fee/a credit to help ensure maintenance and protection of these LID.

Standard 18.5m XS – most common XS in a subdivision ROW. This is what they wish to use going forward.

Cleantech: come a long way, but expensive.

Peterborough is confident in what they want in terms of LID going forward; which is a limited style of LID. Prime focus is to standardize the process, in order to facilitate maintenance and reduce costs.

will look at underground chambers where it makes sense, but for the most part it will be a standardized bioswale/retention unit used going forward. Will also be using Filterra, but they are expensive.

Parking lot LID: problems are partly design. The grass is not growing, and they see more traffic than they should. They have become very compacted. Did not expect the traffic they saw.

- No standing water so they are working, they suppose.
- But the grass looks poor. It was done because it was suggested, but no one really knew about it/how to do it. Contractor was not trained.
- **We can all learn from this**

Peripheral bioswales: they are wet almost 100% of the time. They are below the water table – which is a problem. They might function as a filter, but they are not infiltrating. Designer did not look at the hydrology data. These are internal City projects.

BIG ONE: experience and training. Will be a direct relation to success with LID.

GreenUp = they had a couple of different raingarden installation programs (SUN) Sustainable Urban Neighbourhoods programs. They went into two neighbourhoods and installed 15 rain gardens. Rain gardens are “nice to have”, but not really rain gardens.

Rain garden subsidy in the city … involves taking some measurements of rooftops, finding downspouts, etc. There is an online calculator. If you meet the min requirements you can get $500 to build a rain garden. Initially, you are required to go to training, which Greenup supplied. **Training is required. This helps ensure success!**

ROW bioretention = City engineers ask the residents “do you want plants or sod?” We have though about maintenance a lot. We have tried to work it into the design. The expectation is that these will be cleanout once per year, in accordance with our current maintenance cycle. Peterborough uses salt and sand.

Peterborough engineering construction group still likely complains about these things… extra cost, project delays, etc. However, we’ve bene through enough training to know that these things must go in, and how to do it. Grumblings will quiet down over time.

**Peterborough currently has a requirement to infiltrate 15mm.**

- new (within the last year or two). Responsibility lie withing Ian’s department – they look after the OGS units, ponds, etc. They need to get up to speed with the O&M of LID too. They want to get to the point where minor inspections are done by public works department. The biggest driver to get this done is the new system wide ECA from the MECP.

Ian has some limited experience with winter operation – if they are not properly designed, they may not function in the winter.

- For Permeable Pavement, snow melts a lot quicker. Not using as much salt, etc.

**Drivers:**

- System wide ECAs
- Water quality – we have a couple of sensitive fisheries creeks with brook trout (Fisher and Jackson Cr.). We have a lot of small streams that mean a lot to people.
- Water quantity – we had big flood in 02 and 04, and that is driving it as well. LID alone cannot solve it alone, but it could help
- Strong environmentally-minded community – vocal residents. The university drives this as well.
- CC is a driver too.

AECOM Canada Ltd.
410-250 York St.
London, ON, N6A 6K2
Canada

T: 1-519-673-0510
www.aecom.com

Project Name: Prince George ISMP

Date of Meeting: January 28th, 2021
Time: 9:00 – 10:00
Project #: 60628231
Location: Conference Call

Attendees: Bill Trenouth – AECOM Water Resources Engineering, Ph.D, P.Eng., CAN-CISEC

Adrienne Sonnes – City of London Stormwater Engineering Division

Prepared By: Nick Szendrey

Regrets:

Regarding: LID implementation in the City of London / Considerations for Prince George BC

# Minutes of Meeting

**Discussion**

Implementation:
City of London (CoL) pushing the "third pipe" (EES) system, as they have a hard time allocating budget to look after rain gardens. City staff don't have time or resources to weed roadside ditches.

- CoL still puts rain gardens in subdivisions in retrofit projects. They will do it for retrofits and when soil conditions allow it.
- The expectation is that the homeowner will look after the feature. Sod is the default option. If they want a garden, CoL will include one at no cost to the homeowner.
- At first this was a flop – people were interested in the plantings, but they didn't get taken care of, so now the City (and its consultants) tend to steer homeowners toward sod, unless there is a real demand for plantings.
- Consultants are expected to meet/discuss with property owners what their LID preference would be.

**City has not had any icing complaints about LID infiltrating in the winter. When properly designed (e.g. With subdrain) there does not appear to be any winter maintenance concerns.**

**Standards development:**
This has been a big struggle.
Moving forward, City wants to have design standards. This includes standards for pre-treatment.
Standards would like to be developed in-house and based on City implementation experience so far
City would probably accept three main LID feature types, although this has not been officially decided:

City preferred types are dependent on land use topology. Very preliminary list:

- EES
- Infiltration gallery
- Bioretention (with sod as a default)
- Amended topsoil (looking at providing some sort of credit but not there yet)

City of London has a long-standing and relatively modest SWM utility fee, and is looking at the possibility of offering a credit for amended topsoil and other green infrastructure approaches

*Structurally supported soil systems (e.g. Silva cells) tend to come into play when there are forestry requirements. Forestry is not 100% comfortable with irrigating trees using SW currently, so these systems are not on the short list above.*

Logistical/Management/Communication
Tracking these things is also a problem from an asset management perspective. Location, maintenance needs, timing, level of effort, etc.

Internal silos – this has also been an issue. For implementation, we have tailored our approach to cater to the teams that work well with us.

For pre-treatment, City would accept more than one type. But we need to understand how it works, what level of maintenance is required, and what is the surrounding land use context

City has complete street standards, but note is not at the point where the standards have extended to include design guidance/details for various LID options and associated appurtenances.

Working with Western University has worked very well for the City – both parties have both from the relationship and the City has improved it's understanding of LID. *If Prince George has the opportunity to work with a local university partner as part of their implementation process it is encouraged that they do so.*

**The best learning tool City has had is doing retrofit and pilot projects through the infrastructure renewal program (IRP). IRP in London brings together water, trans and sewer groups, and is run by construction admin.** This has brought all these groups together to work, and it has greatly improved communication. City has seen good support internally through this process for virtually all aspects of LID implementation.

Sewers and Parks departments: have been awesome. They have asked us "just tell us what to do". They tell us what they can take on, and they want to be supportive, but they are limited due to their budgets, etc.

City stormwater engineering is still working with roads to enhance the collaborative relationship as it pertains to implementation. Roads is not yet a core part of the implementation process and they need to be brought into the fold, SWED continues to work with them in this regard (with things like street sweeping, for example).

Public Education:

Public education: people who are interested in LID are seeking it out anyway. It is a bit of a struggle with the public and people have their own attitudes regarding LID (both positive and negative), and education will not always change that.

Local gardeners have "seedy Saturday" which the City attends, and City staff attend the London Home Show too. These are outreach avenues where we talk directly to homeowners. City also has a dedicated webpage to educate/provide LID and stormwater resources

**Fusion Landscaping - City is hosting a FLP training session in Winter 2021 to build a local market of landscape contractors qualified to build water-sensitive landscape installations (rain gardens and other low-tech LID). SEE LINK: https://horttrades.com/fusion**

City of London also has a stormwater rate reduction for private sites. They get a reduction if they implement LID.

- **Post-meeting Notes**

# Appendix B : Plant and Tree Lists for the City of Prince George

CITY OF PRINCE GEORGE

# BOULEVARD, RESIDENTIAL OR NATURAL AREAS RECOMMENDED TREE LIST

**This guide provides information on trees that are recommended for use within boulevards, residential, or natural areas in Prince George.**

## RECOMMENDED TREE LIST

The following list of tree species are recommended for use in Prince George given their suitability for the local climate and planting in locations which include:

- Boulevards or areas adjacent to roadways (B),
- Natural Areas using native or semi-native trees (N),
- Planter beds or Small Yards (P),
- Residential lots (R), or
- the Bowl Area or other Sheltered Sites (*).

The enclosed tables provide detailed information on each tree species such as their size at maturity, leaf colour, characteristics, salt tolerance, and bear resistance.

*Elm trees in the Prince George Millar Addition neighbourhood.*

## SPECIES NOT RECOMMENDED

A list at the end of this guide identifies tree species which are not recommended for use or should be used with caution.

## STREET TREES

A list of recommended street trees is also available in a separate document through the City of Prince George.

## Evergreen Trees (Coniferous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Needle Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|
| **Balsam Fir**<br>Abies balsamea | B, N, R | 10-15m Ht.<br>3-6m W. |  | Low | High | • Dense symmetrical habit and dark green colour<br>• Medium size with smooth bark, soft/flat needles<br>• Generally insect/pest free<br>• Prefers moist, well-drained soil with shelter from strong winds<br>• Not pollution tolerant |  |
| **White Fir**<br>Abies concolor | B, N, R | 20-25m Ht.<br>5-8m W. |  | Low | High | • Larger fir with dense habit that is conical to columnar in shape<br>• Foliage often has a bluish tinge<br>• Prefers moist, well-drained soil<br>• More adaptable than most firs |  |
| **Subalpine Fir**<br>Abies lasiocarpa | N, R | 10-25m Ht.<br>4-10m W. |  | Low | High | • Similar to a Balsum Fir (Abies balsamea) |  |



**Tree Use:**
B – Boulevard N – Natural Area P – Planter/Small Yard R – Residential * Bowl Area/Sheltered Site

## Evergreen Trees (Coniferous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Needle Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|
| **Rocky Mt. Juniper**<br>Juniperus scopulorum<br><br>*'Cologreen'*<br>*'Gray Ice'*<br>*'Medora'*<br>*'Moonglow'*<br>*'Witchita'* | P, R | 4-10m Ht.<br>1-3m W. |  | Low | High | • Nice evergreen for small areas<br>• Upright forms vary from a narrow 'Skyrocket' to the fuller 'Witchita' or 'Moonglow'<br>• Colours range from bright green to intense blue<br>• Drought tolerant once established<br>• Prefers full sun |  |
| **Weeping Larch**<br>Larix decidua<br><br>*'Pendula'* | P, R | 6m Ht.<br>4m W. | <br> | High | High | • Unique specimen tree with strong weeping habit<br>• Soft green needles that turn bright yellow in fall and shed in winter<br>• Prefers a sunny site with moist soil |  |
| **Siberian Larch**<br>Larix siberica | N, R, S | 20m Ht.<br>15m W. | <br> | High | High | • Deciduous with large pyramidal shape<br>• Soft green foliage turns yellow in fall and shed in winter<br>• Requires a sunny site with moist, well-drained soil<br>• Looks especially nice in group |  |



**Tree Use:**
B – Boulevard N – Natural Area P – Planter/Small Yard R – Residential * Bowl Area/Sheltered Site

## Evergreen Trees (Coniferous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Needle Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|
| **Norway Spruce**<br>Picea abies<br><br>*'Pendula'*<br>+ others | B, P, R | 25-30m Ht.<br>10-15m W. |  | Medium | High | • Large graceful spruce with weeping branches<br>• Bright green foliage<br>• Very hardy<br>• 'Pendula' is a small weeping form suitable as a feature tree in large beds or a planter |  |
| **White Spruce**<br>Picea glauca<br><br>*'Densata'*<br>*'Conica'*<br>*'Jean's Dilly'* | N, P, R | 30m Ht.<br>15m W. |  | High | High | • Large native spruce with bluish green foliage<br>• 'Densata' Black Hill Spruce is more compact & tolerant of drier soils<br>• 'Conica' is very compact, with dwarf forms suited to planters & ornamental beds |  |
| **Colorado Spruce**<br>Picea pungens<br><br>*'Bakeri'*<br>*'Fat Albert'*<br>*'Hoopsii'*<br>+ others | B, N, P, R | 30m Ht.<br>15m W. |  | High | High | • Available in many sizes & forms from columnar to weeping<br>• Best known for vivid blue colour<br>• More drought tolerant than other spruce<br>• Allow room for spread & best uniform growth |  |



**Tree Use:**
B – Boulevard N – Natural Area P – Planter/Small Yard R – Residential * Bowl Area/Sheltered Site

## Evergreen Trees (Coniferous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Needle Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|
| **Eastern White Pine**<br>Pinus strobus<br><br>*'Pendula'* | B, P, R | 15m Ht.<br>7m W. |  | Low | High | • Long bluish green needles give it a soft look<br>• Long purple cones are attractive<br>• Requires sun and moist, well-drained soil<br>• 'Pendula' is a smaller weeping cultivar used as a feature plant |  |
| **Scots Pine**<br>Pinus sylvestris | B, N, R | 15m Ht.<br>8m W. |  | Low | High | • Pyramidal shape when young, becoming more spreading with age<br>• Bluish green needles & orange brown bark<br>• Hardy and adaptable<br>• Prefers a sunny site |  |
| **Douglas Fir**<br>Pseudotsuga menziesii | N, R | 20m Ht.<br>10m W. |  | Low | High | • Large evergreen with a conical shape<br>• Nice dark green needles<br>• Interesting cones<br>• Requires moist, well-drained soil<br>• Requires a large area |  |



**Tree Use:**

B – Boulevard N – Natural Area P – Planter/Small Yard R – Residential * Bowl Area/Sheltered Site

# Evergreen Trees (Coniferous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Needle Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|
| **Cedar**<br>Thuga occidentalis<br><br>*'Brandon'*<br>*'Skybound'*<br>*'Techney'*<br>+ others | P, R * | 2-4m Ht.<br>1m W. |  | Low | High | • Upright cedars<br>• Symmetrical, conical form<br>• Used for hedging or as a windbreak<br>• Best in sheltered location<br>• Requires a moist, well-drained soil |  |



**Tree Use:**
**B** – Boulevard **N** – Natural Area **P** – Planter/Small Yard **R** – Residential ***** Bowl Area/Sheltered Site

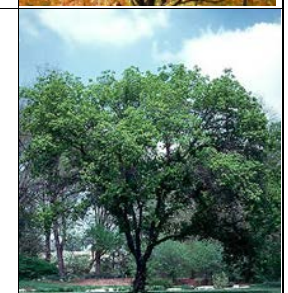
## Shade/Ornamental Trees (Deciduous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **Amur Maple**<br>Acer ginnala<br>*'Compactum'*<br>*'Embers'* | P, R + Shrub Beds | 2-6 m Ht.<br>2-5m W. |  |  | Medium | High | • Multi-stemmed habit<br>• Can be shaped by pruning<br>• Adaptable & hardy<br>• Bright red fall colour<br>• Fits into almost any landscape |  |
| **Norway Maple**<br>Acer platanoides<br>*'Crimson King'*<br>*'Columnar'*<br>*'Prairie Splendor'*<br>*'Easy Street'*<br>+ others | B, R, * | 8-15m Ht.<br>5-9m W. |  |  | High | High | • Various forms from upright to spreading<br>• Several burgundy leaved cultivars<br>• Green leaved cultivars turn bright yellow in fall<br>• Prefers moist soil, but will tolerate other soils<br>• Very few pests problems |  |
| **Red Maple**<br>Acer rubrum<br>*'Autumn Blaze'*<br>*'Columnare'*<br>*'Northwood'*<br>*'Red Sunset'*<br>+others | B, R | 15m Ht.<br>6-10m W. |  |  | Low | High | • Beautiful specimen tree<br>• Dense canopy with strong symmetrical branches<br>• Glossy green leaves turn brilliant red in fall<br>• Prefers moist acidic soil<br>• Shade tolerant when young |  |



**Tree Use:**
B – Boulevard  N – Natural Area  P – Planter/Small Yard  R – Residential  * Bowl Area/Sheltered Site

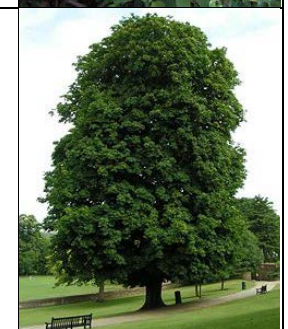
## Shade/Ornamental Trees (Deciduous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **Sugar Maple**<br>Acer saccharum<br>*'Adirondack'*<br>*'Legacy'*<br>*'Green Mt.'*<br>*'Unity'*<br>+others | B, R, * | 15m Ht.<br>12m W. |  |  | Low | High | • Good upright dense, oval shape<br>• Green leaves in summer turn orange/gold in fall<br>• Outstanding gray bark<br>• Not good for restricted growing areas due to canopy spread and surface roots |  |
| **Tatarian Maple**<br>Acer tataricum | B, R | 7-8m Ht.<br>8-10m W. |  |  | Low | High | • Small wide spreading graceful form<br>• Similar to Amur Maple but larger<br>• Nice specimen tree for small yard<br>• Bright red fall colour<br>• Adaptable & drought tolerant |  |
| **Purple blow Maple**<br>Acer truncatum<br>*'Pacific Sunset'* | R, P, * | 9m Ht.<br>8m W. |  |  | Low | High | • Similar to Amur Maple (Acer ginnala), but not as hardy<br>• New growth is red/purple, attracts birds<br>• Very nice fall colours<br>• Use in sheltered sites |  |



**Tree Use:**
B – Boulevard     N – Natural Area     P – Planter/Small Yard     R – Residential     * Bowl Area/Sheltered Site

## Shade/Ornamental Trees (Deciduous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **Ohio Buckeye**<br>Aesculus glabra | B, N, R, * | 8-10m Ht.<br>6-8m W. |  |  | Low | Medium | • Low headed, rounded form<br>• Has prickly nuts that could be a nuisance in yards<br>• Nice orange fall colour<br>• Requires moist soil<br>• Best in natural areas |  |
| **Horse Chestnut**<br>Aesculus hippocastanum | B, R, * | 15-20m Ht.<br>10-15m W. |  |  | Low | Medium | • Dense oval crown<br>• Showy white flower clusters in spring<br>• Spiny nuts in the fall are not edible<br>• Not much fall colour<br>• Requires moist soil |  |
| **Serviceberry**<br>Amelanchier x grandiflora<br><br>*'Autumn Brilliance'* | N, R, P | 8m Ht.<br>5m W. |  |  | Low | Medium | • Often multi-stemmed or small tree<br>• Showy white flowers in spring<br>• Sweet reddish purple edible berries<br>• Outstanding fall colour<br>• Attracts birds |  |



**Tree Use:**
**B** – Boulevard **N** – Natural Area **P** – Planter/Small Yard **R** – Residential ***** Bowl Area/Sheltered Site

## Shade/Ornamental Trees (Deciduous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **River Birch**<br>Betula nigra<br><br>*'Heritage'* | N, B, R | 15m Ht.<br>15m W. |  |  | Low | High | • Nice oval shape<br>• Beautiful exfoliating bark for winter interest<br>• Available in single stem or clump forms<br>• More pest-resistant than other birches<br>• Adaptable to various site conditions |  |
| **Paper Birch**<br>Betula papyrifera<br><br>*'Prairie Dream'*<br>*'Chickadee'*<br>*'Snowy'* | N, R | 12-15m Ht.<br>5-10m W. |  |  | Medium | High | • Prefers heavy watering & well-drained soil<br>• Outstanding white bark<br>• Susceptible to pests during prolonged drought<br>• Not suitable as a street tree |  |
| **Weeping Birch**<br>Betula pendula<br><br>*'Dalcarlica'*<br>*'Purple Rain'*<br>*'Tristis'*<br>*'Youngii'* | B, P, R | 6-12m Ht.<br>5-8m W. |  |  | Low | High | • Similar to Paper Birch but with a weeping form<br>• Very graceful<br>• Cutleaf has finely dissected leaves<br>• 'Youngii' Birch is smaller and useful where space is limited<br>• 'Purple Rain' has striking purple foilage |  |



Tree Use:
B – Boulevard N – Natural Area P – Planter/Small Yard R – Residential * Bowl Area/Sheltered Site

## Shade/Ornamental Trees (Deciduous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **Caragana**<br>Caragana arborescens<br><br>*'Pendula'*<br>*'Walker'* | P, R | 2m Ht.<br>1.5m W. |  |  | Low | High | • Top grafted shrubs that make interesting feature trees<br>• Showy yellow flowers<br>• Bright green foliage<br>• Weeping Branches with thorns<br>• Drought tolerant |  |
| **Hackberry**<br>Celtis occidentalis<br><br>*'Prairie Pride'* | B, N, R | 20m Ht.<br>15m W. |  |  | Low | Medium | • Elm-like in size & form<br>• Large tree that is tough & adaptable for urban use<br>• Berries attract birds<br>• Not much fall colour<br>• Drought tolerant |  |
| **Pagoda Dogwood**<br>Cornus alternifolia<br><br>*'Argentea'* | P, R, * | 4-6m Ht.<br>4-6m W. |  |  | Low | Medium | • Horizontal branching creates a layered effect<br>• Nice for a Japanese style garden & for planters<br>• Showy white flowers<br>• Red/purple fall colour<br>• Shade-tolerant |  |



**Tree Use:**
B – Boulevard N – Natural Area P – Planter/Small Yard R – Residential * Bowl Area/Sheltered Site

# Shade/Ornamental Trees (Deciduous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **Morden Hawthorn** Crataegus x mordensis<br><br>*'Toba'*<br>*'Snowbird'* | P, R | 5m Ht.<br>5m W. | | | Low | Medium | • Small flowering trees with red fruit<br>• Some thorns<br>• Some pest problems<br>• 'Toba' has pink flowers & 'Snowbird' has white |  |
| **Russian Olive** Elaeagnus angustifolia | B, R | 8m Ht.<br>8m W. | | | Medium | High | • Can be grown as a large shrub or trained as a single stemmed tree<br>• Small yellow flowers, silvery small fruit, & 4" sharp thorns<br>• Prefers a dry site<br>• Avoid waterways – can be invasive |  |
| **White Ash** Fraxinus Americana<br><br>*'Autumn Blaze'*<br>*'Autumn Purple'*<br>*'Skyline'* | B, R | 13-15m Ht.<br>12m W. | | | Low | High | • Nice shade tree & better structure than Green Ash<br>• Fall colours range from yellow, orange & purple<br>• Prefers moist well-drained soil but is adaptable<br>• Salt tolerant<br>• 'Autumn Blaze' hardy to zone 3 |  |



**Tree Use:**
**B** – Boulevard  **N** – Natural Area  **P** – Planter/Small Yard  **R** – Residential  ***** Bowl Area/Sheltered Site

## Shade/Ornamental Trees (Deciduous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **Manchurian Ash**<br>Fraxinus mandshurica<br>*'Mancana'* | B, R | 12m Ht.<br>6m W. |  |  | Low | High | • Upright oval trees with lacy foliage<br>• Yellow fall colour<br>• Tolerant of various soil types<br>• Some potential pest problems that proper care & site selection could alleviate<br>• 'Mancana' is a seedless variety |  |
| **Green Ash**<br>Fraxinus pennsylvanica<br>*'Patmore'*<br>*'Prairie Spire'*<br>*'Rugby'* | B, R | 15-18m Ht.<br>7-10m W. |  |  | Low | High | • Hardy & adaptable (but has been overused)<br>• Develops poor structure if not pruned regularly when young<br>• Yellow fall colour<br>• Seedless male cultivars are preferred |  |
| **Butternut**<br>Juglans cinera | B, R, * | 12-18m Ht.<br>10-12m W. |  |  | Medium | High | • Beautiful, wide spreading shade tree<br>• Interesting compound leaves<br>• Oily, edible nuts attract squirrels<br>• Requires deep, rich soil |  |



**Tree Use:**
B – Boulevard N – Natural Area P – Planter/Small Yard R – Residential * Bowl Area/Sheltered Site

## Shade/Ornamental Trees (Deciduous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **Black Walnut**<br>Juglans nigra | B, R, * | 15-22m Ht.<br>15m W. |  |  | Low | Medium | • Upright high headed tree with nice foliage<br>• Long lived<br>• Nuts are attractive to squirrels<br>• Roots produce a compound that is toxic to other plants |  |
| **Amur Maackia**<br>Maackia amurensis | B, P, R | 6-9m Ht.<br>6-7m W. |  |  | Low | High | • Small graceful tree good for a small yard<br>• Fragrant, yellowish flowers in spring<br>• Golden bark<br>• Low maintenance & adaptable<br>• Virtually pest-free |  |
| **Ironwood**<br>Ostrya virginiana | B, R, * | 10-13m Ht.<br>7-10m W. |  |  | Low | High | • Oval to rounded tree that is tough, adaptable & shade tolerant<br>• Attractive foliage turns yellow in fall<br>• Bark is showy & seeds attract birds<br>• Avoid wet soils |  |



**Tree Use:**
**B** – Boulevard **N** – Natural Area **P** – Planter/Small Yard **R** – Residential ***** Bowl Area/Sheltered Site

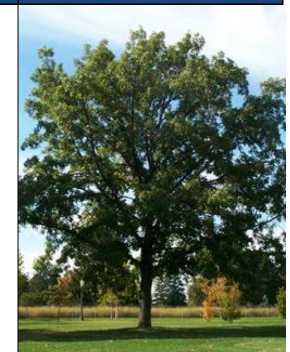
# Shade/Ornamental Trees (Deciduous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **Amur Cork Tree**<br>Phellodendron amurense<br><br>*'Macho'*<br>*'Shademaster'*<br>*'His Majesty'* | B, R | 7-9m Ht.<br>7-9m W. |  |  | Low | Medium | • Unique & beautiful tree that should be used more<br>• Graceful, spreading habit<br>• Nice foliage with fall colour<br>• Interesting bark<br>• Use male cultivars to avoid fruit which is messy and attracts bears |  |
| **Swedish Columnar Aspen**<br>Populus tremula<br>'erecta' | B, N, R | 12m Ht.<br>2m W. |  |  | Medium | High | • Growing in popularity due to it's beautiful columnar habit<br>• Tough, adaptable & fits into restricted spaces<br>• Nice fall colour, no fluffy seeds & non aggressive roots |  |
| **Northern Pin Oak**<br>Quercus ellipsoidalis | B, R | 15m Ht.<br>12m W. |  |  | Low | Medium | • Broad, oval habit<br>• Very stately appearance typical of Oaks<br>• Cold hardy Pin Oak<br>• Rich, green foliage with red to coppery fall colour |  |



**Tree Use:**
**B** – Boulevard **N** – Natural Area **P** – Planter/Small Yard **R** – Residential ***** Bowl Area/Sheltered Site

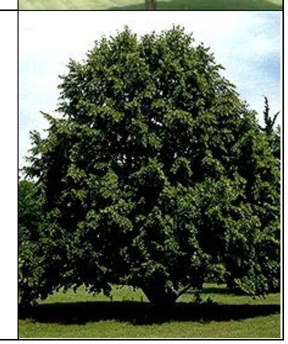
## Shade/Ornamental Trees (Deciduous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **Bur Oak**<br>Quercus macrocarpa | B, R | 20-24m Ht.<br>9-12m W. |  |  | Medium | Medium | • Very hardy native Oak<br>• Interesting bark, leaves & acorns<br>• Adaptable tree & tolerant of urban conditions<br>• Requires large area to reach it's full potential<br>• Birds & squirrels love the acorns |  |
| **Red Oak**<br>Quercus rubra | B, R | 18-21m Ht.<br>9-12m W. |  |  | High | Medium | • One of the faster growing Oaks<br>• Large & very stately tree<br>• Tolerant of most soils except high pH<br>• Fall colour ranges from red to coppery-brown<br>• Leaves often remain on the tree for winter |  |
| **White Willow**<br>Salix alba<br><br>*'Tristis'*<br>*'Vitellina'* | N, R | 15m Ht.<br>12m W. |  |  | Low | High | • Beautiful tree with colourful yellow new growth<br>• 'Tristis' has a weeping habit<br>• Not for the small yard<br>• Willows drop branches constantly & have very aggressive roots<br>• Best used in larger natural areas |  |



**Tree Use:**
B – Boulevard N – Natural Area P – Planter/Small Yard R – Residential * Bowl Area/Sheltered Site

## Shade/Ornamental Trees (Deciduous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **Laurel Leaf Willow**<br>Salix pentandra<br>*'Prairie Cascade'* | N, R | 10-13m Ht.<br>10m W. |  |  | Low | High | • Fast growing tree with shiny green foliage<br>• Use in large, natural areas<br>• Requires moist, wet soils<br>• 'Prairie Cascade' is a hybrid with golden new stems & a weeping habit |  |
| **Japanese Tree Lilac**<br>Syringa reticulate<br>*'Ivory Silk'* | B, P, R | 8-9m Ht.<br>7-8m W. |  |  | Medium | High | • Small tree with oval crown<br>• Very attractive creamy white flower clusters<br>• Nice specimen for small yard or large planter<br>• Tough tree for urban conditions<br>• Probably underused |  |
| **Linden sp.**<br>Tilia Americana<br>Tilia cordata<br>Tilia x flavescens<br>Tilia mongolica<br>*Various species* | B, P, R | 10-30m Ht.<br>7-15m W. |  |  | Medium | High | • Pyramidal to oval in form<br>• Very nice structure & branching habit<br>• Nice foliage with yellow flowers<br>• Very tidy tree & requires little pruning<br>• Tilia americana is larger than other Tilia's |  |



**Tree Use:**
B – Boulevard N – Natural Area P – Planter/Small Yard R – Residential * Bowl Area/Sheltered Site

## Shade/Ornamental Trees (Deciduous)

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| Elm<br>Ulmus Americana<br><br>*'Brandon'*<br>*'Liberty'*<br>*'Valley Forge'*<br>*'New Harmony*<br>*'Discovery'* | B, R | 20m Ht.<br>15m W. |  |  | Low | High | • Nice specimens at City Hall & the Millar addition<br>• Lovely vase-shape with arching branches<br>• Yellow fall colour<br>• Dutch Elm disease (DED) has wiped out entire Elm population in much of North America<br>• Use DED-resistant varieties |  |

Other Tree Species **not recommended for use** or should be **used with caution**, include the following:

- **Poplar & Willow species** – Suitable for natural areas only as root systems are invasive.
- **Manitoba Maple/Box Elder (Acer negundo)** – Self-seeding and root systems are invasive.
- **Silver Maple (Acer saccharinium)** – Hazardous and messy with brittle branches. Root systems are also invasive.
- **Black Ash (Fraxinus nigra)** – Not recommended given pest problems with Black Ash cultivars.
- **Flowering Crabs (Malus species)** – Crab trees produce fruit and are attractants to bears. Fruit must be removed immediately upon ripening for harvest or disposal (composting not recommended as the odour is attractive to bears).
- **Mayday & Chokecherry (Prunus padus)** – Prunus species produce fruit and are attractants to bears. Black knot disease is prominent in some prunus species.
- **Mountain Ash (Sorbus aucuparia/decora)** – Mountain ash trees produce fruit and are attractants to bears. Fruit can also be messy on hard surfaces.

Revision Date: February 21, 2019



Tree Use:
B – Boulevard N – Natural Area P – Planter/Small Yard R – Residential * Bowl Area/Sheltered Site

# SALT TOLERANT PLANTS RECOMMENDED LIST

**This guide provides information on salt tolerant plant species that are recommended for use along sidewalks, roadways, or other paths that are maintained with deicing salts in winter.**

*Maple trees along Queensway in Prince George.*

## SALT TOLERANT PLANTS

Winter maintenance of sidewalks, roadways, and trails in Prince George often includes the use of deicing salt which can be fatal to many of the plant species. Salt spray and excess salt in the soil can also cause branch dieback, stunted growth, and overall vigor.

The following list of plant species are recommended for use in landscaped areas that will be impacted by deicing salts. Note: All high salt tolerant plant species are listed in **bold**.

| Latin Name | Common Name | Salt Tolerance |
|---|---|---|
| **Shade & Ornamental Trees (Deciduous)** | | |
| Acer ginnala | Amur Maple | Medium |
| **Acer platanoides** | **Royal Red Maple** | **High** |
| Betula papyrifera | Paper Birch | Medium |
| **Larix sp.** | **Larch** | **High** |
| Populus tremuloides 'Erecta' | Swedish Columnar Aspen | Medium |
| Quercus macrocarpa | Bur Oak | Medium |
| **Quercus rubra** | **Red Oak** | **High** |
| Syringa reticulata 'Ivory Silk' | Ivory Silk Tree Lilac | Medium |
| Tilia americana | American Linden | Medium |

| Latin Name | Common Name | Salt Tolerance |
|---|---|---|
| **Evergreen Trees (Coniferous)** | | |
| Picea abies species | Norway Spruce | Medium |
| Picea glauca species | White Spruce | High |
| Picea pungens species | Colorado Blue Spruce | High |
| Pinus nigra | Austrian Pine | High |
| **Ornamental Deciduous Shrubs** | | |
| Berberis thunbergii | Japanese Barberry | High |
| Cotoneaster species | Cotoneaster | High |
| Philadelphus species | Mock Orange | Medium |
| Potentilla species | Potentilla | High |
| Rhus species | Sumac | High |
| Rosa rugosa | Hardy Shrub Rose | High |
| Spiraea x vanhouttei varities | Bridlewreath Spiraea | Medium |
| **Ornamental Evergreen (Coniferous) Shrubs** | | |
| Juniperus species | Juniper | High |
| Pinus mugho | Mugho Pine | High |
| **Perennials** | | |
| Alchemilla mollis | Lady's Mantle | High |
| Artemisia schmidtiana 'Silver Mound' | Silver Mound Artemesia | Medium |
| Coreopsis verticullata 'Moonbeam' | Moonbeam Tickseed | Medium |
| Dianthus pulmarius | Pinks | High |
| Euphorbia griffithii 'Fireglow' | Fireglow' Griffith's Spurge | Medium |
| Hemerocallis 'Stella de Oro' | Stella De Oro Daylily | Medium |
| Heuchera micrantha var. | Palace Purple Coral Bells | Medium |
| Hosta plantaginea | Plantain Lily | Medium |
| Iberis sempervirens | Evergreen Candytuft | Medium |
| Iris sibirica 'Caesar's Brother' | 'Caesar's Brother' Siberian Iris | Medium |
| Liriope spicata | Creeping Lilyturf | Medium |
| Sedum spectabile 'Autumn Joy' | Autumn Joy Stonecrop | Medium |
| Stachys byzantina | Lamb's Ears | Medium |
| **Ornamental Grasses** | | |
| Calamagrostis x acutiflora | Karl Foerster Feather Reed | High |
| Elymus arenarius | Blue Lyme Grass | High |
| Festuca glauca 'Elijah Blue' | Elijah Blue Fescue | Medium |

## MINIMIZING SALT INJURY

The following practices are recommended to help avoid injuries to plant material and grass from deicing salt:

- Place temporary winter barriers such as burlap or fencing along landscaped areas
- Avoid the use of deicing salt and apply the salt to hard surface areas after the snow has been removed
- Avoid storing shoveled snow on planting beds
- Alter drainage patterns to avoid the accumulation of salt runoff into landscaped areas
- Flush landscaped areas heavily with water in spring to help move any salt through the soil

# RECOMMENDED STREET TREE LIST

**This guide provides information on tree species which are recommended for use as street trees in Prince George.**

## RECOMMENDED TREE LIST

Street tree environments contain some of the most extreme growing conditions with confined spaces, heat, salt spray, pollution, poor drainage, and vandalism or damage. The following list of street tree species are recommended for Prince George given their suitability within locations that include:

- Raised Planter Beds (S), or
- At grade Street Tree Wells (W).

The enclosed tables provide detailed information on each tree species such as their size at maturity, leaf colour, characteristics, salt tolerance, and bear resistance. Note: Some species may also be available in a columnar form which is suitable for narrow sidewalks.

*Street trees in front of the Wood Innovation & Design Centre in PG.*

## SPECIES NOT RECOMMENDED

A list at the end of this guide identifies tree species which are not recommended for use or should be used with caution.

## BOULEVARD, RESIDENTIAL & NATURAL AREA TREES

A list of recommended trees for boulevards, residential, and natural areas is available in a separate document through the City of Prince George.

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **Norway Maple**<br>Acer platanoides<br>*'Crimson King'*<br>*'Columnar'*<br>*'Prairie Splendor'*<br>*'Easy Street'*<br>+ others | S, W | 8-15m Ht.<br>5-9m W. |  |  | High | High | • Various forms from upright to spreading<br>• Several burgundy leaved cultivars<br>• Green leaved cultivars turn bright yellow in fall<br>• Prefers moist soil, but will tolerate other soils<br>• Very few pests problems |  |
| **Red Maple**<br>Acer rubrum<br>*'Autumn Blaze'*<br>*'Columnare'*<br>*'Northwood'*<br>*'Red Sunset'*<br>+others | S, W | 15m Ht.<br>6-10m W. |  |  | Low | High | • Beautiful specimen tree<br>• Dense canopy with strong symmetrical branches<br>• Glossy green leaves turn brilliant red in fall<br>• Prefers moist acidic soil<br>• Shade tolerant when young |  |
| **Weeping Birch**<br>Betula pendula<br>*'Dalcarlica'*<br>*'Purple Rain'*<br>*'Tristis'*<br>*'Youngii'* | S | 6-12m Ht.<br>5-8m W. |  |  | Low | High | • Similar to Paper Birch but with a weeping form<br>• Very graceful<br>• Cutleaf has finely dissected leaves<br>• 'Youngii' Birch is smaller and useful where space is limited<br>• 'Purple Rain' has striking purple foilage |  |



**Tree Use:**

**S** – Sidewalk Raised Planter Bed **W** – Sidewalk Tree Wells at grade

| **Latin Name/ Common Name** | **Tree Use** | **Mature Height/ Width** | **Summer Leaf Colour** | **Fall Leaf Colour** | **Salt Tolerance** | **Bear Resistance** | **Characteristics** | **Photo** |
|---|---|---|---|---|---|---|---|---|
| **Amur Maackia**<br>Maackia amurensis | S | 6m Ht.<br>6m W. |  |  | Low | High | • Small graceful tree good for a small yard<br>• Fragrant, yellowish flowers in spring<br>• Golden bark<br>• Low maintenance & adaptable<br>• Virtually pest-free |  |
| **Swedish Columnar Aspen**<br>Populus tremula<br>'erecta' | S, W | 12m Ht.<br>2m W. |  |  | Medium | High | • Growing in popularity due to it's beautiful columnar habit<br>• Tough, adaptable & fits into restricted spaces<br>• Nice fall colour, no fluffy seeds & non aggressive roots |  |
| **Japanese Tree Lilac**<br>Syringa reticulate<br>*'Ivory Silk'* | S, W | 7m Ht.<br>5m W. |  |  | Medium | High | • Small tree with oval crown<br>• Very attractive creamy white flower clusters<br>• Nice specimen for small yard or large planter<br>• Tough tree for urban conditions<br>• Probably underused |  |



**Tree Use:**

**S** – Sidewalk Raised Planter Bed **W** – Sidewalk Tree Wells at grade

| Latin Name/ Common Name | Tree Use | Mature Height/ Width | Summer Leaf Colour | Fall Leaf Colour | Salt Tolerance | Bear Resistance | Characteristics | Photo |
|---|---|---|---|---|---|---|---|---|
| **Linden sp.**<br>Tilia cordata<br>Tilia mongolica<br><br>*'Corinthian'*<br>*'Greenspire'*<br>*'Morden'*<br>*'Harvest Gold'*<br>+ others | S, W | 15m Ht.<br>5-10m W. |  |  | Medium | High | • Well-structured tree requiring little pruning<br>• Beautiful foliage & fragrant flowers<br>• Usually pyramidal in form, but some more upright forms may be available<br>• Very tidy tree – an Arborist's favourite |  |

Other Tree Species **not recommended for use** or should be **used with caution**, include the following:

- **Box Elder or Manitoba Maple (Acer negundo) -** Not very pollution, salt, and drought tolerant.
- **Sugar Maple (Acer saccharum)** – Not very pollution, salt, and drought tolerant.
- **Ohio Buckeye (Aesculus glabra)** – Not very pollution, salt, and drought tolerant.  Produces nuts.
- **Hackberry (Celtis occidentalis)** – Large tree that requires room and is susceptible to disease.
- **Morden Hawthorne (Crataegus mordenensis)** – 3" thorns present a risk to pedestrians.
- **Russian Olive (Eleagnus angustifolia)** – Poor form, brittle branching system, and drainage issues can occur.
- **Black Ash & Patmore Ash (Fraxinus species)** – Overabundant in PG and pest concerns are present.
- **Butternut (Juglans cinera)** – Produces nuts, it is not compatible with urban soils, and is susceptible to fungus.
- **Flowering Crabs (Malus species)** – Crab trees produce fruit and are attractants to bears.
- **Burr Oak (Quercus macrocarpa)** – Too large for a street tree environment and branches are at a 90 degree angle.
- **Mayday & Chokecherry (Prunus padus)** – Produces fruit and are attractants to bears.  Black knot disease is prominent.
- **Mountain Ash (Sorbus aucuparia/decora)** – Produces fruit and are attractants to bears.
- **Redmond Linden (Tilia americana 'Redmond')** – Too large for a street tree environment.
- **Elm (Ulmus americana)** – Too large for a street tree environment and roots can be aggressive.



**Tree Use:**
**S** – Sidewalk Raised Planter Bed  **W** – Sidewalk Tree Wells at grade

# Appendix C : PG Airport Precipitation

**Existing IDF Curve**

| | | Recurrence (years) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
| Periods | 5 min | 4.5 | 6.5 | 8.1 | 10.0 | 10.7 | 13.0 | 15.8 |
| | 10 min | 6.1 | 8.6 | 10.6 | 12.8 | 13.6 | 16.3 | 19.4 |
| | 15 min | 7.0 | 9.9 | 12.3 | 15.1 | 16.1 | 19.5 | 23.5 |
| | 30 min | 8.2 | 11.7 | 14.4 | 17.4 | 18.5 | 22.0 | 26.1 |
| | 1 h | 9.8 | 13.6 | 16.6 | 19.9 | 21.0 | 24.8 | 29.1 |
| | 2 h | 11.7 | 15.5 | 18.7 | 22.5 | 23.9 | 28.8 | 34.6 |
| | 6 h | 16.7 | 21.5 | 25.4 | 29.8 | 31.4 | 36.8 | 43.0 |
| | 12 h | 20.8 | 26.1 | 30.4 | 35.2 | 36.9 | 42.7 | 49.4 |
| | 24 h | 27.5 | 34.2 | 38.6 | 42.9 | 44.3 | 48.5 | 52.8 |

**IPCC Climate ChangeScenarios**

***RCP 2.6***

| | | Recurrence periods (years) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
| Periods | 5 min | 4.9 | 6.9 | 8.7 | 10.8 | 11.6 | 14.1 | 17.3 |
| | 10 min | 6.6 | 9.2 | 11.3 | 13.8 | 14.7 | 17.7 | 21.3 |
| | 15 min | 7.6 | 10.6 | 13.2 | 16.2 | 17.4 | 21.1 | 25.8 |
| | 30 min | 8.9 | 12.5 | 15.5 | 18.8 | 20.1 | 23.9 | 28.6 |
| | 1 h | 10.7 | 14.6 | 17.8 | 21.5 | 22.8 | 27.0 | 32.0 |
| | 2 h | 12.7 | 16.5 | 20.0 | 24.1 | 25.8 | 31.0 | 37.9 |
| | 6 h | 18.2 | 22.9 | 27.2 | 32.1 | 33.9 | 39.8 | 47.3 |
| | 12 h | 22.7 | 27.8 | 32.5 | 37.8 | 39.8 | 46.2 | 54.5 |
| | 24 h | 30.0 | 36.7 | 41.4 | 46.3 | 47.9 | 52.9 | 57.8 |

***RCP 4.5***

| | | Recurrence periods (years) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
| Periods | 5 min | 4.9 | 7.1 | 8.9 | 11.0 | 11.7 | 14.2 | 17.2 |
| | 10 min | 6.7 | 9.4 | 11.6 | 14.1 | 14.9 | 17.8 | 21.2 |
| | 15 min | 7.7 | 10.8 | 13.5 | 16.5 | 17.5 | 21.2 | 25.6 |
| | 30 min | 9.0 | 12.8 | 15.8 | 19.2 | 20.3 | 24.0 | 28.6 |
| | 1 h | 10.8 | 14.9 | 18.2 | 21.9 | 23.1 | 27.1 | 32.1 |
| | 2 h | 12.8 | 16.9 | 20.5 | 24.6 | 26.1 | 31.2 | 37.6 |
| | 6 h | 18.4 | 23.5 | 27.9 | 32.7 | 34.5 | 40.0 | 47.2 |
| | 12 h | 22.9 | 28.5 | 33.3 | 38.7 | 40.6 | 46.4 | 54.4 |
| | 24 h | 30.3 | 37.5 | 42.3 | 47.4 | 49.0 | 53.4 | 57.9 |

***RCP 8.5***

| | | Recurrence periods (years) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 5 | 10 | 20 | 25 | 50 | 100 |
| Periods | 5 min | 5.1 | 7.5 | 9.5 | 11.8 | 12.6 | 15.4 | 18.9 |
| | 10 min | 7.0 | 9.9 | 12.4 | 15.1 | 16.1 | 19.3 | 23.2 |
| | 15 min | 8.1 | 11.4 | 14.5 | 17.7 | 18.9 | 23.0 | 28.2 |
| | 30 min | 9.4 | 13.5 | 17.0 | 20.6 | 21.9 | 26.2 | 31.3 |
| | 1 h | 11.3 | 15.8 | 19.6 | 23.5 | 24.9 | 29.6 | 35.0 |
| | 2 h | 13.4 | 17.8 | 22.0 | 26.5 | 28.1 | 33.9 | 41.7 |
| | 6 h | 19.3 | 24.8 | 29.9 | 35.2 | 37.1 | 43.6 | 51.4 |
| | 12 h | 24.0 | 30.1 | 35.8 | 41.6 | 43.6 | 50.8 | 59.1 |
| | 24 h | 31.7 | 39.6 | 45.6 | 50.9 | 52.8 | 57.9 | 62.8 |

**Contact**

Nancy Hill, P.Eng.
Project Manager
T: +1 604.790.1637
E: nancy.hill@aecom.com

# Appendix D

## Technical Working Paper #3 – Policy & Regulatory Review

City of Prince George

# Integrated Stormwater Management Plan

## *Technical Working Paper # 3 - Policy and Regulatory Review*

**Prepared by:**

AECOM Canada Ltd.
3292 Production Way, Floor 4
Burnaby, BC V5A 4R4
Canada

T: 604 444 6400
F: 604 294 8597
www.aecom.com

**Date:** May 2021

**Project #:** 60628231

## Distribution List

| # Hard Copies | PDF Required | Association / Company Name |
|---|---|---|
| | ✓ | City of Prince George |
| | ✓ | AECOM Canada Ltd. |

# Statement of Qualifications and Limitations

The attached Report (the "Report") has been prepared by AECOM Canada Ltd. ("AECOM") for the benefit of the Client ("Client") in accordance with the agreement between AECOM and Client, including the scope of work detailed therein (the "Agreement").

The information, data, recommendations and conclusions contained in the Report (collectively, the "Information"):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the "Limitations");
- represents AECOM's professional judgement in light of the Limitations and industry standards for the preparation of similar reports;
- may be based on information provided to AECOM which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the Report and the Agreement; and
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time.

AECOM shall be entitled to rely upon the accuracy and completeness of information that was provided to it and has no obligation to update such information. AECOM accepts no responsibility for any events or circumstances that may have occurred since the date on which the Report was prepared and, in the case of subsurface, environmental or geotechnical conditions, is not responsible for any variability in such conditions, geographically or over time.

AECOM agrees that the Report represents its professional judgement as described above and that the Information has been prepared for the specific purpose and use described in the Report and the Agreement, but AECOM makes no other representations, or any guarantees or warranties whatsoever, whether express or implied, with respect to the Report, the Information or any part thereof.

Without in any way limiting the generality of the foregoing, any estimates or opinions regarding probable construction costs or construction schedule provided by AECOM represent AECOM's professional judgement in light of its experience and the knowledge and information available to it at the time of preparation. Since AECOM has no control over market or economic conditions, prices for construction labour, equipment or materials or bidding procedures, AECOM, its directors, officers and employees are not able to, nor do they, make any representations, warranties or guarantees whatsoever, whether express or implied, with respect to such estimates or opinions, or their variance from actual construction costs or schedules, and accept no responsibility for any loss or damage arising therefrom or in any way related thereto. Persons relying on such estimates or opinions do so at their own risk.

Except (1) as agreed to in writing by AECOM and Client; (2) as required by-law; or (3) to the extent used by governmental reviewing agencies for the purpose of obtaining permits or approvals, the Report and the Information may be used and relied upon only by Client.

AECOM accepts no responsibility, and denies any liability whatsoever, to parties other than Client who may obtain access to the Report or the Information for any injury, loss or damage suffered by such parties arising from their use of, reliance upon, or decisions or actions based on the Report or any of the Information ("improper use of the Report"), except to the extent those parties have obtained the prior written consent of AECOM to use and rely upon the Report and the Information. Any injury, loss or damages arising from improper use of the Report shall be borne by the party making such use.

This Statement of Qualifications and Limitations is attached to and forms part of the Report and any use of the Report is subject to the terms hereof.

*AECOM: 2015-04-13*

# Authors

**Report Prepared By:**

Ian Rennie

**Report Reviewed By:**

Nancy Hill, P.Eng.
Project Manager

# Executive Summary

As part of the City of Prince George's (City) Integrated Stormwater Management Plan (ISMP) AECOM Canada Ltd. (AECOM) is reviewing how stormwater issues are being addressed through regulation and planning. This Technical Working Paper provides a summary of our work; namely to:

- Summarise the City's policies, regulations, and systems of enforcement with respect to stormwater;
- Compare the City's policies and regulations with those of other municipalities;
- Determine whether stormwater issues are being sufficiently addressed through the City's existing bylaws and plans (i.e. identify any gaps);
- Identify how best to address any gaps; and
- Present findings and make recommendations for the City.

**Existing Stormwater Bylaws, Plans and Policies**

The City has the following bylaws that impact how stormwater is managed in Prince George: Storm Sewer Bylaw; Flood Plain Regulation Bylaw; Soil Removal and Deposit Bylaw; Tree Protection Bylaw; Highways Bylaws; Sanitary Sewer Use Bylaw; Official Community Plan Bylaw; Zoning Bylaw; Subdivision and Development Servicing Bylaw; Development Procedures Bylaw; Development Cost Charge Bylaw; Building Bylaw; Bylaw Notice Enforcement Bylaw; Comprehensive Fees and Charges Bylaw; and the Municipal Ticket Information Utilization Bylaw. In addition, the City has plans, policies and guidelines in the areas of climate change, infrastructure design (i.e. Design Guidelines), asset management, salt management and sustainable financing that also affect how stormwater is managed in Prince George.

In addition to municipal regulations there are Provincial and Federal regulations and guidelines that can affect municipal stormwater management; such as: Federal Fisheries Act; Water Sustainability Act (B.C.); Riparian Areas Protection Act (B.C.); Stormwater Guidelines (DFO) and Beyond the Guidebook (B.C.); and Water Quality Guidelines (B.C. and Federal).

**Identified Issues**

The main issues identified with the City's policies, guidelines and bylaws involve:

- **Cost Recovery**: The need to be able to recover costs for work caused by others such as the clean-up of spills;
- **Prohibited Wastes**: Improve the definition of substances within the Storm Sewer Bylaw that are not allowed to be discharged to any component of the City's stormwater system.
- **Low Impact Development (LID)/Best Management Practices (BMP)**: Lack of requirements for new development to control the quantity and quality of stormwater leaving private property;
- **Climate Change**: The need to integrate climate change adaptation into design criteria;
- **Protection of Trees and Other Natural Assets:** The need to protect trees and other natural assets such as wetlands, non-fish bearing streams and riparian set-backs;
- **Erosion and Sediment Control:** The need for improved erosion and sediment control associated with all development including the clearing of land before subdivision;
- **Culverts:** Responsibilities for replacing driveway culverts are not clearly defined;
- **Design Criteria:** The need to update and mandate existing stormwater design criteria (i.e., 2001 Draft Design Guidelines); and
- **Staffing:** The need for sufficient staffing to enforce bylaw compliance.

**Conclusions and Recommendations**

Based on the issues and gaps identified above we are making the following recommendations to the City of Prince George:

- Update the Storm Sewer Bylaw to improve definitions, to revise the list of prohibited discharges, to allow for in-field measurement of sediment concentration, to clearly specify the types of properties that require an oil and grit separator (including large surface parking lots and industrial properties) and associated maintenance requirements, to be consistent with the Sanitary Sewer Use Bylaw particularly with respect to unauthorized discharges (i.e. spills), to explicitly state who is responsible for maintaining, renewing and upgrading driveway culverts; and to allow for the recovery of City costs (e.g. for spill clean-up). The Bylaw Notice Enforcement Bylaw and/or the Municipal Ticket Information Utilization Bylaw would then need to be updated accordingly to include all contraventions of the Storm Sewer Bylaw
- Update the Subdivision and Development Servicing Bylaw and associated Design Guidelines to enact current best practises in stormwater management that are applicable to the climate and geography of Prince George as it pertains to: climate change; stormwater runoff rates, volumes, and quality; erosion and sediment control; and oil-grit separator design requirements for sizing and maintenance access. Technical Working Paper #2 addresses additional recommended updates such as permitting the new installation of open channels; permitted culvert materials; design standards and O&M plans with cost estimates for detention ponds and constructed wetlands; acceptance of detention ponds once appropriate and approved vegetation is established; sewer relining standards; limiting the installation of basements in high risk areas due to groundwater and flooding; maximum grades and velocities; minimum sewer depth; bike-friendly catch basin grates; and utility disconnect procedures.
- Strengthen the Tree Protection Bylaw by increasing the area covered by the bylaw and allow for the recovery of City costs associated with rectifying problems caused by infractions.
- Increase development permit areas within the OCP bylaw to include all significant flood and slope hazards, and to protect all valuable natural areas, such as riparian areas of streams that provide nutrients to downstream fisheries and wetlands that are not directly connected to fish-bearing streams.
- Develop a new Erosion and Sediment Control bylaw to increase the City's ability to require better erosion and sediment control practices by developers (particularly during land clearing before subdivision), to better monitor the quality of discharges in the field and to have more effective enforcement for non-compliance. As an interim measure, the City may strengthen existing bylaws to help increase the City's ability to require and enforce better erosion and sediment control practices.
- Obtain sufficient permitting and enforcement staffing levels and/or front-end resource prioritization on outreach and education and design submission review in order to encourage bylaw compliance.

# Table of Contents



# List of Tables

# 1. Introduction

As part of the City of Prince George's (City) Integrated Stormwater Management Plan (ISMP) AECOM Canada Ltd. (AECOM) is reviewing how stormwater issues are being addressed through regulation and planning. This Technical Working Paper provides a summary of our work; namely to:

- Summarise the City's policies, regulations, and system of enforcement with respect to stormwater;
- Compare the City's policy and regulatory framework with those of other municipalities;
- Determine whether stormwater issues are being sufficiently addressed through the City's existing bylaws and plans (i.e. identify any gaps);
- Identify how best to address any gaps; and
- Present findings and make recommendations for the City.

# 2. Existing Stormwater Bylaws, Plans and Policies

## 2.1 List of Documents

AECOM compiled and reviewed the following list of City, Provincial and Federal documents. Documents included bylaws, plans, policies, and other internal documents that relate to stormwater management.

City of Prince George Bylaws

- Storm Sewer Bylaw, No. 2656, 1974 (updated 2017);
- Flood Plain Regulation Bylaw, No. 8285, 2010;
- Soil Removal and Deposit Bylaw, No. 9030, 2019;
- Tree Protection Bylaw, No. 6343, 1995;
- Highways Bylaws, No. 8065, 2008;
- Sanitary Sewer Use Bylaw No. 9055, 2019;
- Official Community Plan Bylaw, No. 8383, 2011;
- Zoning Bylaw 7850, 2007 (updated 2020);
- Subdivision and Development Servicing Bylaw, No. 8618, 2014;
- Development Procedures Bylaw No. 7635, 2005
- Development Cost Charge Bylaw, No. 7825, 2007;
- Building Bylaw, No. 8922, 2018 (including the BC Building Code 2018);
- Bylaw Notice Enforcement Bylaw, No. 8813, 2016;
- Comprehensive Fees and Charges Bylaw, No. 7557, 2004;
- Municipal Ticket Information Utilization Bylaw No. 8919, 2017.

Other City of Prince George Documents

- Adapting to Climate Change in Prince George: An overview of adaptation priorities (2009)
- Implementing Climate Change Adaptation in Prince George, BC Volume 4: Flooding (2012)
- Climate Change Impacts on Rainfall and Freeze-Thaw Events in Prince George (2014)
- Climate Change Adaptation Strategies for the Community of Prince George (2020)
- Development Services Department - Design Guidelines (DRAFT)
- Asset Management Policy
- Salt Vulnerable Areas Action Plan (and Recommendations)
- Sustainable Finance Guidelines

Provincial and Federal Regulations

- Fisheries Act (Federal)
- Water Sustainability Act (B.C.)
- Riparian Areas Protection Act (B.C.)
- Stormwater Guidelines (DFO) and Beyond the Guidebook (B.C.)

- Water Quality Guidelines (B.C. and Federal)

## 2.2 Document Summary

This section describes the general intent of each document and how each document affects stormwater management in the City of Prince George.

### Bylaws

Storm Sewer Bylaw

The main purpose of the City's Storm Sewer Bylaw is to regulate the extension of and connection to the storm sewer system. The City's current Storm Sewer Bylaw addresses the following topics: use of the storm sewer system, connections, illegal connections, tampering, prohibited types and levels of discharges, oil and grit separators (OGS), sampling chambers, measurement and testing, storm sewer system extensions, charges for services, inspection and penalties. The bylaw is not as comprehensive as Prince George's Sanitary Sewer Use Bylaw or Storm Bylaws from other municipalities, particularly with regard to definitions and scope. For instance, the Storm Sewer Bylaw does not define the terms "storm sewer" or "storm sewer system". Therefore, it is not clear whether the bylaw applies only to the piped storm sewer system or whether it also applies to ditches, other open channels and associated culverts within the City's storm system. Similar bylaws from other municipalities (e.g. Watercourse Bylaw from the City of Kamloops or the Drainage Bylaw from the City of Surrey) do explicitly state that they apply to sewers, ditches and other open channels.

The Parkridge Creek and West Fraser River Watershed Drainage Plan recommended adding text in the storm sewer system bylaw to prevent the connection of roof leaders or other on-lot connections to the storm system unless specific technical justification is provided and approved by the City's engineering department. Currently the City doesn't allow for the connection of single-family residential roof leaders to the system but does permit multi-family and non-residential roof leaders to connect.

Flood Plain Regulation Bylaw

A flood plain regulation bylaw designates lands as a flood plain in order to protect against loss of life and minimize property damage, injury, and trauma associated with flooding. The City's flood plain regulation bylaw designates the flood plain; setbacks from a watercourse, body of water, or dike; and flood construction levels for buildings. More specifically the flood plains and setbacks for the Nechako and Fraser Rivers are designated based on floodplain mapping completed by Northwest Hydraulics Consultants. The flood plains of other watercourses are set at 30 metres on either side of the natural watercourse boundary (and 3.0 metre vertically), and 15 metres from the top of bluffs, lakes, ponds, swamps or marshes (and 1.5 metre vertically). These setbacks, which are based on modeling or standard practices, are an important and effective means for protecting property from flooding and can also help preserve riparian habitat and wildlife corridors. These setbacks are reiterated in the OCP Bylaw.

The bylaw has a number of exemptions including parking areas, porches and accessory buildings. These exemptions could reduce the value of the setback as a riparian area and wildlife corridor. We therefore recommend that the City identify all watercourse setbacks that are particularly valuable (e.g. provides nutrients to downstream fisheries or key wildlife corridors) where exemptions should not be granted. Some of these have already been identified as part of the City's Watershed Drainage Plans. The bylaw does not address the development of roadways which can be significantly impacted by flooding and can also have a detrimental impact on riparian and wildlife corridors.

Note that development may have occurred within the designated flood plains/setbacks before the 2007 or 2010 Flood Plain Regulation Bylaws were enacted. Any existing structures within the flood plain in 2010 were exempted from the Flood Plain Regulation Bylaw, provided they don't further the contravention (i.e. expand into the flood plain).

Soil Removal and Deposit Bylaw

A soil removal and deposition bylaw regulates, prohibits, and imposes requirements in relation to the removal and deposition activities to ensure that the soil or other materials do not create a risk to public assets, the health and safety of persons and property, the natural environment, and the integrity of soil as a secure and productive resource base. The City uses a permitting system to establish the terms and conditions for soil removal and deposition on land within Prince George. As the removal and deposition of soil can create risks to natural water systems and public infrastructure through the transport and deposition of sediment and other deleterious materials, provisions in this bylaw can be used to ensure that these activities do not negatively affect the drainage system and natural receiving bodies.

Tree Protection Bylaw

A tree protection bylaw is used to prohibit or regulate the removal of trees in a city. Trees provide important stormwater management related benefits as it pertains to the natural hydrologic balance. Trees provide for interception, retention, and evapotranspiration of rainwater which reduces runoff peak flow rates and volumes as well as provide other benefits including improving air quality, sequestering $CO_2$, reducing the urban heat island effect, and providing habitat. The City's tree protection bylaw protects trees and sets out a permitting process for the removal of trees only within the following specific areas of the City: the AG: 'Greenbelt' (See Schedule A of Zoning Bylaw) and Riparian Protection Development Permit Areas (See OCP Schedule D-2).

A tree cutting permit may be revoked when a person has acted contrary to this Bylaw. Penalties under this bylaw include fines (between $2,000 and $10,000), and/or a term of imprisonment not exceeding three months.

The OCP Bylaw outlines a number of policy statements for revising and strengthening the Tree Protection Bylaw. Currently the Tree Protection Bylaw has many exemptions; such that only trees within the AG zoning are truly protected.

Highways Bylaw

A highways bylaw regulates the use of 'highways' within a City. 'Highways' are any public street, road, sidewalk, lane, bridge, boulevard, or any other public way used by or intended for use by the public. The City's Highways Bylaw addresses the following items related to stormwater: violations such as leaving debris on the highway; requirements for property owners to remove snow from sidewalks; requirements for obtaining permits to remove trees, excavate, change ground elevations, inhibit drainage, construct or maintain drainage systems along a highway; and fines and penalties for any violations (up to $10,000 and 3 months of imprisonment). In the absence of an erosion and sediment control bylaw, the City has used the Highways Bylaw to address developments that do not have strong erosion and sediment control practices, resulting in sediment being tracked onto roadways.

Sanitary Sewer Use Bylaw

The Sanitary Sewer Use Bylaw No. 9055 was adopted in 2019 to regulate the use of the sanitary sewer system. The Sanitary Sewer Use Bylaw is considerably more comprehensive than the Storm Sewer Bylaw and could be used to help guide future updates of the Storm Sewer Bylaw. There should be consistency in regulation and language between the Storm Sewer Bylaw and the Sanitary Sewer Use Bylaw particularly with respect to unauthorized discharges (i.e. spills).

Official Community Plan Bylaw

The Official Community Plan (OCP) sets out the objectives and policies that guide decisions on planning and land use management within the City. Although the OCP does not commit or authorize the City to proceed with any projects specified in the plan and does not have an immediate effect on property rights the OCP can have consequences that may increase the regulatory burden of developing a property (e.g., designation of development permit areas). After adoption of the OCP, bylaws enacted or works undertaken by Council must be consistent with the plan. The City's OCP has policies and objective statements that pertain to stormwater management. In general, they address the following:

- Preserving, protecting, and enhancing the quality of water resources;
- Ensuring erosion and sediment control for developments are considered;
- Continuing development of watershed drainage plans;
- Protecting aquifer recharge zones;
- Preserving sensitive ecosystems;
- Rehabilitating, restoring, and enhancing negatively impacted riparian features;
- Adapting to climate change;
- Identifying and planning for growth (e.g. storm network improvements); and
- Protecting property from flooding (e.g. flood hazard designated permit areas).

The OCP states that the City will endeavor to protect environmentally sensitive areas by one or more of the following tools:

- Development Permit Areas and guidelines
- Environment Protection bylaws (ex. Tree Protection Bylaw)
- Land dedication/acquisition
- Leavestrip areas
- Conservation covenants
- Tax exemptions

Schedules B-1, D-1 and D-2 and D-4 of the OCP Bylaw provide context for policies and development permit area guidelines, including: Agricultural Land Reserve (ALR), Parks, Significant Slopes over 20% grade, Watercourses, Bodies of Water, Groundwater Protection Development Permit Areas, Riparian Protection Development Permit Areas and Flood Hazard Development Permit Areas.

The OCP Bylaw states that the City should designate Development Permit areas and guidelines to include riparian areas and sensitive habitats identified through the Sensitive Ecosystem Inventory project. The City currently has only designated Development Permit areas for fish bearing watercourses. Developers are notified of other Sensitive Ecosystems on their properties but they are under no legal obligation to protect them and rarely do so. The upcoming development of a natural asset inventory may help develop the business case for including other waterbodies and their riparian areas (e.g. non-fish bearing streams and wetlands) within development permit areas. As expanding development permit areas to protect natural waterbodies and their riparian areas may negatively impact the interests of developers, there needs to be sufficient political will to approve proposed new areas.

The Parkridge Creek and West Fraser River Watershed Drainage Plan recommended requiring flood hazard development permits in an area upstream of Highway 16 due to the limited capacity of culverts near Gauthier Road and Highway 16. It also recommends updating the hazardous slope mapping and development permit areas based on the results of GeoNorth's detailed mapping of slope hazards.

The McMillian Creek Watershed Drainage Plan recommended limiting development in rural/undeveloped areas, including aggregate extraction.

<u>Zoning Bylaw</u>

The zoning bylaw establishes and provides for zoning and other development regulation in order to implement the Official Community Plan. It outlines development requirements around waterbodies. Within the zoning bylaw waterbodies are defined as fish-bearing streams or wetlands that are directly connected to fish-bearing streams. Therefore, watercourses that are not fish-bearing or wetlands that are not directly connected to fish-bearing streams would not be protected under this bylaw. The definition of waterbody and watercourse within the OCP Bylaw does not specify that it needs to be fish-bearing.

The zoning bylaw outlines riparian setback requirements which are similar to but slightly different from floodplain setbacks required by the Flood Plain Regulation Bylaw.

The zoning bylaw does not include limitations on impervious surfaces which can lead to high rates of stormwater run-off.

The OCP Bylaw states that in order to adapt to climate change, the City should begin to amend the zoning bylaw to consider future impacts.

<u>Subdivision and Development Servicing Bylaw</u>

A subdivision and development servicing bylaw allows a city to regulate the subdivision and development of land in order to promote the orderly and economic development of a city. The bylaw sets the requirements for the provision of works and services for development. This includes Infrastructure Specifications, similar to those found in the Master Municipal Construction Documents (MMCD). This bylaw could be used as a tool to enact current best practises in stormwater management as it pertains to stormwater runoff rates, volumes, and quality. The City of Prince George's Subdivision and Development Servicing bylaw requires the preparation of an erosion and sediment control plan but does not provide comprehensive requirements as to what shall be in the plan or that it shall be prepared by a designated professional.

A more thorough review of the Subdivision and Development Servicing Bylaw and associated Design Guidelines was conducted as part of Technical Working Paper #2.

<u>Development Procedures Bylaw</u>

The Development Procedures Bylaw defines procedures for the issuance of a development permit, development variance permit, or temporary use permit and under which an owner of land may apply to amend the official community plan, zoning bylaw, or a land use contract.. Schedule A of this bylaw lists development permit application information requirements. Application information requirements include the location of any waterbodies (including ditches and streams), 200-year flood plain, appropriate setbacks, underlying geology, terrain stability, proposed land clearing, site grading plan, existing and proposed drainage works, building or structure site coverage. Schedule A does not specifically require site coverage of impervious surfaces that are not a building or structure (i.e. walkway/pavers). This is important if the City wants to reduce imperviousness and wants to charge stormwater fees based on impervious area.

<u>Development Cost Charge Bylaw</u>

A development cost charge (DCC) bylaw allows the City to levy charges on developments for the purpose of providing funds to assist the City in paying the new capital cost burden of providing city services arising from new development. Specifically, services included in the bylaw relate to sewage, water, drainage, highways, and park land. The principal of 'development pays for development' is consistent with the City's OCP. The City is in the process of reviewing its DCC bylaw and the associated DCC rates to ensure that development is paying its fair share towards the construction of new City infrastructure that is required for servicing newly developed areas.

<u>Building Bylaw (including the BC Building Code 2018)</u>

The City's building bylaw regulates building construction and provides for the administration of the British Columbia Building Code. The City's Building Bylaw also notes the requirement for a building permit before excavation can begin. The Plumbing Code (Book II of the BC Building Code) directly relates to the safe conveyance of stormwater away from a building by providing minimum standards for the size and slope of underground drainage pipes. The City's Building Bylaw references the Plumbing Code to address requirements for plumbing systems, plumbing permits and fees and charges. The Plumbing Code also sets restrictions and requirements around stormwater reuse.

Bylaw Notice Enforcement Bylaw

A bylaw notice enforcement (or contravention fines) bylaw establishes a process for the issuance of bylaw notices and fines. The bylaw designates bylaw contraventions that may be dealt with by a notice and establishes the amount of the penalty, the period for paying or disputing the penalty, and the adjudications system to resolve disputes. The City's Bylaw Notice and Enforcement Bylaw outlines fines for contraventions of several bylaws including the Highways Bylaw, Storm Sewer Bylaw and Building Bylaw. The fines are up to a maximum of $500.

For each day an infraction takes place a fine can be levied accordingly. Nominal, repeatable, fines through bylaw notices should be an effective tool for compliance with repeat offenders; however, there are many minor contraventions to the Storm Sewer Bylaw that are not listed in the Bylaw Notice Enforcement Bylaw which limit the tools available for City staff to enforce the provisions in the Storm Sewer Bylaw. The City should update either the Bylaw Notice Enforcement Bylaw or the Municipal Ticket Information Utilization Bylaw to include all contraventions of the Storm Sewer Bylaw.

Comprehensive Fees and Charges Bylaw

The comprehensive fees and charges bylaw details the fees levied for admissions, applications received, services rendered, and goods supplied by the City. Stormwater management fees include permitting fees for installation and repair of building sewers; storm sewer service applications; culvert installations, soil removal and deposit applications, snow dumping, and development applications.

Municipal Ticket Information Utilization Bylaw

This bylaw authorizes the use of the Municipal Ticketing Information System as a means of bylaw enforcement. Tickets can be issued with fines up to $1,000. No stormwater related offences are currently listed in the City of Prince George's Municipal Ticket Information Utilization Bylaw.

## Other Documents

Adapting to Climate Change in Prince George: An overview of adaptation priorities

In 2009, the City, in collaboration with the University of Northern BC, developed a document titled *Adapting to Climate Change in Prince George: An overview of adaptation priorities.* This document noted that more precipitation will likely fall as rain rather than snow and that there will be more frequent incidences of extreme weather events and flooding. The main purpose of the document was to outline the climate change adaptation priorities for the City of Prince George. The second highest priority was flooding. Other high priorities included severe weather/emergency response and medium priorities included slope stability, stormwater and utilities.

Implementing Climate Change Adaptation in Prince George, BC Volume 4: Flooding

In 2012, the City developed a document titled *Implementing Climate Change Adaptation in Prince George, Volume 4: Flooding* to evaluate and recommend flood control options. The Fraser River is vulnerable to springtime freshet flooding events, while the Nechako River is more prone to ice-jam floods. In 2007-2008 Prince George experienced flooding conditions three times; including a winter ice jam in the Nechako which pushed waters above the 200-year flood plain and caused significant damage. These events made flood mitigation an urgent priority.

Climate Change Impacts on Rainfall and Freeze-Thaw Events in Prince George (January 2014)

The study found that due to the limited available rainfall data (mostly Prince George Airport), updating of the IDF curve was not currently warranted. With more funding, the City would like to pursue additional data (through additional and improved rain gauges) to better analyse climatic trends as well as develop future looking predictive models for reviewing IDF curves that consider future climate change. The study also found that the number of freeze-thaw cycles has not recently increased but City staff have reported that the apparent severity or impact of the freeze thaw cycles seems to have increased.

Climate Change Adaptation Strategies for the Community of Prince George

In March 2020, the City in collaboration with ICLEI, finalized the document titled *Climate Change Adaptation Strategies for the City of Prince George, A Preliminary Stakeholder Informed Guiding Document.* It identified the following top climate risks related to stormwater for the City of Prince George:

- More extreme rainfall events and changing freeze thaw cycles leading to overland flooding and increased slope instability;
- Rising annual temperatures increasing invasive species;
- Hotter summers decreasing moisture content in soil and the ability to absorb storm water;
- More extreme rainfall events (including rain on snow events) causing overland flooding;
- Warmer winters and changing freeze/thaw cycles causing localized flooding and affecting infrastructure; and
- Increase in heavy rainfall events causing riverbank erosion and loss of riparian habitat.

Other specific issues mentioned in the document include:

- Extreme rainfall events causing transportation disruptions;
- Increased road salting required (and associated water quality impacts); and
- Riverine flooding, erosion and slope stability.

The document then identified objectives, goals and action items to address the risks. Identified objectives, goals and action items related to stormwater management include:

- An Erosion and Sediment Control bylaw or permitting process;
- Increased resilience of stormwater infrastructure to accommodate increased precipitation and extreme weather events;
- Green infrastructure and nature-based solutions;
- Protecting ground water and surface water resources;
- Protecting of natural assets and ecosystem services; and
- Restricting the spread of invasive species.

Design Guidelines Manual

The City's Design Guidelines were developed in 2001 to guide engineers and the development industry in the design of engineering servicing facilities and systems. The Design Guidelines have been noted as "Draft" since 2001 and are not enacted by bylaw. However, they are used to provide the minimum design criteria and standards for proposed works. Issues addressed include the widths of rights of ways, utility separation, drainage principles, storm runoff computation, minor system design, major system design, storage facility design (including ponds, constructed wetlands and channel storage), infiltration facilities, other storage options and pump stations. This document, in collaboration with the Subdivision and Development Servicing Bylaw, could be used as a tool to enact current best practises in stormwater management as it pertains to stormwater runoff rates, volumes, and quality. A more thorough review of the Subdivision and Development Servicing Bylaw and Design Guidelines was conducted as part of Technical Working Paper #2.

Asset Management Policy

The purpose of an asset management policy is to support the long-term planning, financing, operation, maintenance, upgrade, renewal, replacement and disposal of capital infrastructure assets (including the City's stormwater system) with consideration of climate change, continual improvement and stakeholders. This will be important for addressing the City's stormwater management needs, particularly as stormwater has been historically underfunded at the local, provincial and national levels. The policy includes eight policy statements that define the City's desired objectives with respect to asset management.

<u>Salt Vulnerable Areas Action Plan</u>

The Salt Vulnerable Areas (SVAs) action plan that has been developed for the City of Prince George (CPG) identifies management options and guidelines for road salt management within areas identified as SVAs. This includes the application of road salts as well as the transport of road salts through stormwater runoff. The study does not address private application of salts (i.e. in parking lots) but some of the findings could be used if the City wanted to address salt application on private properties.

<u>Sustainable Finance Guidelines</u>

The Sustainable Finance Guidelines provide the financial management framework for the City. The guidelines address many issues that are relevant to the City's stormwater management program such as the Financial Plan, property tax rates, self funded services, user fees, financial assistance, capital expenditure plan, gaming income, reserves, debt and budget management. Section 3 of the guidelines outlines the City's existing self-funded services including water, sewer, solid waste and off-street parking. The City has investigated making stormwater a self-funded service through the implementation of a stormwater rate. This is discussed further in Technical Working Paper #4: Financing.

Section 8 of the guidelines addresses the need to:

- Coordinate with the Official Community Plan and infrastructure requirements associated with growth and development;
- Align with the City's Asset Management Policy and Strategy to ensure sustainable service delivery that is fiscally, environmentally, and socially responsible; is adaptive to changing circumstances and future conditions; does not compromise the ability of future generations to meet their own needs; and addresses life cycle costs (including operating and replacement), service levels, and risk; and
- Balance the need and desire for major capital expenditures against its ability to fund them.

**Provincial and Federal Regulations**

<u>Fisheries Act and Authorizations Concerning Fish and Fish Habitat Protection Regulations</u>

Fisheries and Oceans Canada (DFO) has ultimate authority over fish habitat through the *Fisheries* Act, which is the main federal legislation protecting all fish, fish habitat, and water quality. Fish and fish habitat protection under the Act defines 'Serious Harm to Fish' as the "the harmful alteration, disruption or destruction of fish habitat" (HADD) and includes temporary effects. 'Fish Habitat' definition: 'water frequented by fish' (all fish) and the 'quantity, timing, and quality of the water flow that are necessary to sustain freshwater or estuarine ecosystems'.

Works that are likely to cause serious harm to fish and fish habitat, including riparian works require an Authorization under the Fisheries Act in order to proceed without potential prosecution under the *Fisheries Act*. The Authorizations Concerning Fish and Fish Habitat Protection Regulations specify what is required to apply for an Authorization. For works unlikely to have an impact, but are not covered by DFO's Code of Practice, a request for review needs to be submitted to DFO to confirm that an Authorization is not required. In this case, often DFO will issue a Letter of Advice describing the conditions that must be followed to avoid a HADD or serious harm to fish.

City staff have found that DFO staff are mainly concerned with projects that are within the watercourse (i.e. below the high water mark) and do not tend to get involved with projects that are only within the riparian zone, even if they may negatively impact the adjacent fish-bearing stream. As there are limited Fisheries staff (currently only two Fisheries Officers in Northern B.C.), DFO has limited capacity to review and follow-up on projects that may impact fish-bearing streams.

<u>BC Water Sustainability Act and Water Sustainability Regulation</u>

Section 11 of the *Water Sustainability Act* requires that anyone wishing to conduct work in or about a stream (fish bearing or not) must obtain a change approval. The Water Sustainability Regulation provides additional criteria on the types of works that are authorized in Part 3, Section 39. The following are examples of authorized changes that only require notification for instream work if all conditions can be met:

- the installation, maintenance or removal of a culvert for crossing a stream for the purposes of a road, trail, or footpath;
- the construction or maintenance of a pipeline crossing of a stream;
- the restoration or maintenance of a stream channel by a municipality or regional district;
- the construction or maintenance of storm sewer outfalls; and
- the installation or cleaning of drainage outlets.

It should be noted that wetlands are part of the definition of a stream within the Water Sustainability Act.

<u>Riparian Areas Protection Act and the Riparian Areas Protection Regulation</u>

The Riparian Areas Protection Regulation (RAPR) was enacted under Section 12 of the *Riparian Areas Protection Act* in February 2016. The RAPR lists the regional districts to which the Regulation apply. Currently, the RAPR does not apply to Prince George or the geographic boundaries of the Regional District of Fraser-Fort George, but it could be added if the government sees the need for it in the context of urban development.

<u>Stormwater Guidelines</u>

In November 2000, DFO released the Urban Stormwater Guidelines and Best Management Practices for Protection of Fish and Fish Habitat, Draft Discussion Document. This paper provides a description of the best management practices (BMP) that are proposed, as well as implementation criteria to describe the development situations they could potentially be applied to. It provides information on the hydrological design criteria best suited for determining impacts of development, implementation of mitigation through application of best management practices, and for watershed hydrological studies.

DFO Urban Stormwater Guidelines have since evolved in ‘Beyond the Guidebook’:

- 2002: Stormwater Planning: A Guidebook for British Columbia
- 2007: Beyond the Guidebook: Context for Rainwater Management and Green Infrastructure in British Columbia.
- 2010: Beyond the Guidebook 2010: Implementing a New Culture for Urban Watershed Protection and Restoration in British Columbia
- 2015: Beyond the Guidebook 2015: Towards a Watershed Health Legacy in the Georgia Basin

“The purpose of the Beyond the Guidebook initiative is to help local governments and the development community establish what level of rainwater runoff volume reduction makes sense at the site, catchment and watershed scales. The objective is to protect stream health, which is broader than how much volume one can infiltrate on a particular development,” (quote from Corino Salomi, DFO).

<u>Water Quality Guidelines (BC and Federal)</u>

BC’s Approved Water Quality Guidelines (BCWQG) and the federal Canadian Council of Ministers of the Environment (CCME) Water Quality Guidelines for the Protection of Aquatic Life are used to:

- Protect water values, including: aquatic life, wildlife and their habitats, drinking water sources, agriculture (livestock watering and irrigation); and recreation;
- Provide the basis for the evaluation of ambient water quality and environmental impact assessments to inform resource management decisions (e.g. wastewater discharge limits);
- Provide the basis for water quality objectives;
- And report to the public on the state of water quality and promote water stewardship.

The criteria commonly monitored related to stormwater are turbidity, total suspended solids, pH, and potential presence of hydro carbons by noting any evidence of a sheen on the water (Table 1).

**Table 1: British Columbia Approved Water Quality Guidelines for the Protection of Freshwater Aquatic Life**

| Parameter | Guidelines |
|---|---|
| Turbidity | ○ Change from background of 8 NTU at any one time for a duration of 24 h in all waters during clear flows or in clear waters<br>○ Change from background of 2 NTU at any one time for a duration of 30 d in all waters during clear flows or in clear waters<br>○ Change from background of 5 NTU at any time when background is 8 - 50 NTU during high flows or in turbid waters<br>○ Change from background of 10% when background is >50 NTU at any time during high flows or in turbid waters |
| Total Suspended Solids | ○ Change from background of 25 mg/L at any one time for a duration of 24 h in all waters during clear flows or in clear waters<br>○ Change from background of 5 mg/L at any one time for a duration of 30 d in all waters during clear flows or in clear waters<br>○ Change from background of 10 mg/L at any time when background is 25 - 100 mg/L during high flows or in turbid waters<br>○ Change from background of 10% when background is >100 mg/L at any time during high flows or in turbid waters |
| pH | ○ 6.5 to 9.0: unrestricted change permitted within this range. This component of the freshwater guidelines should be used cautiously if the pH change causes the carbon dioxide concentration to decrease below a 10 µmol/L minimum or exceed a 1,360 µmol/L maximum, as these concentrations may be toxic to fish. |
| Oil and Grease | ○ Not detectable by sight or smell |

The CCME and BC Water Quality Guidelines are both just guidelines and not regulated. However, DFO will commonly use the CCME water quality criteria for aquatic life as an indicator as to whether a discharge is a deleterious substance and a contravention to the Fisheries Act.

The biggest challenge with the BC Water Quality Guidelines is that they express allowable limits as changes from background levels; which makes measurement and enforcement more difficult. In order to address this challenge, some municipalities have set hard limits within their municipal regulations. For instance, the City of Kelowna's erosion and sediment control requirements within their Design Standards Bylaw stipulates maximum concentration levels of 75 milligrams per litre (ppm) of total suspended solids (TSS) regardless of background levels.

## 2.3 Existing Regulatory Authority, Fines, and Enforcement

The City has the authority to regulate, prohibit, and impose requirements by bylaw. To enforce these rules, the City can engage in a range of bylaw enforcement activities (BC, 2020b) as listed below.

- Educate the public about regulatory rules;
- Conduct inspections to ensure that rules are being followed;
- Leverage voluntary compliance with the rules where possible; and,
- Seek formal consequences for bylaw contraventions where compliance is not forthcoming, or harm has been done to the community.

Provincial regulations provided by the Community Charter, Offence Act, and Local Government Bylaw Notice Enforcement Act allow the City to formally enforce bylaw contraventions. Enforcement can include direct actions, civil proceedings, bylaw notices, municipal tickets, and offence act prosecutions. The City's existing regulatory framework for bylaw enforcement is outlined in Table . General descriptions of enforcement options are provided below.

<u>Direct Actions</u>

In relation to certain hazardous situations or declared nuisances (e.g. the deposition of soil causing flooding of roadways and neighbouring properties), the City may order a person to rectify the situation or take action to eliminate the hazard or damage and in some cases, recover the costs from the person. When there is a license or a permit associated with a bylaw (i.e. Building Bylaw and Building Permit), the City may suspend the licence or permit when there is a contravention of the bylaw, until the person complies (BC, 2020b).

In general, the City tries to work with the developer or property owner to get them to comply. However, if the developer/property owner does not comply then the City will issue a stop-work order, where they are able to do so. The City of Prince George has issued stop-work orders to developers for violations of the building code. The City has not historically issued stop work orders for drainage related issues. As the City investigates better or new means of enforcement (e.g. for erosion and sediment control), it should consider leveraging the power of a permit, where it can issue a stop work order, to encourage compliance.

The City has used funds within security deposits to complete or rectify works that do not meet City standards. This would typically be done to rectify off-site works (i.e. within the City right-of-way) that the developer installed and don't meet City standards, and the developer is unwilling to rectify the works him/herself. The City does not use this approach to rectify on-site works due to legal concerns with entering and completing work on a private property.

<u>Civil Proceedings</u>

When efforts at getting voluntary compliance or using direct actions are not sufficient, a local government must decide whether the contravention of its bylaws justifies administrative or legal action to stop the activity from affecting the community or deter future instances of the behaviour or activity. The City may apply to the Supreme Court of British Columbia for an injunction or court order to enforce, prevent, or restrain a bylaw contravention (BC, 2020b).

If the City has been unable to get a developer or property owner to comply and/or rectify the situation then it has in the past applied for an injunction or court order for serious offences. This approach has not yet been used for stormwater related offences.

<u>Municipal Tickets</u>

Municipal ticketing can be used by the City as a form of prosecution for minor to medium contraventions of their bylaws through the municipal ticket information system. An enforcement officer can certify allegations and deliver tickets to the alleged offender without first visiting a provincial court justice to swear the information and obtain a summons. The alleged offender may then choose to admit to the offence and pay the penalty without appearing in court (BC, 2020d). The City is permitted to issue tickets through their municipal ticketing bylaw: *City of Prince George Municipal Ticket Information Utilization Bylaw No. 8919, 2017*. The bylaw identifies which offences are subject to municipal ticketing, who can issue the municipal ticket for each offence, and what penalties may be imposed for each offence. The current maximum ticketing amount permitted under Community Charter regulation is $1,000 (BC, 2010). To dispute a ticket, the alleged offender is referred to the provincial court for hearing. Note that no stormwater related offences are currently listed in the City of Prince George's Municipal Ticket Information Utilization Bylaw.

<u>Bylaw Notices</u>

The City is permitted to issue bylaw notices (fines) for minor bylaw infractions under the Local Government Bylaw Notice Enforcement Act. Bylaw notices are separate from the municipal ticket information system as they are administered through an alternative adjudication system in which a City managed venue is used by a professional and non-judicial adjudicator to hear ticket disputes (BC, 2020c). The maximum amount permitted through bylaw notice is $500 (BC, 2003). Although the City pays for the costs of the bylaw notice system, it provides a more accessible venue for determining bylaw contraventions, reduces the demand on the court system, is less expensive to administer than the court process, and provides better balances between the penalty imposed and the costs of pursuing the bylaw contravention in court. The penalties under the bylaw notice enforcement system are strictly monetary, the burden of proof is substantially less, and the adjudicator does not have the ability to adjust the penalty amount (BC, 2020c). Several stormwater related offences are currently listed in the City's Bylaw Notice Enforcement Bylaw and therefore bylaw notices could be considered the City's most accessible and common form for enforcing stormwater related offences.

Offence Act Prosecutions

The City may enforce their bylaws by seeking prosecution under the Offence Act. The Offence Act provides a default method of enforcement if the City has not established specific enforcement schemes (such as the municipal ticket information system or bylaw notice system) or if it is deemed to be more appropriate then the established schemes. The proceedings under the Offence Act are intended for serious municipal bylaw contraventions and result in a far more formalized process. The process does not permit the alleged offender to simply pay a fine to end the proceeding as a provincial court justice must hear the case and make a decision (BC, 2020d). The maximum penalty the City may impose is $10,000 and/or six months imprisonment. As this approach can be expensive and time consuming, the City only uses this approach for a serious offense and if all other efforts for compliance have failed.

The enforcement clauses within each of the City's bylaws reviewed as part of this Study are outlined in the following table.

**Table 2: Existing Bylaw Enforcement Clauses**

| **Bylaw** | **Enforcement Clauses Included in Bylaw** |
|---|---|
| Storm Sewer Bylaw, No. 2656, 1974; | Prohibited Discharges to Storm Sewer (Section 2.7)[1]<br>All offences listed below are accompanied by a $500 fine:<br>- Discharge sewage containing human waste<br>- Discharge industrial waste<br>- Discharge liquid over 140 degrees Fahrenheit<br>- Discharge vapor or gaseous substance<br>- Discharge water or waste containing fats, oil, or grease<br>- Discharge noxious or malodorous substance<br>- Discharge sewage, waters or waste containing toxic or poisonous substance<br>- Discharge flammable or explosive liquids, solids or gas<br>- Discharge radioactive wastes or sewage<br>- Discharge garbage<br>- Discharge solids or fiscous substances<br>- Discharge waters containing more than 500 parts per million by weight of suspended solids<br>- Discharge sludge or deposits from a septic tank<br><br>Disconnecting Illegal Connections (Section 2.8)<br>Any building or drain connected to a storm sewer service connection without a permit or any service connection connected to the storm sewer system discharging any substance or matter prohibited by this Bylaw may be disconnect, stopped, and closed at the owner's cost.<br><br>General Offences and Penalties (Section 6.0)<br>Prosecution under the Offence Act: Summary conviction not less than $2,000 and not exceeding $10,000, the cost of prosecution, and any other penalty or order pursuant to the Community Charter or Offence Act. |

| Bylaw | Enforcement Clauses Included in Bylaw |
|---|---|
| Subdivision and Development Servicing Bylaw, No. 8618, 2014; | Security (Section 9.3)<br>If Owner fails to make repairs within 30 days for non-emergency Works from the date of request in writing, or, in the case of emergency situations, within two hours of receiving verbal notification of the emergency, then the City, using its own forces or a contractor hired by the City, may make the necessary repairs and recover the costs by drawing down the Security.<br><br>General Offences and Penalties (Section 11.0)<br>Prosecution under the Offence Act: Summary conviction not exceeding $10,000 or to a term of imprisonment not exceeding three months. |
| Soil Removal and Deposit Bylaw, No. 9030, 2019; | Security (Section 16)<br>If any person does not comply with the terms and conditions of a Long Term Permit, Short Term Permit, or a requirement under this Bylaw and does not within 30 days following a request for compliance remedy the non-compliance or complete the requested repair, any security shall be forfeited to remedy. If no security is held by the City, or the security is insufficient, the City may remedy the non-compliance the expense of the person and recover the costs.<br><br>The security may be used at any time for the cleaning of soil or other debris from Highways, sidewalks, boulevards, or drainage facilities which may be required as a result of the Removal or Deposit Operations.<br><br>General Offences and Penalties (Section 19.0)<br>Prosecution under the Offence Act: Summary conviction not less than $2,000 and not exceeding $10,000, the cost of prosecution, and any other penalty or order pursuant to the Community Charter or Offence Act. |
| Tree Protection Bylaw, No. 6434, 1995; | Stop Work (Section 9.0)<br>City may revoke a tree cutting permit and order immediate suspension of tree cutting authorized by this Bylaw when a person has acted contrary to this Bylaw.<br><br>General Offences and Penalties (Section 10.0)<br>Prosecution under the Offence Act: Summary conviction not less than $2,000 and not exceeding $10,000 or to a term of imprisonment not exceeding three months.<br><br>Replacement Trees (Section 11.0)<br>Any person cutting a tree in contravention of this Bylaw shall replace that tree with two trees if within 5 m from top of bank or one tree if more than 5 m from top of bank. |
| Flood Plain Regulation Bylaw, No. 8285, 2010; | General Offences and Penalties (Section 8.0)<br>Prosecution under the Offence Act: Summary conviction not less than $2,000 and not exceeding $10,000 or to a term of imprisonment not exceeding three months, or both, and the cost of prosecution. |

| Bylaw | Enforcement Clauses Included in Bylaw |
|---|---|
| Highways Bylaws, No. 8065, 2008; | Activities Authorized by Permit (Section 3.0)[1]<br>All offences listed below are accompanied by a $200 fine:<br>- Dig or break up part of highway or cuts down trees or timber<br>- Deposit earth, rocks, stones, logs or stumps or other debris to cave, fall, crumble, slide or accumulate on a highway<br>- Damage vegetation, fence or other things erected by the City<br>- Change level of highway or stops flow of water<br>- Construct or maintain ditch, sewer, or drain causing damage or nuisance to portion of a highway<br><br>Security (Section 10.05)<br>If Permittee fails to repair damage or fulfill the obligation under the terms and conditions of the Permit, the City may apply the security to offset such damage or unfulfilled obligations. If monies are insufficient, the Permittee shall pay the balance upon invoice from the City.<br><br>General Offences and Penalties (Section 11.0)<br>Prosecution under the Offence Act: Summary conviction not less than $2,000 and not exceeding $10,000 or to a term of imprisonment not exceeding three months, or both, and in addition may be charged for any resulting damage to the Highway or users thereof. |
| Zoning Bylaw | General Offences and Penalties (Section 3.2)<br>Prosecution under the Offence Act: Summary conviction not less than $2,000 and not exceeding $10,000, the cost of prosecution, and any other penalty or order pursuant to the Community Charter or Offence Act |
| Building Bylaw, No. 8922, 2018 (including the BC Building Code 2018); | Prohibitions (Section 7.0)[1]<br>- No plumbing permit ($300)<br>- No demolition permit ($300)<br><br>Stop work (Section 6.4)<br>- The *building official* may, in consultation with the *authorized person,* order the immediate correction or suspension of any work that is being or has been done in contravention of this or any other Bylaw, the *Building Code,* the *Plumbing Code* or other enactments respecting safety by posting a *Stop Work Notice* in a conspicuous location on the property.<br><br>General Offences and Penalties (Section 22.0)<br>Prosecution under the Offence Act: Summary conviction not less than $2,000 and not exceeding $10,000, the cost of prosecution, and any other penalty or order pursuant to the Community Charter or Offence Act |
| Development Procedures Bylaw | Penalties under this by-law include fines between $2,000 and $10,000 and/or imprisonment up to 3 months |

*[1]Bylaw section administered through the bylaw notice system under the Bylaw Notice Enforcement Bylaw, No. 8813, 2016.*

## 2.4 Identified Issues

Through review of the City's bylaws and plans, and through discussions with City staff, regulatory and policy challenges were identified and are discussed in Table  below. Primary issues for City staff relate to unavailable or unreasonable enforcement mechanisms and outdated environmental protection provisions. AECOM also identified additional issues when comparing Prince George's bylaws with those from other municipalities. Further comparison of Prince George's bylaws with those of other municipalities are provided in Section 3.2.

**Table 3: Stormwater Related Regulatory and Policy Issues**

| Issues | Description |
|---|---|
| Cost Recovery | Bylaws do not specify mechanisms for cost recovery of work required for repairing or remediating a situation by City forces unless the City is holding a security for the specific project through a development application, soil removal or deposit permit, or a highway use permit. Therefore if a spill or discharge into the storm system (including discharges such as sediment laden water) occurs in the City |

| | |
|---|---|
| | of Prince George, it is difficult for the City to recuperate costs for clean-up or for remediation of infrastructure or natural assets from the responsible person. Additionally, some impacts may require remediation over a time period that is longer than the permitting or development cycle or that resulted from multiple parties.<br><br>Fines under the Storm Sewer Bylaw are limited to $500 and only for the listed prohibited wastes. City will only prosecute major bylaw infractions under the Offence Act (max $10,000 fine) and this is not typically done for stormwater related issues. |
| Low Impact Development (LID), Best Management Practices (BMP) (also addressed in Technical Working Paper #2) | Existing bylaws do not have complete provisions for assessing and mitigating the negative effects to watercourses and the environment from development which include decreased water and sediment quality, increased runoff peak flows and volumes, decrease in stream base flows, increased sedimentation and erosion.<br><br>Concerns related to previous implementations of stormwater infrastructure BMPs are that even though peak flows are reduced, more harm has resulted to downstream watercourses because of increased runoff volume stretched over a longer time period. The City would also like to be confident that any proposed LID/BMP would work well in Prince George in consideration of its climate and context (e.g. snow storage).<br><br>Recommended bylaw modifications from the City's WDP include modifying the storm sewer bylaw to explicitly prevent the connection of roof leaders or other on-lot connections to the storm system unless specific technical justification is provided and approved by the City's engineering department; and limiting the area of impervious surfaces through the zoning bylaw.<br><br>The draft Design Guidelines should provide requirements for controlling run-off rates, volumes and quality (see Technical Working Paper #2 for more details). |
| Climate Change | The Storm Sewer and Subdivision and Development Bylaws or associated Design Guidelines do not have clauses to incorporate climate change mitigation nor adaptation measures in the design of municipal infrastructure. Emerging best practice in engineering design is to incorporate climate change adaptation measures into the design of stormwater infrastructure. Annual temperatures in the region are projected to increase an average of 1.6°C to 2.5°C by 2050 and precipitation is projected to increase by 3% to 10% primarily in winter with possible deceases in the summer (Picketts, et al., 2009). The City has completed several climate change adaptation studies with a number of recommended action items. The City reviewed its IDF curves in 2014 but determined that they did not have sufficient data to develop new IDF curves and would likely need additional and improved rain gauges in order to capture all localized storms that hit various nodes or catchments within the City. The City has not developed future looking IDF curves (i.e. what rainfall events will look like over the next 50-100 years similar to what Vancouver and Edmonton have done) nor confirmed if the summer storm is still the governing event under climate change as opposed to the winter storm with snowmelt. The City has referenced the need for a review in 2022 within its Asset management Strategy & Roadmap 2019. The City's Design Guidelines comment on the need to consider partial blockages due to ice in ditches when urban areas drain to them. But the Guidelines do not present or require the assessment of a rain on snow event whose frequency may increase due climate change. Recommended modifications to the Design Guidelines and a rainfall monitoring program was addressed in Technical Working Paper #2. |
| Oil and Grit Interceptors | Within the Storm Sewer Bylaw property types that require oil and grit interceptors are limited or too vague. No enforcement mechanisms are in place to ensure interceptors are maintained. In addition the draft Design Guidelines should include design requirements for oil-grit separators. |
| Tree Protection | The reach of the Tree Protection Bylaw is limited to a relatively small area of the City which have been set aside as environmentally sensitive areas. Areas protected by permits: AG: 'Greenbelt' (See Schedule A of Zoning Bylaw) and Riparian Protection Development Permit Areas (See OCP Schedule D-2). In addition, there are exemptions within the AG and Riparian areas that further limit the applicability of the Tree Protection Bylaw. |
| Protection of Other Natural Assets | Wetlands and watercourse riparian areas are critical for maintaining the natural hydrological cycle and moderating peak flows, preventing erosion, providing aquatic and terrestrial habitat/corridors and supporting downstream fisheries. The existing floodplain bylaw allows the development of roadways, |

| | |
|---|---|
| | parking areas, accessory buildings and loading areas within these areas. The Zoning Bylaw only protects fish-bearing streams or wetlands that are connected by surface flow to fish-bearing streams. The zoning bylaw only requires 15 metre leave strips for riparian function in agricultural and low-density residential areas. The zoning bylaw requires 30 metre leaves strips in non-residential areas but is silent on requirements for medium to high density residential areas. In addition, the zoning bylaw allows exemptions and will reduce riparian areas if an R.P.Bio. states that a smaller leave strip is sufficient. Developers have also been known to ignore the City's riparian requirements and provincial wetland preservation requirements but the City does not have the capacity to review all possible illegal development within riparian areas/wetlands and enforce the requirements under the zoning bylaw.<br><br>The City will be soon developing a natural asset inventory which should help identify and strengthen the case for protecting natural assets using development permit areas. |
| Land Clearing Activities | As a result of insufficient watercourse protection, ESC regulations, and tree protection requirements, developers clear land months or years prior to subdivision or building permits with no ESC measures in place. This occurs before and after the current land use application regulatory triggers. As previously mentioned, it is important that negative environmental and infrastructure impacts and resulting liability from insufficient erosion and sediment control lies with the developer and not the City. |
| Erosion and Sediment Control (ESC) | Existing bylaws do not have the required provisions to ensure erosion and sediment control (ESC) best practices are followed. The Storm Sewer Bylaw prohibits discharge for sediment (>500 ppm) which is significantly higher than best practice and requires laboratory testing to confirm. Federal CCME guidelines and Provincial guidelines for turbidity and total suspended solids (TSS) are based on increases above background levels but monitoring background levels is not practical in many circumstances due to staff time and costs. Therefore, it is recommended to use a specific value that is easily measured and does not exceed provincial limits (e.g. 75 mg/L during wet conditions and 25 mg/L under dry conditions). For example, the City of Kelowna does not permit discharges of TSS above 75 mg/L and samples must be submitted for lab testing of TSS if field samples have a turbidity of greater than 60 NTU (Schedule 4 of Bylaw 7900). The use of field testing for turbidity allows city staff and ESC supervisors to practically monitor the effectiveness of ESC measures.<br><br>The City of Prince George's Design Guidelines require erosion and sediment control during construction but does not require oversight by a qualified professional or any specifications on monitoring, reporting and ongoing maintenance. Whereas, the City of Kelowna requires developers to retain a Qualified Professional (P.Eng, RPBio, P.Ag, AScT, CPESC, CISEC or CESCL) responsible for inspecting and monitoring the ESC Facilities (Schedule 4 of Bylaw 7900). It is important that negative environmental and infrastructure impacts and resulting liability from insufficient erosion and sediment control lies with the developer and not the City.<br><br>The City is currently looking at amending existing regulations, particularly the Subdivision Development Servicing Bylaw, to increase the City's ability to require and enforce good erosion and sediment control practices. |
| Staffing Levels | Effective permitting and bylaw enforcement is a time-consuming effort that requires a multi-tiered approach including outreach, education, testing, reporting, follow-up visits, ticketing, and legal proceedings. Consequently, increased staffing levels and/or front-end resource prioritization on outreach and education are required to ensure acceptable levels of bylaw compliance. |
| Prohibited Wastes | List of materials prohibited for discharge into the stormwater system by the Storm Sewer Bylaw does not align with current environmental standards, do not directly reference provincial or federal regulations, and do not allow for easy measurement in the field for enforcement. As a result, City staff do not have the regulatory authority to address all harmful discharges.<br><br>The Storm Sewer bylaw does not specifically address ditches, ponds or watercourses, including discharges to them. The definitions within the Storm Sewer Bylaw need to be updated to include all assets within the City's stormwater system. |
| Driveway Culverts | Responsibilities for maintaining, repairing, replacing and upgrading driveway culverts are not specified within any legislation. Therefore it is not clear whether the City or the property owner is responsible for |

| | |
|---|---|
| | replacing existing driveway culverts when they have deteriorated or when they need to be upgraded to allow for fish passage. |

# 3. Benchmarking

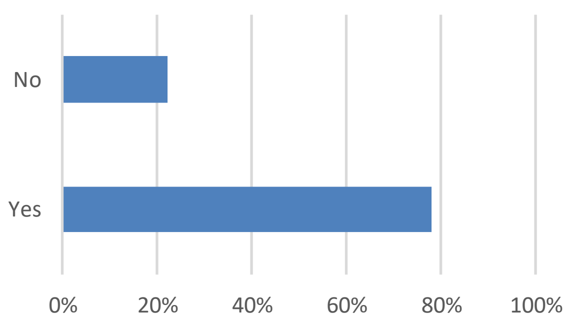
## 3.1 Benchmarking Survey

A survey was sent to municipalities that participate in the Stormwater module of the National Water and Wastewater Benchmarking Initiative. This is a Canadian benchmarking initiative with over 30 participating municipalities. Questions asked are listed below.

1. Are developers/property owners in your jurisdiction required to obtain a permit to clear land (i.e. clearing only, not including excavation)?
2. Do you ever have an issue with developers clearing land before receiving the necessary approvals?
3. Do you require individual developments to implement low impact development measures (also known as on-site stormwater best management practices)?
4. If you require on-site measures, how do you ensure that these on-site measures are maintained?

The results of the survey are outlined below. Nine (9) Responses were received from Kelowna, Sudbury, Whistler, Saskatoon, Calgary, Guelph, Kitchener, Squamish and North Vancouver.

1. Are developers/property owners in your jurisdiction required to obtain a permit to clear land (i.e. clearing only, not including excavation)?

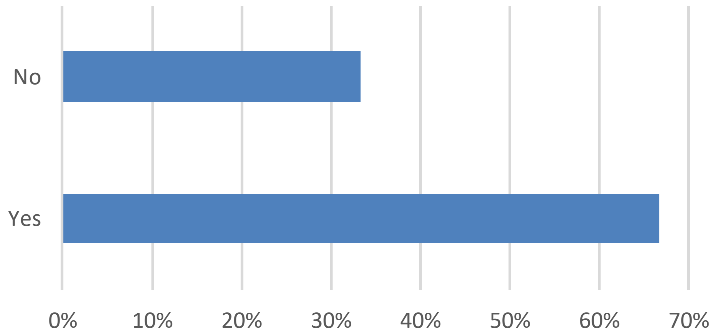



**Yes 78%**
**No 22%**

Additional comments from municipalities that require permits for land clearing are provided below.

- Kelowna: In most areas, especially sensitive ones, they have Development Permit areas that require permits prior to clearing. They are working towards a Tree Protection Bylaw on private property. They will also use ESC and stormwater management requirements in their bylaws to enforce proper clearing that does not have detrimental downstream impacts.
- Saskatoon: Their wetland policy needs to be followed for any work done in and around wetlands. The policy requires a wetland study to be completed, submitted and approved by the City prior to any work being done.
- Guelph: They have site alteration permits.
- Calgary: They require ESC and environmental permits.
- Kitchener: Has controls through their tree conservation bylaw.

2. Do you ever have an issue with developers clearing land before receiving the necessary approvals?

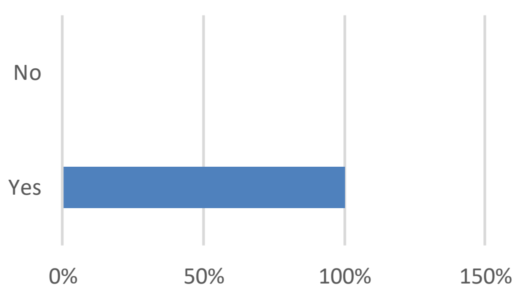



**Yes 67%**
**No 33%**

If yes, have you found any successful mechanisms for encouraging compliance?

- District of West Vancouver: They can issue a stop work order for anything that isn't in conformance with their bylaws.
- Guelph: Site Alteration Bylaw.
- Kitchener: Tree Conservation Bylaw.
- Squamish: Site Alteration Bylaw and enforcement; Tree Management Bylaw; Soils Management Bylaw, and Erosion control requirements in the Subdivision Development and Control Bylaw;
- Kelowna: They follow-up on soil tracking on roads or sediment plumes in the storm system to enforce bylaw compliance.

3. Do you require individual developments to implement low impact development measures (also known as on-site stormwater best management practices)?



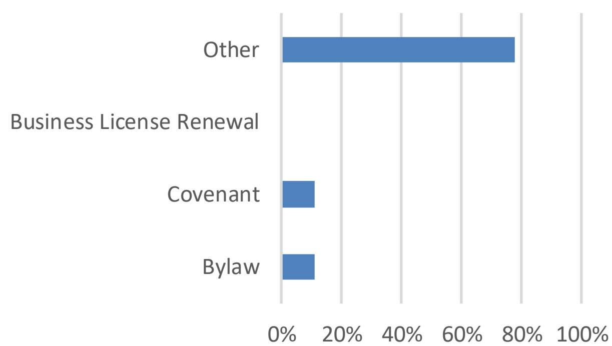

**Yes 100%**
**No 0%**

If yes, please describe any specific targets you require for runoff reduction:

- Kelowna: Requires matching post-development rate & volume to pre-development levels which generally requires extensive on-site retention and detention. 100-year stormwater quality is set to 50% of the 2-year storm.
- District of West Vancouver: No net increase in runoff from pre-development to post-development. First 31mm of run-off to be infiltrated or re-used. Maximum discharge is 31.8 L/s/Ha. They are challenged with lots of steep slopes and bedrock.
- Saskatoon: On-site stormwater management is required for every parcel other than single family or duplexes. The allowable stormwater release rates are based on design runoff coefficient for each parcel. The on-site stormwater management calculations and formulas are listed in the City of Saskatoon Design and Development Standards Manual, Section 6. The on-site stormwater management could be achieved through traditional BMP's (parking lots storage, roof tops, underground tanks etc) or LID's. The City of Saskatoon has adopted LID design guidelines that are available on the City's web site for the developers.
- Guelph: Post-development flow rates must match pre-development flow rates or meet Provincial guidelines.

- Calgary: They follow their 2014 Interim Stormwater Targets which vary by watershed (see https://www.calgary.ca/UEP/Water/Pages/Specifications/Submission-for-approval-/Development-Approvals-Submissions.aspx).
- Sudbury: They require post-development flows to match pre-development flows for certain watersheds that have supporting watershed studies.
- Kitchener: Requires first 12.5 mm of run-off to be infiltrated (see //https://www.kitchener.ca/en/city-services/stormwater-master-plan.aspx).
- City of North Vancouver: Requires capturing and infiltrating the first 56 mm of run-off over 24 hours, or releasing run-off at a rate at 0.5 l/s per hectare.
- District of Squamish: Requires development to have a Stormwater Management Plan. No net increase in flow rates for the 10 year design storm. Further detention and treatment requirements may be required at the discretion of the Development Engineer.

4. If you require on-site measures, how do you ensure that these on-site measures are maintained?




**Bylaw 11%**
**Covenant 11%**
**Business License Renewal 0%**
**Other 78%**

The measures listed under "other" and additional comments are provided below.

- Sudbury: Site Plan Agreement but no inspection for compliance
- Kitchener: Maintenance required through Council Policy and enforced through stormwater rate credit program
- Squamish: Bylaw
- Kelowna: They have very limited assurances at the moment. They are working to incorporate it into business license renewal. We have the right to access and inspect all on-site storm infrastructure but no resources to do so.
- Saskatoon: They don't currently have anything in place but are looking to implement something, perhaps a bylaw.
- Guelph: Maintenance requirements are enforced through ECA approval requirements (through the provincial Ministry – MECP)
- Calgary: In principle, maintenance can be enforced through their Drainage Bylaw; however, enforcement is still challenging. Calgary recently started an educational program aimed at commercial and industrial property owners, informing them as to their responsibilities.
- Sudbury: Maintenance is required through a site plan agreement, but the City does not inspect for compliance yet.
- Kitchener: Council Policy, MUN-UTI-2003, ://https://www.ryerson.ca/content/dam/green/sponsors/7.Gollan_Ryerson.pdf
- City of North Vancouver: Current bylaw provisions are weak. They are looking to provide a fee-based incentive to encourage good maintenance. They also include provision for monitoring for bigger sites and have monitoring facilities placed on public ROW to allow easy municipal inspection.

Some of the information collected through this survey is also included in the following Section 3.2.

## 3.2 Other Municipalities Reviewed

Policies and bylaws from other municipalities were reviewed to develop a range of options for mitigating the key issues around stormwater management for the City. In addition to municipalities with characteristics similar to the City of Prince George, several larger municipalities with robust policy systems were reviewed to identify best practices. It is important to note that larger municipalities may have more staff dedicated to permitting and compliance then may be realistic for the City of Prince George.

The following table below outlines some of the more significant policy gaps identified and how “comparable” municipalities, as chosen by City staff, address these issues. As can be noted in the table, some of the comparable municipalities have some of the same gaps as Prince George but some of them have well developed cost recovery mechanisms, on-site stormwater control requirements, climate change criteria for development, oil-grit separator requirements, tree protection requirements and erosion and sediment control requirements.

**Table 4: Regulatory Comparison of Key Stormwater Issues amongst Municipalities**

| | Mechanism for cost-recovery in bylaws | On-site LID/BMP requirements | Development criteria considers climate change | Well developed OGS requirements | Well developed tree protection requirements | Well developed land clearing controls | Well developed ESC requirements |
|---|---|---|---|---|---|---|---|
| **Prince George** | Only from limited securities | None | No | Vague and don't address maintenance | Limited area | None prior to subdivision and building permit | Can't ensure best practices are followed |
| **Kelowna** | Yes | Yes – post rate ≤ pre rate | Yes. IDF curve + 15% | Yes, installation & maintenance | Yes, within designated areas. Looking to broaden. | Somewhat | Yes – performance requirements and qualified professional for monitoring |
| **Nanaimo** | Yes | Yes | Yes. Updated IDF curves that consider climate change. | Yes | Yes | With respect to subdivisions | No – focus on education |
| **Thunder Bay** | Yes | Yes, installation & maintenance | Yes. Updated IDF curve + 15% | Yes, installation & maintenance | Only public trees. | With respect to subdivisions or soil removal | Yes, ESC plan requirements and monitoring |
| **Sudbury** | Yes | Yes – post rate ≤ pre rate | Yes | Yes | No | No | Yes |
| **Kamloops** | Not found | Yes | No | Not found | Yes | Adjacent to water courses | Requirements vague but design engineer required. |
| **Surrey** | Yes | Yes | Yes | Yes, maintenance | Yes | Yes | Yes |
| **Other** | | Yes – Kitchener, Squamish and others | Yes – Edmonton, Vancouver and others | | Yes – Comox, Kitchener and others | Yes – Squamish, Kitchener and others | Yes – Abbotsford and others |

Further description about these "comparable" municipalities and best practices from other municipalities are provided in the following sub-sections.

**Cost Recovery**

Examples where municipalities have mechanisms for cost recovery include:

- City of Thunder Bay's Sewage and Stormwater Discharge By-law states that" people who violate the by-law are liable for all damages occasioned by their actions or non-actions". It also specifically mentions recovering costs resulting from spills.
- The City of Kelowna's Sanitary Sewer Storm Drain Bylaw states "Where any person contravenes any provision of this bylaw and thereby causes damage to the sewerage or drainage system, such person shall be liable to the City for all costs incurred in making repairs or taking remedial action."
- The City of Nanaimo's Storm Sewer Regulation and Charge Bylaw states "If the owner fails to correct any violation the City may, without prejudice to any other remedy it may have, enter the owner's property and correct such violation at the owner's cost."
- The City of Greater Sudbury can apply any costs to "fix" bylaw contraventions to the property's tax roll for recovery (see City Bylaw to Regulate the Removal of Topsoil).
- The City of Surrey has mechanisms for cost recovery within their bylaws (e.g. recuperating costs such as spill clean-up costs). The City's Stormwater Drainage Regulations and Charges Bylaw requires property owners to maintain on-site stormwater facilities and gives City staff the right to inspect private stormwater facilities. The Bylaw does not specifically state that the City can/will charge property owners for maintaining on-site stormwater facilities that the owner did not maintain.

**On-site LID/BMP**

Municipalities that require developing properties to adopt and maintain on-site Low Impact Development/ Stormwater Best Management Practices include:

- City of Thunder Bay's Engineering and Development Standards outline requirements for stormwater rate, volume and control. The standard requires on-site controls such that the post development discharge rate for all storms is not greater than the pre discharge rate. It also requires that the post-development stormwater volume for the 2-year storm is not greater than the pre-development volume. The standard also addresses stormwater quality and requires treatment for sediment removal. The standard describes overall goals, including the reduction in impervious cover and the use of BMP/LID treatment trains. City of Thunder Bay's Sewage and Stormwater Discharge By-law outlines maintenance responsibilities for private stormwater treatment facilities;
- City of Kamloops requires the capture and retention of all small storms (less than 10mm in 24 hours) on site for re-use, infiltration, evaporation, and/or transpiration. In areas where infiltration is not feasible detention in lieu of retention may be acceptable. BMPs designed to attenuate peak flows and remove TSS must be implemented on large parking areas (>1,000m$^2$).
- City of Kelowna requires matching post development rate & volume to pre-development levels, generally requiring extensive onsite retention & detention. 100-yr storm Water Quality is set to 50% of 2-yr storm. They are working to incorporate proof of maintenance into business license renewal. They have the right to access and inspect all on-site storm infrastructure, but insufficient resources to do so.
- City of Greater Sudbury requires the implementation of on-site measures such that post development flow rates are equal to or less than pre-development flow rates for certain watersheds with supporting watershed studies. The maintenance of on-site facilities is required through site plan agreements, but the City does not inspect for compliance yet.
- City of Surrey's on-site requirements are specified in ISMPs, neighbourhood plans, and master drainage plans. Commercial and industrial properties must show proof of maintenance prior to the renewal or issuance of a business license;
- City of Kitchener requires the first 12.5 mm of run-off to be retained on-site and requires proof of maintenance for on-site stormwater measures before issuing a credit on a property's stormwater rate;
- City of Vancouver requires the first 24 mm of run-off to be retained on site and the next 24 mm to be treated before being discharged;

- District of Squamish requires developments to produce a stormwater management plan which must demonstrate no net increase in flow rates for the 10-year design storm. Further detention and treatment may be required at the discretion of the Development Engineer. Maintenance of these measures are required through a bylaw;
- City of North Vancouver requires 56 mm of rainfall to be captured/infiltrated over 24 hours, or stormwater to be released at a rate of 0.5 l/ha/s. Current maintenance requirements through a bylaw are too weak so they are looking for other tools (e.g. fee based) to encourage maintenance; and
- Sudbury requires post-development flows to equal pre-development flows for certain watersheds that have supporting watershed studies.

Municipalities which limit the amount of impervious area on-site include:

- Vancouver's zoning bylaw which limits impervious area (e.g. 60% for RS-1)

**Climate Change**

Municipalities that consider the future impacts of Climate Change within their development criteria include: -

- City of Thunder Bay has updated their IDF curves using recent data and better statistical analysis plus they require adding 15% flow.
- City of Kelowna's Design Standards require adding 15% to the existing IDF curves.
- The City of Nanaimo updated their IDF curve to consider climate change based on the Engineers and Geoscientists of British Columbia's guidance and current down scaled climate model projections from the Pacific Climate Impacts Consortium.
- The City of Greater Sudbury reviewed their IDF curve to consider climate change. They actually found that their current design storm which is based on a historical extreme weather event was sufficiently conservative to consider climate change.
- Edmonton (future looking IDF curves and modeling assessment)
- Vancouver (future looking IDF curves); and
- District of North Vancouver (future looking IDF curves).

**Oil Grit Separators**

Municipalities that have well developed requirements for the installation and maintenance of oil grit separators (OGS) include:

- City of Kamloops requires sediment control on all parking lots > 1,000 m2
- City of Kelowna requires OGS units for parking lots > 50 vehicles, all industrial properties, gas stations, vehicle service/storage sites and construction equipment service/storage sites. Proof of maintenance is tied to business license renewal.
- Thunder Bay which has a public education program and strict maintenance requirements in their Sewage and Stormwater Discharge By-law, has over 90% of the private side OGS units being inspected and/or cleaned annually. The bylaw requires OGS units for vehicle and equipment service-related properties. Sediment removal requirements as per the City's Engineering and Development Standards may also lead to the installation of OGS units.
- The City of Nanaimo requires all uncovered parking areas greater than 100 m² in size to include treatment to remove oil, total suspended solids (TSS), and other contaminants.
- City of Greater Sudbury requires OGS for all motor vehicle service stations, repair shops, vehicle wash stations etc. and requires that they be maintained and be able to produce maintenance records upon request.
- Surrey requires proof of maintenance of any on-site OGS to obtain or renew a business license.

**Tree Protection**

Municipalities that have well developed Tree Protection requirements include:

- The City of Kamloops' Tree Protection Bylaw;
- The City of Kelowna's Tree Protection Bylaw limits tree clearing in designated areas which includes tree cutting permit areas, along stream corridors and on steep slopes. The City of Kelowna are working on regulating better tree protection on private property;
- The City of Nanaimo's Tree Protection Bylaw
- The City of Surrey (more stringent controls and penalties than the City of Prince George including a list of priority trees);
- The City of Abbotsford (required permit with security);
- City of Chilliwack (Tree Management Land Development Bylaw);
- The City of Maple Ridge (special provisions for addressing tree removal in rural areas);
- Town of Comox (Tree Management and Protection Bylaw);
- City of Courtney (Tree Protection and Management Bylaw); and
- The City of Kitchener (Tree Conservation Bylaw and Permit with fines up to $50,000).

**Land Clearing**

Municipalities that have well developed practices for controlling land clearing before subdivision include:

- District of Squamish which has a Site Alteration Bylaw (with enforcement), Tree Management Bylaw and Soils Management Bylaw; and
- City of Kitchener controls land clearing through their Tree Conservation Bylaw and associated permitting process (with fines up to $50,000).
- City of Kelowna requires a permit for land clearing in Development Permit areas which includes most areas, especially sensitive ones. The Development Permit areas that require permits prior to clearing. Kelowna also uses their ESC and Stormwater Bylaws to enforce good land clearing practices.

**Erosion and Sediment Control**

Municipalities that have well developed systems for erosion and sediment control include:

- City of Kelowna (erosion and sediment control requirements within their Design Standards Bylaw). Maximum concentration levels are 75 milligrams per litre (ppm) of total suspended solids (TSS). A sample measuring > 60 nephelometric turbidity units (NTU) will be sent to the lab for analysis. A security deposit is taken and a Qualified Professional is responsible for inspecting and monitoring the ESC Facilities
- City of Thunder Bay's Engineering and Development Standards outline the requirements for an ESC plan, along with requirements for monitoring during construction. It does not require the services of a registered professional. ESC plan requirements are outlined in the Soil Removal bylaw.
- The City of Greater Sudbury prohibits discharges to sewers and watercourses > 15 mg/L TSS. An erosion and sediment control plan must be prepared and monitored by a Professional and a security must be provided.
- City of Burnaby (sediment control system permits and information pamphlets for builders)
- City of Abbotsford (erosion and sediment control bylaw)
- City of Surrey (erosion and sediment control bylaw) requires an ESC permit with a security deposit. The security deposit can be used by the City to complete the ESC facilities if the developer fails to do so. The ESC plan must be sealed by a Professional Engineer.
- City of Maple Ridge (watercourse protection bylaw), and
- Township of Langley (erosion and sediment control bylaw).

**Other**

Municipalities where Stormwater Infrastructure Design Criteria were referenced to rather than included within its bylaws are:

- Cities of Surrey and Maple Ridge references its criteria in its Subdivision and Development bylaw
- City of Thunder Bay references its Engineering and Development Standard within its Sewage and Stormwater Discharge By-law.

Municipalities where the list of prohibited substances for discharge into the stormwater system meet current environmental standards and only make reference to (rather than include) provincial or federal regulations include:

- City of Surrey (e.g. reference to the Environmental Management Act);
- Thunder Bay's bylaw references the Ontario Water Resource Act, the Environmental Protection Act and Fisheries Act.
- Kamloops Watercourse bylaw references Fisheries Act, Water Act and Environment and Land Use Act.
- City of Kelowna's Design Standards references the BC Ministry of Environment Recreational Water Quality Guidelines.

# 4. Key Findings and Recommendations

AECOM's bylaw review and discussions with staff indicated the primary concerns for stormwater management, as listed in Section 2.4. Recommendations for areas of bylaw and policy improvement are discussed in detail below.

**Cost Recovery for Bylaw Infractions**

In general, the City is permitted to direct a person to rectify a bylaw infraction and in some cases is able to correct the situation, if required, while recovering the costs from the person. However, the Storm Sewer Bylaw currently doesn't explicitly allow for the City to rectify the situation and recover costs. The City is permitted to 'shut off' service to a property. Shutting off a storm service may not be feasible, desirable or an effective means of enforcement.

Cost recovery is important for cleaning-up spills, removing accumulated sediment and rectifying other downstream issues due to insufficient on-site stormwater management facilities and practices. If the City were able to recover these costs, then potential responsible persons would be encouraged to implement better spill prevention and containment measures and better on-site stormwater management practices. It also allows the City to allocate more staff time to spill related activities knowing that some costs can be recovered. Implementing mechanisms for the recovery of spill related costs should not be done in such a way that deters the reporting of spills.

***Recommendation #1:*** *The City should update the Storm Sewer Bylaw and Tree Protection Bylaw with procedures for notification, rectification, spill reporting and cost recovery for bylaw infractions.*

**Low Impact Development/ Best Management Practices**

In keeping with the policy direction of the Official Community Plan, the recommendations within the City's Watershed Drainage Plans, and increasingly common practices amongst Canadian municipalities, the City should require newly developed and re-developed areas to implement approved low impact development measures (also known as stormwater best management practices), where feasible, to maintain the natural water balance as much as possible. This will help protect downstream ravines and natural water bodies and reduce the loading on the City's engineered stormwater system.

Retention and infiltration area requirements could be made simpler for smaller lots (i.e. <1000 $m^2$) in order to simplify the process for builders and City staff. Additional work will be required with stakeholders to ensure that proposed changes are generally acceptable to and understood by the development community.

The City could also consider setting restrictions within the Zoning Bylaw on the allowable percent imperviousness for specific land uses. Targets could be based on total impervious area or effective impervious area. In combination with setting targets for on-site stormwater management requirements and/or restricting impervious surfaces, educations and outreach programs can provide for a less legislative approach to improving stormwater management. If the City revises its policies and bylaws, educational material should be used to communicate the changes and best practices to developers and the public. These types of materials should be readily available and promoted by City staff.

A detailed review of the City's Subdivision and Development Servicing Bylaw and draft Design Guidelines was completed as part of Technical Working Paper #2 – Engineering Issues.

***Recommendation #2:*** *The City should develop performance-based requirements for on-site retention, infiltration, and release of stormwater runoff from private property in the Engineering Design Guidelines, with consideration for situations where infiltration or detention may cause undesired consequences (i.e. slope stability concerns,* *increased creek erosion etc.). The Design Guidelines should be referenced within the Subdivision and Development Services Bylaw so that they are binding and enforceable.*

**Climate Change**

Emerging best practice in engineering design is to incorporate climate change adaptation measures into the design of stormwater infrastructure.

Applying climate change into the design of the stormwater system will require having multiple operational rain gauges around the City in order to capture all localized storms. The City should also look at climate change modeling to develop future IDF curves (i.e. year 2080) to help in the design of new stormwater infrastructure that will be in operation for the next 50-100 years. The ultimate goal is to increase the resiliency of the City's stormwater system. More details are provided within the Rain Gauge Monitoring portion of Technical Working Paper #2.

***Recommendation #3:*** *The City should integrate future climate change projections into the design of the stormwater system, by updating its Design Guidelines to consider future rainfall projections.*

**Oil and Grit Interceptors**

The current wording of Clause 2.9 Interceptors in the Storm Sewer Bylaw is vague as to which properties should have an oil and grit interceptor and does not allow the City to require an interceptor on any property that the City deems necessary. Instead, it permits the City to waive the requirement through permitted discharges. Some municipalities (i.e. Kelowna) require all Industrial properties to have an oil and grit interceptor. Kelowna also requires all parking lots for more than 50 vehicles to have an oil-grit separator (OGS), whereas Kamloops requires all parking lots with a surface area greater than 1000m$^2$ to have an OGS. Cities such as the City of Kelowna require proof of OGS maintenance (i.e. receipt from cleaning company/vac truck) when they renew their business license.

***Recommendation #4:*** *The City of Prince George should update the Storm Sewer Bylaw to clearly specify the types of properties that require an oil and grit interceptor (including large surface parking lots and industrial properties) and to include maintenance requirements. The City should also update the Design Guidelines to specify design requirements for the sizing of oil and grit separators and access for maintenance.*

The bylaw and Design Guideline updates should include provisions that allow the City to require an oil and grit interceptor on any property deemed necessary; that the interceptor should be located in a readily and easily accessible location for cleaning and inspections; and that the interceptor should be maintained at the owner's expense in a continuously efficient operation at all times.

**Prohibited Substances**

Current language in the Storm Sewer Bylaw including the list of prohibited substances do not meet current standards for the protection of the storm sewer system, the public, and aquatic life. The City has a legal responsibility when unauthorized discharges enter its system. This is a risk that makes the City liable to contain and to some extent, remediate even if it is not the responsible party. The current bylaw includes out of date provincial and federal regulations. The City bylaws should only reference the existence of, rather than reiterate or interpret Provincial and Federal guidelines, standards and regulations. That way, as Provincial and Federal guidelines, standards or regulations change (i.e. change in allowable concentrations), the City's bylaw is still up to date. The updates should also be written to ensure that any current and future contaminants of concerns are included in the bylaw. The bylaw only addresses discharges to "storm sewers" and to the "storm sewer system" and does not explicitly include other aspects of the drainage system such as ditches and watercourses.

Currently, the City is permitted to issue bylaw notices of $500 through the Local Government Bylaw Notice Enforcement Act for the discharge of prohibited wastes. However, there are many minor contraventions to the Storm Sewer Bylaw that are not listed in the Bylaw Notice Enforcement Bylaw which limit the tools available for City staff to enforce the provisions in the Storm Sewer Bylaw.

***Recommendation #5:*** *The City should update the section in the Storm Sewer Bylaw on prohibited discharges to reflect current environmental standards, to allow for easy measurement in the field for enforcement, to only reference Provincial and Federal standards (rather than reiterate them) as well as to broadly include materials, concentrations and quantities of substances that may negatively impact the stormwater system, any infrastructure, health or safety of personnel, and the City's ability to meet Provincial and Federal obligations. The bylaw should explicitly address discharges to the entire drainage system (e.g. ditches and watercourses) and not just storm sewers.*

Any updates to the City's Storm Sewer Bylaw should be reviewed to ensure that all relevant contraventions are included in the Bylaw Notice Enforcement Bylaw or the Municipal Ticket Information Utilization Bylaw.

**Protection of Trees and Other Natural Assets**

The City's Tree Protection Bylaw requires permits for trees to be removed in the AG: Greenbelt and Riparian Protection Development Permit Areas. The Riparian Protection Development Permit Area and Zoning Bylaw do not include all creeks and wetlands, just fish-bearing watercourses and wetlands that are directly tied to fish-bearing streams. The Flood Plain Regulation Bylaw identifies setbacks from watercourses

These protections do not appear to be robust enough given the importance of the tree canopy, wetlands, non-fish bearing streams and riparian corridors throughout the City to manage stormwater runoff, maintain the natural water balance and provide other environmental, economic and social benefits.

Valuable natural assets can be defined through the City's Sensitive Ecosystem Inventory and the City's pending Natural Asset Inventory being conducted through the Municipal Natural Asset Initiative.

***Recommendation #6:*** *The City should consider amending the Tree Protection Bylaw for better environmental protections by increasing the area covered by the bylaw.*

***Recommendation #7:*** *The City should consider increasing its development permit areas within the OCP bylaw to include and protect additional valuable natural areas, such as riparian areas of streams that provide nutrients to downstream fisheries and wetlands that are not directly connected to fish-bearing streams. The Flood Plain Regulation Bylaw and its permissible exemptions should also be aligned, where relevant, to support the protection of the new development permit areas.*

**Land Clearing Activities and Erosion and Sediment Control (ESC)**

Current development activities in the City result in land being cleared well ahead of construction activities. This practice is a direct contravention of two erosion and sediment control best practices:

- Time the clearing and excavation activities so that they occur no sooner than is necessary for subsequent construction activities; and
- Remove as little of the existing vegetation as possible.

Currently, the City does not have a robust policy framework with regards to erosion and sediment control (ESC). The City only requires developers to produce erosion and sediment control plans for certain types of development. The City does not specify what the ESC plans should contain nor that they be prepared and monitored by a qualified professional. The prohibited waste list in the Storm Sewer Bylaw specifies a total suspended solids limit of 500 ppm which is much higher than best practice for ESC and does not allow for easy measurement in the field. The City does not have a cost recovery mechanism such that it can recover costs incurred due to insufficient on-site ESC practices.

The City would be able to better encourage and enforce good ESC practices, if ESC was tied to a permit with a security. The City is currently looking at strengthening existing regulations, particularly the Subdivision Development Servicing Bylaw, to help increase their ability to require and enforce effective erosion and sediment control practices.

***Recommendation #8:*** *The City should develop a new Erosion and Sediment Control Bylaw and update the total suspended solids limit in the Storm Sewer Bylaw to better protect the natural environment and the City's infrastructure, and to allow for field testing.*

An erosion and sediment control bylaw should specify the permitting process including required securities, the ability of the City to conduct on-site inspections, issue stop work orders and recover costs, what type of information is required within an erosion and sediment control plan, that the plan be developed by a qualified professional, that the ESC system be monitored by a qualified professional, and clear ESC performance reporting requirements. . ESC plan requirements could be based on parcel size (e.g. simpler requirements for developments < $1000m^{2)}$. The subdivision bylaw should refer to the new Erosion and Sediment Control Bylaw, if the City decides to develop one.

The goal of enforcement measures should be to move developers and builders towards best practices in ESC which will require a combination of clear requirements, education, and enforcement. If the City updates its ESC regulations and policies, then it may need to update its educational material and enforcement practices accordingly.

As it can take years to develop a new Bylaw, the City may want to first consider strengthening its Storm Sewer Bylaw, Subdivision and Development Servicing Bylaw and Design Guidelines to help address some of the ESC issues in the interim. Updating allowable sediment concentrations, enabling the ability for field measurements, and adding cost recovery mechanisms within the Storm Sewer Bylaw will help the City address and ultimately reduce the impact of poor ESC practices. The City could also investigate updating its development and building permit requirements to extend the need for an ESC plan to more types of development and require that ESC plans be prepared and monitored by a Qualified Professional for larger developments. Once a new ESC bylaw is in place the City will also be able to extend and better control ESC requirements to land clearing activities that occur before rezoning or the development/building permit stage.

**Driveway Culverts**

Driveway culverts need to be regularly inspected, periodically cleared of debris, replaced at the end of their service life and in some cases, upgraded to allow for fish passage. It is not specified in any of the City's regulations, who is responsible for maintaining and renewing driveway culverts.

***Recommendation #9::****The Storm Sewer Bylaw should be updated to explicitly state who is responsible for inspecting, maintaining, repairing, replacing and upgrading driveway culverts.*

**General**

With respect to the nine recommendations outlined above, it is important that the City's legal council review any proposals for new or amended bylaws.

Most municipalities reviewed in the preparation of this TWP have separate bylaws to address drainage assets, tree protection and erosion and sediment control. Although, these separate bylaws need to be co-ordinated, we are not recommending that the City combine all these functions into one single bylaw.

# 5. References

Office of the Ombudsperson (Ombudsperson), (2016). Bylaw Enforcement: Best Practices Guide for Local Governments, Special Report No. 36 to the Legislative Assembly of British Columbia.

Picketts, I.M., Werner, A.T., Murdock, T.Q., (2009). Climate Change in Prince George: Summary of Past Trends and Future Projections. Pacific Climate Impacts Consortium, University of Victoria, Victoria BC.

Province of British Columbia (BC), (2019). British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture Summary Report. Water Protection & Sustainability Branch, Ministry of Environment &

Climate Change Strategy.
Province of British Columbia (BC), (2020b). Local Government Bylaw Enforcement. Retrieved from https://www2.gov.bc.ca/gov/content/governments/local-governments/governance-powers/bylaws/bylaw-enforcement

Province of British Columbia (BC), (2020c). Local Government Bylaw Notices. Retrieved from https://www2.gov.bc.ca/gov/content/governments/local-governments/governance-powers/bylaws/bylaw-enforcement/bylaw-notices

Province of British Columbia (BC), (2020d). Municipal Ticketing. Retrieved from https://www2.gov.bc.ca/gov/content/governments/local-governments/governance-powers/bylaws/bylaw-enforcement/municipal-ticketing

Province of British Columbia (BC), (2020e). Offence Act Prosecutions. Retrieved from https://www2.gov.bc.ca/gov/content/governments/local-governments/governance-powers/bylaws/bylaw-enforcement/offence-act-prosecutions

Province of British Columbia (BC), (2010). Community Charter Bylaw Enforcement Regulation. Retrieved from http://www.bclaws.ca/civix/document/id/complete/statreg/425_2003#:~:text=Maximum%20fine%20amount,the%20Community%20Charter%20is%20%241000.

Province of British Columbia (BC), (2003). Local Government Bylaw Notice Enforcement Act [SBC 2003] Chapter 60. Retrieved from http://www.bclaws.ca/civix/document/id/complete/statreg/03060_01#section4

Vancouver, City of (COV), (2017). Erosion and Sediment Control Large Lot Development (1,000m$^2$ or More), Bulletin 2002-003-EV. Vancouver BC.

BC MOE. 2005. A User’s Guide to Working In and Around Water. Understanding the Regulation Under British Columbia’s Water Act. Originally issues: May 18, 2005.

Fisheries and Oceans Canada. 2000. Urban Stormwater Guidelines and Best Management Practices for Protection of Fish and Fish Habitat, Draft Discussion Document, Revision 4.

BC MWLAP. 2002. Stormwater Planning: A Guidebook for British Columbia

Government of BC and Fisheries and Oceans Canada. 2007. Beyond the Guidebook: Context for Rainwater Management and Green Infrastructure in British Columbia. June 2007.

Government of BC, et. al. 2010. Beyond the Guidebook 2010: Implementing a New Culture for Urban Watershed Protection and Restoration in British Columbia

Government of BC, et. al. 2015. Beyond the Guidebook 2015: Towards a Watershed Health Legacy in the Georgia Basin

**Contact**

Nancy Hill, P.Eng.
Project Manager
T: +1 604.790.1637
E: nancy.hill@aecom.com

# Appendix E

## Technical Working Paper #4 – Financing Options

City of Prince George

# Integrated Stormwater Management Plan

## *Technical Working Paper # 4 – Financing Options*


**Prepared by:**

AECOM Canada Ltd.
3292 Production Way, Floor 4
Burnaby, BC   V5A 4R4
Canada

T: 604 444 6400
F: 604 294 8597
www.aecom.com



**Date:** July, 2021

**Project #:** 60628231

# Distribution List

| # Hard Copies | PDF Required | Association / Company Name |
|---|---|---|
| | ✓ | City of Prince George |
| | ✓ | AECOM Canada Ltd. |

# Statement of Qualifications and Limitations

The attached Report (the “Report”) has been prepared by AECOM Canada Ltd. (“AECOM”) for the benefit of the Client (“Client”) in accordance with the agreement between AECOM and Client, including the scope of work detailed therein (the “Agreement”).

The information, data, recommendations and conclusions contained in the Report (collectively, the “Information”):

- is subject to the scope, schedule, and other constraints and limitations in the Agreement and the qualifications contained in the Report (the “Limitations”);
- represents AECOM’s professional judgement in light of the Limitations and industry standards for the preparation of similar reports;
- may be based on information provided to AECOM which has not been independently verified;
- has not been updated since the date of issuance of the Report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the Report and the Agreement; and
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time.

AECOM shall be entitled to rely upon the accuracy and completeness of information that was provided to it and has no obligation to update such information. AECOM accepts no responsibility for any events or circumstances that may have occurred since the date on which the Report was prepared and, in the case of subsurface, environmental or geotechnical conditions, is not responsible for any variability in such conditions, geographically or over time.

AECOM agrees that the Report represents its professional judgement as described above and that the Information has been prepared for the specific purpose and use described in the Report and the Agreement, but AECOM makes no other representations, or any guarantees or warranties whatsoever, whether express or implied, with respect to the Report, the Information or any part thereof.

Without in any way limiting the generality of the foregoing, any estimates or opinions regarding probable construction costs or construction schedule provided by AECOM represent AECOM’s professional judgement in light of its experience and the knowledge and information available to it at the time of preparation. Since AECOM has no control over market or economic conditions, prices for construction labour, equipment or materials or bidding procedures, AECOM, its directors, officers and employees are not able to, nor do they, make any representations, warranties or guarantees whatsoever, whether express or implied, with respect to such estimates or opinions, or their variance from actual construction costs or schedules, and accept no responsibility for any loss or damage arising therefrom or in any way related thereto. Persons relying on such estimates or opinions do so at their own risk.

Except (1) as agreed to in writing by AECOM and Client; (2) as required by-law; or (3) to the extent used by governmental reviewing agencies for the purpose of obtaining permits or approvals, the Report and the Information may be used and relied upon only by Client.

AECOM accepts no responsibility, and denies any liability whatsoever, to parties other than Client who may obtain access to the Report or the Information for any injury, loss or damage suffered by such parties arising from their use of, reliance upon, or decisions or actions based on the Report or any of the Information (“improper use of the Report”), except to the extent those parties have obtained the prior written consent of AECOM to use and rely upon the Report and the Information. Any injury, loss or damages arising from improper use of the Report shall be borne by the party making such use.

This Statement of Qualifications and Limitations is attached to and forms part of the Report and any use of the Report is subject to the terms hereof.

*AECOM: 2015-04-13*

# Authors

**Report Prepared By:**

Nancy Hill, P.Eng.
Project Manager

**Report Reviewed By:**

Pippy Warburton, P.Eng.
Senior Water Resources Engineer

# Executive Summary

AECOM has been contracted by the City of Prince George to develop an Integrated Stormwater Management Plan (ISMP) so the City can fully understand and work towards sustainable service delivery of stormwater management. One of the major tasks of this assignment was to review the previously proposed stormwater utility funding model and provide recommendations for the best options for sustainable funding. A summary of this review and recommendations for sustainable stormwater funding is provided in this Technical Working Paper (TWP#4). More specifically this TWP describes the City's current stormwater funding model and needs; the previous stormwater financing work completed by the City; additional work or changes that have occurred since the previous stormwater funding study; municipal stormwater funding options available to the City; a comparison of stormwater financing models used by other, similar, municipalities in B.C. and across Canada; and conclusions and recommendations for next steps.

**City's Current Stormwater Funding Model**

The City currently funds its stormwater program through property taxes (general levy), debt, reserves and grant funding when available. Two of the City's dedicated tax levies, Road Rehabilitation and General Infrastructure Reinvestment Fund (GIRF), may help fund stormwater capital projects but neither levy is dedicated to stormwater projects.

Since the City does not have a dedicated stormwater funding source, preventative maintenance and capital improvement projects are often delayed until infrastructure fails, typically during storm events. Letting infrastructure run to failure can be an acceptable strategy for some low-risk assets but for most assets it can cause physical, environmental, and reputational damage, and typically leads to costly repairs. Having the funds to implement a predictive and preventative maintenance program allows for a more cost-effective approach to repairs and can also help extend the life cycle of the City's assets, reducing their overall life-cycle costs.

**City's Stormwater Funding Needs**

Over the last 5 years (2016-2020) the City has spent, on average, $4.4 million per year on stormwater management, which included the replacement of deteriorated assets at the end of their service life, maintenance activities such as inspecting culverts and providing new infrastructure to service development when it was not 100% funded through Development Cost Charges (DCC's). In 2021, the City has budgeted to spend $5.6 million on stormwater management. As part of this assignment, we developed a high-level estimate of what the City should be spending annually to achieve sustainable service delivery of stormwater management. We have estimated the City should be spending approximately $9.1 million annually to maintain, renew and upgrade its stormwater system. This is equivalent to approximately $9 per metre of system which is slightly less than the median of current expenditures amongst Canadian municipalities involved in the National Water and Wastewater Benchmarking Initiative.

**Previous Stormwater Funding Study**

In 2013, AECOM completed a study for a stormwater utility for the City of Prince George, which included public consultation. AECOM, with City staff support, completed a stormwater rate analysis and completed extensive public consultation. Public feedback was mixed, depending on the amount of knowledge they had about the City's stormwater system and funding needs. Most residents thought that the existing stormwater management program was sufficient and had no knowledge of additional stormwater funding needs.

In November 2013, City staff proposed a stormwater rate (based on a tiered Single-Family Unit (SFU) model with an option for credits for non-residential properties) to the Finance and Audit Committee and recommended draft bylaw approval. The proposed bylaw was not approved by the Committee and the Committee decided not to pursue a stormwater utility further.

A future attempt to implement a stormwater rate may be more successful if Council and the public were better informed of stormwater funding needs. Recent problems such as the Winnipeg Street storm sewer failure and resulting sinkhole may help in this regard.

**Stormwater Funding Options**

As part of this study stormwater funding options were reviewed that would allow the City to increase the stormwater funding level from current levels. Common municipal funding models that could be used to finance the City's entire stormwater program (i.e. capital and operating) include: General Tax Levy (property taxes), Dedicated Stormwater Tax Levy (if it was applied to capital and operating), Stormwater Rate/User Fee, and Water/Wastewater Rate Surcharge. These funding models would be complimented by other funding sources such as development charges and grants from senior levels of government.

**Conclusions & Recommendations**

From the previous stormwater funding work and more recent public consultation work for general municipal budgeting, it appears that historically stormwater management has not been the most pressing issue for residents of of Prince George. This may make it difficult for the City to engage residents about the need for a new stormwater funding model and will also make it difficult for stormwater managers to obtain sufficient funding from the general and existing dedicated tax levies when Council is being pressed by residents for other infrastructure such as recreational facilities and better sidewalks.

However, due to the on-going lack of stormwater funding and the associated risks (e.g. collapsing culverts), it is recommended that the City pursue additional stormwater funding. In order to be successful, it is recommended that the City do the following:

- Explore simpler stormwater funding models than the tiered SFU model proposed in 2013, to reflect the desires of residents and City Finance staff; and
- Educate staff, public officials and the public on the need for improved stormwater management. Use real examples such as the recent collapsed culverts to demonstrate the need for increased stormwater funding. Use financial information (e.g. the cost of emergency repairs vs planned maintenance) to demonstrate the financial benefits of maintaining the system in a planned rather than a reactive manner.

Given current challenges with reduced municipal revenues due to COVID-19 and competing priorities for funding from the General Tax Levy, City staff may want to consider a phased approach to stormwater funding. In the short-term, City staff may want to pursue additional stormwater funding through existing mechanisms (i.e. GIRF). If City staff are successful in consistently achieving sustainable stormwater funding levels through the general tax levy and the GIRF, then the City could continue funding stormwater through these mechanisms. However, if the City cannot achieve long-term sustainable stormwater funding levels through the general tax levy and the GIRF, then we recommend that the City consider the following two funding models:

- A dedicated stormwater tax levy (example: Delta); and
- An Equivalent Residential Unit (ERU) based variable stormwater rate (example: Guelph) which is similar to but simpler than the previously proposed tiered SFU model proposed in 2013.

If the City chooses to gradually increase stormwater funding to sustainable levels, then we recommend they use a risk-based approach to identify the highest priority needs. The risk analysis completed as part of TWP #2 and the project prioritization framework completed as part of TWP #1, will help in this regard. In general, the following key elements are important for developing a cost-effective stormwater program:

- Strong bylaws that prevent contamination of the stormwater system, ensures that polluters pay for any required clean-up, and ensures that developers pay their fair share for new infrastructure;
- Strong Design Guidelines to ensure that new infrastructure is effective and has an acceptable life-cycle cost; and
- A strong maintenance program that allows the City to prevent costly infrastructure failures, extend the life of its assets and prioritize infrastructure spending.

# Table of Contents

page



# List of Figures

# List of Tables

# 1. Introduction

AECOM has been contracted by the City of Prince George to develop an Integrated Stormwater Management Plan (ISMP) so that the City can fully understand and work towards sustainable service delivery of stormwater management. One of the major tasks of this assignment is to review the previously proposed stormwater utility funding model and provide recommendations for the best options for sustainable funding. A summary of this review and recommendations for sustainable stormwater funding is provided in this Technical Working Paper (TWP#4). More specifically this Technical Working Paper #4 describes:

- The City's current stormwater funding model;
- The previous stormwater financing work completed by the City;
- Additional work or changes that have occurred since the previous stormwater funding study;
- Municipal stormwater funding options available to the City;
- A comparison of stormwater financing models used by other, similar, municipalities in B.C. and across Canada; and
- Conclusions and recommendations for next steps.

## 1.1 Prince George Current Stormwater Funding Model

The City currently funds its stormwater program, both operating and capital, primarily through property taxes (tax levy), which are based on assessed property value. In addition to the general tax levy, the City has several dedicated tax levies. Two of the levies, the Road Rehabilitation and General Infrastructure Reinvestment Fund (GIRF), may help fund capital projects that are related to stormwater management but neither levy is dedicated to stormwater projects. Stormwater capital projects may also be partially funded through other sources such as development cost charges (when related to new development), gaming revenue/reserves and grants (when available). The City does have a storm drainage reserve fund for funding capital projects related to stormwater; however, this fund has very little balance and no ongoing source of funds.

The main challenge with the City's stormwater funding model is that preventative maintenance and improvement projects are often delayed until infrastructure fails, often during storm events. Letting infrastructure run to failure can be a good strategy for low-risk assets but for other assets it can cause physical, environmental and reputational damage and typically leads to costly repairs. Having the funds to implement a predictive and preventative maintenance program allows for a more cost-effective approach to repairs and can also help extend the life cycle of the City's assets, reducing their overall life-cycle costs.

## 1.2 Prince George Current Stormwater Funding

Over the last 5 years (2016-2020) the City has spent, on average, $4.4M per year on its stormwater system. This year (2021) the City has budgeted to spend $5.6M on its stormwater system. The breakdown of stormwater spending or budget from 2016 to 2021 is shown in Table 1 where stormwater spending is broken into the following four categories:

- Renewal - replacement or significant rehabilitation of existing infrastructure (i.e. at the end of its service life).
- Upgrades – making improvements to the existing system, such as through the addition of water quality treatment (e.g. ponds).
- New (not DCC funded) – new infrastructure that typically expands the system to service new areas. The amounts shown in Table 1 exclude contributions from development cost charges (DCC), so that it only includes contributions from the City.
- O&M – operations and maintenance activities such as storm sewer cleaning.

**Table 1: City of Prince George Stormwater Funding 2016-2021**

| | Actual | | | | | Budget | Average |
|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | |
| **Renewal** | $1,425,683 | $3,087,343 | $2,514,895 | $1,079,798 | $505,307 | $1,940,596 | $1,758,937 |
| **Upgrades** | $0 | $66,441 | $1,719,250 | $167 | $0 | $0 | $297,643 |
| **New – not DCC funded** | $1,208,170 | $21,402 | $1,739,037 | $586,157 | $42,405 | $1,900,000 | $916,195 |
| **O&M** | $1,178,461 | $1,734,648 | $1,664,428 | $1,701,389 | $1,934,164 | $1,791,669 | $1,667,460 |
| **Total** | **$3,812,314** | **$4,909,834** | **$7,637,610** | **$3,367,512** | **$2,481,876** | **$5,632,265** | **$4,640,235** |

The City primarily funds its stormwater program from property taxes. More specifically, the City funds its stormwater program through the following mechanisms:

- Approximately $1.3M is directly allocated annually to stormwater operating from the General Levy (i.e. property taxes);
- Debt servicing (Note: repayment of debt also uses property taxes); and
- Reserves (Note: some reserves are still funded by property taxes, e.g. the General Infrastructure Reinvestment Fund).

Currently the average home in Prince George contributes approximately $100 annually towards stormwater management through property taxes.

## 1.3 Prince George Stormwater Funding Needs

From Table 1, we can see that the City has spent an average of $4.4M ($4.6M if you include the budgeted amount for 2021) annually on stormwater for asset renewal, system upgrades, new infrastructure and O&M. As part of this assignment, we wanted to estimate what the City should be spending annually to achieve sustainable service delivery of stormwater management.

More description about our estimate of the City's stormwater funding needs in the areas of renewal, upgrades, new infrastructure, planning studies & policy work, and O&M are provided in the five sections below.

**Renewal**

Using the City's asset management tools PowerpPlan/BUILDER, the City has estimated average annual renewal (AAR) needs for its storm sewer system (e.g. sewers, culverts, and pumping stations) of $4,300,000. This is the amount that has been included in the City's Infrastructure Report Cards within the 2021-2025 Financial Plan. The renewal costs assume a like-for-like replacement of existing infrastructure. If infrastructure needs to be larger due to climate change projections, then the costs will increase accordingly. The renewal needs show average annual needs and have not been prioritized based on risk.

The City must also consider the renewal/rehabilitation of its stormwater ponds. The City currently owns 26 ponds, 20 of which are wet ponds that will require significant sediment removal every 10-30 years. We have developed a high-level estimate that each wet detention pond will be cleaned at a cost of $100,000 every 20 years. This results in an annual pond cleaning cost of $100,000 which has been added to the AAR estimate of $4.3M to determine total stormwater renewal needs. Once the City completes more sediment surveys of its existing ponds and removes sediment from these ponds, it will be able to provide a better estimate of its annual pond sediment removal needs.

**Upgrades**

Upgrades include projects where improvement are made to the existing system (i.e. adding water quality treatment with the addition of a detention pond) rather than simply replacing existing infrastructure (which is considered "renewal") or upsizing the system to service new development (typically funded by new development).

The City's six watershed drainage plans (WDPs) have recommended over 250 action items, some of which are considered "upgrades". A cost estimate for 167 of these 250 action items was provided. The remaining action items were deemed to have only internal costs (i.e. for staffing) or a cost estimate was simply not provided. Since the WDPs have been developed, some of the recommended action items have been completed and a few new action items have been identified. Completed action items and new action items were eliminated and added to the list respectively. As pipe (sewer or culvert) renewal needs are included within the stormwater AAR needs from PowerPlan, any WDP pipe renewal projects were assumed to be already accounted for. The only exception is if a culvert needs to be replaced with an open span bridge as this level of upgrade would not have been considered within the AAR needs from PowerPlan.

The remaining "upgrade" action items from the WDPs have a total estimated cost of $31M, when corrected for inflation (see inflation rates provided in TWP#1) and climate change (simply added 15% if the WDP didn't consider climate change). The breakdown of projects by priority where 9 is the highest priority and 1 is the lowest priority is outlined in the following table.

**Table 2: City of Prince George Stormwater Upgrade Projects by Priority Level**

| Priority | Estimated Cost | Cumulative Estimated Cost |
|---|---|---|
| **9** | $1,000,000 | $1,000,000 |
| **8** | $0 | $1,000,000 |
| **7** | $65,000 | $1,065,000 |
| **6** | $3,714,000 | $4,779,000 |
| **5** | $6,189,000 | $10,969,000 |
| **4** | $11,684,000 | $22,653,000 |
| **3** | $2,618,000 | $25,271,000 |
| **2** | $5,437,000 | $30,708,000 |
| **1** | $0 | $30,708,000 |

To determine a sustainable funding level, we have taken the cost of completing the higher priority upgrade projects (i.e. priority level 5-9) over a ten (10) year time span. This represents a total cost of $11 M or $1M per year.

Watershed Drainage Plans (WDP) have not been completed for the whole City, so the estimate for upgrades may increase as additional Watershed Drainage Plans are completed. In addition, some of the WDPs did not provide cost estimates for all recommended projects so the cost of completing all recommended upgrades will likely increase.

**New (not DCC Funded)**

The "New-not DCC funded" needs estimate is zero as it is assumed development will pay for all development related costs. However, Development Cost Charges (DCC's) may not cover all development related infrastructure upgrades so the cost here may be higher than zero.

**Studies and Policy Work**

The City needs to periodically develop, review and revise bylaws, policies, Design Guidelines and planning studies for stormwater management. We have included the following within our high-level estimate of the main stormwater related studies that the City should be completing:

- The City completes a new Watershed Drainage Plan or reviews one of its previous Watershed Drainage Plans every 2 years (at a cost of $250k per plan). The City has developed 6 drainage plans for different watersheds thus far which covers most of the developed areas within the City boundaries. This level of frequency would result in a watershed being looked at once every 15 years.
- The City should review this ISMP (at an estimated cost of $200k) and its Design Guidelines (at an estimated cost of $50k) every 10 years.
- The City spends $10k per year in the tracking and monitoring of this ISMP and the resulting action items.

The resulting total cost of studies is $185k per year. The City may need to spend additional money in the development and revision of stormwater related bylaws.

**Operating (Maintenance)**
We have estimated that it would cost $3.5M annually for the City to complete a full stormwater O&M program. This stormwater O&M cost estimate includes activities such as;

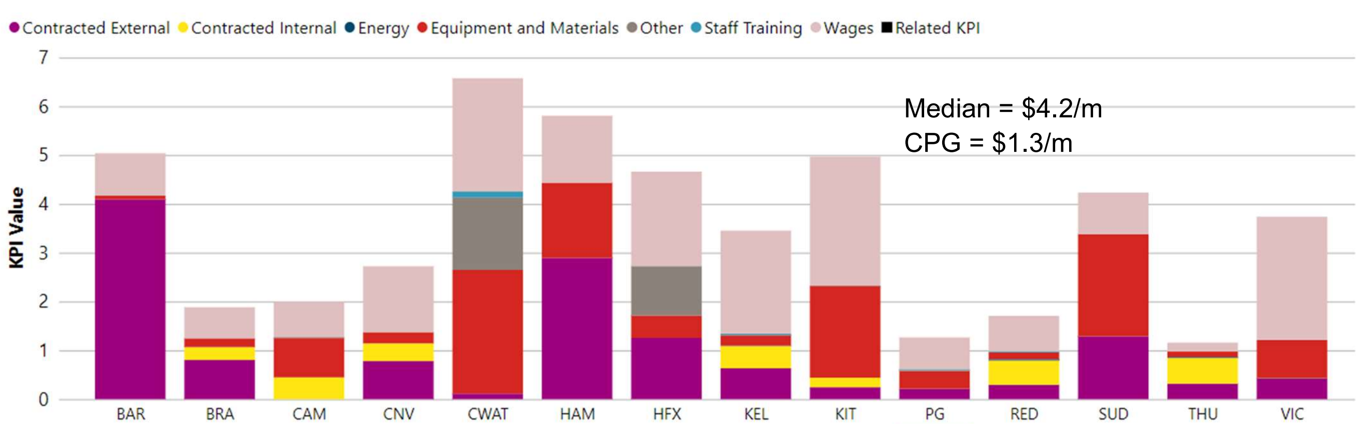
- cleaning catch basin sumps annually,
- inspecting the storm sewer system with CCTV every 20 years,
- maintaining the ditch network on a 20-year cycle,
- inspecting the City's 919 culverts annually (outside visual inspection only for notable blockages/erosion),
- cleaning the culverts every 10 years,
- inspecting each pond annually (with basic maintenance such as trash pick-up and vegetation control),
- continuing with the current pump station maintenance program, and
- some stormwater monitoring and periodic repairs of stormwater infrastructure.

The proposed O&M program does not include street sweeping, leaf pick-up, street flushing, sidewalk cleaning, pond sediment removal, screen/inlet maintenance, or infiltration facility maintenance. The City has budgeted $1.2 M for its street sweeping program (summer sweeping and winter sand pick-up). If the City wanted to include this activity within its future stormwater funding model, then it would need to add $1.2 M to its stormwater budget.

Currently the City spends $1.7M annually, on average, towards the maintenance of its stormwater system. This is equivalent to approximately $1.3-1.5 per metre of system (depending on the length of assumed sewer and ditch used). The median O&M cost amongst Canadian municipalities that participate in the National Water and Wastewater Benchmarking Initiative (NWWBI) is $4.2 per metre of system. If the City of Prince George spent $4.2 per metre of system on O&M then that would equate to a total O&M budget of $4.7M annually. Coincidently this is equivalent to our $3.5 M cost estimate plus $1.2 M for street sweeping.

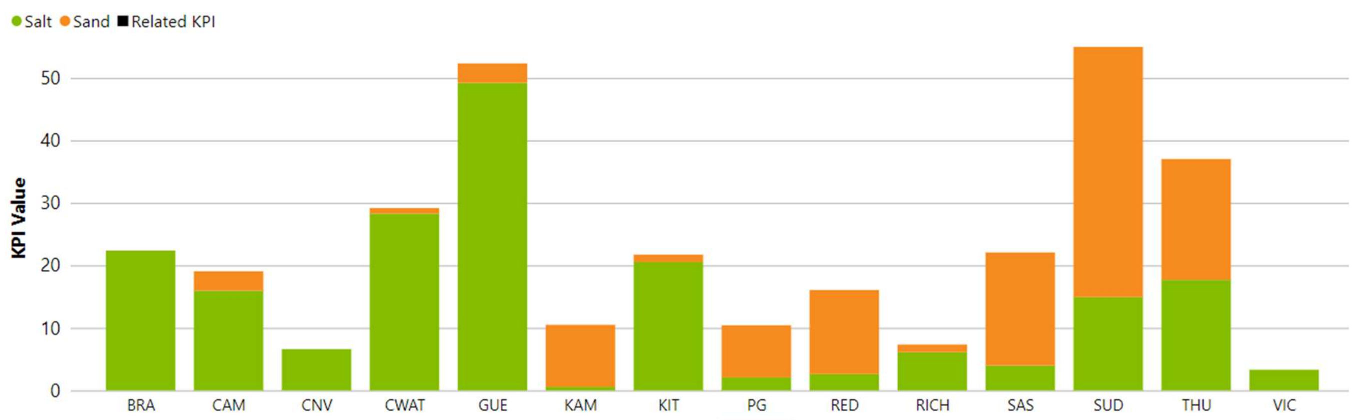
The figure below shows the O&M costs per metre of system for the municipalities participating in the NWWBI, including the City of Prince George (labeled as PG).

**Figure 1: 2019 Stormwater O&M Costs per metre of Sewer and Ditch- NWWBI**



The City has noted that the current lack of stormwater funding has impacted their ability to complete maintenance activities such as catch basin sump cleaning. In 2020 the City cleaned only 11% of its catch basin sumps. As can be seen in the following figure from the NWWBI, sediment management is important for northern communities such as Prince George, where the climate requires significant amounts of sand to be applied to the roadways in the winter.

**Figure 2: 2019 Tonnes of Sand and Salt Applied per km of Roadway- NWWBI**




In TWP#2 we addressed condition assessment needs for the City's stormwater system. We estimated that it costs significantly less to inspect and proactively repair the City's storm sewer system rather than to allow the system to "run to failure" and to respond (i.e. emergency repairs), only as needed.

**Total**

When the cost estimates for the five different sections are totalled, we have estimated the City should be spending approximately $9.1M annually for the sustainable service delivery of stormwater management. A breakdown of the estimate is shown in Table 3 below.

**Table 3: Annual Stormwater Funding Needs**

| Stormwater Expenditure Type | Annual Funding Needs | Supporting Information |
|---|---|---|
| **Renewal** | $4,400,000 | AAR from Power Plan/BUILDER + pond sediment removal |
| **Upgrades** | $1,000,000 | Highest priority WDP upgrade projects over 10 years |
| **New – not DCC funded** | $0 | Assume development pays for dev't related works |
| **Planning Studies** | $185,000 | New/revised WDP every 2nd year, updated Design Guidelines/ISMP every 10 years & annual ISMP Roadmap tracking/review |
| **O&M** | $3,468,000 | Based on estimated sustainable O&M program for CPG. Does not include street sweeping. |
| **Total** | **$9,053,000** | |

The full future stormwater funding needs may be greater than $9.1M per year, as future studies are completed and sewers are inspected, but the City could apply a risk-based approach to determine high priority short-term funding needs (i.e. 2022 -2026).

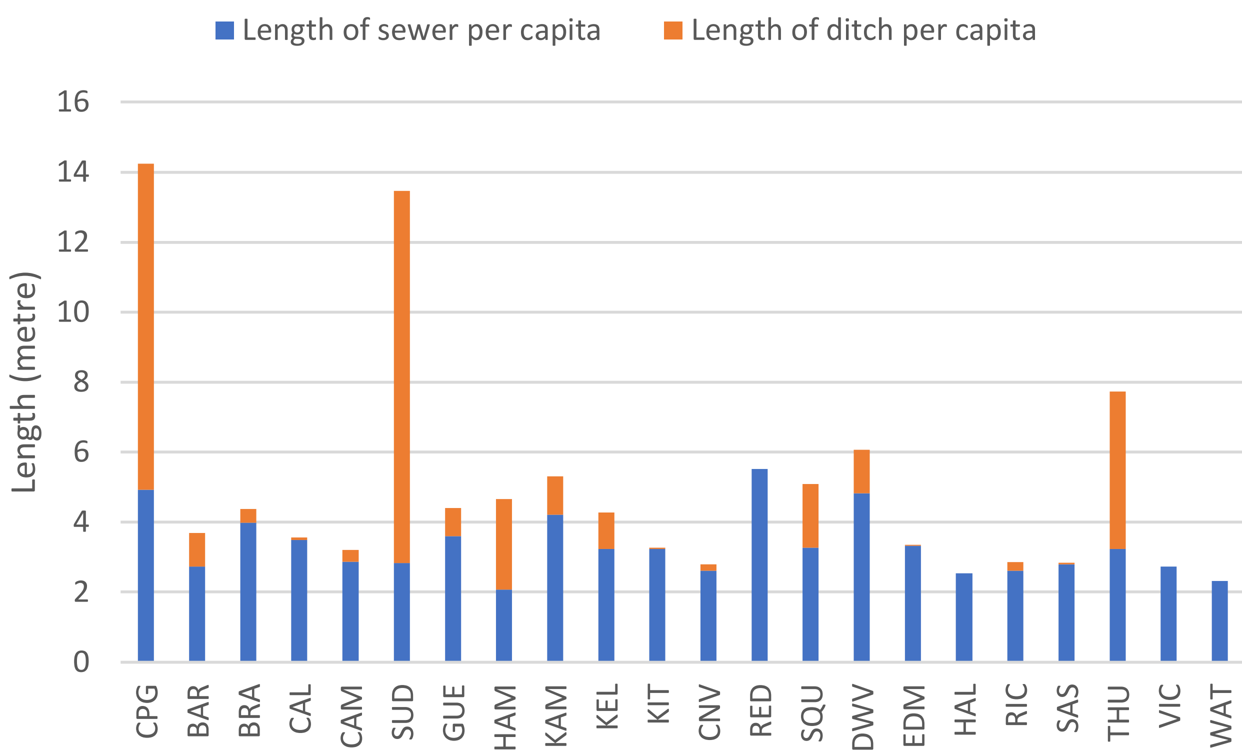
If the City were to spend $9.1M per year on stormwater, and it was to be funded entirely through the tax levy (general and dedicated levies) then the average homeowner would contribute $183 per year towards stormwater management. In order to increase stormwater funding from the $3.4M budget in 2019 to the long-term sustainable amount of $9.1M the City would need to increase the overall tax rate by 5% (assuming that other budgets for services funded from the general tax levy stayed the same).

If the City chooses to gradually increase stormwater funding to sustainable levels, then we recommend they use a risk-based approach to identify the highest priority needs. The risk analysis completed as part of TWP #2 and the project prioritization framework completed as part of TWP #1, will help in this regard. In general, the following key elements are important for developing a cost-effective stormwater program:

- Strong bylaws that prevent contamination of the stormwater system, ensures that polluters pay for any required clean-up, and ensures that developers pay their fair share for new infrastructure;
- Strong Design Guidelines to ensure that new infrastructure is effective and has an acceptable life-cycle cost; and
- A strong maintenance program that allows the City to prevent costly infrastructure failures, extend the life of its assets and prioritize infrastructure spending.

The City of Prince George has an extensive stormwater system due to the spread-out nature of development combined with a relatively low population. The following graph shows the length of system (sewer and ditch) per capita for various municipalities across Canada that participate in the NWWBI. The City of Prince George is denoted as “CPG” and has the highest length of stormwater system per resident of all the Canadian municipalities included. This poses a challenge for funding infrastructure as the City of Prince George has “fewer taxpayers” per unit of infrastructure to financially support the maintenance and renewal of the infrastructure.

**Figure 3: Length of Stormwater System (m) per Capita- NWWBI**



# 2. Previous Work

## 2.1 Previous Prince George Stormwater Utility Study

In 2013, AECOM completed a study for a stormwater utility for the City of Prince George, which included public consultation. Initially the study looked at including snow removal as well as stormwater management within one "stormwater utility", but part way through the study, the snow removal activities were removed from the stormwater utility study.

A rough timeline of the work involved in the 2013 stormwater utility study is presented below.

- *December 2012*: Council approved the creation of a stormwater utility using a tiered single-family unit rate structure (i.e. tiered SFU).
- *Spring/summer 2013*: AECOM completes a rate analysis for a stormwater utility.
- *September 9, 2013*: Proposed stormwater fees were presented to the Finance and Audit Committee and a method for calculation of the different rate categories. Average fees from the following variable rate structures were presented: Equivalent Residential Unit (ERU), Single Family Unit (SFU), and Tiered SFU.
- *October 2013*: Information regarding stormwater runoff, the City's infrastructure funding challenges and the need to consider a user fee-based stormwater utility was uploaded to the City's website.
- *October 7, 2013*: A stormwater utility project update was made to the Finance and Audit Committee. It provided the Finance and Audit Committee with the Stakeholder and Public Consultation Plan as the next step in establishing a Stormwater Utility for the City of Prince George.
- *October/November 2013*: Conducted two stakeholder meetings (School District #57 and Chamber of Commerce), media briefing, two public open houses, an online survey (received 545 surveys and 26 telephone calls), and notified owners of large properties and organizations currently receiving permissive tax exemptions, regarding the proposed stormwater utility, rates, and the methods for calculating different rate categories. See Table 4 for more information.
- *October 30, 2013*: Different funding alternatives were reviewed in light of feedback received during the public consultation. The following funding models were reviewed: SFU (no tiers), ERU, blended SFU/assessed value, and 100% assessed value. Ultimately, it was decided to continue with the tiered SFU model but to simplify it by combining some of the multiple family categories (i.e. from seven to three).
- *November 2013*: Stormwater utility implementation analysis, including bylaw and IT considerations.
- *November 18, 2013*: Presented stormwater utility public consultation results and proposed rate structure to the Finance and Audit Committee and recommended draft bylaw approval. Staff proposed a tiered SFU model with an option for credits for non-residential properties. The proposed bylaw was not approved by the Committee and the Committee decided not to pursue a stormwater utility further.

The intent of the proposed stormwater utility was to remove the existing funding for stormwater infrastructure from the general tax levy and to collect revenues for sustainable funding through a stormwater and drainage utility. The proposed stormwater and drainage utility would have collected approximating $4M per year.

The funding model proposed to the Finance and Audit Committee was a tiered SFU rate. The proposed rate structure had three rates for small, medium and large single-family detached homes, three rates for multi-family residential types, and one rate for all non-residential and mixed property types (e.g. mixed commercial/residential). The residential charges were based on typical impervious areas determined through statistical sampling. The non-residential rates would be determined for each property based on actual impervious area measurements. Although

Council had approved the creation of a tiered rate structure in December 2012, the Finance and Audit Committee did not approve the implementation of the proposed tiered rate structure in November 2013. Details of the proposed rate structure and associated charges by parcel type are shown in the following table.

**Table 4: Proposed Rate Structure to the Finance and Audit Committee (November 2013)**

| Parcel Type | Prop Annual Charge SW Charge |
|---|---|
| **Single Family – Small (<125m$^2$)** | $58.21 per lot |
| **Single Family – Medium(123<226m$^2$)** | $83.16 per lot |
| **Single Family – Large (>226m$^2$)** | $116.42 per lot |
| **Multi-Family – Duplex/Townhouse** | $49.90 per unit |
| **Multi-Family – Triplex/Quadplex** | $33.26 per unit |
| **Multi-Family – 4+ Units/Condo** | $24.95 per unit |
| **Non-Residential Mixed-Use** | $26.57 per 100m$^2$ impervious area |

### *2.1.1 Public Consultation*

AECOM with sub-consultant Radloff developed and implemented a Stormwater Utility Consultation Plan as part of the 2013 study. Education and outreach focused on describing the stormwater management services currently provided by the City. Emphasis was placed on the economic, environmental and social benefits of these services and the cost to provide them. This was complemented by the following key messages to clarify the purpose behind the proposed stormwater utility:

- Why is Stormwater Management Important?
- Asset Management and the Need for Long-Term, Adequate Funding
- Fairness and Equity
- Greater Transparency and Accountability

The key audiences and stakeholders identified are outlined below.

**External Customers**

- All property owners in the City
- Landowners who receive a permissive property tax exemption
- Large property owners (either owner of large parcels and/or many small parcels)

**Internal Customers**

- City Council and Council Committees (e.g. Standing Committee – Finance & Audit)
- City Staff (e.g. Operations, Customer Service, Finance, Asset Management and IT Services)

Specific education and outreach techniques that were used included:

- Traditional media advertisements (Meeting announcements and Your City Matters)
- Fact sheets and meeting handouts
- Briefing notes for internal customers
- Media briefing
- Information repositories (Library and City Hall)
- Comprehensive web-site updates for storm water information
- Public meetings
- Facilitated meetings with key audiences and stakeholders
- Surveys
- Feedback received through customer service centre and webpage

- Internal information meetings

The table below outlines the contacts made during the stormwater utility consultation process in October and November 2013.

**Table 5: Contacts Made During the Stormwater Utility Public Consultation Process**

| Dates | Organization | # of Participants |
|---|---|---|
| **Oct 17** | Media Briefing | 3 |
| **Oct 17** | Public Meeting #1 | 18 |
| **Oct 17** | Public Meeting #2 | 10 |
| **Oct 18-Nov 15** | Survey – on-line and in person | 545 |
| **Oct 29** | School District #57, Administration | 3 |
| **Nov 7** | Chamber of Commerce, Advocacy Committee | 8 |
| **Oct 18-Nov 15** | Contacted large property owners | 50 |
| **Oct 18-Nov 15** | Contacted non-profit org and places of worship | 64 |
| **Oct 18-Nov 15** | Individual inquiries and feedback (phone and email) | 26 |

At the open houses, the project team heard that residents preferred a simple funding model for the following reasons:

- Determining how much run-off each property contributes is more difficult than just measuring impervious area as some impervious area (i.e. roofs) may drain to landscaped areas;
- The perceived level of service that each resident receives varies widely (ditches, curb and gutter, infrastructure work in their area etc.) and according to residents does not appear to relate to the amount of impervious area on their property;
- One of the largest areas of imperviousness are the roadways, which is considered a common good and should be paid for by everyone, regardless of the amount of impervious area on their property.

The input received by Prince George residents from all the consultation methods can be summarised as follows:

- The majority of respondents indicated that stormwater infrastructure, flooding & landslide protection, and protecting the water quality in streams, creeks, rivers and ponds is important to them.
- The majority of respondents felt that existing storm water infrastructure was being managed adequately or very well, but concerns were expressed regarding ponding and pollution in certain areas of the City, or as a result of new development activity.
- Many respondents did not believe that their property had any impact on the stormwater infrastructure in the City but felt that any increase to fees or taxes should result in a corresponding improvement to service levels to address existing problem areas and replace aging infrastructure.
- A majority of survey respondents do not wish to see any increases in taxes or fees for stormwater infrastructure. Many responses demonstrated a general concern over the City's current expenditure of tax dollars and were sceptical that the creation of a stormwater utility fee would result in a corresponding reduction to their current tax burden.
- A majority of survey respondents preferred the existing system of stormwater funding (i.e. through taxation). By contrast, most Public Meeting attendees saw merits with a new funding system based on impervious area, however considerable debate and difference of opinion was evident over the implementation of the rate structure for different types of properties.
- If the stormwater utility was created, the majority of respondents supported a credit or refund system for property owners that implemented measures to reduce the volume or improve the quality of drainage leaving their site, provided it was simple to administer. The majority of attendees to the public meetings thought credits should be available to industrial, commercial, and institutional properties,

while indicating that the administration of a credit system for residential properties would be problematic.

- Responses were divided on whether or not agencies who currently receive a permissive tax exemption should pay fewer annual fees should the storm water utility be created.

Throughout the stormwater funding study, the strongest proponents for a new stormwater funding model based on a variable stormwater rate were Utilities and Environmental staff who saw and understood the negative implications of the on-going lack of stormwater funding (e.g. deteriorating infrastructure, environmental degradation etc.). Utilities and Environmental staff valued a stormwater rate that was based on fairness, transparency, financial and environmental sustainability, and hence pursued the Tiered SFU stormwater funding model. This funding model closely resembled a user pay fee (i.e. property owners pay based on the impact they have on the public stormwater system), with “reasonable” set-up and on-going administration costs, that would provide for sustainable funding and encourage environmentally sustainable forms of development.

Other City departments, such as IT, were receptive to and cooperative in reviewing the impact of employing a new stormwater funding model (i.e. modified billing systems). There was mixed support for a variable stormwater rate at the senior management level. Although there was some support within Council for the tiered SFU funding model, there was also a strong desire to heed residents’ concerns.

The public consultation process revealed a range of opinions. Those residents and stakeholders who attended meetings developed a better understanding of stormwater management and supported the City in addressing funding needs. Interestingly, however, the majority of residents who provided feedback seemed to favour simplicity over equity when developing a stormwater funding model.

## 2.2 Additional Public Consultation Work

Since the 2013 Stormwater Utility Study the City has not completed further public consultation specific to stormwater funding. However, the City does continue to engage residents and seek feedback on a variety of municipal issues through face to face workshops and online communications.

The City began conducting face to face and online community events as part of their “Talktober” initiative. These events, that occur in October of each year, invite residents to give feedback on budget priorities. The City also uses “CITIZEN BUDGET by Ethelo”, which is an interactive online budget simulator where residents can select their preferences for budget allocations across various City services. They can then use their own residential assessment value to get an idea of how much they pay for the various municipal services.

In 2016 the City conducted Talktober events in five communities across Prince George where they could rate their priorities for capital investment across ten City services. The results in order of priority are:

1. Parks and trails
2. Sports and recreational facilities
3. Culture and community events
4. Roadway and lighting
5. Sidewalks/pedestrian services
6. Bicycle routes
7. Public bus services
8. Water and sewer
9. Stormwater management
10. Government services facilities

The results are shown in the following figure.

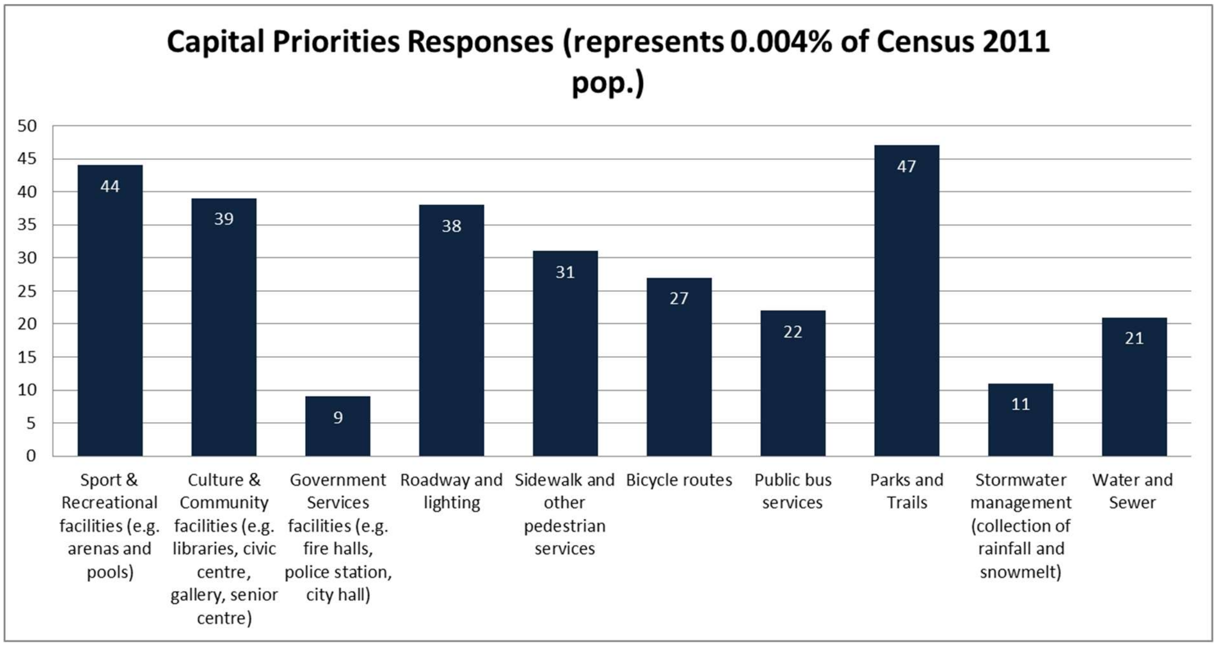



**Figure 4: Resident Capital Priority Responses at 2016 Talktober Community Events**

Not surprisingly, the services provided by assets that residents can see ranked highest. Whereas services provided by assets that residents do not directly see or experience (e.g. underground pipes, inside firehalls and police stations etc.) ranked lowest. This does not necessarily reflect residents' values as most residents would choose clean drinking water over a new waterslide, but it does reflect where residents think future spending should occur based on their knowledge of existing services and assets. Most residents do not know the condition of the City's underground pipes and since clean water comes out when they turn on the tap, they did not prioritize capital spending on water and sewer. However, they do know the condition of the City's main roads and the condition of the local recreational facilities and therefore prioritized capital spending in these areas. Therefore, the fact that citizens did not prioritise capital spending in the area of stormwater management, probably indicates that they are not aware of many of the issues related to a lack of historical funding for stormwater (e.g. collapsed culverts).

## 2.3 Prince George Policy/Regulatory/Strategy Analysis

The Official Community Plan Bylaw No. 8383,2011, approved by Council in April 2012, states under Policy 31.2.14 that the City should review its Storm Sewer Bylaw and consider a stormwater utility to fund the ongoing operating and maintenance of its storm water network. This led to the 2013 Stormwater Utility Study. The Storm Sewer Bylaw No. 2656 (1974) and the Comprehensive Fees and Charges Bylaw No. 7557 (2004) would need to be updated to implement a stormwater utility.

Achieving sustainable funding for the City's stormwater management program was identified as a priority under the Environmental Leadership and Climate Action myPG pillar. It assists with three of Council's focus areas:

- Incorporate adaptation to climate change in relevant operations;
- Prioritize infrastructure re-investment and renewal to ensure the delivery of critical recreation emergency, transportation, and utility services; and
- Maintain fiscal sustainability, balance service levels with the affordability of the City's services, facilities, and operations.

## 2.4 Recent Events and Changes

Since the City completed its Stormwater Utility Study in 2013, some changes and events have occurred that could impact decisions around future funding of the City's stormwater program. Recent events and changes include:

- New City Councillors, who have different priorities and may or may not champion the implementation of a stormwater rate;
- Recent large culvert collapses which required borrowing to fund the repairs (e.g. Winnipeg St. sinkhole shown in Figure 4);
- New and updated municipal policies and strategies in the areas of climate change adaptation and asset management;
- Increasing Provincial and Federal requirements and enforcement with respect to water and sustainability, particularly regarding McMillan Creek and salmon populations. Changes in Provincial and Federal statutes include the Water Sustainability Act that was brought into force in 2016 and periodic amendments to the Fisheries Act and Species at Risk Act;
- Increased inventory of detention ponds, which increases pond maintenance costs, particularly for sediment removal;
- Impact of beavers on natural stormwater assets; and
- Impact of COVID-19 on City revenues (e.g. from City facility closures).


**Figure 5: Winnipeg St. Sinkhole (2018) - $1.7M**

# 3. Financing Options

## 3.1 Overview of Funding Mechanisms

To support current and future stormwater management (SWM) needs, there are four general types of funding for the major components of municipal SWM programs in North America, including:

- Taxes, which are mandatory levies authorized through legislation, collected by a public body, and not related to any specific benefit or government service (i.e., these are for general services to support the public good)
- Special levies that have specific designations and limitations for usage
- Fees and special charges, which are payments made to offset the cost of a specific service and payable by those people who benefit from the service (includes stormwater rates)
- Other means such as public-private partnerships, federal or provincial economic stimulus grants for infrastructure investment, debentures, and long-term debt-financing strategies

Property taxes are the primary source of funding for SWM programs in the City of Prince George and across Canada, although stormwater rates are becoming increasingly used. Details of the most common SWM funding mechanisms are presented below.

1. Property Tax - general tax fund and dedicated levy
2. Stormwater Rate – flat rate
3. Stormwater Rate – variable rate based on land use and/or property size
4. Stormwater Rate – variable rate based on actual or estimated impervious area
5. Water/Wastewater Rate
6. Development Related Charges and Fees
7. Grants

Development related charges and grants can provide important funding to specific projects but will not be able to fund an entire stormwater program (e.g. operations and maintenance, on-going renewal etc.). They are typically used to complement other stormwater funding models. Therefore, we will explore stormwater funding models numbered 1 to 5 above for the City of Prince George, understanding that any funding model would be supplemented by development cost charges and grants, where applicable.

## 3.2 Property Tax

### *3.2.1 General Tax Fund*

Local property taxes are the most significant revenue source to support municipal SWM programs in Prince George and other municipalities in Canada such as the Cities of Red Deer, Kelowna, Kamloops and Greater Sudbury. Revenue derived from the municipality's portion of property tax goes into a general fund which covers the operating and capital expenditures of most municipal services. Property tax is determined based on the property value assessment multiplied by the applicable tax rate which depends on the classification of the property.

Property tax rates are established on an annual basis by Canadian municipalities to meet their projected funding needs and in consideration of the total current value assessment of all taxable properties within their jurisdiction.

Tax-exempt properties generally do not contribute tax funds to the municipality's SWM program. Tax-exempt properties include governmental parcels (e.g., municipal, regional, provincial, and federal buildings) as well as institutional parcels (e.g., schools, hospitals, and churches) and other charitable organizations that are registered with the Canada Revenue Agency.

Some municipalities charge a core service fee or tax-like payment to tax-exempt properties. For example, the federal government administers the Payments in Lieu of Taxes (PILT) program which distributes funds on behalf of eligible tax-exempt institutions to property taxing authorities to compensate for valuable services such as SWM, police protection, fire protection, and roads.

### *3.2.2 Dedicated Tax Levy*

A dedicated levy can be administered specifically to raise revenue for stormwater services, such that a fixed property tax rate is applied and itemized on the property owner's annual tax bill. A by-law would be required to dedicate these funds specifically to SWM. The Cities of Delta and Langley are examples where a dedicated tax levy is dedicated specifically to stormwater. The City of Thunder Bay has a sewage & drainage special area levy that funds a portion of Thunder Bay's SWM program.

The City of Prince George currently administers many dedicated tax levies, some for third parties (e.g. schools, hospital, and Regional District), and some for municipal services (e.g. snow control, road rehabilitation and the General Infrastructure Reinvestment Fund).

Although, some of the funding from the City's current dedicated tax levies for snow control, road rehabilitation and the General Infrastructure Reinvestment Fund (GIRF) may get used for stormwater related activities (e.g. ditching or replacing culverts and sewers), none of the funds are dedicated specifically to stormwater management. The existing GIRF can only be applied to capital reinvestment projects and cannot fund new capital or operating. As the City is familiar with the use of dedicated tax levies it may like to consider the use of a dedicated tax levy for stormwater management.

The presence and naming of a dedicated tax levy for SWM can be important for raising public awareness and obtaining buy-in. As many residents are not familiar with what stormwater management is and how it benefits them, some municipalities have used other words that resonate more with its citizens and their priorities. For instance, the Cities of Delta, Pitt Meadows, West Vancouver, Surrey and Abbotsford uses the word "Drainage" for naming its tax levy as opposed to the Township of Langley, City of Victoria and City of Markham who elected to use the word "Stormwater" The City of North Vancouver combines the two terms and has a "Storm Drainage Levy". The City of Chilliwack has two separate levies; one for drainage and one for dyking. The City of Richmond has a Drainage and Dyking Utility which includes a "flood protection rate". The City of Barrie is working on the implementation of a new fee for its "Stormwater Climate Action Fund".

### *3.2.3 Advantages and Disadvantages*

Funding a municipal SWM program through property taxes offers several advantages, including:

- Property-tax based revenues are already accepted as the primary existing source of revenue for Prince George
- Can be used to fund all SWM program activities
- The billing system already exists and is well established

Funding a municipal SWM program through property taxes presents several disadvantages, including:

- Inequitable: Property taxes are based on a property's assessed value, which does not typically correlate with its runoff contribution, so the fairness and equity of this revenue source is low
- Inequitable: Tax-exempt properties, even those that are major producers of stormwater runoff, contribute very little (i.e., through payments in lieu of taxes) or nothing to support the SWM program
- Unpredictable: Except in the case of a dedicated stormwater tax levy, funding is not dedicated to stormwater and can be diverted to other municipal services

- Unsustainable: There is no incentive for property owners to reduce stormwater runoff and pollutant discharge which could potentially reduce City costs in the operation and renewal of the stormwater system
- Unsustainable and Unpopular: Council and residents are sensitive to tax increases and the ability to increase funding is constrained. As outlined in Section 1.3, the City would need to increase taxes by at least 4.7% to fully fund the City's stormwater program such that it is both financially and environmentally sustainable.

## 3.3 Stormwater Rate

A stormwater rate is a financing mechanism that allocates costs to individual properties based upon a "user pay" formula, in a similar fashion as a water/wastewater rate. This is known as a stormwater utility in the U.S.

The principal advantage associated with a stormwater rate (except for the flat fee option) is that all parcels can be assessed a user fee that reflects their relative stormwater contribution to the municipal SWM system, including tax-exempt properties (e.g., places of worship, provincial and federal agencies, and other tax-exempt buildings and entities). For example, each tax-exempt parcel could be charged a stormwater user fee that is proportional to the stormwater runoff from the property. This method is similar to the manner in which other public utilities charge tax-exempt property based on usage (e.g., water and sewer utility fees).

Applying a user pay approach to water is fairly simple, it is based on the amount of water one consumes, which is commonly measured continually through a meter. Applying a user pay approach to stormwater is slightly more challenging because you cannot continually measure the amount and quality of stormwater runoff from a property. However, you can approximate the amount of stormwater runoff, to varying degrees of accuracy, as discussed below.

It is important to note that there is a large range of stormwater rates across Canadian municipalities. Some of them are very simple and are not proportional to the amount of stormwater runoff from a property (i.e. flat fee option), some of them are fairly simple and are loosely related to the amount of stormwater runoff from a property (i.e. variable rate based on land use and/or property size), whereas others are based on actual or estimated imperviousness and are therefore more proportional to the amount stormwater runoff from a property (i.e. variable rate based on impervious area). In other words, some stormwater rates closely resemble a "user-pay" approach, whereas other stormwater rates do not really apply "user-pay" principles. Stormwater rates that apply a "user-pay" approach (i.e. impervious based rate) are considered more equitable but some municipalities prefer a simpler approach (i.e. flat fee option).

The fee for a stormwater rate is typically applied on a monthly or occasionally annual basis. The revenue generated through a stormwater rate can be used for any SWM program related costs.

The basic calculation for a stormwater rate is simply the municipal SWM program expense divided by the number of billing units within the municipality. How one allocates the number of billing units to each property depends on the type of stormwater rate selected (e.g. allocate billing units based on land use, property size or impervious area). The following types of stormwater rates (and hence billing unit methods) have been used throughout North America and are listed in increasing order of equity.

1. Flat Fee
2. Variable Rate Based on Land use and/or Property Size
3. Variable Rate Based on Impervious Area
    a. Equivalent Residential Unit (ERU)
    b. Single Family Unit (SFU)
    c. Tiered SFU
    d. SFU with geographical consideration

e. Impervious area measured for every property

These types of rates listed above are described further in the following sub-sections.

### *3.3.1 Flat Fee*

In a flat fee funding model, the charge does not vary according to usage of the property (e.g., a charge of $5 per month per water meter account). *Example: City of Calgary.*

### *3.3.2 Variable Rate – based on land use/property size*

Industrial, commercial and institutional properties tend to have greater impacts on a municipal stormwater system for two reasons:

- They generally have more impervious area resulting in higher peak flows and volumes of stormwater run-off; and
- They generally include uses (such as surface parking) that create run-off with poor water quality.

Larger properties also tend to have greater impacts on a municipal stormwater system for two reasons:

- They generally require a greater length of network (e.g. fronting storm sewer or ditch to service the property); and
- They generally have more impervious area than smaller properties of similar land use.

Therefore, some municipalities, such as the cities of Edmonton, Vaughan, London and Newmarket have decided that land use and/or property size is an appropriate approximation of a property's impact on the stormwater system and should form the basis to determine a stormwater fee for each property.

Three examples of a variable stormwater rate based on land use and property size that we have seen in North America are:

1. **Tiered Flat Fee**: this extends the Flat Fee by offering different ratepayer categories (e.g., $5 per month per residential property, and $1,000 per year per commercial/industrial property). *Example: City of London.* The *City of Vaughan* has additional tiers that also consider property size and type of development ($51 for low-density residential, $33 for medium density residential, $46 for non-residential properties less than an acre, $1,187 for non-residential properties 1-10 acres etc.).
2. **Runoff Coefficient**: the charge varies by property size and an assumed stormwater runoff potential by property type. An example of this approach is the *Town of Newmarket* where they charge \$0.017 per $m^2$ for natural areas, \$0.082 per $m^2$ for residential/institutional properties and \$0.163 per $m^2$ for commercial, industrial and mixed-use buildings.
3. **Intensity of Development Factor**: similar to Runoff Coefficient billing method however adjustment factors are applied to account for the property's development status (e.g., a factor of 0.0 for undeveloped properties, 1.0 for fully developed properties, and a factor between 0.0 and 1.0 for properties considered to be underdeveloped within their underlying zoning category). *Example: City of Edmonton*

### *3.3.3 Variable Rate – based on imperviousness*

A variable rate based on impervious area accounts for the contribution of stormwater runoff from each property to the local drainage system (e.g., ditches, sewers, and channels) and water quality control facilities. The area of impervious ground cover (e.g., rooftops, driveways, and parking lots) is typically used as the basis for the stormwater rate because impervious area is a common indicator of stormwater flow and pollution discharge potential.

Figure 6 illustrates the impervious area for a non-residential property, highlighting the building footprint in the left panel and the driveway and parking areas in the right panel. The sum total of these areas within the lot boundary represents the total impervious area for this property.

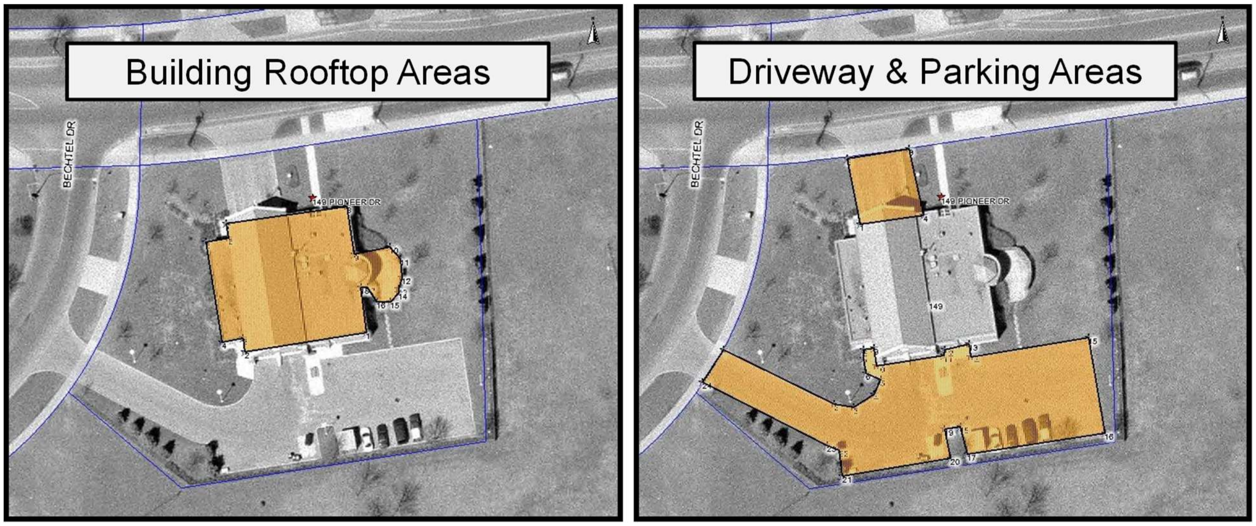



**Figure 6: Example of Impervious Areas**

Canadian cities with variable stormwater rates based on impervious area include Kitchener, Waterloo, Saskatoon, Mississauga, Guelph and Victoria. A stormwater rate based on impervious area offers a more equitable funding mechanism than other funding sources, because fees assessed to each parcel of land are based on runoff contribution to the municipal SWM system rather than property value or size.

There will be certain properties that will have characteristics that do not fit the exact model that states: "increased imperviousness correlates to increased runoff". Examples include developments that disconnect their impervious areas from the storm sewer/drainage system (e.g., by discharging onto pervious surface areas or into porous media). Likewise, developments that incorporate source controls or private SWM facilities prior to discharge to the municipal collection system should be charged less than developments that do not adopt best management practices. These two examples could be addressed through an effective credit policy that acknowledges and reduces the fees for properties that manage their stormwater run-off on-site.

The use of impervious area as the basis for setting a stormwater rate is supported by standard manuals of practice. These manuals confirm the use of impervious area as a technically sound, fair and equitable basis for allocating SWM program costs, and include:

- Water Environment Federation. User-Fee-Funded Stormwater Utilities. This manual was prepared by the Water Environment Federation's Task Force on User-Fee-Funded Stormwater Utilities and summarizes stormwater rate implementations throughout the U.S.
- Florida Stormwater Association (2003). Establishing a Stormwater Utility in Florida - 2003 Edition. This manual was developed from the state with the largest number of stormwater rate implementations in the U.S.
- American Public Works Association – Financing Stormwater Utilities 2nd Edition – 2020. This publication defines stormwater utilities, and their potential for revenue generation.

A stormwater rate based on measured impervious area is a relatively new concept in Canada, but has been successfully implemented throughout the U.S. There are well over 1,500 stormwater user fees across the U.S. and over 700 of these are based on measured impervious area.

The average impervious area per dwelling unit (in square meters) for residential land use categories is typically designated as the base unit for the user fee structure. The base unit represents the stormwater discharge potential of the average residential dwelling and its associated lot. For example, if a commercial parcel has four times the impervious area of the average residential dwelling, then the commercial parcel would be billed four times the monthly flat fee for residential dwelling units.

There are many ways to develop a stormwater rate based on impervious area. Outlined below are five methods that are listed in increasing order of accuracy, complexity and equity,

1. **Equivalent Residential Unit (ERU)**: a statistical sampling of measured impervious area for all types of residential dwelling units is performed to determine the average ERU size (i.e., square meters of impervious area for average residential dwelling). The average ERU size then becomes the base billing unit. Each residential property (regardless of density) is assigned one stormwater billing unit. The charge for non-residential properties is determined by dividing the measured impervious area by the average ERU size. *Example: City of Guelph.*
2. **Single Family Unit (SFU)**: a statistical sampling of measured impervious area for single-family detached homes is performed to determine the average SFU size (i.e., square meters of impervious area for the average single-family detached home). The average SFU size becomes the base billing unit with one stormwater billing unit assigned to each single-family detached home. Fractional billing units are assigned to other residential property types based on statistical sampling of their measured impervious area. Multi-family residential properties such as apartments, condominiums, and townhouses have a smaller footprint than single-family detached homes and would therefore be charged less than single-family detached homes. The charge for non-residential properties is determined by dividing the measured impervious area by the average SFU size.
3. **Tiered Residential Rate** (e.g. Tiered SFU): the Tiered SFU billing unit method extends the SFU method by accounting for the variability in impervious area among residential properties by assigning three tiers to single-family detached homes (e.g., Small, Medium and Large). *Example: Cities of Kitchener, Mississauga and Waterloo.*
4. **Level-of-Service/Geography Base**: the ERU and SFU billing unit methods can be extended to include separate rate structure calculations that vary by the level of service provided within distinct geographical boundaries (e.g., a higher rate in urban areas that receive more frequent O&M activities and have facilities that provide a higher level of flood protection than in rural areas).
5. **Impervious Area Measurement** (Complete Coverage): the most accurate of all billing unit methods is to measure the impervious area of all properties within a given jurisdiction. *Closest example is the City of Victoria which uses building footprint for residential and measured imperviousness for ICI.*

As noted above, the methods listed are in increasing order of accuracy with respect to allocating charges among property types based on relative contribution of stormwater runoff and pollutant loading. However, with increasing accuracy the cost to administer and manage the stormwater rate also increases.

### *3.3.4 Advantages and Disadvantages*

Funding a municipal SWM program through a stormwater rate offers several advantages, including:

- Dedicated funding source
- Fair and equitable fee that is based on runoff contribution rather than property value (this will vary based on the type of stormwater rate selected)
- Costs for municipal SWM services are distributed to all privately and publicly owned developed properties within the municipality (i.e. includes tax exempt properties)
- With a credit program, provides an incentive for property owners to reduce stormwater runoff and pollutant discharge
- A stable funding source for all SWM program activities to allow for long-range planning, large-scale capital improvements, and leverage for debentures
- A mechanism to ensure privately owned SWM infrastructure is properly maintained
- Can take a variety of forms to tailor to a municipality’s desire for simplicity or accuracy

Funding a municipal SWM program through a stormwater rate also presents several disadvantages, including:

- Additional implementation costs (e.g., rate study, database management, billing and customer service). These costs would depend on the type of rate structure selected.
- Required to update the system as properties redevelop
- A portion of the public will express disapproval of a new fee

Implementation costs for database management are typically less for municipalities like Prince George that have high-quality, established Geographic Information Systems (GIS) and an existing in-house utility billing system. Further, public reception can be improved through a structured public consultation program.

We are aware of 20 to 30 municipalities across Canada that have either implemented or are in the process of implementing a stormwater rate (e.g. user fee) and Table 7 includes details for many of these.

## 3.4 Water Rate Surcharge

Some Canadian municipalities fund all or a portion of their wastewater programs through a rate surcharge added on the water or wastewater utility bill. However, some municipalities also fund all or portion of their stormwater programs through a rate surcharge added on the water/wastewater utility bill. For example, the City of Thunder Bay funds a portion of their stormwater program through the use of the wastewater rate.

### *3.4.1 Advantages and Disadvantages*

Funding a municipal SWM program through a water/wastewater rate offers several advantages, including:

- Dedicated funding source
- Costs for municipal SWM services are distributed to all privately and publicly owned developed properties with water service within the municipality (i.e. includes tax exempt properties)
- A stable funding source for all SWM program activities to allow for long-range planning, large-scale capital improvements, and leverage for debentures
- Existing billing system
- Existing and accepted form of funding

Funding a municipal SWM program through a water/wastewater rate also presents several disadvantages, including:

- Tracking revenue transfers from water/wastewater to stormwater can be complicated
- Lack of fairness and equity in allocating stormwater costs based on water consumption
- Might be legally challenged as it bears little relation to the amount of stormwater runoff generated from a property
- Since the charge is based on water metering, there may be properties that do not contribute to municipal servicing costs (e.g., un-serviced areas with private wells or properties without water meters such as parking lots).

## 3.5 Comparison of Funding Options

The main funding options explored in this memo were evaluated. Table 6 compares the various stormwater funding options with respect to several criteria, including:

- **City-Wide Applicability**: This category indicates whether or not the funding method can be used throughout the municipality's jurisdiction.
- **Meets Entire Revenue Needs**: Identifies the eligibility for funds to be used to support capital improvement projects, operations and maintenance activities, engineering, support, and overall administration of the SWM program.
- **Equitable**: This category indicates whether or not the funding method charges the property according to their loading on the SWM system.
- **Dedicated Funding Source**: Identifies those funding methods that are sustainable and dedicated solely to SWM program expenditures.
- **Effort to Set-up**: This category identifies the relative effort to set-up the funding option (i.e., options with low set-up effort are considered to be advantageous). Note that we are only addressing set-up costs since all the options presented below could be set up with the proper procedures to minimize on-going maintenance costs as new properties develop and rates change. The only exception would be if the City chose to implement a credit program that had significant uptake.
- **Public Accountability**: This category identifies how well the amount that is charged to each property can be justified to a property owner or the general public.
- **Environmental Benefits**: This category identifies the relative scale of environmental benefits provided by the option (i.e., options with high environmental benefit are considered to be advantageous and generally include those options that provide incentives to reduce stormwater and pollutant loads using source control measures).
- **Social Benefits:** This category identifies the extent to which each funding option can positively impact social behaviour (e.g. encourage property owners to reduce their impact on the environment or stormwater system).

**Table 6: Comparison of Stormwater Funding Options**

| Funding Method | City Wide Applic-ablity | Meets All Revenue Needs | Equitable | Dedicated Funding Source | Effort to Set-up | Public Account-ability | Environ-mental Benefits | Social Benefits |
|---|---|---|---|---|---|---|---|---|
| General Tax Fund (Property Tax) | Yes | Rarely | Low | No | Low | Low | Low | Low |
| Dedicated Tax Levy | Yes | Possibly | Low | Yes | Low | Medium | Low | Medium |
| Development Charges | No | No | Medium | Yes | Medium | Medium | Low | Medium |
| Water Rate Surcharge | Partly | Rarely | Low | Partly | Low | Medium | Medium | Medium |
| Stormwater Rate - flat fee | Yes | Yes | Low | Yes | Medium | Medium | Medium | Low |
| Stormwater Rate - variable based on land use and/or property size | Yes | Yes | Medium | Yes | Medium | Medium | Medium | Medium |
| Stormwater Rate based on imperviousness - ERU | Yes | Yes | High | Yes | Medium | High | High | High |
| Stormwater Rate based on imperviousness - tiered SFU | Yes | Yes | Higher | Yes | High | High | High | High |

An ideal funding source should have the following characteristics:

- Consistent with provincial and federal legislation
- Applicable for use on a City-wide basis and across all land use types
- Provides a sustainable, stable and dedicated funding source to support SWM program needs
- Revenue meets the requirements for the City's desired level of service provided
- Costs and benefits are equitably distributed across the community
- Appropriate reserve funding levels are maintained
- Sound policies are in place for credits, adjustments and appeals, and rate study recommendations are publicly supported
- Reasonable implementation costs (e.g., billing systems and administration)

The following table outlines a number of Canadian municipalities that have implemented a dedicated tax levy or a stormwater rate and describes the type of funding model that they have implemented.

### Table 7: Summary of Stormwater Rates, Fees and Levies in Canada

| Municipality | Rate Type | Details | Annual Rate for Typical Single Family Residential |
|---|---|---|---|
| **Ontario** | | | |
| City of London | Tiered Flat Fee | Storm Drainage Charge - Land area 0.4 hectares or less \$16.71/month - Residential land area 0.4 hectares or less without a stormdrain within 90m \$12.56/month - Land area above 0.4 hectares \$139.10/ hectare/month | \$200.52 |
| City of Guelph | ERU | The City's stormwater service fee is based on an Equivalent Residential Unit (ERU) of 188 m2. Residential fee of \$6.40/month is applied to every residential unit.. | \$76.80 |
| City of Waterloo | Tiered SFU | 13 rate tiers based on typical impervious coefficients . Residential broken into large = \$18.61/month; medium = \$12.75/month; and small = \$8.50/month | \$153.00 |
| City of Hamilton | Sewer / SW Flat Fee | Fixed daily charges are applied for all properties based on meter size. Wasteweter/stormwater combined rate is \$0.39/day. | \$131.40*<br>*combined with WW |
| City of Kitchener | Tiered SFU | Residential single detached small = \$9.26/month; Residential single detached medium = \$15.46/month; Residential single detached large = \$20.32/month | \$185.52 |
| City of Mississauga | Tiered SFU | Residential Stormwater Charge is calculated based on the residential property size and charged based on 5 tiers (ranges from \$54.10 to \$183.94 per year). | \$108.20 |
| Town of Newmarket | Runoff Coefficient | Stormwater Charge = property size x rate.<br>Low runoff group (natural areas, vacant properties, golf courses etc.): \$0.016698 per m²<br>Medium runoff level group (residential and institutional properties): \$0.081633 per m²<br>High runoff level group (commercial, industrial and mixed-use buildings): \$0.163325 per m² | \$73.80 |
| City of Vaughan | Tiered Flat Fee | Stormwater Charge is based on property type: Residential (low density): \$51.25; Residential (medium density): \$33.28; Residential (high density): \$201.35; Non-res (small): \$45.96; Non-res (medium)\$1,187.54; Non-res (large) \$18,137.30; Non-res (large, rural) \$10,680.83; Agricultural/vacant \$640.04 | \$51.25 |
| City of Ottawa | Tiered Flat Fee | Stormwater rates are based on estimated hard surface area. Following discounts apply: Townhouse/apartment receive a 50% discount; Urban non-connected properties receive a 30% discount; Rural non-connected properties receive a 50% discount. | \$140.65 |
| City of Markham | Flat Fee/ Property Tax | Annual fee of \$47.00 per residential property and/or \$26.00 per \$100,000 of Current Value Assessment (CVA) for non-residential properties. | \$47.00 |
| City of St. Thomas | Tiered Flat Fee | Storm Drainage Rate, Res'l \$10.11/mo, Comm'l/Inst'l \$10.11/mo or \$139.35/ha/mo if land area >1800m². | \$121.32 |
| Town of Richmond Hill | Tiered Flat Fee | The annual rate is \$73.95 for residential, and \$214.83 for Industrial, Commercial, and Multy-Unit and Condominium properties | \$73.95 |
| **Saskatchewan** | | | |
| City of Regina | Water Use Surcharge | Daily charges are applied for all properties based on size. \$0.57/day for up to 1000m² | \$208.05 |
| City of Saskatoon | ERU | The 2020 rate for one ERU is \$79.80 (\$6.65 monthly). The temporary Flood Protection Program (FPP) levy of \$27.00 (\$2.25 monthly) is charged for each water meter . | \$106.80 |
| **Alberta** | | | |
| City of Calgary | Flat Fee | Storm Drainage Service Charge, \$15.63/mo to fund capital improvement projects. Currently investigating a move towards a variable rate charge. | \$187.56 |
| City of Edmonton | Tiered Flat Fee | The charges are calculated as follows: A (property size) x I(development intensity) x R (runoff coefficient) x Rate = Land Drainage Utility Charge. | \$167.36 |
| St. Albert | Tiered Flat Fee | Storm Sewer Utility, monthly billing, Res'l \$16.11/mo, Res'l (stacked/ condo) \$11.08; Non-Res'l \$43.09 | \$193.32 |
| **British Columbia** | | | |
| Township of Langley | Parcel tax | Universal User Rate based on property tax for Stormwater. | \$54.03 |
| City of Surrey | Flat Fee | Distinguishes lowland from upland service areas, used for dyke measures. Rates determined by property class (Res/Recreational, Farm, Non-Res. | \$227.00 |
| City of Pitt Meadows | Tiered flat fee | Includes a utility charge based on assessed value of the property (drainage assessment) and a flat rate for residential properties or a charge per area for rural and commercial properties. | \$98.31 |
| District of West Vancouver | Drainage Levy | Drainage levy (flat fee) that depends on the type of property (single family residential, multi-family, or commercial). | \$496.68 |
| City of Richmond | Land Drainage Fee and Tax Levy | Annual Residential Drainage and Dyke System Fee = \$171.72 (Flood Protection System Fees), Storm Drainage Residential Tax Rate = \$0.03448 | \$207.03 |
| City of Delta | Drainage Levy | Delta does not have a stormwater fee specifically, but there is a levy included in the taxes. In 2018, Drainage Levy is \$0.1220/ \$1000 taxable property value. | \$67.10 |
| City of Victoria | Stormwater User Fees | Rate based on impervious area, street type, land use and # of parking spaces. | \$187.20 |
| City of Chilliwack | Dedicated Tax Levy | Drainage Residential \$0.15461/\$1000 of Assessed Taxable Value | \$61.84 |
| City of Port Moody | Dedicated Tax Levy | Storm Drainage Residential \$0.0745/\$1000 of Assessed Taxable Value | \$76.70 |
| City of North Vancouver | Dedicated Tax Levy | Drainage levy is billed as part of the annual tax notice. Storm drainage tax rate: \$0.05966 /\$1000 taxable property value | \$32.81 |
| City of Abbotsford | Dedicated Tax Levy | Urban storm drainage levied on gross land. \$0.14808 for >\$5,000 improvements, \$0.06581 for <\$5,000 improvements, * \$1000 assessed value. Assume average assessed value is \$429,000 | \$63.53 |
| City of Penticton | Tiered Flat Fee | Rate being phased in over 7 years. Categories include SFD, MF apart < 4 units, MF apart > 4 units, Condo, Farm/rec/nonprofit/supportive housing, Business/Industry < \$300k CVA, Business/Industry 300k-800k CVA, Business/Industry >\$800k CVA. | 26.70 (but will increase significantly until 2025) |

Knowing that the City is interested in a simple but sustainable stormwater funding solution, we will look at the following three options and how specific Canadian municipalities have implemented them in more detail:

- Dedicated Tax Levy
- Variable Stormwater Rate - Tiered Flat Fee
- Variable Stormwater Rate - ERU

## 3.6 Municipal Example – Dedicated Tax Levy

There are many examples of dedicated tax levies including the City of Prince George's GIRF, the Township of Langley's Stormwater Levy and the City of Delta's Drainage Levy. All of these levies were instated through a by-law and are charged through the City's property tax bill.

The greatest challenge with dedicated tax levies is that they are part of "property taxes" they receive public and political scrutiny if increases are proposed. Therefore, the amount of stormwater revenues tends to be limited when it is generated through property taxes or a dedicated tax levy (e.g. $50-$75 for an average single-family home). Whereas stormwater revenues tend to be greater (e.g. $100-$150 for an average single-family home) when the main revenue source is a stormwater rate. In 2019, the average singe family home in Prince George contributed approximately $62 to SWM. If the City were to fund its stormwater program at sustainable levels this would need to increase to $165 per household, which equates to a total tax increase of 3-5%.

## 3.7 Municipal Example – Tiered Flat Fee

Both the City of Vaughan and City of Penticton have implemented a stormwater rate that resembles a tiered flat fee. Their funding models are described in further detail below.

### *3.7.1 City of Vaughan*

The City of Vaughan recently developed a stormwater rate that can be summarised in the following table. The charges shown are annual charges.

**Table 8: City of Vaughan Annual Stormwater Charges**

| Property Type | Criteria | 2020 Charge |
|---|---|---|
| **Residential (low density)** | | $51.25 |
| **Residential (medium density)** | | $33.28 |
| **Residential (high density)** | | $201.35 |
| **Agricultural/vacant** | | $640.04 |
| **Non-residential (small)** | < 1 acre | $45.96 |
| **Non-residential (medium)** | 1-10 acre | $1,187.54 |
| **Non-residential (large,rural)** | 10 acre | $10,680.83 |
| **Non-residential (large)** | 10 acre | $18,137.30 |

As can be seen in the table, the rates are based on:

- property type (residential by density, agricultural/vacant, non-residential urban, non-residential rural); and
- property size (by tiers) for non-residential properties, as well.

### 3.7.2 City of Penticton

The City of Penticton's stormwater rate can be summarised in the following table. As can be seen in the table, the rates are based on:

- Whether the property is directly connected to the municipal stormwater system;
- Property type (single family, multi-family apartments < 4 units, multi-family apartments > 4units, multi-family - strata, farm/recreational/non-profit, industrial/commercial); and
- Assessed value.

**Table 9: Penticton Stormwater Fee Schedule**

| Property Type | 2019-connected | 2019 – no connection |
|---|---|---|
| **SFD, farm, rec, non-profit** | $26.70 | $20.50 |
| **MF < 4 units** | $42.80 | $32.90 |
| **MF > 4 units, strata** | $14.30/unit | $11.00/unit |
| **Business/industry < $300k CVA** | $54.10 | $41.60 |
| **Business/industry $300k - $800k CVA** | $81.20 | $62.40 |
| **Business/industry > $800k CVA** | $121.80 | $93.70 |

## 3.8 Municipal Example – Variable Rate (ERU)

The City of Guelph has recently implemented a variable stormwater rate based on the Equivalent Residential Unit (ERU) funding model. Under the ERU funding model, all residential properties (from single family to condo) pay the same amount. Non-residential properties pay based on the amount of impervious surface on their properties. Non-residential properties can apply for a credit for up to 50% off their stormwater rate for peak flow reduction, runoff volume reduction, water quality treatment, education and pollution prevention.

# 4. Conclusions and Recommendations

## 4.1 Prince George Considerations and Recommended Funding Models

From the previous stormwater funding work and more recent public consultation work for general municipal budgeting, it appears that stormwater management is not the most pressing issue for residents of the City of Prince George. This will make it difficult for the City to engage residents about the need for a new stormwater funding model and will also make it difficult for stormwater managers to obtain sufficient funding from the general and existing dedicated tax levies when Council is being pressed by residents for other infrastructure such as recreational facilities and better sidewalks.

Due to the on-going lack of stormwater funding and the associated risks (e.g. collapsing culverts), it is recommended that the City pursue additional stormwater funding. In order to be successful, it is recommended that the City do the following:

- Explore simpler stormwater funding models than the tiered SFU model proposed in 2013, to reflect the desires of residents and City Finance staff; and
- Educate senior management, Council and the public on the need for improved stormwater management. Use real examples such as the recent collapsed culverts to demonstrate the need for increased stormwater funding. Also use financial information (e.g. the cost of emergency repairs vs planned maintenance) to demonstrate the financial benefits of maintaining the system in a planned rather than a reactive manner, and to demonstrate that the City of Prince George spends significantly less than other comparable municipalities on stormwater management..

Given current challenges with reduced municipal revenues due to COVID-19 and competing priorities for funding from the General Tax Levy City staff may want to consider a phased approach to stormwater funding. In the short-term, City staff may want to pursue additional stormwater funding through existing mechanisms (i.e. GIRF). If City staff are successful in achieving sustainable stormwater funding levels through the general tax levy and the GIRF, then the City could continue funding stormwater through these mechanisms. However, if the City cannot achieve long-term sustainable stormwater funding levels through the general tax levy and the GIRF, then we recommend that the City consider the following two funding models:

- A dedicated stormwater tax levy (example: Delta)
- An ERU based variable stormwater rate (example: Guelph)

The advantages and disadvantages for the two funding models listed above are outlined in the following table.

If the City chooses to gradually increase stormwater funding to sustainable levels, then we recommend they use a risk-based approach to identify the highest priority needs. The risk analysis completed as part of TWP #2 and the project prioritization framework completed as part of TWP #1, will help in this regard. In general, the following key elements are important for developing a cost-effective stormwater program:

- Strong bylaws that prevent contamination of the stormwater system, ensures that polluters pay for any required clean-up, and ensures that developers pay their fair share for new infrastructure;
- Strong Design Guidelines to ensure that new infrastructure is effective and has an acceptable life-cycle cost; and
- A strong maintenance program that allows the City to prevent costly infrastructure failures, extend the life of its assets and prioritize infrastructure spending.

**Table 10: Advantages and Disadvantages of Two Funding Models for Prince George**

| | Advantages | Disadvantages |
|---|---|---|
| Dedicated Tax Levy | • simple<br>• could likely be administered by existing staff on an on-going basis<br>• can fund all existing and future activities within the City's stormwater program<br>• use existing billing system<br>• dedicated stormwater funding source | • inequitable: no correlation with a property's impact on the stormwater system<br>• associated with the general tax levy, so will be subject to tax sensitive scrutiny<br>• a credit system cannot be applied to properties that install on-site stormwater measures<br>• tax exempt properties will not contribute |
| ERU Variable Rate | • relatively simple<br>• could likely be administered by existing staff on an on-going basis<br>• can fund all existing and future activities within the City's stormwater program<br>• outside the general tax levy, so will not burden City revenues from property tax<br>• a credit system can be applied to properties that install on-site stormwater measures<br>• all properties (including tax exempt properties) will contribute<br>• sustainable and dedicated stormwater funding source<br>• equitable: the fee is proportional to the amount of stormwater runoff generated on-site<br>• will encourage non-residential properties to reduce the imperviousness of their properties | • will require some effort to set-up, particularly with respect to the billing of properties that do not currently receive a utility bill (e.g. well and septic system) and the impervious area measurement of non-residential properties |

With either of the two funding models, the City of Prince George may need to address rural versus urban properties since it is often perceived that rural areas receive a lower level of service with respect to stormwater management even though it is often not the case.

## 4.2 Public Education

In the previous stormwater financing work in 2012-2013 it was found that:

- Residents generally disapproved of any new fees or raising taxes;
- Residents were generally satisfied with the City's stormwater system and did not see a need to increase expenditures; and
- Residents/property owners who attended information sessions (e.g. open houses) were more amenable to a stormwater rate, albeit a simple model.

More recently, the City's public education work, including Talktobers show that stormwater management is not a high priority for City residents. At the same time, City staff are reporting the historical lack of funding for stormwater management and how that has begun to result in failing infrastructure and high repair costs. It appears that the public is unaware of the historical lack of stormwater funding and the risk that poses. Therefore, before residents accept a new stormwater funding model or increased stormwater funding, they must understand:

- The risks that low stormwater funding poses with real, short term examples that will directly impact residents; and
- The real benefits that residents will experience in the short term with increased funding.

**Contact**

Nancy Hill, P.Eng.
Project Manager
T +1 (604) 790-1637
E Nancy.hill@aecom.com

Janie Bergeron, P.Eng.
Deputy Project Manager
T +1 (604) 444-6400
E janie.bergeron@aecom.com